Questions for Standard Grade, Intermediate 2 and Higher Physics

- **click on bookmark topic in left column to go to start page**
- **topics that are for Higher Physics are bookmarked in red**
- **topics are grouped under three headings:**

  Mechanics (motion, forces, energy etc)

  Electricity (circuits, a.c., electromagnetism, electronics etc)

  Light, Heat etc (optics, properties of matter, radioactivity, uncertainties and miscellaneous)

- **click on triangle at left of group name to open or close list**
- **answers are grouped under same headings and are in topic order**

Speed = distance ÷ time

1. Use the formula: "**speed = distance ÷ time**" to calculate the missing values from the table.

distance in m	time in s	speed in m/s
100	10	-
990	3	-
2×10^{3}	5	-
-	10	330
-	5	3×10^{8}
-	0.2	640
3600	-	12
1.2×10^{9}	-	3×10^{8}
1.7×10^{4}	-	340

2. A marathon race is run over a **distance** of 42730 metres. A top runner can complete the course in 2 hours 10 minutes.
Calculate the **average speed** of the runner in **metres per second**.

3. How **far** would a person run in 15 seconds at an **average** speed of 7 m/s?

4. How **long** would a car take to travel 2.4 km at an average speed of 30 m/s?

5. A good long distance runner has a typical **average speed** of 6 m/s.
How far would the runner go in 30 minutes?

6. A top woman marathon runner has an **average speed** of 5 m/s.
The marathon race is run over 26.3 miles.
Calculate her time for the race to the **nearest** minute. (1 mile = 1625 metres)

7. Concorde has a top speed of around Mach 2; (that is, twice the speed of sound in air.)
Calculate its time to fly across the Atlantic Ocean from London to New York at this speed, a distance of 7600 km. (Speed of sound in air = 340 m/s.)

8. The London-Glasgow shuttle takes approximately 60 minutes to fly a distance of 650 km. Estimate its **average speed** in m/s.

9. The wandering albatross can fly at speeds of up to 32 m/s (the speed limit on Motorways!) One albatross was found to have flown 16250 km in 10 days.
Calculate its **average speed** in metres per second.

10. A cross-channel ferry travels at about 7 m/s. At the *same* average speed, how **long** would it take to cross the Atlantic Ocean, a distance of 6700 km?
Answer to the nearest **hour**.

11. How **long** would a car, travelling at an average speed of 50 mph (miles per hour), take to travel a distance of 600 miles?

12. A bus travels between two towns which are 20 km apart in a time of 30 minutes.

    Calculate the **average speed** of the bus in km/h (kilometres per hour.)

13. How **far** would a cyclist travel in 2 hours 30 minutes at a steady speed of 15 km/h?

14. How **many laps** of a 400 metre running track would a runner make in 5 minutes at an average speed of 4 m/s?

15. A bullet, fired from a rifle, moves through the air at 500 m/s.

    How **long** would it take to reach a target 25 metres away?

16. Calculate the **average speed** of a tortoise which takes 40 seconds to walk across a 4 metre wide room. Express your answer in:

    (a) metres per second, (b) centimetres per second.

17. The national record for the 100 m sprint for men in a certain country is 10.3 s.

    Calculate the **average speed** run over the distance by the holder of the record (to the nearest *tenth* of a metre per second.)

18. A sock on the rim of a washing machine drum whilst it is spinning goes round in a circular path of radius 20 cm at a rate of 15 times per second.

    Calculate the **speed** of the sock in metres per second (to the nearest whole number.)
    Remember that the circumference of a circle, $c = 2\pi r$.

19. A cheetah can run for a short time at a speed of 36 m/s.

    At this speed, how **far** could the cheetah run in 2.5 s?

20. In making an emergency stop to avoid hitting a broken down car, a motorist brings her car to a halt at an *average* speed of 14 m/s in a time of 4.4 s.

    Show **whether or not** she *did* avoid the car if it was 62 m away from her own car when she *began* braking.

21. A typical walking speed is 1.2 m/s. At that speed, how **long** would someone take to walk the distance that a car would travel in 30 minutes at 24 m/s?

22. At what approximate **speed** does a bowler bowl a cricket ball if it travels the length of the pitch to the batsman (20 metres) without bouncing in 0.4 s?

23. The swimming record for the men's 200 metre breaststroke is 2 min 10 s. Calculate the average **speed** of the swimmer over the distance (to the nearest *hundredth* of a metre per second.)

24. The speed of sound through the air is 340 m/s. How **long** would the sound from a singer take to reach from the stage to the back of a concert hall which is 55 m long?

25. In astronomy, a 'light-year' is the **distance** travelled through space by **light** at 300 million metres per second. How **far** is one light-year in ***kilometres***?

Acceleration = change of velocity ÷ time

1. Use the formula "**acceleration = change of velocity ÷ time**" to calculate the missing entries in the table.

accel. (m/s^2)	change of velocity (m/s)	time (s)
-	20	5
-	- 30	3
10	-	2.5
15	-	0.5
9.8	19.6	-
2×10^3	20	-

2. Use the formula **$a = (v-u)/t$** to calculate the missing entries in the table.

accel. (m/s^2)	v (m/s)	u (m/s)	time (s)
-	20	0	4
-	26	12	2
-	0	10	4
-	4	20	4
-	6	6	10
10	-	20	2
4	-	2	2.5
- 5	-	10	2
-10	-	70	6
20	40	-	2
5	10	-	1
-3	30	-	10
-5	-10	-	10
10^3	2000	0	-
0.5	20	15	-
-6	0	36	-
-4	-6	22	-

3. A sprinter is found to take 3.0 seconds to reach his top sprinting speed of 10.5 m/s in a straight line. Calculate his average **acceleration**.

4. A car starts from rest and reaches a speed of 40 m/s in a time of 8 seconds. Calculate its average **acceleration**.

5. A certain make of car can reach 60 m.p.h. from rest in a time of 9.0 seconds. Calculate its average **acceleration** in m/s^2. (1 m.p.h. = 0.45 m/s)

6. Calculate the **change of speed** experienced by a train which accelerates for 9 seconds at a rate of 2.5 m/s^2 in a straight line.

7. In overtaking a lorry on a straight section of road, a driver increases speed from 50 m.p.h. to 70 m.p.h. in 5 s. Calculate the **acceleration** in:
(a) miles per hour per second, (b) m/s^2 **(1 m.p.h. = 0.45 m/s)**

8. In making an emergency stop, a car driver brings her car to rest in a straight line without skidding. If the car had been travelling at 18 m/s before the braking began and it stopped after 3 seconds, calculate the value of the average **acceleration**. Why does it have a **negative** value?

9. How **long** would it take a train, travelling at 35 m/s, to stop with a uniform deceleration of 2.5 m/s^2?

10. A car, travelling along a straight section of road, accelerates at a uniform rate of 2 m/s^2 for 5 seconds. Calculate its **change of velocity**.
(Can you state what its *final* speed would be? Why?)

11. A cyclist in a long distance race decides to put on a spurt to break away from the pack, which is moving along a straight road at 14 m/s. He accelerates uniformly for 3 seconds at 1 m/s^2. What **speed** does the cyclist reach?

12. A piece of rock tumbles from the top of a crater on the Moon. It free-falls from rest to a speed of 19.2 m/s in 12 seconds before hitting the ground.
Calculate the value of the Moon's **gravitational acceleration**.

13. In a trolley 'explosion' experiment, one trolley reaches a top speed of 50 cm/s in 0.2 s. Calculate its average **acceleration** in **cm/s^2** and **m/s^2**.

14. In a car crash, a passenger, restrained by his seat belt, is brought to rest in 150 milliseconds from a speed of 10 m/s. Calculate his average **deceleration**.

15. A light plane has to reach a speed of 36 m/s on the runway to achieve lift-off.
How **long** would it take to reach this speed from rest with an average acceleration of 4 m/s^2 ?

16. Give an example of an object moving at a **constant speed** whilst **accelerating**.
(Hint: remember that acceleration describes the change of an object's **velocity**.)

17. A bullet, fired from a rifle, reaches a speed of 500 m/s in a time of 0.2 s.
Calculate the **average acceleration** of the bullet during firing.

18. The engines of a large ship on the open sea are stopped and the ship, which *had been* moving at 8 m/s, takes 16.7 minutes to stop dead in the water.
Calculate the **average deceleration** of the ship in m/s^2.

19. An electron accelerates from rest to a speed of 3×10^7 m/s in a time of just 1.5 ns. Calculate its average **acceleration**. (1ns = 1 nanosecond = 10^{-9} s)

20. A runner, during a race, accelerates past another runner at a rate of 0.1 m/s^2 for 4s.
(a) During this time, how much **faster** does the runner run?
(b) If she *was* running at 3 m/s, what is her **speed** after accelerating?

Equations of motion

For the following questions, use the following '**equations of motion**' for an object moving in a straight line with uniform acceleration:

$$v = u + at$$
$$s = ut + \tfrac{1}{2} at^2$$
$$v^2 = u^2 + 2as$$
$$s = \frac{(u + v)}{2}\, t$$

Unless stated otherwise, take Earth's gravitational acceleration to be **10 m/s^2.**

1. In the 'equation of motion': **$v = u + at$**, in what **unit** is the term **'at'** measured?

2. For a uniformly accelerated motion, what is calculated by halving the **sum** of the initial velocity '**u**' and the velocity '**v**' after time '**t**'?

3. A car accelerates uniformly from 10 m/s to 24 m/s. What is its **average** speed?

4. A car starts at rest and accelerates uniformly at 3 m/s^2 for 4 seconds in a straight line. Find its **speed** after 4 seconds and how **far** it has travelled.

5. Which **quantity** is represented by the term '**$\frac{1}{2} at^2$**' and in which **unit** could it be measured?

6. A car moving at 8 m/s accelerates at 4 m/s^2 for 5 s in a straight line. Find the **extra distance** travelled by the car from the **start** of the acceleration.

7. What is the **final** velocity of an object which accelerates in a straight line over a distance of 13 m at a steady rate of 6 m/s^2 from a starting velocity of 10 m/s?

8. In the equation '**$v = u + at$**', what do the terms '**u**' and '**at**' represent?

9. What **time** has elapsed if an object, accelerating uniformly at 4 m/s^2 from 20 m/s in a straight line, travels an **extra distance** of 150 m?

10. In what **unit** might the term '**$\sqrt{2as}$**' be expressed?

11. What was the **initial** velocity of an object, accelerating uniformly in a straight line at 12.5 m/s^2, which has a displacement of 20 m in reaching a velocity of 30 m/s?

12. Find the **average** speed of a car which decelerates at 4 m/s^2 for 3 s from an initial speed of 20 m/s.

13. A stone is thrown vertically upwards at 40 m/s. How **long** does it take to reach its **highest** point? ('g' = 10 m/s^2)   **Where** is it after 8 seconds?

14. A train travelling in a straight line at 100 m/s decelerates to rest at a **uniform** rate and travels an **extra** distance of 1250 m.
Find the size of the train's **deceleration**.

15. How **long** would an object take to travel 210 m from an initial velocity of 20 m/s with a uniform acceleration of 5 m/s^2?

16. What is the **greatest** height a ball could reach if kicked at a speed of 8 m/s at the surface of the Moon where the gravitational field strength is 1.6 N/kg?

17. A train, travelling at a steady velocity, starts to **decelerate** at a rate of 4 m/s^2.
After 3 seconds it has travelled a **further** displacement of 102 m in a straight line.
Find the **velocity** *from which* it decelerated.

18. For an object accelerating from **rest**, which quantity is calculated by taking the **square root** of double the **product** of acceleration and displacement?

19. An object, travelling at 10 m/s in a straight line, starts to accelerate and, after 2 seconds, has travelled 24 metres. How much ***further*** would it have travelled in the same time with **double** the acceleration?

20. A boy jumps from the top of a 4 metre diving board. Calculate his **speed** just before hitting the water, ignoring the effect of air resistance and taking 'g' as 10 N/kg.
(Assume he falls vertically.)

21. The gravitational acceleration near the surface of Mars is 3.7 m/s^2.
A rock **free falls** from the top of a 200 metre high cliff. How **long** would it take to reach the foot of the cliff and what would its **maximum speed** be?

22. A car, travelling at a speed of 30 m/s in a straight line, brakes and decelerates at a uniform rate of 2 m/s^2. How much **further** does it travel before coming to rest?

23. A car accelerates along a straight road from 10 m/s to 20 m/s in 5 seconds.
How **far** does it travel during this period of acceleration?

24. In the 'equation of motion' $\mathbf{s = ut + {}^1/_2\, at^2}$, which **quantities** are represented by the terms '**ut**' and '$\mathbf{{}^1/_2\, at^2}$'?

25. A car, which was travelling at 20 m/s, accelerates in a straight line for 5 s at 2 m/s^2 . Calculate its **average speed** and the extra **distance** moved.

26. A stone, thrown vertically upwards from the very edge of a cliff at 10 m/s, reaches the foot of the cliff after 5 seconds. What is the **height** of the cliff?

27. A steel ball is dropped from rest and timed electronically over 40 cm.
If the measured time is 0.29 seconds, what value does this give for **'g'**?

28. A stone is thrown vertically upwards at 15 m/s. After what **time** is the stone 10 m **above** its starting point and **falling**? (take g = 10 m/s^2.)

29. A swimmer dives vertically from the 6 metre board and, in doing so, his centre of gravity reaches a height of 1.5 metres above the board.
Find the swimmer's approximate **speed** on hitting the water.

30. Calculate the **acceleration** of a car which, from 20 m/s, travels a **further** 78 metres in a straight line in 3 seconds.

31. A car, travelling along a straight road at 50 m/s, decelerates uniformly to rest in a time of 10 seconds. How **far** does it move in coming to rest?

32. A stone is thrown **horizontally** from an 80 m high cliff at 30 m/s. Find **how long** it takes to fall to the sea below and its **velocity** (size and direction) as it enters the water.
('g' = 10 m/s^2)

33. On Mars, where the gravitational field strength is 3.7 N/kg , a stone is projected horizontally at 24 m/s from the edge of a cliff which is 200 m high.
After what **time** would the stone be falling at an angle of 45^o to the vertical?

34. When travelling at 30 m/s, a car's engine cuts out and it starts to decelerate because of frictional forces. If the frictional forces total 1 kN and remain constant and the car's mass is 1600 kg, how **fast** is it moving after 4 seconds?

35. A stone is thrown **horizontally** from the edge of a cliff at 24.5 m/s. Ignoring the effect of air resistance and taking 'g' as 9.8 m/s^2 , calculate how **long** after being thrown the stone's motion makes an angle of 45^o to the horizontal.

36. A fireworks rocket 'burns out' at a height of 150 m and a speed of 40 m/s.
What is its **acceleration** 1 second later, neglecting air resistance?

37. A shell is fired from a cannon with a muzzle velocity of 200 m/s at an angle of 30^o to the horizontal.
How **long** does it take to reach its maximum height and how **far** does it travel before hitting the ground? (Take 'g' = 10 m/s^2.)

38. A train, travelling at 60 m/s, decelerates uniformly to rest at 2 m/s^2.
How **far** does it travel during the braking?

39. How **long** would a stone, thrown horizontally from the top of a 122.5 m high cliff, take to reach the sea below?
Would the horizontal speed matter?
('g' = 9.8 m/s^2)

40. At the surface of the Moon, the gravitational field strength is approximately 1.6 N/kg.

(a) How **long** would a **1kg** rock take to fall to the bottom of a 2880 metre high crater, projected horizontally from the edge?

(b) How long would a **2 kg** rock take to fall?

Vertical Motion

[Unless stated otherwise, all questions relate to the Earth for which you should assume the gravitational acceleration, 'g', to be 10 m/s^2. Also, the effects of air resistance should be ignored .]

1. For an object dropped vertically from rest, what is its **speed** after:

   (a) 1 s (b) 2 s (c) 3 s (d) 3.4 s (e) 0.6 s ?

2. For an object dropped vertically from rest, how **far** has it fallen after:

   (a) 1 s (b) 2 s (c) 3 s (d) 3.4 s (e) 0.6 s ?

3. (a) How **long** would it take a 1kg object to fall 45 metres from rest?
   (b) How long would it take for a 2 kg object to fall the **same** distance?

4. A boy drops a coin into a wishing well and discovers that it takes 1.8 seconds to reach the bottom. How **deep** is the well?

5. A bomb is released from the bomb-bay of a plane in level flight at 3000 metres. How **far** has the bomb fallen when it is *falling* at a speed of 40 m/s?

6. A child jumps straight down from a 10 metre high diving board into a swimming pool. For how **long** would the child be in the air?

7. The Grand Canyon in Colorado, USA, is more than one mile deep in places. If it *is* exactly one mile (1625 metres) deep at one spot, how **long** would a rock take to fall down from top to bottom? Would the **weight** of the rock affect the time?

8. On Mars, in the year 2397, a metal plate falls from the top of the 3000 m high 'Federation Tower' and hits the ground 40 seconds later. Calculate the value of the **gravitational acceleration** on Mars.

9. On the Moon, the acceleration due to its gravity is 1.6 m/s^2. How **fast** would an object be moving when it hit the Moon's surface if it was dropped from rest from a height of 2.1 metres? (Answer to two significant figures).

10. A girl drops a coin down a well from rest. It takes 2.0 seconds to hit the water at the bottom.
   (a) How **deep** is the well?
   (b) It she *threw* another coin down and it left her hand at a speed of 15 m/s, how **long** would it take to reach the bottom?

11. A stone is *thrown down* from the top of a high cliff with an initial vertical velocity of 10 m/s. What is the stone's vertical **velocity** after:

   (a) 1 s (b) 2 s (c) 3 s (d) 3.4 s (e) 0.6 s ?

12. A stone is *thrown down* from the top of a high cliff with an initial vertical velocity of 10 m/s. What is the stone's vertical **displacement** after:

   (a) 1 s (b) 2 s (c) 3 s (d) 3.4 s (e) 0.6 s ?

13. A stone is thrown vertically *upwards* from the top of a high cliff with an initial velocity of -12 m/s. What is the stone's vertical **velocity** after:

(a) 1 s (b) 2 s (c) 3 s (d) 3.4 s (e) 0.6 s ?

14. A stone is thrown vertically *upwards* from the top of a high cliff with an initial velocity of -12 m/s. What is the stone's vertical **displacement** after:

(a) 1 s (b) 2 s (c) 3 s (d) 3.4 s (e) 0.6 s ?

15. If an object is projected vertically upwards at 30 m/s, how **long** does it take to reach its highest point and how **high** does it reach?

16. A man fires a stone from a catapult, aiming it straight up.
If the stone leaves the device at a speed of 28 m/s, what **height** does it reach?

17. A stone is projected vertically upwards from a catapult at 32 m/s.

(a) **Where** is it after 2.0 seconds, what is its **speed** and in which **direction** is it moving?

(b) Find its **position**, **speed** and **direction** of motion after **4.0** seconds.

(c) What is the **size** and **direction** of the stone's **acceleration** on the way up, on the way down and at its highest position?

18. A coin is *thrown down* a 60 m deep well with an initial speed of 20 m/s.

(a) What is its **acceleration** 1.3 seconds later?

(b) How **long** does the coin take to reach the bottom of the well?

19. A stone is thrown straight up from the edge of a very deep well at a speed of 15 m/s.

(a) How **long** does it take to reach its highest point?

(b) How **high** above the edge of the well does it reach?

(c) How **long** does the stone take to come back to the top of the well?

(d) **Where** is the stone 4.0 seconds after being thrown?

(e) How **deep** is the well if the stone is moving at 35 m/s when it hits the water?

20. A cricketer catches a ball to dismiss a batsman and throws the ball straight up in the air to celebrate. If he catches it again 3.6 seconds later, how **high** did the ball go?

21. A lift is moving upwards at 3.0 m/s when a bolt breaks loose from its bottom edge and falls to the bottom of the lift shaft. If it takes 6.0 seconds to hit the foot of the shaft, at what **height** above the foot of the shaft was the bottom edge of the lift when the bolt fell off?

22. A tennis ball is hit straight upwards.

(a) At what **speed** was it hit if, 5.0 seconds later, it is moving *downwards* at 20 m/s.

(b) What **height** does the ball reach?

Graphs - straight line motion

1. How does the **slope** (or gradient) of a velocity-time graph for a moving object depend on the **size** of the object's acceleration?

2. Sketch the **shape** of a velocity-time graph for an object moving with a **decreasing** acceleration, starting from rest.

3. Sketch the **shape** of a velocity-time graph for the motion of an object which starts at rest and has an **increasing** acceleration.

4. Which **quantities** are calculated by the **areas** under:

   (a) a speed-time graph (b) a velocity-time graph?

5. Sketch the velocity-time graph for the first **three** bounces of a ball dropped vertically from rest, assuming that **some** mechanical energy is lost during each bounce.

6. Sketch the likely shape of the **speed-time** graph for the motion of a stone released from rest from the surface of a deep loch.

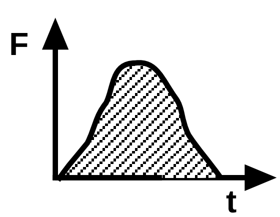
7. Sketch a speed-time graph for an object which moves with **decreasing** deceleration from a starting speed '**u**' to rest in '**t**' seconds.

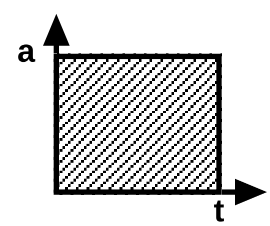
8. Sketch a possible speed-time graph for a sky diver from the instant of jumping out of a stationary balloon till ***just before*** the parachute is opened when he is travelling with a **terminal velocity** of 60 m/s.

9. Describe the **shape** of graph which would be obtained if, for a moving object of a certain mass, its kinetic energy at different velocities was plotted against the **square** of its velocity.

10. Which **quantities** are found from the areas under the lines of:

   (a) a force-time graph (b) an acceleration-time graph?





11. Which quantities are found from the **gradients** of:

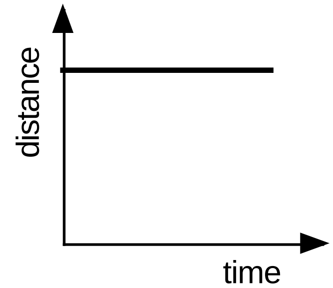
   (a) velocity-time graphs (b) distance-time graphs?

12. The **areas** under which graphs would calculate, for an object:

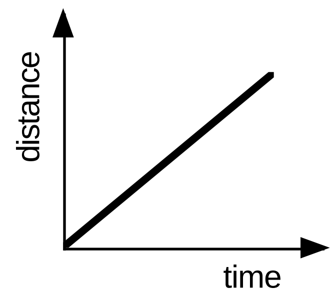
   (a) **change of momentum** (b) **distance** (c) **change of velocity**?

13. The **gradient** of a velocity-time graph at one point is found to be **2.5**. If the velocity is measured in 'metres per second' and the time in 'seconds', state the value of the **acceleration** at that point?

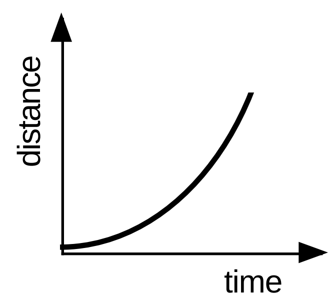
14. Describe the **motion** of the object for which the distance-time graph has been constructed.



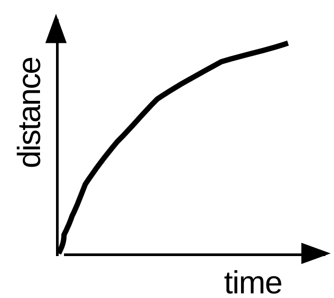
15. Describe the **motion** of the object for which the distance-time graph has been constructed.



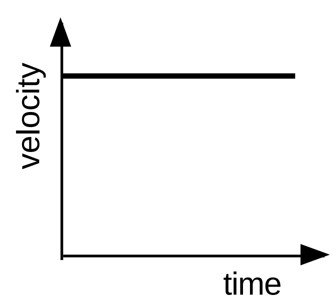
16. Describe the **motion** of the object for which the distance-time graph has been constructed.



17. Describe the **motion** of the object for which the distance-time graph has been constructed.



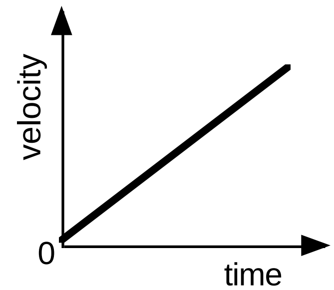
18. Describe the **motion** of the object for which the velocity-time graph has been constructed.



19. For the motion described by the velocity-time graph in Q18, sketch a possible **distance-time** graph.

20. In Q18, what is the **gradient** of the velocity-time graph?

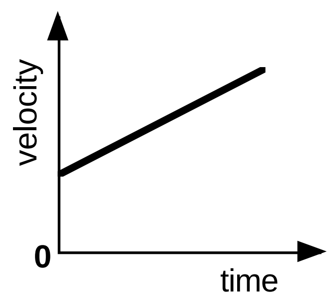
21. Describe the **motion** of the object for which the velocity-time graph has been constructed.



22. For the motion described by the velocity-time graph in Q21, sketch:

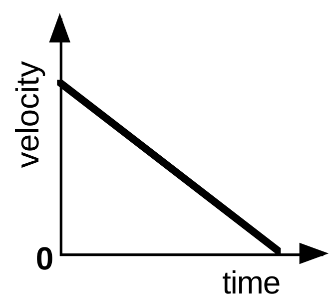
(a) a possible **distance-time** graph
(b) a possible **acceleration-time** graph.

23. Describe the **motion** of the object for which the velocity-time graph has been constructed.



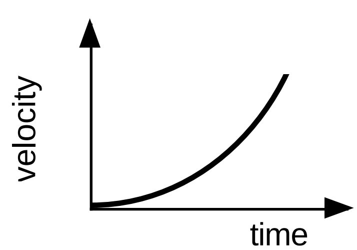
24. For the motion described by the velocity-time graph in Q23, sketch a possible **acceleration-time** graph.

25. Describe the **motion** of the object for which the velocity-time graph has been constructed.



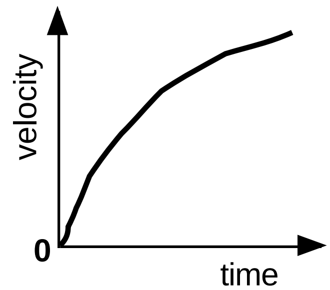
26. For the motion described by the velocity-time graph in Q25, sketch a possible **acceleration-time** graph.

27. Describe the **motion** of the object for which the velocity-time graph has been constructed.



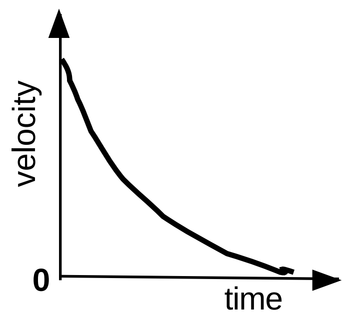
28. For the motion described by the velocity-time graph in Q27, sketch a possible **acceleration-time** graph.

29. Describe the **motion** of the object for which the velocity-time graph has been constructed.



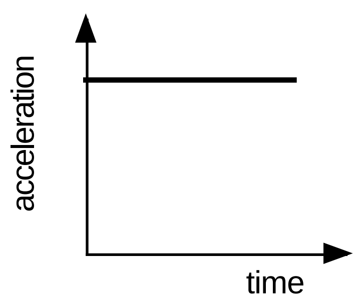
30. For the motion described by the velocity-time graph in Q29, sketch a possible **acceleration-time** graph.

31. Describe the **motion** of the object for which the velocity-time graph has been constructed.



32. For the motion described by the velocity-time graph in Q31, sketch a possible **acceleration-time** graph.

33. Describe the **motion** of the object for which the acceleration-time graph has been constructed.



34. For the motion described by the acceleration-time graph in Q33, sketch:

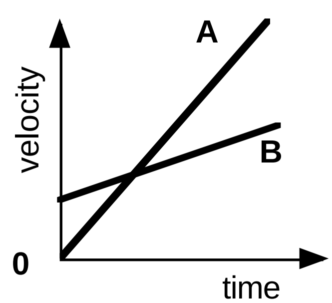
(a) a possible **velocity-time** graph and
(b) a possible **distance-time** graph.

35. For the velocity-time graphs, which show the motion of two vehicles, **A** and **B**, state which vehicle:

(a) has the **greater acceleration**,

(b) reaches the **higher speed** and

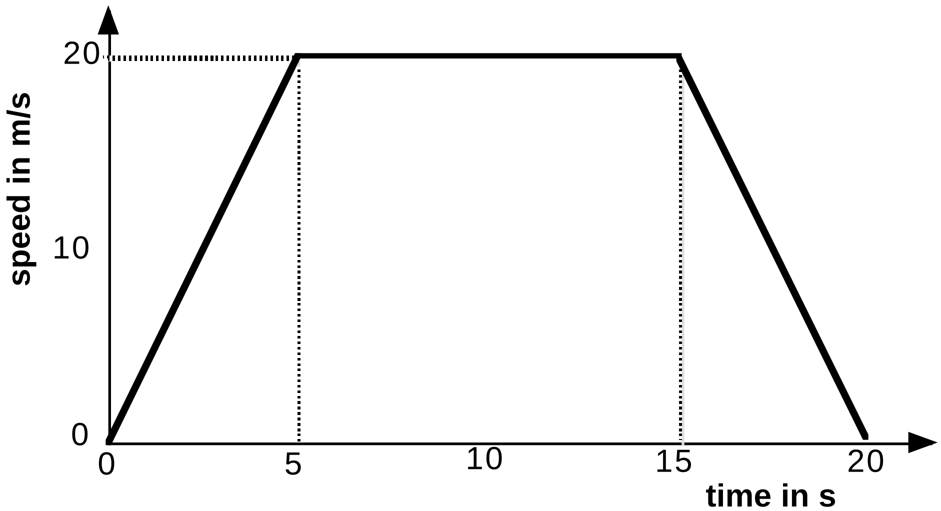
(c) covers **more distance.**



36. In Q35, is the **acceleration** of each vehicle **uniform** or **non-uniform**?

37. Sketch a possible **velocity-time graph** for an object moving with a **uniform** negative acceleration.

38. **Describe** the motion of the vehicle as shown in the **speed-time graph** below.



39. For the motion described by the speed-time graph in Q38, calculate

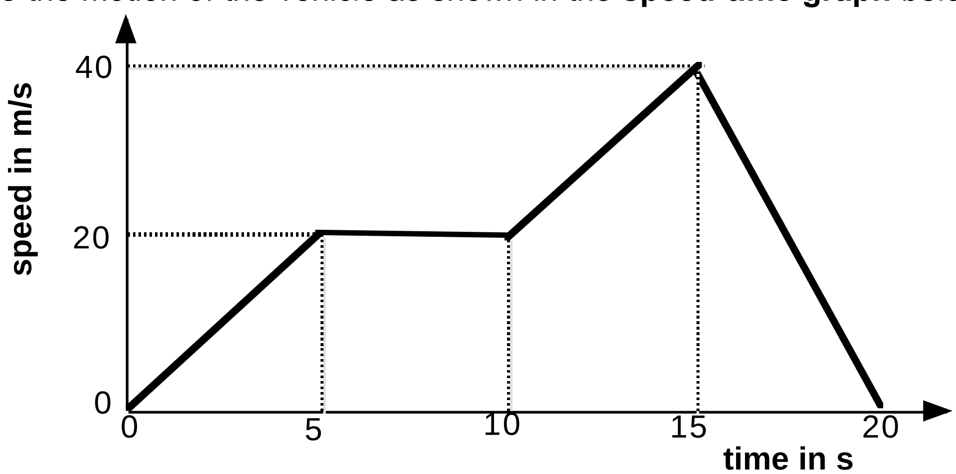
(a) the **distance** moved in the **first 5 s**,

(b) the **total distance** moved,

(c) the **average speed** of the vehicle and

(d) the **acceleration** over the first 5 s.

40. **Describe** the motion of the vehicle as shown in the **speed-time graph** below.



41. For the motion described by the speed-time graph in Q40, calculate

(a) the **distance** moved in the **first 5 s**,

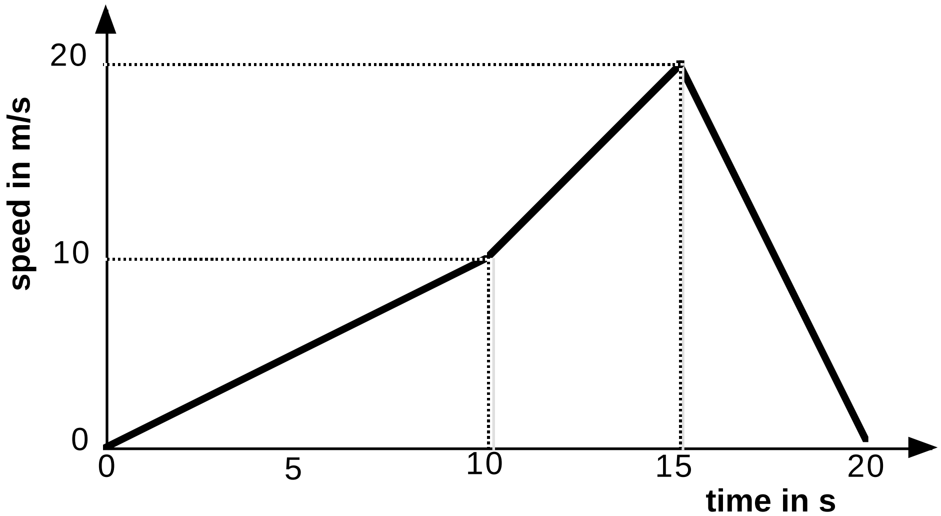
(b) the **distance** moved in the **first 10 s**,

(c) the **total distance** moved,

(d) the **average speed** of the vehicle and

(e) the **deceleration** over the last 5 s.

42. **Describe** the motion of the vehicle as shown in the **speed-time graph** below.



43. For the motion described by the speed-time graph in Q42, calculate

(a) the **distance** moved in the **first 10 s**,

(b) the **distance** moved in the **first 15 s**,

(c) the **total distance** moved,

(d) the **average speed** of the vehicle

(e) the ***smaller*** **acceleration** and

(f) the ***larger*** **acceleration**.

44. Which **two** criteria must be met for a line graph to indicate **direct proportionality** between two quantities?

45. Given a table of data with pairs of values for the **kinetic energy** and **speed** of a moving object, which **graph** would be drawn to show the mathematical relationship between the two quantities, by a **straight line through the origin**?

46. Given data consisting of pairs of velocity-time measurements for an object accelerating uniformly from rest, what **graph** could be constructed using the measurements which would be a **straight line through the origin**?

47. Given data consisting of pairs of distance-time measurements for an object accelerating uniformly from rest, what **graph** could be constructed using the measurements which would be a **straight line through the origin**?

48. Draw a **speed-time** graph for the motion of a car described thus:

"the car starts from rest and accelerates uniformly to a top speed of 15 m/sin 5 s.
It remains at this speed for 10 s before decelerating uniformly to rest in 10 s".
Calculate the **acceleration** during the first 5 s and the **distance** travelled over the whole journey.

49. Draw a **speed-time** graph for the motion of a car described thus:

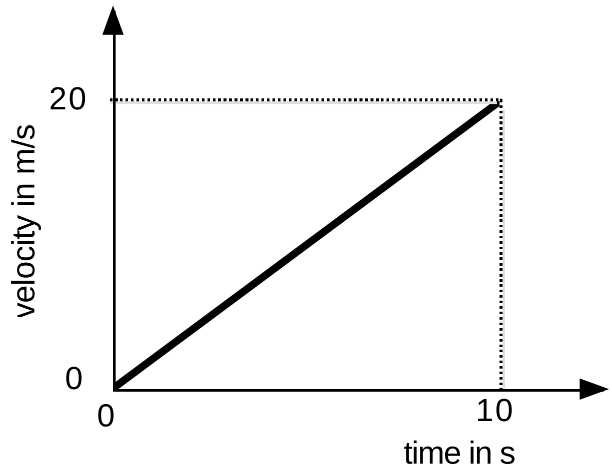
"the car starts from rest and accelerates uniformly to a speed of 10 m/s in 4 s. It stays at this speed for 6 seconds and then accelerates uniformly over 5 s to a top speed of 20 m/s. It travels at this speed for a further 5 s before decelerating uniformly to rest. The total motion lasts for 30 s".

Calculate the value of the larger **acceleration**, the **total distance** moved and the **average speed** of the car.

50. For the velocity- time graph, calculate:

(a) the **acceleration**

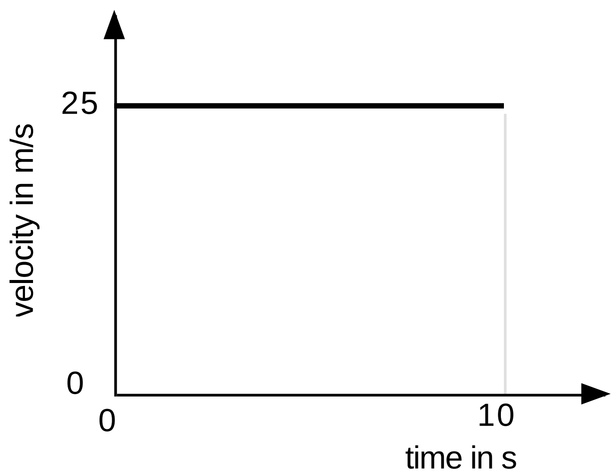
(b) the **distance** moved



51. For the velocity- time graph, calculate:

(a) the **acceleration**

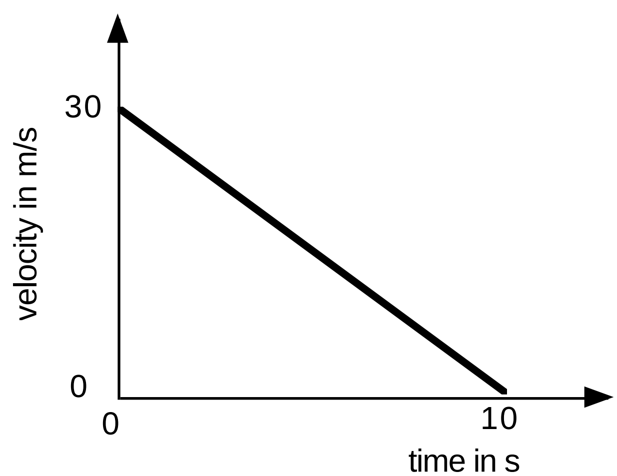
(b) the **distance** moved



52. For the velocity- time graph, calculate:

(a) the **acceleration**

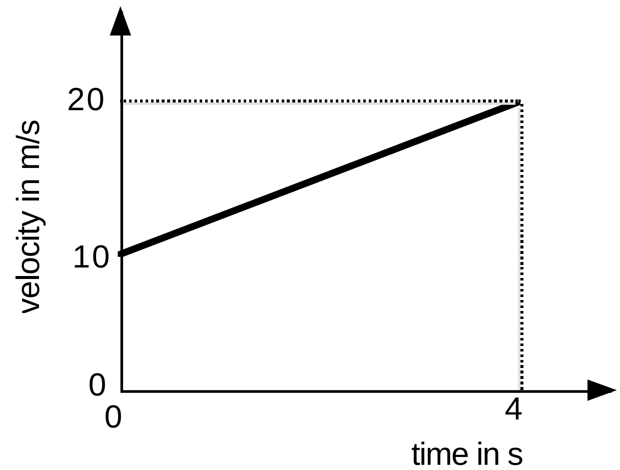
(b) the **distance** moved



53. For the velocity- time graph, calculate:

(a) the **acceleration**

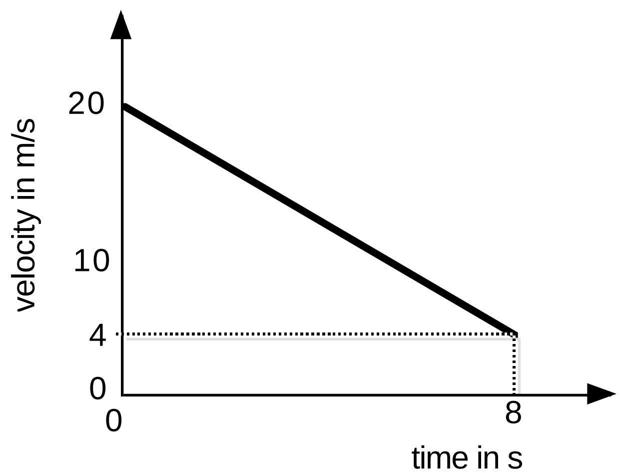
(b) the **distance** moved



54. For the velocity- time graph, calculate:

(a) the **acceleration**

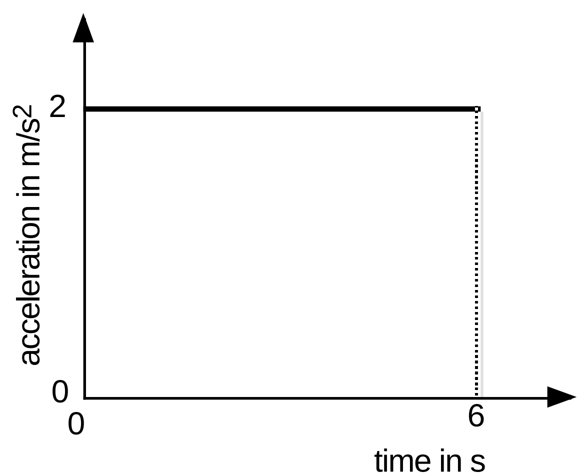
(b) the **distance** moved



55. For the acceleration-time graph of a moving object, calculate:

(a) the **change of velocity**

(b) the **final velocity** if the acceleration started when the object was moving at 10 m/s



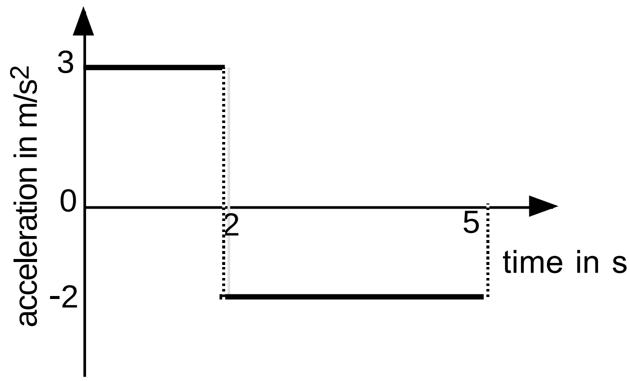
56. For the motion described by the acceleration-time graph in Q55, construct the corresponding **velocity-time** graph.

From the velocity-time graph, calculate the **total distance** moved.

57. For the acceleration-time graph of a moving object, calculate:

(a) the **change of velocity**

(b) the **final velocity** if the acceleration started when the object was at rest.

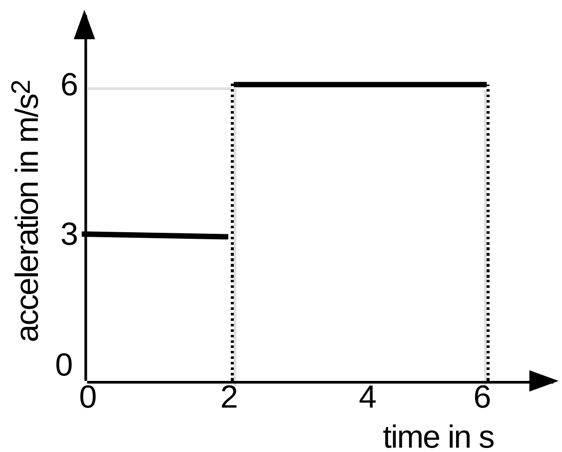


58. For the motion described by the acceleration-time graph in Q57, construct the corresponding **velocity-time** graph for the whole motion. From the velocity-time graph, calculate the **total distance** moved.

59. For the acceleration-time graph of a moving object, calculate:

(a) the **change of velocity**

(b) the **final velocity** if the acceleration started when the object was at rest.

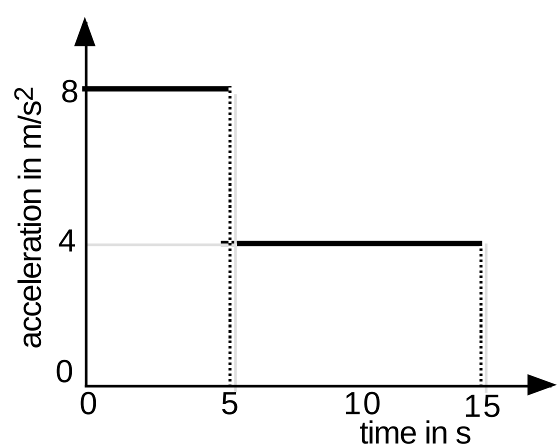


60. For the motion described by the acceleration-time graph in Q59, construct the corresponding **velocity-time** graph for the whole motion. From the velocity-time graph, calculate the **total distance** moved.

61. For the acceleration-time graph of a moving object, calculate:

(a) the **change of velocity**

(b) the **final velocity** if the acceleration started when the object was moving at 20 m/s.



62. For the motion described by the acceleration-time graph in Q61, construct the corresponding **velocity-time** graph for the whole motion. From the velocity-time graph, calculate the **total distance** moved

Using Vectors

1. Explain, by using examples, the **difference** between a ‘scalar’ and a ‘vector’ quantity.

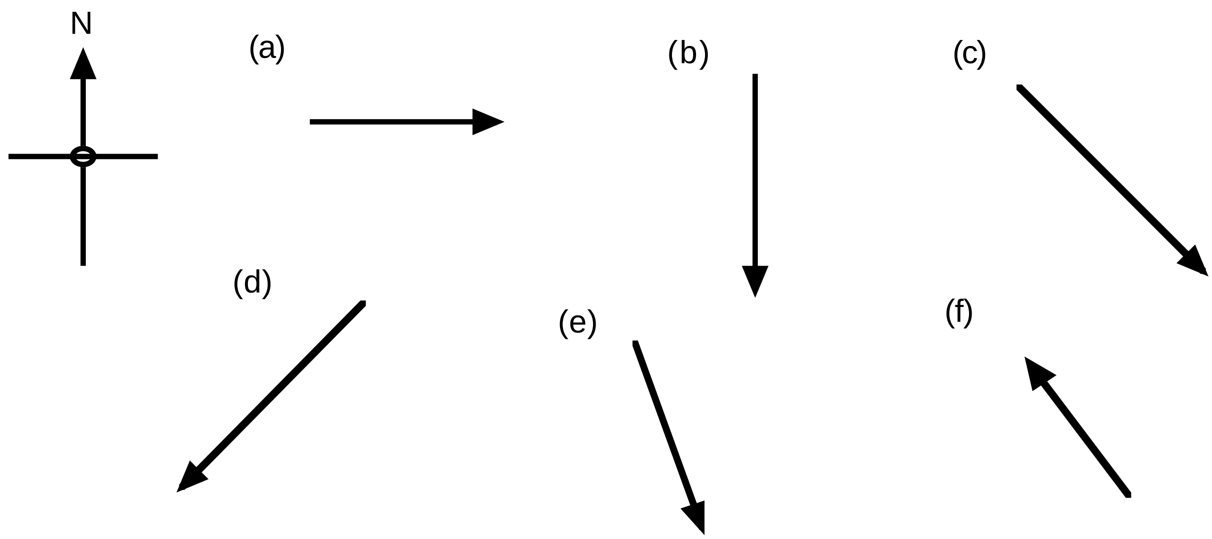
2. From the following list, identify the two **vector** quantities:

   mass **weight** **distance** **speed** **acceleration** **heat**

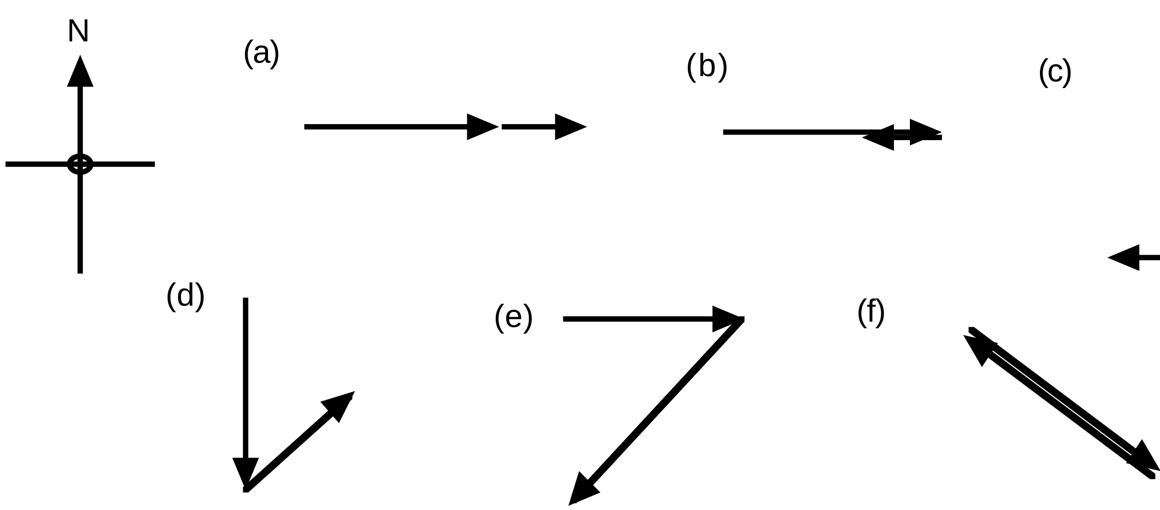
3. From the following list, identify the two **scalar** quantities:

   force **velocity** **speed** **mass** **acceleration** **displacement**

4. For each of the following **displacement** vectors, using a scale of 1cm to each metre, state the size and direction of the displacement.
   State the direction as a three figure bearing from North. (e.g. East is 090º).



5. Copy each of the following **vector diagrams**, in which two **displacement** vectors are shown **added**, and draw in the **resultant vector**.
   Measure the **resultant displacement** (size *and* direction).
   [Take the scale as 1 cm equivalent to 1 m]



6. On an orienteering course, a girl runs due north from point A to point B, a distance of 3km. She then heads in an easterly direction for 4 km to point C.

(a) How **far** has the girl run from A to C?

(b) What is the girl's **displacement** from point A when she reaches C?

7. Draw a vector diagram to represent the following displacements which occur one after the other and measure the **final displacement** (size and direction):

3 km north, then **4 km east** and finally **7 km south-west (225^o)**

8. The distance between the wickets on a cricket pitch is 22 yards. On one pitch, the wicket has a north-south orientation. A batsman scores **three** runs off one ball.

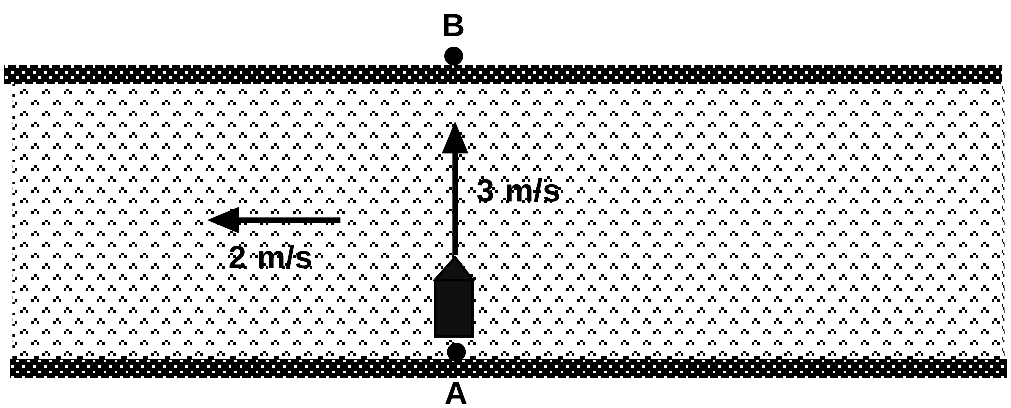
(a) What **distance** does he run?

(b) What is his final **displacement** if the wicket at which he batted is at the *south* end?

9. A sculler is rowing his boat at 3 m/s *through the water* straight across a river which is flowing at 1 m/s. What is the boat's **velocity** relative to the ground?

10. A boat is being rowed at 1.5 m/s east through the water in a river which is flowing north at 2.0 m/s. Calculate, by vector diagram, the **resultant velocity** of the boat relative to the ground.

11. A river is 24 m wide. A boat is moving through the water at 90^o to the river's current at 3 m/s. The current is flowing at 2 m/s west.



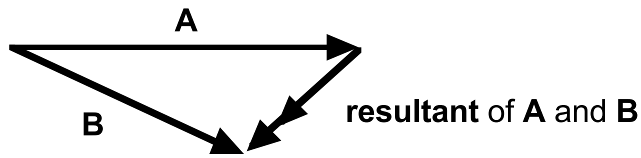
(a) How **long** will the boat take to reach the far bank of the river?

(b) What is the boat's **velocity** relative to the bank?

(c) What is the boat's **displacement** from point **B** when it reaches the far bank?

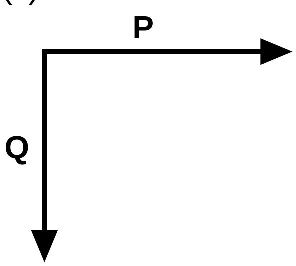
(d) Later, another driver takes the boat from point **A** and reaches point **B**. The boat still moves at 3 m/s through the water. In what **direction** did this driver steer the boat and **how long** did it take to move from **A** to **B**?

12. Criticise this vector diagram.

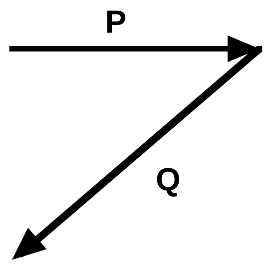


13. In each diagram, find the resultant of the two **velocity** vectors by vector addition.
State the **magnitude** and **direction** (relative to vector **P**) of the resultant.
Use a scale of 1 cm to 1 m/s.
CAREFUL: remember that vectors **must** be added 'head to tail'.

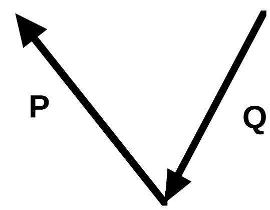
(a)



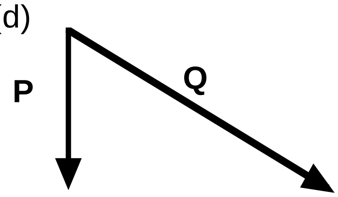
(b)



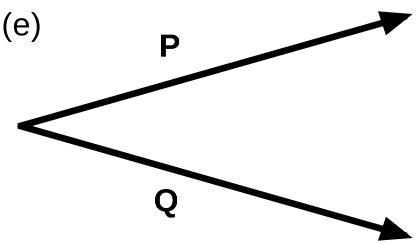
(c)



(d)

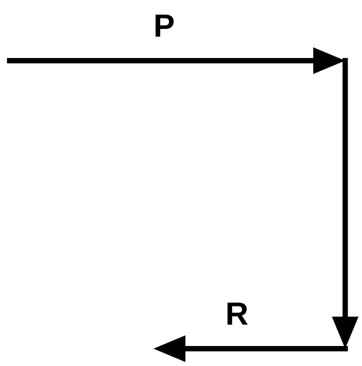


(e)

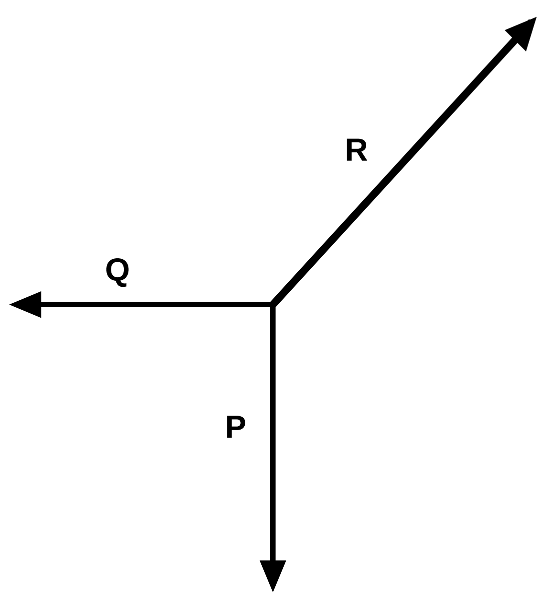


14. Find the **resultant** of these groups of three vectors (magnitude and direction relative to vector **P**).
Remember that the vectors must be added 'head to tail' in any order.

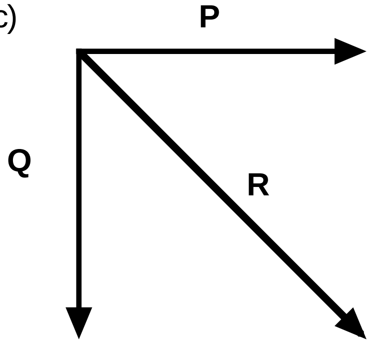
(a)



(b)



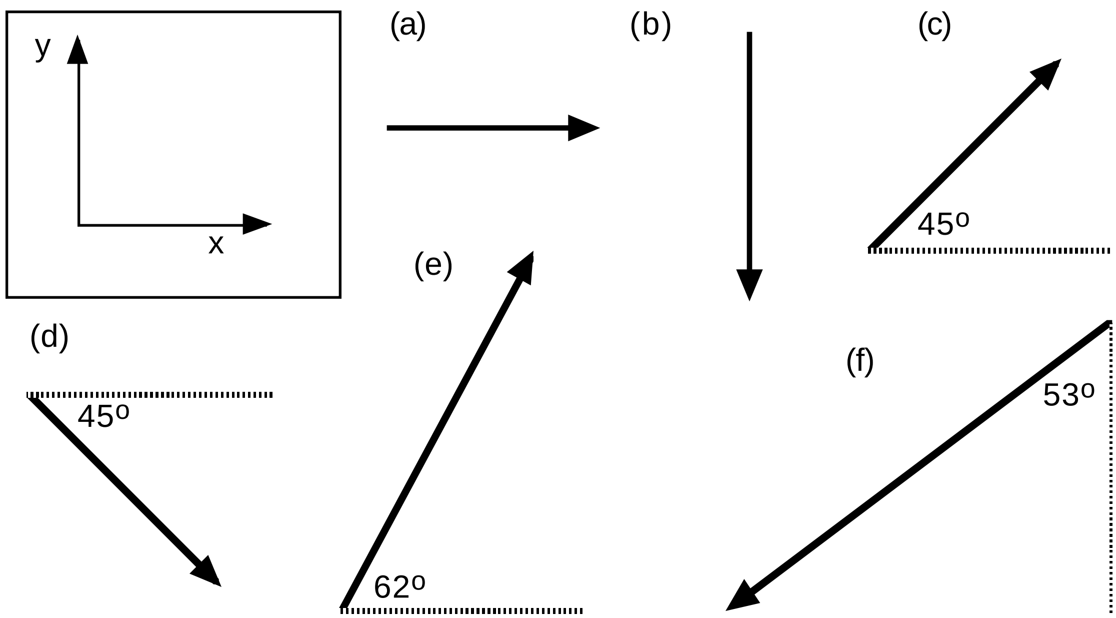
(c)



Resolving Vectors

1. For each velocity vector, find its horizontal (x) and vertical (y) **components**. For each component, calculate its magnitude and direction (that is, left or right, up or down). Do each calculation by vector diagram *and* by trigonometry.

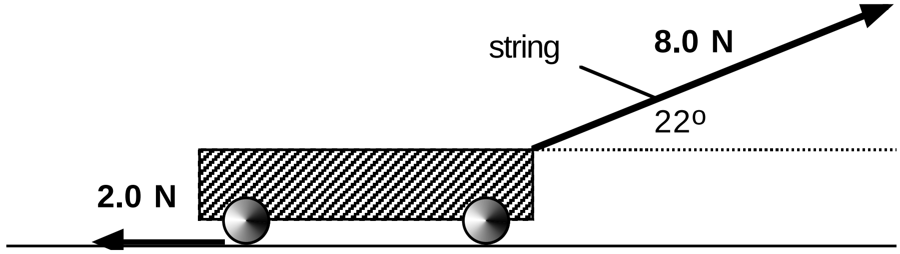
   Assume a scale of 1 cm to 1 m/s.



2. Find the values of:

   (a) sin 30° (b) sin 60° (c) cos 30° (d) cos 60° (e) sin 0°
   (f) cos 0° (g) 10 sin 30° (h) 50 cos 60° (i) 60 sin 45° (j) 60 cos 45°

3. A 2.0 kg trolley is being pulled along a horizontal surface by a string. The **tension** force in the string is 8.0 N but it makes an angle of 22° with the horizontal. There is a friction force of 2.0 N acting parallel to the surface, as shown below.

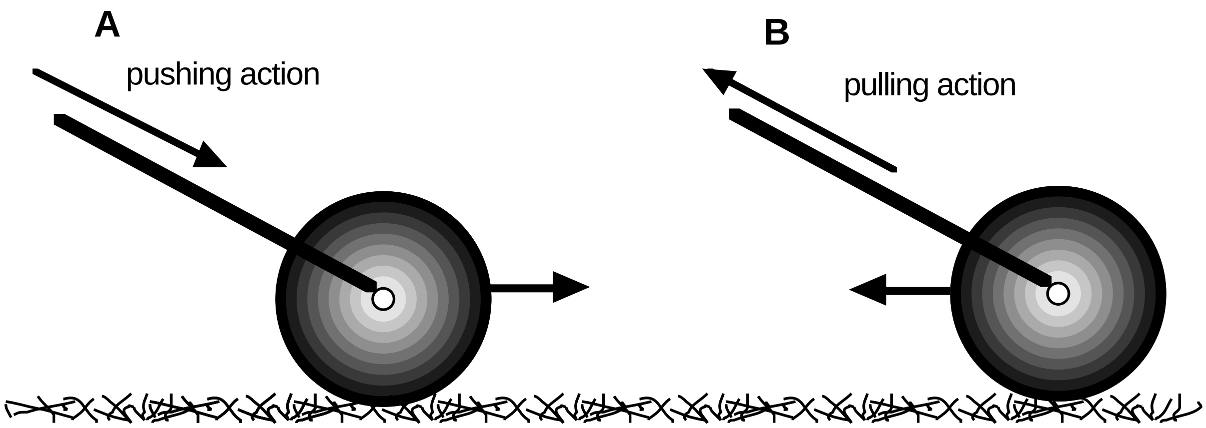


   (a) Find the **component** of the pulling force *parallel* to the surface.

   (b) What **unbalanced force** acts on the trolley?

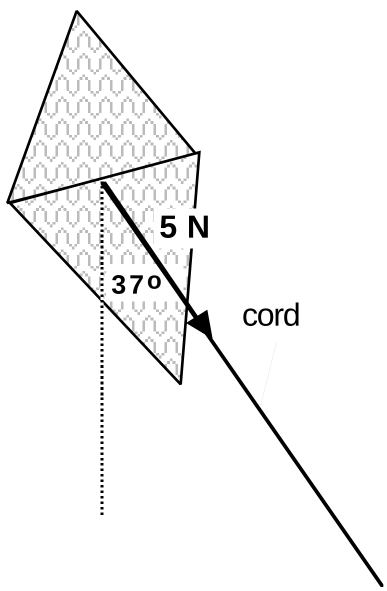
   (c) Calculate the **acceleration** of the trolley.

4. A heavy roller is being used to roll the grass on a bowling green. It is *pushed* in one direction across the green (**A**) and *pulled* in the other direction (**B**).



In which situation would the grass have the **greater** force pushing down on it as the roller passed over? Explain.

5. A 0.50 kg kite is held *at rest* in the air by a nylon cord. The **tension** in the cord is 5 newtons.



Where the cord meets the kite body, it makes an angle of 37° to the vertical.

(a) Calculate the **vertical component** of the cord's tension.

(b) What **force** is the air exerting *vertically* on the kite? Justify your answer. ['g' = 10 N/kg]

6. A footballer kicks a stationary ball. It leaves his foot at an angle of 30° to the pitch and with a speed of 18 m/s.

(a) What is the ball's **velocity** (magnitude *and* direction) just after being kicked?

(b) What are:

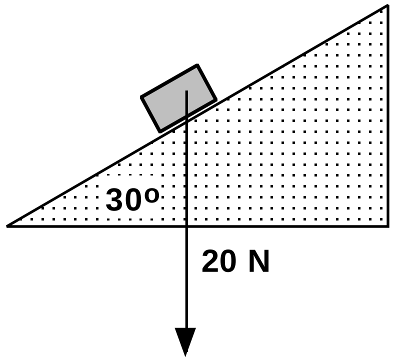
(i) the **horizontal** component of the ball's velocity

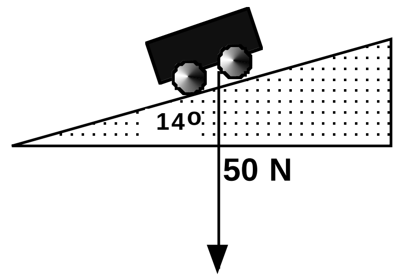
(ii) its **vertical** component, just after being kicked?

7. In each example, using trigonometry or vector diagram, calculate the **components** of the weight vector:

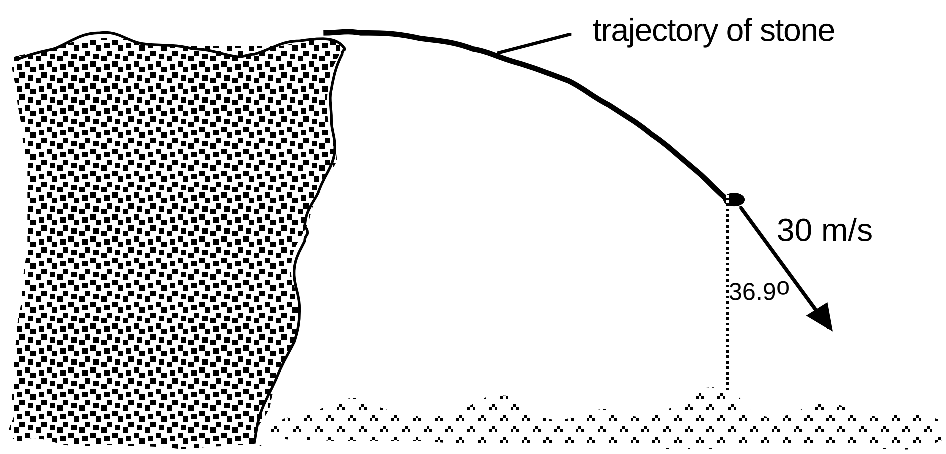
(i) **parallel** to the slope (ii) **normal** (at 90°) to the slope.

(a) (b)





8. A girl throws a stone over the edge of a cliff. After a couple of seconds, the stone has a speed of 30 m/s and is moving at an angle of 36.9° to the vertical..



(a) Calculate: (i) the **horizontal component**

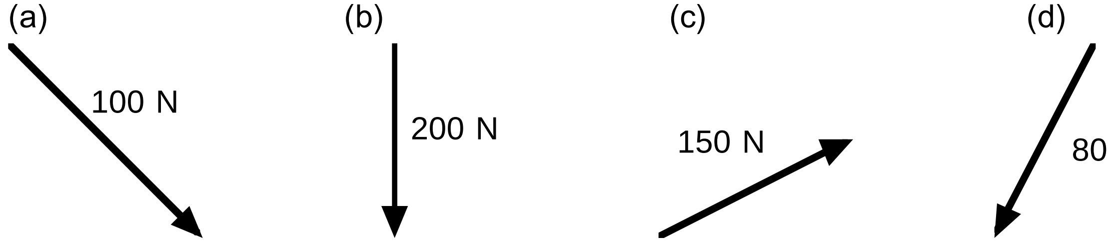
(ii) the **vertical component** of the stone's velocity at that point.

(b) The horizontal component of the stone's velocity stays the same but its vertical component increases with time.
How would the **direction** of the stone's velocity change as time went on?

9. Which of these *horizontal components* goes with which force vector?

0 N **71 N** **36 N** **134 N**

(a) (b) (c) (d)



Projectiles

1. Which of these situations could be described as examples of **projectile** motion? **Explain** why the others are **not** projectiles.

   (a) a plane flying at a steady height (b) a bullet moving along the barrel of a rifle
   (c) a tennis ball in the air after being hit
   (d) a hockey ball rolling in a straight line along the pitch
   (e) a bullet after leaving the end of the rifle barrel
   (f) a bird of prey diving to catch a rabbit (g) a satellite in orbit round the Earth
   (h) a flying fish, after leaping out of the water
   (i) an artillery shell, just after been fired from a cannon
   (j) a bomb dropped from an aircraft
   (k) a trolley rolling down a friction-compensated slope
   (l) a fireworks rocket just after launch

[In all subsequent problems, unless otherwise stated, take 'g' as 9.8 m/s^2 and assume the effects of air resistance are negligible.]

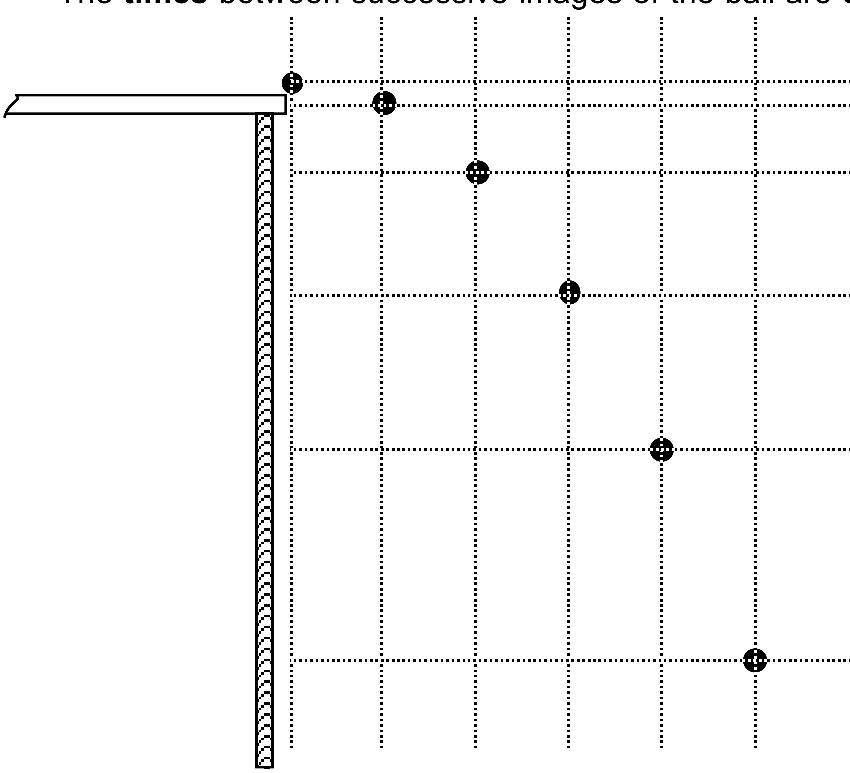
2. Ignoring the effect of air resistance, in which **direction** does a projectile have a constant **velocity** whilst it is in motion above the ground?

3. Ignoring the effect of air resistance, in which **direction** does a projectile have a constant **acceleration** whilst it is in motion above the ground?

4. Close to the Earth's surface, and ignoring the effects of air resistance, what are the size and direction of a projectile's **acceleration** if its **mass** is:

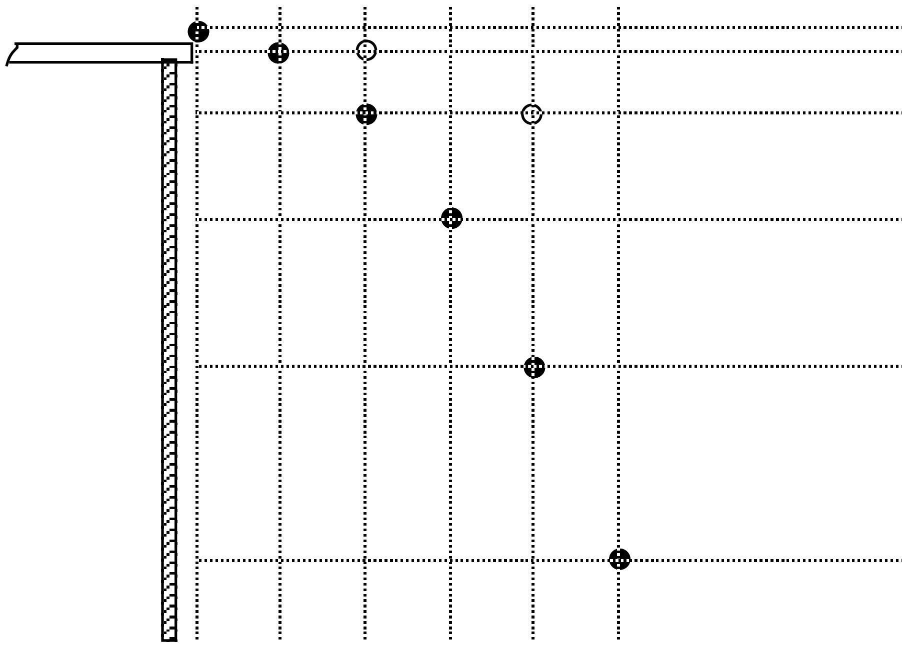
   (a) 1 kg (b) 10 kg (c) 500 g (d) 3 tonnes?

5. The diagram shows a strobe 'photo' of a ball which has rolled off the edge of a table. The **times** between successive images of the ball are **equal**.



By making measurements on the diagram, **show** that the ball has a **uniform horizontal velocity** and a **uniform vertical acceleration**.

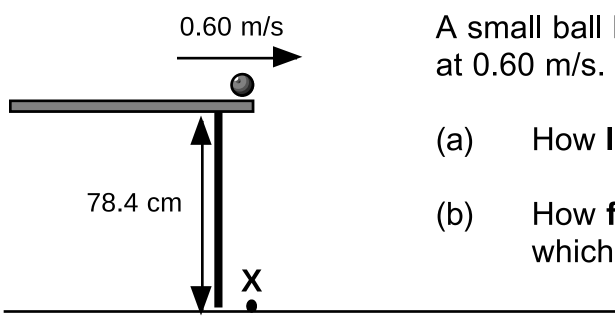
6. The diagram shows a strobe ‘photo’ of two balls, one black, one white, which have rolled off the edge of a table at the *same* instant but with *different* horizontal speeds. The **times** between successive images of the balls are **equal**. The ‘photo’ for the white ball is incomplete. Trace the position of the balls and grid lines and add the positions of the **next three** images of the *white* ball.



7. Ignoring the effect of air resistance on compact, heavy projectiles such as rocks, which **shape** of path (trajectory) do projectiles have:

diagonal straight line, parabola, arc of circle or section of an ellipse?

8.



A small ball bearing rolls off the edge of a horizontal table at 0.60 m/s. The table is 78.4 cm high.

(a) How **long** does it take to reach the floor?

(b) How **far** along the floor does it land from point **X** which is directly underneath the table’s edge?

9. A stone is kicked *horizontally* over the edge of an 80 metre high cliff. It hits the sea below 60 metres from the foot of the cliff. [Take ‘g’ as 10 m/s^2]

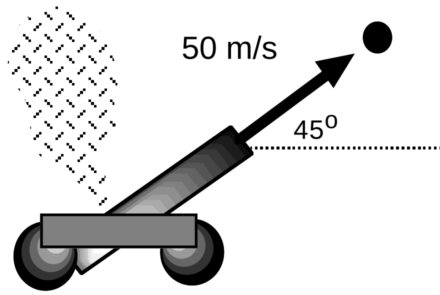
(a) How **long** does the stone take to fall down to the sea?

(b) With what **speed** was it kicked off the edge?

(c) What is the stone’s **velocity** (size *and* direction) *just before* hitting the sea?

10. During a cricket match, a fielder lobs the ball back to the bowler in a high, curving trajectory. What is the **size** and **direction** of the ball’s acceleration at **all** points of its flight between being thrown and caught?

11. A cannonball is fired from ground level at a speed of 50 m/s.
The initial direction of its trajectory is 45º to the horizontal.



(a) What are the initial **horizontal** and **vertical components** of the cannonball's **velocity**?

(b) What is the ball's **vertical velocity** when it reaches its *highest* point?

(c) What **height** does the ball reach?

(d) What is its **acceleration** (size and direction) at its highest point?

(e) Assuming level ground, how **long** does the cannonball take to come back down to ground level?

(f) What is the cannonball's horizontal **range**?

12. A stone is projected horizontally from a cliff top at 18 m/s. By constructing vector diagrams, find the **magnitude** and **direction** of the stone's **velocity** after the following time intervals, taking 'g' as 10 m/s^2:

(a) 1.0 s (b) 1.8 s (c) 2.4 s (d) 3.0 s (e) 5.2 s

[Check your answers using trigonometry.]

13. A ball is kicked over the edge of a high cliff with a horizontal speed of 30 m/s.
Take 'g' as 10 m/s^2.

(a) After how **long** does it make an angle of 45º with the horizontal?

(b) Calculate the ball's **velocity** (magnitude and direction) after 4 seconds.

(c) How **far** has the ball fallen vertically after 4 seconds?

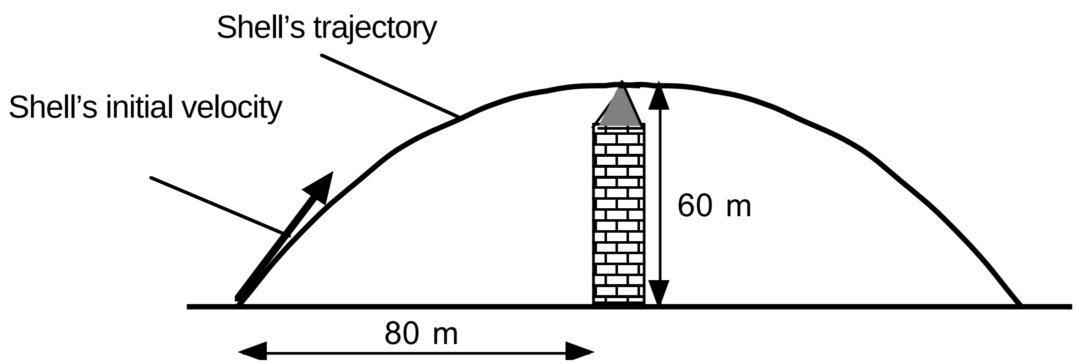
(d) How **far** from the edge of the cliff is the ball after 4 seconds?

(e) If it takes 5.0 seconds to reach the bottom of the cliff, what is the cliff's **height**?

(f) What is the size and direction of the ball's **acceleration** *just before* hitting the foot of the cliff?

14. A missile is fired from a gun with an elevation of 30º to the horizontal.
It reaches a height of 45 m. Find the **speed** with which it left the gun. ['g' = 10 m/s^2]

15. A shell is fired from a cannon at a certain angle above the horizontal.

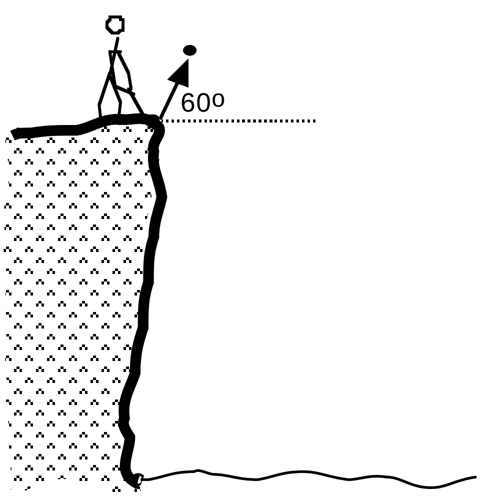


When it is at its greatest height, it *just* clears a 60 m tall building which is 80 m away from the cannon. Calculate the **initial velocity** of the shell, both size and direction.

16. (a) With what **horizontal speed** would a snooker ball need to be projected from the edge of a 78.4 cm high table to strike the floor 2.8 metres from a point directly under its point of projection?

(b) Calculate the ball's **velocity** (size and direction) *just before* striking the floor.

17. A golfer is practising his chipping from the very edge of a cliff. In one shot, he chips a ball at a speed of 30 m/s and at an angle of 60º to the horizontal.



(a) What **height** above the top of the cliff does the ball reach?

(b) What is the ball's **velocity** after 4 s?

(c) How **high** above the cliff is the ball after 4 s?

(d) If the cliff is 112 m high, for how **long** is the ball in the air?

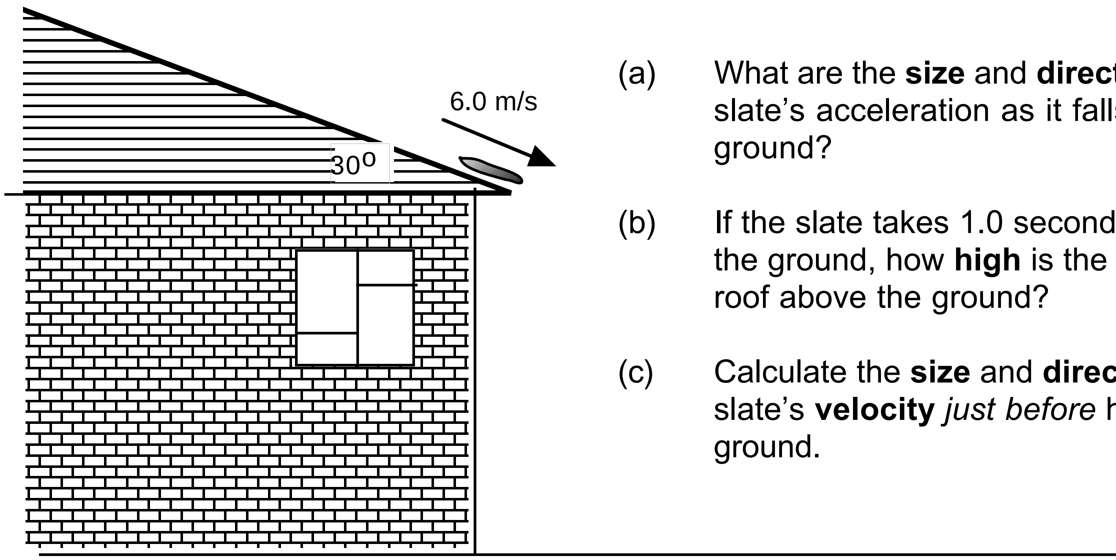
(e) What are the ball's **velocity** and **acceleration** at its highest point?

18. (a) At what **angle** to the horizontal was a ball kicked from the ground if it reached a greatest height of 7.2 m with a projected speed of 20 m/s?

(b) How **long** would the ball take to fall back to the ground from being kicked?

(c) With what **speed** would the ball hit the ground?

19. A piece of slate slides down a house roof and leaves the end at 6.0 m/s. The roof is at an angle of 30º to the horizontal. The slate becomes a projectile as soon as it loses contact with the roof.

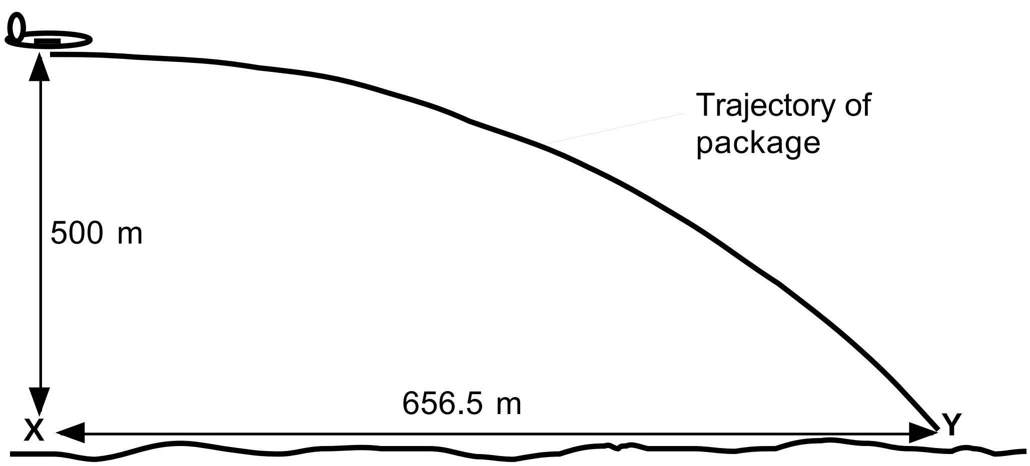


(a) What are the **size** and **direction** of the slate's acceleration as it falls to the ground?

(b) If the slate takes 1.0 second to fall to the ground, how **high** is the edge of the roof above the ground?

(c) Calculate the **size** and **direction** of the slate's **velocity** *just before* hitting the ground.

20. A plane, flying horizontally at a height of 500 m above point **X** on the ground, drops a package which hits the ground at point **Y**. The distance from **X** to **Y** is 656.5 m.



At what **speed** was the plane flying when the package was released?

21. A cannonball's range depends on its speed and the angle at which it is fired.

(a) For a cannonball fired at a speed of 50 m/s, find the **horizontal range** (to 3 sig. figs.) when the cannon is elevated at these angles to the horizontal:

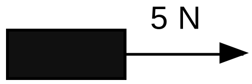
(i) 30º (ii) 35º (iii) 40º (iv) 45º (v) 50º (vi) 55º

(b) From the pattern of your results, suggest which **angle** would yield the biggest horizontal range for *any* projection speed.
Confirm your choice by calculating the range at, 50 m/s, for a projected angle **one degree above** and **one degree below** your answer. [You will need to make the calculations correct to 5 significant figures.]

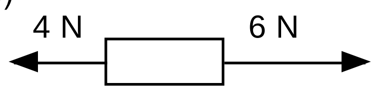
Unbalanced Force

In each example, state the **size** and **direction** of the **unbalanced force** acting on the object.

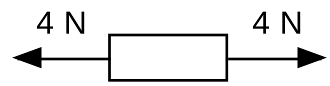
(a)



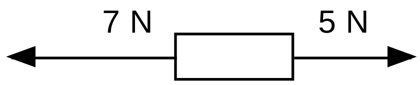
(b)



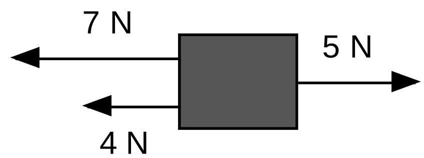
(c)



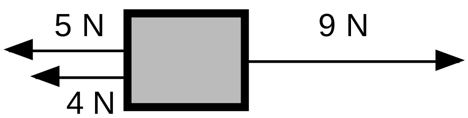
(d)



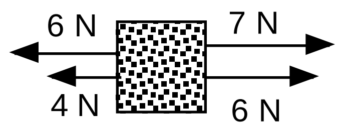
(e)



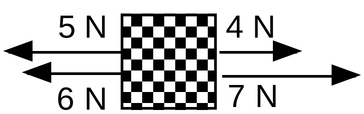
(f)



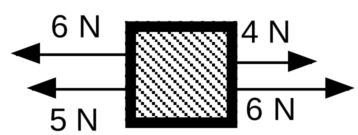
(g)



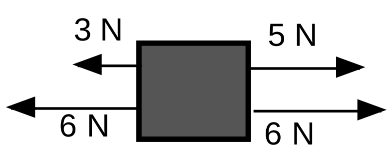
(h)



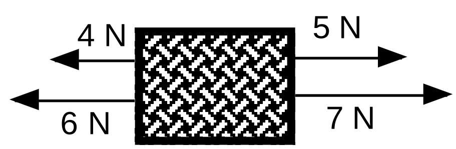
(i)



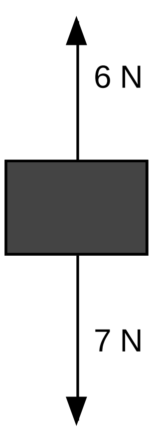
(j)



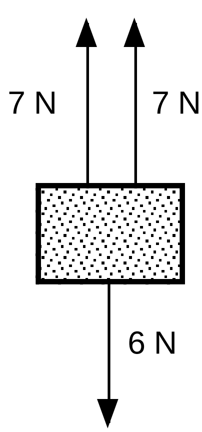
(k)



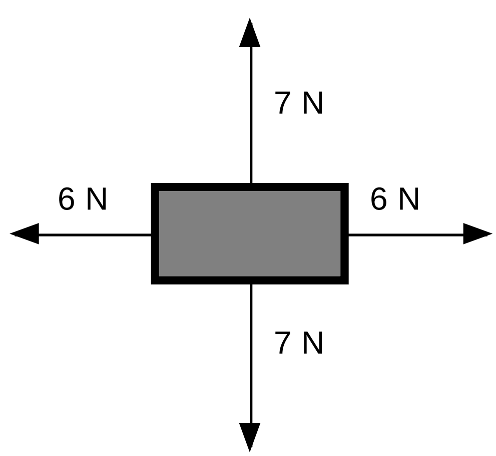
(l)



(m)



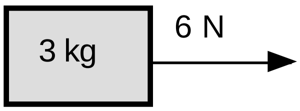
(n)



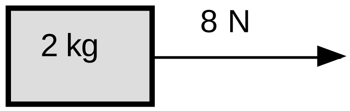
Newton’s 2nd Law

In each of the following examples, use the formula **F = ma** to calculate the **size** and **direction** of the **acceleration** of the object, by firstly finding the **unbalanced force** acting on it.

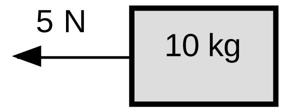
(a)



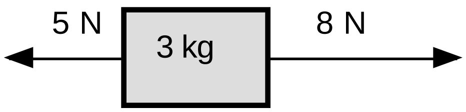
(b)



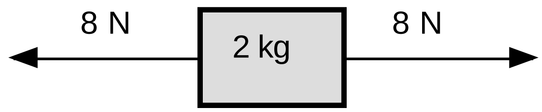
(c)



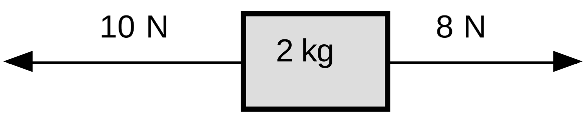
(d)



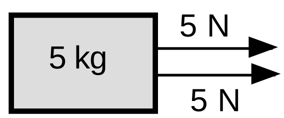
(e)



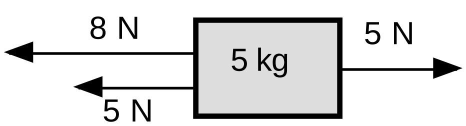
(f)



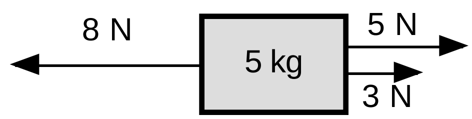
(g)



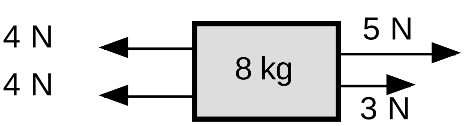
(h)



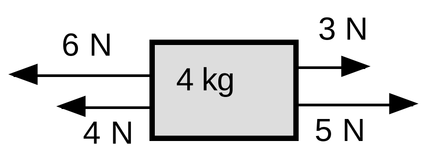
(i)



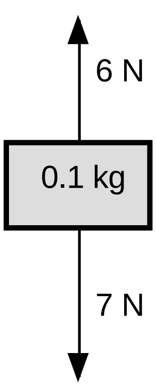
(j)



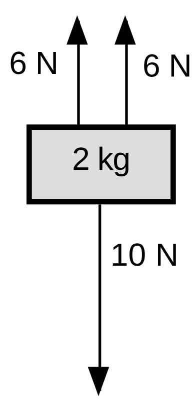
(k)



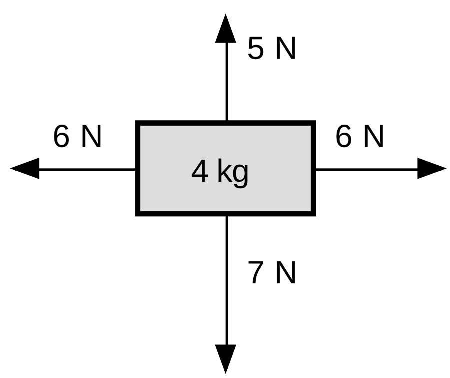
(l)



(m)



(n)



Force = mass x acceleration

1. Use the formula **force = mass x acceleration (F = ma)** to calculate the missing entries in the table.

force (N)	mass (kg)	accel. (m/s^2)
-	3	0
-	4	2
-	5	0.2
0	2	-
10	1	-
0.5	2	-
19.6	-	9.8
50	-	100

2. What **unbalanced force** acts on a 70 kg mass if it accelerates at a rate of 1.6 metres per second per second?

3. What is the **acceleration** of a 10 kg mass which has **no** unbalanced force acting on it?

4. A 1200 kg vehicle is accelerating along a straight road at 3 m/s^2. What is the magnitude of the **unbalanced force** acting on it?

5. What unbalanced force acts on a mass of 3 kg which accelerates at 4 m/s^2 on a horizontal surface if :

(a) there is **no** friction and (b) if there **is** friction of 4 N? (Careful!)

6. What is the size of the **friction** force if a 3 kg mass accelerates along a horizontal surface at 2.5 m/s^2 when acted on by a pulling force of 10 N?

7. What is the **unbalanced** force acting on a car of mass 1800 kg being driven along a flat, horizontal road if the forward engine force is 5000 newtons and friction amounts to 500 newtons? What is its **acceleration**?

8. A bicycle is being ridden along a horizontal road by a “pedal” force of 400 N. Its speed is **constant** at 12 m/s. What is the total value of the **frictional** forces acting on the bike and its rider?

9. A 1500 kg car accelerates at 1.5 m/s^2 along a horizontal road. If the frictional forces acting against the car’s motion total 1000 N, what **driving** force is exerted on the road by the car’s wheels?

10. Two men are pushing a broken down car, mass 1800 kg, along a horizontal road with a combined horizontal force of 1000 N. At one instant, the car accelerates at 0.25 m/s^2. What is the value of the **frictional force** acting on the car at this **instant**?

11. Two men, each exerting a horizontal push of 500 newtons, accelerate a broken-down car from rest at 0.3 m/s^2 along a flat, horizontal road. If the car's weight is 14000 newtons, calculate the total value of the **frictional forces** acting on the car. (Take 'g' = 10 N/kg.)

12. The engines of a hovercraft, mass 12 tonnes, travelling in a straight line at a constant speed of 15 m/s, develop a forward thrust of 30 kN.

What is the total magnitude of the frictional **forces** acting on the vessel?

13. A 1400 kg car is travelling at 14 m/s along a flat, straight section of road. The driver allows the car to 'free-wheel' and finds that it takes 10 seconds to slow down to 11 m/s. Calculate:

(a) the size of the car's **deceleration,** (b) the size of the **force** slowing the car.

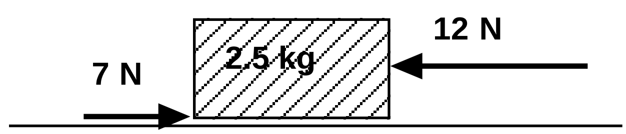
14. A 1200 kg car accelerates uniformly from 14 m/s to 22 m/s in a time of 5 s along a straight, flat section of road.

(a) Calculate the car's **acceleration** and the **unbalanced force** causing it to accelerate.

(b) If the total frictional force acting on the car is 450 N, what is the size of the **'engine' force**?

15. A mass of 2.5 kg is acted on by a 12 N force, with 7 N of **friction** acting in the opposite direction.

Calculate the **unbalanced** force on the mass and the **magnitude** of its acceleration.



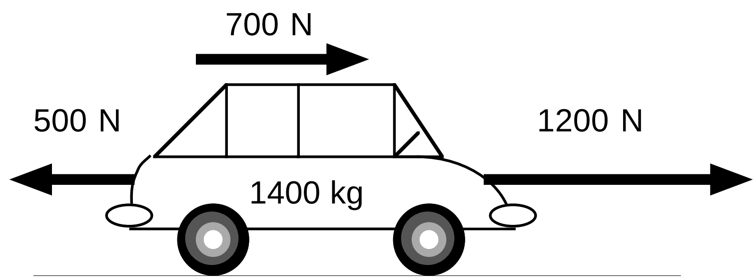
16. A car driver puts her car in a low gear on a straight, level stretch of road and, without using the brakes, decelerates uniformly from 10 m/s to 4 m/s in 8 s.

(a) If the car's mass is 1200 kg, calculate its **deceleration** and **unbalanced force** on the car.

(b) Later, the driver is able to go down a gentle slope at a **constant** speed of 7 m/s in the **same** gear without using the engine or the brakes.
What size is the **force** on the car **down the slope** likely to be?

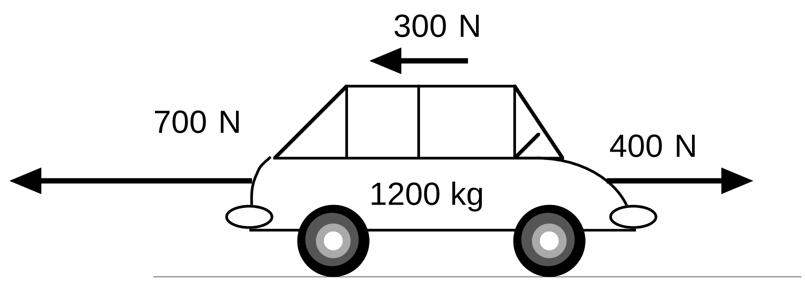
17. What **forward force** would be needed to accelerate a 5 kg mass at 2 m/s^2 in a straight line along a level surface if the frictional force between the mass and the surface is 10 N?

18. The drawing shows a 1400 kg car travelling along a flat, straight road.



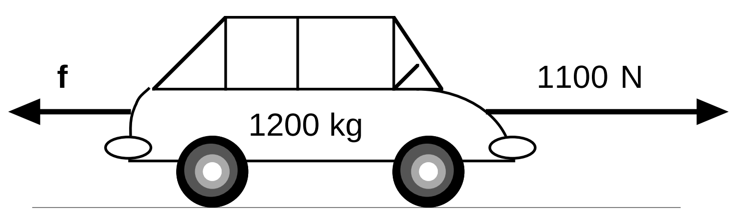
Identify the **engine force**, the **frictional force** and the **unbalanced force**.
Calculate the car's acceleration with these forces acting on it.

19. The drawing shows a 1200 kg car travelling along a flat, straight road.



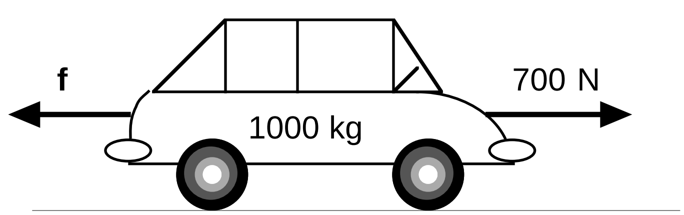
Identify the **engine force**, the **frictional force** and the **unbalanced force**.
Calculate the car's acceleration with these forces acting on it.

20. The car in the drawing is travelling along a straight, horizontal road.



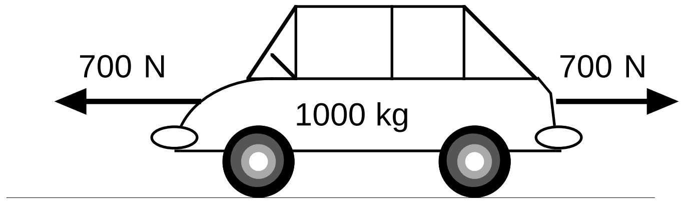
The car's mass is 1200 kg and it is accelerating forward at 0.5 m/s^2.
Calculate the **unbalanced force** acting on the car and the size of **'f'**, the **friction** force.

21. The car in the drawing is moving at a steady velocity along a straight, horizontal stretch of road. Its mass is 1000 kg.



(a) What is the value of the **friction force**, **f**, acting on the car?
(b) If the 'engine' force was now removed, what would be the initial size of the car's **deceleration**?

22. The car in the drawing is moving along a straight, horizontal stretch of road. Its mass is 1000 kg.



(a) What is the **unbalanced force** acting on the car?

(b) What can be stated about the car's **motion**?

(c) If the frictional forces stayed the same and the **'engine' force** was increased to 1200 N, what would the car's **motion** now be?

23. A shopping trolley, loaded with items, has a total mass of 100 kg. It is being pushed by a man at a steady speed in a straight line at 0.5 m/s with a horizontal force of 5 newtons.

(a) What is the size of the **frictional force** acting on the trolley?

(b) If the man stopped pushing the trolley, what would its motion become?

(c) Assuming the frictional force did **not** vary with speed, how **long** would the trolley take to stop on its own?

24. A ball of mass 200 grams rolls down a steep hill. Its acceleration is measured to be 4 m/s^2. What **unbalanced force** acts on the ball?

25. What **forward force** would be needed to accelerate a 2 kg mass at 3 m/s^2 in a straight line along a level surface if the frictional force between the mass and the surface is 2 N?

26. What **forward force** would be needed to accelerate a 6 kg mass at 3 m/s^2 in a straight line along a level surface if the frictional force between the mass and the surface is 10 N?

27. Use the formula **force = mass x acceleration** to calculate the missing entries in the table.

force (N)	**mass (kg)**	**accel. (m/s^2)**
-	2×10^3	10
-	3×10^4	0.10
-	10^6	0.001
3×10^4	2×10^3	-
1.6×10^3	2.0	-
2.4×10^3	4.8×10^4	-
0.1	-	0.01
3.2×10^{-3}	-	10^{-4}

28. A 50 kg boy, who weighs 500 N, is standing in a lift which is accelerating **upwards** at a rate of 1 m/s^2.

(a) What is the size and direction of the **unbalanced force** on the boy?

(b) With what size of force does the lift **floor** push on his feet?

29. A man of weight 800 N is standing on scales in a lift moving at a **constant velocity** of 2 m/s between floors. What do the scales read if the lift is moving (a) **up** (b) **down**?

30. Taking 'g' as 10 N/kg, what **thrust** would be needed to accelerate a rocket of mass 500 x 10^3 kg vertically upwards at 2.5 m/s^2?

31. What **unbalanced** force acts on a 40 kg girl travelling downwards in a lift which is increasing its speed at the rate of 2.5 m/s^2?

32. A 70 kg man is in a lift accelerating upwards between floors at 2.5 m/s^2. How **heavy** does he ***feel*** and what is his ***actual*** **weight**?

33. A 90 kg man is standing on a set of scales in a moving lift. At an instant when the lift is moving **down** and getting faster at the rate of 3 metres per second per second, what would the scales **read**? (Take 'g' as 10 N/kg).

34. A 40 kg girl, who weighs 400 N, is standing in a lift which is accelerating **upwards** at a rate of 1.5 m/s^2.

(a) What is the size and direction of the **unbalanced force** on the girl?

(b) With what size of force does the lift **floor** push up on her feet?

35. An 80 kg man, who weighs 800 N, is standing in a lift which is accelerating **downwards** at a rate of 1.5 m/s^2.

(a) What is the size and direction of the **unbalanced force** on the man?

(b) With what size of force does the lift **floor** push up on his feet?

36. A 60 kg woman, who weighs 600 N, is standing in a lift which is accelerating **downwards** at a rate of 2 m/s^2.

(a) What is the size and direction of the **unbalanced force** on the woman?

(b) With what size of force does the lift **floor** push up on her feet?

37. An 80 kg man, who weighs 800 N, is standing in a lift. The lift floor is pushing **upwards** on his feet with a force of 880 N.

(a) What is the size and direction of the **unbalanced force** on the man?

(b) What is the **acceleration** of the lift (size and direction)?

38. A 60 kg woman, who weighs 600 N, is standing in a lift. The lift floor is pushing **upwards** on her feet with a force of 540 N.

(a) What is the size and direction of the **unbalanced force** on the woman?

(b) What is the **acceleration** of the lift (size and direction)?

39. A 1 kg mass is hanging from a newton balance in an **upward** moving lift. What is the lift's **motion** when the balance reads 10.3 N? ('g' = 10 N/kg)

40. An 80 kg man, who weighs 800 N, is standing in a lift. The lift floor is pushing **upwards** on his feet with a force of 800 N.

(a) What is the size and direction of the **unbalanced force** on the man?

(b) What is the **motion** of the lift?

41. A 60 kg boy, standing on a set of scales in an upward moving lift, *appears* to weigh 690 N. What is the **actual** weight of the boy and what is the **motion** of the lift?

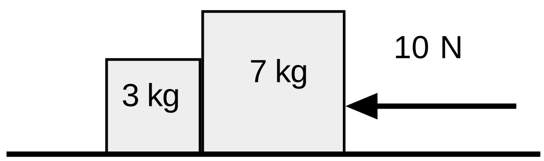
42. A woman of mass 60 kg is in a lift which is moving **down** between floors. At one instant, the lift is **accelerating down** at 1.5 m/s^2.

What is her ***apparent*** weight at that instant and her ***actual*** weight?

43. In the situation below, two blocks are in contact and on a **frictionless** surface. Calculate:

(a) the **acceleration** of the blocks.

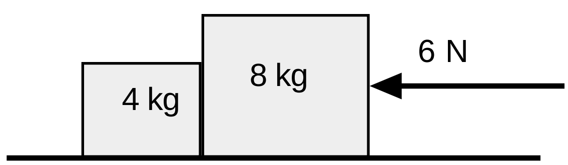
(b) the **force** pushing the **smaller** block.



44. In the situation below, two blocks are in contact and on a **frictionless** surface. Calculate:

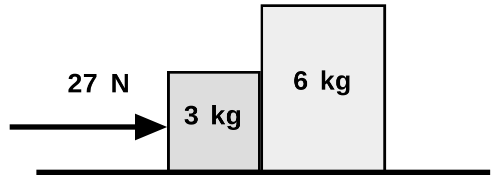
(a) the **acceleration** of the blocks.

(b) the **unbalanced force** pushing the **larger** block.



45.

Two masses are pushed along a smooth, horizontal surface by a force of 27 N. There is **no** friction. Calculate the **acceleration** of the masses and the **force** pushing the **6 kg** mass.

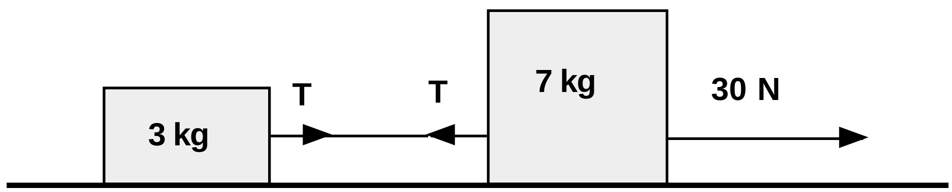


46. Two masses, joined by a light cord, are being pulled along a **frictionless** surface, as shown, by a **30 N** force. Calculate:

(a) the **acceleration** of the masses,

(b) the **unbalanced force** on the **3 kg** mass,

(c) the **tension**, **T**, in the cord.



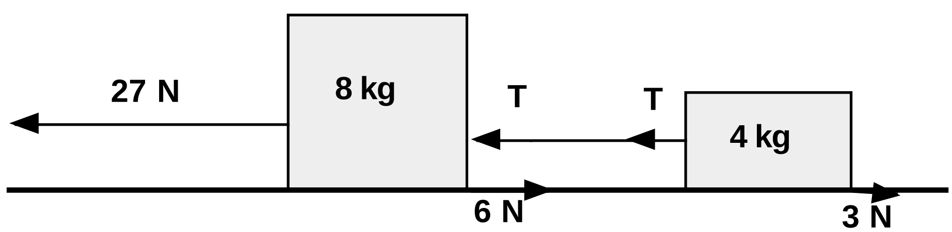
47. Two masses, joined by a light cord, are being pulled along a surface, as shown, by a **27 N** force. There is **6 N** of friction between the larger mass and the surface and **3 N** between the smaller mass and the surface. Calculate:

(a) the **acceleration** of the masses,

(b) the **unbalanced force** on the **4 kg** mass,

(c) the **unbalanced force** on the **8 kg** mass and

(d) the **tension**, **T**, in the cord.

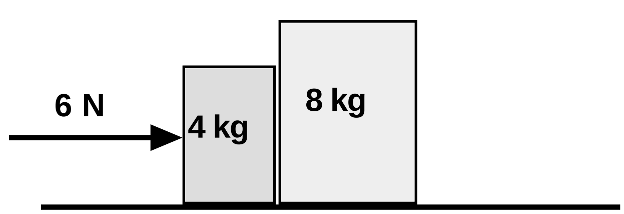


48. Two blocks are pushed along a **frictionless** surface, as shown, by a force of 6 N. Calculate:

(a) the **acceleration** of the blocks,

(b) the **unbalanced force** on the **4 kg** block and

(c) the **force** exerted by the 8 kg block on the 4 kg block.



49. A 250 tonne rocket accelerates vertically upwards from the launchpad on Earth at 1.5 m/s^2.

(a) What is the **unbalanced force** on the rocket ?

(b) What **thrust** is developed by the rocket's engines in meganewtons (MN)?

('g' for Earth = 10 N/kg; 1 tonne = 1000 kg)

50. A small spacecraft of mass 2.3 tonne is designed to lift off from the Moon's surface at 3 m/s^2 vertically upwards.

(a) What is the **unbalanced force** on the spacecraft?

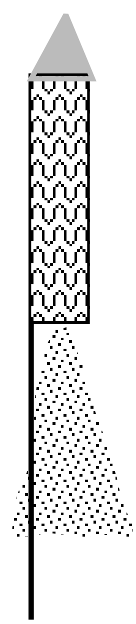
(b) What **thrust** is developed by its engines?

('g' for Moon = 1.6 N/kg; 1 tonne = 1000 kg)

51. What is the **mass** (in tonnes) of a rocket taking off from the Earth's surface if a thrust of 3.2×10^5 N from the engines produces an upward acceleration of 0.67 m/s^2?

('g' for Earth = 10 N/kg; 1 tonne = 1000 kg)

52. A fireworks rocket with a mass of 40 g is set off. Immediately after lift off, its acceleration is measured at 25 m/s^2.



Calculate the **thrust** developed by the rocket at lift off.
(Assume the effect of air resistance is negligible).

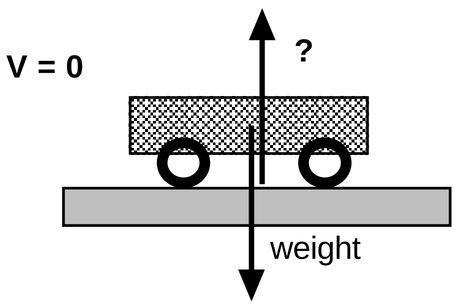
53. What minimum rocket **thrust** would be required to enable a 4510 kg spacecraft to lift off from the surface of Mars with a vertical acceleration of 2.5 m/s^2?

(Answer to **two** significant figures). Take 'g' for Mars to be 3.7 N/kg.

Force Diagrams

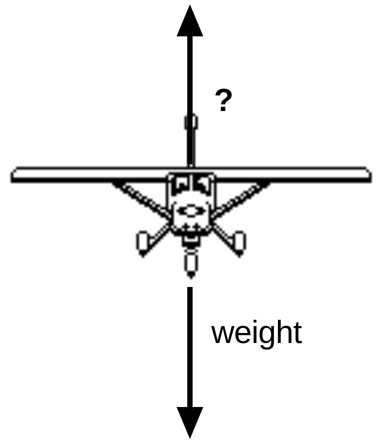
1. **Name** the force marked '**?**'

   How does its **size** compare to the trolley's weight?



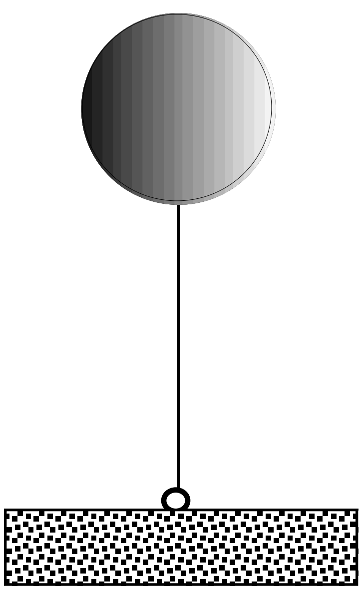
2. The plane is in level flight.
   Name the force marked '**?**'

   How does its **size** compare to the plane's weight?



3. The helium balloon is tethered to a ring on the ground by a very light cord. Copy the diagram and use arrows to show the **forces** acting on:

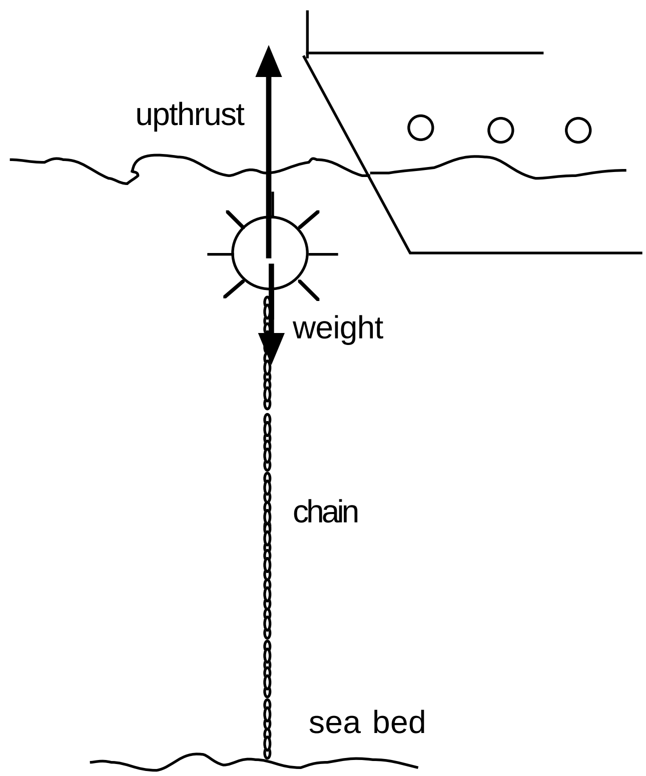
   (a) the ring (b) the balloon



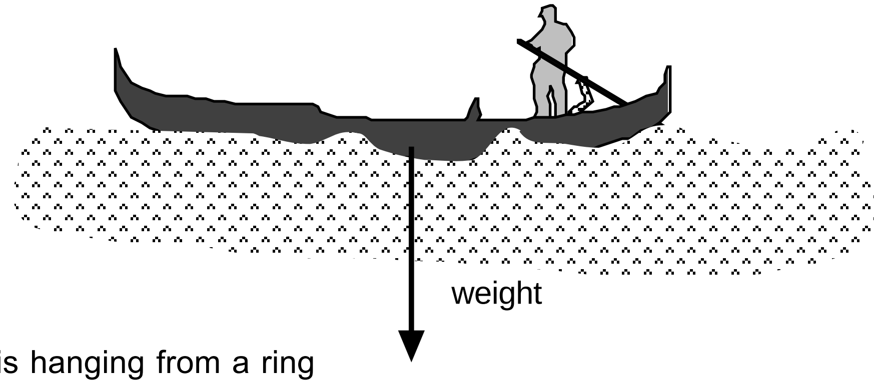
4. The mine is stationary - the forces acting on it are balanced.

   (a) Which **force** is missing?

   (b) What **length** should its vector be and in what **direction** should it point?

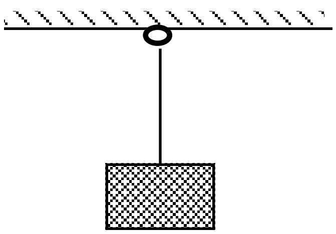


5. The gondola is not moving. Identify the other **force** on the boat and state how its **magnitude** and **direction** compare with the boat's **weight**.

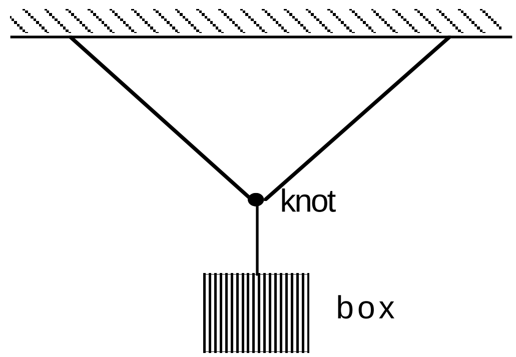


6. The mass is hanging from a ring fixed to the ceiling. Copy the diagram and indicate, with arrows, the **forces** acting on:

(a) the ring (b) the mass



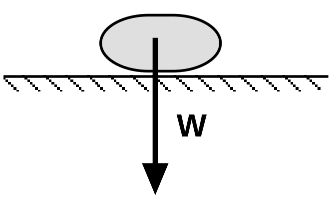
7.



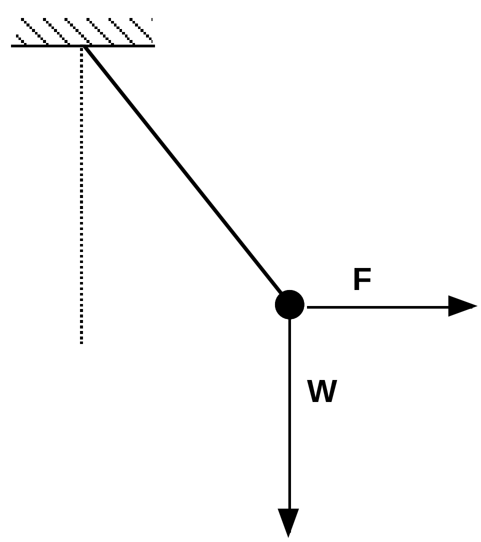
The box is hanging at rest.
Draw **vector diagrams** to show:

(a) the **three** forces acting on the knot,
(b) the two forces acting on the box.

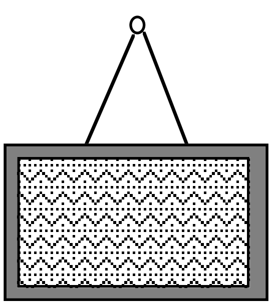
8. A mass is at rest on a horizontal surface. Its weight is shown as the vector '**W**'. Copy the diagram and add a vector to show and **name** the other **force** acting on the mass.



9. The pendulum bob, weight **W**, is at rest. A horizontal force **F** pulls it to one side. The forces acting on it are in equilibrium. Which **force** is missing from the diagram? Copy the diagram and draw in the missing force, showing its correct **size**.



10.

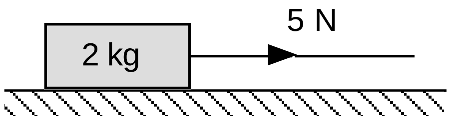


The picture frame is held at rest on a wall by two cords attached to a nail.
(a) Identify the **forces** acting on the nail.
(b) Which forces balance the **weight** of the frame?

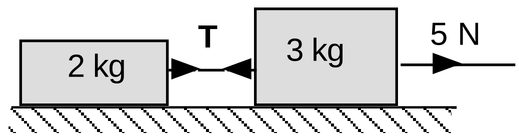
Blocks on surfaces (1)

In the following examples, the masses are being pulled along a frictionless, horizontal surface by forces acting on light cords. In each case, calculate the acceleration of the masses and/or the tension(s) (**T**) in the cord(s) or mass **m** of the block.

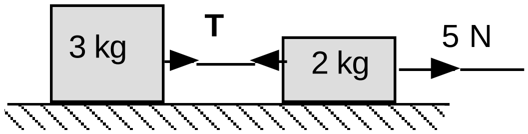
1.



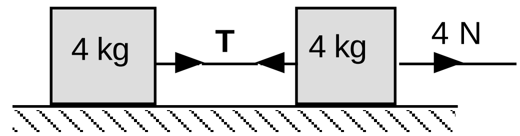
2.



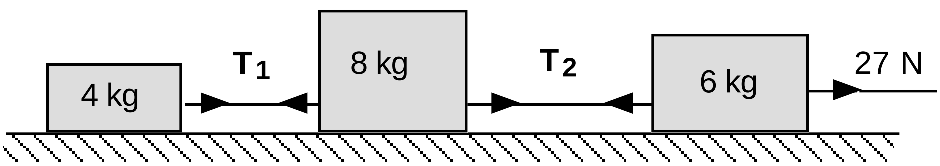
3.



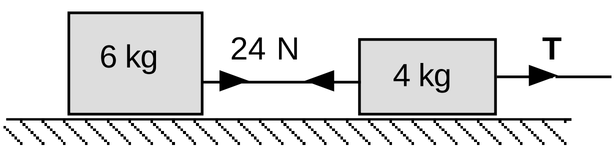
4.



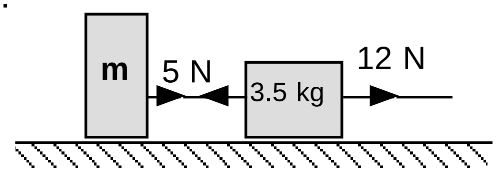
5.



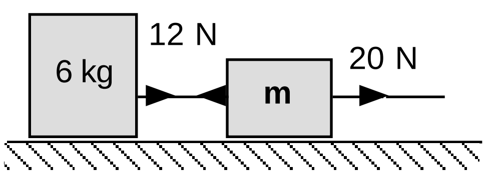
6.



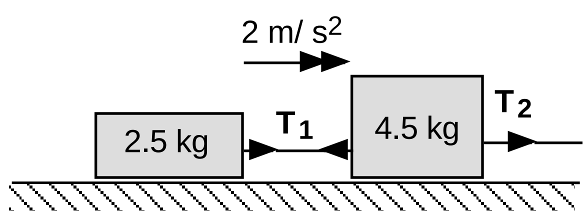
7.



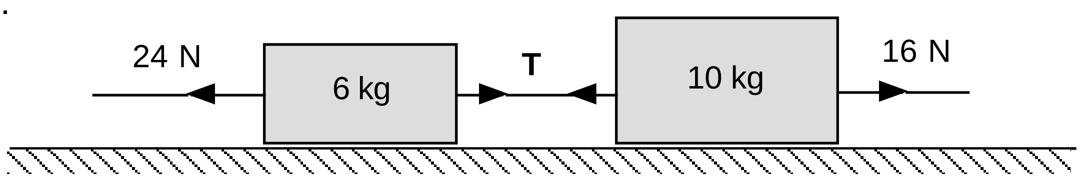
8.



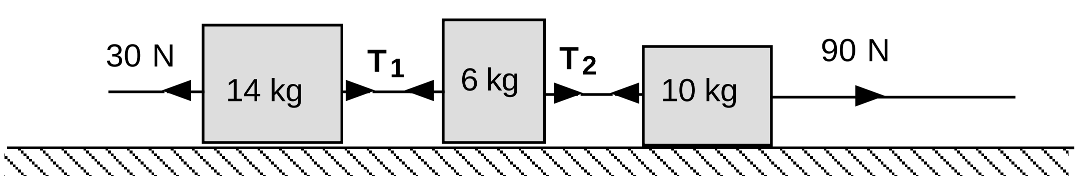
9.



10.



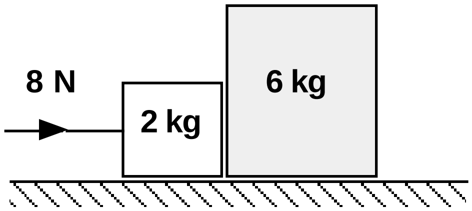
11.



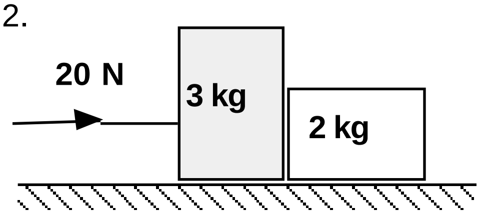
Blocks on surfaces (2)

In these examples, blocks are being pushed along a frictionless surface by the action of one or two forces. In each case, calculate the **acceleration** of the blocks and the **unbalanced force** acting on the *shaded* block.

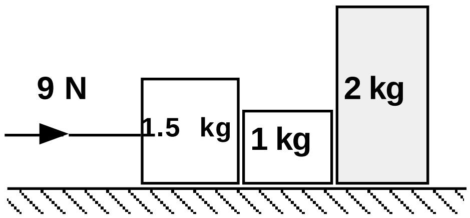
1.



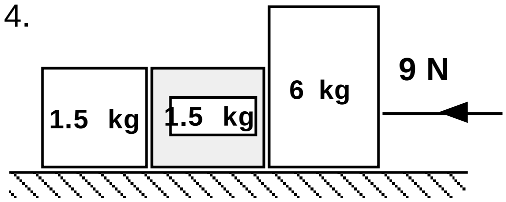
2.



3.

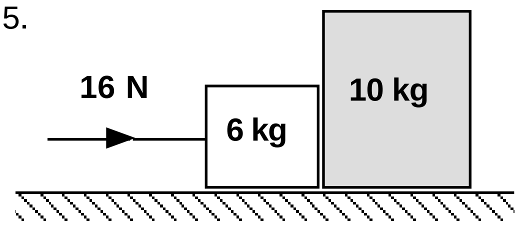


4.

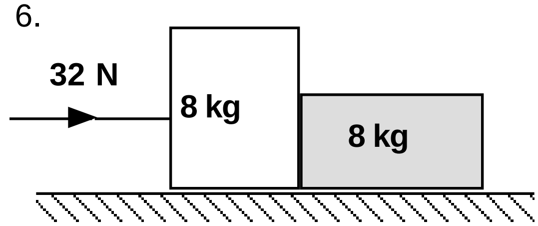


In these examples, the blocks are on a horizontal, frictionless surface. In each case, calculate the **acceleration** of the blocks and the **force** which one block exerts on the other.

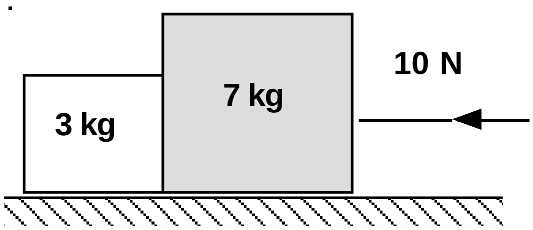
5.



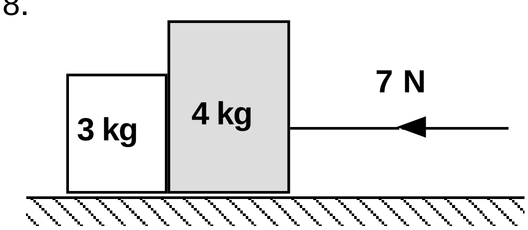
6.



7.

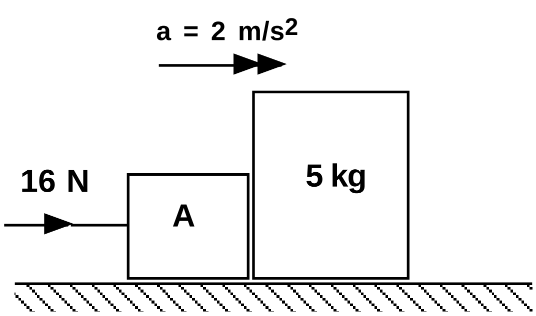


8.

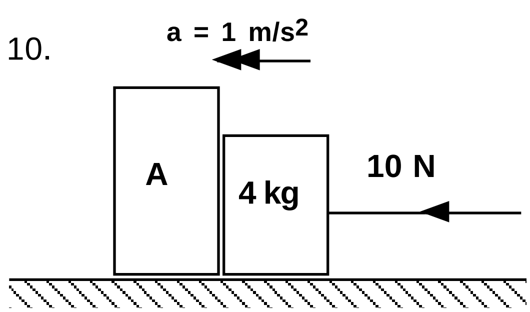


In questions 9 and 10, calculate the **mass** of block **A** and the **force block** A exerts on the *other* block.

9.



10.

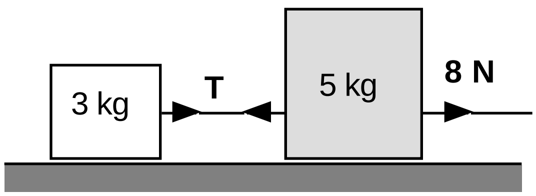


Blocks on surfaces (3)

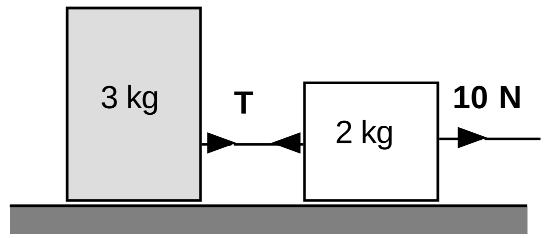
In these examples the blocks lie on surfaces which are **not** frictionless. There *is* friction between each block and the surface of 1 newton for each kilogram of mass.

Calculate the **acceleration** of the blocks and the **tension** in the cords joining the blocks.

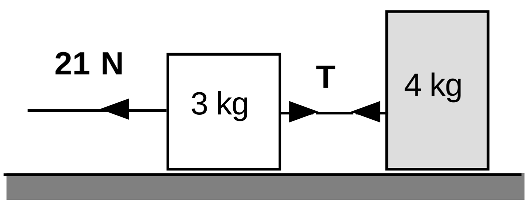
1.



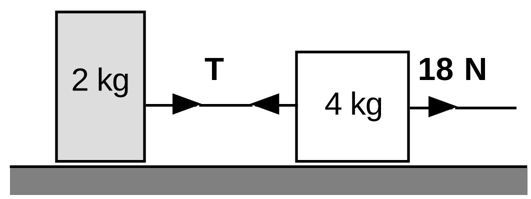
2.



3.

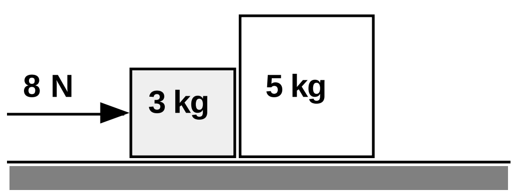


4.

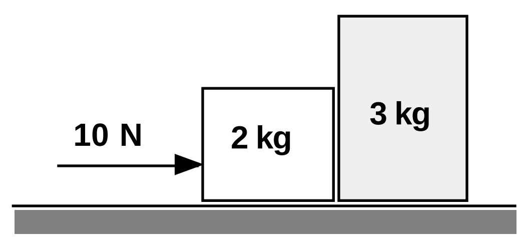


In these examples the blocks lie on surfaces which are **not** frictionless. There *is* friction between each block and the surface of 1 newton for each kilogram of mass.
Calculate the **acceleration** of the blocks and the **unbalanced force** acting on the *shaded* block.

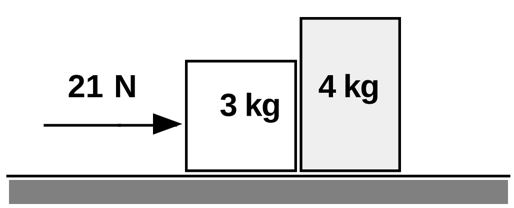
5.



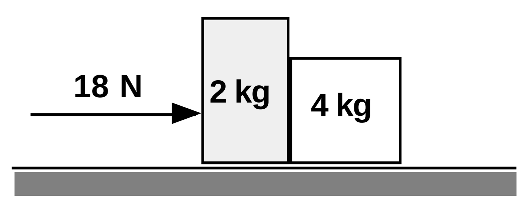
6.



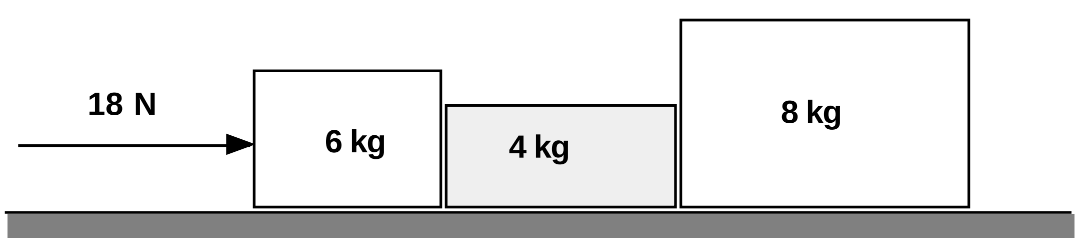
7.



8.



9.

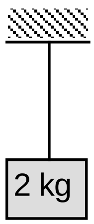


Hanging masses

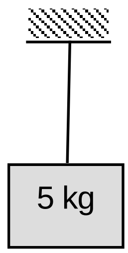
In each example, calculate the **tension** in each cord which is supporting a hanging mass.

Take the gravitational field strength 'g' as 10 N/kg and assume that the weights of the cords are negligible.

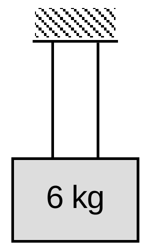
1.



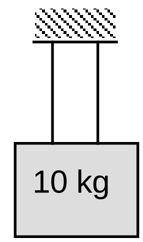
2.



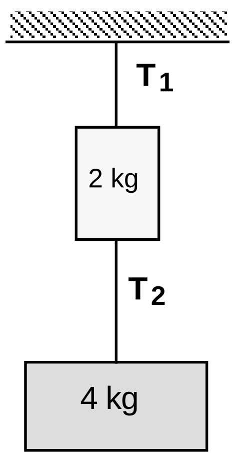
3.



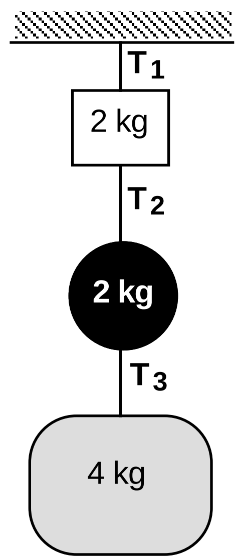
4.



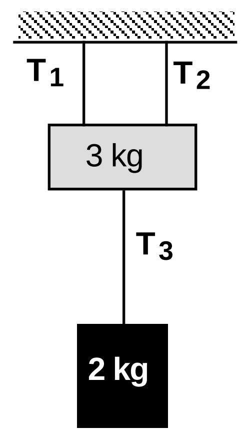
5.



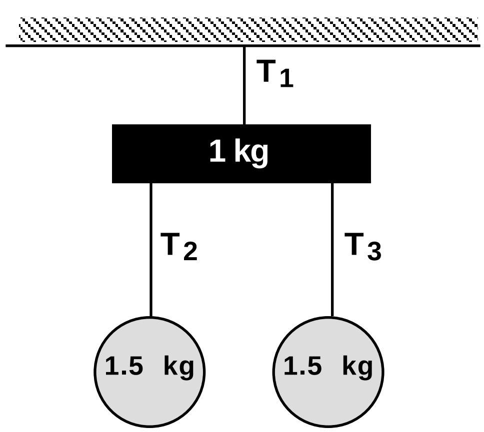
6.



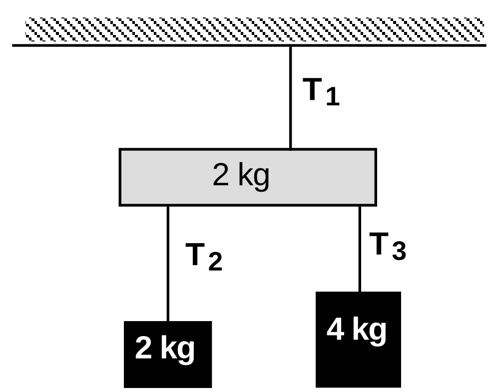
7.



8.



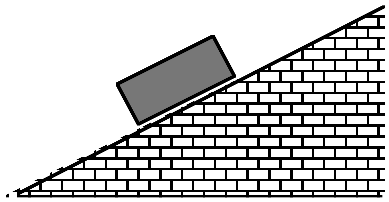
9.



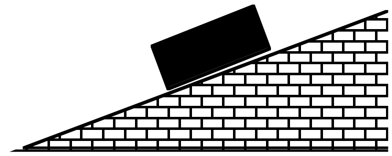
Masses on surfaces

In these examples, the blocks lie on frictionless slopes.
Measure the angle of each slope and calculate the block's **acceleration** down the slope.
Answer to *two* significant figures. [Take the gravitational field strength, 'g', to be 10/ kg.]

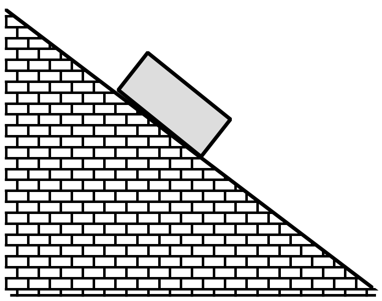
1.



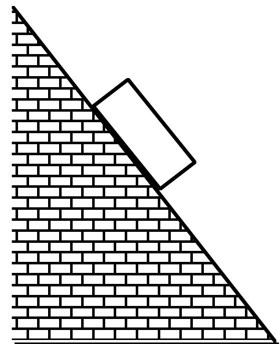
2.



3.

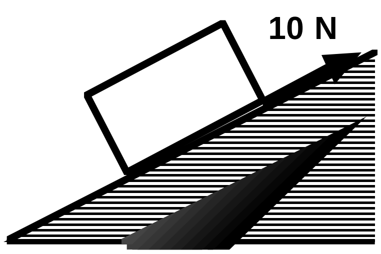


4.

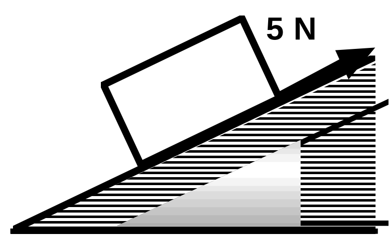


In these examples, there *is* friction between the blocks and the slopes as indicated.
Measure the angle of each slope and calculate the block's **acceleration** down the slope.
Answer to *two* significant figures.

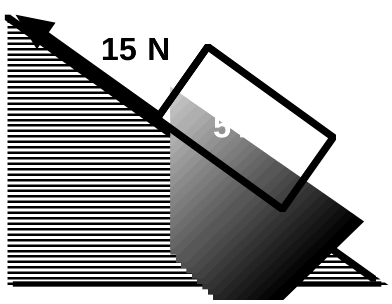
5.



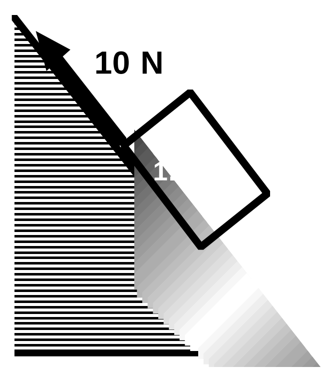
6.



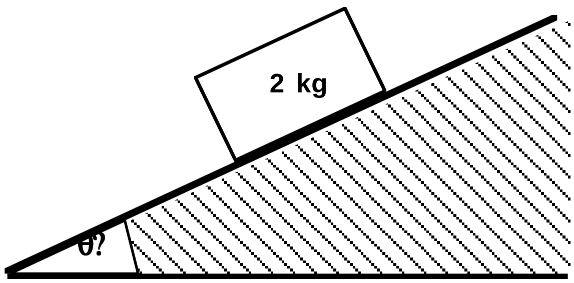
7.



8.



9. A 2 kg mass is released from rest on a frictionless slope.



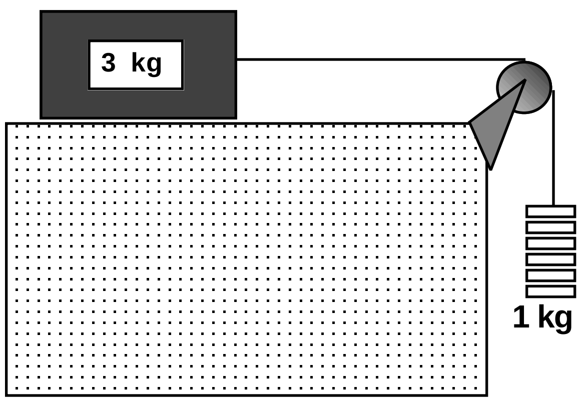
(a) What would the **angle** '**θ**' of the slope be if the acceleration of the mass was:

(i) 5 m/s^2 (ii) 6.7 m/s^2 (iii) 3.1 m/s^2?

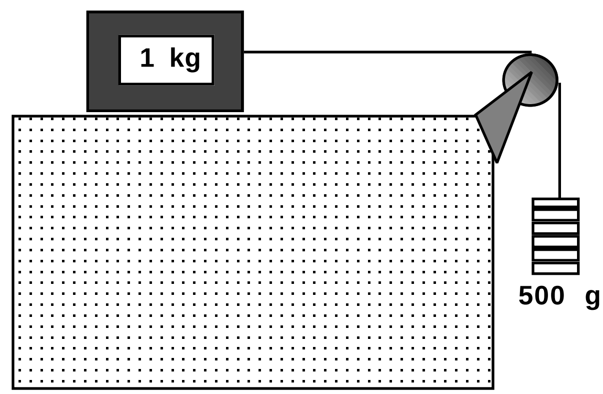
(b) Would there be any **difference** to the answers to part (a) if the block's mass was ***4 kg***?

In these examples, a block, lying on a frictionless, horizontal surface, is pulled along by a weighted cord. The pulley wheel has **no** friction. In each case, calculate the **acceleration** of the block, the **unbalanced force** acting on it and the **tension** in the cord.

10.

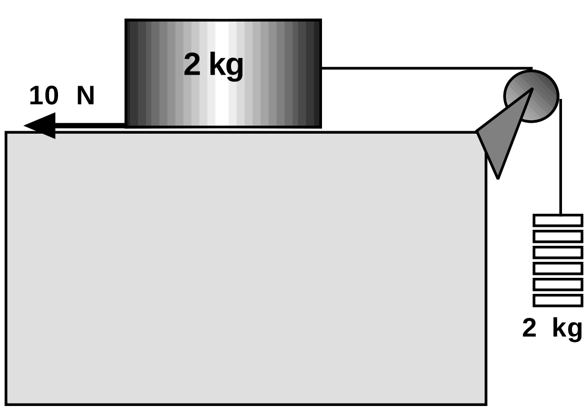


11.

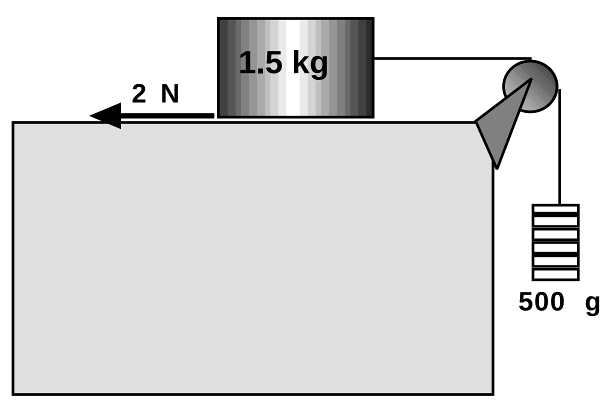


In these examples, a block is pulled along a rough surface by a weighted cord. The friction between the block and the surface is shown in the diagrams. The pulley wheel has no friction. In each case, calculate the **acceleration** of the block, the **unbalanced force** acting on it and the **tension** in the cord.

12.



13.



Action and Reaction

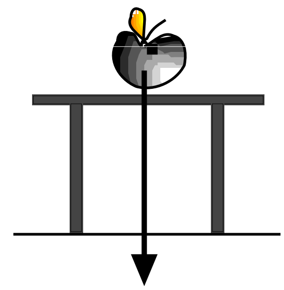
1. Complete this statement of Newton's **3rd Law of Motion**:

   "to every action, there is an _______ and ___________ reaction"

2. When two bodies collide, how does the **size** of the change of momentum of one body **compare** with the **size** of the change of momentum of the other body?

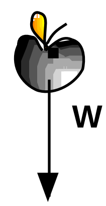
3. In answer to a test question about action and reaction between an apple and the Earth, a boy wrote: "the reaction to the force of the Earth on the apple is the force of the apple on the table."

   What is **wrong** with the boy's answer?



4. In a rocket engine, what is the **reaction** to the force exerted on the exhaust gases by the rocket?

5. What is the **reaction** force to the **weight** of an apple?



6. What is the **reaction** to the force of a horse pulling a cart along a farm track?

7. What is the **reaction** to the force of a footballer's foot on the ball?

8. What is the **reaction** force to the gravitational force exerted by the Earth on the Moon?

9. In a water rocket, what is the **reaction** to the force exerted by the compressed air on the water?

10. At one point on a car's journey, one of the rear drive wheels is pushing on the road surface with a force of 800 N. In comparison to the car's motion, in what **direction** does the tyre push on the road surface and what is the **reaction** to this force?

11. On the point of service, a tennis player's racquet strikes the ball with a peak force of 250 N.

    What **force** does the ball exert on the racquet at that instant and in what **direction** is the force?

12. A fireworks rocket explodes into two parts of ratio 2:1 in mass. The *larger* piece experiences a force of 25 N straight up due to the explosion.

    What are the **size** and **direction** of the force on the *smaller* piece due to the explosion?

Momentum = mass x velocity

1. Use the formula **momentum = mass x velocity (P = mv)** to calculate the value of the missing quantities in the table.

mom. (kgm/s)	mass (kg)	vel. (m/s)
-	2	10
-	0.5	100
1000	-	50
3×10^4	-	20
0.6	0.05	-
250	0.5	-

Remember: when calculating energy, speeds and velocities need to be be in **m/s**.

2. Calculate the **momentum** of a 1400 kg car moving at 10 m/s.

3. What is the **size** of the momentum of a 600 gram stone moving at 20 m/s?

4. What is meant by an '**elastic**' collision between two objects?

5. Calculate the **momentum** of a 20000 tonne ship moving through the water at a speed of 12 m/s. [1 tonne = 1000 kg]

6. An 80 kg sprinter is running at 10 m/s in a race.
What is the value of his **momentum**?

7. On the Moon, where the gravitational field strength is 1.6 N/kg, a 500 kg vehicle is travelling up a 10^o slope at 4 m/s. What is the size of the vehicle's **momentum**?

8. A car is travelling in a straight line at 15 m/s. It has 18000 kgm/s of momentum.
What is the car's **mass**?

9. A girl on a 10 kg bicycle is riding it at a speed if 6 m/s. If the momentum of the girl **and** bicycle is 360 kgm/s, what is the **mass** of the **girl**?

10. At what **speed** is a 20 gram air rifle pellet moving if it has momentum of 1.6 kgm/s?

11. Two cars are travelling in the *same* direction. One has a mass of 1000 kg and is moving at 10 m/s, the other's mass is 1200 kg and it is moving at 15 m/s.
What is the **total momentum** of the cars?

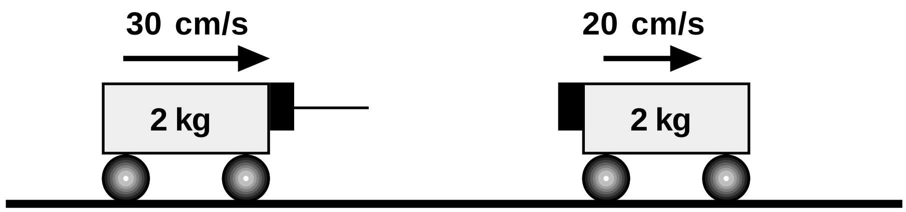
12. Two cars are moving in *opposite* directions. One is 1200 kg and is moving at 10 m/s, the other is 1000 kg and is moving at 12 m/s.
What is the **total momentum** of the cars?

13. A 3 kg trolley moving at 40 cm/s collides with and **joins** to a stationary trolley of mass 2 kg on a horizontal, frictionless surface. Calculate the **speed** at which the trolleys move after the collision and the **loss** of **kinetic energy**.

14. Two trolleys, each of mass 2 kg, collide and stick together on a smooth, horizontal surface. One trolley is at rest *before* the collision.

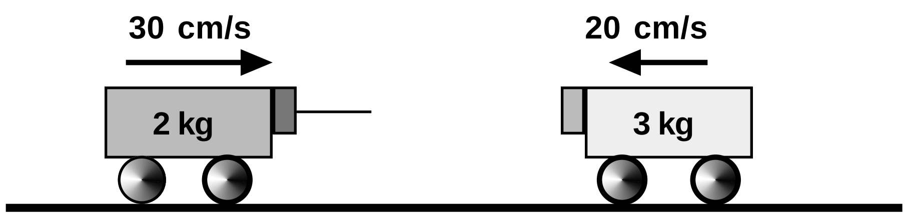
Calculate the combined **velocity** (size and direction) of the trolleys after the collision.

15. Two trolleys are moving in the *same* direction along a smooth surface.
One is moving faster and catches up on the other. The trolleys collide and stick together.



Calculate the combined **velocity** (size and direction) of the trolleys after the collision.

16. Two trolleys are moving in *opposite* directions along a smooth surface.
The trolleys collide and stick together.

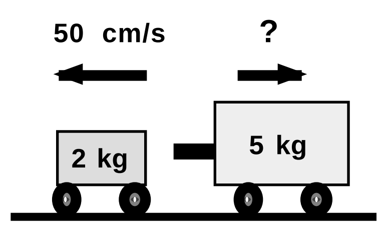


(a) What is the **total momentum** of the trolleys before **and** after the collision?

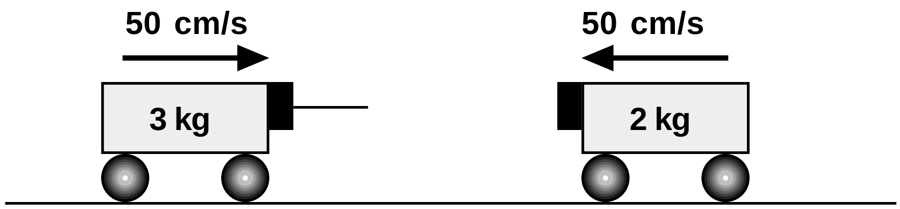
(b) What is the trolleys' combined **velocity** after the collision?

17. A car of mass 1500 kg, travelling at 15 m/s, collides 'head on' with a second car, mass 1000 kg, which has a speed of 16.5 m/s in the opposite direction.
Find the **speed** and **direction** of the cars immediately **after** the collision, assuming that they remain locked together.

18. Two trolleys are at **rest** and in contact on a smooth, level surface. A coiled spring in one trolley is released so that they 'explode' apart. The lighter trolley moves off at 50 cm/s.
Find the **speed** of the other trolley and the **minimum energy** which was stored in the coiled spring before release.

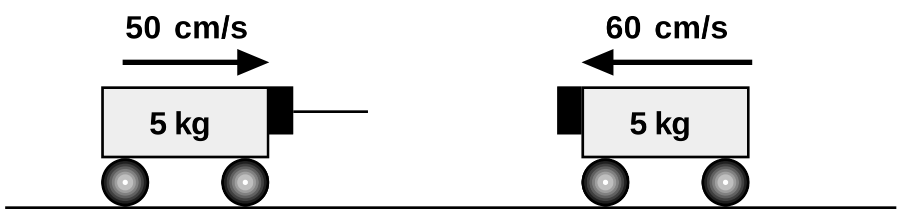


19. Two trolleys are moving in *opposite* directions at the same speed along a smooth surface. The trolleys collide and stick together.



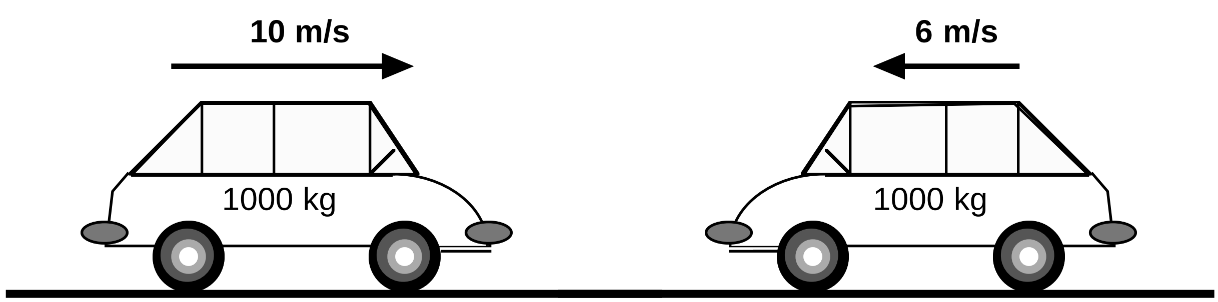
(a) What is the **total momentum** of the trolleys before **and** after the collision?
(b) What is the trolleys' combined **velocity** after the collision?

20. Two trolleys of equal mass are moving in *opposite* directions along a smooth surface. The trolleys collide and stick together.



(a) What is the **total momentum** of the trolleys before **and** after the collision?
(b) What is the trolleys' combined **velocity** after the collision?

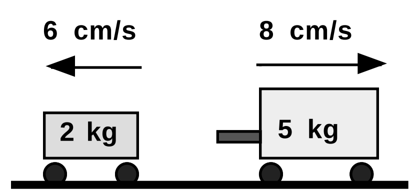
21. Two cars, each of mass 1000 kg, collide head on on a level road. The wreckage stays as one mass after the collision.



Calculate: (a) the **velocity** of the wreckage immediately *after* the collision and (b) the loss of **kinetic energy**.

22. Two trolleys have just '**exploded**' apart on a smooth, horizontal surface, as shown.

What was their **combined velocity** just **before** the event?

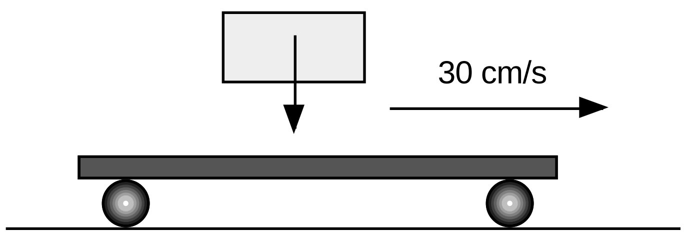


23. Two trolleys, initially at rest and touching on a smooth, level surface, explode apart when a spring loaded pole is released on one trolley.

The 5 kg trolley moves off at 60 cm/s.

(a) What is the value of the **total momentum** of the trolleys after they have exploded apart?
(b) Calculate the **velocity** of the 3 kg trolley.

24. A 2 kg trolley is rolling at 30 cm/s along a smooth, level surface when a 3 kg mass, which is *not* moving horizontally, is lowered onto it.



The trolley continues to move at a slower speed with its extra load.
Calculate: (a) its new **speed** and (b) the loss of **kinetic energy**.

25. A model rocket of mass 3 kg is rising vertically through the air at 20 m/s when it explodes into two parts. One part, 1 kg in mass, moves vertically upwards at a speed of 30 m/s immediately after the explosion.

What is the **speed** and **direction** of the other piece immediately after the explosion?

26. If, after exploding apart on a level surface, a 2 kg trolley moves to the right at 30 cm/s and a 3 kg trolley moves to the left at 10 cm/s, calculate the **size** and **direction** of the combined trolleys' **velocity** *before* the explosion.

27. Two trolleys are on a level surface. One, of mass 2 kg, is moving at 3 m/s towards the other, a 3 kg trolley, which is at rest.

The trolleys collide **elastically** and, as a result, the 3 kg trolley moves off at 2.4 m/s. Calculate the **speed** and **direction** of the 2 kg trolley after the collision and confirm that the collision *was* completely elastic.

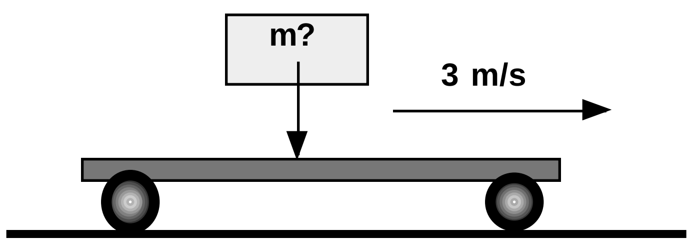
28. Two trolleys are on a level surface. One, of mass 4 kg, is moving at 3 m/s towards the other, a 2 kg trolley which is at rest.

The trolleys collide elastically and, as a result, the 2 kg trolley moves off at 4 m/s. Calculate the **speed** and **direction** of the 4 kg trolley after the collision and confirm that the collision *was* completely elastic.

29. Two trolleys, each of mass 2 kg, are on a level surface and moving towards each other.

The trolleys collide elastically and, as a result, the darker trolley moves off at 3 m/s. Calculate the **speed** and **direction** of the other trolley after the collision and confirm that the collision *was* completely elastic.

30. A 2 kg trolley is rolling at 3 m/s along a smooth, level surface when a box of mass '**m**', which is *not* moving horizontally, is dropped onto it.



The trolley and box continue to move at the slower speed of 1 m/s.

Calculate: (a) the value of the box mass '**m**' and (b) the loss of **kinetic energy**.

31. A 1600 kg car, travelling at 20 m/s, crashes into the back of a **stationary** vehicle of mass 2400 kg.
Calculate:

(a) the combined **speed** of the wreckage immediately after the collision,

(b) the loss of **kinetic energy** due to the impact, assuming that the cars lock together on impact.

Impulse

1. Show that the **unbalanced force** acting on a mass is equal to its rate of change of momentum; (that is: the change of momentum divided by time.)

2. What is the **unit** in which **momentum** is measured?

3. Is **momentum** a *scalar* or a *vector* quantity? Explain.

4. **Complete** this statement: "for a mass acted on by an unbalanced force, the impulse of the force is equal to the _ _ _ _ _ _ of _ _ _ _ _ _ _ _ _ of the momentum."

5. What is the **unit** in which **impulse** is measured?

6. Is the quantity '**impulse**' a *vector* or *scalar*? Explain.

7. What is the ***difference*** between the quantities '**impulse**' and '**force**'?

8. Complete the table by calculating the **magnitude** of the missing quantities.

unbalanced force (N)	**time** (s)	**impulse** (Ns)	**change of momentum** (kgm/s)
1	1	-	-
10	1	-	-
1	10	-	-
20	0.5	-	-
0.5	0.2	-	-
500	0.001	-	-
-	2	2	-
-	0.1	1	-
-	0.001	-	50
-	0.02	-	100
40	-	0.2	-
2.5	-	5.0×10^{-4}	-
-	5×10^{-6}	10	-

9. A mass is acted on by an unbalanced force of 10 newtons for 0.5 s.
   (a) What is the **impulse** imparted to the mass?
   (b) What is the **change of momentum** of the mass?

10. A force of 2 kN acts on an object for 4 milliseconds.
    (a) What is the **impulse** on the object?
    (b) What other **measurement** would be needed before the **change of velocity** of the object could be calculated?

11. A bullet becomes embedded in a sandbag which has a mass of 10 kg. The sandbag moves off at 0.5 m/s. What **impulse** was given to the sandbag?

12. A tennis ball has a mass of 40 g. It is struck from rest by a player who can serve at 50 m/s.

(a) What is the **change of momentum** of the ball?

(b) What **impulse** does the player's racquet impart to the ball?

13. A hockey ball's mass is 150 grams. It is travelling at 5 m/s when a player hits it back in exactly the opposite direction with the same speed.

(a) What is the **change of momentum** of the hockey ball?

(b) What is the **impulse** on the ball?

(c) The **force** with which the stick hit the ball cannot be calculated. Why?

14. A tennis ball of mass 40 grams is struck by a racquet with an impulse of 1.5 Ns. If the impact with the racquet lasted for 1 ms, calculate the **average force** on the ball.

15. During a football match, the centre forward heads a cross towards the goal. In doing so, he changes the **momentum** of the ball by 9 kgm/s.

(a) Calculate the **change of velocity** of the ball if its mass is 300 g.

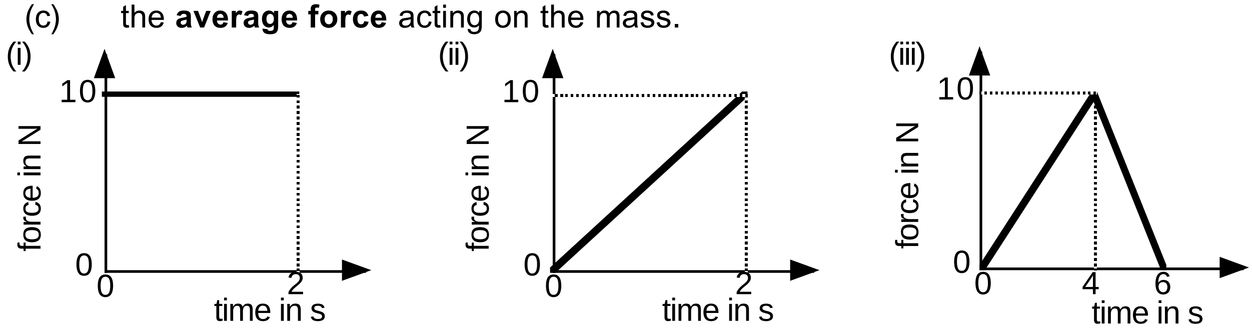
(b) If the impact between the ball and the player's head lasted for 20 ms, what was the **average force** exerted on the ball by the player?

16. Which quantity can be calculated from the **area** under a force-time graph?

17. Sketch the likely **shape** of the force-time graph for the force acting on a football by a player's foot during a free-kick.

18. The graphs record the **unbalanced force** acting on a mass for a time. In each case calculate:

(a) the **impulse** imparted to the mass,
(b) the **change of velocity** if the object's mass is 2 kg and
(c) the **average force** acting on the mass.



19. In each case, calculate the **change of momentum** (size and direction) of the object:

(a) A mass of 2 kg moving to the right at 1.0 m/s and given an impulse which causes it to move to the left at 2.0 m/s.
(b) An object with an initial momentum of -4.0 kgm/s and a final momentum of +5.0 kgm/s.

Weight and Mass

1. Use the formulae **force = mass x acceleration (F = ma)** or **weight = mass x gravitational field strength (W =mg)** to calculate the missing entries in the table.

weight (N)	mass (kg)	'g' (N/kg)
-	2.0	10
-	4.5	10
-	3.0	1.6
330	-	10
784	-	9.8
480	-	1.6
4.9	0.5	-
74	20	-

2. Calculate the **weight** of these masses which are at the Earth's surface, taking the gravitational field strength to be 10 N/kg:

(a) 1.5 kg (b) 3.2 kg (c) 500 g (d) 2 tonne

(e) 3.2×10^5 kg (f) 10^4 kg (g) 0.035 kg (h) 2.6×10^{-3} kg (i) 350 mg

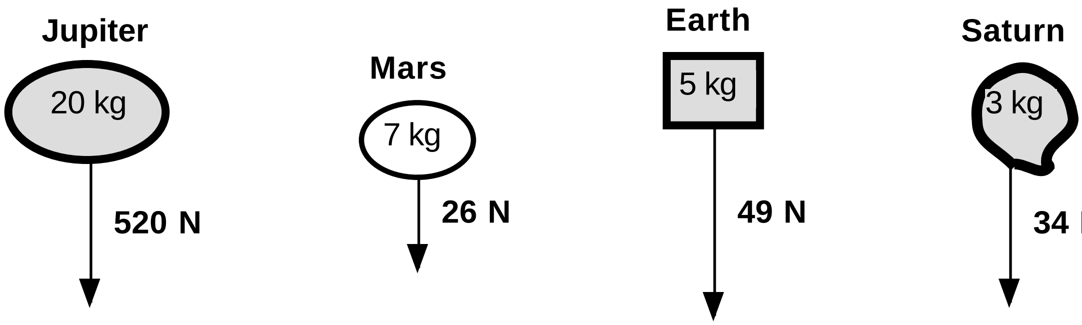
3. What is the value of the **gravitational field strength** at the surface of a planet if a 2 kg mass weighs 52 newtons?

4. What is the **gravitational field strength** at the surface of a planet where an 80 kg woman would weigh 520 N?

5. What is the value of the **gravitational field strength** near the surface of a planet if a 3 kg mass falls with an acceleration of 1.6 m/s^2?

6. At a certain height above the Earth's surface, the gravitational field strength is just 3 N/kg. At this height, what would be the **gravitational acceleration** of a falling object? (Ignore the effect of friction.)

7. The drawings show objects free-falling near the surface of various planets. For each, calculate the **gravitational field strength** of the planet.



8. An astronaut in her spacesuit has a mass of 90 kg before launch on Earth. What would be her **mass** and **weight** on the surface of the Moon where the gravitational field strength is 1.6 N/kg?

9. An astronaut has a weight of 833 N on the surface of the Earth where the gravitational field strength is 9.8 N/kg. What would be the astronaut's **weight** and **mass** on the surface of another planet where the gravitational field strength is just 4.0 N/kg?

10. An astronaut weighs 735 N on Earth where 'g' is 9.8 N/kg.

    What is her **mass** (a) on the Earth and (b) on the Moon where 'g' is 1.6 N/kg?

11. What are the (a) **mass** and (b) **weight** of a man on the surface of the Earth, where 'g' is 9.8 N/kg, if his *mass* on Mars, where 'g' = 3.7 N/kg, is 80 kg?

12. A girl weighs 539 newtons on Earth, where 'g' is 9.8 N/kg. What would be her **mass** and **weight** on a planet where the gravitational field strength at the surface is 14 N/kg?

13. In a geostationary orbit above the equator, a communications satellite, which has a mass of 300 kg, experiences a force of 69 N. Calculate the Earth's **gravitational field strength** at this height.

14. In orbit around the Earth, astronauts on board the Shuttle float around inside the craft and appear to be '**weightless**'. Are they weightless? **Explain**.

15. Weight is a force. Force is a **vector** and so it has a **direction**. In what direction does your own **weight** point in these situations:

    (a) not moving (b) moving sideways (c) moving in a circle?

16. What is the actual **weight** of an 80 kg man in a lift which is:

    (a) stationary (b) moving upwards with a steady speed
    (c) accelerating upwards at 1 m/s^2 (d) accelerating down at 2 m/s^2?

    (Take 'g' = 10 N/kg.) Explain your answers.

17. Who **weighs** more: a 10 kg child on Earth ('g' = 9.8 N/kg) or a 60 kg woman on the Moon where 'g' = 1.6 N/kg?

18. An astronaut lands on Mars and finds that his weight is only 333 newtons, whereas it would have been 900 newtons on Earth, where 'g' = 10 N/kg.

    Calculate: (a) his **mass** on Earth, (b) his **mass** on Mars and (c) the **gravitational field strength** on Mars.

19. A lifting machine applies an upward force of 92 N to lift a 20 kg box of rocks on the Moon where 'g' = 1.6 N/kg. Calculate the size and direction of the **unbalanced force** exerted on the box and its **acceleration**.

20. On Mars, where 'g' is 3.7 N/kg, what **mass** does a rock have that weighs the *same* as a 10 kg rock on the Moon where 'g' = 1.6 N/kg?

Work = force x distance

1. Use the formula **'work = force x distance'** to calculate the value of missing quantities in the table.

work (J)	force (N)	distance (m)
-	10	5
-	5000	3
200	40	-
3000	0.1	-
4×10^5	2×10^3	-
10000	-	10^5
9×10^6	-	10^4

Take 'g' = 10 N/kg

2. How much **work** is done by a 20 N force which moves an object for a total distance of 50 metres in the direction of the force?

3. How much **work** is done by a force of 6 newtons when it moves a total distance of 7 metres in its **own** direction?

4. A boy does 72 J of work in dragging a 30 kg mass along a floor for 3 metres. What **force** does he apply? (Assume the force is **parallel** to the floor.)

5. How much **work** is done by a man on a bag of shopping of weight 300 newtons if he carries it a **distance** of 200 metres at a **constant** height?

6. How much **work** would be done in slowly lifting a 50 kg box from the floor to a table which is 80 cm high?

7. A man pushes his broken down car with a horizontal force of 600 newtons. How much **work** has he done when the car has moved 5 metres?

8. What **word** is missing from the following statement: the work done by a force is found by multiplying the force by the distance moved in the ____________ of the force?

9. A shopper pushes a trolley with a steady force of 50 N. How **far** has he moved the trolley if he has done 1000 J of work on it?

10. How **high** is a table if 480 J of work is done in lifting a 60 kg box from the floor to the table?

11. A weight lifter lifts a bar and weights through a height of 2.5 m. If he does 3000 J of work, what is the **mass** of the weights?

12. A caravan needs a towing force of 400 N at 30 m.p.h. How much **work** would a car engine need to do to tow the caravan at this speed along a level stretch of road for 5 km?

13. A yacht needs a pushing force of 400 N to move through the water at a steady speed of 5 knots. How **far** has the yacht moved at this speed if the wind has done a total of 4 MJ of work on it?

14. What type of **energy** is produced when the force of **friction** acts between moving surfaces?

15. What type of **energy** is produced by a force which *slowly* lifts a weight through a certain height?

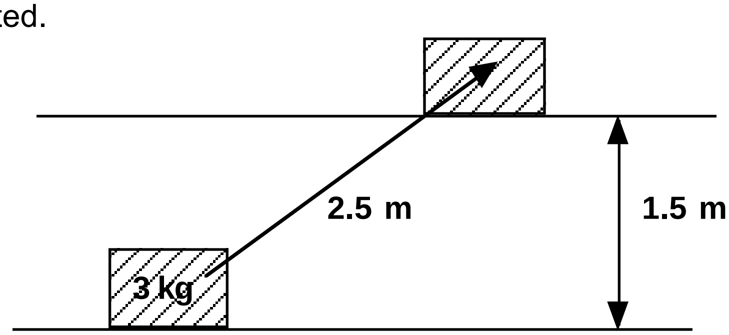
16. What type of **energy** is produced when an **unbalanced force** pushes an object in the direction of the force along a horizontal path?

17. What types of **energy** are produced when an **unbalanced force** pushes an object in the direction of the force up a steady, frictionless incline?

18. What type of **energy** is produced when a **force** pushes an object in the direction of the force at a *steady* speed up a frictionless incline?

19. How much **work**, in kilojoules, is done by a crane's motor in lifting a 3 tonne machine slowly through a height of 20 metres?

20. A 3 kg box is slowly lifted through a height of 1.5 metres and finishes 2.5 metres from where it started.



How much **work** must be done in moving the box?

21. The force of gravity pulls down on a 2 kg brick which has fallen from a tall chimney stack. How **far** has the brick fallen when gravity has done 100 J of work on it?

22. A girl carries a box of mass 4 kg along a level floor for a total distance of 5 metres at a constant **height**.

How much **work** does the girl do against the force of gravity? **Explain**.

23. Calculate the **work done** by an unbalanced force in accelerating a car of mass 2 tonnes from rest at 1.5 m/s^2 in a straight line for 10 seconds.

24. A 20 g bullet, travelling at 400 m/s, strikes a sand bag and becomes embedded to a depth of 20 cm.

Calculate the **average** stopping **force** acting on the bullet.
(Hint: consider the work done by the stopping force.)

Kinetic Energy

1. Use the formula $E_k = {}^1/_2\, mv^2$ to calculate the value of missing quantities in the table.

E_k (J)	m (kg)	v (m/s)
-	2	1
-	1	2
-	0.5	10
-	2×10^3	0.1
8	-	2
125	-	5
4×10^4	-	2×10^3
36	2	-
500	10	-
5	1000	-

2. Calculate the **kinetic energy**, in kilojoules, of a 1400 kg car travelling at 15 m/s.

3. Calculate the **kinetic energy** of a mass of 2 kg moving with a speed of 3 m/s.

4. At what **speed** is a 250 g stone moving if its kinetic energy is 3.5 joules?

5. What is the **mass** of an object travelling at 8 m/s which has 96 J of kinetic energy?

6. An air gun pellet has a mass of 20 g and is fired from the gun with a speed of 50 m/s. Calculate the **kinetic energy** of the pellet**.**

7. Complete the following statement by adding the **missing words**:

   "The **kinetic energy** of a moving body is directly __________________
   to the __________ of its **speed**."

8. A car of mass 1200 kg slows down from a speed of 20 m/s to 10 m/s. How much **kinetic energy** does the car lose?

9. How **fast** is a 90 kg man running if his kinetic energy is 720 J?

10. How **fast** was a 1400 kg car travelling if it lost 280 kJ of kinetic energy in coming to a stop?

11. What is the **mass**, in grams, of an air gun pellet which has 12.5 J of kinetic energy when fired at a speed of 50 m/s?

12. A car of mass 800 kg accelerates from a speed of 2 m/s to 6 m/s. Calculate the **kinetic energy** gained by the car.

13. A 100 m runner has a mass of 80 kg. Calculate his **kinetic energy** when running at his top speed of 10 m/s.

14. A 20000 tonne ship is moving through the water at 12 m/s.
Calculate its **kinetic energy** and express the answer in **megajoules (MJ.)**
(1 tonne = 1000 kg.)

15. A car, travelling at a speed of 20 m/s, has 240 kJ of kinetic energy.
What is the car's **mass**?

16. A runner of mass 60 kg is moving with 1080 J of kinetic energy.
At what **speed** is she running?

17. What is the **speed** of a 1100 kg car which is moving with kinetic energy of 55 kJ?

18. What is the **mass** of a bullet fired from a rifle at 500 m/s if it has 6.25 kJ of kinetic energy?

19. What happens to the amount of **kinetic energy** carried by a moving mass if its speed **doubles**?

20. The **kinetic energy** of a moving mass is 500 J.
What would it be if the **speed** of the mass **doubled**?

21. A 2 kg rock, falling from the top of a cliff on the Moon, gains speed at the rate of 1.6 m/s every second. Calculate its **kinetic energy** after 3 s.

22. In slowing down by use of the brakes, a car's speed is reduced from 50 m/s to 30 m/s. If the brakes and other frictional forces acting on the car generate 1.04 MJ of heat due to the reduction in speed, find the value of the car's **mass**.

23. During its re-entry to the Earth's atmosphere, a spacecraft, of mass 2 tonnes, slows down from 1000 m/s to 400 m/s.

How much **kinetic energy** is lost by the spacecraft? Answer in megajoules (MJ).

24. What is the **mass** of a woman who gains 360 J of kinetic energy in doubling her speed from 2 m/s to 4 m/s?

25. A pupil had a table of data which showed how an object's **kinetic energy** depended on its **speed**.

He plotted a graph of '**kinetic energy** against **speed**' and hoped that it would be a straight line passing through the origin.

It wasn't !

Sketch the graph he obtained and suggest what graph he ***should*** plot to give a straight line through the origin.

26. A 1000 kg car has 50 kJ of kinetic energy when travelling at a certain speed .

(a) What is the **speed** of the car?

(b) What would its **kinetic energy** become if its speed **trebled**?

(c) How much **kinetic energy** would a 1500 kg car have at the *slower* speed?

Potential Energy

1. Use the formula **E_p = mgh** to calculate the value of missing quantities in the table.

E_p (J)	m (kg)	g (N/kg)	h (m)
-	2	10	3
-	0.5	10	20
-	3×10^4	4	100
180	-	10	6
2×10^6	-	10	100
60000	300	-	20
4800	100	-	30
10^6	2000	10	-
3.7×10^7	4×10^5	-	25

2. A pupil with a mass of 50 kg runs from the playground to her class on the school's top floor which is 12 metres above the playground.
   How much **potential energy** does the girl gain?

3. How much gravitational **potential energy** does a 60 kg boy lose when he walks down a flight of stairs which is 4.5 m high?

4. A weight-lifter raises a barbell of mass 20 kg and, in so doing, does 490 J of work. Through what **height** does he lift the barbell?

5. How much gravitational potential energy is **lost** by a rock of mass 3 kg falling to the foot of a 250 m cliff on the Moon where 'g' is 1.6 N/kg?

6. A stone of mass 3 kg falls vertically from a cliff and reaches a speed of 40 m/s **just before** hitting the ground. What was its **potential energy** *before* it fell, assuming that it fell from rest? (Ignore air resistance.)

7. One of the world's largest roller coasters has a vertical drop of 68.57 m. Calculate the **potential energy** lost by a 70 kg person in making the drop on the roller coaster. Answer in kilojoules (kJ).

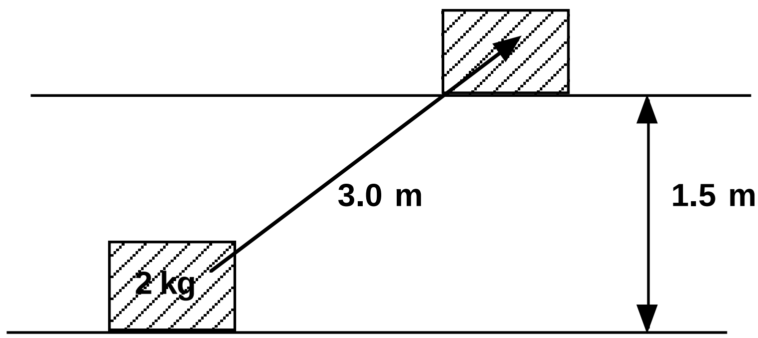
8. The Eiffel Tower in Paris was the world's tallest building during the last century. It is 300.5 m high.

   (a) How much **potential energy** would a stone of mass 2 kg lose if it fell from the top to the ground below?
   (b) What **type** of energy would replace most of this lost potential energy?

9. Which of these loses **more potential energy**: a 3 kg rock falling through a height of 15 metres near the Earth's surface or a rock of *three* times the mass falling through *double* the height near the Moon's surface, where the gravitational field strength is 1.6 N/kg?

10. In a hydroelectric power station, how much **potential energy**, in megajoules (MJ) is lost by 100 tonnes of water flowing down through the pipes and falling a ***vertical*** distance of 200 metres?

11. A 2 kg box is lifted through a height of 1.5 metres and finishes 3.0 metres from where it started.



Calculate the gain in **potential energy** of the box.

12. Compared to ground level, how much **potential energy** does a 500 kg plane have when flying at a height of 3000 m?

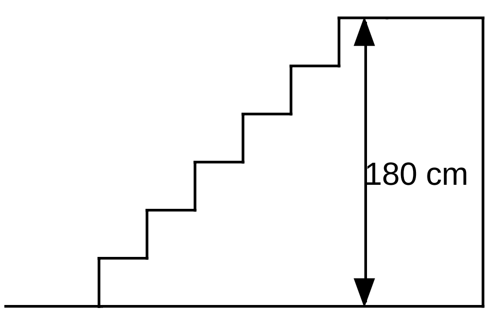
13. How **high** has a goalkeeper managed to kick a 450 g ball if it has a maximum potential energy of 67.5 joules compared to ground level?

14. On Mars, a personnel vehicle of mass 400 kg gains 7400 J of potential energy when it climbs a 5 m hill. Calculate the **gravitational field strength** of Mars.

15. A diver prepares to dive from the 7 metre board in a swimming pool. What is his **mass** if he has lost 5.25 kJ of potential energy just before entering the water?

16. What is the **mass** of a woman who gains 3 kJ of potential energy in climbing 5 metre high stairs?

17.



How much **potential energy** would be gained by a man with a mass of 100 kg in climbing to the top of these stairs from the very bottom?

18. The gravitational field strength near the surface of the planet Mars is 3.7 N/kg. What is the *least* quantity of **energy** which a 1500 kg buggy's electric motor would have to supply to allow the buggy to climb up a 324 m hill? (Answer to 2 significant figures.)

Kinetic Energy to and from Potential Energy

1. A mass of 2 kg falls from rest through a height of 5 m.

   (a) Calculate its **speed** just before hitting the ground.

   (b) What would the **speed** be if the mass were just 1 kg?

2. A footballer kicks a 300 g ball vertically upwards from a height of 1 m and it reaches a height of 6 m before it starts to fall again. Calculate:

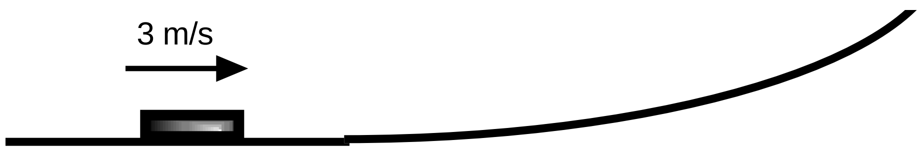
   (a) the **potential energy** gained by the ball,

   (b) the **kinetic energy** given to it by the footballer and

   (c) the **speed** at which it was kicked.

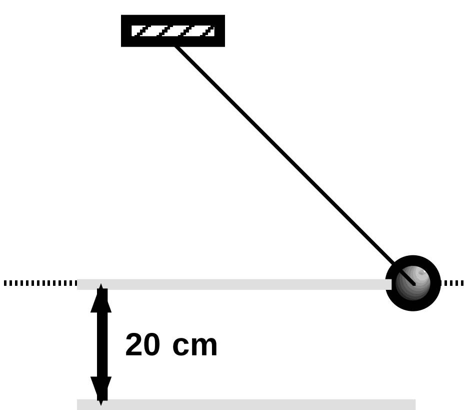
3. A large rock becomes dislodged from a cliff at a height of 80 m from the sea below. It falls freely down. What is its **speed** *just before* reaching the water?

4. A puck is sliding along a *frictionless* horizontal surface at 3 m/s and begins to move up a slope.



Assuming that no energy is lost due to frictional forces, how **high** would the puck reach up the slope?

5.



A pendulum bob is at rest 20 cm above the lowest point of its swing. It is released and allowed to swing freely downwards.

(a) What would be its **speed** at the bottom of its swing?

(b) If no energy is lost due to frictional forces, how **high** would the bob reach at the other end of the swing?

6. A stone of mass 4 kg is dropped from a height of 3 m. If air friction can be ignored, calculate the **kinetic energy** of the stone just before hitting the ground.

7. A stone of mass 500 g is fired vertically upwards from a catapult with a speed of 20 m/s. Assuming that air friction can be neglected, how much **potential energy** has the stone gained just before it starts to fall back down?

8. A 1200 kg car’s brakes fail at the top of a steep hill which is 20 metres high. It rolls down to the foot of the hill, gaining speed. If it *loses* 45600 J as heat as it rolls down, calculate its **speed** at the bottom.

9. When a car is stopped by its brakes, into what kind of **energy** is its kinetic energy converted?

10. A high board diver executes a standing dive from the seven metre board. If no energy is lost due to friction, calculate his **speed** just before entering the water. (Assume the diver’s centre of mass has fallen by 7 m.)

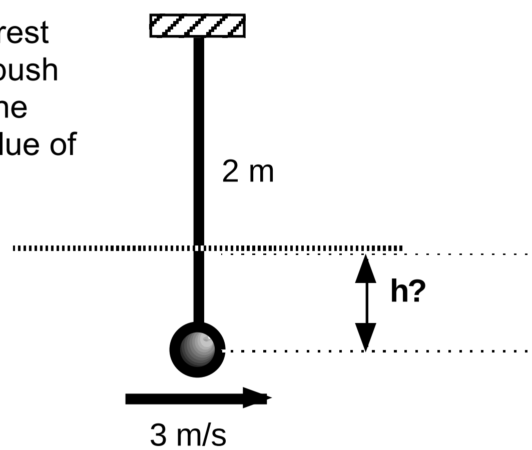
11. On the Moon, where the gravitational field strength is 1.6 N/kg, an object of mass 2 kg falls from the top of a building (this is the 23rd century!) which is 20 metres tall. Calculate:

(a) the **kinetic energy** of the object as it hits the Moon’s surface

(b) its **speed** as it hits the surface.

12.

A pendulum bob on a 2 m string, at rest at its lowest point, is given a sharp push to start it moving at 3 m/s. Ignoring the effects of air friction, calculate the value of **h**, the highest point of its swing.



13. A 2 kg trolley,with very light wheels,moving along a horizontal surface at 5 m/s, runs up an increasingly steep slope and stops at a certain height.

(a) Assuming that it rolls without loss of energy due to friction, calculate how **high** it reaches up the slope.

(b) If the trolley *did* lose some energy because of friction, how would you expect the height reached to compare with your answer to (a)? Why?

Power = Energy ÷ time

1. Use the formula $P = {}^{E}/_{t}$ to calculate the value of the missing quantities in the table.

power (W)	energy (J)	time (s)
-	1000	20
-	100	0.01
-	2×10^4	50
2000	-	5
10^6	-	200
600	36000	-
3×10^3	6	-

Where appropriate, take Earth's gravitational acceleration to be 10 N/kg.

2. Calculate the output **power** of an electric motor which can do 30 kJ of work in one minute.

3. How much **energy** would be used in ten minutes by an electric motor with an input power of 750 W? Answer in **kilojoules**.

4. An electric motor raises a container of mass 120 kg on the Moon through a height of 4 m in a time of 6 s at a steady speed.
Calculate the **output power** of the motor. (g = 1.6 N/kg.)

5. A machine raises a mass of 250 kg through a height of 3 m in a time of 5 s.
Find the **output** power of the machine. (Take 'g' as 10 N/kg.)

6. A boy's legs generate 400 watts of power when pedalling an exercise bike.
At this rate, how **long** would he take to do 120 kJ of work on the pedals?

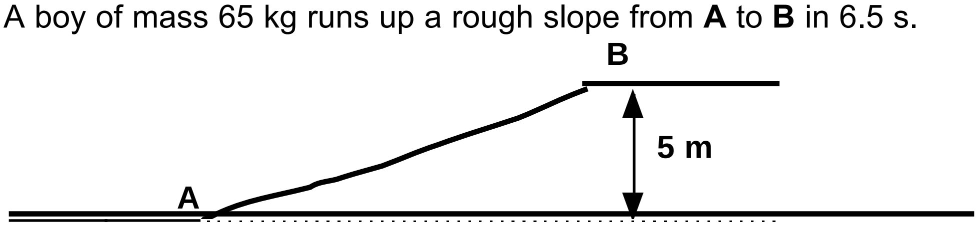
7. When moving at a steady speed of 10 m/s along a horizontal road, a car needs a forward force of 600 newtons. What **power** is developed by its engine to do this?

8. A 50 kg girl ran up a flight of stairs in 5 s. The stairs were 4 m high. Calculate:

(a) the **potential energy** gained by the girl

(b) the **power** developed by her legs against the force of gravity.

9. A boy of mass 65 kg runs up a rough slope from **A** to **B** in 6.5 s.



What **average power** do the boy's legs develop in overcoming gravity?

10. A storage tank requires 15 MJ of heat to raise its water temperature to a certain value. Assuming that no heat escapes from the water, how **long** would a 5 kW immerser take to supply the heat? Answer in **minutes**.

11. A 30 watt immerser supplies heat to a beaker of water for 10 minutes. How much **heat** is supplied, in **kilojoules**?

12. A block of wood is pulled at a **constant** speed of 6 m/s along a rough horizontal table by a pulling force of 12 N.

(a) What is the value of the **friction** force between the block and the table?
(b) How much **heat** is generated by the friction force in 5 seconds?
(c) What is the **rate** of heat production in joules per second (watts)?

13. Crane **S** has a power output which can raise a load through a certain height in 20 seconds. Crane **T** can raise *double* the load through the *same* height in 10 seconds. How do the cranes' **power outputs** compare?

14. A 5 kilowatt immerser supplies heat to a beaker of water for 30 minutes. How much **heat**, in megajoules, is supplied in this time?

15. A 40 gram mouse takes 5 s to run 2.5 m up a curtain. Calculate the **average power** developed by its legs.

16. A catapult projects a stone of mass 20 g at a speed of 20 m/s in a time of 20 ms. Calculate the **average power** output of the catapult. (1ms = 0.001 s)

17. An electric motor has a power output of 300 W. Through what **height** could it raise a 50 kg box in 5 s?

18. Calculate the **minimum power** developed by a 60 kg girl's **legs** in running up a 12 metre high flight of stairs in 15 seconds.

19. What is the **minimum** time it would take a 60 kg boy to run up a 20 metre high flight of stairs if his legs can develop a power of 400 watts?

20. An electric motor has a power output of 400 W and can raise a certain mass through a height of 2 metres in 12 s. How **long** would the same motor take to raise the *same* mass through the *same height* on the Moon where the gravitational field strength is **one-sixth** that of Earth?

21. While walking along a level floor at 1 m/s, a 70 kg man raises a 100 N load through a height of 1 m in 4 s. What is the **average** power output of his arms?

22. A ship's crane lifts a 2 tonne crate from the bottom of a hold onto the deck, 20 metres above, in a time of 20 seconds. What is the **output power** of the crane's engine?

23. How much **electric energy**, in **kiljoules**, is consumed by a 60 watt light bulb when it is switched on for a total of 2 hours?

24. What is the **power rating** of a light bulb which uses 1.62 MJ of electricity when on for a total of 3 hours? (1 MJ = 10^6 J)

Efficiency

1. Complete this formula for calculating the percentage **efficiency** of a machine, in terms of **work**, by identifying the missing words:

$$\frac{\text{\_\_\_\_?\_\_\_\_ work output}}{\text{\_\_\_?\_\_\_ work input}} \times 100\%$$

2. Complete this formula for calculating the percentage **efficiency** of a machine, in terms of **power**, by identifying the missing words:

$$\frac{\text{\_useful\_power ? \_\_\_\_\_\_}}{\text{\_\_\_?\_\_\_ power input}} \times 100\%$$

3. What **form** of ‘useless’ energy is mainly produced by a machine such as an electric motor which makes it *less* than 100% efficient?

4. Is it **possible** for a real machine to be 100% efficient? Explain.

5. Why is it impossible for **any** device to be **more than** 100% efficient?

6. A machine uses 100 W of electric power in producing 60 W of mechanical power. What is its **efficiency**?

7. An electric motor uses 50 watts of power from a low voltage power supply and produces 35 watts of power in lifting a weight. Calculate its **efficiency**.

8. A filament light bulb is found to emit 80 joules of light energy for every 1000 joules of electricity used. What is its **efficiency**?

9. A machine is 60% efficient. How much **useful output work** would it do if supplied with a total input of 500 J?

10. An electric fan is 90% efficient at converting electrical energy into kinetic energy. How much **kinetic energy** would it produce if supplied with 800 J from a battery?

11. A toy steam engine burns solid paraffin to make heat which is used to boil water into steam. The steam operates a piston which turns the driving wheels.

    (a) If 18 J of useful mechanical energy is produced when 300 J of chemical energy is extracted from the paraffin, calculate the **efficiency** of the steam engine.

    (b) How many **joules** out of every hundred are **wasted**?

12. A 50 W electric motor is 90% efficient. **How long** could it run before 900 J of energy was **wasted**?

13. A diesel engine, which is 25% efficient, is generating electric power and is able to light three 100 W lamps at the same time. What is the **input power** from the diesel fuel?

14. A mains transformer has an input power of 2 kW and is 90% efficient.

(a) How much **energy** would wasted in 10 minutes?

(b) What **form** of energy would most of the wasted energy be?

15. A machine has an efficiency of 60%. If the *useful* power output is 150 W, what is the **total input power?**

16. An electric motor consumes 10 watts of electric power when lifting a weight with a pulley system. If the motor is 80% efficient, calculate how much **potential energy** would be gained by the weight in 5 s.

17. An electric motor uses 3 watts of electric power when lifting a weight. If the weight gains 10 joules of potential energy in 5 seconds,

(a) what is the **useful output power** of the motor and

(b) what is the motor's **efficiency** in carrying out the operation?

18. A car engine is 25% efficient at converting the chemical energy in the petrol into useful mechanical energy. How many **joules** of mechanical energy are produced when 600 joules of chemical energy have been used by the engine?

19. A model hydroelectric power station produces just enough electric power to light a 6 W lamp. If the model is found to be **80%** efficient at converting the potential energy of the water into electricity, what is the **input power** of the water running through the pipes?

20. A clockwork toy car's 'engine' works by using the potential energy stored in a wound-up spring to turn the driving wheels. A toy car's spring has 5 J of energy stored when fully wound up. When released at the foot of a hill, the car climbs up to a height of 1 m. If the car's mass is 0.2 kg, calculate:

(a) the **potential energy** gained by the car and

(b) the **efficiency** of its 'engine' in changing the spring's energy into useful energy. (Take 'g' = 10 N/kg.)

21. An electric motor draws 2 A from a 12 V supply. It can lift a weight so that the weight gains 54 J of potential energy in 3 s. Calculate:

(a) the **input power** of the motor,

(b) the **useful output power** of the motor and

(c) the **efficiency** of the motor.

22. A water pump, rated at 12 V; 5 A raises 30 kg of water through a height of 2 m in a time of 15 seconds. Calculate the pump's **efficiency**.
(Assume the water has no kinetic energy on reaching the top and take 'g' = 10 N/kg.)

23. A hydroelectric power station generates 44 MW of electric power from an input of 70 MW of water power.
Calculate the **efficiency** of the power station.

24. Experiment shows that, of 600 joules of electricity delivered to a filament lamp, 440 joules turns into heat energy.
Calculate the **efficiency** of the lamp at converting electric energy to **light** energy.

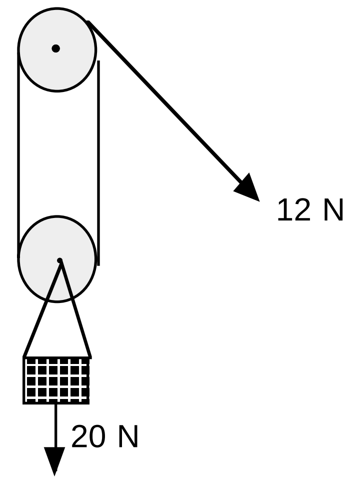
25. In lifting the 20 N weight by a height of 1 m with the pulley system, an effort force of 12 N is moved through 2 m.

Calculate:

(a) the **work done** in moving the effort,

(b) the **potential energy** gained by the weight and

(c) the **efficiency** of the pulley.

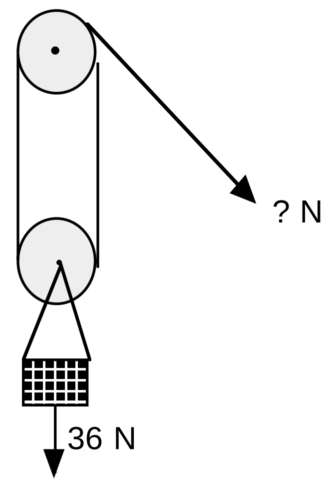


26. In lifting the 36 N weight by a height of 1 m with the pulley system, the effort force is moved through 2 m. The pulley has an efficiency of 90%.

Calculate:

(a) the **potential energy** gained by the weight and

(b) the **size** of the **effort force**.



27. An electric motor is used to raise a 2 kg mass at a speed of 10 cm/s.
The **input** power to the motor is found from the voltage of its supply (5.5 V) and the current drawn from the supply (0.48 A.)
Calculate the **efficiency** of the operation.

28. An experimental wave-power generator consisting of a line of 'nodding ducks' can change 50% of the waves' energy into electric power.

What is the **input power** from waves if 25 kW of electric power is generated?

29. A man cranks a hand-operated generator to power a heater, immersed in an insulated container of water. He does 60 kJ of work in a certain time and raises the temperature of 2 kg of water by 6 C^o in that time. Ignoring heat loss from the water, calculate the **efficiency** of the generator.
(Use $E = cm\theta$ to calculate the heat delivered to the water and take 'c' to be 4200 J/kgC^o.)

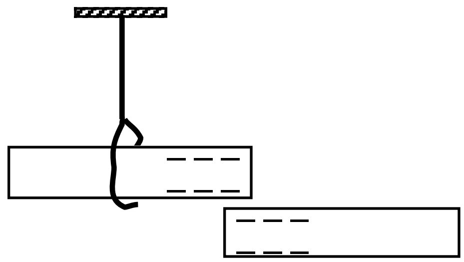
Electrostatics

1. Copy and **complete** the following statement. When a plastic rod is rubbed with a dry cloth, it acquires an electrostatic __________ .
   This charge is caused either by the plastic ________ or _________ electrons.

2. When a plastic rod is rubbed with a cloth and *gains* extra electrons, what **kind** of charge does it have? What kind of **charge** does the cloth acquire?

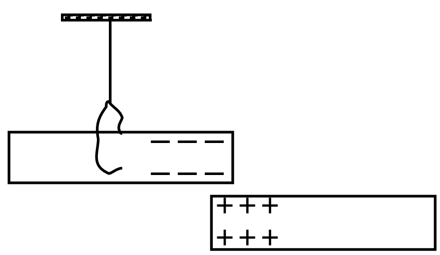
3. When a plastic rod is rubbed with a cloth and *loses* electrons, what **kind** of charge does it have? What kind of **charge** does the cloth acquire?

4. A polythene rod is rubbed with a cloth at one end and acquires a *negative* charge. It is hung from a thread and a second, charged, polythene rod is brought close to it.



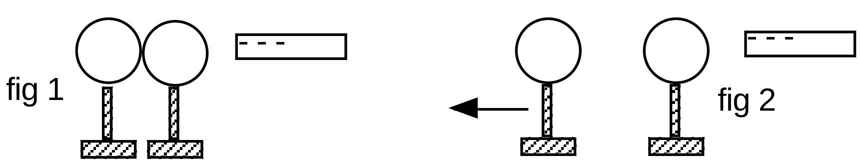
   (a) **Describe** what happens to the suspended rod.
   (b) What would have happened if the rods had been made of another material and both charged ***positively***.
   (c) Complete this statement: "LIKE CHARGES _________" .

5. A *negatively* charged polythene rod is suspended by a thread and a *positively* charged acetate rod held close to it.



   (a) **Describe** what happens to the polythene rod.
   (b) Complete this statement : "UNLIKE CHARGES _________" .

6. A *negatively* charged rod is held close to two uncharged metal spheres on insulated stands (fig 1), while they are separated.(fig 2).



   Copy each diagram and show the position of **negative** and **positive charges** on the spheres.

Charge = current x time (Q = It)

1. Use the formula **charge = current x time** to calculate the value of the missing quantities in the table.

Charge (C)	Current (A)	Time (s)
-	3	10
-	0.6	60
60	2	-
1200	0.5	-
100	-	25
3×10^4	-	6×10^3

2. A car headlamp bulb draws 2 A from the battery. How much **charge** flows through the bulb in 5 minutes?

3. How much **charge** flows through a lamp in 2 minutes if it carries a **steady** current of 0.3 amperes?

4. What **current** flows through a resistor if 1200 C of charge move through it in 5 minutes?

5. How **long** would a charge of 600 coulombs take to move round a circuit at a steady rate of 12 C/s?

6. With a steady current of 5 coulombs per second, how **long** would it take to move 200 coulombs of charge through a resistor?

7. In an electric circuit, an ammeter, in series with a 2700 Ω resistor, reads 4.5 mA. How many **coulombs** of charge pass through the resistor in a time of 5 minutes?

8. How **long** has a lamp been switched on if it draws 2.5 amps from its power supply and 75 coulombs of charge have passed through it?

9. In part of an electronic circuit, a capacitor is charged in 9.0 s by an average current of 5 mA. How much **charge** is delivered to the capacitor in this time?

10. Car batteries are rated in units called **amp-hours**. What **quantity** is measured by this unit?

11. A rechargeable battery is marked 1.2V1.2Ah. According to this rating, how much **charge** does the fully-charged battery store, in coulombs?

12. A car battery is rated at 40 Ah. In *theory*, how **long** does this suggest the battery could light a headlamp bulb which draws 2 A from the battery?

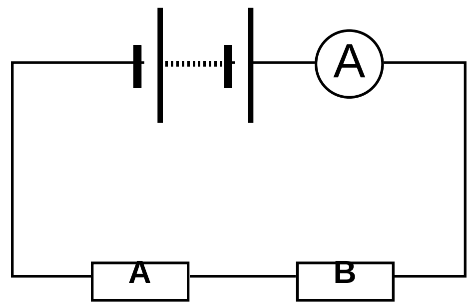
13. A capacitor is an electrical device which can store charge. A certain capacitor can store 0.06 C of charge. How **long** would it take to deliver this quantity of charge to the capacitor with a steady current of 5 mA?

14. In charging a capacitor in an electronic timing circuit, a steady current of 12 mA is delivered for exactly 1 minute.
How much **charge** is delivered to the capacitor in that time?

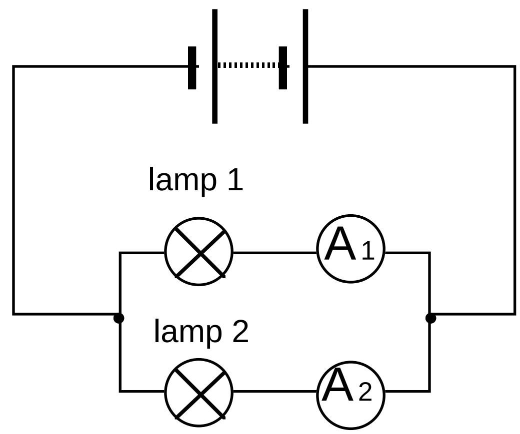
15. What **average current** flows in charging a capacitor with 0.1 C of charge in exactly 40 s?

16. A low voltage heater draws a current of 3 amps from a 12 volt d.c. supply.
Its resistance is 4 Ω.
How much **charge** moves through the heater in 10 minutes?

17. In the circuit shown, the reading on the ammeter is 0.25 amps.
Resistor **A** is double the resistance of resistor **B**.
In 30 seconds, how much **charge** flows through:
(a) resistor **A** (b) resistor **B**?



18. In the circuit shown, the reading on ammeter A_1 is 0.5 A and the reading on ammeter A_2 is 0.3 A.
(a) How much **charge** flows through each lamp in 20 seconds.
(b) How much **charge** leaves the *positive* end of the battery in 20 seconds?
(c) How much **charge** goes into the *negative* end of the battery in 20 seconds?



19. A typical lightning strike delivers a charge of 20 coulombs in 1 millisecond.
Calculate the average **current** during the strike.

20. What is the steady **current**, in milliamps, flowing through a circuit if a total charge of 36 coulombs leaves the power supply in 2 minutes?

21. A rechargeable cell is designed to be charged at 120 mA for 16 hours.
Calculate the total **charge** delivered to the cell in that time.

22. A certain current delivers 1000 coulombs of charge in a certain time.
How much **charge** would be delivered by *double* the current in *half* the time?

23. What has happened to the **size** of the **current** in a circuit if the *same* quantity of charge moves through a circuit component in *half* the time?

24. In 50 seconds, 100 C of charge pass through a lamp in an electric circuit.
A brighter lamp, in parallel with the first, draws a current from the supply which is one and a half times larger. How much **charge** moves through it in 50 s?

Potential difference (voltage) = Energy ÷ Charge ($V = {}^{E}/_{Q}$)

Note: the terms 'potential difference' and 'voltage' have the same meaning.

1. Use the formula '**potential difference = energy ÷ charge**' to calculate the value of the missing quantities in the table:

p.d. (V)	energy (J)	charge (C)
-	24	2
-	180	20
12	240	-
1.32×10^5	6.60×10^8	-
4.5	-	450
230	-	15

2. What one **word** may be used in place of the electrical term '**potential difference** or **p.d.**'?

3. Complete this statement:

   'the **p.d.** between two points in an electric circuit is the e ___________ t _______________ in moving one unit of c ________between the points.'

4. What is the **potential difference** across a lamp if 120 joules of light and heat energy are released when 10 C of charge has passed through it?

5. What is the **potential difference** across a resistor if 125 J of heat is made when a current of 2.5 A flows through it for 2 s?

6. How much **energy** is converted into heat when 2 coulombs of charge moves through a resistance across which there is a **p.d.** of 12 volts?

7. What is the **p.d.** across a lamp if 24 joules of electric energy are transferred to other forms when 8 coulombs of charge has passed through it?

8. A car headlamp lights up correctly if connected across a p.d. of 12 volts.
   How much **energy** is used by the lamp when 3 coulombs of charge have gone through its filament?

9. How much **energy** is transferred from chemical to electrical when 10 coulombs of charge pass through a cell of **e.m.f.** 1.5 volts?

10. A voltmeter, connected across a resistor in an electric circuit, reads 3 V.
    How much **heat energy** is made in the resistor when 50 coulombs of charge have moved through it?

11. How much **energy** is converted to heat when 2 millicoulombs of charge pass through a resistance across which there is a voltage of 9 volts?

12. A 6 volt lamp is operated at its rated value. How many **joules** of heat and light energy are produced when 3 coulombs of charge pass through the lamp?

13. How much **charge** flows through a resistance if 10 joules of energy is transferred from electricity to other forms and the p.d. across the resistor is 4 volts?

14. What is the more usual **name** for the unit '**joule per coulomb**'?

15. What is the **p.d.** across a lamp if 4600 joules of electric energy are transferred to other forms when 20 coulombs of charge has passed through it?

16. A typical lightning strike delivers a charge of 20 C in 1 millisecond.
If the average p.d. between the cloud and the ground during the above lightning strike is 50 million volts, calculate the **energy** transferred by the strike.

17. When 3 coulombs of charge flows through a cell, 3.6 joules of chemical energy is converted to electrical energy. What is the **e.m.f.** of the cell?

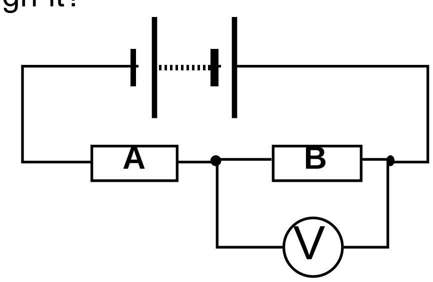
18. How much **energy** is transferred from chemical to electrical when 20 coulombs of charge pass through a rechargeable cell of **e.m.f.** 1.2 volts?

19. An electron, which carries an electric charge of magnitude 1.6×10^{-19} C, is accelerated from rest across a potential difference of 2000 volts.
Calculate the **kinetic energy** gained by the electron.

20. An aquarium heater works from the 230 V mains. How much **charge** has passed through its element if 13.8 kJ of heat has been added to the water in the aquarium?

21. What would be the **reading** on a voltmeter connected across a resistor if the resistor made 180 J of heat when 20 C of charge passed through it?

22. In the circuit shown, the reading on the voltmeter is 2.5 volts.
How much **heat energy** would be produced in resistor **B** when a charge of 10 coulombs had passed through it?



23. Find the **kinetic energy** gained by an object carrying a charge of 2 nanocoulombs accelerated across a gap by potential difference of 120 kilovolts.

24. Calculate the **energy** gained by an electron accelerated by a p.d. of **60 kV** in an X-ray machine. (Charge on the electron = 1.6×10^{-19}C)

25. What **speed** is reached by an electron, accelerated from rest by a potential difference of 160 volts, assuming all the work done on the electron becomes kinetic energy?
(Mass of the electron = 9.1×10^{-31} kg)

26. What is the maximum **speed** reached by electrons accelerated from **rest** by a voltage of 2.6 kilovolts, assuming all the work done on the electron becomes kinetic energy?
(Mass of the electron = 9.1×10^{-31} kg)

Ohm’s Law

1. Use the formula ‘**resistance = potential difference ÷ current**’ or ‘$\mathbf{R = V/I}$’ (Ohm’s Law) to calculate the missing entries in the table.

Resistance (Ω)	P.D. (V)	Current (A)
-	12	2
-	9	0.5
-	230	11.5
4	12	-
70	3.5	-
3300	12	-
12	-	0.1
500	-	0.46

2 A room light has a current of 0.43 amps flowing through it when working from the 230 volt mains. What is the lamp’s filament **resistance**?

3. A car headlamp bulb has a filament resistance of 6 Ω. If the car battery is 12 volts, how much **current** does the bulb take from the battery when lit?

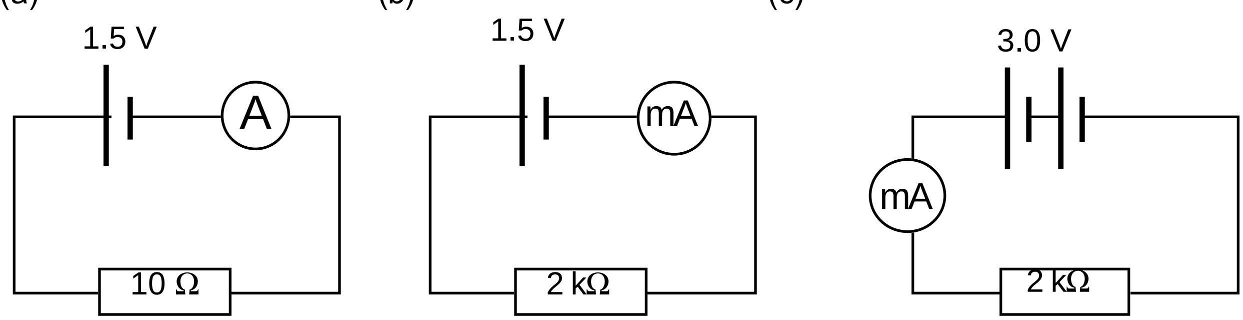
4. The heater of a toilet hand drier uses 9 amps from the 230 volt mains. What is the **resistance** of the heater’s element?

5. In part of an electric circuit, the potential difference across a 12 Ω resistor is 16 V. What is the **current** through the resistor?

6. A current of 3.33 mA flows through a 2.7 kΩ resistor. Calculate the **potential difference** across the resistor.

7. Calculate the **reading** on the meter in each circuit.

(a) (b) (c)



8. Calculate the **resistance** of the filament of a torch bulb which is rated at 2.5V0.2A.

9. How much **current** would flow through a 2 MΩ resistor when connected across a p.d. of 9 volts? Answer in **microamps (µA)**.

10. Why is the resistance of a lamp **bigger** when it is lit than when it is off?

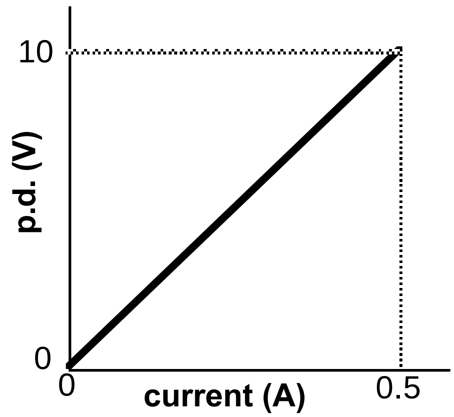
11. A statement about Ohm's Law in a textbook was partly hidden.
What are the missing **words**?

"The ____________________ flowing through a conductor is ___________ to the potential difference across the ends of the conductor if its ______________________ does not alter."

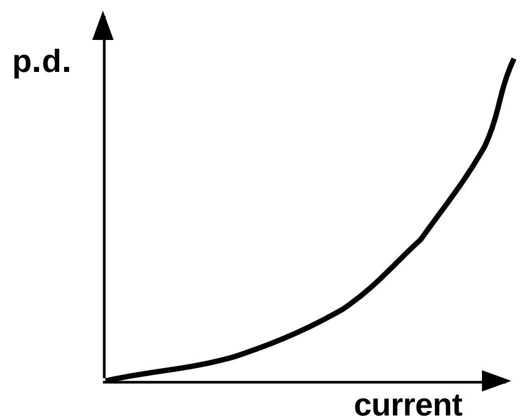
12. For a conductor at constant temperature, describe the graph which would result if the **potential difference** across its ends was plotted against the **current** flowing through it.

13. For a conductor, a graph of **potential difference** across its ends is plotted against **current** flowing through it.
What **quantity** can be found from the **gradient** of the graph at any point?

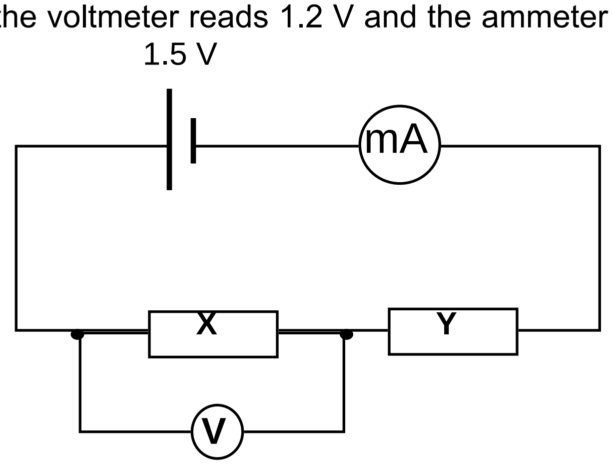
14. The graph shows how the potential difference (p.d.) across a conductor varied with the current through it.
Calculate the **resistance** of the conductor.



15. The graph shows how the potential difference (p.d.) across a conductor varies with the current through it.
How does the **resistance** of the conductor change as the current *inceases*?



16. In the circuit below, the voltmeter reads 1.2 V and the ammeter reads 50 mA.



Calculate the value of **resistor X**.

$P = IV$ $P = I^2R$ $P = V^2/R$

1. Use the formula **power = current x voltage** to calculate the value of the missing quantities in the table:

power (W)	current (A)	voltage (V)
-	5	12
-	10	230
2.64×10^6	-	132000
1000	-	250
72	6	-
0.36	0.06	-

2. How much **current** does a 2 kW electric fire draw from the 230 V mains?

3. What is the **power rating** of a lamp which draws 0.26 A from the 230 V mains?

4. A torch bulb has 2.5V0.2A stamped on it. What is its **power rating**?

5. What is the **potential difference** across a heater which develops power of 42 W when a current of 3.5 A flows through it?

6. A 50 Ω resistor carries a current of 2 A. Calculate the **power** developed in it.

7. What is the **resistance** of a resistor which develops 1000 watts of power when 10 amps flows through it?

8. Calculate the **power** of a hair dryer element which is designed to operate from the 230 V mains and has an element of resistance 53 Ω.

9. What electric **power** is used by a light bulb which has a filament resistance of 1323 Ω and works on 230 V?

10. The power of the heater element of a toilet hand dryer is 2100 W. It operates from the 230 V mains.
    Calculate the **current** drawn from the mains.

11. What **current** is carried in the element of a 2.4 kW kettle connected to the 230 V mains?

12. What **power** is dissipated in a 48 Ω resistor when 2 amps flows through it?

13. Calculate the **power dissipated** in a 60 Ω resistance wire carrying a current of 4 amps.

14. What is the **power** rating of a 529 Ω light bulb which operates from the 230 V a.c. mains?

15. Which **quantity** is calculated by the **square** of the p.d. across a resistor **divided** by the value of its resistance?

16. Calculate the ‘on’ **resistance** of a mains 60 watt lamp, taking the voltage as 230 V r.m.s.

17. Two 1 kW electric fire elements are normally wired in parallel to give a power output of 2 kW when connected to 230 V. If they were connected in **series** to 230 V, what would their power output be? (Assume their resistances are **constant** at all temperatures).

18. Calculate the **power dissipated** by an 80 Ω resistor connected to a 240 V supply.

19. The mains electricity has been reduced from 240 V a.c. to 230 V a.c. Assuming that the resistance of the element of an electric fire does not change with temperature, calculate the percentage **drop** in the **power output** from the element.

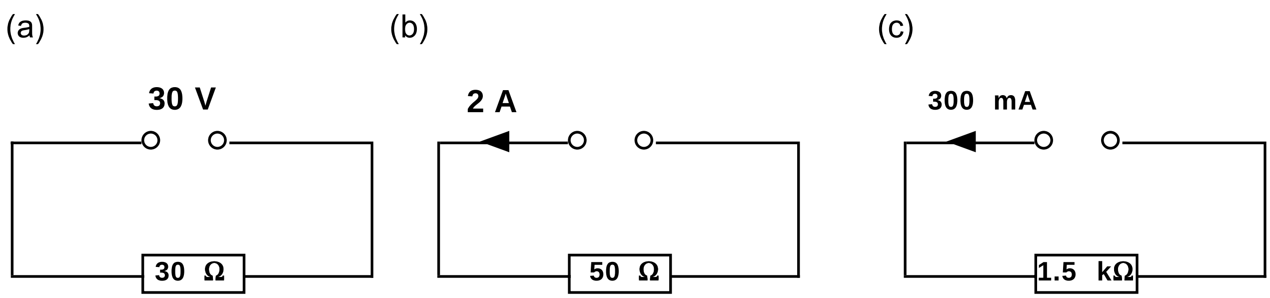
20. What is the **resistance** of a toaster element that produces power of 300 watts when operated from 230 V a.c.?

21. Assuming its resistance is constant, by what **factor** does the power dissipated in a resistor **increase** if the p.d. across it doubles?

22. Which **unit** could be expressed otherwise as an ‘**ampere squared - ohm**’?

23. A 10 Ω resistor has a **power** rating of 1 watt.
Calculate the **maximum current** the resistor can carry.

24. In each of these circuits, calculate the **power** dissipated in the resistor:



25. An immersion heater is marked 230 volt; 1 kilowatt.
How many **joules** of heat does it produce each second?

26. What is the **highest power** of appliance that should be connected to a plug which has a 3 amp fuse connected to a 230 volt supply?

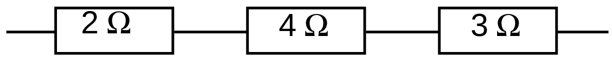
27. An electric iron is marked 230 V 650 W. What is its normal operating **current**?

28. What is the **resistance** of the element of a kettle which is marked 2.2 kW; 230 V?

29. An electric can opener has a power rating of 35 W when operated from a 230 V power supply.
How much **current** does it draw from the supply, in *mA*?

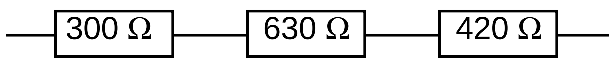
Combinations of resistors

1 What is the **combined** resistance of these three resistors?

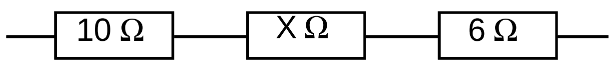


How are the resistors **connected** to each other?

2. What is the **combined** resistance of these three resistors?



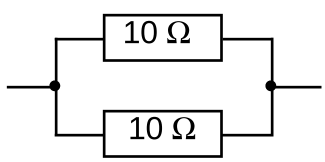
3. The **combined** resistance of these resistors is **20 Ω**.



What is the value of resistor X?

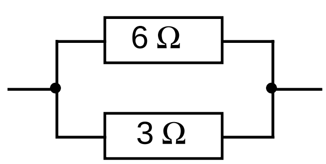
4. A set of Xmas tree lamps consists of twenty lamps wired in **series**.
If the identical lamps each have a resistance of 24 Ω, calculate the **total** resistance of the set.

5. What is the **combined** resistance of the two resistors connected as shown below.



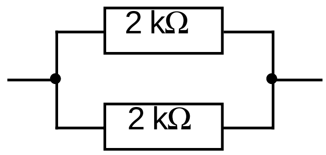
How are the two resistors **connected** to each other?

6. Calculate the **combined** resistance of the two resistors, connected in parallel.

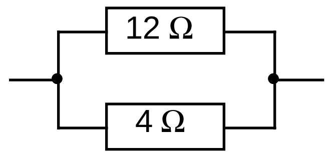


7. In each case, calculate the **combined** resistance of the two resistors, connected in parallel.

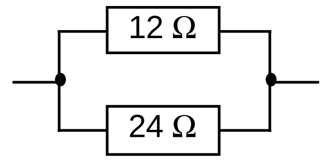
(a)



(b)

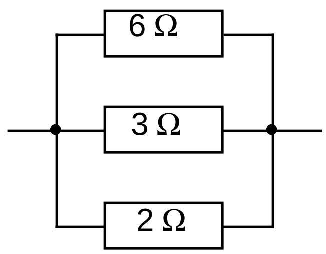


(c)

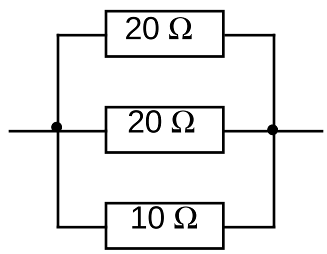


8. In each case, calculate the **combined** resistance of the three resistors, connected in parallel.

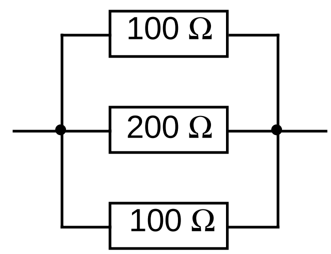
(a)



(b)

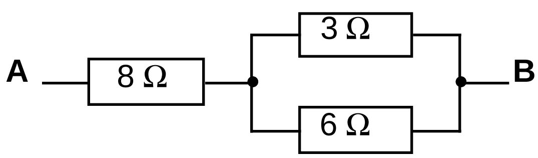


(c)

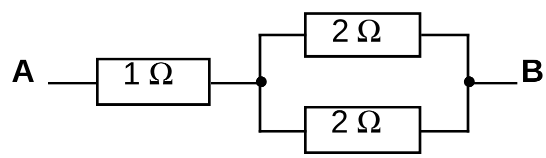


9. In each case, calculate the **combined** resistance between **A** and **B**.

(a)

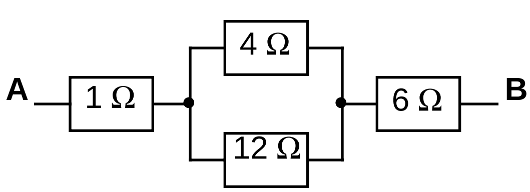


(b)

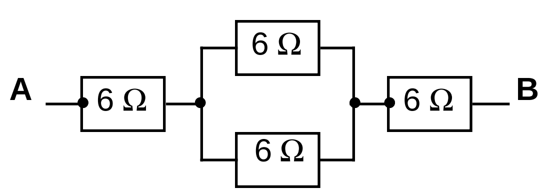


10. In each case, calculate the **combined** resistance between **A** and **B**.

(a)



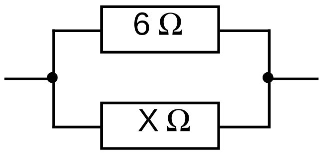
(b)



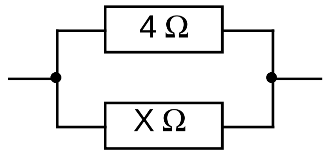
11. In each of these parallel resistor combinations, the **combined** resistance is **2 Ω**.

Calculate the value of resistor **X** in each combination.

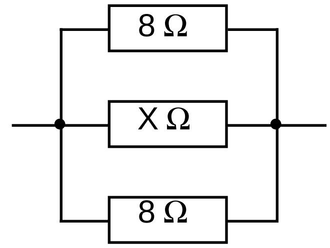
(a)



(b)

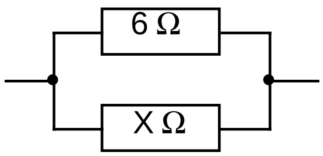


(c)

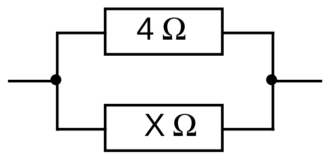


12. In each of these parallel resistor combinations, the **combined** resistance is **3 Ω**.
Calculate the value of resistor **X** in each combination.

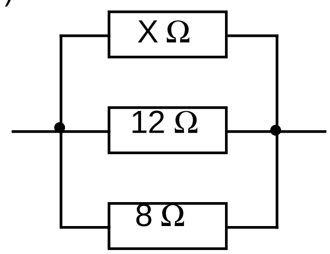
(a)



(b)

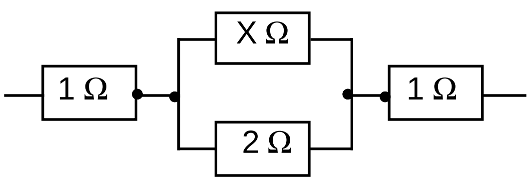


(c)

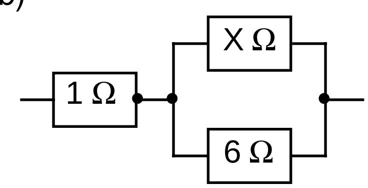


13. In each of these parallel resistor combinations, the **combined** resistance is **3 Ω**.
Calculate the value of resistor **X** in each combination.

(a)



(b)



14. What is the **total** resistance of two 10 Ω resistors connected to each other:

(a) in series (b) in parallel?

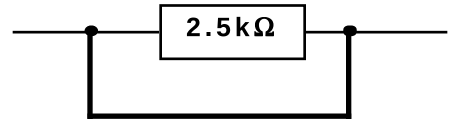
15. Two resistors in **parallel** have an effective resistance of 20 Ω.
One of the resistors is 30 Ω. Calculate the value of the other.

16. How does the **total** resistance of **any two** resistances **connected in parallel** compare to the value of **either** of the individual resistances?

17. Two resistors connected in **parallel**, one of which is 10 Ω, have a **total** resistance of 5 Ω.

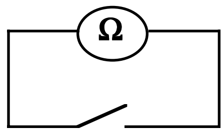
Calculate their **total** resistance when connected in **series**.

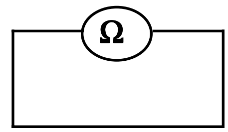
18. What is the **effective** resistance of a 2.5 kΩ resistor **short-circuited** by a length of thick conducting wire?



19. What is the **effective** resistance across:

(a) an **open** switch, (b) a **closed** switch?





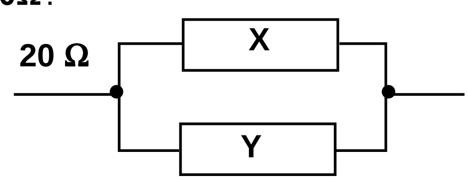
20. Three resistors connected in parallel have an effective resistance of 10 Ω.
Two of them are **each** 40 Ω.
What would be the total resistance of the three resistors if connected in **series**?

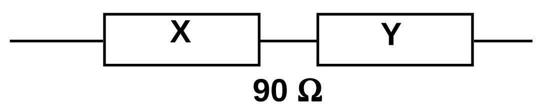
21. What value of resistor, connected in **series** to a 20 Ω resistor, would create a ***total*** resistance of **four times** that produced if it was connected in **parallel** to the 20 Ω resistor?

22. Three resistors, **10Ω**, **10Ω** and **20Ω**, are connected in **parallel** to each other.
A high resistance voltmeter connected across the **20 Ω** resistor reads 3 V.
What would the vlotmeter's **reading** be across **each** of the other resistors?

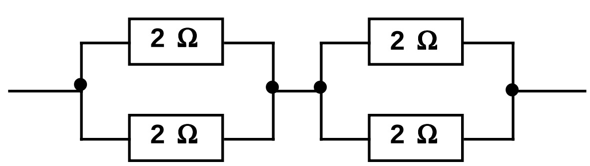
23. Sketch the arrangement of four resistors, values **1 Ω**, **1 Ω**, **3 Ω** and **6 Ω** which would create a **total** effective resistance of **1Ω.**

24. What are the **values** of two resistors **X** and **Y** which, when connected in **series**, make a total resistance of **90Ω** and, when in **parallel**, make a total resistance of **20Ω**?





25. What is the total resistance when two **2 Ω** resistors, in **parallel**, are themselves in **series** with another pair of **parallel 2 Ω** resistors?



26. What **two** resistances, measuring **16 Ω** when connected in **series**, make a total resistance of **3 Ω** when connected in parallel?

27. How would four resistors, (**2 Ω**, **3 Ω**, **6 Ω** and **10 Ω**) be connected to make a **total** resistance of **11 Ω**?

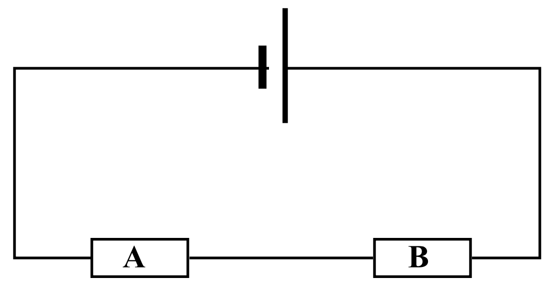
28. Three resistors, values **10 Ω**, **15 Ω** and **30 Ω** are connected so as to make a **total** resistance of **20 Ω**. Sketch the **arrangement** of the resistors.

Circuit rules - current and voltage

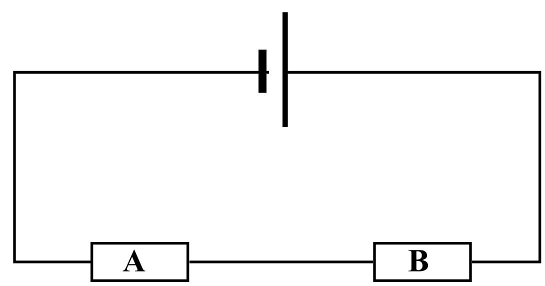
1. Describe how an **ammeter** should be **connected** to measure the current through a circuit component and state what its ideal **resistance** would be.

2. Describe how a **voltmeter** should be **connected** to measure the potential difference (voltage) across a circuit component and state what its ideal **resistance** would be.

3. Copy and complete the circuit diagram to show how an **ammeter** should be connected to measure the current between resistors A and B.

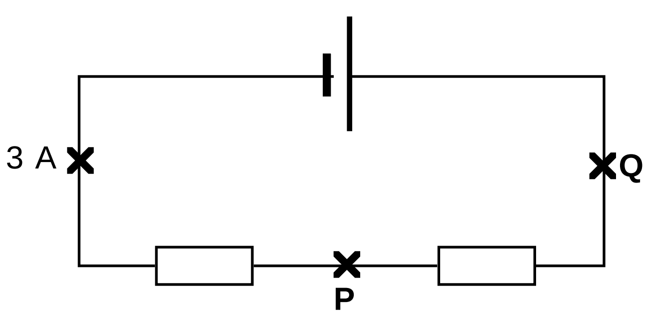


4. Copy and complete the circuit diagram to show how a **voltmeter** should be connected to measure the potential difference across resistor A.

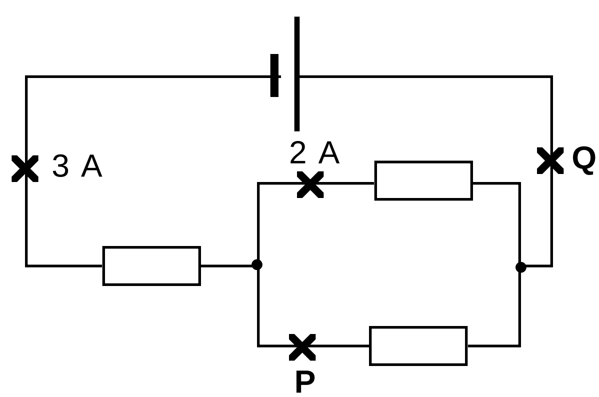


5. In each circuit, state the **current** at positions **P** and **Q**.

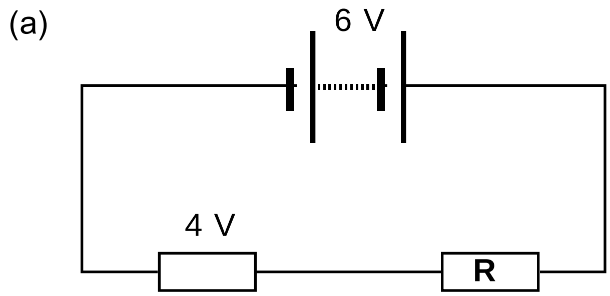
(a)

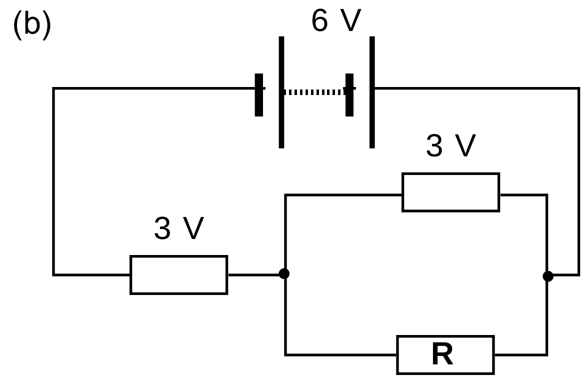


(b)

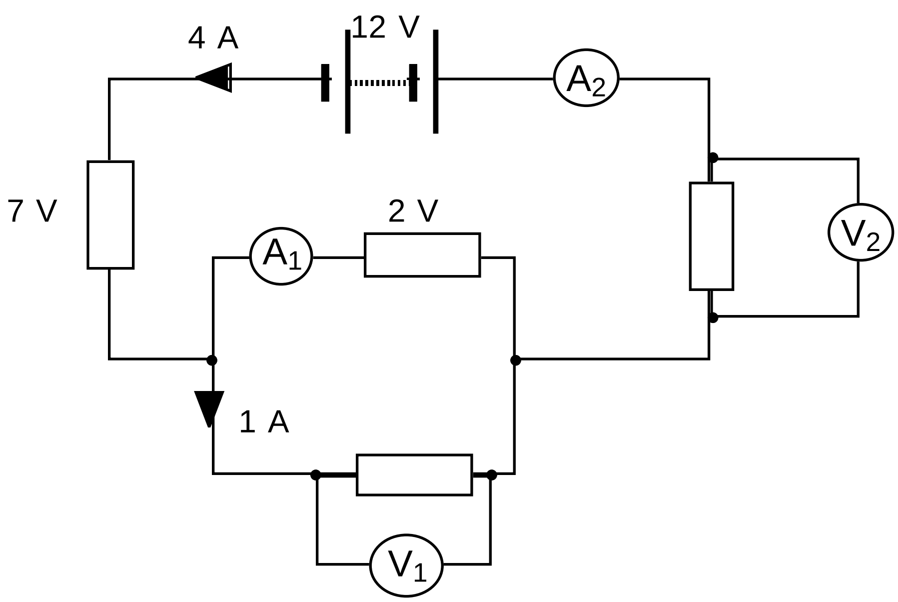


6. In each circuit, state the **potential difference** (voltage) across resistor **R**.

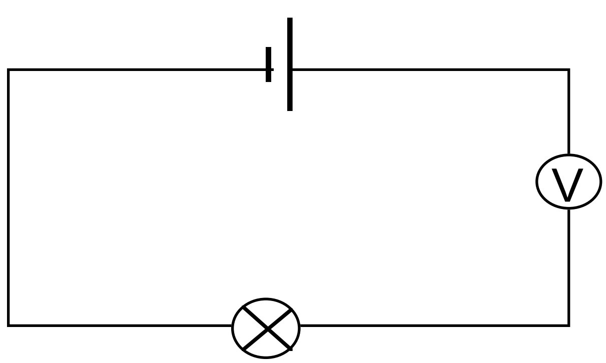




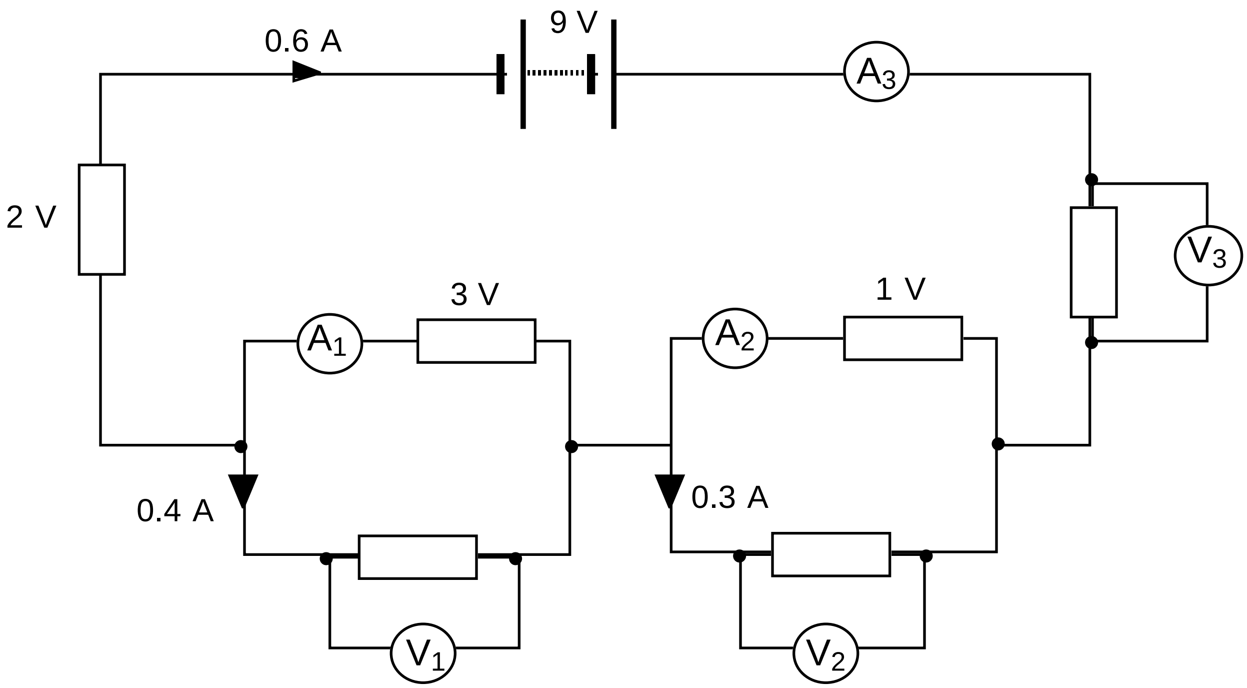
7. In the circuit below, what are the **readings** on the ammeters **A_1** and **A_2** and the voltmeters **V_1** and **V_2**?
(The currents and voltages at several points in the circuit are given).



8. A boy is asked to measure the current through a low voltage lamp.
He sets up a circuit as shown and complains that the lamp is not working.
In fact, the lamp *is* working.
What **mistake** has the boy made and why has the lamp **not** lit up?

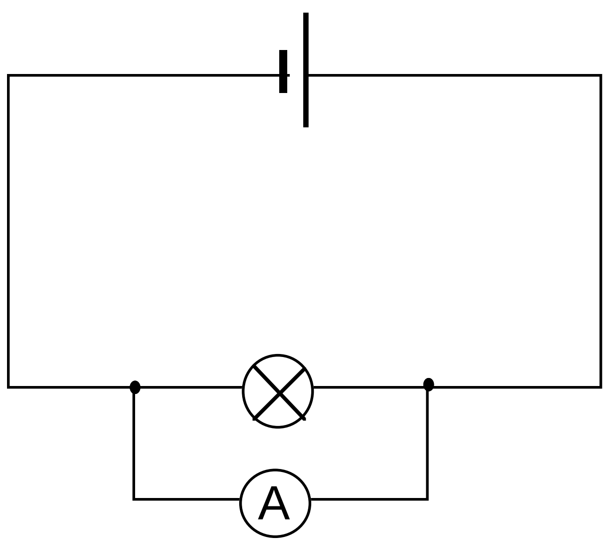


9. In the circuit below, what are the **readings** on the ammeters $\mathbf{A_1}$, $\mathbf{A_2}$ and $\mathbf{A_3}$ and the voltmeters $\mathbf{V_1}$, $\mathbf{V_2}$ and $\mathbf{V_3}$?



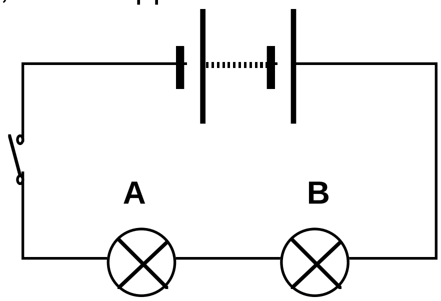
10. The lamp does not light up.
Tests show that the lamp is not burst.

What mistake has been made in this circuit? Why does the lamp not light?



D.C. circuits

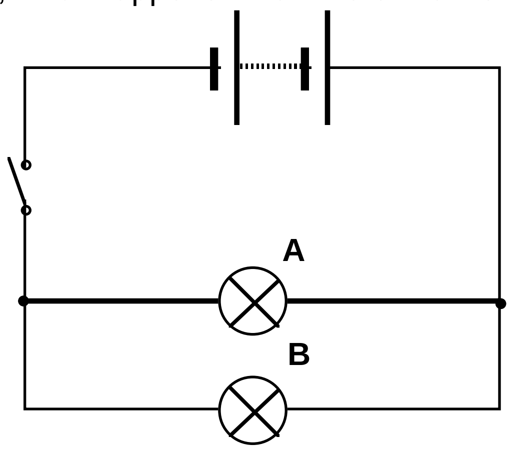
1. (a) In the circuit shown, what happens when the switch is closed?



(b) What would happen if lamp **A** was to break?

(c) Are the lamps wired in **series** or **parallel**?

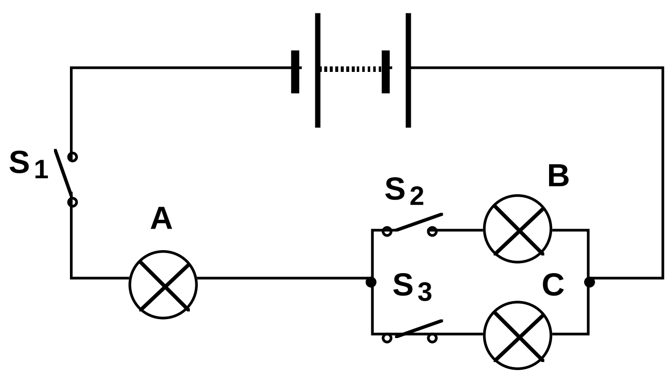
2. (a) In the circuit shown, what happens when the switch is closed?



(b) What would happen if lamp **A** was to break?

(c) Are the lamps wired in **series** or **parallel**?

3.



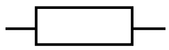
(a) In this circuit, how many **lamps** are lit if switch $\mathbf{S_1}$ only is closed?

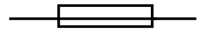
(b) How many **lamps** are lit if only switches $\mathbf{S_2}$ and $\mathbf{S_3}$ are closed?

(c) If all three switches are closed, which **lamps** are lit?

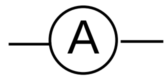
(d) If all the lamps are identical, which would light **brightest** if all three were lit?

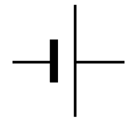
4. What circuit components are represented by these **symbols**?

(a) 

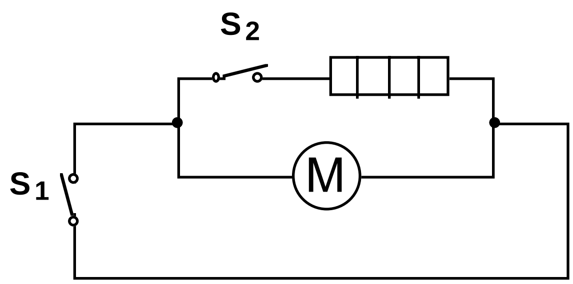
(b) 

(c) 

(d) 

(e) 

5. The circuit below is for a simple fan heater.

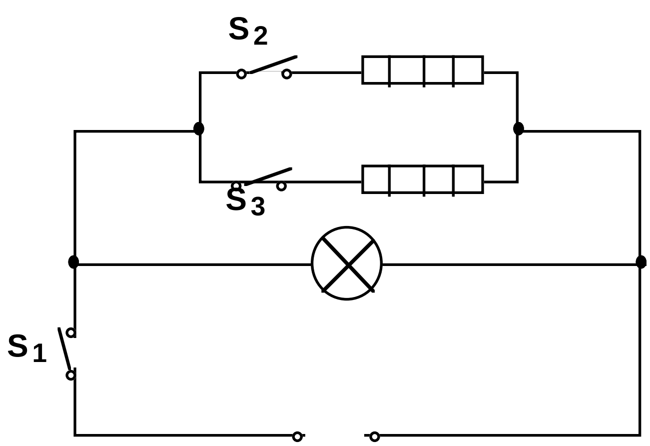


(a) Which switch or switches would be closed if the **motor** was **on** but not the heat?

(b) Which switch or switches would be closed if the **motor** was to be **on** to blow hot air from the heater?

(c) Explain whether it is possible to have the heater **on** but not the motor?

6. The circuit below shows a simple electric heater with two heating elements **A** and **B**. The elements are identical. The circuit also contains a lamp.



(a) How are the lamp and heating elements wired - in **series** or **parallel**?

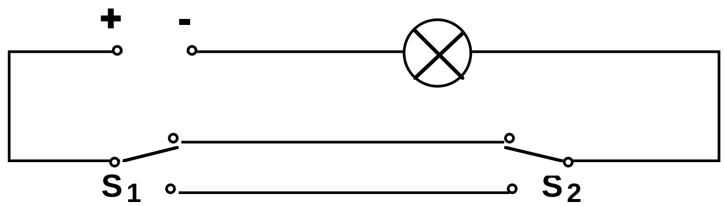
(b) Can either or both elements be **on** without the lamp?

(c) Which **switches** could be closed for **half** heating?

(d) Which **switches** must be closed for **full** heating?

(e) Could either or both of the elements be switched **on** if the lamp was broken?

7. The circuit below shows a lighting circuit which can be used to light the lamp from **either** of two switches; this is useful in a long hallway or for the top and bottom of a flight of stairs.

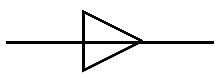


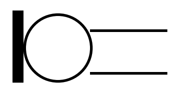
(a) With the switches in the positions shown, would the lamp be **on** or **off**?

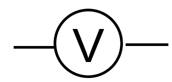
(b) What would happen if the **position** of first one *then* the other switch was **changed**?

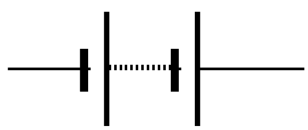
(c) What would happen if the position of **either** switch was **now** changed?

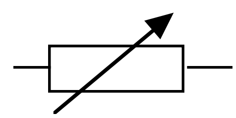
8. What circuit components are represented by these **symbols**?

(a) 

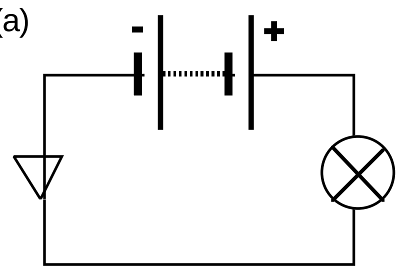
(b) 

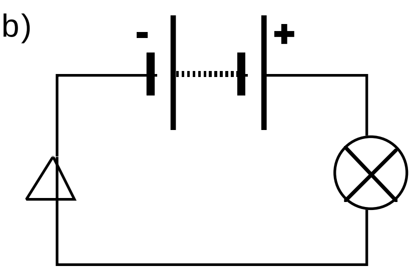
(c) 

(d) 

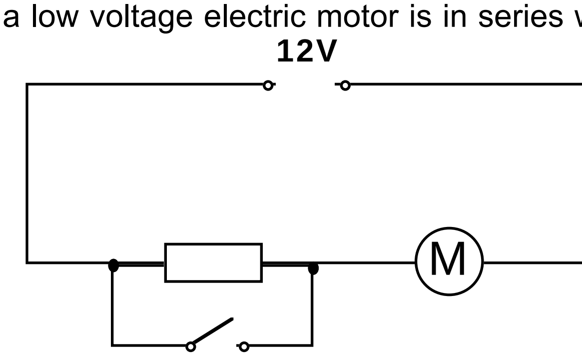
(e) 

9. In which of the circuits shown would the lamp **light**? (Assume both lamps are in working order). Explain.

(a) 

(b) 

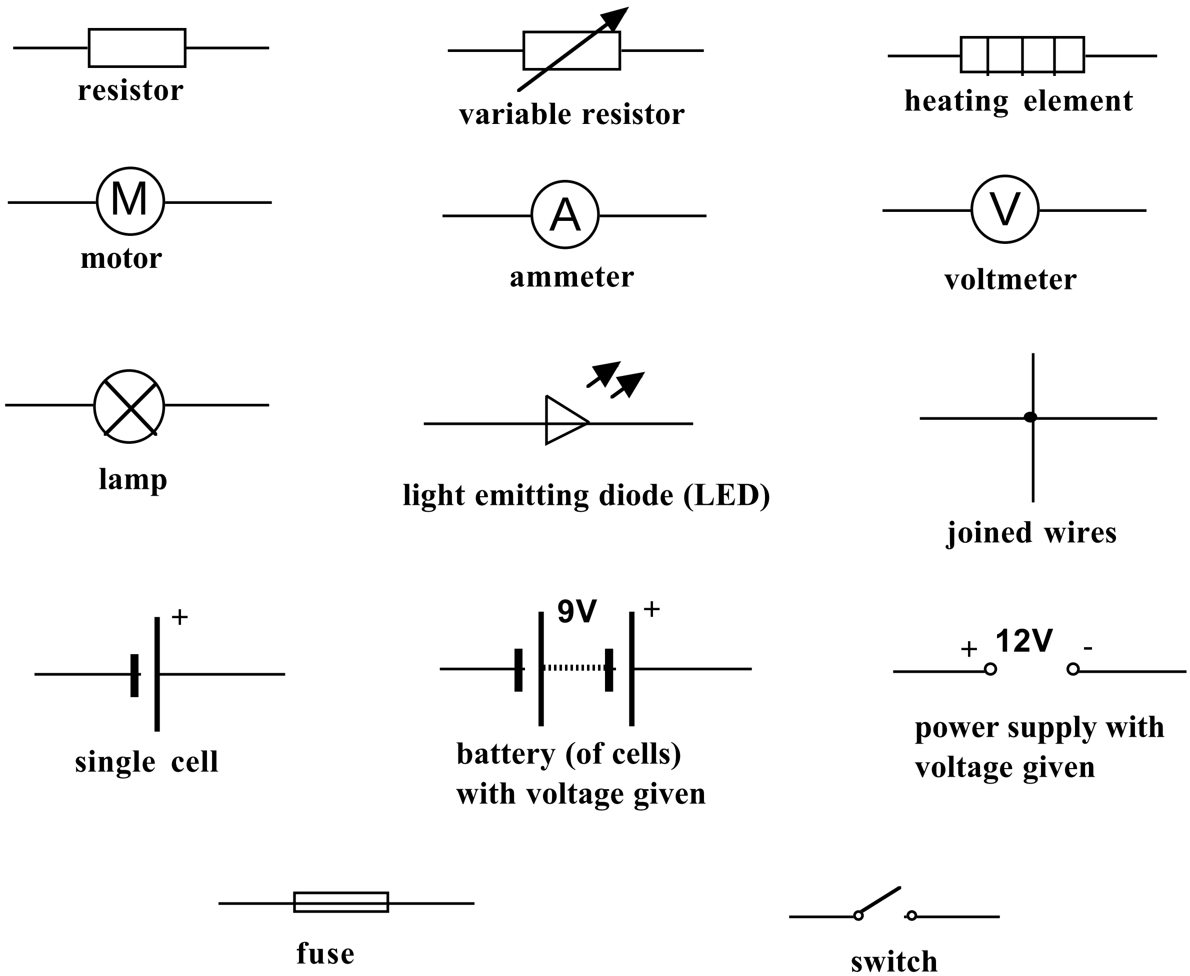
10. In the circuit shown, a low voltage electric motor is in series with a resistor.



With the switch **open**, as shown, the potential difference across the motor is 9 V.
What would happen to the **speed** of the motor if the switch was now **closed**? Explain.

[In the questions which follow, use a **ruler** to draw connecting wires and make corners to be 90^{o}.]

Use these circuit symbols where appropriate:



11. Draw a **circuit diagram** for the following circuit, using the usual circuit symbols:

    a single **cell** in series with a **lamp** followed by a **switch**, with the lamp wired to the positive side of the cell.

12. Draw a **circuit diagram** for the following circuit, using the usual circuit symbols:

    a 9 V **battery** in series with two **lamps** and a **switch**, with the switch between the two lamps.

13. Draw a **circuit diagram** for the following circuit, using the usual circuit symbols:

a single **cell** in series with a **switch**, connected to the negative side of the cell, followed by two lamps wired in parallel.
The switch should control *both* lamps.

14. Draw a **circuit diagram** for the following circuit, using the usual circuit symbols:

a 9 V **battery** connected to a **switch**, on its positive side, which controls two **lamps** wired in parallel. One of the two lamps has its *own* switch so that it can be switched on and off without the other lamp being lit.

15. Draw a **circuit diagram** for the following circuit, using the usual circuit symbols:

a 12 V **power supply** connected to two **resistors** in series.
The p.d. across one of the resistors is being measured by a **voltmeter**.

16. Draw a **circuit diagram** for the following circuit, using the usual circuit symbols:

a 12 V **power supply** connected to two **resistors** in series.
The current *between* the resistors is being measured with an **ammeter**.

17. Draw a **circuit diagram** for the following circuit, using the usual circuit symbols:

a 12 V **battery** supplying current to two **resistors** in parallel with a **switch** controlling the current through *both* resistors.
Ammeters are measuring the current through each resistor.

18. Draw a **circuit diagram** for the following circuit, using the usual circuit symbols:

a 20 V **power supply** in series with a single **resistor** followed by two **resistors** connected in parallel.
An **ammeter** measures the current drawn from the supply and a **voltmeter** measures the potential difference across the parallel resistors.

19. Draw a **circuit diagram** for the following circuit, using the usual circuit symbols:

a 6 V **battery** supplying current to a **light emitting diode (LED)** in series with a **resistor**.
The circuit is arranged so that the diode will conduct.

20. Draw a **circuit diagram** for the following circuit, using the usual circuit symbols:

a 230 V **power supply** in series with a **motor** and **resistor**.
The resistor has a **switch** in parallel with it and a **voltmeter** measures the p.d. across the motor.

21. Draw a possible **circuit diagram** for the following situation, using the usual circuit symbols:

a **motor** and a **heating element** have to be wired in parallel to a 230 V **power supply**. The circuit must include two **switches**. One switch should allow the motor to be switched on without the heater; the other switch should allow the heater to be switched on **only** if the motor is **also** on.

22. Draw a possible **circuit diagram** for the following situation, using the usual circuit symbols:

a 12 V **battery** has to light two pairs of 12 V **lamps**.
The circuit must have two **switches**, connected so that one pair of lamps can be switched on **only** when the other pair is switched **on**.
The circuit is protected by a **fuse** wired to the positive side of the battery.

23. Draw a possible **circuit diagram** for the following situation, using the usual circuit symbols:

a 12 V **battery** wired in series with a 12 V **lamp** and **resistor**.
The circuit also has a **switch**, connected so that, when it is **open**, the lamp is *dull* and, when it is **closed**, the lamp is *bright*.

24. Draw a possible **circuit diagram** for the following situation, using the usual circuit symbols:

a **power supply** is connected to two **lamps** in series.
Two **two-way switches** are wired so that *either* switch is able to turn the lamp on *or* off.

General Circuit problems

1. By what **name** is the unit 'volt-ampere' better known?

2. By what **name** is the 'volt per amp' better known?

3. A lamp operating at its normal rating of 2.5 V 0.3 A is switched on for 5 minutes.

   How much **energy** is used by the lamp during this time?

4. An old moving coil voltmeter has a resistance of 10 kΩ.

   How much **current** is passing through it when it reads 5 volts?

5. How would four resistors, **2 Ω**, **3 Ω**, **5 Ω** and **7.5 Ω** be **connected** to make a total resistance of **10 Ω**?

6. What value of **resistance** would be connected in **parallel** to a 2.4 kΩ resistor to make a **total** resistance of 800 Ω?

7. What is the **approximate** resistance of **2 Ω** in **parallel** with **2 kΩ**?

8. Three resistors, **11 Ω**, **30 Ω** and **40 Ω** are connected in series with a 9.0 V battery.

   What would a high resistance voltmeter **read** if connected across the **30 Ω** resistor?

9. A hair drier has a heating element and a fan motor.

   Should they be wired in **series** or **parallel**? How should the **switches** be wired?

10. A circuit has to be protected by a 10 A fuse but there are only two **5 A** fuses available. How could they be connected to protect the circuit?

11. Calculate the **current** in a set of twenty 12 V 1.2 W Xmas tree lights wired to the 230 V mains.

12. The p.d. across a 12 Ω resistor in a circuit is 1.7 volts.
   What would be the **p.d.** across a 24 Ω resistor in the **same** circuit and in **series** with the first resistor?

13. What can **always** be stated about the **current** at all points in a **series** circuit?

14. The p.d. across a source supplying current to an external load of three resistors measures 12 volts. The p.d. across each resistor measures 6 volts.
   Is this **possible**? Explain.

15. Which **unit** is otherwise known as the '**coulomb per second**'?

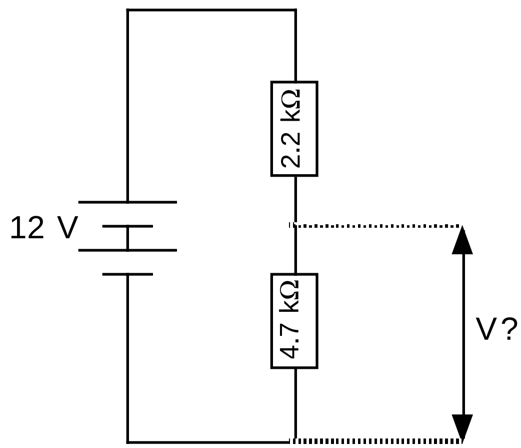
16. What is the more common **name** for the unit '**amp-second**'?

17. In part of an electric circuit, two resistors, values **3 Ω** and **6 Ω** are connected in **parallel**.

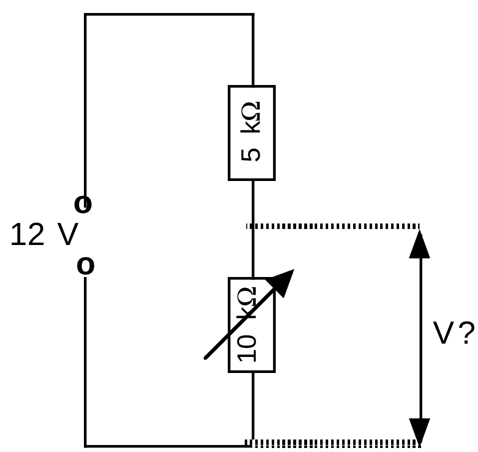
If the current flowing through the **3 Ω** resistor is **4 A**, what **current** flows through the other and what is the **voltage** across each resistor?

18. How much **charge** moves through a resistance if 10 joules of energy is transferred from electricity to other forms and the p.d. across the resistor is 4 volts?

19. A 2.2 kΩ resistor and a 4.7 kΩ resistor form a voltage divider across a 12 volt battery. Calculate the **voltage** across the **larger** resistor.



20. In a voltage divider consisting of a **5 kΩ resistor** and a **10 kΩ rheostat**, what **range of voltages** would be available across the rheostat if the supply voltage was 12 V?



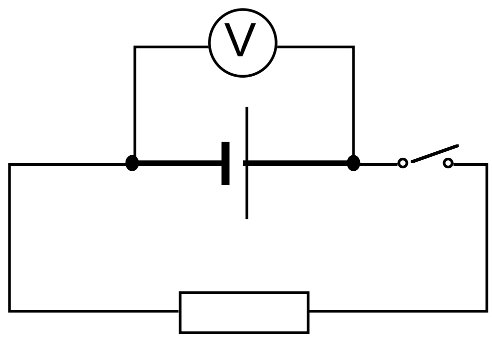
21. A current of 2 amps flows through a 10 Ω resistor which is in **parallel** with a second resistor of **double** the resistance.

What is the **voltage** across the second resistor and the **current** through it?

22. Three resistors, **7 Ω**, **8 Ω** and **12 Ω** are connected in series with a 9.0 V battery. What would a high resistance voltmeter **read** if connected across the **12 Ω** resistor?

Internal Resistance

1. What do the letters '**e.m.f.**' stand for?
2. In what **unit** is the quantity 'e.m.f.' measured?
3. In what **unit** is the quantity 'internal resistance' measured?
4. In what **unit** is the quantity 'potential difference' measured?
5. What do the letters '**t.p.d.**' stand for?
6. In this circuit, a high resistance voltmeter is connected across a cell which has an internal resistance.



(a) What happens to the **reading** on the voltmeter when the switch is closed?
(b) How would you calculate the value of the '**lost volts**' due to the cell's internal resistance?
(c) What other **measurement** would be needed to allow the cell's **internal resistance** to be calculated?

7. In the circuit for Q6, would the cell's **e.m.f.** be measured with the switch *open* or *closed*? Explain your answer.

8. A high resistance voltmeter is connected across a cell. On open circuit, the meter reads 1.65 V. When the cell delivers a current to an external load resistance, the reading *falls* to 1.52 V.

(a) What is the value of the cell's **e.m.f.**?

(b) What is the value of the **lost volts**?

9. A cell has e.m.f. '**E**', internal resistance '**r**' and delivers a current '**i**' to an external load '**R**'.

(a) Show that the **terminal potential difference** of the cell, '**V**', is given by the equation:

$$V = E - ir$$

(b) **Complete** these equations, by changing the subject:

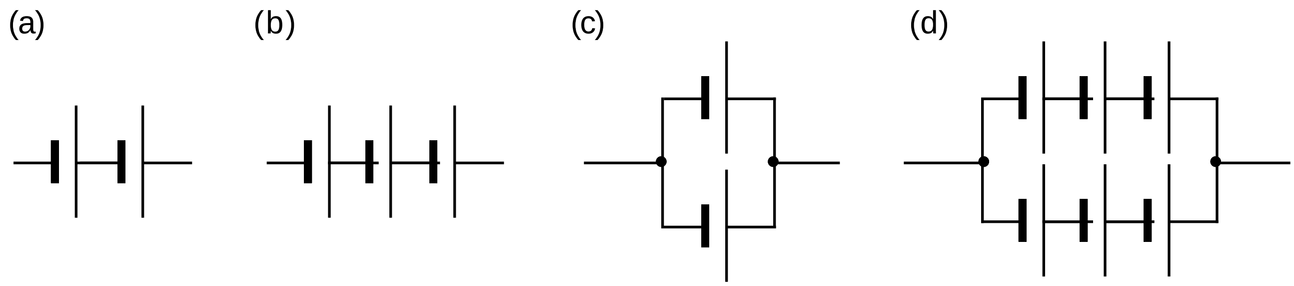
(i) **E = ?** (ii) **i = ?** (iii) **r = ?**

10. What would be the **reading** on a voltmeter connected across a cell of e.m.f. 1.55 V if the **lost volts** inside the cell were:

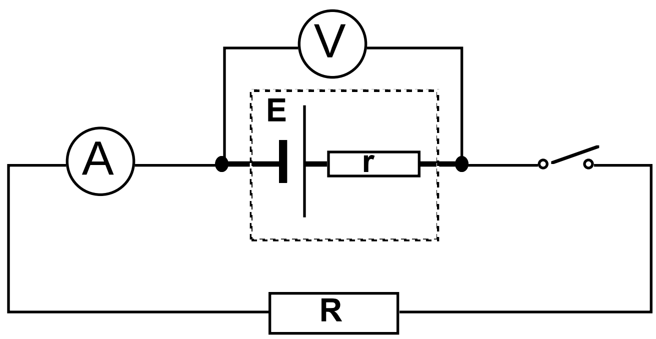
(a) 0 V (b) 0.15 V (c) 0.23 V (d) 1. 25 V?

11. What is **generated** inside a cell when current passes through its internal resistance?

12. A certain type of cell has an e.m.f. of 2 V and an internal resistance of 1Ω.
For each of the **batteries** made from these cells, state the **e.m.f.** and **internal resistance**.



Questions 13 - 18 refer to the circuit shown. A cell has e.m.f. **E** and internal resistance **r**. A high resistance voltmeter is connected across the cell terminals and a low resistance ammeter measures the current delivered by the cell to a load resistor, **R**. The dotted line indicates the actual cell which is shown as if it was a source of e.m.f in series with a resistor.



13. If **E** = 1.5 V ; **r** = 1 Ω; **R** = 4 Ω, calculate the **readings** on the ammeter and voltmeter when the switch is: (a) *open* (b) *closed*.

14. If **E** = 2.0 V ; **r** = 0.5 Ω; **R** = 9.5 Ω, calculate the **readings** on the ammeter and voltmeter when the switch is: (a) *open* (b) *closed*.

15. If **E** = 1.20 V ; **r** = 0.2 Ω; **R** = 1.8 Ω, calculate the **readings** on the ammeter and voltmeter when the switch is: (a) *open* (b) *closed*.

16. With the switch *open*, the reading on the voltmeter is 1.50 V. When the switch is closed, it falls to 1.30 V and the ammeter reads 0.25 amps.

(a) What is the value of the '**lost volts**'?

(b) Calculate the size of the cell's **internal resistance**.

(c) Calculate the value of the **load resistor**.

17. The e.m.f. of the cell is 2.0 V, its internal resistance is 1 Ω and the load resistor measures 4 Ω. With the switch *closed*, calculate:

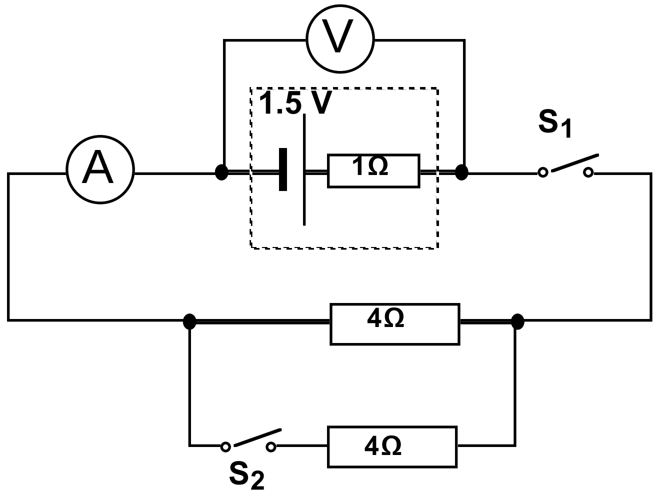
(a) the **ammeter reading**,

(b) the cell's **terminal potential difference**

(c) the value of a *different* **load resistor** which draws 0.2 amps from the cell.

18. Calculate the **ammeter** reading and the value of the cell's **e.m.f.** if the voltmeter reads 1.1 V, the load resistor is 5.5 Ω, the internal resistance is 0.5 Ω and the switch is *closed*.

19.



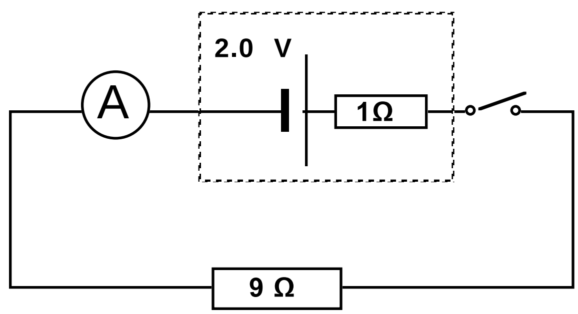
The dotted line represents the case of a cell of e.m.f. 1.5 volts and internal resistance 1Ω.

(a) What is the **voltmeter** reading with switch $\mathbf{S_1}$ open?

(b) What are the readings on the **ammeter** and **voltmeter** with switch $\mathbf{S_1}$ closed and $\mathbf{S_2}$ open?

(c) What do the **readings** become if switch $\mathbf{S_2}$ is now closed?

20.



In the circuit above, when the switch is closed, calculate:

(a) the **current** flowing through the cell

(b) the **power** dissipated in the internal resistance

(c) the **potential difference** across the load resistor.

21. Repeat the **calculations** of Q20 with the e.m.f. as 1.5 V, internal resistance 0.8 Ω and load resistance 2.2 Ω.

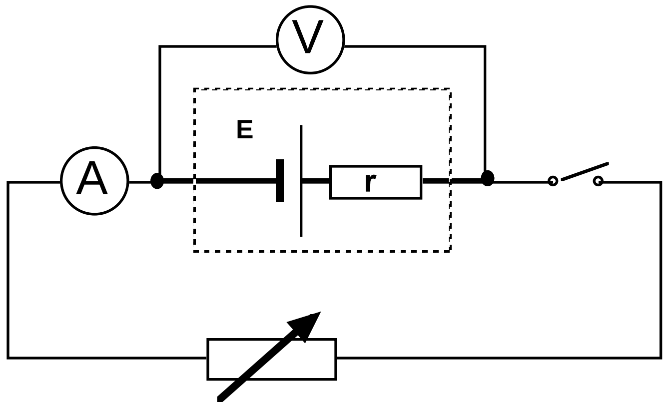
22. Three cells each have an e.m.f. of 1.5 V and internal resistance of 1.2 Ω. Calculate the **current** delivered to an external component of resistance 8 Ω when the cells are connected:

(a) in **series** (b) in **parallel**. [Answer in each case to 2 significant figures.]

23. A high resistance voltmeter, connected across the terminals of a cell on open circuit, reads 1.55 volts. The short circuit current of the cell is measured as 1.75 amps.

Calculate the value of the cell's **internal resistance**.

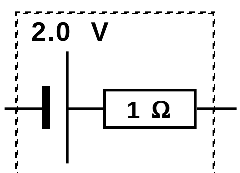
24.



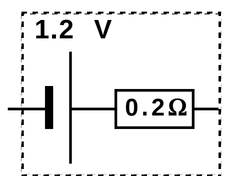
In this circuit, a variable resistor (or rheostat) acts as a load on a cell of e.m.f. **E** and internal resistance **r**. What happens to the **readings** on the ammeter and voltmeter as the resistance of the rheostat is *increased*?

25. It can be shown that the maximum power that a power supply, such as a battery, can supply to an external load occurs when the load's resistance is equal to that of the internal resistance of the power supply. Calculate the **maximum power** that these cells and battery can supply to an external load?

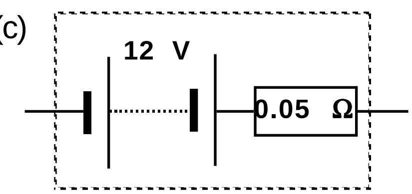
(a)



(b)



(c)



26. For a cell of e.m.f. '**E**' and internal resistance '**r**', the potential difference '**V**' across the cell terminals is measured for different values of current '**I**' delivered to an external load.

(a) Assuming that **E** and **r** are constants, sketch the **graph** which would be obtained if '**V**' was plotted against '**I**'.

(b) Which feature of the **cell** is found from the **intercept** of the line on the y-axis?

(c) Which feature of the cell could be found from the **gradient** of the line?

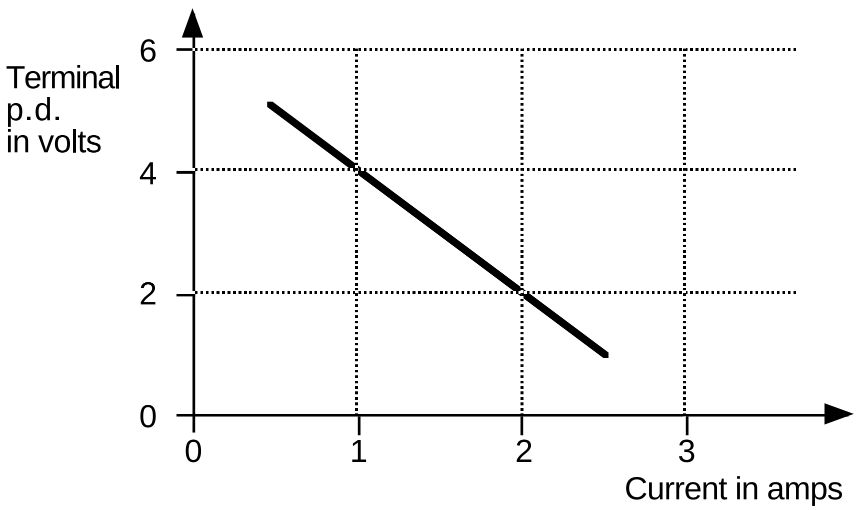
27. For a cell of e.m.f. '**E**' and internal resistance '**r**', the current '**I**' drawn from the cell is measured for a number of different values of load resistance '**R**'.

(a) Assuming that **E** and **r** are constants, sketch the **graph** which would be obtained if '**R**' was plotted against the 'inverse of **I**' (that is 1 ÷ **I**).

(b) What feature of the **cell** is found from the **intercept** of the line on the y-axis?

(c) What feature of the cell could be found from the **gradient** of the line?

28. The graph shows how the potential difference across the terminals of a cell varies with current drawn from the cell.



Use the graph the estimate:

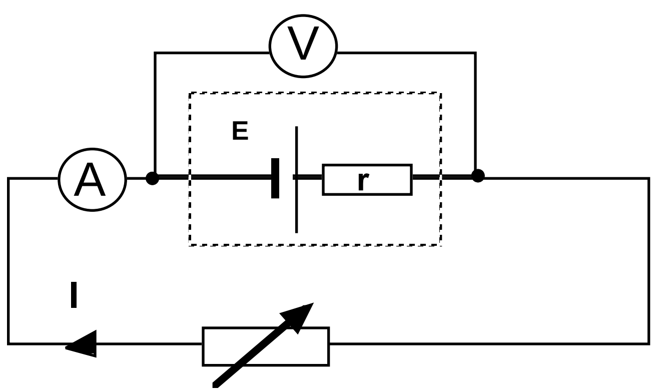
(a) the **e.m.f.** of the cell (b) its **internal resistance**

29. On graph paper, copy the graph of Q28 and add:

(a) the graph that would be obtained for a cell of the ***same*** **e.m.f.** but ***double*** the internal resistance

(b) the graph that would be obtained for a cell of the e.m.f. **4.0 volts** and the ***same*** internal resistance as the cell in Q27.

30.



A cell delivers current to a load whose resistance can be varied.
The table gives values for the voltmeter and ammeter readings for a number of different load resistances.

Voltage in volts	1.8	1.7	1.6	1.5	1.4	1.3
Current in amps	1.0	1.5	2.0	2.5	3.0	3.5

(a) Draw a graph, on graph paper, of **voltage** against **current**.

(b) By using the straight line of the graph, estimate:

(i) the cell's **internal resistance**. (ii) the cell's **e.m.f.**

31. Using the same circuit as in Q27, the current, **I**, delivered by the cell to the load resistor, **R**, is measured for a number of values of the resistance.

Resistance (Ω)	0.2	0.4	0.6	0.8	1.0	1.2
Current (A)	1.50	1.25	1.07	0.94	0.83	0.75

(a) **Show** that: $\mathbf{R = \frac{E}{I} - r}$

(b) On graph paper, draw a graph of **resistance** against the **inverse of current** (that is 1 ÷ current). The graph should be a straight line.

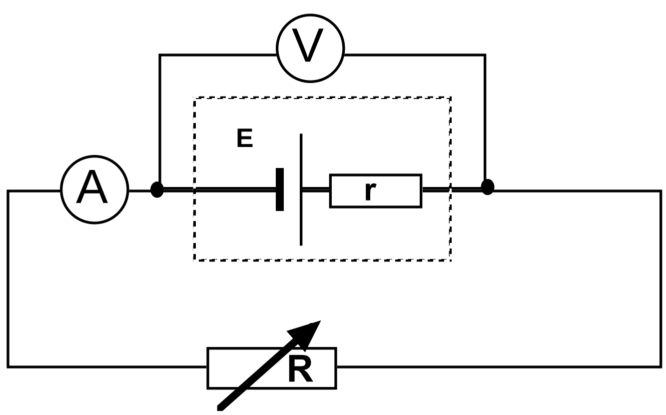
(c) **From** the graph, deduce the values of:

(i) the cell's **internal resistance**.

(ii) the cell's **e.m.f.**

(iii) the **short circuit current** (that is, the current delivered to a load of zero resistance.)

32.



For this circuit, show that:

(a) **E = V + Ir**, where **I** is the reading on the ammeter

(b) $\mathbf{R = {}^{E}/_{I} - r}$

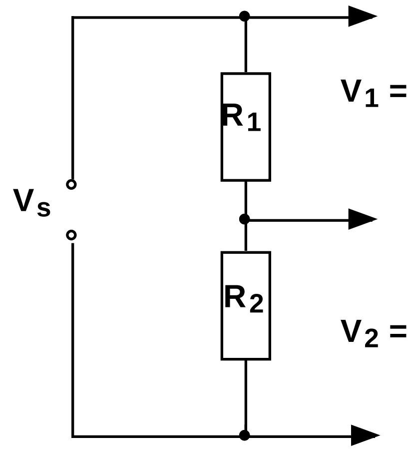
(c) Assuming that **E** and **r** are constants, sketch the graph obtained when **R** is plotted against $^{1}/_{I}$ for pairs of values of **R** and **I**.

(d) Which quantity would be calculated from the **gradient** of the line?

(e) Which quantity would be obtained from the intercept of the line on the 'y-axis'?

Voltage or Potential Dividers

1. Complete the formula for the **voltage** or **potential difference** across resistors 1 and 2 in this voltage divider.

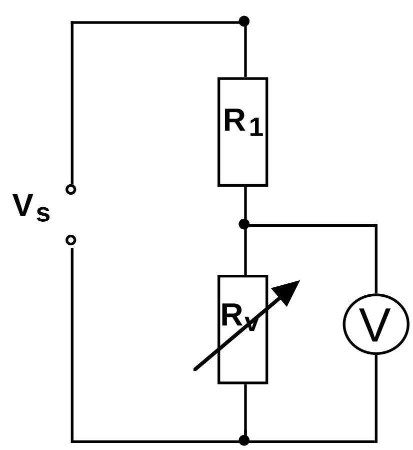


2. For the voltage divider in Q1, calculate the **voltage** or **potential difference** across each resistor where the resistors and the supply voltage have these values:

	V_s	R_1	R_2
(a)	10 V	500 Ω	500 Ω
(b)	10 V	1000 Ω	250 Ω
(c)	12 V	1 kΩ	3 kΩ
(d)	50 V	2.2 kΩ	3.3 kΩ
(e)	5 V	1.2 kΩ	300 Ω
(f)	20 V	5.6 kΩ	2.2 kΩ

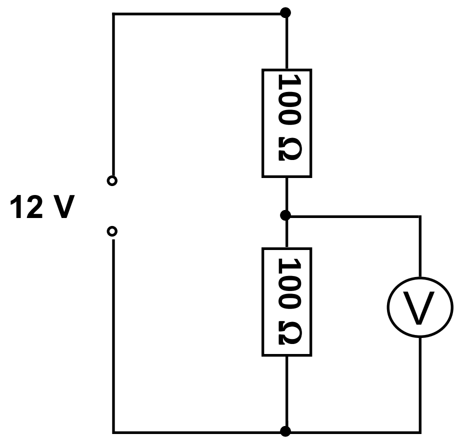
3. $\mathbf{R_1}$ is a fixed resistor and $\mathbf{R_v}$ a variable resistor in this voltage divider.
In each case, calculate the **range** of possible voltage readings on the voltmeter :

	V_s	R_1	R_v
(a)	12 V	5 kΩ	0 - 10 kΩ
(b)	10 V	40 kΩ	0 - 10 kΩ
(c)	6 V	10 Ω	0 - 10 Ω
(d)	20 V	25 kΩ	0 - 25 kΩ
(e)	12 V	50 kΩ	0 - 25 kΩ

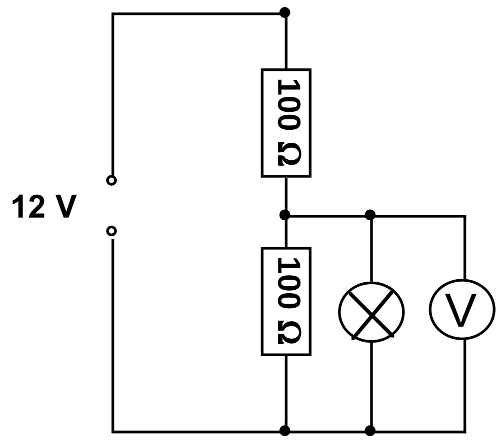


4. Two 100 Ω resistors form a potential divider across a 12 volt supply.

(a) Calculate the **reading** on the voltmeter.

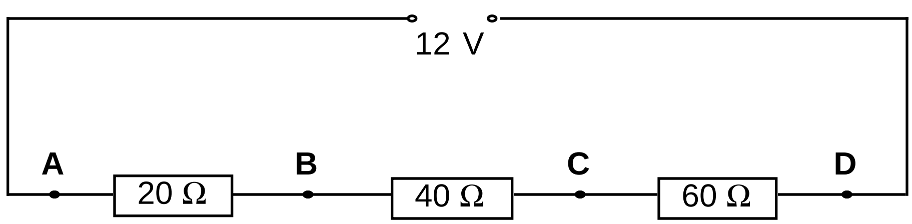


(b) A 6V lamp is now connected in parallel to the *lower* resistor. Suggest and explain what would happen to the **reading** on the voltmeter.



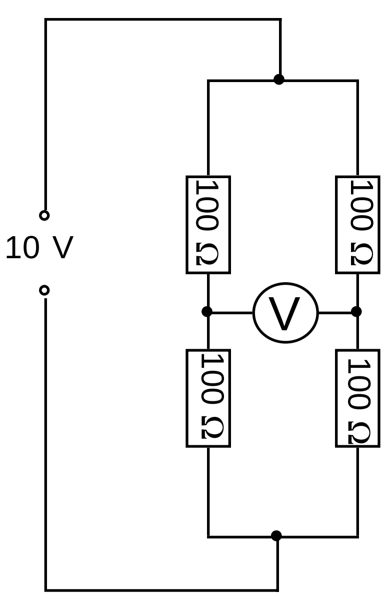
(c) If the lamp's resistance was 100 Ω, what would be the **reading** on the voltmeter?

5. In this potential divider, calculate the potential difference (or voltage) across the points **AB**, **BC**, **CD**, **AC**, **BD** and **AD**.

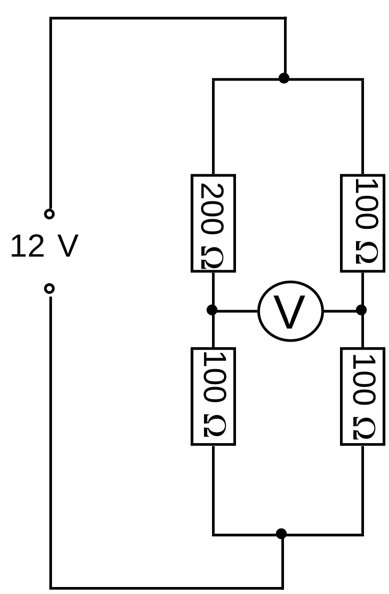


6. In these circuits, the voltmeter has a very high resistance.
In each case, calculate the **reading** on the meter.

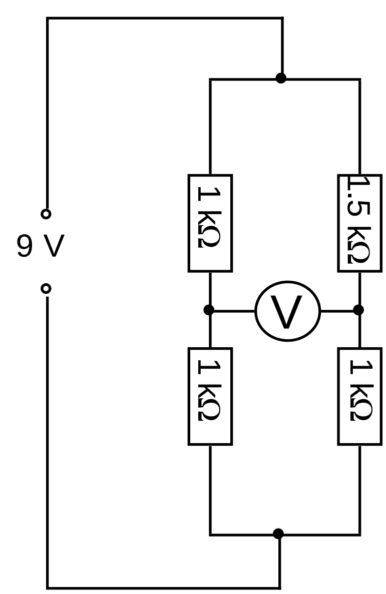
(a)



(b)



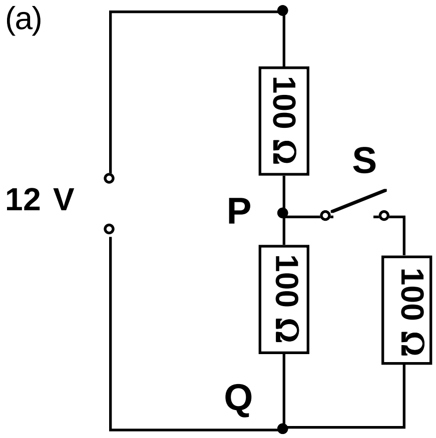
(c)



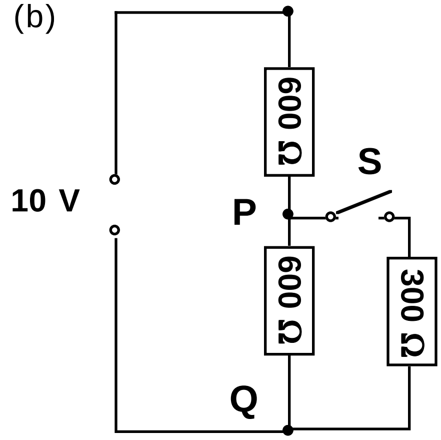
7. In each example, calculate the **p.d.** between the points **P** and **Q**:

(i) with switch **S open** (ii) with switch **S closed**.

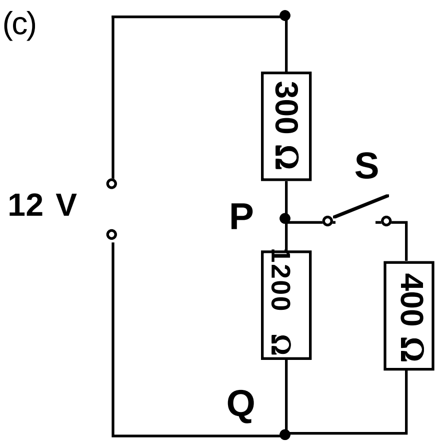
(a)



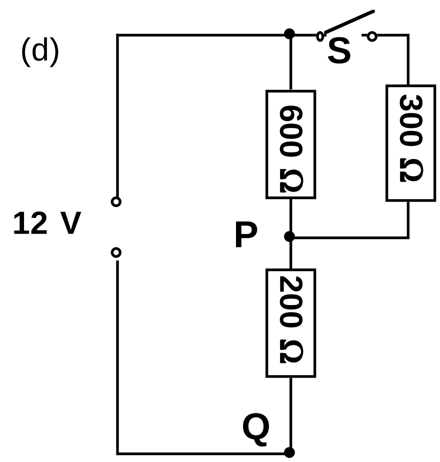
(b)



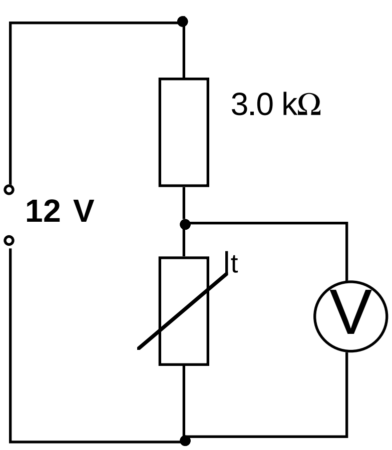
(c)



(d)



8. This potential divider has a thermistor and a resistor in series. The table gives the thermistor's resistance at different temperatures.



Temperature	***Resistance***
10ºC	9.0 kΩ
50ºC	4.5 kΩ
100ºC	1.0 kΩ

(a) Calculate the **reading** on the voltmeter when the thermistor is at each of the three temperatures in the table.

(b) What is the thermistor's **resistance** when the voltmeter reads 2.0 V?

Wheatstone Bridge

1. Which statement about an electric circuit *could* be correct: “the **potential** at a point in the circuit is 3 volts” *or* “the **voltage** at a point in a circuit is 3 volts”?

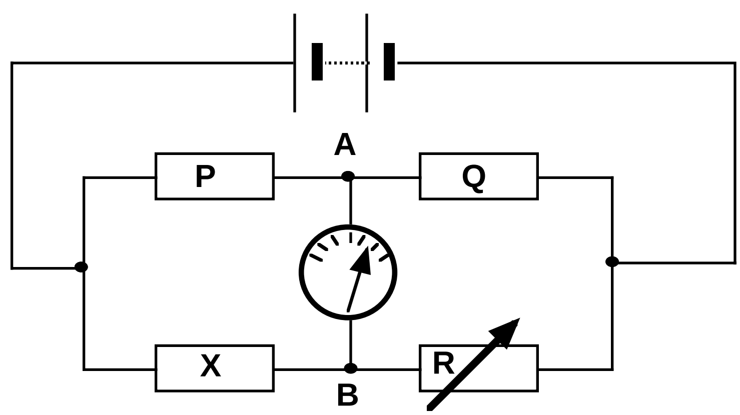
2. The **voltage** across a circuit component is 4.0 volts. An alternative way of stating this is:

   “ the **p**-------- **d**--------- across a circuit component is 4.0 volts”.

3. The potential at point **A** in a circuit is 2.0 volts and, at point **B**, 5.0 volts.
   (a) What is the **potential difference** between points **A** and **B**?
   (b) What is the **voltage** across **AB**?

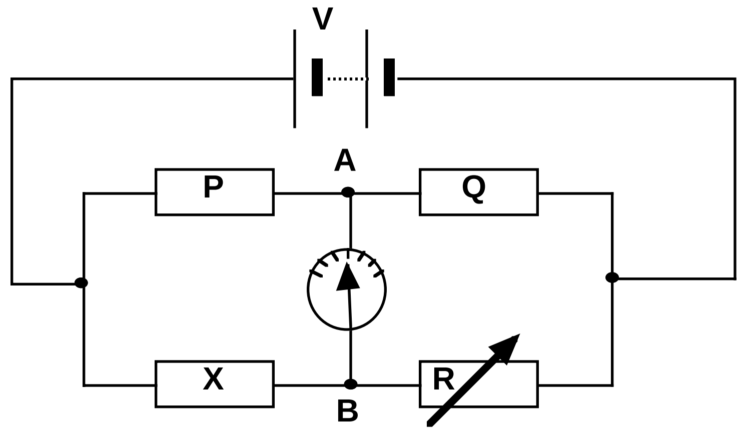
4. (a) If the potential at the *negative* terminal of a 1.5 V cell is taken as 0 V, what would be the **potential** at the *positive* terminal?
   (b) If the potential at the *positive* terminal of a 1.5 V cell is taken as 0 V, what would be the **potential** at the *negative* terminal?

5. In the circuit shown, the meter is a centre-zero galvanometer.



   Assuming that the meter reads ‘zero’ when there is no current flowing through it, explain whether or not the **potential** at point **A** is equal to the **potential** at point **B**.

6. In the circuit shown, the meter is a centre-zero galvanometer.



   Assuming that the meter reads ‘zero’ when there is no current flowing through it, explain whether or not the **potential** at point **A** is equal to the **potential** at point **B**.

7. For the circuit in Q6, at balance point, what is the relationship between the resistors **P**, **Q**, **R** and **X**?

8. For the circuit in Q6, at balance point, what change, if any, would happen to the **reading** on the meter if the battery voltage gradually *decreased*?

9. For the circuit in Q6, for what purpose is **R** a variable resistor?

10. For the centre-zero meter used in the circuit in Q6, explain why it is important that the meter is *sensitive* rather than *accurate*.

11. In each case, the centre-zero meter in the circuit of Q6 has been carefully zeroed by adjusting **R**, a resistance box. Resistors **P** and **Q** are standard resistors and resistor **X** is 'unknown'. Calculate each value of **X**.

P (Ω)	**Q** (Ω)	**R** (Ω)
10	10	63
10	10	102
50	10	25
10	50	25
50	50	14
20	100	8.3
100	20	1.0
10	100	886

12. The accuracy of the calculated value of the 'unknown' resistor in a balanced Wheatstone Bridge circuit depends on certain factors. In each case, as for the circuit of Q6, explain whether or not this accuracy is affected by:

(i) the sensitivity of the centre-zero meter,

(ii) the zeroing of the centre-zero meter before use,

(iii) the accuracy of the meter is measuring a small current,

(iv) the voltage **V** of the driver cell or battery and

(v) the accuracy of the standard resistors **P** and **Q** and the variable resistor **R**.

13. If, for a *balanced* Wheatstone Bridge with resistors **P**, **Q**, **R** and **S**, the following relationship is true,

$$\frac{\mathbf{P}}{\mathbf{Q}} = \frac{\mathbf{R}}{\mathbf{S}}$$

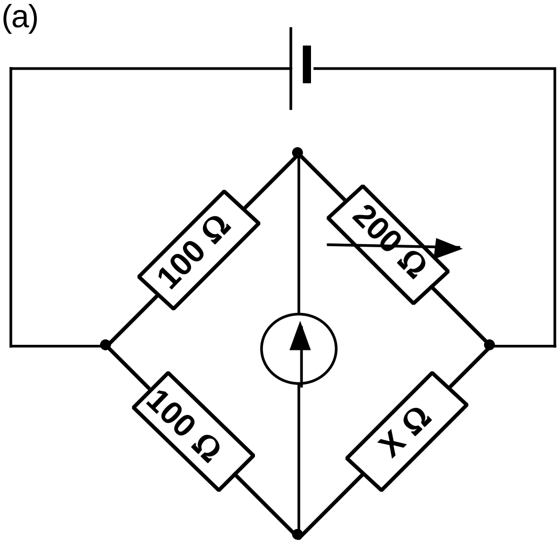
complete these relationships:

(a) $\frac{\mathbf{P}}{\mathbf{R}} =$ (b) $\frac{\mathbf{S}}{\mathbf{R}} =$ (c) **PS =** (d) **Q =**

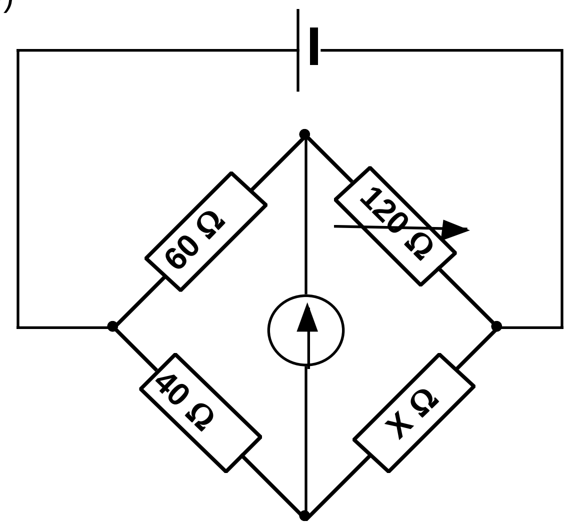
(e) **R =** (f) **S =** (g) **P =**

14. In each case, where the Wheatstone Bridge has been balanced, calculate the **value** of the ‘unknown’ resistor ‘**X**’:

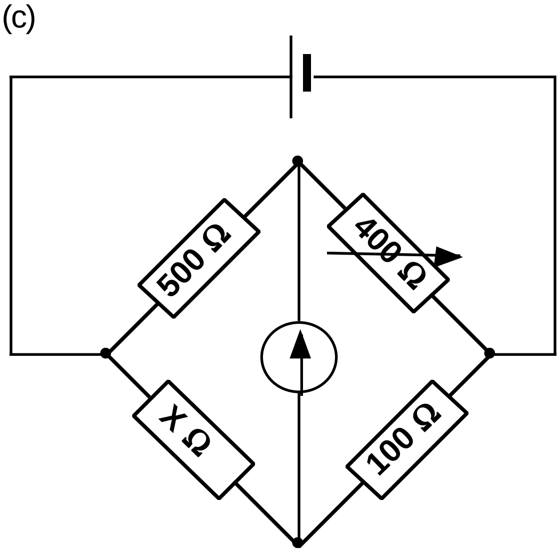
(a)



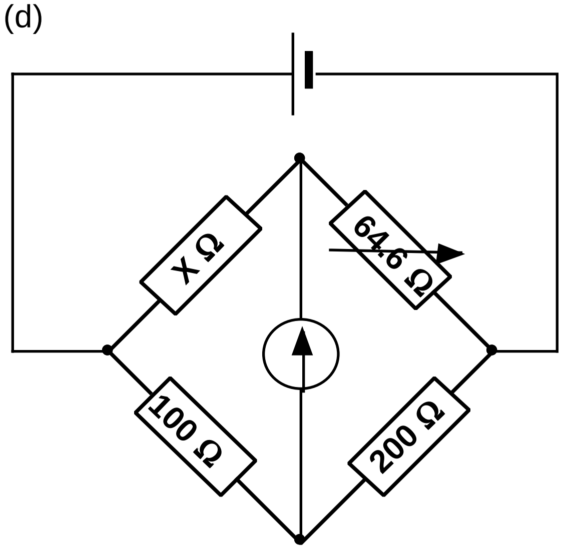
(b)



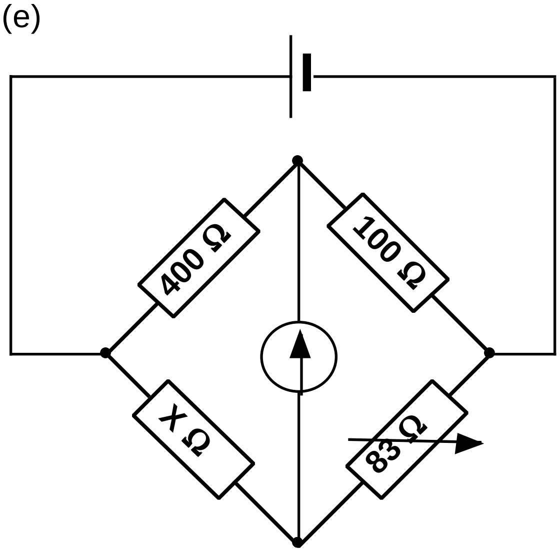
(c)



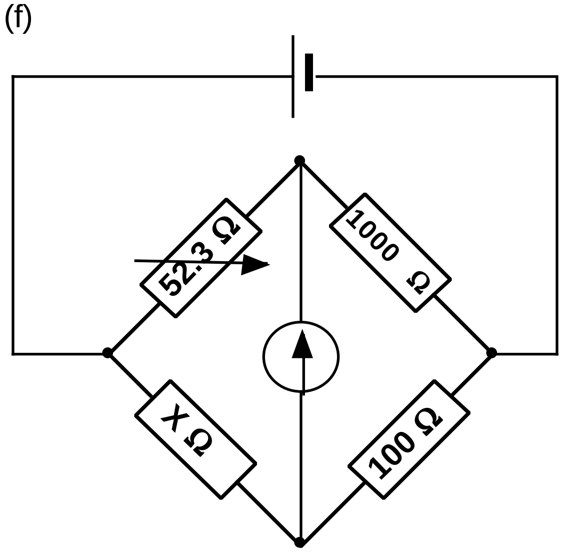
(d)



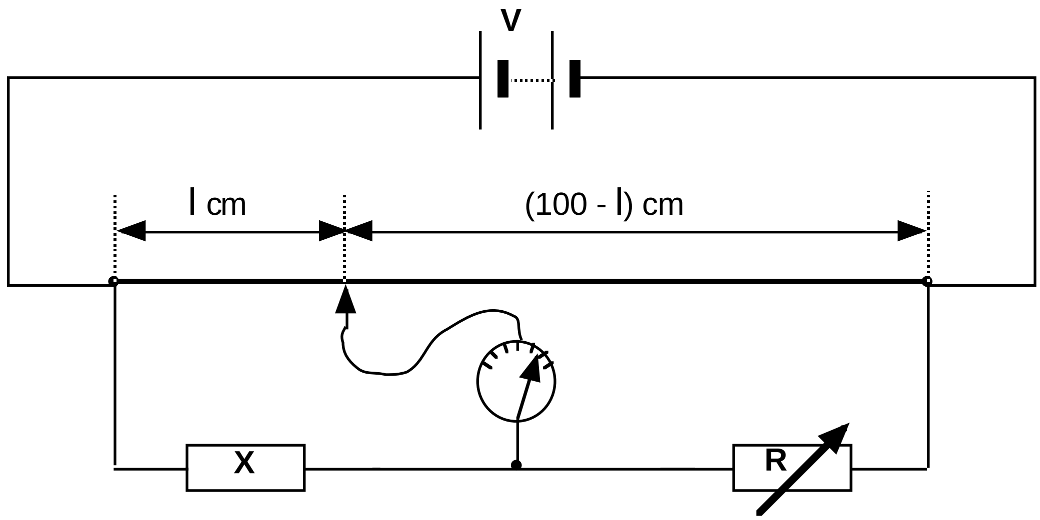
(e)



(f)



The diagram shows a ‘metre bridge’ set up to measure the resistance of resistor **X**. The meter is a centre-zero galvanometer which has been adjusted to read zero with no current flowing though it.



Questions 15 - 20 refer to this metre bridge arrangement.

15. As shown in the diagram, is the metre bridge **balanced** or **not**? How do you know?

16. What would the **meter** read when the bridge was ‘balanced’?

17. Why is the resistor **R** a *variable* resistor such as a rheostat or resistance box?

18. Under balance conditions, what is the relationship between **X**, **R**, **l** and **(100 - l)**?

19. Copy and complete the table, using the formula for ‘**balance**’ conditions.

l (cm)	(100 - **l**)	**R** (Ω)	**X** (Ω)
30.0	-	60	-
50.0	-	120	-
60.0	-	24	-
45.5	-	502	-
56.4	-	254	-
-	50.0	98	-
-	45.7	588	-
-	52.3	2510	-

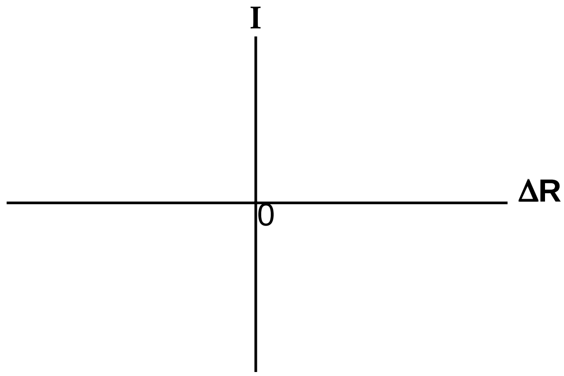
20. With the bridge **balanced**, what, if anything, would happen to the meter reading if the voltage ‘**V**’ of the driver cell decreased?

21. The resistance wire that is used to make a metre bridge has to have a very uniform resistance along the whole of its length.

    Explain **why** this matters.

22. Suppose that the position of the knife-edged jockey, which makes contact with the resistance wire, can be 'read' from a metre rule alongside the wire to the nearest millimetre; [for example l = (45.6 $^{+}/_{-}$ 0.1) cm]. Explain why it would be **best** to adjust **R** so that the bridge balanced with the jockey at around the **midpoint** of the wire rather than close to one end.
[Hint: consider how the *accuracy* of the calculated value for **X** would be affected.]

23. A Wheatstone bridge is balanced. The value of just *one* of the resistors is changed by a small amount above and below its balance setting (by less than 15% of its 'balance setting'.) Readings of **current** are taken for each new setting.
A line graph of '**current** '**I**' against **change of resistance** '**Δ R**' is constructed.
(a) Copy the axes and sketch in the resulting graph.

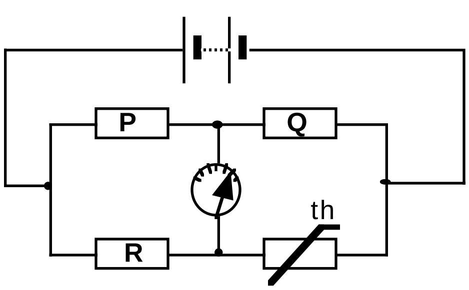


(b) What is the **relationship** between current and change of resistance?

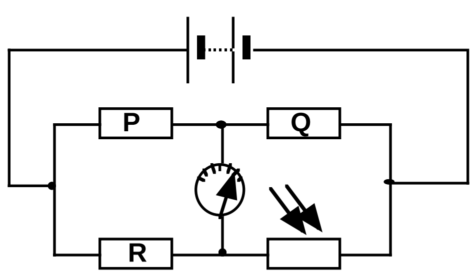
24. In an 'out-of-balance' bridge, is the **magnitude** of the current affected by changes to the voltage '**V**' of the driver cell?

25. In an 'out-of-balance' bridge, is it important that the meter reads current **accurately**, or does it merely have to be **sensitive** to small changes in current?

26. In these bridge circuits, **Circuit A** has a **thermistor** in one arm and **Circuit B** has a **Light Dependent Resistor** (**LDR**).



Circuit A



Circuit B

(a) Suitably **calibrated**, which quantity could be measured or monitored by the meter in each circuit?

(b) What is meant by the term '**calibrated**'?

27. What effect, if any, would the **reversal** of the driver cell terminals have on the meter reading in an out-of-balance Wheatstone Bridge?

Household Electricity

1. Use the formula '**units used = power x time**' to calculate the value of the missing quantities in the table:

units (kWh)	power	time (h)
-	3 kW	2
-	1.5 kW	10
-	500 W	2
10	2.5 kW	-
240	3 kW	-
0.5	0.1 kW	-
2	-	4
6	-	2
10	-	100

2. A 2 kW kettle is used for a total time of 2 hours over a whole week.
How many **units (kWh)** of electricity is used and what is the total **cost** if each unit is priced at 7 pence?

3. How many **hours** could a 100 W lamp be lit before it used 4 kWh of electric energy?

4. What is the **power rating**, in *watts*, of a hair dryer which uses 4 kWh in a time of 5 hours?

5. How many **hours** could a 60 W lamp be lit for 42 pence if 1 kWh costs 7 pence?

6. The '**kWh**' is a unit of **energy**; so is the '**joule**'. Calculate the **number** of joules in each kWh (kilowatt-hour).

7. Change 9×10^6 J into kilowatt-hours (**kWh**).

8. Show, by calculation, which would **cost more**:

   a 100 W lamp lit for 3 day non-stop or a 2.5 kW fire switched on for 3 hours.

9. At 7p per unit (kWh), how much **more** would it cost to run a 3 kW fire for 4 hours than a 100 W lamp for 100 hours?

10. For how **long** could a 60 watt lamp be lit for the *same cost* as a 3 kW fire on for 2 hours?

11. An electric shower is rated at 10 kW. How much would it **cost** to run, in total, for a whole year at 7 pence per unit (kWh) if it was used on average for 3 hours per week?

12. What is the **power** of a hair dryer which costs *twice* as much to run for 20 minutes as a 2 kW kettle costs to run for 5 minutes?

13. A householder's electricity bill states that the number of units used has cost £31.50.
If each unit costs 7p, how **many units** have been used and for **how long** could they have run a 3000 W electric fire?

14. Given a choice of the following cartridge fuses for mains plugs: 3 A, 5 A,10 A and 13 A, which would be **most suitable** for fitting in the plugs for these appliances? Support your choice by indicating the **current** supplied to each appliance. Take the mains voltage as 230 V.

(a) a 2.2 kW kettle **(b) a 100 W table lamp** **(c) a 3 kW fire**

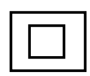
(d) a 1 kW hair dryer **(e) a 1.3 kW fan heater**

15. What is the **purpose** of the fuse in a plug; (i.e. what does it *protect*)?

16. What **happens** to a fuse when *too much* current flows through it? (Avoid stating that the fuse '*blows*').

17. To which **part** of an appliance should the **earth wire** be connected and what is its **function**?

18. Which **colour** of wires would be found in the flex of an appliance which has the symbol shown below stamped on its plastic case?



19. An appliance with a plastic case is **double insulated**. State which **wire** is 'missing' from its flex and **explain** why is in not required?

20. In some houses, the mains electricity is earthed by strapping a thick wire to the cold water pipe. Lately, these pipes are often made of plastic. Why would this be **unsuitable** for connecting the earth wire?

21. Household appliances plugged into the ring power circuit are connected to each other in parallel. If the following appliances are all switched on in the same ring circuit, calculate the total **current** drawn from the 230 V mains:

a 3 kW fire, a 2 kW kettle, two 150 watt table lamps and a 300 watt television.

22. Calculate the **maximum power** which an appliance should have if it is connected to the 230 V mains by a 5 A cable.

23. How would the **thickness** of the wire inside a plug cartridge fuse rated at 13 A compare with one rated at 3A? **Why**?

24. Why, after being on for a while, does the **live pin** of the plug supplying current to an appliance often feel *warm*, but the other two pins are *cold*?

25. In which wire, live, neutral or earth, should the **fuse** be connected? Why?

26. In which wire of an appliance should its **switch** be connected? Why?

27. If the metal casing of a mains appliance becomes *live* due to a fault, explain why would it be **dangerous** if the appliance was *not* earthed.

Alternating Current and Voltage

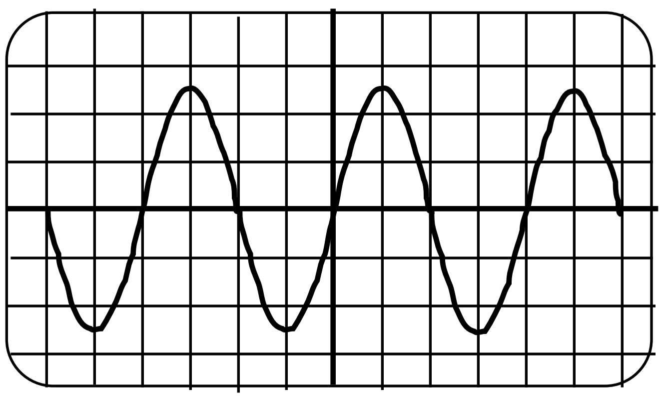
1. What is meant by the '**frequency**' of an a.c. supply?

2. An electricity source has a frequency of 60 Hz. How **many** complete cycles occur in:
   (a) 1 s (b) 5 s (c) 10 s (d) 0.5 s (e) 2 minutes?

3. An alternating electricity source produces 500 complete cycles in 10 seconds.
   What is the **frequency** of the supply?

4. The handle of a model dynamo is turned at the rate of **120** turns per minute.
   It is geared so that the magnet rotates **4** times for each turn of the handle.
   What would be the **frequency** of the alternating voltage induced in the coil surrounding the magnet?

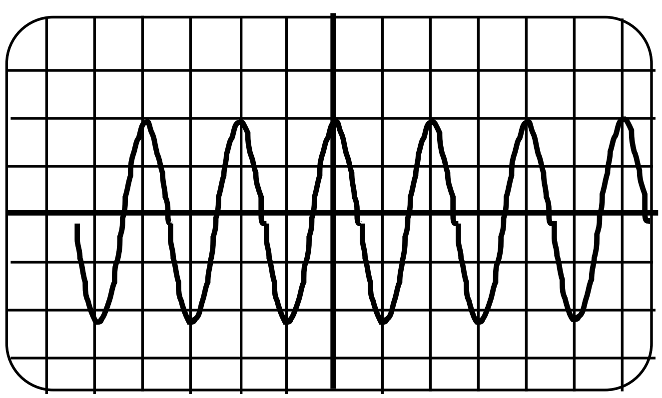
5. The diagram shows the screen of a CRO, displaying an a.c. waveform.



(a) What would the **peak** voltage be if the 'Y-gain' control was set at
   (i) 1 V/div (ii) 2 V/div (iii) 5 V/div (iv) 10 V/div?

(b) What would the **frequency** be if the 'time base' control was set at
   (i) 10 ms/div (ii) 5 ms/div (iii) 1 ms/div (iv) 500 μs/div?

6. The diagram shows the screen of a CRO, displaying an a.c. waveform.



What would the **frequency** be if the 'time base' control was set at
   (i) 10 ms/div (ii) 5 ms/div (iii) 1 ms/div (iv) 500 μs/div?

7. For the sine wave voltage displayed in Q6, what is the **average** of the voltage over the whole display?

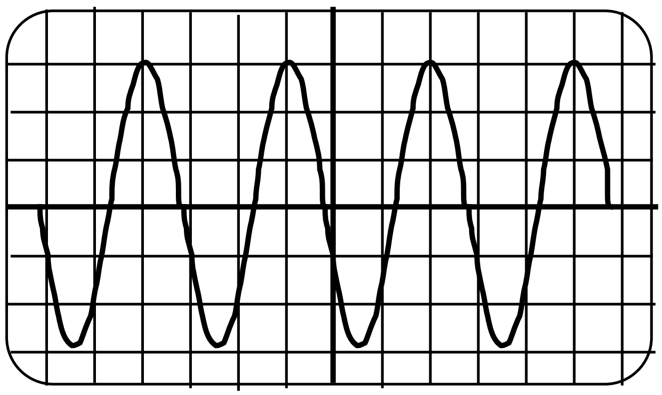
8. In the term '**r.m.s. voltage**', what do the letters 'r.m.s.' stand for?

9. In each case, calculate the value of the **r.m.s. voltage** for these peak a.c. voltages:

(a) 5.0 V (b) 10 V (c) 156 V (d) 339 V (e) 325 V

10. For the a.c. voltage displayed on this CRO screen, calculate the **r.m.s. voltage** if the 'y-gain' control is set at:

(a) 1 V/div (b) 2 V/div (c) 5 V/div (d) 10 V/div



11. In each case, calculate the value of the **peak voltage** for these r.m.s. voltages:

(a) 14.1 V (b) 212 V (c) 7.1 V (d) 200 V (e) 40 mV

12. What is the '**peak-to-peak**' voltage for a 5.0 volt r.m.s. a.c. supply?

13. Calculate the **r.m.s. voltage** for a supply which has a peak-to-peak voltage of 56.6 volts.

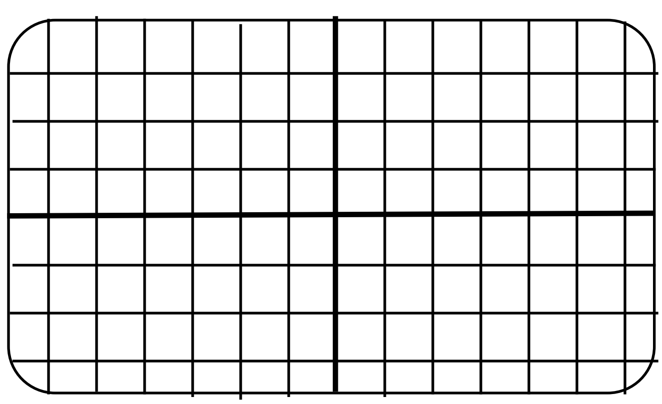
14. If the r.m.s. value of the alternating current flowing in a circuit is 5 amps, what is the **peak current**?

15. If $V_{rms} = V_{peak} \div \sqrt{2}$ and $I_{rms} = I_{peak} \div \sqrt{2}$, show that the **average power** dissipated in a resistor connected to an a.c. supply is equal to half of the ***peak*** power.

16. Copy the CRO 'screen' and trace the appearance of a 50 Hz, 20 V r.m.s. waveform with these control settings:

time base: 5 ms/div

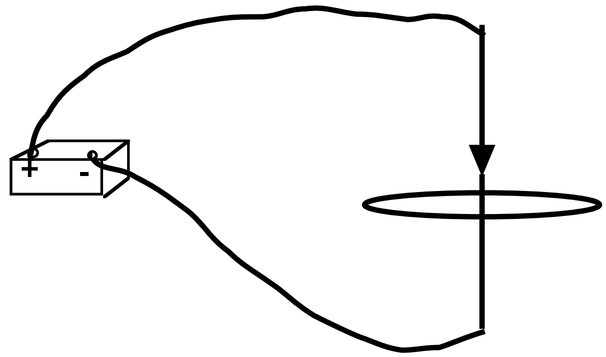
Y-gain: 10 V/div



Electromagnetism and Electromagnetic induction

1. What kind of invisible force **field** exists around a conductor when there is a **current** flowing through it?

2. In the diagram, a current (from + ve to -ve) is flowing through a long, straight conducting wire.

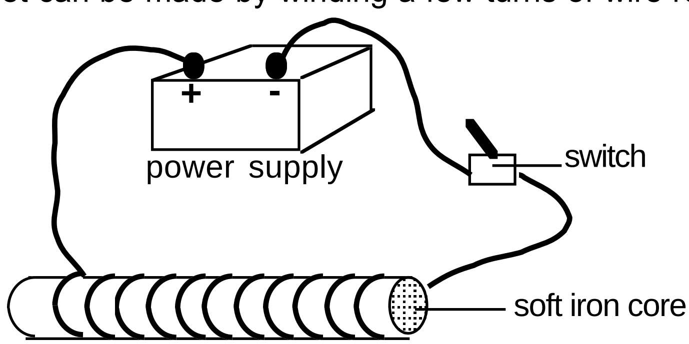


One of the magnetic field lines surrounding the wire is shown.

(a) Copy the diagram and mark the **direction** of the field on line.
(b) State what would happen to the field **direction** if the current was reversed.

3. What happens to the **strength** of the magnetic field round a long, straight current-carrying conductor as the distance from the conductor increases?

4. An electromagnet can be made by winding a few turns of wire round a soft iron core.



(a) How is the **magnetism** turned on?

(b) Suggest **two** ways in which the **strength** of the electromagnet could be increased.

5. Why is **soft iron** rather than steel used for the core material of an electromagnet?

6. When a current-carrying conductor is in a magnetic field, a force acts on the conductor.

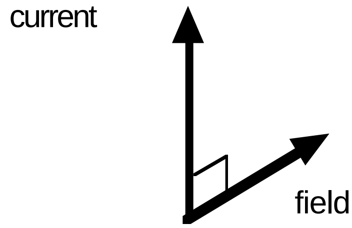
(a) How does the **direction** of the force on the conductor compare with the direction of the field and the direction of the current?

(b) State **two** ways of **reversing** the direction of the force on the conductor.

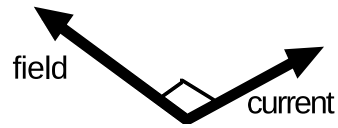
(c) State **two** ways of **increasing** the size of the force on the conductor.

7. The diagrams show the direction of current (+ve to -ve) flowing through a conductor in a magnetic field.
The direction of the field (north to south) in each case is also given.

(a)

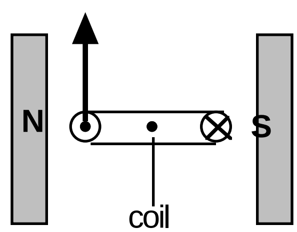


(b)



Copy the diagram and **add** an arrow to show the direction of the force acting on the conductor.

8. The diagram of a simple d.c. motor shows the two edges of the rotating coil inside the magnetic field of the magnets. (The field lines are **not** shown).
The direction of the force acting on the left side edge of the coil is shown.



(a) Copy the diagram and draw a second arrow to show the size and direction of the **force** acting on the right side edge of the coil.

(b) Explain, in terms of **current direction**, why the force is in the direction you have indicated.

(c) What is the name of the **part** of the motor which **reverses** the direction of current through the coil every half turn?

9. In a **real motor**:

(a) what is used in **place** of permanent magnets?

(b) why are the **coils** wound on armatures made of **soft iron**?

(c) why is a **number of coils** wound on the armature at different angles?

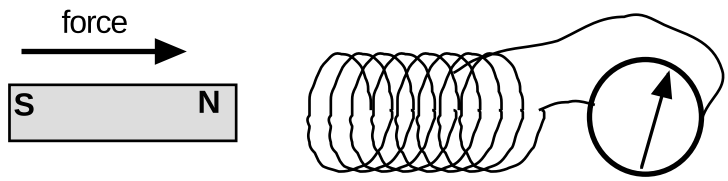
10. Copy the following statement about **electromagnetic induction** and complete it by inserting the missing words:

" when there is a _________ in the ___________ flux linking a circuit,

there is an ______ induced in the circuit."

11. If a magnet is pushed into a conducting coil which is part of a complete circuit,

electric energy is generated in the circuit.

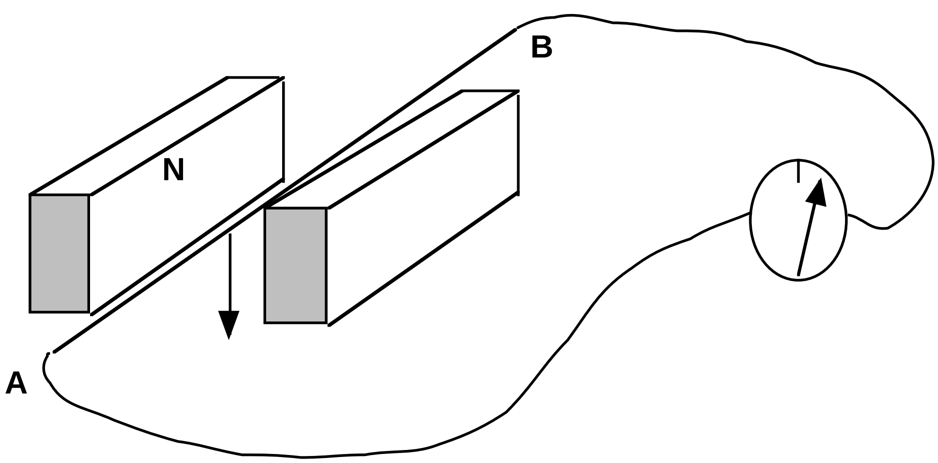


Since **work** must be done by the magnet to transfer energy to electricity, explain why:

(a) a **force** is needed to push the magnet into the coil.

(b) the magnet has to be **moved**.

12. A long wire, connected to a centre-zero galvanometer, is moved downwards through a magnetic field. The field is between two permanent magnets, with opposite poles facing each other.



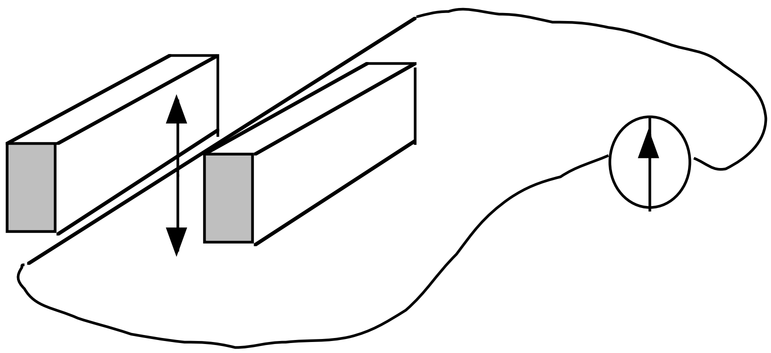
(a) Is the direction of the **induced current** (+ve to -ve) from **A** to **B** or **B** to **A**?

(b) How would the **pointer** on the galvanometer move if the wire was moved **up** through the magnetic field?

(c) What would the **induced current**, if any, be in the conductor if it was held still in the **centre** of the magnetic field?

(d) State **three** ways of **increasing** the deflection of the pointer on the galvanometer when the wire is moved through the magnetic field.

13. A boy is investigating the effects of electromagnetic induction.



He moves a conducting wire up and down between two permanent magnets, expecting the pointer on the galvanometer to show a deflection.
However, the pointer does not move. The meter is working and is sensitive enough for the experiment. There are no breaks in the wires.

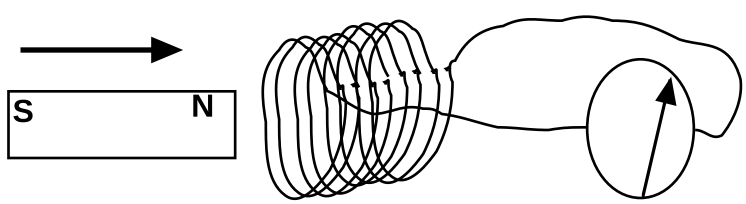
What must be **wrong**?

14. **Complete** this statement about Lenz' Law:

" the ______________ of an induced ________________ is always such as to §

_______ the change causing it."

15. A bar magnet is pushed into a conducting coil which is connected to a centre- zero galvanometer meter. The pointer is deflected to one side showing that there is an induced current in the coil.



(a) Is a **north** or **south pole** produced at the **left** end of the coil?

(b) Explain your answer to (a) in terms of Lenz' Law.

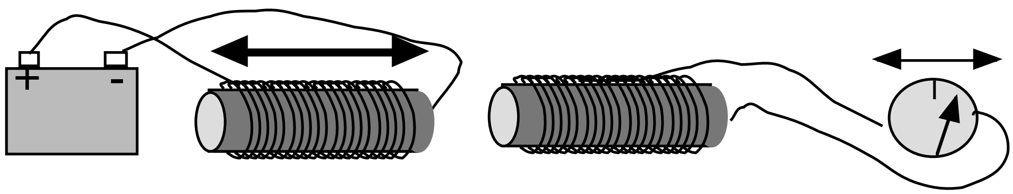
(c) Where does the **energy** come from to generate the electric energy in the coil?

(d) Which **pole** would appear at the left end of the coil if the magnet was pulled **out** of the coil?

16. A student wrote in an exam that the direction of an induced e.m.f. always **assisted** the change causing it. **Explain** why this is impossible.
(Hint: remember that electric energy cannot be created from 'nothing'.)

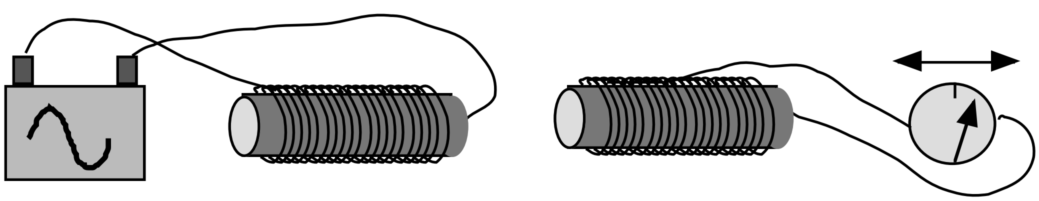
17. A cyclist notices that he has to pedal **harder** to keep his cycle moving at a steady speed when it gets dark and he connects his dynamo to the rear wheel.
Explain why, in terms of Lenz' Law. (The bicycle dynamo works by the wheel making a permanent magnet rotate inside a coil of wire connected to the cycle's lamps.)

18. Two conducting coils are wound on soft iron cores. One is connected to a battery, the other to a centre-zero galvanometer.



(a) When ***either*** coil is moved back and forth, there is a corresponding back and forth deflection on the meter. **Explain**.
(b) What deflection, if any, would the meter show if **both** coils were at rest?
(c) What deflection, if any, would the meter show if **both** coils were moved back and forth at the same rate, with the **gap** between them steady?

19. Two conducting coils are wound on soft iron cores. One is connected to a low frequency a.c. supply set at 3 hertz, the other to a centre-zero galvanometer.



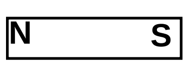
There is **no** relative movement between the two coils and yet the meter pointer moves back and forth three times every second.

(a) Explain **why** an e.m.f. is induced in the second coil even though there is no movement involved.

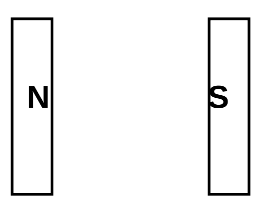
(b) What important **device** is based on this effect?

20. Copy the diagrams of permanent magnets and draw **lines** to show the shape of the magnetic field surrounding the magnets. Mark an arrow on each line to indicate the **direction** of the field.

(a)



(b)



21. Given a soft iron core, a long conducting wire and a battery, how could an electrical device be made which would have a **magnetic field** similar to that of a permanent **bar magnet**?

Transformers

1. Use the formula for an ideal transformer,

$$\frac{\text{secondary voltage.}}{\text{primary voltage}} = \frac{\text{turns in secondary}}{\text{turns in primary}} \quad or \quad \frac{V_s}{V_p} = \frac{N_s}{N_p}$$

to calculate the **value** of the missing quantities in the table.

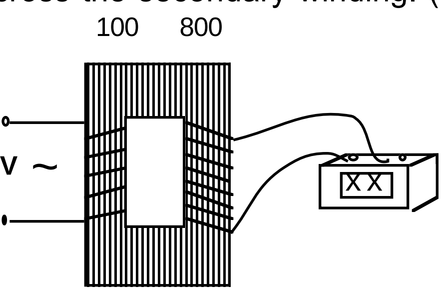
V_s(V)	V_p(V)	N_s	N_p
30	240	-	4000
8	240	-	6000
12	240	30	-
300	12	500	-
-	240	50	1200
20	-	500	6000

2. A **step-down** transformer has a turns ratio of 30:1. It has 6000 turns in the primary coil. Calculate the **number** of turns in its secondary coil.

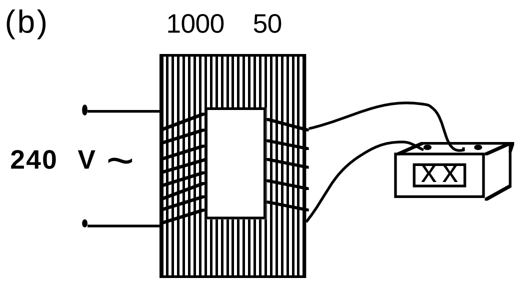
3. How many **turns** are in the primary winding of a transformer if, when connected to 230 V a.c., the 200 turn secondary has a voltage of 8 volts?

4. For each of the transformers below, state the **reading** on the **voltmeter** connected across the secondary winding. (Careful!)

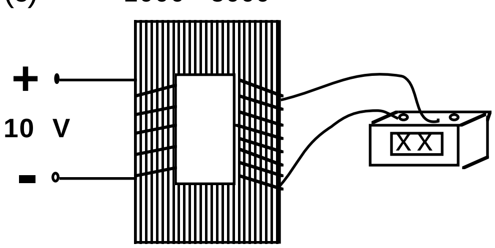
(a)



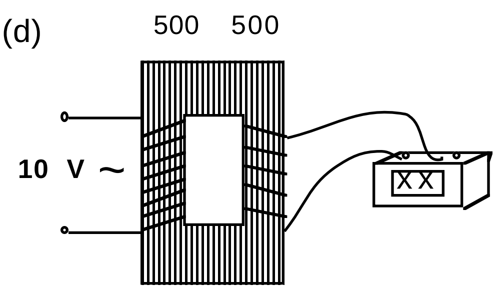
(b)



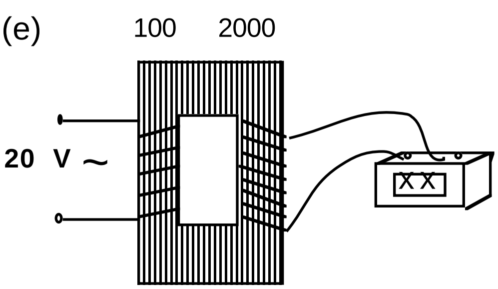
(c)



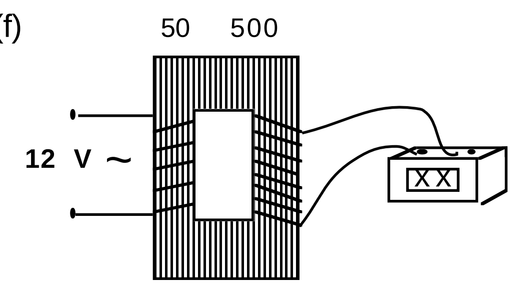
(d)



(e)



(f)

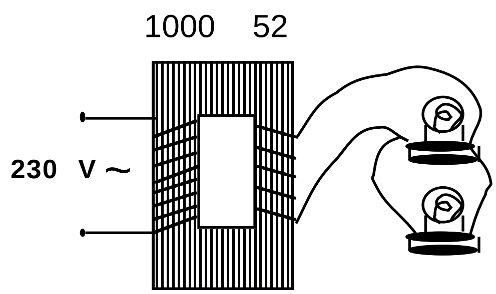


5. In a very well constructed transformer which has very few energy losses, how does the **secondary output power** compare with the **primary input power**?

6. Assuming that a transformer is 100% efficient, how much **power** would need to be supplied to the primary if a 12 volt, 24 watt lamp was lit at its rated voltage from the secondary?

7. Calculate the **current** drawn from the 230 V a.c. mains by the primary winding of a transformer which supplies 23 watts of power to a lamp across the secondary winding. (Assume the transformer does not lose any energy).

8. In the circuit shown, a mains step-down transformer supplies power to two 12 V, 24 W lamps in parallel.



Calculate: (a) the **current** in the secondary winding

(b) the **current** in the primary winding. (Assume the transformer is 100% efficient).

9. A doorbell for a house works from 8 V a.c. To operate the bell from the 230 V mains supply, a transformer can be used.
How many **turns** would be in the *primary* winding for *each* turn in the secondary winding?
Would the transformer be a *step-up* or a *step-down* type?

10. To produce an output of 48 V a.c. from an input of 230 V a.c., how many **turns** would be required in the primary winding if there were 100 in the secondary?

11. State the **output voltage** produced by a transformer with 100 turns in the primary coil and 600 turns in the secondary coil when connected to the following input voltages:

(a) 12 V a.c. (b) 12 V d.c. (c) 230 V a.c.

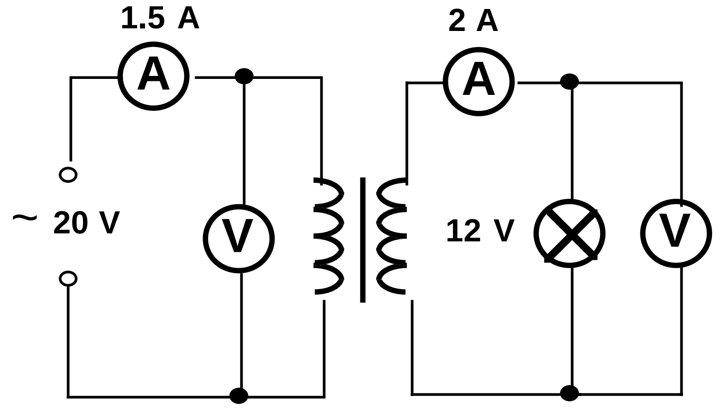
12. The input voltage to a step-down transformer is 230 V a.c. at a frequency of 50 Hz. If the primary winding has 6000 turns and the secondary 314 turns, what is the **voltage output** and what is its **frequency**?

13. A step-up transformer has 500 turns in the primary coil and 10000 turns in the secondary coil. If a voltage of 250 V a.c. is applied to the primary at 50 Hz, what are the **voltage** and **frequency** of the output at the secondary?

14. A 12 volt car battery is placed across the primary coil of a 1:20 step-up transformer.

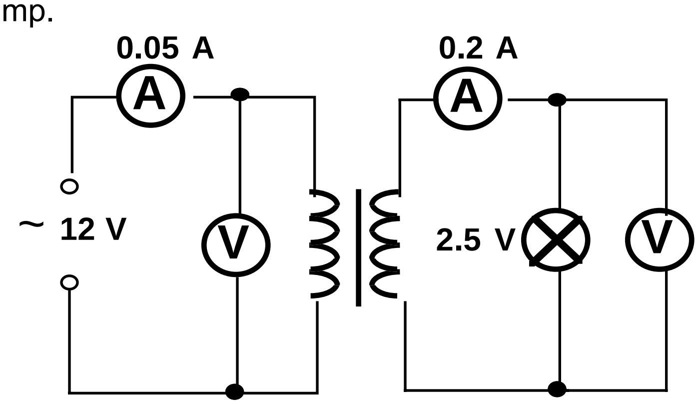
What is the **output voltage** across the secondary?

15. A pupil makes a basic step-down transformer and sets up the circuit shown to light a 12 V lamp.



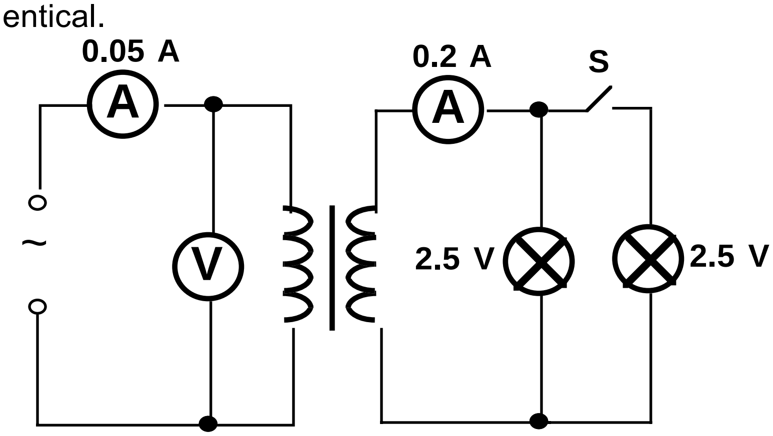
(a) Calculate the **input power** and the **output power** of the transformer.
(b) How much **energy** is *wasted* every second in the transformer?

16. A transformer is used to step down the voltage from a 12 V a.c. supply to light a 2.5 V lamp.



Calculate: (a) the **energy per second** wasted in the transformer
(b) the **percentage efficiency** of the transformer.

17. A transformer is operated from a constant voltage a.c. supply. The readings on the ammeters in the primary and secondary circuits are as shown when just *one* lamp is lit. The lamps are identical.



What would the **readings** on the meters be when the switch '**S**' was closed? (Assume the transformer is 100% efficient).

Power transmission

1. A 24 W lamp is to be lit from a 12 V a.c. supply with two long wires connecting the lamp to the supply. The wires have a total resistance of 1Ω.

(a) If the supply delivers 24 W to the wires and lamp, calculate the **current** in the wires and the **power** lost in the wires.

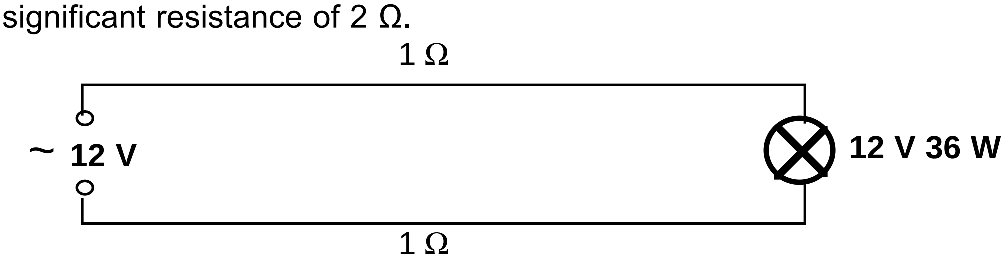
(b) The system is now changed so that the power supply voltage is increased by a step-up transformer to 120 V and, as before, 24 W of power is delivered to the resistance wires and lamp. At the other end of the wires, the output of a step-down transformer is connected to the 12 V lamp.

Calculate the **current** in the wires and the **power lost** in the wires.

2. Electricity is generated in power stations at 11 kV. It is then stepped-up, by transformers, to 132 kV or 400 kV to be transmitted cross-country on the grid.
What is the **advantage** of transmitting the power at such high voltages?

3. 50 kW of power is to be transmitted through long cables to a small hamlet.
The cables have a total resistance of 0.5 Ω. Calculate the **power lost** in the cables if the power is delivered to the cables at (a) 250 V a.c. and (b) 250 kV a.c., after being stepped-up by a transformer.

4. A 12 V 36 W lamp is to be lit from a 12 V a.c. supply but the connecting wires are very long and have a significant resistance of 2 Ω.



Assuming that the lamp's resistance is constant,

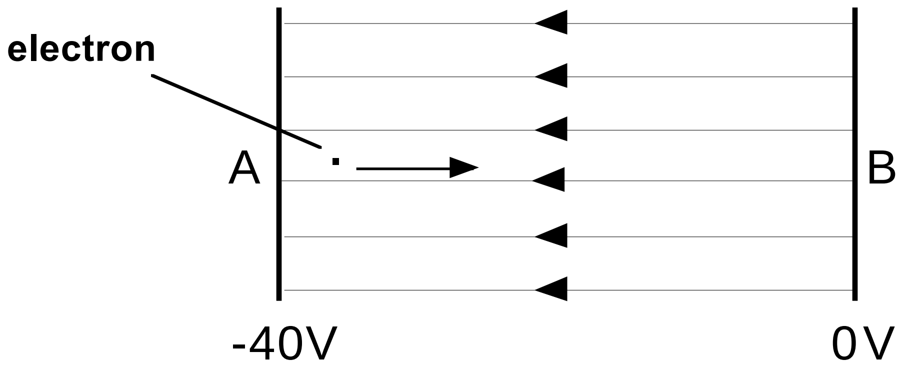
(a) Calculate the **current** delivered to the wires by the power supply.
(b) Calculate the **heat** generated every second in the wires.
(c) What is the **potential difference** across the lamp?
(d) How much **power** is delivered to the lamp?
(e) Explain how *two* identical transformers, each able to change the input voltage by a factor of ten, could be added to the circuit to enable almost **all** of the **power** from the supply to reach the lamp.

Electric fields

charge on the electron, e = -1.6 x 10^{-19} C **mass of the electron, m_e = 9.1 x 10^{-31} kg**

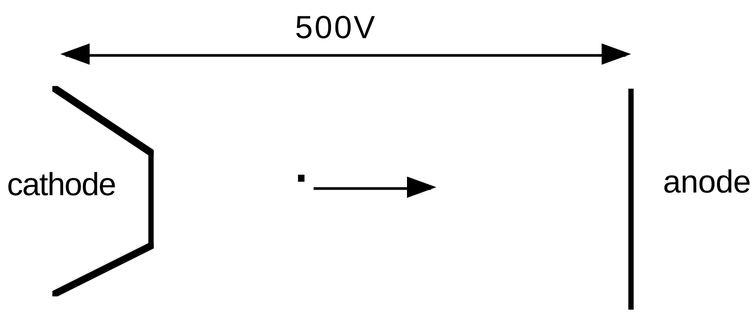
1. It takes 3.2 x 10^{-18} J of work to move an electron between two points in an electric field. What is the **potential difference** between the points?

2. An electron 'falls' from rest through an electric field from point **A** to point **B**.



(a) What is the p.d. between **A** and **B**?
(b) How much work is done by the field in accelerating the electron from **A** to **B**?
(c) Calculate the electron's **speed** as it reaches **B**.

3. In an 'electron gun', an electron is accelerated from rest by a voltage (p.d.) of 500V between the cathode (-) and anode (+).



(a) How much work is done by the electric field in accelerating the electron between the cathode and anode?

(b) Calculate the electron's **speed** as it reaches the anode.

4. Non-relativistic calculations for calculating the speed reached by an electron accelerated across a voltage apply up to around 15% of the speed of light. Above that speed, the increase in mass of the electron due to relativistic effects becomes significant and the speed calculated too large.

(a) What speed does an electron have at 15% of the speed of light?

(b) Calculate the voltage that would accelerate an electron from rest to that speed. Answers coorect to **2** significant figures.

Capacitance

1. Use the formula '**capacitance = charge ÷ potential difference**' $C = Q/V$, to calculate the values of the missing entries in the table.

capacitance (F)	**charge (C)**	**p.d. (V)**
-	2×10^{-6}	1.0
-	0.018	9.0
-	1.2×10^{-3}	12
0.01	-	6.0
1.5×10^{-12}	-	9.0
10^{-9}	1.2×10^{-8}	-
2×10^{-6}	4×10^{-4}	-

2. Express the following capacitances in **microfarads**:
   (a) 2.0×10^{-6} F (b) 1.6×10^{-5} F (c) 10000 nF (d) 10^{-7} F

3. Explain the **difference** in meaning between the terms 'capacitor' and 'capacitance'.

4. What is the value of the **capacitance** of a capacitor which has a charge of 96 μC on its plates when the potential difference across the plates is 12 volts?

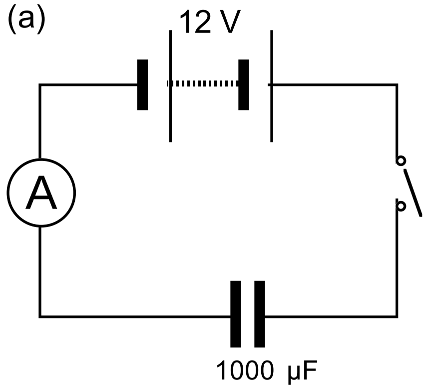
5. It takes 9×10^{-5} C of charge to raise the potential difference across the plates of a capacitor to 9.0 volts.
   (a) Calculate its **capacitance** in microfarads.
   (b) How much *more* **charge** would be added to its plates if the p.d. became 12 volts?

6. How much **charge** would be needed to raise the potential difference across the plates of a 100 μF capacitor to 9 volts?

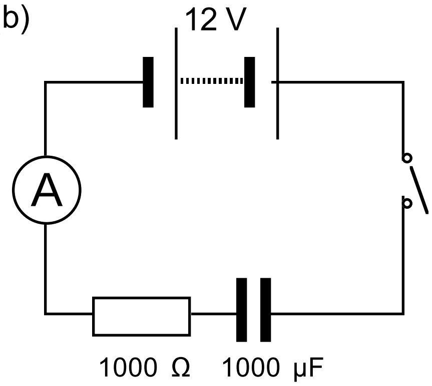
7. Calculate the **charge** on the plates of a 1 pF capacitor connected to a 1.5 V cell.
   [1 pF = 1 picofarad = 10^{-12} F.]

8. How much **charge** would be on the plates of the capacitor in each circuit after the switch was closed and the ammeter reading had fallen to **zero**?

(a)



(b)

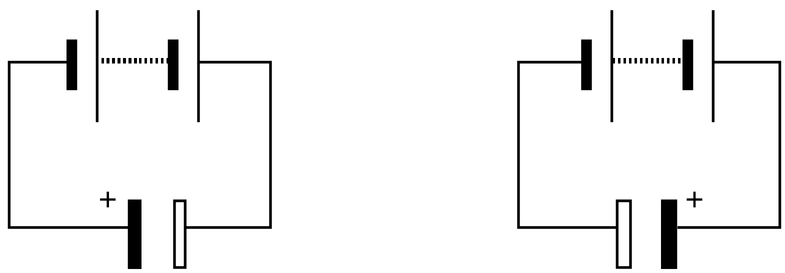


9. An electrolytic capacitor is connected to a 12 volt battery. The ‘negative’ plate of the capacitor acquires a total charge of electrons of -0.06 coulombs.

   (a) What is the value of the **capacitance**?
   (b) How much **charge** is on the ‘positive’ plate of the capacitor?

10. A 10000 μF capacitor is connected to a 9 volt battery.
    How much **charge** is there on **each** of the capacitor’s plates when fully charged?

11. (a) Which diagram shows an electrolytic capacitor *correctly* connected to a d.c. power supply?



    (b) What is **dangerous** about connecting this type of capacitor with incorrect polarity?

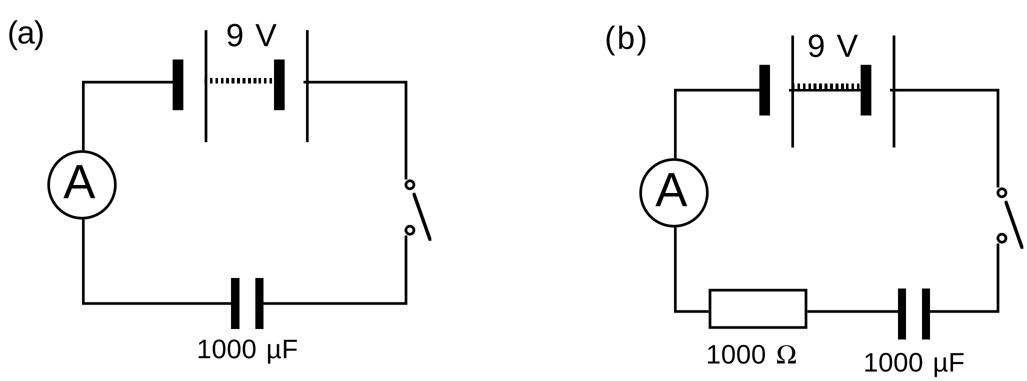
12. The case of a capacitor reads: ‘8 μF 63 V’. What is the significance of the ‘**63 V**’?

13. How much **energy** is stored in a fully charged 5000 μF capacitor connected to a 12 volt battery?

14. An 8 μF capacitor is charged from a 9 volt battery.
    How much **energy** does it store when fully charged?

15. When a 10000 μF capacitor is charged from a battery, 720 mJ of energy is stored.
    What is the battery **voltage**?

16. How much **energy** is stored by the capacitor in each circuit when the switch has been closed and the reading on the ammeter has fallen to **zero**?



17. A 2000 μF capacitor stores 36 millijoules of energy when charged from a d.c. power supply.

    How much **charge** has the power supply delivered to the capacitor?

18. Which **quantity** is given by the **gradient** of a ‘charge against voltage (p.d.) graph’ for a capacitor?

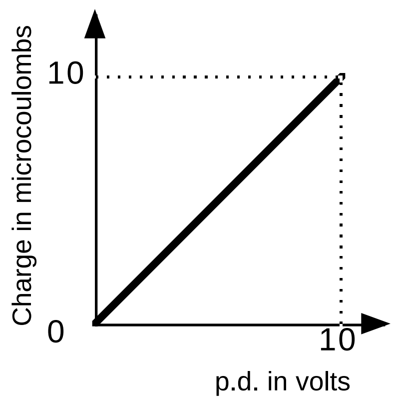
19. Which **quantity** is given by the **area** under a ‘charge against voltage (p.d.) graph’ for a capacitor?

20. For each of the ‘charge against pd.’ graphs for a capacitor, calculate:

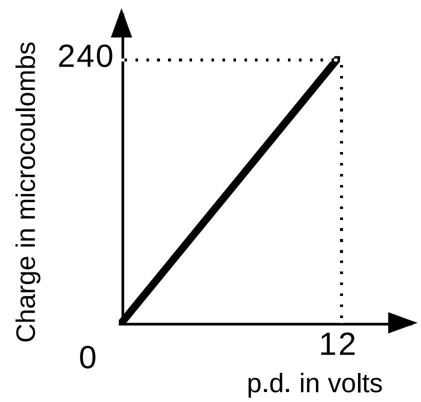
(a) the **capacitance**

(b) the **energy stored** by the capacitor when fully charged.

(A)

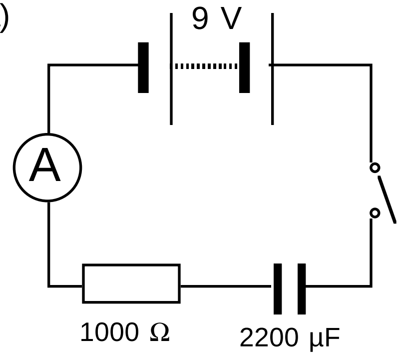


(B)

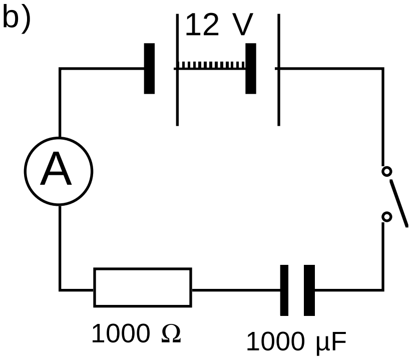


21. For each circuit, calculate the **initial charging current** when the switch is closed.

(a)



(b)



22. An uncharged 100 μF capacitor is connected in a series to a 6.0 volt battery, a 2 kΩ resistor and a switch.

(a) What is the magnitude of the **current** in the circuit just after the switch is closed?

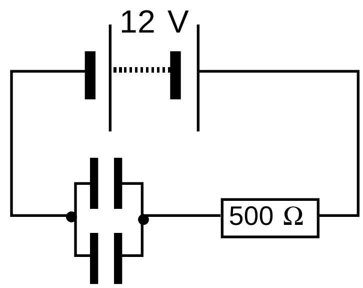
(b) At a certain point in the charging process, the charging current is 1.5 mA. At this instant, what is the **potential difference** across the resistor?

23. What **constant charging current** would be needed to fully charge a 10000 μF capacitor from a 12 volt battery in 2 minutes?

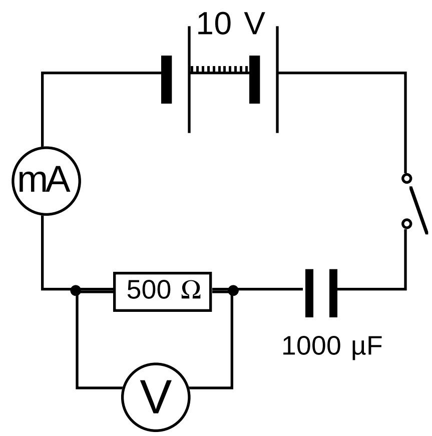
24. (a) How **long** would a constant charging current of 2.5 mA take to fully charge a 2000 μF capacitor from a 10 V d.c. power supply?

(b) What would the **resistance** in the circuit need to be at the start of the charging process?

25. When capacitors are connected in parallel, their capacitances *add*.
How much **energy** is stored when the capacitors in the circuit below are fully charged if each has a value of 500 μF?



26. In the circuit shown, a 1000 μF capacitor is being charged by a 10 volt battery.
A 500 Ω resistor is in series with the capacitor.



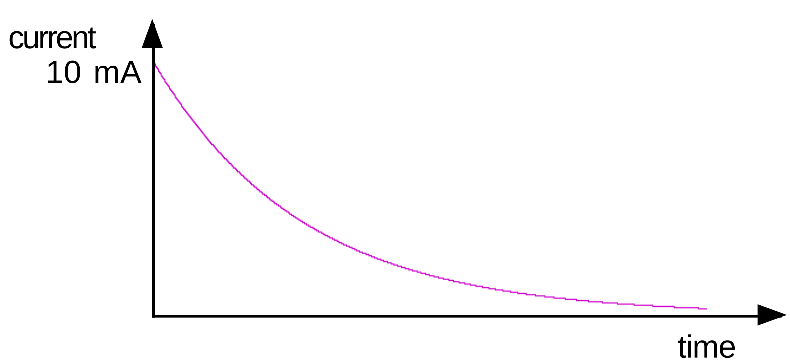
At one instant, the voltmeter reads 4.2 V. At this instant:

(a) what is the **p.d.** across the capacitor,

(b) how much **charge** is on the capacitor's plates and

(c) what is the **reading** on the milliammeter?

27. The graph shows how the charging current for a capacitor in series with a resistor varies with time. The initial charging current is 10 mA.

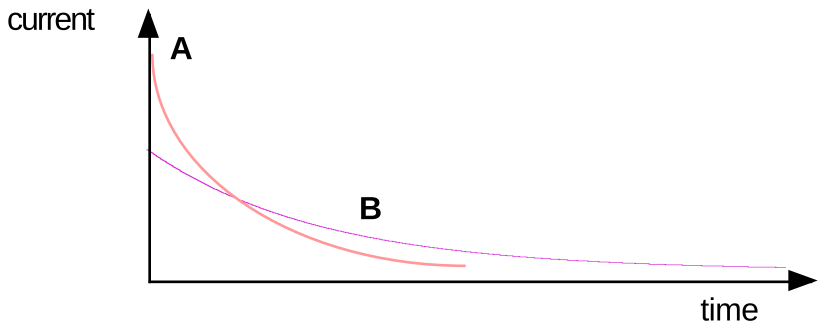


(a) What would the initial charging current be for a capacitor of **double** the capacitance, with the *same* resistor and battery.

(b) What would the initial charging current be if the original capacitor was charged from the same battery but with a resistor of **double** the resistance?

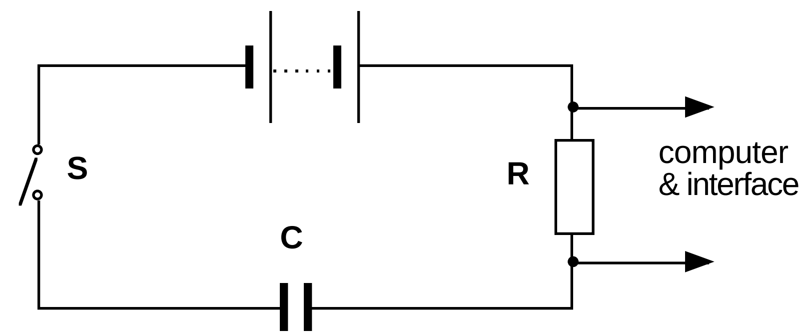
28. What **quantity** is given by the **area** under the current-time graph for a charging capacitor?

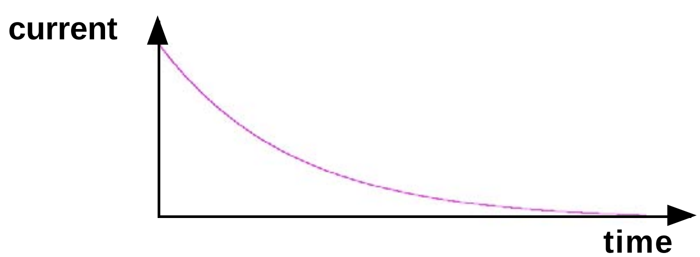
29. A capacitor, in series with a resistor, is charged from a battery. The current varies with time as shown by curve **A**. The same capacitor is charged from the same battery, but is in series with a larger resistor.
The variation of current with time is shown as curve **B**.



What can you deduce about the **areas** under curve **A** and curve **B**? Explain.

30. The graph shows how the charging current for a capacitor '**C**' in series with a resistor '**R**' varies with time after the switch '**S**' is closed. The capacitor is charged by a battery.
A computer and interface is connected across the resistor.



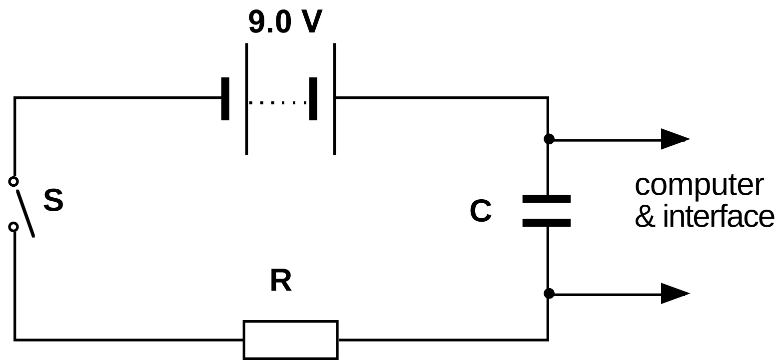


(a) The computer and interface measure the *potential difference* across the resistor. **Explain** how the computer is able to plot a graph of *current* against time.

(b) The switch is opened and the capacitor is fully discharged. The resistor is replaced with one of greater value. No other changes are made to the circuit. Copy the graph and, on it, sketch a possible curve for the charging **current** of the capacitor with the new resistor.

(c) The experiment is repeated with the *original* resistor in place but a capacitor with a *smaller* value of capacitance. Sketch a possible **charging** curve.

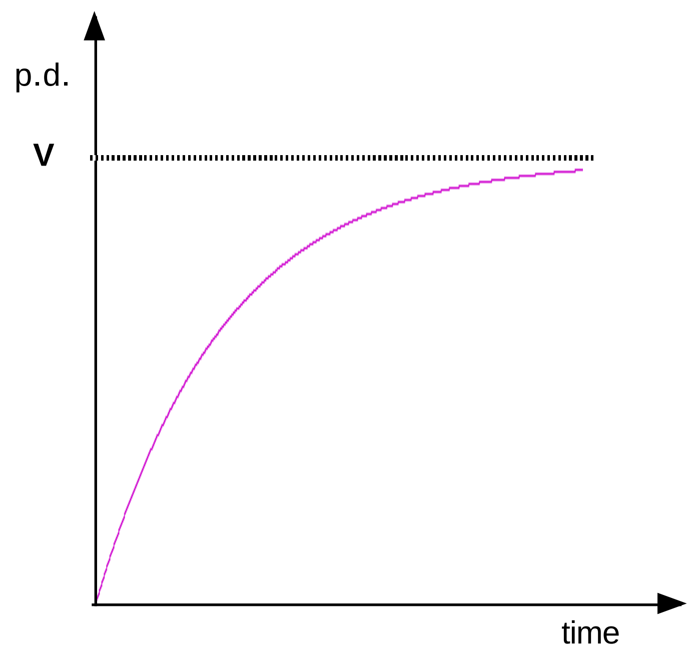
31. The graph shows how the potential difference across a capacitor '**C**' in series with a resistor '**R**' varies with time after the switch '**S**' is closed. The capacitor is charged by a 9 V battery. A computer and interface is connected across the capacitor.



(a) What is the value of the p.d. '**V**' as marked on the graph? Explain.

(b) Copy the graph and sketch a possible **curve** for the charging of a *larger* value of capacitor from the same battery and with the same resistor. Label it.

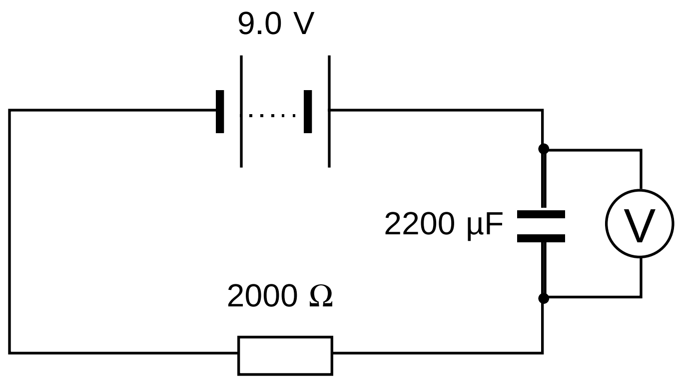
(c) Sketch a possible **curve** if the *original* capacitor was charged with the same battery but a smaller value off resistor. Label it.



32. A capacitor, in series with a resistor, is being charged from a 12 volt battery. High resistance voltmeters are connected across the capacitor and resistor.

At any instant during the charging of the capacitor, what would the **sum** of the readings on the voltmeters equal? Explain.

33. A 2200 μF capacitor, in series with a 2000 Ω resistor, is being charged from a 9.0 volt battery. A high resistance voltmeter is connected across the capacitor.



At certain instants during the charging process, the p.d. across the capacitor has the following values:

(i) 2.0 V (ii) 3.5 V (iii) 6.2 V (iv) 8.3 V

(a) At each of these instants, what would be the **p.d.** across the resistor?

(b) Calculate the **initial** charging current of the capacitor, in milliamps (mA).

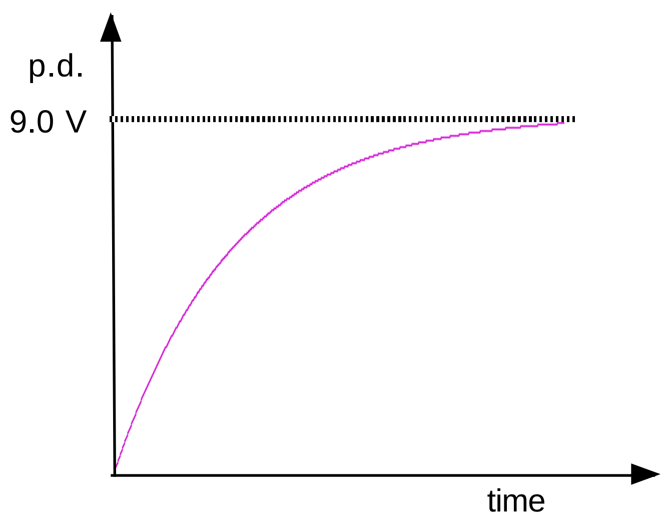
(c) When fully charged, what would be the **p.d.** across the capacitor?

(d) When fully charged, what would be the **p.d.** across the resistor?

(e) How much **charge** is on the capacitor plates when it is *fully* charged?

(f) What would be the value of the charging **current** at the instant when the p.d. across the capacitor was 6.0 V?

34. The graph shows how the p.d. across a capacitor varies with time as it is charged from a 9.0 V battery, through a series resistor.



Copy the graph and add a curve to show how the p.d. across the ***resistor*** (which is in series with the charging capacitor) varies with time.

35. The '**reactance**' X_C of a capacitor is a measure of its opposition to the passage of alternating current.

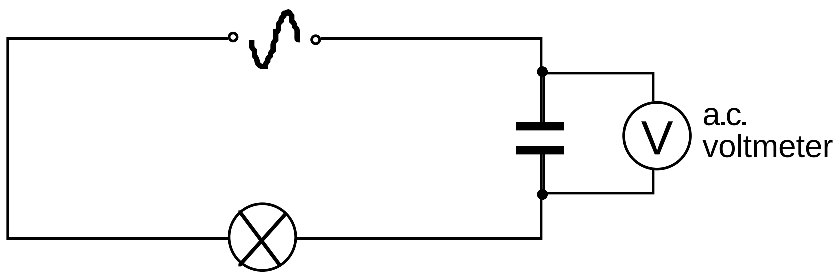
How is the **magnitude** of the reactance affected by:

(a) the value of the capacitance and

(b) the frequency of the current?

36. Describe the graph which would result if the **current** delivered from a signal generator with a constant r.m.s. output voltage through a capacitor was plotted against **frequency**.

37. An a.c. power supply, which has a constant output voltage but variable frequency, delivers alternating current to a capacitor in series with a lamp.
At a certain frequency, the lamp is glowing dimly.

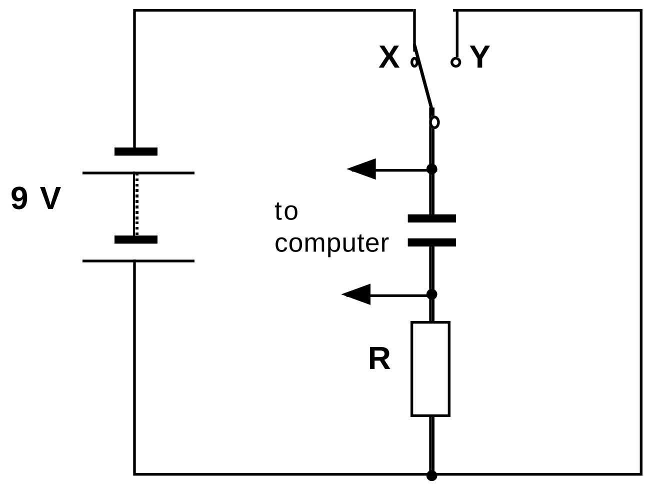


(a) What happens to the **brightness** of the lamp as the frequency is increased. Explain.

(b) What would happen to the **reading** on the voltmeter as the frequency was increased? Explain.

38. In the circuit shown, a capacitor is continuously charged and discharged from a 9.0 volt battery through a series resistor by moving the two-way switch between positions **X** and **Y**.

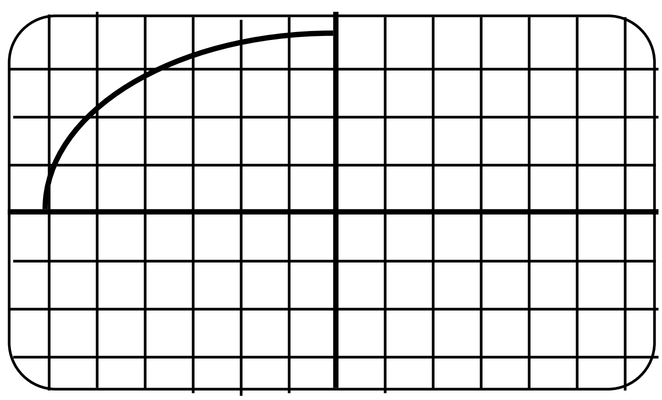
A computer plots a graph of the **voltage** across the capacitor against **time** as it charges and discharges.



(a) Which switch position results in the capacitor **charging**?

(b) Copy the 'screen' of the computer and extend the trace to show what would happen if the switch was moved to position **Y**.

Computer 'screen'

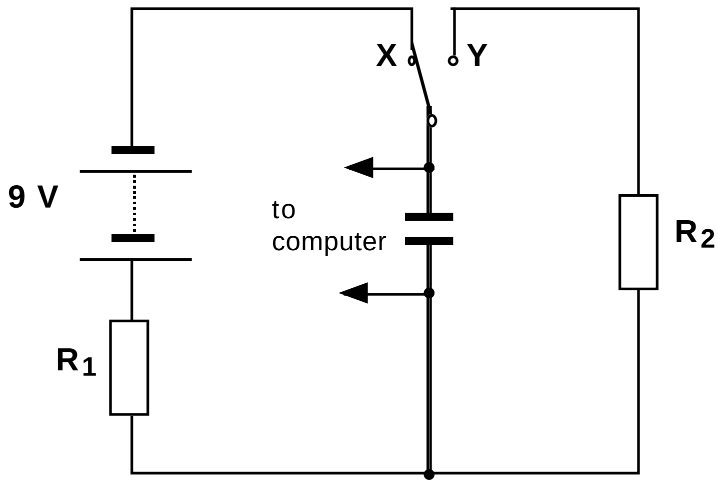


(c) Add possible traces to show how the charging and discharging voltage would differ if :

(i) the *capacitor* had a **smaller** value

(ii) the *resistor* had a smaller value.

39. In the circuit shown, a capacitor is continuously charged and discharged from a 9 volt battery through series resistors '**R_1**' and '**R_2**' by moving the two-way switch between positions **X** and **Y**. A computer plots a graph of the voltage across the capacitor as it charges and discharges.

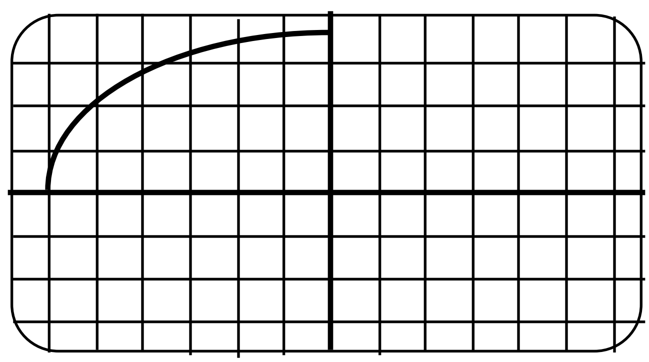


(a) Copy the 'screen' of the computer and extend the **trace** to show what would happen if the switch was moved to position **Y** if

(i) resistor '**R_2**' was larger than '**R_1**'

(ii) resistor '**R_2**' was smaller than '**R_1**'

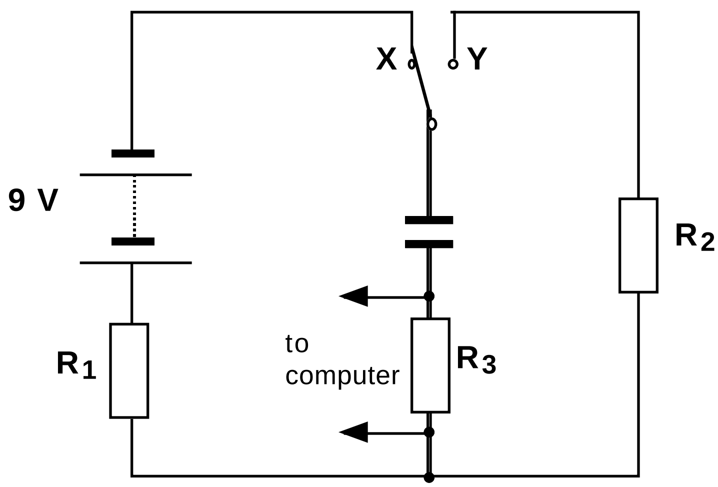
Computer 'screen'



(b) In each case, what is the **maximum voltage** reached by the capacitor?

40. In the circuit shown, a capacitor is continuously charged and discharged from a 9 volt battery through series resistors 'R_1' and 'R_2' by moving the two-way switch between positions **X** and **Y**.

A computer plots a graph of the charging and discharging current by measuring the p.d. across a resistor 'R_3' in series with the capacitor.

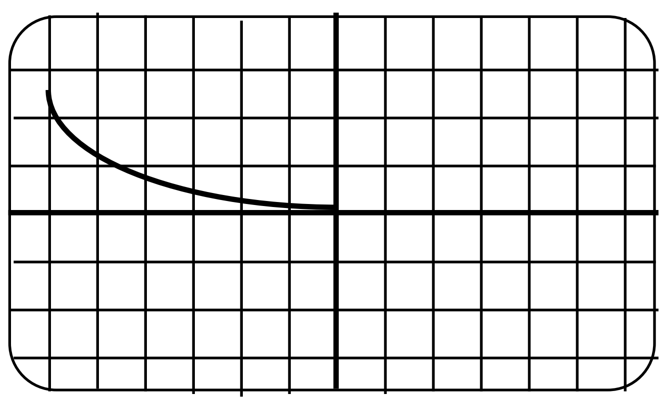


(a) Copy the 'screen' of the computer and extend the **trace** to show what would happen if the switch was moved to position **Y** if

(i) resistor 'R_2' was larger than 'R_1' and

(ii) resistor 'R_2' was smaller than 'R_1'.

Computer 'screen'



(b) How would the **initial charging current** of the capacitor be calculated?

(c) How would the **initial discharging current** of the capacitor be calculated?

(d) What effect, if any, would the value of the **resistors** have on the final **charge** stored on the capacitor plates?

(e) Calculate the **charge** stored on the capacitor plates, when fully charged, if its value is 20 μF.

(f) Calculate the **energy** stored in the 20 μF capacitor when fully charged.

Digital Electronics

1. The block diagram of an electronic system has one term missing from the 'middle' stage. What is the **missing term**?

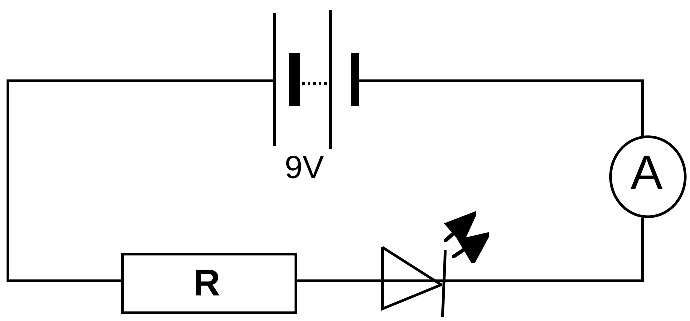
2. From the following list, identify which **four** items could be used as **input devices** of an electronic system:

thermistor **LED** **filament lamp** **microphone**

motor **LDR** **pressure switch** **transistor**

battery **buzzer** **LCD**

3. In the circuit below, the ammeter reads 10 mA and the value of the resistor **R** is 700 Ω.



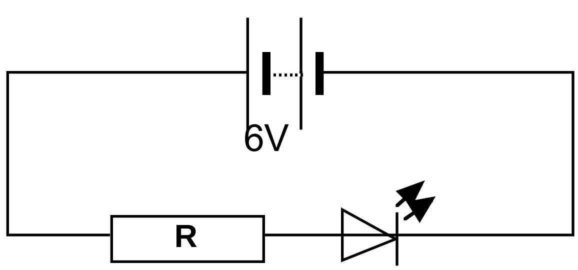
(a) Calculate the **potential difference** across the resistor.

(b) Calculate the **potential difference** across the LED.

(c) What is the **current** through the LED?

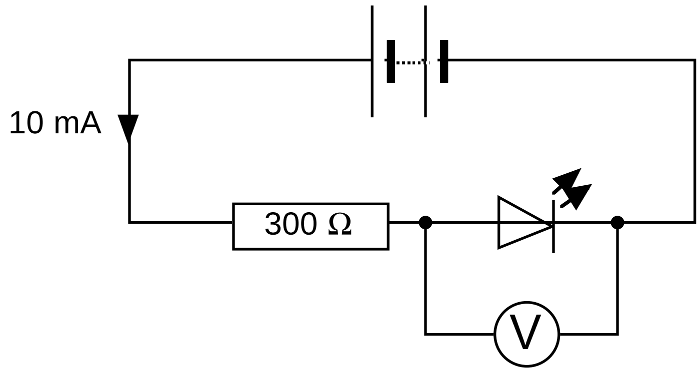
(d) Calculate the forward **resistance** of the LED.

4. An LED is to be operated from a 6 V supply at its rated p.d. of 2 volts. Its forward current is 10 mA.

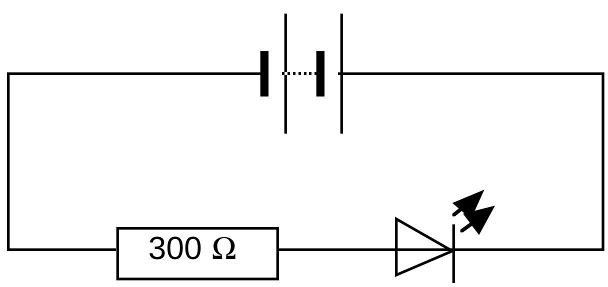


Calculate the value of the 'protecting' resistor **R** needed to limit the current through the LED to 10 mA.

5. From the information given in the circuit diagram, calculate the value of the **supply voltage**. The voltmeter reads 2.0 volts.

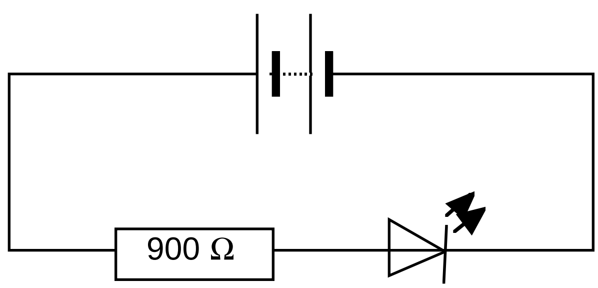


6. A girl sets up the circuit shown to observe the operation of an LED. The LED fails to light up.



What is **wrong** with her circuit? (None of the components is faulty).

7. A boy sets up the circuit shown to observe the operation of an LED. The LED, rated at 2V;20mA, fails to light up.



What is **wrong** with his circuit? (None of the components is faulty).

8. A transistor has a **current gain** of 200. If the collector current is 10 mA, calculate the value of the **base current**. State the answer in **microamps**.

9. A transistor has a collector current of 12.5 mA when the base current is 25 μA. Calculate its **current gain**.

10. What is the **base current** (in μA) of a transistor with a current gain of 250 when the collector current is 5 mA?

11. (a) In the circuit shown, what is the **p.d.** across

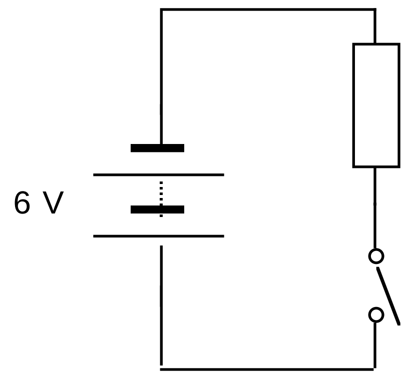
(i) the resistor,

(ii) the switch when the switch is **open**?

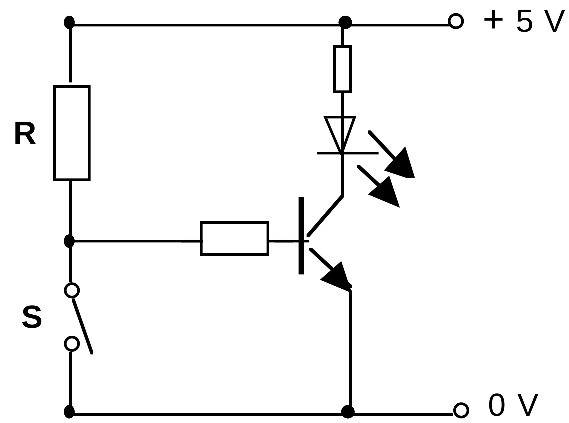
(b) What is the **p.d.** across:

(i) the resistor,

(ii) the switch when the switch is **closed**?



12. In this circuit, the transistor acts as a switch.



(a) Is the transistor switched **on** or **off** when the switch is **open**?

(b) Is the LED **on** or **off**?

(c) What happens when the switch is **closed**?

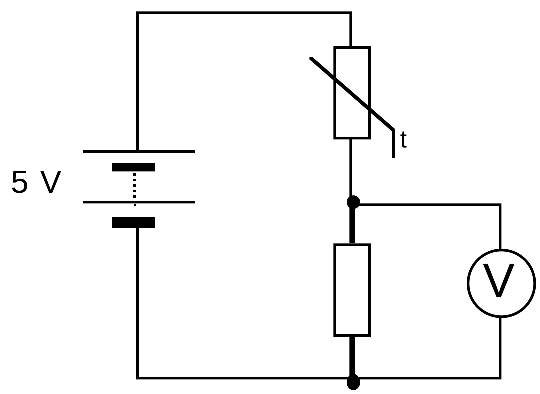
13. Redesign the circuit in Q12, using the same components so that the LED is **on** when the switch is **closed**.

14. The resistance of a thermistor falls as its temperature increases.
In the potential divider shown below, what happens to the **p.d.** across:

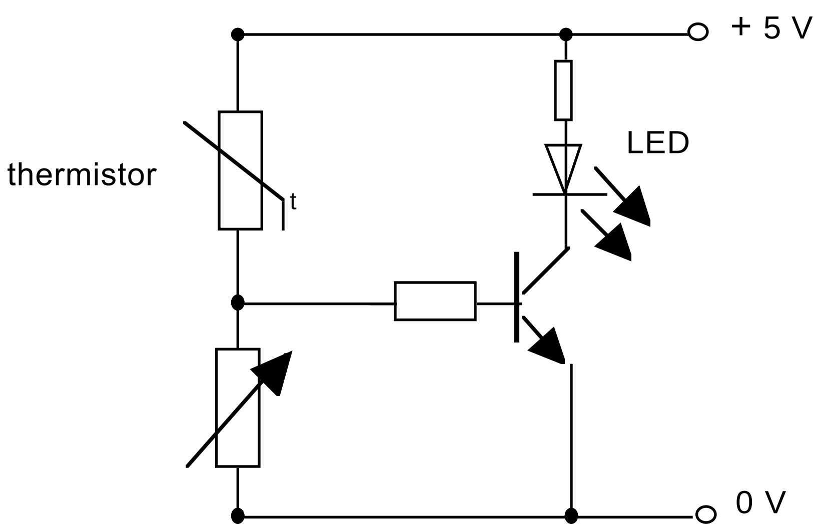
(i) the **resistor**,

(ii) the **thermistor** as the temperature increases?

(b) What is the **p.d.** across the thermistor when the voltmeter reads 2.4 V?



15. The circuit below is designed to switch **on** the LED when the temperature falls **below** a certain value.



Explain whether or not it would operate as **planned**.

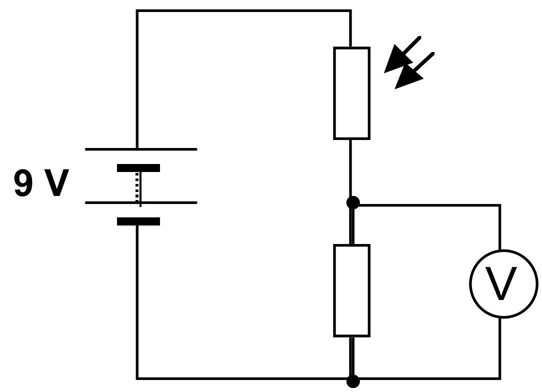
16. The resistance of a light dependent resistor (LDR) falls as the light level increases.

(a) In the potential divider shown below, what happens to the **p.d.** across:

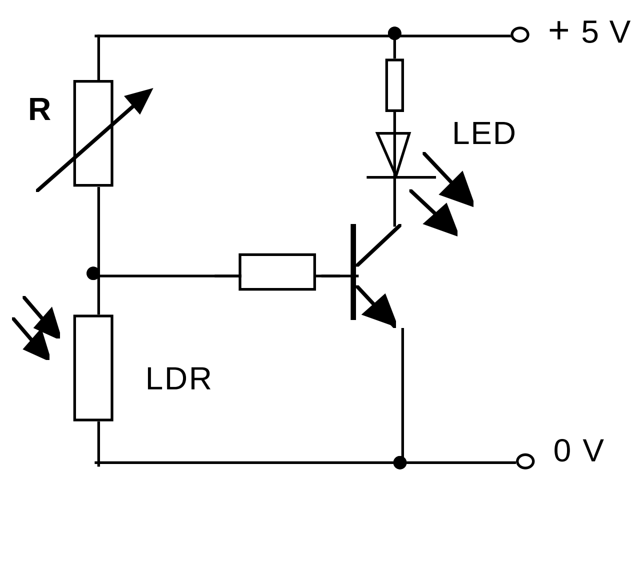
(i) the **resistor**

(ii) the **LDR** as the light level increases?

(b) What is the **p.d.** across the LDR when the voltmeter reads 6.2 V?



17. The circuit below is designed to switch **on** the LED when the light level falls **below** a certain value.

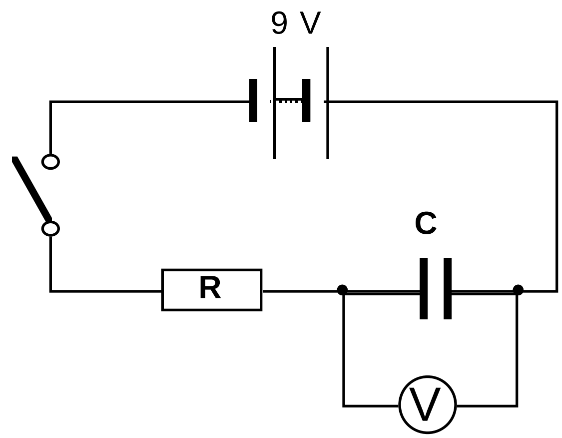


(a) Explain **how** the circuit operates, in terms of the voltage across the variable resistor.

(b) If the LED is found to light when the light level is still too *bright*, suggest what adjustment should be made to the circuit.

18. In this circuit, a high resistance voltmeter is connected across a capacitor which is in series with a resistor.

The capacitor is totally **uncharged**.

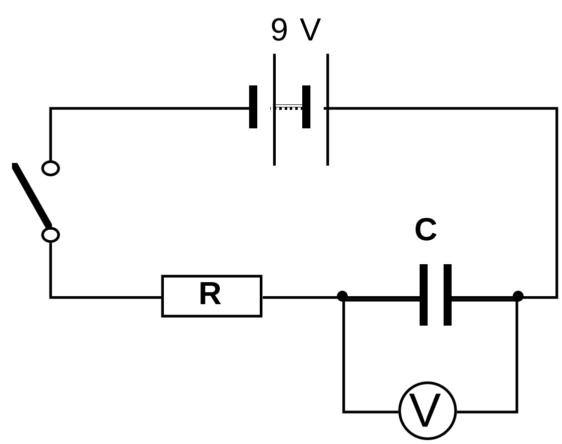


(a) What is the **reading** on the voltmeter when the switch remains **open**?

(b) When the switch is **closed**, describe what happens to the **reading** on the voltmeter.

(c) What is the **maximum reading** on the voltmeter?

19. A capacitor and resistor can be used as part of a time delay circuit.

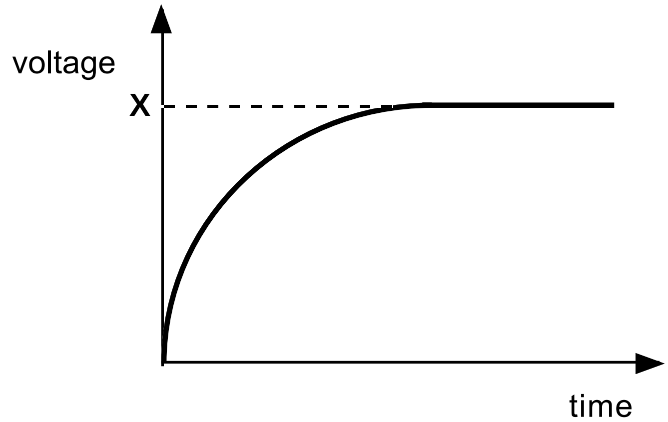


In the circuit shown above, the capacitor charges when the switch is closed. The **time** it takes to charge to a certain voltage depends on **two factors** other than the battery voltage.

(a) What are the **two** factors which affect the time to charge the capacitor?

(b) State **two** *different* changes which could be made to circuit components, each of which would **increase** the charging time.

20. The voltage-time graph shows how the voltage across a charging capacitor varies with time.



(a) Which **component** in the charging circuit has a voltage equal to **X**?

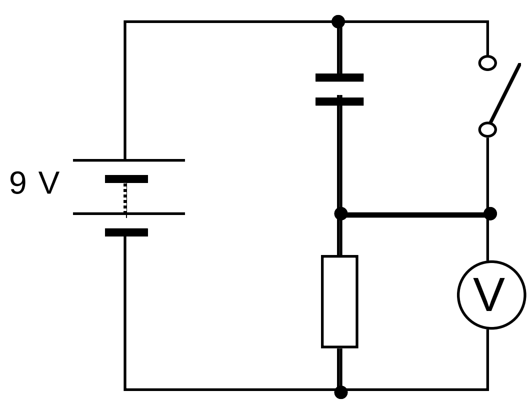
(b) Copy the graph and add to it a sketch of a possible **curve** for charging the *same* capacitor from the *same* battery but with a **larger** value resistor in series with it.

21. (a) In the potential divider shown below, what happens to the **p.d.** across:

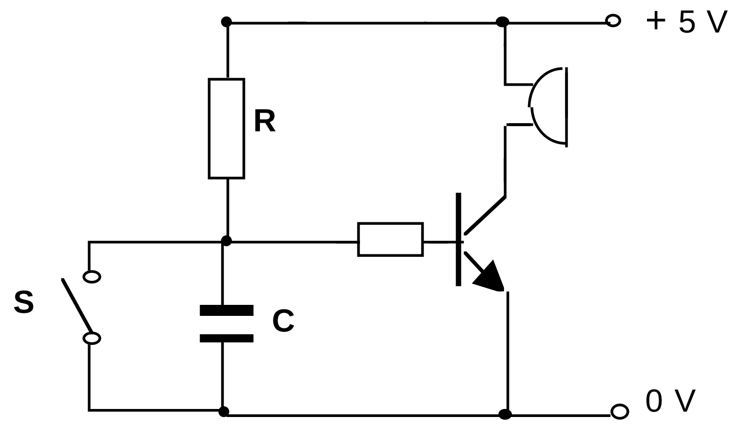
(i) the **resistor**?

(ii) the **capacitor** as the time passes *after* the switch has been **opened**?

(b) What is the **p.d.** across the capacitor when the voltmeter reads 5.4 V?



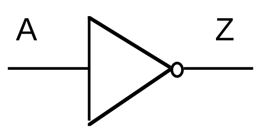
22. The circuit below is designed to switch **on** the buzzer a certain time after the switch is **opened**.



(a) Explain **how** the circuit operates, in terms of the voltage across the capacitor.

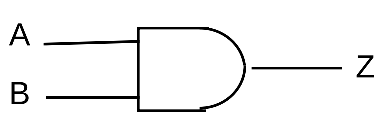
(b) If the buzzer is found to sound too *quickly*, suggest **two** changes which could be made to circuit components, each of which would **increase** the time taken for the buzzer to sound.

23. Copy and **complete** the truth table for a **NOT gate**.



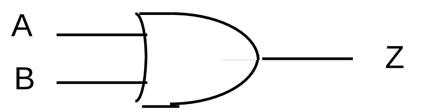
input	**output**
A	Z
	1
1	

24. Copy and **complete** the truth table for a two input **AND gate**.



inputs		**output**
A	B	Z
0	0	
0		0
1		0
		1

25. Copy and **complete** the truth table for a two input **OR gate**.



inputs		**output**
A	B	Z
0	0	
0		1
	0	1
		1

26. State the **name** of the logic gates which have these truth tables and **draw** their circuit symbols.

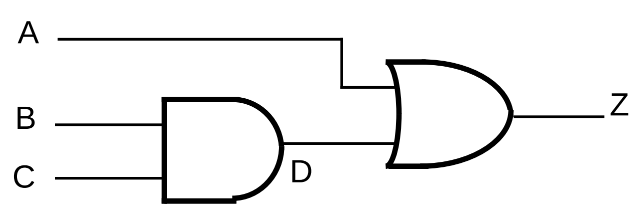
(a)

inputs		**output**
A	B	Z
0	0	1
0	1	0
1	0	0
1	1	0

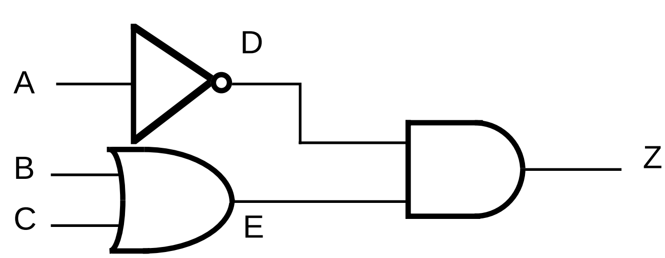
(b)

inputs		**output**
A	B	Z
0	0	1
0	1	1
1	0	1
1	1	0

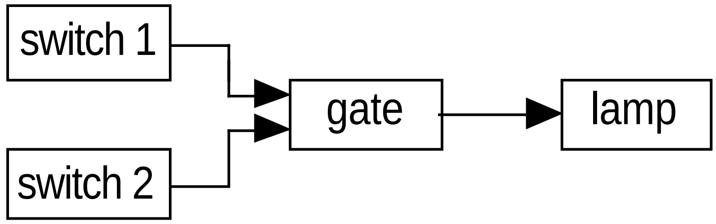
27. For the following logic circuit, construct the **truth table** for all possible inputs to A, B and C.



28. For the following logic circuit, construct the **truth table** for all possible inputs to A, B and C.



29. Design a **logic circuit** which will operate the electronic system given in the block diagram for a car's interior light. Closing each switch gives a **high** (**1**) and a **high output** is needed to switch on the light. Only *one* logic gate is needed.

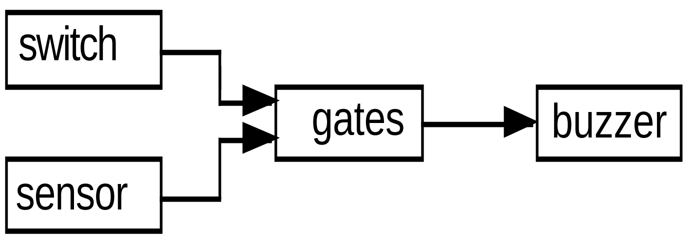


30. Design a **logic circuit** which will operate the electronic system given in the block diagram for a greenhouse heater.

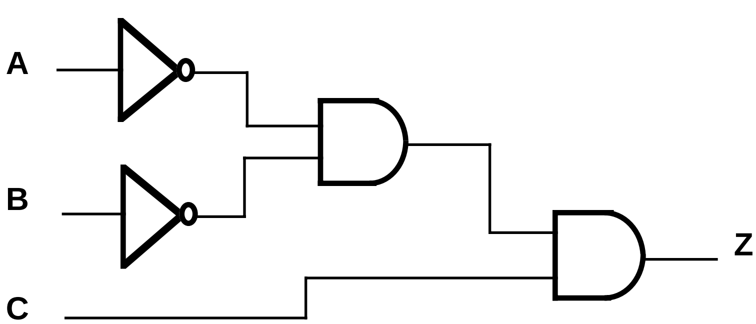
The temperature sensor gives a **high** when it is *warm and* the switch gives a high when it is *on*.

The buzzer alarm should sound when it gets too *cold* and the alarm will work only if the switch is *on*.

Two logic gates are needed.



31. The logic circuit shown gives a **high output** at **Z** *only* when there are *low* inputs at **A** and **B** and a *high* input at **C**.

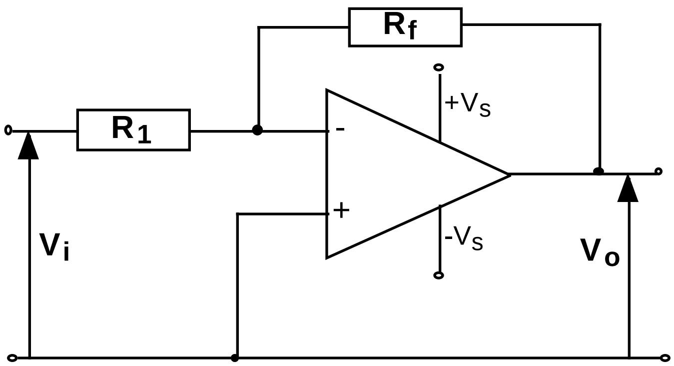


The circuit can be simplified by using only two gates (one each of **AND** and **NOR**).

Show **how** they are connected to perform the *same* function.

Analogue Electronics

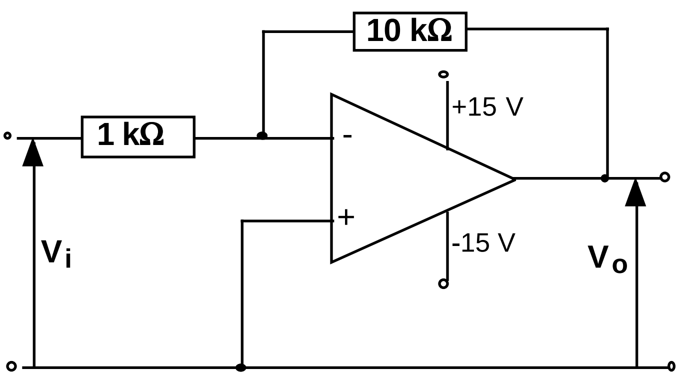
1.



The op-amp is in the inverting mode.

Write down the expression for calculating the value of the output voltage $\mathbf{V_o}$ in terms of the input voltage $\mathbf{V_i}$, the input resistor $\mathbf{R_1}$ and the feedback resistor $\mathbf{R_f}$.
(Assume that the output is **not** saturated).

2.



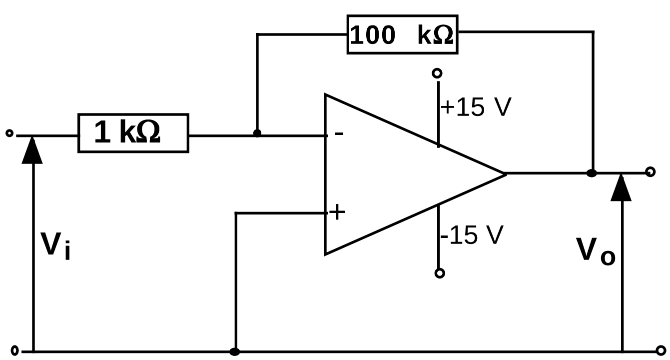
What is the value of the output voltage $\mathbf{V_o}$ when the input voltage $\mathbf{V_i}$ is

(a) 0 V (b) 0.2 V (c) 0.5 V

(d) 1.0 V (e) - 0.4 V (f) - 1.2 V

(g) - 0.7 V (h) 3.0 V (i) - 4.5 V?

3.



What is the value of the output voltage $\mathbf{V_o}$ when the input voltage $\mathbf{V_i}$ is:

(a) 0 V (b) 0.02 V (c) 0.05 V

(d) 95 mV (e) - 0.02 V (f) - 0.12 V

(g) - 0.07 V (h) 1.2 V (i) - 1.5 V?

4. An op-amp is in the **inverting mode**. Its input resistor is 20 kΩ and its feedback resistor is 120 kΩ. The power supply is 9 - 0 - 9 volts.

(a) Calculate the **output voltage** when the input voltage is:
(i) 0 V (ii) 0.5 V (iii) 0.9 V (iv) - 0.6 V (v) - 2.0 V (vi) 9 V

(b) If the power supply was changed to 15-0-15 volts, which, if any, of the **output voltages** calculated in (a) would have a different value?

5. An op-amp in the inverting mode gives an output voltage of -0.6 volts when the input voltage is 0.05 volts. The input resistor is 10 kΩ.

What is the value of the **feedback resistor**?

6. For an op-amp in the inverting mode, the ratio of the feedback resistor to the input resistor is 50:1. Its power supply is 15-0-15 V.

What would be the **input voltage** when the output voltage had the following values:

(a) - 10 V (b) 7.5 V (c) 150 mV (d) - 2.5 V (e) 0 V (f) - 100 μV (g) 12 V?

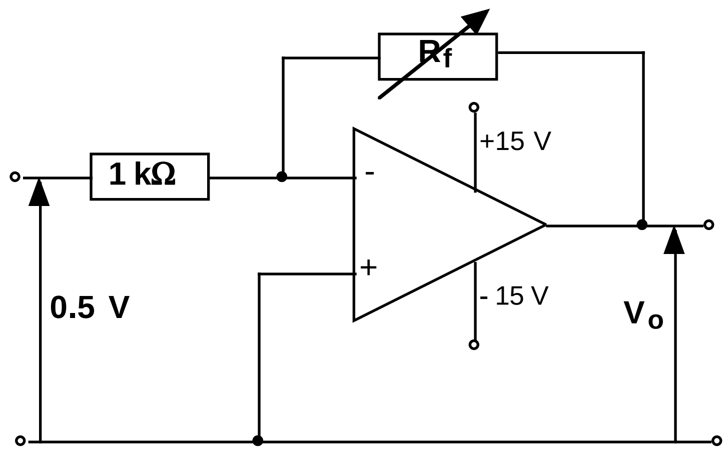
7. An op-amp is in the inverting mode. It has a 10 kΩ input resistor.
If the input voltage is -1.0 volts, what values of **feedback resistor** would be needed to obtain *output* voltages of:

(a) 1.0 V (b) 2.0 V (c) 5.0 V (d) 0.5 V (e) 10 V (f) 0.1 V?

8. The a.c. input to an inverting amplifier has a peak value of 100 μV.
If it is amplified by a factor of 500 and the *feedback* resistor is 100 kΩ, find:

(a) the **peak value** of the output voltage, (b) the value of the **input resistor**.

9.



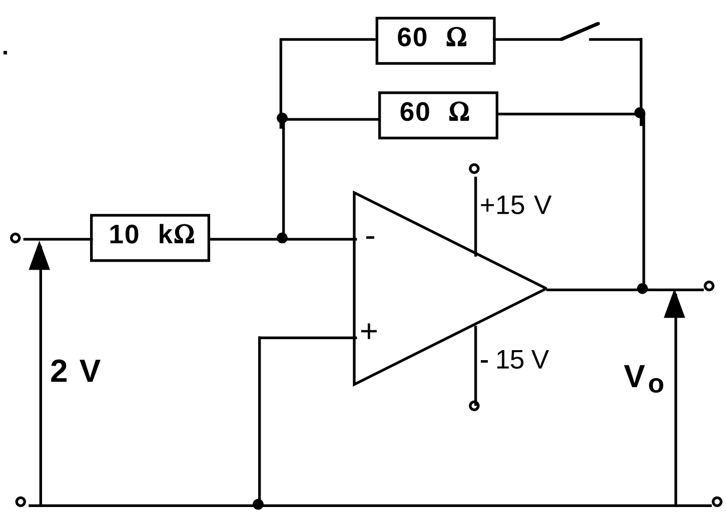
The feedback resistor $\mathbf{R_f}$ can vary from 0 Ω to 50 kΩ. For an input voltage of 0.5 volts, what **setting** would the feedback resistor have if the output voltage was:

(a) - 0.5 V (b) - 1.0 V (c) - 5.0 V

(d) - 10 V (e) - 12 V

(f) What would the **output voltage** be if the feedback resistor was at its *maximum* setting?

10.



For this inverting amplifier, calculate the value of the **output voltage** when the switch is:

(a) open

(b) closed.

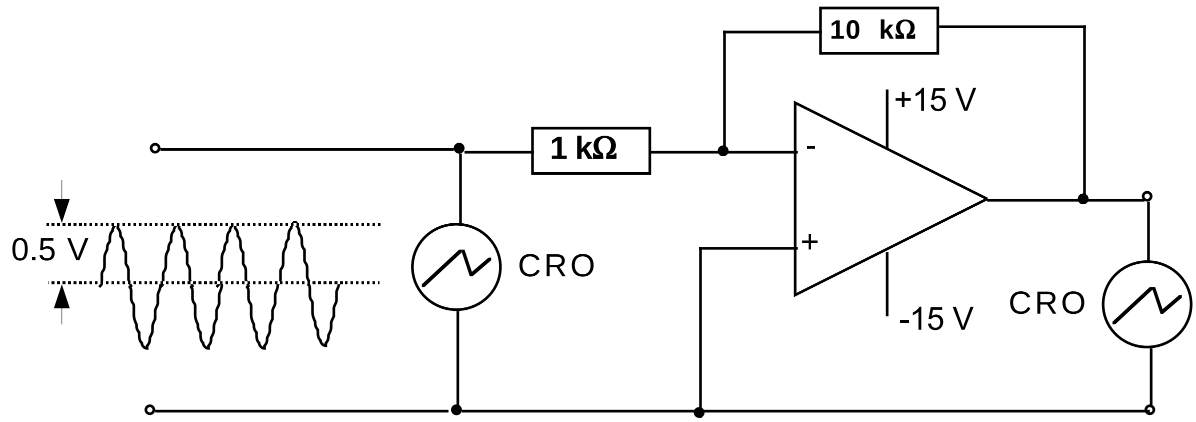
11. From the following list of resistors, choose ***two*** which could be used to construct an inverting amplifier with a gain of:

(a) 10 x (b) 100 x (c) 0.5 x (d) 4 x

In each case, state which would be the **input** and which the **feedback resistor**.

1 kΩ 5 kΩ 10 kΩ 20 kΩ 500 kΩ

12. An a.c. voltage is applied to the input of an op-amp in the inverting mode, as shown.

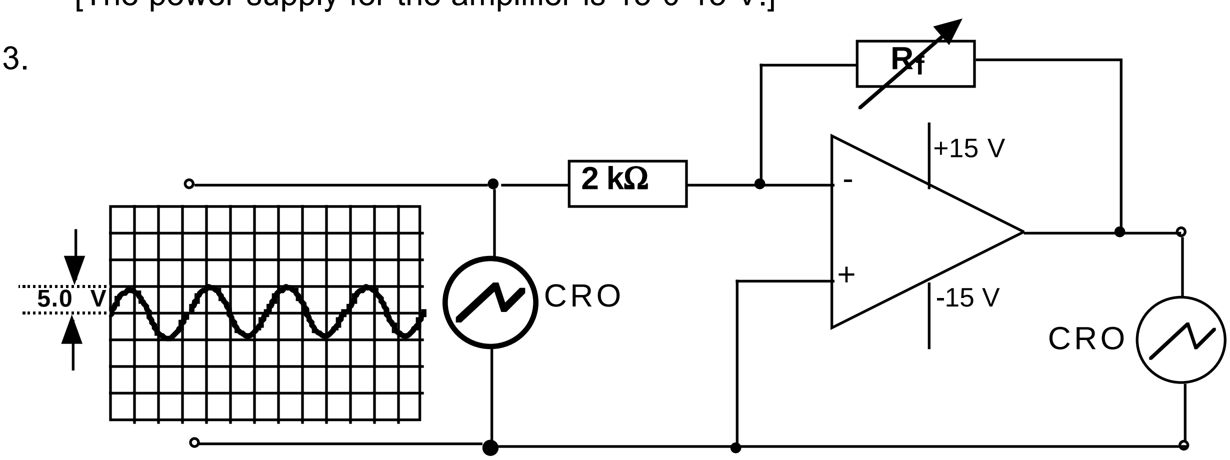


Four cycles of the input voltage are shown as they appear on the screen of a CRO connected across the input. Its peak value is 0.5 V.
A CRO is also connected across the output of the amplifier.
Its Y-gain and time base settings are the **same** as on the first CRO.

(a) Sketch the four cycles of the **output voltage** as they would appear on the CRO screen and indicate the value of the **peak voltage**.

(b) If the feedback resistor is changed to 100 kΩ, what would the effect be on the **output voltage**? Sketch how it would appear on the CRO screen.
[The power supply for the amplifier is 15-0-15 V.]

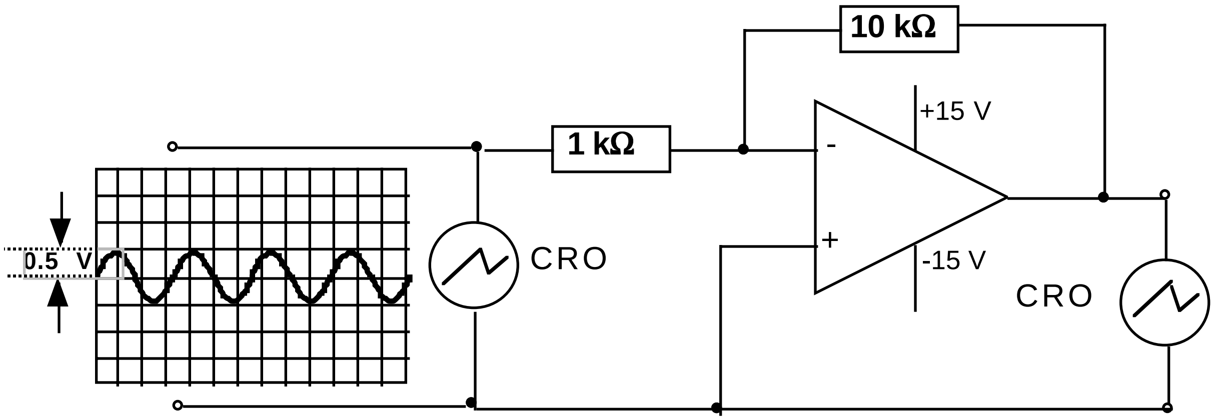
13.



In this op-amp circuit, the input voltage from a signal generator is displayed on the screen of a CRO connected across the input. Its peak voltage is 5.0 volts.
The feedback resistor is variable and can be adjusted from **0** to **10 kΩ**.
Make four copies of the CRO screen grid and, on them, sketch how the **output voltage** would appear on the screen of a CRO connected across the output with $\mathbf{R_f}$ at these settings assuming the *same* time-base and Y-gain settings on the CRO:

(a) 1 kΩ (b) 2 kΩ (c) 4 kΩ (d) 10 kΩ

14. In the op-amp circuit below, an a.c. voltage is connected across the input. The input voltage is displayed on the screen of a CRO. The appearance of the trace is shown when the input voltage has a peak of 0.5 volts.

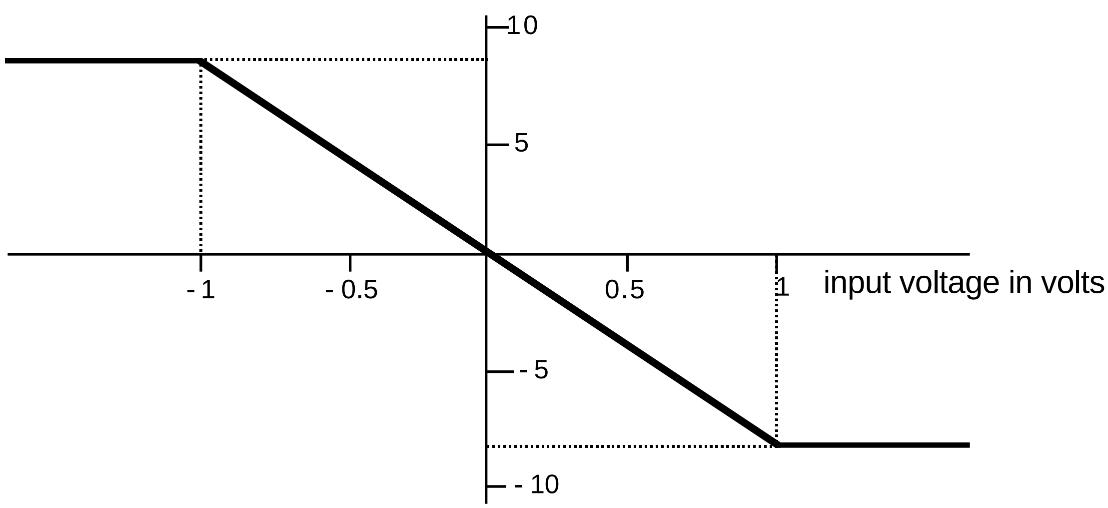


Make four copies of the CRO screen grid and, on them, sketch how the **output voltage** would appear on the screen of a CRO connected across the output with the peak input voltage at the following values (assuming that the CRO has the *same* time-base setting but the Y-gain is 10 times *less* sensitive):

(a) 0.5 volts (b) 1.0 volts (c) 2.0 volts (d) 3.5 volts.

15. An op-amp, in the inverting mode, is powered by a 9-0-9 volt regulated supply. The input resistor is 1 kΩ and the feedback resistor is 100 kΩ. What is the **largest** input voltage which can be amplified without saturation occurring?

16. Study the graph of output voltage against input voltage for an inverting amplifier.



(a) Estimate the **voltage** of the power supply for the amplifier.

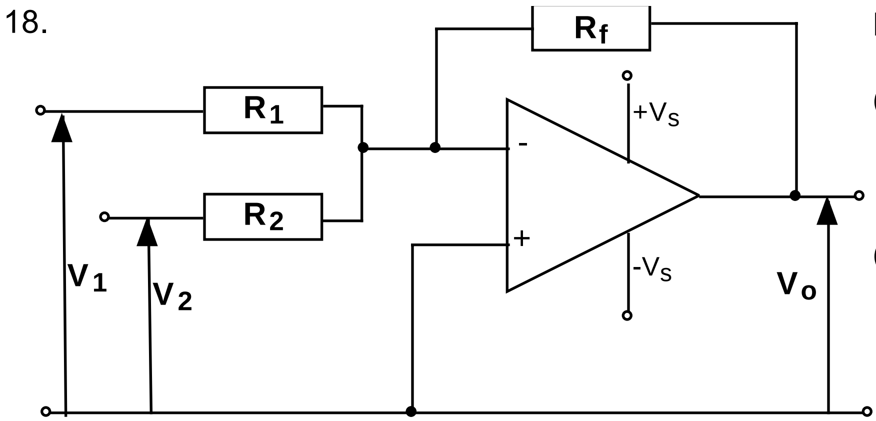
(b) Calculate the **gain** of the amplifier.

17. An inverting amplifier increases the r.m.s voltage of an a.c. input from 0.2 V to 12.0 V.

(a) If the amplifier's input resistor is 500 Ω, calculate the value of the **feedback resistor**.

(b) Apart from the increase in voltage, in what *other* way is the output voltage **different** from the input?

18.

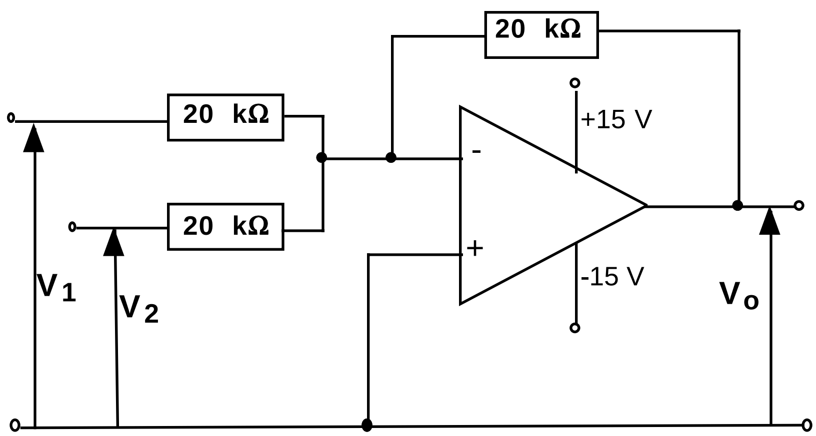


For this inverting amplifier:

(a) write down an expression for the output voltage $\mathbf{V_o}$ in terms of the input voltages and three resistors.

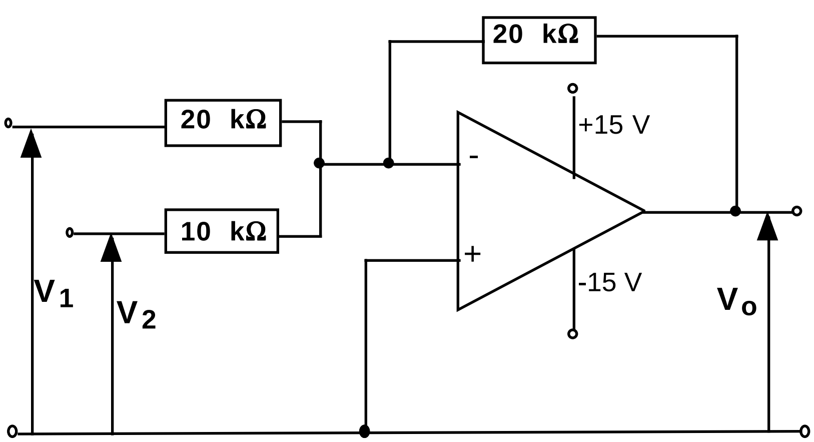
(b) In the special case where the resistors are all the *same* value, what is the relationship between $\mathbf{V_o}$, $\mathbf{V_1}$ and $\mathbf{V_2}$.

19. For the amplifier shown, which is in the inverting mode, calculate the value of the **output voltage** when the two input voltages are as stated.



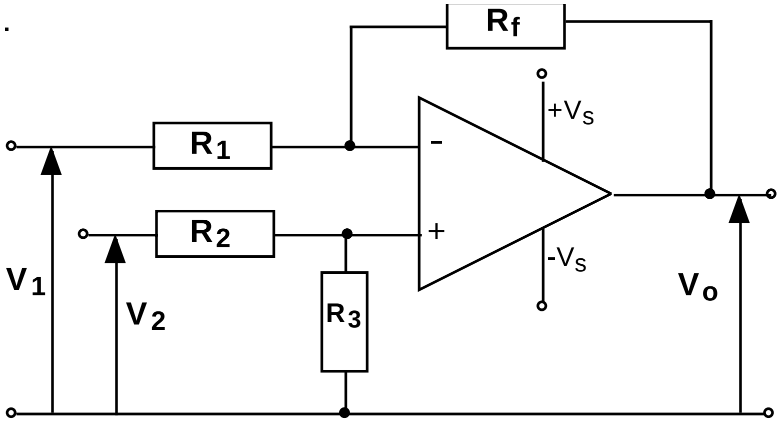
	V_1(V)	V_2 (V)
(a)	0	0
(b)	1	1
(c)	-1	-1
(d)	-1	1
(e)	5	4
(f)	-4	5
(g)	6	0
(h)	7	-8

20. For the amplifier shown, which is in the inverting mode, calculate the value of the **output voltage** when the two input voltages are as stated.



	V_1(V)	V_2 (V)
(a)	0	0
(b)	1	1
(c)	-1	-1
(d)	-1	1
(e)	2	4
(f)	-4	5
(g)	6	0
(h)	-7	5

21.



The op-amp is connected in the differential mode. Write down the expression for calculating the value of the output voltage $\mathbf{V_o}$ in terms of the input voltages $\mathbf{V_1}$ and $\mathbf{V_2}$, and the resistors input resistors $\mathbf{R_1}$, $\mathbf{R_2}$ and $\mathbf{R_f}$. (Assume that the output is **not** saturated.)

22. (a) Draw the **circuit diagram** for an op-amp connected in the differential mode with these values of resistors:

$R_1 = R_2 = 10\ k\Omega$ $\qquad$ $R_3 = R_f = 20\ k\Omega$.

(b) For this circuit, calculate the value of the **output voltage** with these input voltages, assuming that the op-amp has a 15-0-15 volt power supply:

(i) V_1 = 2.0 volts; V_2 = 3.0 volts $\qquad$ (ii) V_1 = 2.5 volts; V_2 = 2.5 volts

(iii) V_1 = 3.0 volts; V_2 = 2.5 volts $\qquad$ (iv) V_1 = 2.5 volts; V_2 = 2.5 volts

(v) V_1 = 0 volts; V_2 = 3.5 volts $\qquad$ (vi) V_1 = 4.0 volts; V_2 = 0 volts

(vii) V_1 = 2.5 volts; V_2 = 5.8 volts $\qquad$ (viii) V_1 = 2.0 volts; V_2 = 12.0 volts

23. An op-amp with a 15 -0 -15 volt power supply,in the **differential mode**, has these input voltages:

V_1 = 2.0 volts and V_2 = 3.0 volts.

(a) Calculate the **output voltage** when the resistors have the following values:

(i) $R_1 = R_2 = 20\ k\Omega$; $R_3 = R_f = 20\ k\Omega$ $\qquad$ (ii) $R_1 = R_2 = 10\ k\Omega$; $R_3 = R_f = 20\ k\Omega$

(iii) $R_1 = R_2 = 20\ k\Omega$; $R_3 = R_f = 10\ k\Omega$ $\qquad$ (iv) $R_1 = R_2 = 10\ k\Omega$; $R_3 = R_f = 10\ k\Omega$

(v) $R_1 = R_2 = 10\ k\Omega$; $R_3 = R_f = 50\ k\Omega$ $\qquad$ (vi) $R_1 = R_2 = 50\ k\Omega$; $R_3 = R_f = 10\ k\Omega$

(vii) $R_1 = R_2 = 10\ k\Omega$; $R_3 = R_f = 100\ k\Omega$ $\qquad$ (viii) $R_1 = R_2 = 1\ k\Omega$; $R_3 = R_f = 100\ k\Omega$

(b) For each of the answers to part (a), what **difference**, if any, would there be if the input voltages were **reversed**?

Speed = distance ÷ time *(for speed of sound)*

1. The speed of sound through the air is 340 m/s. How **far** would a sound travel in:

   (a) 1 s (b) 2 s (c) 10.5 s (d) 0.5 s (e) 1 ms (millisecond)?

2. A whale's sound takes 50 seconds to travel to another whale which is 75 km away. Calculate the **speed** of sound through water.

3. How **long** would a sound take to travel 1530 metres through the air at speed of 340 m/s?

4. Sound moves through steel at 5000 m/s.

   (a) How **far** would a sound move through a steel rail in 0.5 s?

   (b) How **long** would it take a sound to travel along a 10 metre length of steel rod?

5. From a distant thunderstorm, the lightning flash moves so quickly that it reaches you almost at once. The sound of the thunder takes much longer to arrive.
   Taking the speed of sound through air as 340 m/s, how **far** away is a storm if the gap in time between the flash and bang is 15 seconds?

6. A boy is watching a military display from far off. At one point, a cannon is fired. The boy is surprised to see a puff of smoke come out of the cannon before he hears the bang.
   In fact, there is a gap of 2.5 seconds.

   (a) The boy doesn't study Physics at school. How would you **explain** to him the reason for what he has observed?

   (b) Calculate how **far** the boy was from the cannon when it was fired.
   (Speed of sound = 340 m/s)

7. A race judge is positioned at the finish line of a 100 m sprint. He sees the puff of smoke from the starter's pistol just before he hears the bang.
   Taking the speed of sound through the air as 340 m/s, calculate the **time interval** between the appearance of the puff of smoke and the bang.
   (State the answer to **two** significant figures).

8. While walking in the mountains, a girl shouts to her friend who is some way off. She hears a faint echo of her shout after a delay of 1.4 seconds. Her sound has been reflected from a cliff.
   How **far** was the girl from the cliff if the speed of sound was 340 m/s?

9. The speed of sound through carbon dioxide gas is slower than through air.
   A sound will travel 135 metres through the gas in half a second.
   Calculate the **speed** of sound through carbon dioxide.

10. To measure the speed of sound, a girl stands 150 m away from a large building and bangs two pieces of wood together. Her friend uses a stop-watch to time the interval between the bang and its echo. The watch reads 0.97 s.

   (a) What value would the girls calculate for the **speed** of sound?

   (b) Their value is rather *low*. Can you explain why this might have happened?

Speed = distance ÷ time (for speed of light)

In these examples, take the **speed of light** through air or a vacuum (space) to be 3×10^8 m/s. The speed of radio and TV waves is the same as the speed of light in air or a vacuum.

1. Express the speed of light as a 'normal' number in:
   (a) metres per second (b) kilometres per second.

2. Calculate the value of the speed of light through air in **miles per second**.
   (1 mile = 1625 metres). Give your answer to the nearest **thousand**.

3. How **far**, in metres, would a pulse of light travel through the air in the following times:
   (a) 2 s (b) 3.5 s (c) 0.1 s (d) 0.02 s (e) 10^{-5} s (f) 4.1×10^{-6} s?

4. How **long**, in seconds, would a pulse of light take to travel the following distances:
   (a) 1.2×10^9 m (b) 1.5×10^8 m (c) 3000 m (d) 600 m (e) 1 light-year?

5. The speed of light is different in different materials. How **fast**, in metres per second, does it travel through a glass fibre if it takes 2.5 ns to travel along a 50 cm fibre?
   (1 ns = 1 nanosecond = 10^{-9} s).

6. The distance from the Earth to the Moon can be measured by timing how long a beam of light takes to travel to the Moon and back, bouncing off a mirror on the Moon.
   If a pulse of light takes 2.56 s to travel to and from the Moon, what value does this lead to for the Earth - Moon **distance**?

7. A geostationary satellite, positioned 36 000 km above the equator, relays a T.V. signal, by microwave radiation, from a ground station in Scotland to one in the U.S.A.
   Assuming that the total distance travelled by the microwaves is approximately double the height of the satellite, calculate the **time** for the signal to reach the ground station in the U.S.A.

8. On television programmes where there is a *live* 'satellite link' to America and a celebrity in America is being interviewed by a presenter in Britain, there is a noticeable delay between the end of the interviewer's question and the start of the celebrity's answer.
   Explain why this happens.

9. Light and heat radiation reaches us from the Sun at the speed of light across the vacuum of space. The Sun is 1.5×10^{11} m distant. How **long**, in minutes, does it take the radiation to reach the Earth?

10. In the film '2001 - a Space Odyssey', radio messages are sent from Earth to a manned spacecraft orbiting the planet Jupiter. The messages take 35 minutes to reach the spacecraft. How **far** is Jupiter from the Earth, in kilometres?

11. The distance from Glasgow to London is about 650 km. If they were directly linked by optical fibre, how **long** would a telephone message take to travel between the cities?
   (Speed of light though glass is 2×10^8 m/s.)

Wave speed, frequency, wavelength, period

1. Use the formula '**wave speed = frequency x wavelength**' **($v = f\lambda$)** to calculate the value of the missing quantities in the table.

v (m/s)	f (Hz)	λ (m)
-	10	2.5
-	50	0.02
-	10^5	10^{-3}
340	170	-
3×10^8	2×10^6	-
2.4	0.5	-
310	-	0.5
3×10^8	-	3.33

[In the questions that follow, use the relationships: (1) frequency = number of cycles per second and (2) frequency = 1 ÷ period]

2. How many **waves** are made in 3 minutes by a pleasure pool's wave machine if its frequency is 0.25 hertz?

3. A tuning fork vibrates at 256 hertz. How **many times** does one of its prongs vibrate back and forth in 5 seconds?

4. The mains electricity in some countries has a frequency of 60 Hz.
Calculate the **period** of one cycle of the supply.

5. With the **time base** of a CRO set at 0.5 ms/cm, three cycles of an alternating voltage, displayed on the screen, occupy 6.0 cm, horizontally.
Calculate the **frequency** of the voltage.

6. A CRO has the time base set at 10 ms/cm. How many **centimetres** would **one** cycle of a 25 Hz signal occupy on the screen, horizontally?

7. What is the **time** for one cycle of an alternating voltage with a frequency of 50 hertz?
What **term** is used for this time?

8. Calculate the **frequency** of a water wave which has a wavelength of 1.5 m and travels a distance of 10 metres in 5.0 seconds.

9. A water wave, travelling at 2.5 m/s, has a wavelength of 50 cm.
What are the wave's: (a) **frequency** (b) **period**?

10. What is the **period** of a wave whose frequency is 4 Hz?

11. On a stormy day, a girl counts the number of wave crests breaking on the shore and finds that there are 60 in 4 minutes. Calculate the water waves' **frequency** in hertz (waves per second.)

12. What is the **frequency** of the tuning fork which makes the musical note one octave above 'middle C' if its prongs vibrate 2560 times in 5 s?

13. What is the **wavelength** of a 200 Hz sound wave if the speed of sound in air is 340 m/s?

14. Calculate the ***difference*** in **wavelength** between sounds of frequency 567 Hz and 618 Hz in air where the speed of sound is 340 m/s.

15. Sound waves travel at 1500 m/s through water.
Calculate the **wavelength** of a 300 Hz sound made under water.

16. What is the **speed of sound** through an aluminium rod if a sound vibration of frequency 13 kHz has a wavelength of 40 cm?

17. An ultrasound generator produces sounds of frequency 40 kHz. Calculate:

(a) the **period** of the sound waves

(b) their **wavelength**, in **microseconds**, if the speed of sound in air is 340 m/s.

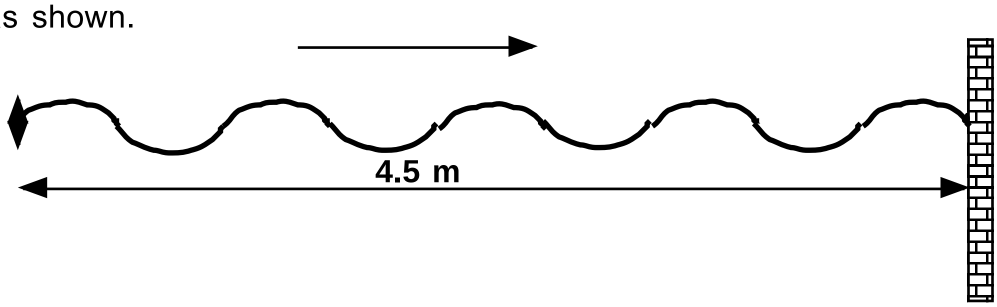
18. Medical ultrasounds of 2.0 MHz are generated and sent through a person's abdomen. If the speed of sound in the abdominal tissues is 1500 m/s, calculate the **wavelength** of the ultrasound waves inside the person. Answer in **millimetres**.

19. A sound has a wavelength of 60 cm in air where its speed is 340 m/s.
What would the **wavelength** of the sound become if it passed into water, where its speed is 1500 m/s?

20. Water waves in a ripple tank are found to measure 2.0 cm between successive crests.
The vibrating bar which generates the waves is set to make 25 waves in 5 s.
Calculate the **speed** of the waves.

21. As water waves approach the shore, the water becomes shallower and the wave speed decreases. What happens to the **wavelength** and **frequency** of the waves?

22. A boy makes waves on a long rope by attaching one end to a wall and moving the other end up and down rapidly *three times* a second.
At one instant, just as the first part of the wave reaches the wall, the wave on the rope appears as shown.

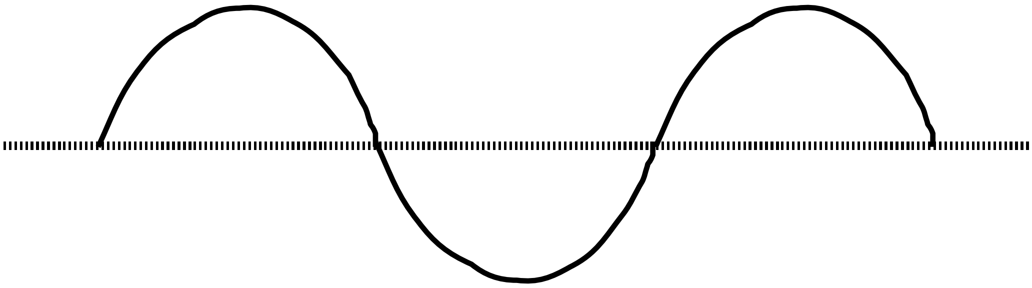


Calculate: (a) the **time** taken to travel from the boy's hand to the wall.

(b) the **speed** at which the wave moves along the rope.

(c) the **wavelength** of the wave

23. By making measurements on this page, find the **amplitude** and **wavelength** of the wave drawn below to actual size.



Note: in questions 24- 35 , take the speed of waves of the electromagnetic spectrum to travel through the air at 3.0×10^{8} m/s.

24. What is the **frequency** of a wave of red light in the air if its wavelength is 6.8×10^{-7} m?

25. Calculate the **wavelength** of BBC Radio 4 which broadcasts on a frequency of 198 kHz.

26. Certain X-rays have a frequency of 1.0×10^{19} Hz. Calculate their **wavelength** in the air.

27. BBC Radio 5 is broadcast on 330 m on the Medium Wave.
Calculate the **frequency** of the carrier wave in **kilohertz**.

28. What is the **wavelength** of a radio station which sends out radio waves of frequency 1.15 MHz?

29. A certain radio station broadcasts on a frequency of 101.7 MHz.
Calculate the **wavelength** of the radio wave.

30. Calculate the **frequency**, in kilohertz, of a radio station which broadcasts on the Medium Wave with a wavelength of 1053 m.

31. An orange street lamp gives out light which has a very short wavelength of around 6.0×10^{-7} m. What is the **frequency** of the light?

32. An X-ray tube produces waves of frequency 2.0×10^{18} Hz.
Calculate the **wavelength** of the X-rays.

33. Calculate the **wavelength** and **period** of microwaves which have a frequency of 10^{11} Hz (that is, 1.0×10^{11} Hz) , when travelling through the air.

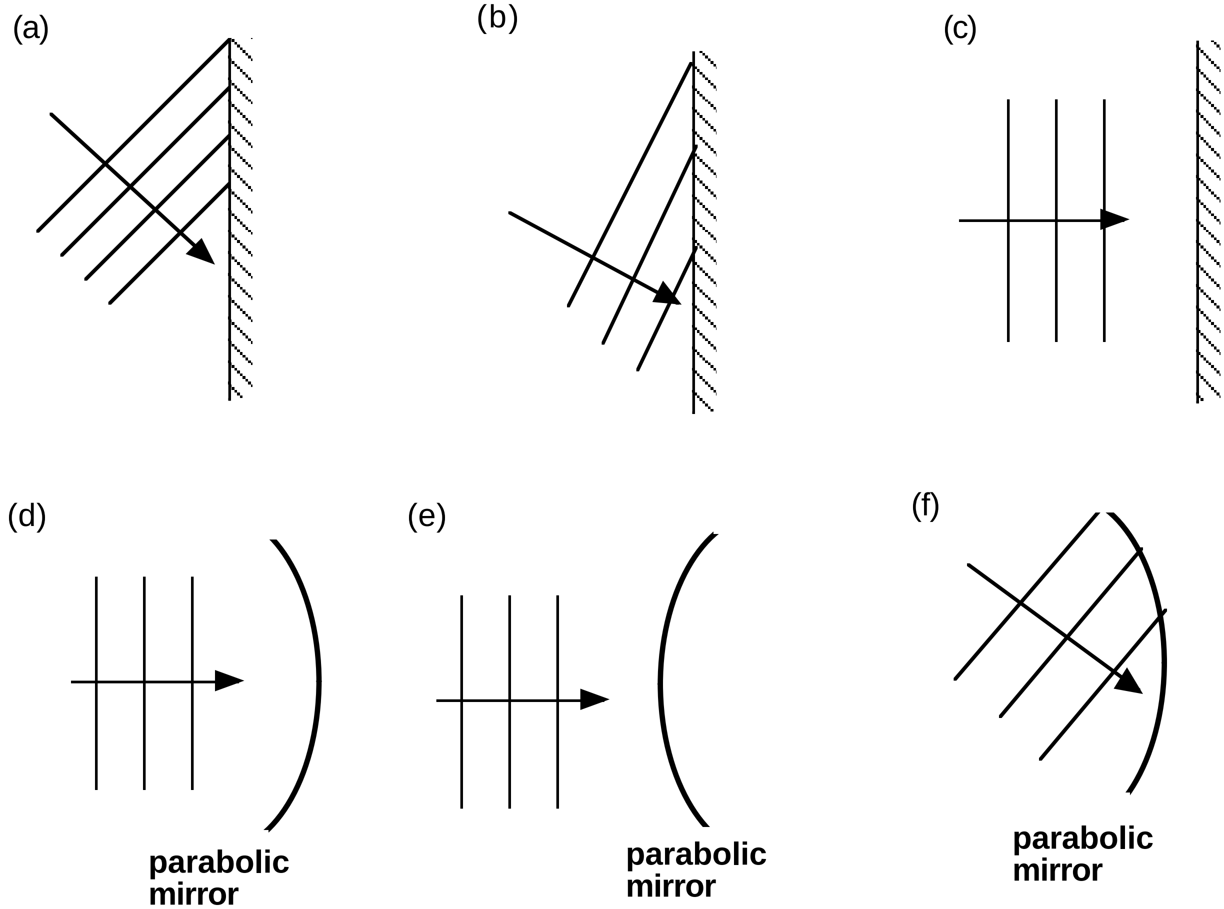
34. A radio station broadcasts on 250 m,1200 kHz.
Show that the radio wave travels through the air at 3×10^{8} m/s.

35. Extra Low Frequency (ELF) waves are used to communicate with submarines.

Calculate the **wavelength** in air of an ELF wave of frequency 1.5 kHz.
Answer in **kilometres**.

Wave properties

1. Copy and complete the following diagrams by drawing the position of the wave fronts *after* they have been **reflected** from the barriers:

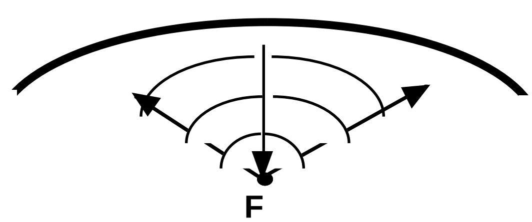


2. When *parallel* wave fronts of water waves **reflect** at any angle from a *straight* barrier, what is the effect on: (a) the **wavelength** of the waves, (b) the **frequency** of the waves, (c) the **speed** of the waves and (d) the **shape** of the wave fronts?

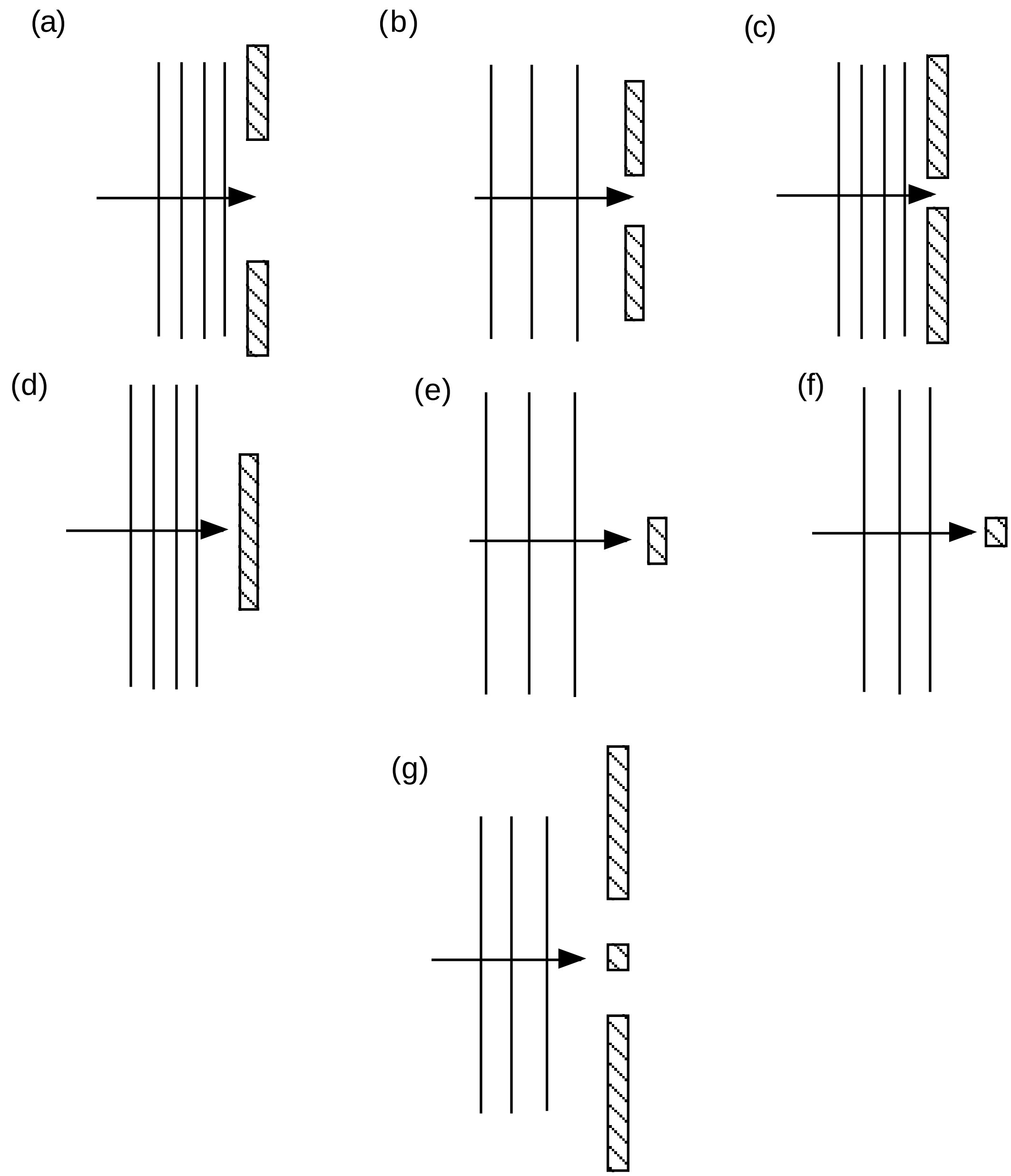
3. When *parallel* wave fronts of water waves **reflect** from a *concave* barrier,what is the effect on: (a) the **wavelength** of the waves, (b) the **frequency** of the waves, (c) the **speed** of the waves and (d) the **shape** of the wave fronts?

4. What is the **name** for the point to which wave fronts converge after being reflected from a concave (parabolic) barrier?

5. The diagram shows circular wave fronts approaching a concave (parabolic) barrier, having been generated at the barrier's **focal point**. Draw a diagram to show what happens to the wave fronts after **reflection** from the barrier.



6. Copy and complete the following diagrams by drawing the position of the water wave fronts *after* they have been **diffracted** by passing through the gaps in the barriers or passing the obstacles:



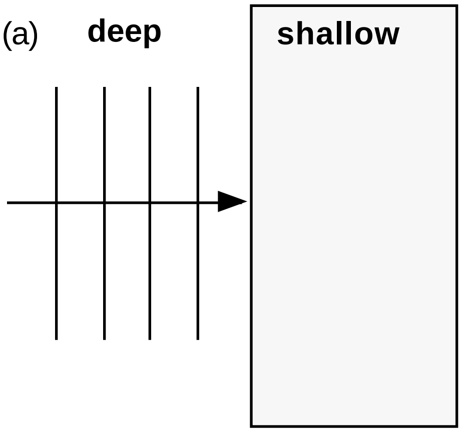
7. If plane water waves undergo **diffraction** by passing through a gap in a barrier, compare the effect when the gap **width** is: (a) about the *same* size as the wavelength (b) much *larger* than the wavelength.

8. Draw a **wave diagram** to show what happens when parallel water waves pass an obstacle that is: (a) about the *same* size as the wavelength (b) much *larger* than the wavelength.

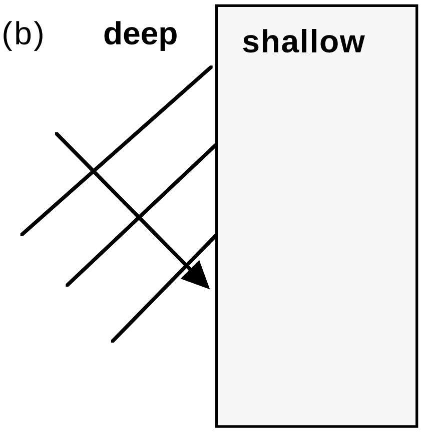
9. The wave properties **refraction** and **diffraction** are often confused. Explain the difference between them by giving an example of the effect of each on **water waves**.

10. Copy and complete the following diagrams by drawing the position of the water wave fronts after they have been **refracted** in slowing down moving from **deep** to **shallower** water.

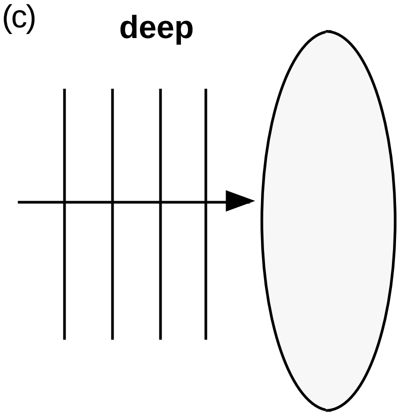
(a)



(b)

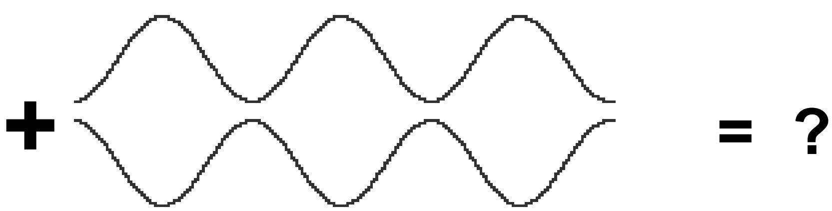


(c)



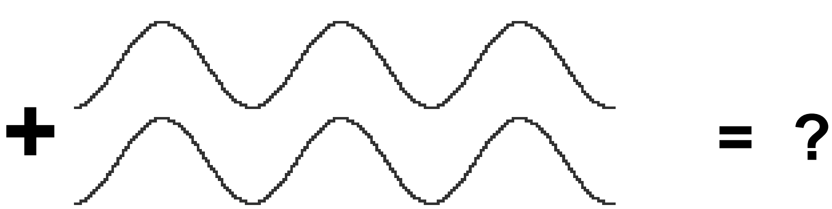
:

11. The diagram shows two waves arriving at the same point **out of step** (or **out of phase**) with each other.



Draw a diagram to show the **combined wave** and state the **name** of this wave effect.

12. The diagram shows two waves arriving at the same point **in step** (or **in phase**) with each other.



Draw a diagram to show the **combined wave** and state the **name** of this wave effect.

Waves and Interference

1. How does the **frequency** of a wave compare with the frequency of the **source** which produces it?

2. What is meant by the **period** of a wave?

3. State the **relationship** between the **frequency** of a wave and its **period**.

4. A water wave has a **period** of 2.0 s. Calculate its **frequency**.

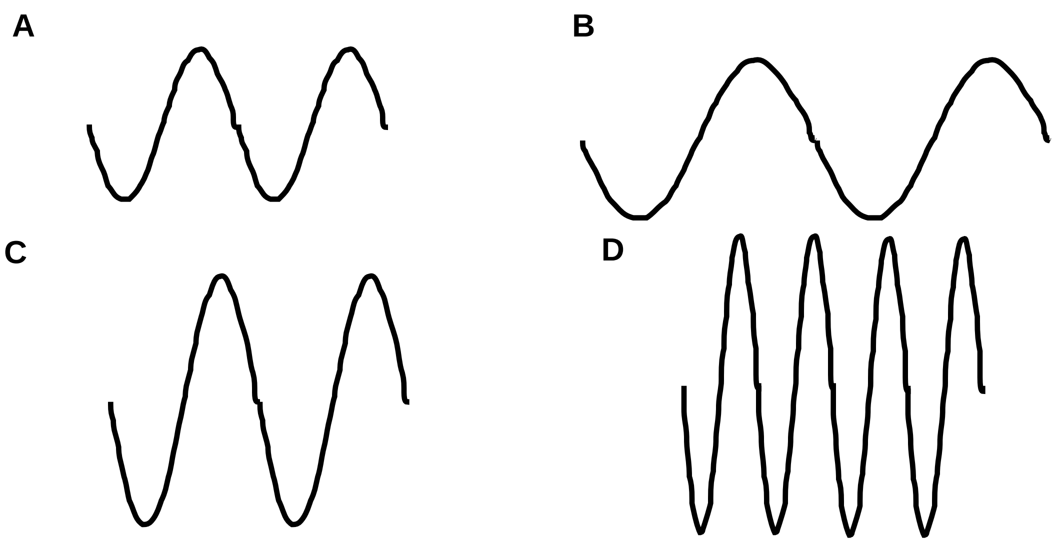
5. A bar in a ripple tank vibrates at 10 Hz and generates water waves.

   (a) What is the **frequency** of the water waves?

   (b) What is the **period** of the water waves?

6. How does the **energy** of a wave affect its **amplitude**?

7. The questions refer to the four ‘waves’ in the following diagram. They are all travelling through the same medium at the same speed.

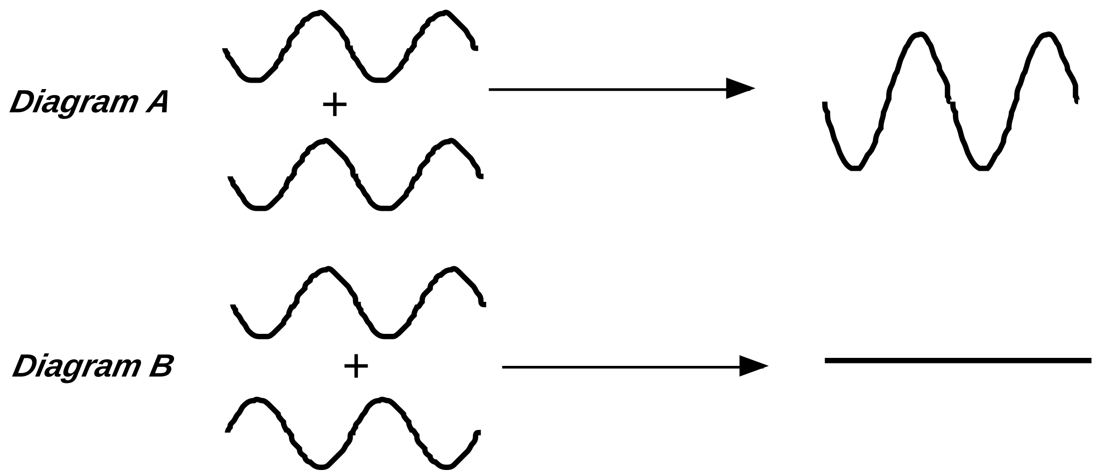


   (a) Which wave has the largest **amplitude**?
   (b) Which wave has the largest **frequency**?
   (c) Which wave has the shortest **period**?
   (d) Which **two** waves have the same **frequency** but different **amplitudes**?
   (e) Which **two** waves have the same **amplitude** but different **frequencies**?

8. Out of the waves properties **reflection**, **refraction** and **interference**, which is a ***test*** for a wave? Explain why the other two properties ***could*** be shown by **particles**.

9. Interference is easily demonstrated when two **coherent** sources of waves overlap. Explain what is meant by the term ‘**coherent**’.

10. (a) Which diagram shows **constructive interference** between two waves of the same frequency?

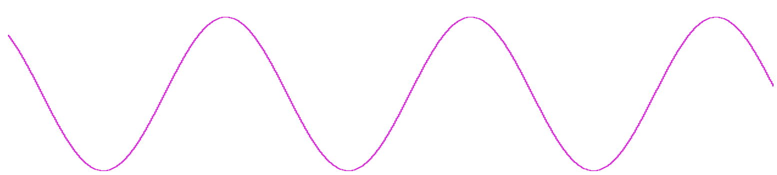


(b) What term is used for the **interference** shown in the *other* diagram?

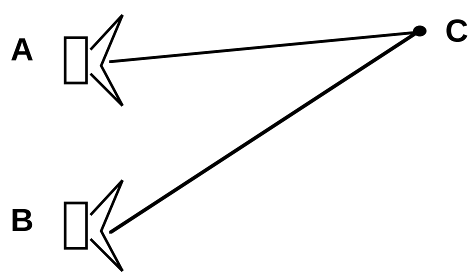
(c) In which diagram are the waves said to be **in phase**?

(d) In which diagram are the waves said to be **out of phase**?

11. Copy the wave diagram and, on it, mark (a) one **wavelength** and (b) the **amplitude.**



12. Two loudspeakers emit **coherent** sound waves of the wavelength 50cm.



For each of the following **positions** of point **C**, state whether it is a point of **constructive** or **destructive interference** of the sound waves.

(a) **AC = BC =** 50cm

(b) **AC =** 50cm; **BC =** 100cm

(c) **AC =** 25cm; **BC =** 50cm

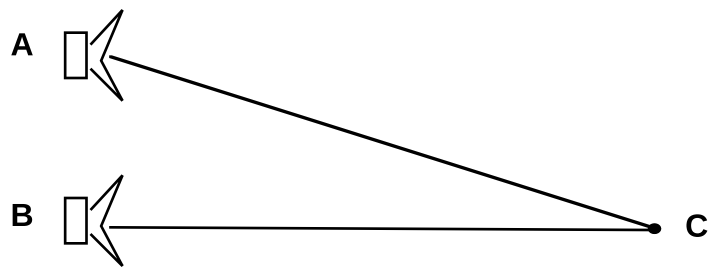
(d) **AC =** 100cm; **BC =** 75cm

(e) **AC =** 50cm; **BC =** 150cm

(f) **AC =** 50cm; **BC =** 175cm

(g) **AC =** 67.5cm; **BC =** 67.5cm

13. Two loudspeakers emit **coherent** sound waves of **frequency** 170Hz in air where the speed of sound is 340m/s.



For each of the following **positions** of point **C**, state whether it is a point of **constructive** or **destructive interference** of the sound waves.

(a) **AC = BC =** 100cm

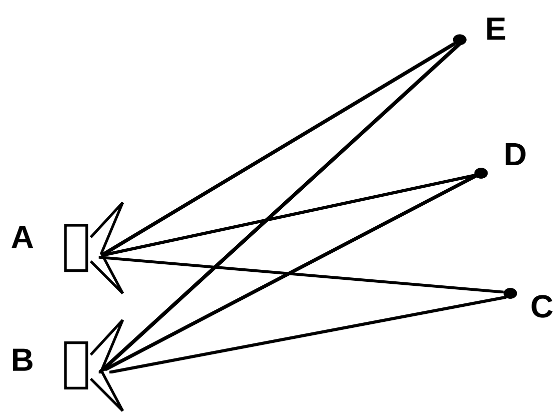
(b) **AC =** 50cm; **BC =** 150cm

(c) **AC =** 75cm; **BC =** 275cm

(d) **AC =** 290cm; **BC =** 190cm

(e) **AC =** 200cm; **BC =** 200cm

14. Two loudspeakers emit **coherent** sound waves in air where the speed of sound is 340m/s.



AC = BC = 50 cm

BD = 52 cm

AD = 48 cm

BE = 58 cm

A point of **constructive interference** is detected at point **C** and the *nearest* point of **destructive interference** is at point **D**.

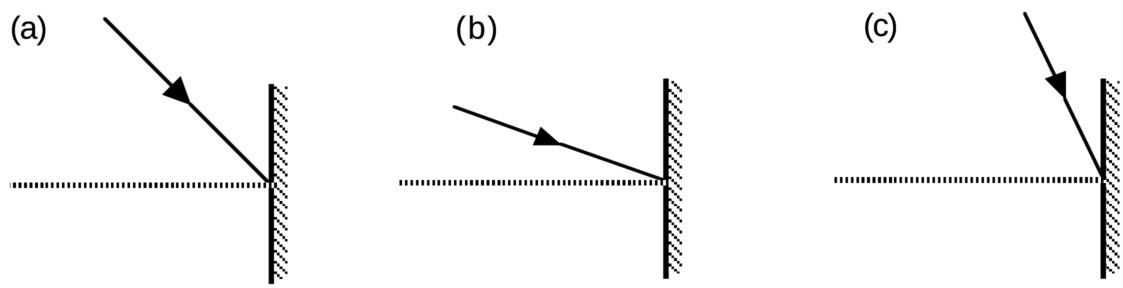
(a) Use the distances shown in the diagram to calculate the **wavelength** of the sound waves.

(b) Calculate the **frequency** of the signal generator driving the loudspeakers.

(c) Point **E** is the first point of **constructive interference** after **C**.
Calculate the distance **AE**.

Properties of Light

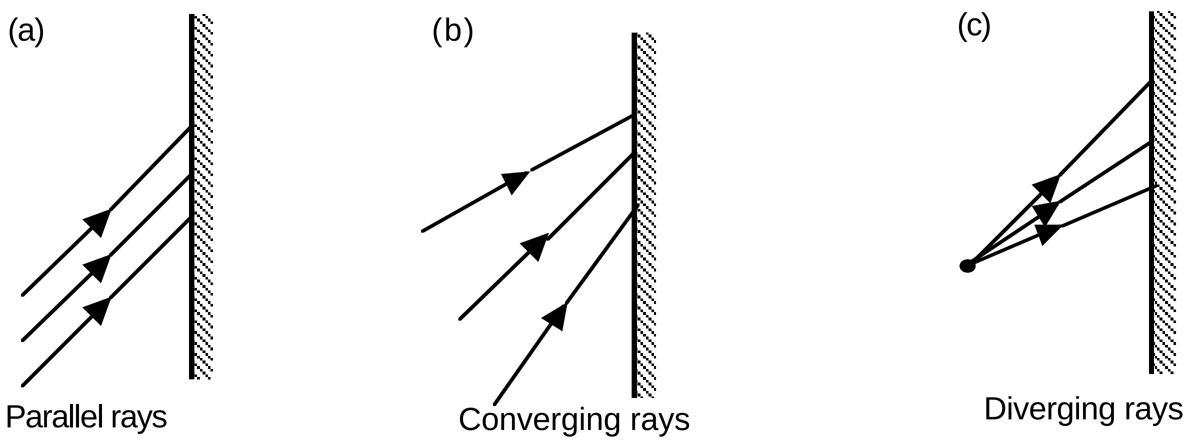
1. Copy and **complete** these ray diagrams, each showing a ray of light incident on a plane mirror, by drawing in the **reflected ray** at the correct angle to the normal:



2. Complete this statement for a ray of light reflected from a plane mirror:

   angle of incidence = angle of ________________

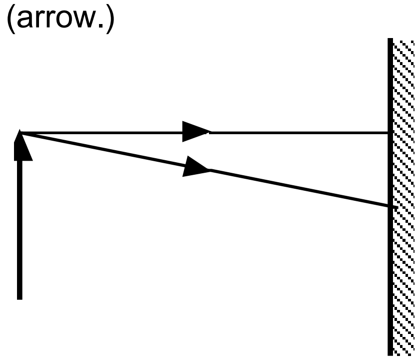
3. For each of the ray diagrams which show three rays of light incident on a plane mirror, copy and complete the diagram by drawing in the **reflected rays**.



4. (a) In Q3, in which diagram do the reflected rays form a **real image**?

   (b) In which diagram do the reflected rays form a **virtual image**?

5. Copy and complete the ray diagram to show how the plane mirror makes a **virtual image** of the object (arrow.)

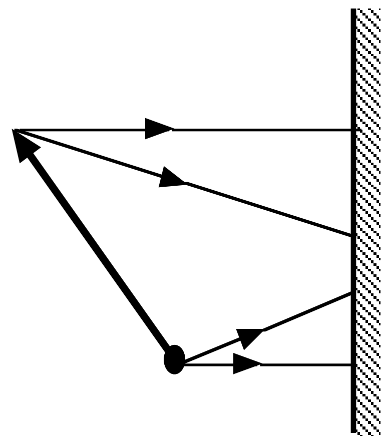


   What do you notice about the **distance** of the *image* from the mirror compared to the distance of the *object* from the mirror?

6. The image formed of an object by a plane mirror is said to be '**laterally inverted**'.

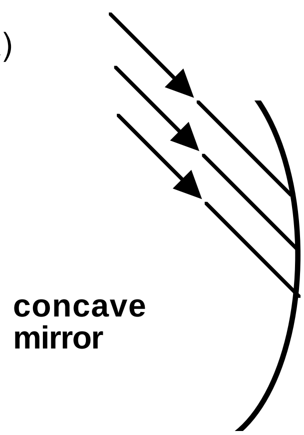
(a) What is meant by the image being 'laterally inverted'?

(b) **Complete** the ray diagram, of a plane mirror viewed from *above*, to illustrate that the image of the object *is* laterally inverted.

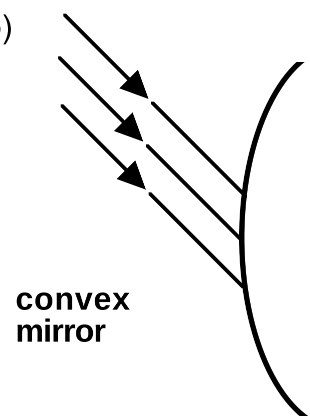


7. Copy and complete the ray diagrams, which each show three parallel light rays incident on a curved (parabolic) mirror, by drawing in the **reflected rays**.

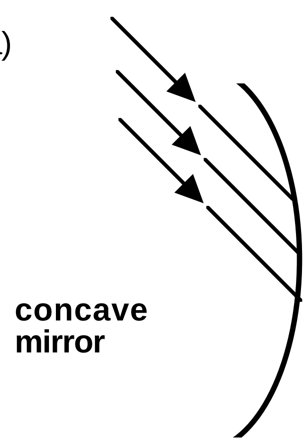
(a)



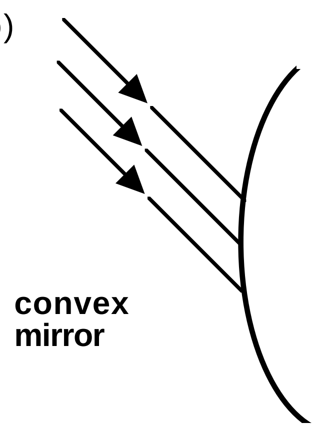
(b)



(a)

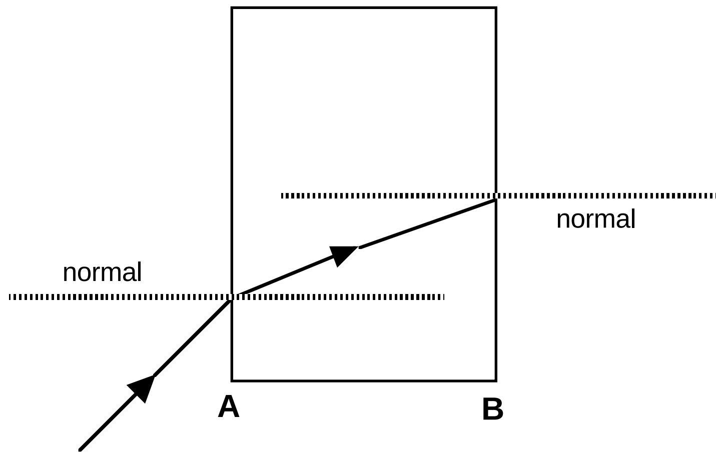


(b)



8. In Q7, which mirror forms a **real image** and which a **virtual image**?

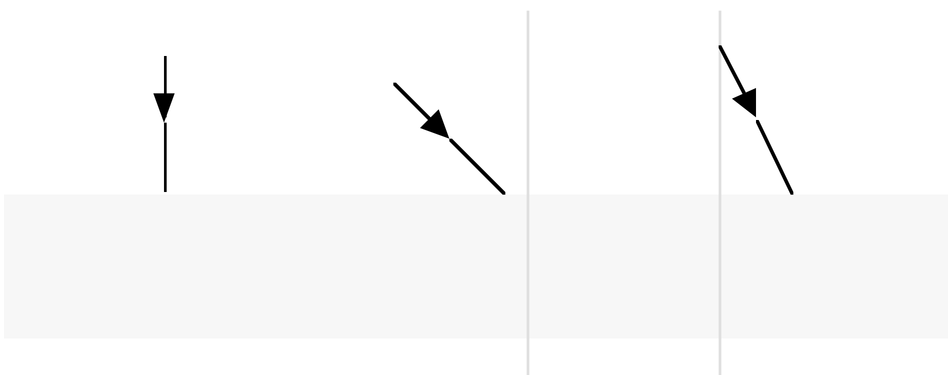
9. The diagram shows a ray of light incident on a transparent block of material.



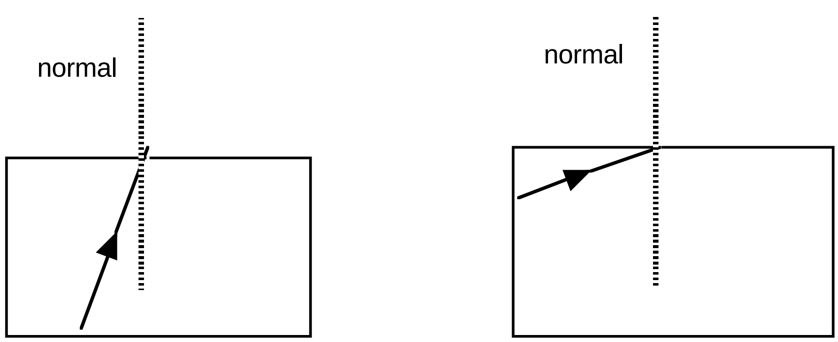
Copy and complete the diagram to show the position of the **reflected ray** at surface **A** and the **refracted ray** at surface **B**.

10. What happens to the **direction** of a ray of light entering water or glass from the air if it is **not** at 90^{o} to the surface?

11. Copy and complete the diagram, which shows three rays of light incident on the surface of water from the air at different angles to the normal, by drawing in the **refracted rays** of light.

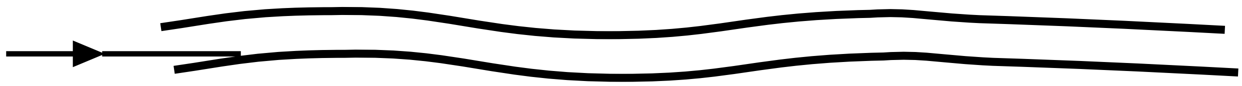


12. In each diagram, a ray of light is shown travelling through glass and meeting the boundary with air. The **critical angle** at the boundary is 42^{o}.
Copy and complete each diagram to show what happens to the ray of light.

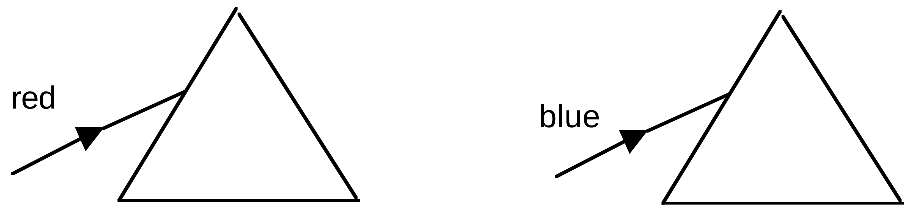


13. What **name** is used for the behaviour of light travelling through glass and meeting its boundary with air at an angle *greater* than the **critical angle**?

14. Complete the following diagram to show how a ray of light can travel through a thin piece of glass without escaping into the surrounding air.



15. Copy and complete the ray diagrams, which show rays of **red light** and **blue light** incident on one edge of a triangular glass prism, by drawing the **refracted rays** in the glass and the **rays** which **emerge** out of the glass into the air.



16. When light is **refracted** by passing from air into glass at an angle *other than* 90°, which colour of light is refracted through the ***bigger*** angle, red or blue?

17. Complete this statement about **refraction**:

"the ratio of the sine of the angle of incidence to the sine of the angle of refraction is a ______________".

18. What happens to the **speed** of a ray of light when it enters a transparent material such as glass from the air?

19. A ray of light makes an angle of incidence of 40° with the **normal** between air and a liquid. The angle of refraction in the liquid is 28°.

Calculate the value of the **refractive index** of the liquid.

20. The critical angle for a particular kind of glass is 47°. Describe what would happen to a ray of light travelling through the glass and incident on its boundary with the air at:

(a) **49°** to the normal, (b) **41°** to the normal.

21. The index of refraction of a kind of glass for a certain wavelength of red light is 1.51. It is 1.55 for violet. A ray of white light is incident on a prism made of the glass at 30° to the normal. Calculate the angle **between** the red and violet rays in the **glass**.

22. Calculate the **speed** of light through glass with a refractive index of 1.5. (Speed of light in a air = 3×10^8 m/s.)

23. Calculate the **critical angle** for water which has a refractive index of 1.33.

24. Calculate the **wavelength** of light in water of absolute refractive index 1.33 which has a wavelength of 347 nm in **glass** (n = 1.50).

25. A ray of monochromatic light, travelling through glass, is incident on the glass/air boundary at an angle of 60º to the **surface** of the glass. Calculate the **angle** it makes with the **normal** in the air, if the refractive index of the glass is 1.52.

26. Above what angle to the normal will light be **totally internally reflected** striking the surface of glass of absolute refractive index 1.49?
(Assume that the glass is surrounded by air.)

27. A ray of monochromatic light, travelling through air, makes an angle of 30º with the **surface** of a rectangular block of a certain type of transparent plastic. It makes an angle of 53º with the **surface** inside the plastic.
What is the value of the plastic's **refractive index**?

28. Calculate the **critical angle** for diamond. (Refractive index of diamond, 'n' = 2.4).

29. Light, moving through water (n = 1.33), strikes a block of glass (n = 1.51) at an angle of 40º to the normal.

What **angle** does the light make to the normal inside the **glass**?

30. In entering a transparent material from the air, the wavelength of a laser's light decreases from 600 nm to 451 nm. Calculate the **refractive index** of the material.

31. The critical angle of a particular type of glass is 38.4º. What is its **refractive index**?

32. At what **speed** would light travel in glass of refractive index 1.54?

33. A ray of light enters an oblong glass block at an angle of 40º to the **surface** of the glass. The refracted ray makes an angle of 61º to the **surface** of the glass.

What is the **refractive index** of the glass?

34. Two rays of light, travelling through glass (n = 1.51) which is under water (n = 1.33), strike the surface at angles to the normal of 59º and 63º respectively.

Determine what **happens** to **each** ray.

35. A tube of glass of refractive index 1.65 is **surrounded** by glass of refractive index 1.51. Calculate the **critical angle** for light travelling along the tube and incident on the boundary between the two types of glass.

36. At what **speed** does light travel through water of refractive index 1.33?

37. A thin ray of monochromatic light enters a block of pure ice at an angle of 42.0º to the normal from the air. If the refracted angle in the ice is 30.7º, calculate the **critical angle** for ice?

38. The refractive index of glass for light of wavelength 452 nm in air is 1.58.
What are the **speed** and **wavelength** of the light in the **glass**?

39. The critical angle for perspex is 42.5°.
Calculate its **refractive index** (to 3 significant figures.)

40. An optical fibre has a refractive index of 1.52 and is surrounded by a cladding material, refractive index 1.43.

Calculate the **minimum** angle for which light can be **totally internally reflected** at the boundary between the two materials.

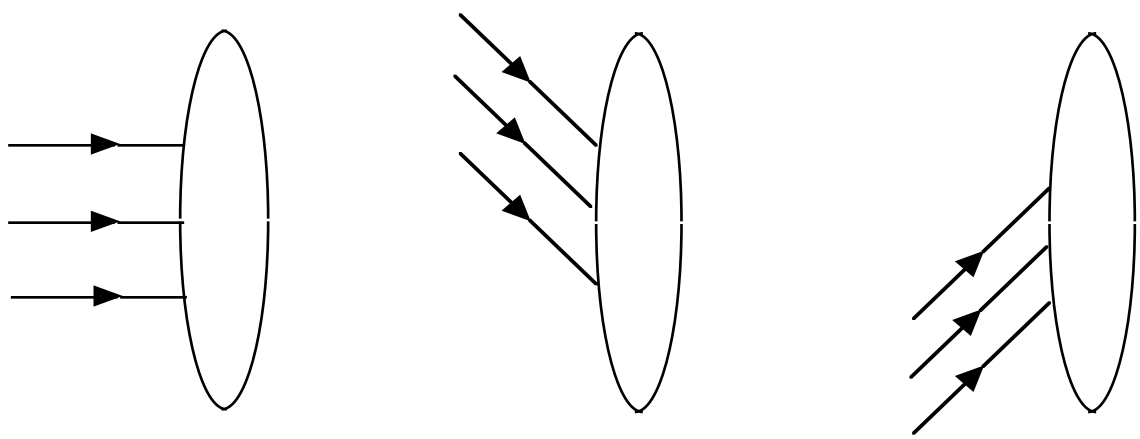
41. Light of wavelength 5.9 x 10^{-7} m, travelling through water (n = 1.33), enters a block of glass (n = 1.60). What are its **wavelength** and **frequency** in the glass?

42. Light of frequency 4 x 10^{14} Hz travels from air into glass with a refractive index of 1.60. What are the **speed**, **wavelength** and **frequency** of the light in the **glass**?

43. The diagrams each show three parallel rays of light incident on a **converging lens**.

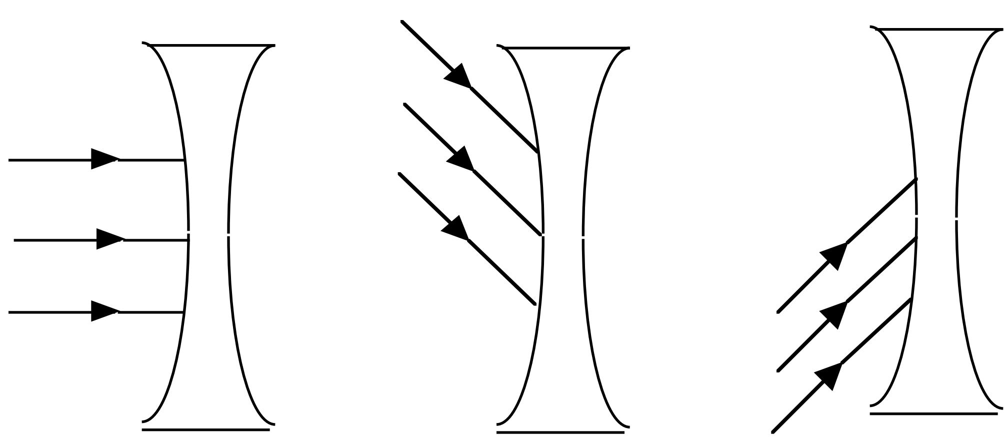
Copy and complete the diagrams to show how the lens **refracts** the rays.

Use a ruler to draw the rays.



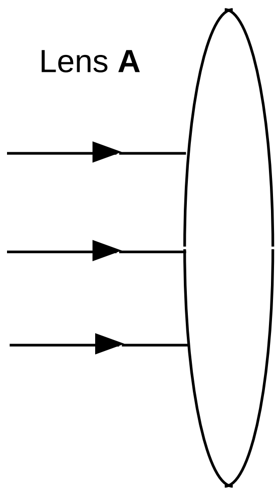
44. The diagrams each show three parallel rays of light incident on a **diverging lens**.
Copy and complete the diagrams to show how the lens **refracts** the rays.

Use a ruler to draw the rays.

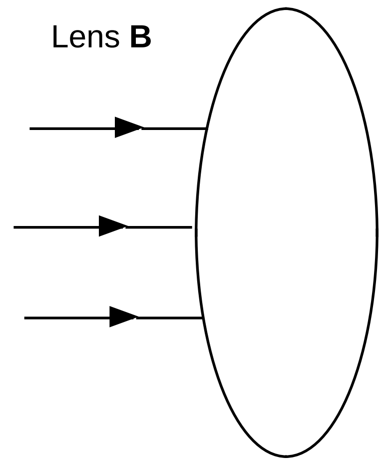


45. The diagrams show three parallel rays of light incident on two converging lenses of different optical **powers.** Copy and complete the diagrams to show how each lens brings the rays of light to a **focus**.

Lens **A**



Lens **B**



46. In Q45, which lens' **power**, measured in **dioptres**, would be the *larger* number?

47. Calculate the **focal lengths**, in centimetres, of these converging lenses with the optical powers given:

(a) + 20 D (b) + 2.5 D (c) + 10 D (d) + 14 D (e) + 2.0 D

48. Calculate the **power**, in dioptres, of a converging lens with a focal length of 40 cm.

49. What is the **power** of a lens if parallel rays of light are brought to a focus at a distance of 20 cm from the centre of the lens on the principal axis?

50. Which lens has the larger **optical power**: a lens of focal length 10 cm or one with a focal length of 50 cm?

51. Why is the **focal length** of a diverging lens called said to be '**virtual**'?

52. A lens has a focal length of **-**10 cm.
What does the **negative** sign indicate about the lens?

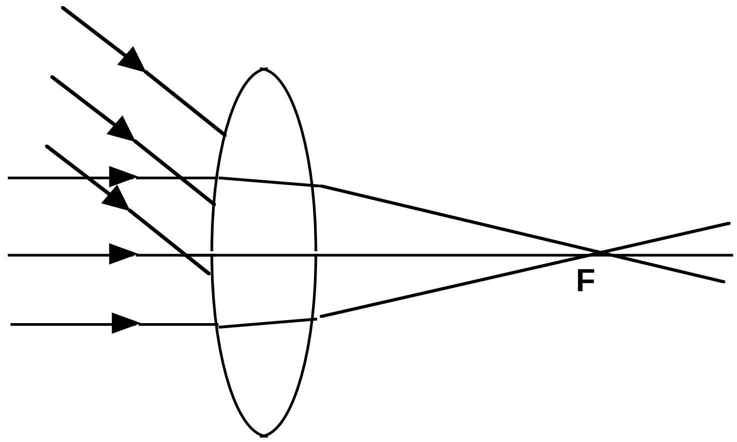
53. A diverging lens has a focal length of -15 cm.
Draw a ray diagram with parallel rays passing through the lens and show that the rays **do not** pass *through* the focal point.

54. A converging lens has a power of + 20 D.

(a) How **far** from the centre of the lens is the focal point of the lens?

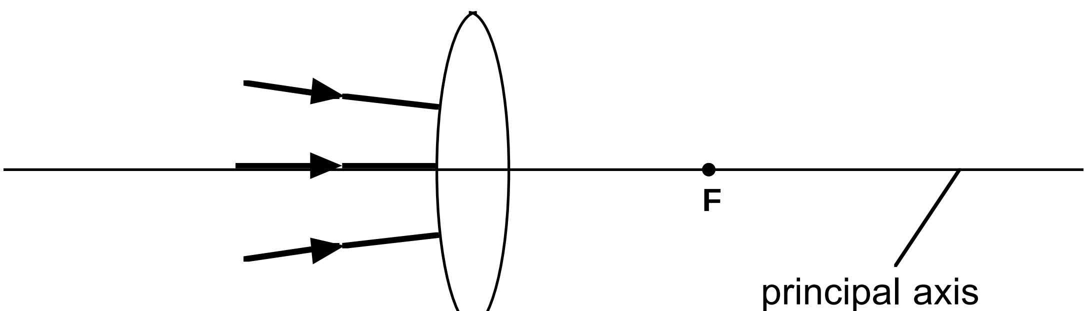
(b) Draw a ray diagram to show how parallel rays of light, which are also parallel to the principal axis, pass through the focal point.

55. The ray diagram shows parallel rays of light passing through a converging lens.



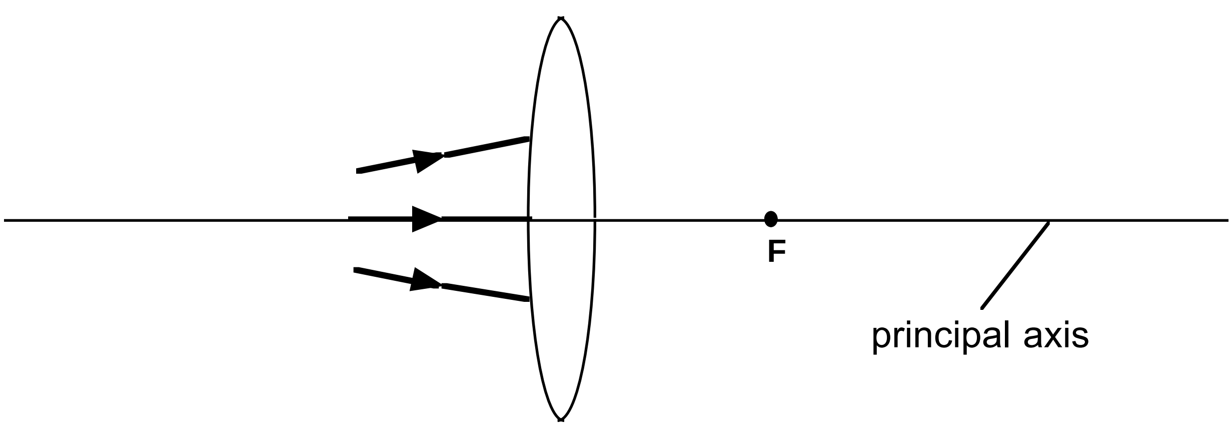
Copy and complete the diagram to show what happens when the rays are **not** parallel to the principal axis.

56. The ray diagram shows rays of light passing through a converging lens.



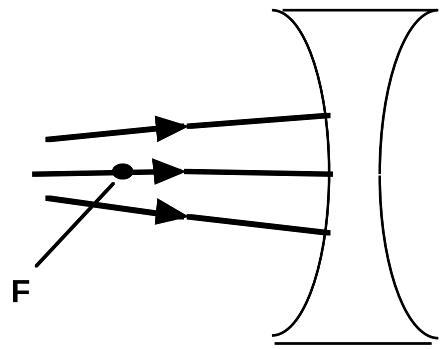
Copy and complete the diagram to show where the rays come to a **focus**.
['**F**' is the **principal focus** of the lens.]

57. The ray diagram shows rays of light passing through a converging lens.



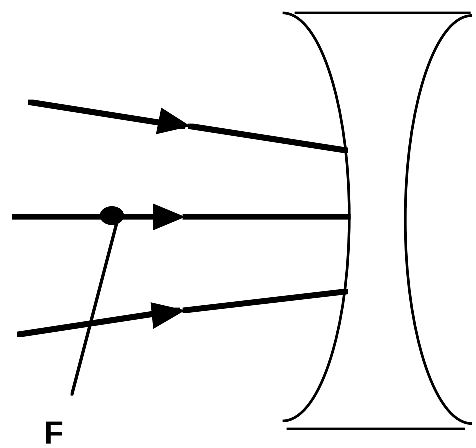
Copy and complete the diagram to show where the rays come to a **focus**.
['**F**' is the **principal focus** of the lens.]

58. The ray diagram shows rays of light passing through a diverging lens.



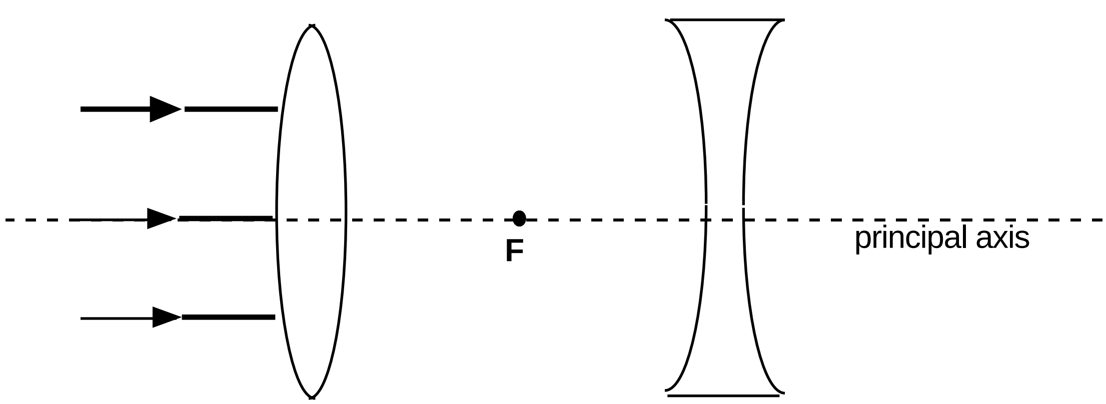
Copy and complete the diagram to show where the rays *appear* to come from after passing through the lens.
'**F**' is the **principal (virtual) focus** of the lens.

59. The ray diagram shows rays of light passing through a diverging lens.



Copy and complete the diagram to show where the rays *appear* to come from after passing through the lens.
'**F**' is the **principal (virtual) focus** of the lens.

60. Complete the ray diagram which shows a converging and a diverging lens of *equal* and *opposite* powers. The principal focus of the converging lens is at the *same* point as the principal focus of the diverging lens.



Grating equation

[Note: 1nm = 10^{-9} m]

1. In the '**grating equation**', **$n\lambda = d\sin\theta$**, state what each letter represents.

2. A **diffraction grating** has 300 lines per millimetre. Calculate the value of '**d**', the line separation in: (a) **millimetres** (b) **metres**.

3. A **diffraction grating** has 15000 lines per inch.
Calculate the value of '**d**', the line separation in:
(a) **millimetres** (b) **metres** [Take 1 inch to be equal to 2.5cm.]

*In the examples which follow, use the '**grating equation**', **$n\lambda = d\sin\theta$**.*

4. A diffraction grating has d = 1.67 x 10^{-6}m. A **red** line in the **first order spectrum** of cadmium is observed at an angle of 22.7°.
(a) Calculate the **wavelength** of the red light in nanometres.
(b) At what **angle** would the line be found in the **second** order spectrum?

5. A diffraction grating has d = 1.50 x 10^{-6}m. A **green** line in the **second order spectrum** of mercury is observed at an angle of 46.7°.
(a) Calculate the **wavelength** of the green light in nanometres.
(b) At what **angle** would the line be found in the **first** order spectrum?

6. A diffraction grating has 300 lines per mm.
(a) At what angle would the **violet** line in the spectrum of mercury be observed in the **first** order spectrum? (λ = 405nm)
(b) At what **angle** would this line be found in the **second** order spectrum?
(c) Which of these lines would be found in the **second** order spectrum at 20.3°:

yellow 579nm **green 546nm** **blue-violet 436nm**?

7. A diffraction grating forms a spectrum of gaseous sodium. The yellow doublet (λ = 589nm) is observed through a spectrometer telescope in the **second** order spectrum at an angle of 70.5°. Calculate
(a) the **grating's line spacing** in metres and
(b) the **number** of lines per millimetre in the grating.

8. A diffraction grating has 600 lines per mm.
(a) Calculate the angle, in the **second** order spectrum, ***between*** the two lines of the sodium doublet (λ = 589.0 nm and 589.6 nm).
(b) What difference, if any, would be made to this **angle**, if a grating with 800 lines per mm were used instead?

Inverse square law

1. (a) Write down the relationship between the **intensity** of radiation from a **point** source of light and the **distance** from the source.

   (b) Explain why this relationship does **not** hold for an **extended** source, such as a fluorescent strip lamp.

2. Sketch the shape of the **graphs** which would result if:

   (a) **intensity** was plotted against **distance** and

   (b) **intensity** was plotted against '**one divided by the square of the distance**'.

3. The table has the results of an experiment to measure how the **intensity** of light varies with **distance** from a point source of light.

Distance in cm	5	10	15	20	25	30
Intensity in units	80	-	8.9	5.0	-	2.2

   (a) Two '**intensity**' readings are missing from the table: **calculate** what they should be.

   (b) Construct a **graph** to show what the **relationship** is between intensity and **distance**.

4. A **radioactive source** emits **gamma rays**. It is small enough to be considered to be a **point source**. The count rate on a detector at a distance of 1 metre from the source is measured as 64000 c.p.m. The background count can be ignored.

   (a) What would be the **count rate** at distances of:

   (i) 2 m (ii) 5 m (iii) 50 cm?

   (b) At what **distance** from the source would the count rate be 4000 c.p.m.?

5. A man working at a laboratory bench for 4 hours receives an **absorbed dose** from gamma radiation of 600 µGy. The cause of this is a small (point) gamma source which is 2 metres from his bench. The man wishes to move the **position** of the gamma source so that the absorbed dose over the same time is only 150 µGy.

   How **far** from the bench must the source be placed?

6. A small (point) gamma source is in the centre of a laboratory. Four people are working at different parts of the laboratory. Smith, who is 4 metres from the source, receives a **dose equivalent rate** of 32 μSvh^{-1}.

   (a) Jones is only 2 metres from the source.
   What would be her **dose equivalent rate**?

   (b) Burke's **dose equivalent rate** is just 8 μSvh^{-1}. How **far** is he from the source?

   (c) Hare's **dose equivalent rate** is **half** of Burke's.
   How **far** is she from the source?

Specific Heat Capacity

1. In the table below, calculate the value of the missing quantity in each row, using the formula for the heat required to raise the temperature of a substance:

$$E = cm\theta \quad \text{or} \quad E = cm\Delta T$$

heat (J)	shc (J/kgK)	mass (kg)	temp. change (K)
-	4200	2	10
-	4200	0.5	40
8000	400	1	-
2.5×10^4	1000	0.5	-
90000	450	-	10
10500	2100	-	20
2.1×10^5	-	10	5
67500	-	5	30

2. An experiment to measure the **specific heat capacity** of water, 'c', gave these results: mass of water = 500 g; heat added = 46200 J; temperature rise = 21 C^o
Calculate the value obtained for 'c'.

3. The specific heat capacity of ice is 2100 J/kgK. A 1.8 kg block of ice, removed from a freezer at a temperature of -18 ^{o}C, is placed in a fridge which has a temperature of 0^{o}C. After a few hours, the ice has warmed up to the fridge temperature.
How much **heat** has the block absorbed?

4. The specific heat capacity of air is 1000 J/kgK.

   (a) How much **heat** would be needed to raise the temperature of the air in a room by 5 celsius degrees, if the room measures 4 m x 4 m x 3 m?
   (Density of air = 1 kg/m^3.)
   Assume that the room has no furniture and that the walls absorb no heat.

   (b) How **long** would a 1 kW convection heater take to do the heating?

5. A carpet cleaning machine holds 40 litres of water. It is filled with water at 15^{o}C and the water is heated by a 3 kW element to a temperature of 70^{o}C.

   (a) How much **heat** is added to the water? (Mass of 1 litre = 1 kg; s.h.c. = 4200 J/kgK)

   (b) Assuming no heat loss to the machine or air, what is the least **time** the heater takes to heat the water?

6. 75600 J of heat are needed to raise the temperature of a 2 kg block of ice removed from a freezer at -18^{o}C to its melting point.
Calculate the **specific heat capacity** of ice suggested by these figures.

7. Calculate the **specific heat capacity** of a metal if 3 kg of the metal experiences a temperature rise of 25 C^o when heat is supplied to it at a rate of 60 watts for 10 minutes, and a total of 3000 joules **escapes** to the surroundings.

8. Assuming no heat is lost to the air or other surroundings, what **temperature** would 490 g of water reach, starting at 15^oC, if a 60 watt heater delivered heat to it for 20 minutes? (Specific heat capacity of water = 4200 J/kgK)

9. Calculate the **heat** needed to raise the temperature of a 2.5 kg block of ice to its melting point, if it is stored in a freezer at -20^oC. (c_{ice} = 2.1 kJ/kgK)

10. The specific heat capacity of iron is 440 J/kgK. How much **heat energy** would be needed to raise the temperature of a piece of mass 800 g by 120 celsius degrees?

11. Copper has a specific heat capacity of 390 J/kgK. A 20 g piece of copper at a temperature of 120^oC is dropped into a large tank of water which is at 15^oC. How much **heat** does the water gain as the copper cools down to the tank's temperature?

12. It takes 260 joules of heat to raise the temperature of 40 g of gold by 50 celsius degrees. From these figures, calculate the **specific heat capacity** of gold.

13. In the term 'specific heat capacity', what is **meant** by the word 'specific'?

14. 100 g of hot water at 80^oC is thoroughly mixed with 200 g of water at 20^oC. Assuming that no heat escapes to the surroundings, calculate the **temperature** of the mixture.
[Hint: assume that the heat *lost* by the hot water equals the heat *gained* by the cold water.]

15. How **long** would a 40 watt heater take to raise the temperature of 200 g of water from 20^oC to 50^oC, assuming that *all* of the heat supplied by the heater is absorbed by the water? (Take c_{water} = 4200 J/kgK.)

16. A 40 gram piece of iron at a temperature of 120^oC is dropped into a beaker containing 100 grams of water at 20^oC. Assuming that *all* the heat lost by the iron in cooling down is absorbed by the water is heating up, find the **temperature** reached by the water, to the *nearest* degree.
(Take c_{water} = 4200 J/kgK and c_{iron} = 440 J/kgK.)

17. An electric kettle's element is rated at 2400 W. The kettle is filled with 1.2 kg of water from a cold tap at 10^oC. Assuming that *no* heat escapes to the surroundings, how **long** would the kettle take to raise the water's temperature to boiling point?
(Take c_{water} = 4200 J/kgK)

18. A 100 gram solution of sea water is heated from 24^oC at the rate of 50 watts. After 10.4 minutes, the solution reaches boiling point. If *no* heat has escaped to the surroundings, calculate the **boiling point** of sea water suggested by these figures.
('c' for sea water = 3900 J/kgK)

19. A typical bath requires 90 kg of hot water at 50^oC. If the water had to be heated to this temperature during the winter from 6^oC, calculate:
(a) how much **heat** would be needed and
(b) how long, to the nearest **minute**, a 5 kW heater would take to supply the heat, assuming no loss to the surroundings. ('c' for water = 4200 J/kgK)

Specific Latent Heat

1. In the table below, calculate the value of the missing quantity in each row, using the formula for the heat required to change the **state** of a substance:

$$E = ml_f \text{ or } E = ml_v.$$

heat (J)	mass (kg)	specific latent heat capacity (J/kg)
-	2	334 000
-	0.5	334 000
3.34×10^6	-	334 000
904 000	-	2 260 000
-	2.5	3.34×10^5
-	0.2	2.26×10^6
455 000	3.5	-
5 800	0.02	-

For questions 2 - 8, use the following data:

specific latent heat of fusion of ice = 3.34×10^5 J/kg

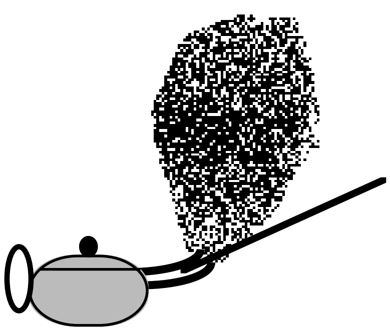
specific latent heat of vaporisation of water = 2.26×10^6 J/kg

2. How much heat would be needed to totally melt a 3.5 kg block of ice at 0ºC into water at 0ºC?

3. How much **heat** would a freezer need to extract from 600 grams of water in a container, once it was cooled to its freezing point, to turn it completely into ice at 0ºC? (Answer to 3 significant figures.)

4. The water in a kettle on a gas stove reaches boiling point. How much **heat** will have been added to the water in the kettle once 400 grams of water have turned into steam?

5.



The temperature of the water in a boiling kettle is measured and found to be 100ºC.

The thermometer is now held inside the kettle's spout to measure the temperature of the **steam**.

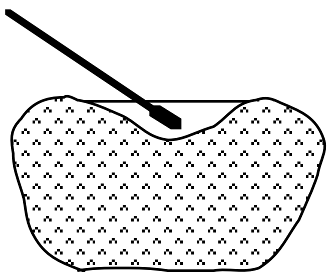
What would its temperature be?

6. How many **grams** of ice would melt from a large block of ice *at its melting point* if 6780 joules of heat were absorbed from the air?

7. An electric kettle brings its water to boiling point but fails to switch off. What **mass** of water will turn to steam if a further 113 kilojoules of heat are supplied from the kettle's element?

8. A steam generator's element is rated at 2.5 kW. Once it has brought its water to boiling point, the element continues to add heat to it.
   (a) What **mass** of water will turn to steam if the element adds a further 125 kJ to the water? (Answer to the nearest gram.)
   (b) Assuming that **all** the heat is absorbed by the water, how **long** would the element take to supply that quantity of heat?

9. A block of ice sitting in a room with an air temperature of 10^{o}C has a concave dent in its top surface that fills with melt water from the block.



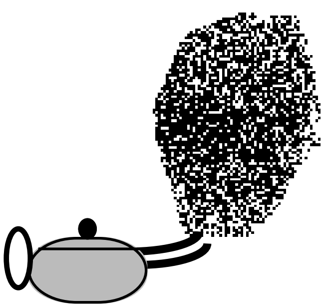
The temperature of the water is measured.

(a) What would be the **temperature** of the water?

(b) Explain your answer to (a).

10. It is often said that a scald from steam is much **worse** than a scald from the *same mass* of boiling water. Why is this?

11.



The cloud of 'steam' in the diagram of a boiling kettle is **not** really steam at all.

(a) What is it?

(b) **Where**, in the diagram, would you put a label to indicate the presence of *actual* steam?

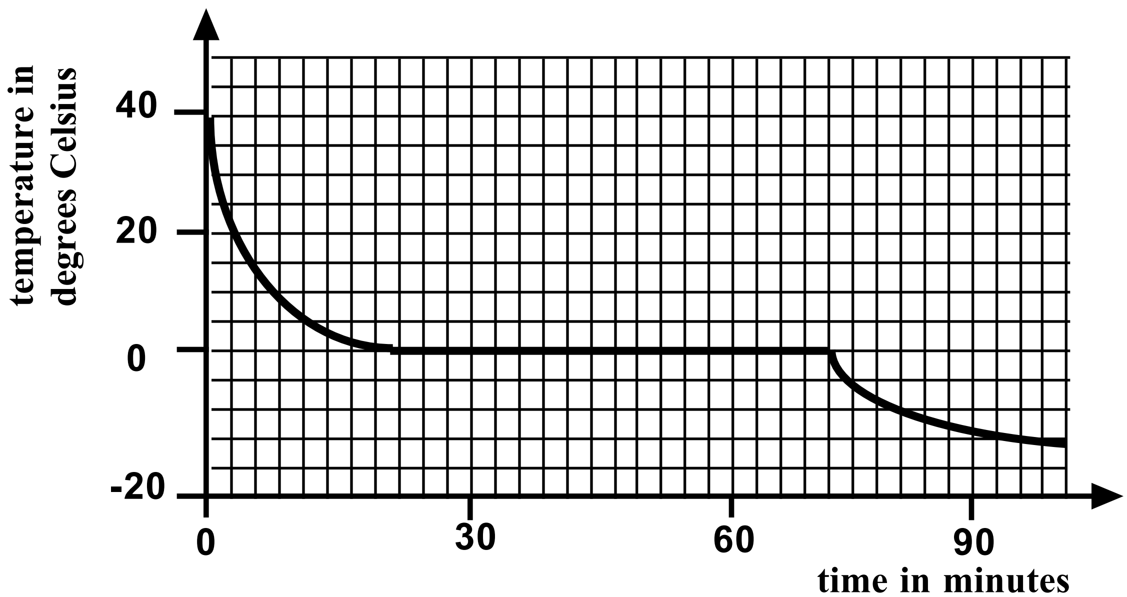
12. It takes 320 J of heat to melt 5 grams of gold, at its melting point. Calculate the **specific latent heat of fusion** of gold.

13. If liquid mercury is heated to 357^{o}C, it boils into its vapour. It takes 5880 J to vaporise 20 grams. Use these figures to calculate mercury's **specific latent heat of vaporisation**.

14. Which requires **more** heat: boiling 20 g of water at 100^{o}C into steam or melting 135 g of ice at 0^{o}C?

15. Which liquid has the **larger** specific latent heat of vaporisation: **vinegar**, which needs 195 kJ to vaporise 500 g at its boiling point, or **benzene**, which requires 320 kJ to boil away 800 g?

16. A container of water, which has been heated to a temperature of 40°C, is placed in a freezer with a cabinet temperature of -18°C. An electronic thermometer measures the temperature of the container's contents and sends regular readings to a data capture device. The data is displayed on a computer as the temperature-time graph shown below.



(a) Explain what is happening to the cnntainer's contents in the **three** distinct sections of the curve.

(b) What is the freezing point of the water?

(c) Predict and explain what temperature the container's contents will eventually reach.

17. A test tube of naphthalene (moth balls) is removed from a water bath that has melted the substance and taken its temperature to 100°C. Its temperature is recorded every minute for 20 minutes in a laboratory where the air temperature is 24°C.

Time (mins)	0	1	2	3	4	5	6	7	8	9	10
Temp. (°C)	100	92	87	82	81	81	81	81	81	81	81
Time (mins)		11	12	13	14	15	16	17	18	19	20
Temp. (°C)		81	81	81	81	80	73	67	62	58	54

(a) Plot a **line graph** of temperature against time for the naphthalene over the 20 minute period.

(b) From the graph, estimate the **melting point** of naphthalene.

(c) Predict the temperature eventually reached by the naphthalene if left in the same surroundings.

Density = mass ÷ volume ($\rho = {}^{m}/_{V}$)

1. Use the formula '**density = mass ÷ volume**' or $\rho = {}^{m}/_{V}$ to calculate the value of the missing quantities in the table.

ρ (kg/m^3)	m (kg)	V (m^3)
-	100	0.1
-	2.86	2.00
2.0×10^{-4}	1.5	-
0.80	4.0	-
1000	-	0.05
800	-	4×10^5

2. 68.0 g of mercury occupy a volume of 5 cm^3.
Calculate the **density** of mercury in: (a) g/cm^3 and (b) kg/m^3.

3. A quantity of metal has the following measurements:

mass = 88.4 g; volume = 6.5 cm^3.

Calculate its **density** in (a) g/cm^3 and (b) kg/m^3. **Identify** the metal.

4. A piece of wood with a mass of 30 grams has a volume of 25 cm^3.
Calculate its **density** in **kg/m^3**.

5. What **volume** would 30 g of ethanol occupy if its **density** is 0.79 g/cm^3?

6. What **volume** would 30 g of mercury occupy if its **density** is 13.6 g/cm^3?

7. A lump of nickel with a mass of 267 grams has a volume of 30 cm^3.
Calculate its **density** in kg/m^3.

8. The density of mercury is 13600 kg/m^3.
What **weight** of mercury would fill a 250 cm^3 container? (Take g = 10 N/kg.)

9. Calculate the **weight** of 1.25 litres of mercury. [1 litre= 1000 cm^3.]
[The density of mercury is 13600 kg/m^3.]
What **volume** of **water** would weigh the same as the mercury?

10. An oblong, waterproof object measures 2 cm x 8 cm x 18 cm. It weighs 3.5 N.
When lowered into water, show whether the object will **float** or **sink**.
[Hint: is its density *less than* or *greater than* 1 g/cm^3?]

11. Any object with a density *below* 1 g/cm^3 will float in fresh water.
An oblong, waterproof object measures 3 cm x 10 cm x 20 cm. It *weighs* 5.5 N.

When lowered into water, show whether the object will **float** or **sink**.

12. An experiment to measure the density of air gave this data:

mass of air =1.5 g ; volume of air = 1200 cm^3

Calculate the **density** of air suggested by this data, in kg/m^3.

13. An empty room measures 5m x 4m x 3m. Calculate the **mass** of air in the room. [Density of air = 1.23 kg/m^3.]

14. The density of chloroform is 1.48 g/cm^3.

(a) Express this value in **kg/m^3** and **grams per litre**.

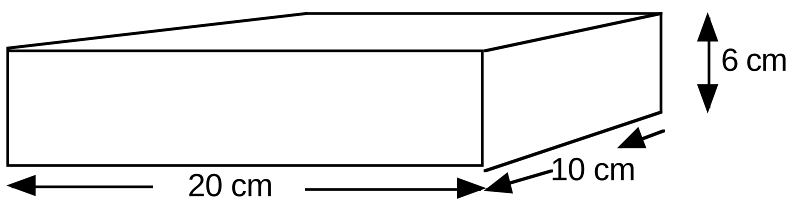
(b) What **volume** of chloroform would *weigh* 4 newtons?

15. The density of sea water is 1020 kg/m^3. What **volume**, in cubic centimetres, would be occupied by 51 g?

16. An oblong, solid copper block has the measurements 10 cm x 2 cm x 2.5 cm. It has a mass of 448 g.
Calculate the **density** of copper from these measurements.

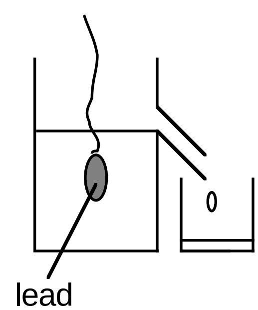
17. What would be the **mass**, in **grams**, of 60 cm^3 of iron which has a density of 7.9×10^3 kg/m^3?

18. A block of cork has the dimensions shown in the diagram.



The block is weighed on an accurate balance and its mass found to be 288 grams. Calculate the **density** of cork in g/cm^3.

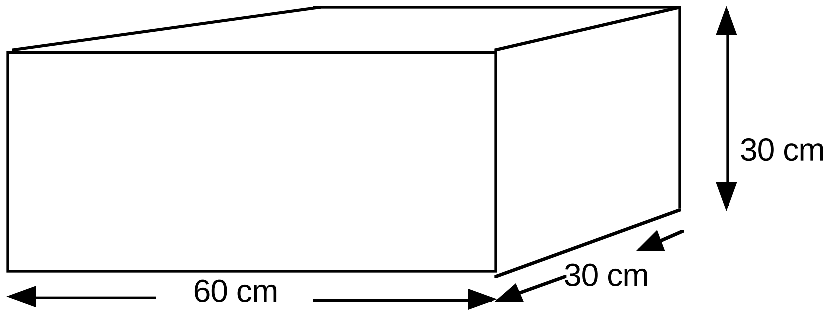
19. When lowered carefully into a displacement vessel, a 253 g lump of lead displaces 22 cm^3 of water.
What value do these measurements give for the **density** of lead?



20. Gold's density is 19.3 g/cm^3. To check if a 77 g coin is made of gold or a cheap metal of much lower density, it is lowered into water and displaces 4 cm^3.

Calculate the **density** of the coin and state whether or not it is gold.

21. A box of shopping has the measurements shown in the diagram.



It weighs 227 newtons.
Calculate the **average density** of the contents of the box in g/cm^3. ('g' = 10 N/kg)

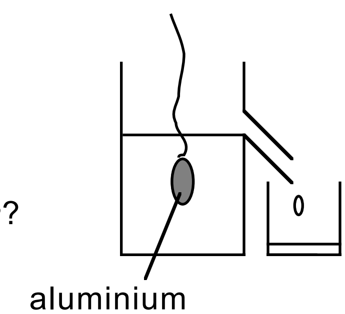
22. A 25 m x 15 m swimming pool is filled to an average depth of 1.5 m.
If the density of water is 1000 kg/m^3, what is the **mass** of water in the pool, in tonnes?
[1 tonne = 1000 kg]

23. Carbon dioxide gas has a density of about 2 kg/m^3. Being *more* dense than air, it sinks to the floor when in a room. If 1.2 kg of carbon dioxide gas is released into a room, whose floor measures 4 m x 3 m, to what **height** above the floor will the gas reach? (Assume none escapes from the room and there is no furniture in the room.)

24. A cardboard box of shopping measures 50 cm x 40 cm x 30 cm.
It weighs 500 newtons.
(a) What is the **mass** of the box of shopping? (Take 'g' = 10 N/kg.)
(b) Calculate the **density** of the box of shopping in g/cm^3.
(c) If the box was waterproof, would it **float** or **sink** in water?

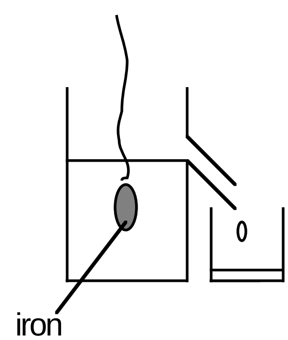
25. When lowered carefully into a displacement vessel, a lump of aluminium displaces 50 cm^3 of water.

What **mass** is the lump if the density of aluminium is 2.7 g/cm^3?



26. The density of iron is 7.8 g/cm^3. A piece of iron with a mass of 273 g is lowered on the end of a piece of thread into a displacement vessel.

What **volume** of water is displaced into the beaker?



Pressure = force ÷ area

1. Use the formula **pressure = force ÷ area** to calculate the value of the missing quantities in the table.

pressure (Pa)	force (N)	area (m^2)
-	10	2
-	1.0	4.0×10^{-5}
-	10^6	2.5×10^{-5}
10^5	400	-
5×10^6	2000	-
4×10^{-3}	8×10^{-3}	-
2.5×10^5	-	0.02
10^7	-	10^{-3}

2. If **pressure = force ÷ area**, complete these rearranged formulae:

   (a) **force = ?** (b) **area = ?**

3. The flat soles of a boy's shoes *each* have an area of 250 cm^2.
If the boy weighs 500 N, calculate the **pressure** exerted on a floor when the boy stands:

   (a) with his weight equally spread between both feet (b) on one foot.

4. The pressure of the atmosphere at sea level is 100000 pascals.
Calculate the **force** exerted by the atmosphere on the surface of the water in a swimming pool which measures 25 metres long by 15 metres wide.

5. At sea level, where the atmospheric pressure is 10^5 Pa, what horizontal **area** would experience a force of 10^4 N?
Give the answer in (a) **square metres** and (b) **square centimetres**. [1m^2 = 10000 cm^2]

6. The atmospheric pressure at the surface of the planet Venus is thought to be **90** times that of our planet - that is, 9.0×10^6 Pa. What would be the inward **force** on each **square centimetre** of the body of a space probe if it managed to reach the surface of Venus?

7. Mars has a very thin atmosphere. At its surface, the force on each *square centimetre* of an object's body is just 67 mN.

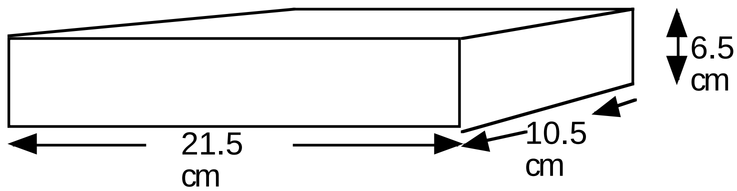
   (a) Calculate the value of Mars' atmospheric **pressure** in pascals.

   (b) To the nearest ten times, how much *smaller* is Mars' atmospheric pressure than Earth's.

8. The air inside a sealed glass flask has a pressure of 1.0×10^5 N/m^2.
The flask is now heated and the air pressure increases by a factor of **four**.
With the new pressure, what total outward **force** does the air exert on a flat section of the flask which has an area of 2 cm^2?

9. A boy becomes trapped on dangerously thin ice on a pond. Which **action** would be *safer* for the boy to take:
   (a) walking normally but slowly to the edge of the pond or
   (b) shuffling with both feet on the ice at all times? **Explain** your choice.

10. A standard brick has dimensions of 21.5 cm x 10.5 cm x 6.5 cm and weighs 35 N.



Calculate: (a) the *smallest* **pressure** exerted by the brick when lying with one side on a flat surface.
(b) the *greatest* **pressure** it can exert on one side.

11. An 80 kg man sits on the blunt end of a drawing pin which has an area of 0.7 cm^2. Calculate the **pressure** (in pascals) exerted by the pin on the man. (Take 'g' = 10 N/kg)

Note: for questions 12-19: the pressure at a given depth '**h**' in a liquid of density '**ρ**' is calculated using the formula **p = ρgh** where '**g**' is the gravitational field strength.

12. Show that **ρgh** (density x gravitational field strength x depth) has the same dimensions as **pressure**.

13. Calculate the **pressure** (above that of the atmosphere) at a depth of 10 m in water which has a density of 1000 kg/m^3. (Take 'g' as 10 N/kg.)

14. At what **depth** in mercury (density 13600 kg/m^3) would the pressure be the *same* as at a depth of 68 cm in water (density 1000 kg/m^3)?

15. Sketch a graph to show the relationship between **pressure** and **depth** in a liquid of uniform density.

16. The pressure at a depth of 50 cm in water is 5000 pascals above atmospheric pressure. What would it be at the ***same depth*** in a liquid with a density 90% that of water?

17. The pressure at a depth of 0.5 metres in a certain liquid is 4500 Pa above atmospheric pressure. At what **depth** would the pressure rise to 13.5 kPa?

18. The pressure at a certain depth of fresh water is 20 kPa above atmospheric pressure. What would the **pressure** be at the **same** depth in another liquid with a density **1.3 times** that of water?

19. An ocean temperature probe is lowered from a survey ship into the water. The *maximum* pressure that the probe is designed to withstand is 100 MPa. What is the greatest **depth** to which the probe could be safely lowered? (Density of sea water = 1020 kg/m^3.)

20. Which **unit** could also be the 'pascal-metre squared'?

Buoyancy and Flotation

1. What is the relationship between **pressure** and **depth** in a liquid of uniform density?

2. Sketch a **graph** to show how the **pressure** of a liquid of uniform density varies with **depth**.

3. What is the relationship between the **pressure** at a certain depth in a liquid and the **density** of the liquid?

4. Sketch a **graph** to show how the **pressure** of a liquid at a certain depth varies with **density**.

5. Complete this statement about a **floating** object (Archimedes' principle):

   "the __________ on a floating object is equal to the ________

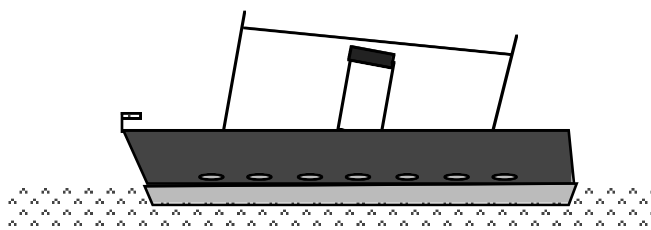
   of the liquid ____________ ."

6. A ship is said to have a "displacement 20000 tonnes".

   (a) What is meant by this statement?
   (b) What is the ship's **mass**?

7. Explain, in terms of **water pressure**, why a ship floats in water **below** the surface of the water.

   Why does it sink to a certain **depth**?

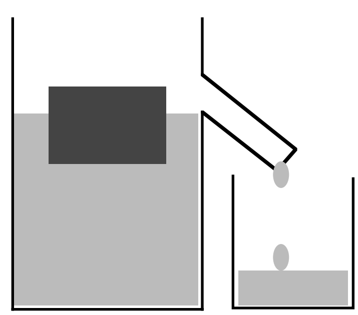


8. A ship, in harbour, is loaded with cargo. Explain, in terms of **pressure**, why it sinks lower into the water as the cargo is loaded.

9. A ship sails up river from the sea. As it does so, it sinks lower and lower into the water. Explain, in terms of **pressure**, why this happens. (Assume that the weight of the ship is constant.)

10. A piece of wood, of mass 15 grams and which is less dense than water, is gently lowered into a displacement vessel. The displaced water is collected and measured with a measuring cylinder.

    What **volume** of water would be collected?
    [The density of water is 1.0 g/cm^3.]



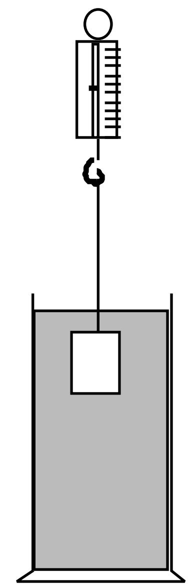
11. Explain why it is easier to **float** in the sea than in an inland, fresh water loch.

    Your answer must make mention of pressure.

12. (a) In which conditions of **temperature** and **salinity** ('saltiness') would a ship float *lowest* in the water?
(b) Explain the purpose of the '**Plimsoll Line**' which is painted on the side of ships' hulls.

13. When a object with a large density is suspended in water, it doesn't feel so heavy.
(a) Has the object's **weight** changed? Explain.
(b) Explain, in terms of pressure, why there is an **upthrust** (or buoyancy force) on the object.

14. An object, with a density greater than that of water and suspended from a newton balance, is lowered into a tall cylinder of the liquid. The reading on the balance decreases from 6.4 N to 4.4 N.



(a) What is the object's **weight**?

(b) Explain why the reading on the balance decreases.

(c) What is the size of the **buoyancy force** on the object?

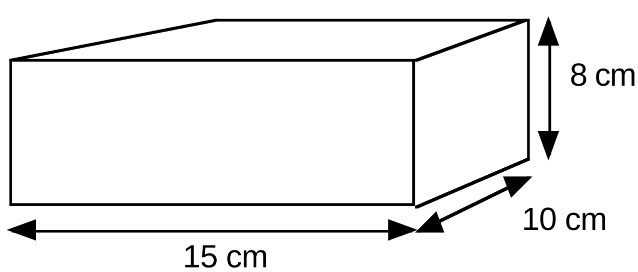
(d) What happens to the **reading** on the balance as the object is lowered further into the water? Explain.

15. Which factor or factors, for an object *submerged* in a liquid determine(s) the size of the upthrust which acts on the object?

(a) the liquid's density (b) the depth to which the object is submerged
(c) the volume of the object (d) the density of the object
(e) the shape of the object

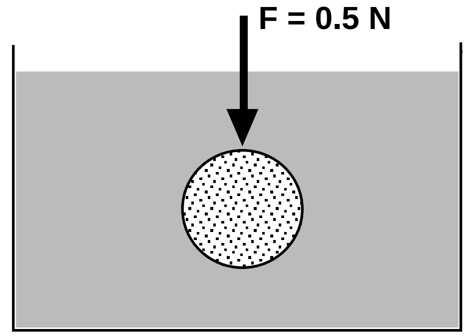
16. The upthrust on a submerged object is equal to the weight of the displaced water.

(a) Taking the density of water as 1g/cm^3 and 'g' as 10 N/kg, calculate the **upthrust** which would exist on this oblong piece of iron if suspended in a tank of water.



(b) If the block was made of *polystyrene* and it had to be pushed down to submerge it in the water, what would be the size of the **upthrust** on the block?

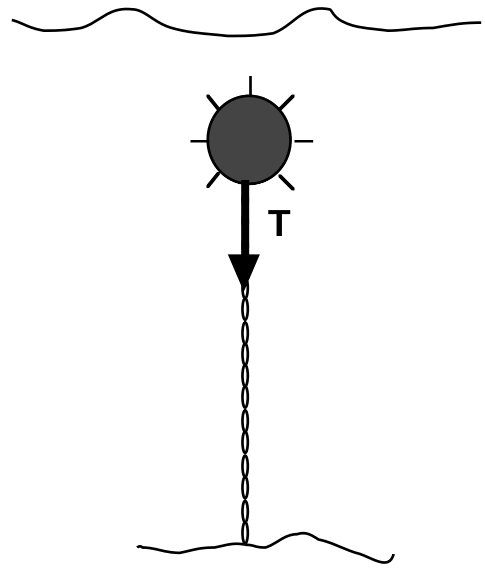
17. A large polystyrene ball is held submerged in a tank of water by a downward force '**F**'. If the ball's weight is small enough to be ignored and the force is found to be 0.5 newtons,



(a) what **upthrust** acts on the ball and

(b) what **volume** is the ball ?
[Water's density = 1 g/cm^3; 'g' = 10 N/kg]

18. A shipping mine, which is less dense than water, is tethered to the sea-bed by a chain.

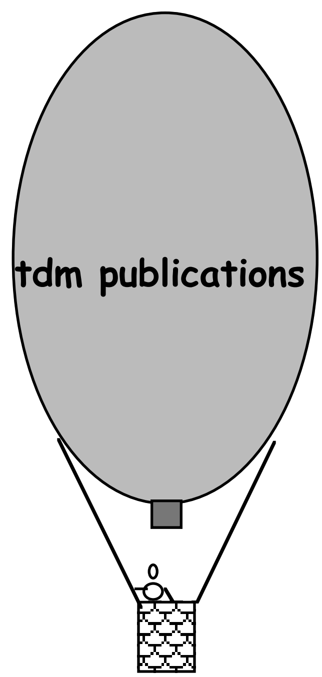


The mine's mass is 400 kg and it has a volume of 0.5 m^3.

Calculate the **tension** '**T**' in the tethering chain.

[Take 'g' = 10 N/kg and the density of sea water as 1020 kg/m^3]

19. (a) Explain how a hot-air balloon achieves sufficient of a lifting force to accelerate upwards from the ground.



(b) The balloon is drifting sideways at a constant height. If the burner is switched off and hot air is released from the top of the balloon, allowing cold air to enter the bottom, with *no change* to the balloon's volume,what happens to:

(i) the **buoyancy force**,

(ii) the **weight** of the balloon and

(iii) the **unbalanced force**

20. Explain why a balloon filled with *helium* gas floats upwards in the air and yet a balloon filled to the same volume with *carbon dioxide* gas falls down when released.

Gas Laws

1. Boyle's Law, which describes the behaviour of a fixed mass of gas at constant temperature, can be written as '**pV = constant**'.
   Given a set of data for a gas under these conditions, consisting of the **volume** of the gas at a number of different **pressures**, which graph should be constructed to show a 'straight line through the origin'?

2. Complete the following table which has the results for the **volume** and **pressure** of a fixed mass of gas in a 'Boyle's Law' experiment.

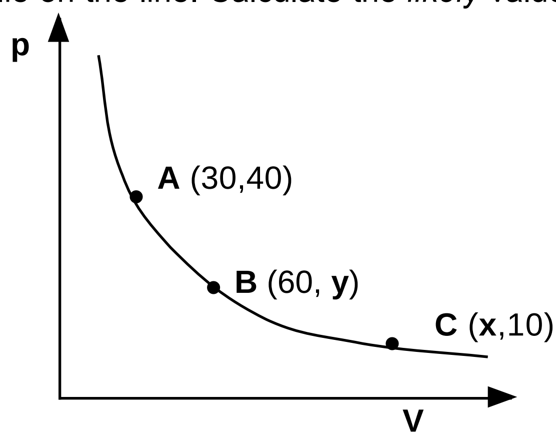
Volume (cm^3)	pressure (units)	pV
10	30	300
15	-	-
20	-	-
30	-	-
-	7.5	-
-	6	-

3.The air inside a bicycle pump is at atmospheric pressure (1.01×10^5 Pa.)

The hole is blocked and the piston slowly pushed in till the air inside is reduced to **one quarter** of its original volume.
What is the **air pressure** inside the pump now?

4. An air bubble forms at the bottom of a deep lake and rises to the surface.
   If there is no change in the bubble's temperature, what **changes** happen to its **volume** and **pressure** as it gets closer to the surface?

5. The co-ordinates of a point **A** on the line of a **pressure-volume** graph constructed for a fixed mass of gas at constant temperature are (40, 30.)
   Points **B** and **C** also lie on the line. Calculate the *likely* values of '**x**' and '**y**'.



6. A certain car's suspension works by having a fixed mass of gas sealed inside a flexible capsule. Its pressure is usually 2.4×10^5 Pa and its volume is 2 litres. On a bumpy road, at one point, the gas inside the capsule is compressed to 1.5 litres.
   What is its **pressure** at this point? (Assume the gas temperature remains constant.)

7. If the temperature of a fixed mass of gas remains constant, what happens to its **volume** if the pressure is: (a) doubled (b) halved?

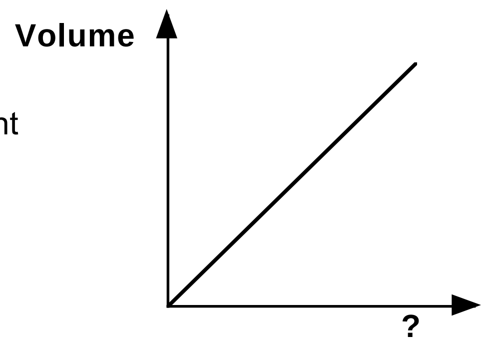
8. A child lets his helium-filled balloon go and it floats up, higher and higher into the air, becoming larger and larger. When it was at ground level, its volume was 4000 cm^3 and the helium was at a pressure of 1.5×10^5 Pa.
What would the helium's **pressure** become if the volume increased to 6000 cm^3 with no change of temperature?

9. Complete this statement of Charles' Law with the missing words:

" the **volume** of a fixed mass of gas at constant _______________ is directly proportional to the _____________ **temperature** of the gas."

10.

For a fixed mass of gas at a constant pressure, which **quantity** should be on the x-axis of this graph to give a straight line through the origin?



11. How is a temperature on the Celsius scale **converted** to the equivalent temperature on the **kelvin** (or **absolute**) scale?

12. Convert these Celsius temperatures into **kelvin temperatures**:

(a) 0°C (b) 100°C (c) 20°C (d) 37°C (e) - 273°C
(f) - 196°C (g) 327°C (h) 273°C

13. Convert these kelvin temperatures into **Celsius temperatures**:

(a) 0 K (b) 273 K (c) 373 K (d) 294 K (e) 261 K

14. A large advertising balloon contains 25000 m^3 of gas when it is at a temperature of 15°C. A cold front of air arrives and the balloon's temperature falls to - 5°C.
Assuming that the gas pressure remains constant, calculate the **volume** of the gas inside the balloon at the lower temperature.

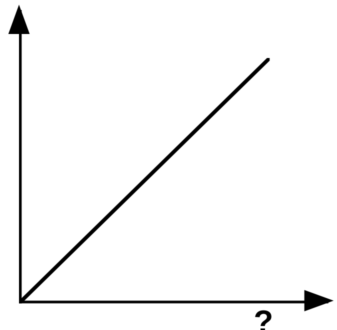
15. 100 cm^3 of nitrogen gas at -196°C warms up in an expandable container to room temperature of 20°C. What does the **volume** of the nitrogen become, if its pressure remains unchanged?

16. A fixed mass of a gas has a volume of 200 cm^3 when at -10 °C.
Assuming that its pressure has not changed, what is its **temperature** if its volume doubles?

17. What is the **difference** between 100°C and 100 C°?

18. Complete this statement of the 'Pressure Law' with the missing words: " the **pressure** of a fixed mass of gas at constant ______________ is directly proportional to the ____________ **temperature** of the gas."

19. For a fixed mass of gas at a constant volume, which **quantity** should be on the x-axis of this graph to give a straight line through the origin?



20. A gas trapped in a **rigid** container is at a pressure of 1.2×10^5 Pa when its temperature is 20^{o}C. Calculate its **pressure** at 80^{o}C.

21. A car tyre's pressure is checked at 30 units when the air temperature inside it is -2^{o}C. After a journey, the pressure is checked again and found to have risen to 32 units. Assuming no change in volume, what is the new **temperature** of the air inside the tyre?

22. After a long journey, a car tyre's pressure is 30.5 units at a temperature of 24^{o}C. During the night, its pressure falls to 26.9 units. What was the **temperature** of the air in the tyre during the night? (Assume no change occurs in the tyre's volume.)

23. The air in a sealed flask exerts a pressure of 1.50×10^5 Pa on the walls of the flask when its temperature is 26^{o}C. What would the **pressure** become if the flask was immersed in a large container of ice and water?

24. A gas in a rigid flask has a pressure of 9×10^4 Pa. Its temperature is 9^{o}C. Calculate the **Celsius temperature** to which the flask should be heated for its pressure to increase to 1.5×10^5 Pa.

25. A gas, at -1^{o}C and 1.01×10^5 Pa, is heated in a rigid container until its pressure has increased by 50%. What is its new **temperature**?

26. A car tyre pressure is 28.1 lb/in^2 at a temperature of 10^{o}C. What would the **pressure** become if the tyre's **air** temperature increased *by* 15 C^o?

27. A gas bubble of volume 3 cm^3 forms at the bottom of a loch where the pressure is 3 atmospheres and the temperature 4^{o}C. What is its **volume** on reaching the **surface** where the water temperature is 13^{o}C?

28. The pressure in a flexible plastic flask is 1000 kPa when its volume is 500 cm^3 and its temperature 10^{o}C. What would the **pressure** become if the gas volume was reduced to 400 cm^3 and it was heated to a temperature of 90^{o}C?

29. If a syringe contains 100 cm^3 of a gas at 20^{o}C and its pressure is atmosphere, calculate the **volume** occupied by the gas if the pressure is increased to 1.5 atmospheres and the temperature becomes 240 ^{o}C.

30. Calculate the **Celsius** temperature of a fixed mass of gas in a rigid container if its **pressure** has increased from 1.2×10^5 Pa at 12°C to 2.8×10^5 Pa.

31. What temperature ***rise*** would cause a fixed volume of gas with a pressure of 1.2×10^5 Pa at 10°C to increase in pressure to 1.4×10^5 Pa?

32. The air in a bicycle pump, with the plunger pulled out, has a volume of 100 cm^3.
The pump is open to the air, where the pressure is 1.01×10^5 Pa.
The outlet hole is now blocked and the plunger pushed slowly in until the volume is just 20 cm^3.
Calculate the new **air pressure** inside the pump.

33. A diver has an aqualung which contains 12 litres of air at a pressure of 10000 kPa.

(a) How much **space** would the same *mass* of air occupy at a pressure of just 250 kPa? (Assume that the **temperature** does *not* change.)

(b) If the diver breathed air from the aqualung at the rate of 20 litres per minute, at a depth in the sea where the pressure was 250 kPa, how **long** would the air last? (Assume that *all* the air from the aqualung was able to be breathed by the diver.)

(c) Why, in fact, would **less** air than this be available to the diver?

34. A gas bubble, formed at the bottom of a deep lake where the pressure is 1200 kPa and the temperature of the water 4°C, rises to the surface, where the pressure is 100 kPa and the temperature 16°C. Just before reaching the surface, the bubble's volume is 62.6 cm^3. Calculate the **volume** which the bubble had when it was formed at the bottom of the lake.

35. A boy has a flat tyre on his bicycle. What is the value of the **air pressure** inside the tyre? ***(Careful!)***

36. Air pressure at sea level is about 15 lb/in^2 (pounds per square inch.)
A motorist checks the pressure of one of his tyres on an accurate garage pressure gauge and it reads 29 lb/in^2.

What is the actual **air pressure** inside the tyre?

37. Why is the **air pressure** smaller at the top of Mount Everest than at sea level?

38. Steam is at a temperature of 100°C and a pressure of 1 atmosphere inside a pressure vessel.

What does the **pressure** become if the temperature of the steam increases to 273°C?

39. The co-ordinates of one point on the straight line graph of **pressure** of a gas against **absolute temperature** (at constant volume) are (420,280.)

Another point on the line is given as (**x**, 360.) What is the value of **x**?

Radioactivity

1. For the following **isotopes**, denoted thus:

$$^{A}_{Z}X$$

where **Z = atomic number**, **A = mass number** and **X = element**, state the number of **protons** and **neutrons** in the nucleus of the atom and name the **element**:

(a) $^{12}_{6}C$ (b) $^{14}_{6}C$ (c) $^{235}_{92}U$ (d) $^{238}_{92}U$

(e) $^{218}_{82}Pb$ (f) $^{228}_{88}Ra$ (g) $^{4}_{2}He$

2. If a radioactive nucleus emits an **alpha particle**, state what happens to:
(a) the number of **protons** left in the nucleus, (b) the number of **neutrons.**

3. If a radioactive nucleus emits a **beta particle**, state what happens to:
(a) the number of **protons** in the nucleus, (b) the number of **neutrons.**

4. A radioactive nucleus often emits a **gamma ray**, following the emission of an alpha particle or beta particle. On emission of the *gamma ray*, state what happens to:
(a) the number of **protons** in the nucleus, (b) the number of **neutrons.**

5. In the following examples of nuclear disintegrations, identify the missing **numbers**, **elements** or **particles**:

(a) $^{238}_{92}U \longrightarrow ^{X}_{Y}Th + ^{4}_{2}He$

(b) $^{234}_{90}Th \longrightarrow ^{X}_{Y}Pa + ^{0}_{-1}e$

(c) $^{234}_{91}Pa \longrightarrow ^{X}_{Y}? + ^{0}_{-1}e$

(d) $^{222}_{86}Rn \longrightarrow ^{X}_{Y}Po + ^{4}_{2}He$

(e) $^{210}_{82}? \longrightarrow ^{210}_{X}Bi + ^{Y}_{-1}e$

(f) $^{14}_{6}C \longrightarrow ^{x}_{y}? + ^{0}_{-1}e$

6. What is meant by the term **half-life** of a radioactive isotope?

7. A certain radioisotope has a half-life of 3 minutes. What **fraction** of the *original number* of atoms is still unchanged after:
(a) 3 minutes (b) 6 minutes (c) 9 minutes?

8. What **percentage** of the *original* activity of a radioactive substance remains after **four** half-lives have passed?

9. The activity of a radioisotope falls from 8000 kBq to 2000 kBq in a time of 4 days.
What is the **half-life** of the radioisotope?

10. Cobalt-60 is used in hospitals as a gamma emitter and has a half-life of 5.3 years.
To the **nearest year**, how long would it take a new cobalt-60 source to lose **seven-eighths** of its original activity?

11. Radon-220 gas emits alpha particles and has a half-life of just 55 seconds.
Some of the gas escapes from its container into a laboratory. After how long would it be **safe** to enter the laboratory if a safe level was considered to be **less than 1%** of the activity which the gas had when it was was released?

12. Radon-222 has a half-life of 92 hours. How **long** would it take for the activity of a sample of the gas to be reduced to about **3%** of its initial value?

13. In a laboratory where the background count is 25 counts per minute (c.p.m.),
the **uncorrected** count rate from a radioisotope falls from 960 c.p.m. to 54 c.p.m. over 1 hour 15 minutes. What is the **half-life** of the radioisotope in minutes?

14. The half-life of a radioisotope is 3.7 days. How **long** would it take for the **activity** of a sample of the isotope to fall to one-sixty fourth of its original value?

15. A radioactive source has an activity of 1.5 MBq.
How many **decays** would occur in one hour? [Note: 1 Bq = 1 decay per second]

16. If one gram of carbon from a living tree has an **activity** of 15 decays per minute due to the radioisotope carbon-14 which has a half-life of 5600 years, what **count rate** per gram would be expected from a wooden artifact made in 3500 B.C.?

17. A radionuclide's activity falls to **6.25%** of its initial value in a time of 24 hours.
What is the value of its **half-life**?

18. The table has the results of an experiment to measure the half-life of a radioactive sample. The counts *exclude* the background radiation.

Count rate in counts per minute	6400	3900	2600	1800	1010	690	500
Time in minutes	0	5	10	15	20	25	30

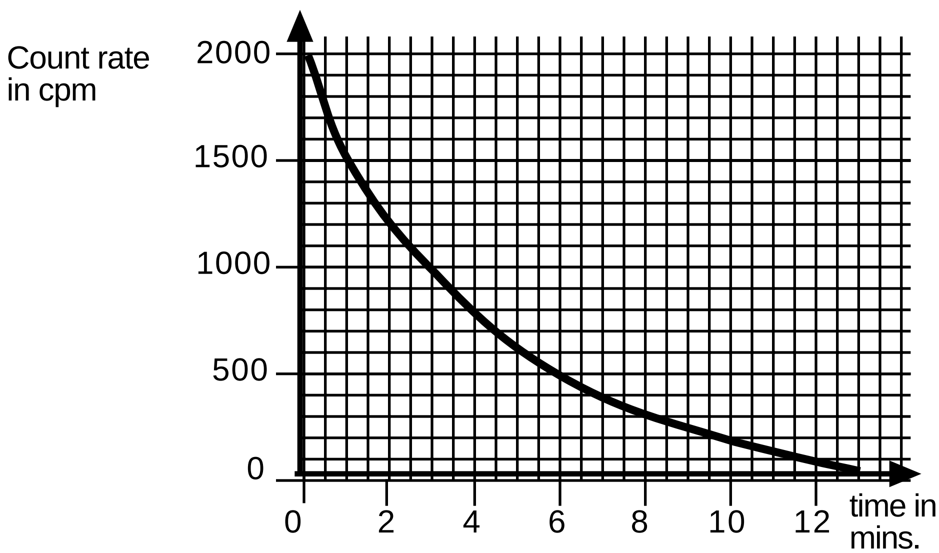
Plot a **line graph** of count rate against time and use it to estimate the **half-life** of the sample.

19. The table has the results of an experiment to measure the half-life of a radioactive sample. The counts *include* the background radiation.

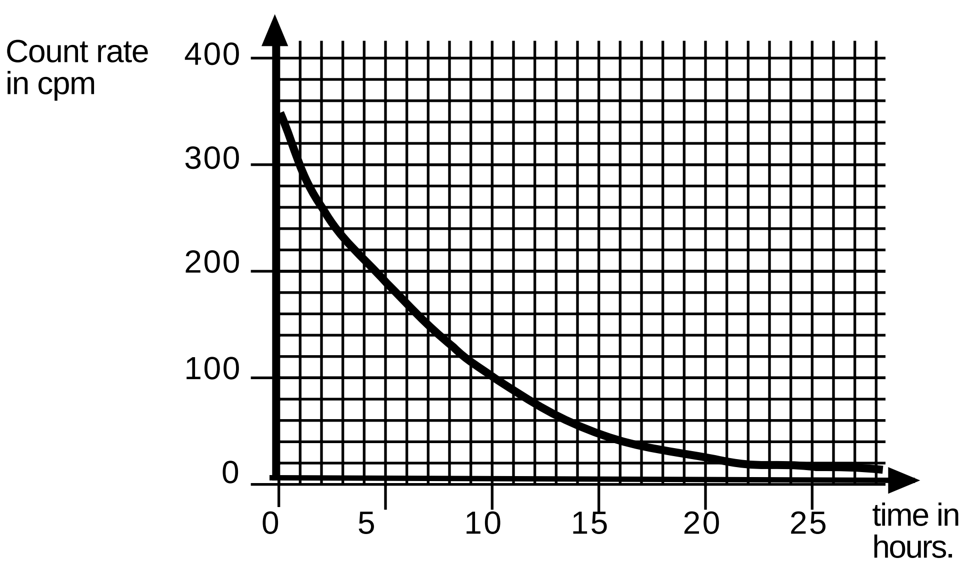
Count rate in counts per minute	425	255	194	136	110	64	53
Time in minutes	0	3	6	9	12	15	18

Plot a **line graph** of count rate against time and, from it, estimate:
(a) the **background count**, (b) the **half-life** of the sample.

20. Calculate the **half-life** of the substance whose count-rate has been plotted against time in the graph shown. The count-rate has been corrected for background radiation.



21. Calculate the **half-life** of the substance whose count-rate has been plotted against time in the graph shown. The count-rate has been corrected for background radiation.



$E = mc^2$

1. When nuclear fission occurs, the nucleus of an atom splits into two approximately equal pieces and a number of neutrons is released. How does the **total mass** of the particles ***after*** the fission compare with the total mass before?

2. In a nuclear fission event, energy is released. What is the **source** of this energy?

3. Write down the **equation** which allows the **energy** created from a certain quantity of **mass** to be calculated. State what each **letter** in the equation represents.

4. When a nucleus of uranium-235 captures a neutron, fission takes place.
One possible fission is:

$$^{235}_{92}\mathbf{U} + ^{1}_{0}\mathbf{n} \longrightarrow ^{90}_{36}\mathbf{Kr} + ^{144}_{56}\mathbf{Ba} + \mathbf{?}\ ^{1}_{0}\mathbf{n}$$

By ensuring that the numbers of protons and neutrons are each the same *before* and *after the* fission, calculate how many **neutrons** are released.

5. When a nucleus of uranium-235 captures a neutron, fission takes place.
One possible fission is:

$$^{235}_{92}\mathbf{U} + ^{1}_{0}\mathbf{n} \longrightarrow ^{95}_{36}\mathbf{Kr} + ^{\mathbf{x}}_{\mathbf{y}}\mathbf{Ba} + \mathbf{3}\ ^{1}_{0}\mathbf{n}$$

By ensuring that the numbers of protons and neutrons are each the same *before* and *after the* fission, calculate the values of **x** and **y**.

6. When a nucleus of plutonium-239 captures a neutron, fission takes place.
One possible fission is:

$$^{239}_{94}\mathbf{Pu} + ^{1}_{0}\mathbf{n} \longrightarrow ^{137}_{52}\mathbf{Te} + ^{\mathbf{x}}_{\mathbf{y}}\mathbf{Z} + \mathbf{3}\ ^{1}_{0}\mathbf{n}$$

By ensuring that the numbers of protons and neutrons are each the same *before* and *after* the fission, calculate the values of **x** and **y** and identify element '**Z**'.

7. In a certain fission event, 3.67×10^{-28} kg of mass is converted to energy.
Calculate the **energy released** in joules. ('c' = 3.00×10^{8} m/s)

8. In a fission event, 1.46×10^{-11} J of energy is released. How much **mass** was converted to energy by the fission? ('c' = 3.00×10^{8} m/s)

9. In the Sun, 'light' nuclei are fused together at very high temperatures with the loss of a small quantity of mass. What is the **name** for this process?
What is the mass **converted** into?

10. The Sun is 'burning' its nuclear fuel at the rate of 4 million tonnes per second.
Calculate how much **energy** is released every second. (1 tonne = 1000 kg).

Nuclear reactions

1. Write down the equation which calculates the quantity of **energy** released when matter is destroyed in nuclear disintegrations.

2. Uranium-238 is radioactive and decays to thorium-234 with the emission of an alpha particle. The mass that is lost in the reaction is 5.0 x 10^{-30} kg.
   Calculate the **energy** released.

3. An alpha particle from the radionuclide americium-241 has 8.8 x 10^{-13} J of kinetic energy. Calculate the **mass** lost in the disintegration.

4. Rewrite each of these examples of **nuclear fission** with **numbers** in place of the letters **x** and **y** and the **element symbol** in place of the letter **Z**.

(a) $${}^{1}_{0}n + {}^{235}_{92}U \longrightarrow {}^{138}_{56}Ba + {}^{94}_{\mathbf{x}}\mathbf{Z} + \mathbf{y}\,{}^{1}_{0}n$$

(b) $${}^{1}_{0}n + {}^{235}_{92}U \longrightarrow {}^{98}_{42}Mo + {}^{136}_{\mathbf{x}}\mathbf{Z} + \mathbf{y}\,{}^{1}_{0}n + \mathbf{4}\,{}^{0}_{-1}e$$

(c) $${}^{1}_{0}n + {}^{239}_{94}Pu \longrightarrow {}^{\mathbf{x}}_{52}Te + {}^{100}_{\mathbf{y}}\mathbf{Z} + 3\,{}^{1}_{0}n$$

5. Use the data in the table to calculate the loss of **mass** in this nuclear reaction involving a nucleus of uranium -235 and the **energy** released.

$${}^{1}_{0}n + {}^{235}_{92}U \longrightarrow {}^{134}_{52}Te + {}^{98}_{40}Zr + 4\,{}^{1}_{0}n$$

Particle	***Mass in kg***
${}^{1}_{0}n$	0.017 x 10^{-25}
${}^{235}_{92}U$	3.901 x 10^{-25}
${}^{134}_{52}Te$	2.221 x 10^{-25}
${}^{98}_{40}Zr$	1.626 x 10^{-25}

6. Use the data in the table to calculate the loss of **mass** in this nuclear reaction involving a nucleus of uranium -235 and the **energy** released.

$$^{1}_{0}n + ^{235}_{92}U \longrightarrow ^{144}_{56}Ba + ^{90}_{36}Kr + 2\,^{1}_{0}n$$

Particle	*Mass in kg*
$^{1}_{0}n$	0.017×10^{-25}
$^{235}_{92}U$	3.901×10^{-25}
$^{144}_{56}Ba$	2.388×10^{-25}
$^{90}_{36}Kr$	1.492×10^{-25}

7. For the following **fission reaction**, use the data in the table to calculate:

(a) the **mass** lost (ignore the mass of the four electrons) in (i) **u** (ii) **kg**.

(b) the **energy** released. [Note: 1u = 1.660×10^{-27} kg]

$$^{1}_{0}n + ^{235}_{92}U \longrightarrow ^{98}_{42}Mo + ^{136}_{54}Xe + 2\,^{1}_{0}n + 4\,^{0}_{-1}e$$

Particle	*Mass in u*
$^{1}_{0}n$	1.009
$^{235}_{92}U$	234.993
$^{98}_{42}Mo$	97.883
$^{136}_{54}Xe$	135.878

8. For the following **fission reaction**, use the data in the table to calculate:

(a) the **mass** lost (ignore the mass of the four electrons) in (i) **u** (ii) **kg**.

(b) the **energy** released. [Note: 1u = 1.6600 x 10^{-27} kg]

$$^{1}_{0}n + ^{239}_{94}Pu \longrightarrow ^{137}_{52}Te + ^{100}_{42}Mo + 3\,^{1}_{0}n$$

Particle	***Mass in u***
$^{1}_{0}n$	1.0087
$^{239}_{94}Pu$	239.0006
$^{137}_{52}Te$	137.0000
$^{100}_{42}Mo$	99.8850

9. When a nucleus of uranium-235 undergoes **fission**, 3.2 x 10^{-11} J of energy is released on average. The fuel pellets used in a certain nuclear reactor contain 5.9 x 10^{22} atoms of uranium-235 in every kilogram.

(a) How many **fissions** per second would produce 1000 MW of heat?

(b) At what **rate** is the 'fuel' used up, in **grams per second**?

10. A power station **reactor** produces a net electrical power output of 624 MW at an efficiency of 45%. On average, each fission of a uranium-235 nucleus produces 3.17 x 10^{-11} J of energy.

(a) What '**heat**' power is produced by the fissions in the reactor?

(b) Calculate how many **fissions** are needed per second.

11. In the following **nuclear fusion** reactions, identify the missing **numbers** or **element**.

(a) $$^{2}_{1}H + ^{3}_{\mathbf{x}}H \longrightarrow ^{\mathbf{y}}_{2}\mathbf{Z} + ^{1}_{0}n$$

(b) $$^{2}_{1}H + ^{\mathbf{x}}_{1}\mathbf{Z} \longrightarrow ^{3}_{\mathbf{y}}He + ^{1}_{0}n$$

12. A nuclear **fusion** reaction is shown below.

$$^{2}_{1}H + ^{3}_{1}H \longrightarrow ^{4}_{2}He + ^{1}_{0}n$$

(a) Use the data in the table to calculate the **mass** lost and the **energy** released by the reaction.

Particle	***Mass in kg***
$^{2}_{1}H$	3.44441×10^{-27}
$^{3}_{1}H$	5.00890×10^{-27}
$^{4}_{2}He$	6.64632×10^{-27}
$^{1}_{0}n$	1.67490×10^{-27}

(b) How **many** fusion events per second would be needed to generate a 'heat' **power** of 5 MW?

13. A nuclear **fusion** reaction is shown below.

$$^{2}_{1}H + ^{2}_{1}H \longrightarrow ^{3}_{2}He + ^{1}_{0}n$$

(a) Use the data in the table to calculate the **mass** lost and the **energy** released by the reaction. [Note: $1u = 1.660 \times 10^{-27}$ kg]

Particle	***Mass in u***
$^{2}_{1}H$	2.013
$^{3}_{2}He$	3.015
$^{1}_{0}n$	1.009

(b) How **many** fusion events per second would be needed to generate a 'heat' at the rate of 20 MW?

E = hf (photons)

Note: (1) the velocity of light in air (or a vacuum), $c = 3.00 \times 10^8$ m/s,
(2) Planck's constant, $h = 6.63 \times 10^{-34}$ Js.

1. Use the equation '**E = hf**' to calculate the **energy** carried by photons of electromagnetic radiation with **frequencies**:

   (a) 6.00×10^{14} Hz (b) 3.75×10^{14} Hz (c) 10^{15} Hz

2. Calculate the **energy** carried by photons of electromagnetic radiation with **wavelengths**:

   (a) 4.00×10^{-7} m (b) 6.50×10^{-10} m (c) 700 nm

   [1 nm = 1×10^{-9} m]

3. Calculate the **wavelength** of a photon carrying 3.98×10^{-19} J of energy:

   (a) in **metres** (b) in **nanometres** (nm)

4. What is the **frequency** of a monochromatic light source that emits photons which each carry 2.88×10^{-19} J of energy?

5. An X-ray machine produces X-rays of **wavelength** 2.5×10^{-11} m.

   Calculate the **energy** of an X-ray photon.

6. A laser beam emits light of **wavelength** 633 nm and has a **power** of 1 mW.

   (a) Calculate the **energy** of a photon in the beam.

   (b) The beam makes a spot of 1 cm diameter on a distant screen.
   Calculate the **intensity** of the beam on the spot in watts per square metre (W/m^2.)
   [Note: 1 m^2 = 10 000 cm^2]

   (c) Calculate the **number** of photons emitted by the laser every second.

7. Estimate the number of photons of *visible* radiation emitted by a 100 watt light bulb each second.

   Assume the light bulb is 25% efficient at converting electric energy light energy.
   Take the average wavelength of light to be 500 nm.

Dosimetry and Safety

1. Name the **unit** in which the **activity** of a radioactive source is measured and state its abbreviation.

2. How **many** becquerels are: (a) 1 kBq (b) 1 MBq

3. Use the formula **average activity = number of decays ÷ time** to calculate the missing entries in the table.

average activity	number of decays	time
-	20000	10 s
-	6×10^5	10 s
-	1.11×10^7	1 m
-	1.50×10^7	1 m 15 s
2.5 kBq	-	30 s
185 kBq	-	2 s
3 MBq	-	5 s
2.5 MBq	-	10 m
185 kBq	925000	-
1.2×10^7 Bq	5.4×10^8	-

4. Describe the difference between the terms '**activity**' and '**count rate**'.

5. The background count is measured in a science laboratory with a Geiger counter. Over a time of 15 minutes, 480 events are counted. Calculate the **average background count** for the laboratory in counts per minute (cpm).

6. Name the unit in which the quantity '**absorbed dose**' is measured and state its abbreviation.

7. Use the formula **absorbed dose = energy absorbed ÷ unit mass [$D = {}^E/_m$]** to calculate the missing entries in the table.

absorbed dose	energy (J)	mass (kg)
-	10	50
-	3×10^{-4}	60
20 mGy	-	50
100 µGy	-	80
50 mGy	3.5	-
200 µGy	0.016	-

8. Over the course of a working day, a man's body, of mass 80 kg, receives 0.2 mJ of energy from various types of radiation. Calculate his **absorbed dose** in micrograys.

9. A man receives an absorbed dose of 160 µGy from fast neutrons during an 8 hour shift. Calculate his **absorbed dose rate** in µGyh^{-1}.

10. A worker in a nuclear power station experiences an absorbed dose rate from thermal neutrons of 0.1 μGyh^{-1}. What would the worker's total absorbed dose be over a 5 day working week of 8 hour shifts?

11. How **long** would a person need to experience an absorbed dose rate of 10 micrograys per hour to receive a total absorbed dose of 2 milligrays?

12. Name the unit in which the quantity '**dose equivalent**' is measured and state its abbreviation.

13. In the relationship '**H = DQ**', what quantity is represented by the letter '**Q**'?

14. A worker in a nuclear power station receives an annual absorbed dose of 200 μGy from thermal neutrons. If the quality factor for thermal neutrons is **5**, calculate the worker's annual **dose equivalent**.

15. The quality factor for gamma radiation is **1**.
What would be the **dose equivalent** if the absorbed dose is measured as 30 mGy?

16. A woman receives an absorbed dose of 2 μGy from fast neutrons.
If her dose equivalent is 20 μSv, what is the **quality factor** for fast neutrons?

17. If a worker is exposed to a dose equivalent rate of 10 μSvh^{-1} for a total of 200 hours, what is his total **dose equivalent** in mSv?

18. During a 40-hour week, a radiotherapy technician receives a dose equivalent of 200 μSv from X-rays. Calculate the **dose equivalent rate** in μSvh^{-1}.

19. State the average *annual* effective dose equivalent in the UK which a member of the public receives.

20. A person receives a total effective dose equivalent of 5 mSv over a whole year. Calculate the average **dose equivalent rate** in μSvh^{-1}. (Answer to 2 significant figures).

21. A radiation worker should not be exposed to an *annual* whole body dose equivalent of more than 50 mSv. Assuming a 40 hour working week and a 45 week year, calculate the *maximum* **dose equivalent rate** in μSvh^{-1} to which she should be exposed (to 2 significant figures.) Ignore the relatively small dose received in non-work time.

22. A man receives a radiation dose from two different sources:

80 mGy from thermal neutrons (Q = 5) and 20 mGy from alpha particles (Q = 10)

Calculate:

(a) the man's total **absorbed dose** and
(b) his total **dose equivalent**.

23. Explain why **dose equivalent** is a better measure of the danger to health of exposure to radiation than **absorbed dose**.

24. A worker absorbs a radiation dose from three different types of radiation at the following rates:

Type	**Absorbed dose rate**	**Quality factor**
1	10 μGyh^{-1}	10
2	40 μGyh^{-1}	5
3	100 μGyh^{-1}	2

(a) Calculate his total **absorbed dose rate** from the three types of radiation.

(b) Calculate his total **dose equivalent rate** from the three types of radiation.

(c) What would be his total **dose** equivalent over a time of 5 hours?

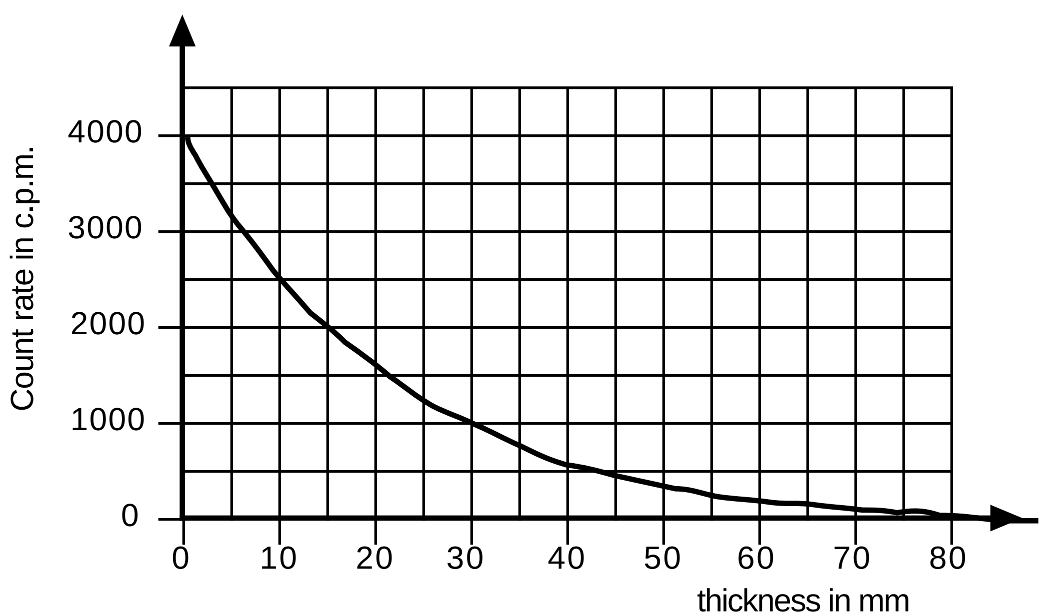
25. The half-value thickness of a certain material for X-rays is 1 mm. What **thickness** of the material would be required for a shield to reduce penetration by X-rays to $^{1}/_{16}$ th of the intensity *without* the shield?

26. The count rate from a gamma source is measured by a Geiger counter as 6000 c.p.m. When 22 mm of lead is placed between the source and counter, the count rate becomes 1500 c.p.m.

(a) What is the **half-value thickness** of the lead for gamma rays?

(b) What would the **count rate** be if the thickness of lead was increased to 33 mm?

27. The **half-value thickness** of a material for gamma-rays is calculated by measuring the count rate from a gamma source with different thicknesses of the material between the souce and detector. A graph of count rate against thickness is constructed.



From the graph, estimate the **half-value thickness** of the material.

Solar System and Universe

1. Copy and complete the following passage by inserting the missing **words**:

   "The solar system consists of nine _________ which orbit round the Sun. The Sun is a _____. The time for a planet to make one full orbit of the Sun is called a _____ . For our planet, Earth, this is $365^{1}/_{4}$ ______ . The Moon is a natural ___________ of the Earth and takes about 27 days to make one whole orbit.

   This time is called a lunar ________ . As well as going round the Sun, the Earth is spinning on its own axis. It takes 24 _____ to turn round once. This time is also called a ______ ."

2. What is the **nearest star** to Earth called?

3. When it is **night** in Britain, where is the **Sun**?

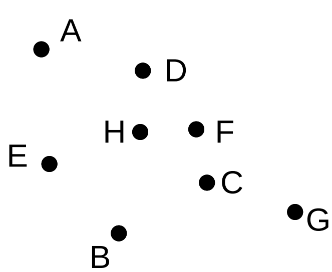
4. Is it possible to be either daytime or night-time **everywhere** on the Earth at once? Explain.

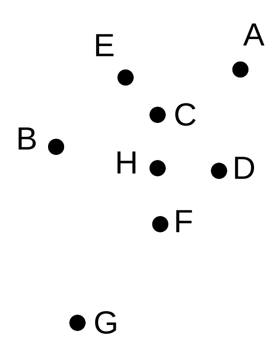
5. The Sun and Moon both appear to be very nearly the **same size** as seen from the Earth and yet the Sun is more than four hundred times **wider** than the Moon.
   Explain why they ***appear*** to be the same size.

6. The Sun is one of millions of stars in the Milky Way.
   What is the **name** for a group of millions of stars such as the Milky Way?

7. The planets used to be known as wandering stars because they **change** their position in the night sky. The **stars** appear fixed, although it is now known that they are moving at high speeds. Why do the **planets** appear to move, but the stars appear to be fixed?

8. The two diagrams show the **same** part of the night sky on different nights.
   One of the objects is a **planet**.





Identify which object is the **planet** and explain **why** you chose it.

9. The nine planets of the Solar System are (in random order):

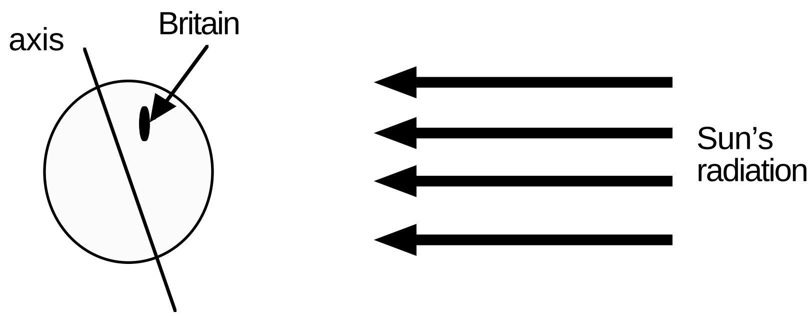
Earth Pluto Mercury Jupiter Venus Saturn Uranus Mars Neptune

(a) Write them out in order of **distance** from the Sun, starting with the planet which is **nearest** to the Sun.

(b) Which planet has the **shortest** year?

(c) What happens to the **length** of a planet's year as the distance from the Sun **increases**?

10. The diagram shows heat and light radiation from the Sun reaching the Earth.
The Earth is tilted on its axis by about 23^o.

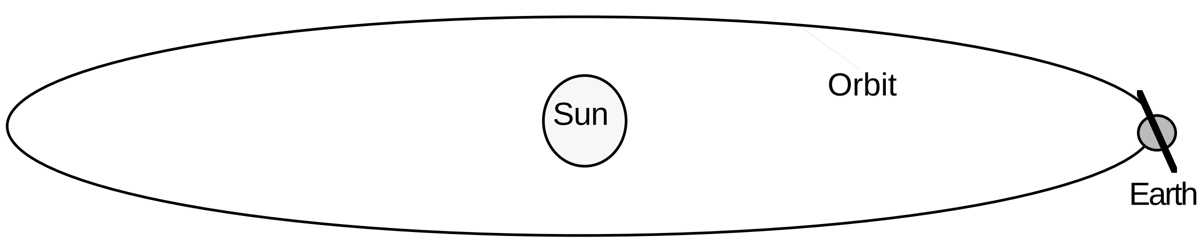


Explain whether it is **summer** or **winter** in Britain.

11. Draw a diagram to show how the Earth's axis is tilted in relation to the Sun when the Northern Hemisphere is in **summer**.

12. If the Earth's axis was **not** tilted but was at right angles to the plane of its orbit round the Sun, explain why there would be no change of season in Britain.

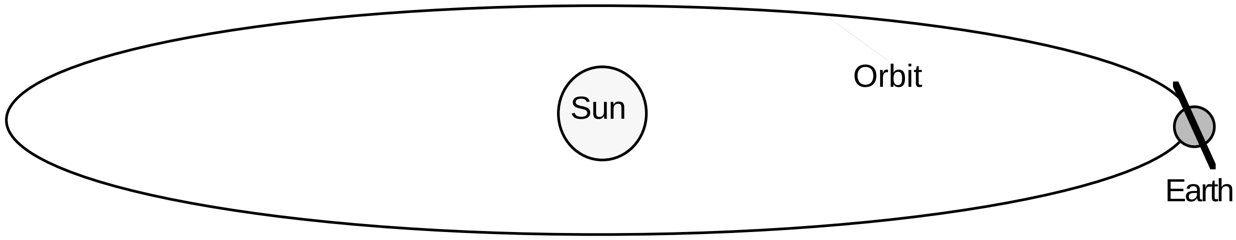
13. The diagram shows the position of the Earth in its orbit of the Sun at a certain point of the year.



Copy the diagram and on it mark letter **A**, **B** and **C** to show the **position** of the Earth:

(a) three months, (b) six months and (c) nine months later.

14. The diagram shows the position of the Earth when it is **mid-summer** in the northern hemisphere.



Copy the diagram and mark, with the letters **N**, **S** and **E**, the positions of the Earth when:

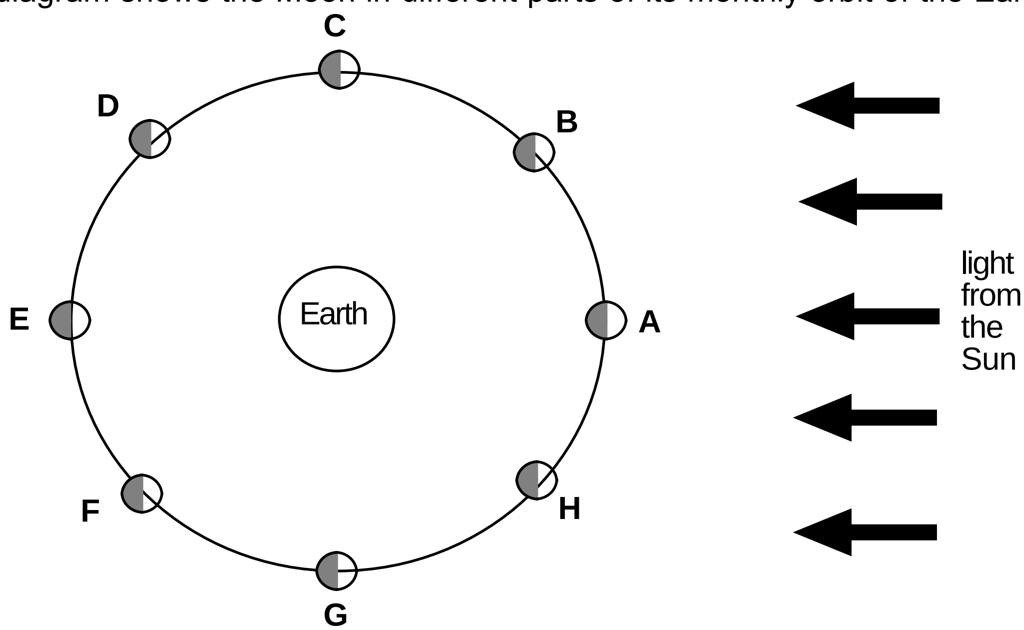
(a) it is **mid-winter** in the northern hemisphere,
(b) it is **mid-winter** in the southern hemisphere and
(c) day and night are the **same length** everywhere - the equinox).
(Note: there are **two** possible positions for **E**).

15. (a) State the name of the **force** which holds the planets in orbit round the Sun.
(b) How does the size of the force depend on the **mass** of the planet?
(c) How does the size of the force depend on the **distance** of the planet from the Sun?

16. What would happen if the Earth **slowed down** in its orbit round the Sun?

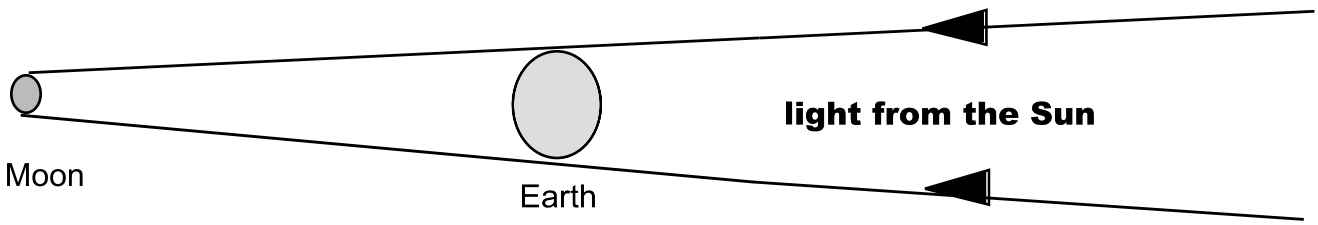
17. The Moon doesn't emit light on its own. Why, then, can we **see** it?

18. The diagram shows the Moon in different parts of its monthly orbit of the Earth.



Position **A** is for a **New Moon** (invisible from the Earth).
(a) Which positions give: (i) a **full Moon** (ii) a **half Moon**?
(b) Draw how the Moon would appear from Earth at position **B**.
(c) Draw how the Moon would appear from Earth at position **H**.
(d) If position **A** occurred on 1st May, **when** would position **E** next occur?
(e) At which **position** would the Moon be on 28th May?

19. What kind of **eclipse** is shown in the diagram?



20. A **total** eclipse of the Sun (or Solar eclipse) happens when the Moon casts its shadow over part of the Earth's surface.

    (a) Draw a diagram to illustrate this, showing the relative positions of the Earth, Moon and Sun.

    (b) Total eclipses of the Sun are very rare, and yet the Moon orbits the Earth once every Month.

    Can you explain **why** there is not a total eclipse every month?

21. The tides are caused mainly by the gravitational attraction of the Moon causing water to bulge on opposite sides of the Earth in line with the Moon.

Draw a **diagram** to illustrate this and explain why the tide **changes** approximately every six hours.

22. Extra high tides (called **spring tides**) happen when the Moon and Sun are in certain positions relative to the Earth.

Draw **labelled diagrams** to show **how** the Moon, Sun and Earth are lined up at **spring tides** and **explain** why the tide is extra high.

Measurements

1. Convert the following **volumes** into **cubic metres (m^3)**:

(a) 2000 cm^3 (b) 60 cm^3 (c) 3000 litres

2. Convert the following **volumes** into **litres (l)**:

(a) 2500 cm^3 (b) 2 m^3 (c) 500 cm^3

3. How many **cubic centimetres (cm^3)** are there in these volumes?

(a) 1.6 litres (b) 3 m^3 (c) 0.065 m^3 (d) 0.08 litres

4. Convert these measurements into **metres (m)**:

(a) 200 cm (b) 1500 cm (c) 90 cm (d) 7×10^3 cm

5. Convert these **areas** into **square metres (m^2)**:

(a) 4000 cm^2 (b) 5×10^4 cm^2 (c) 2 km^2 (d) 10 cm^2

6. Calculate the number of **square centimetres (cm^2)** in

(a) 1 m^2 (b) 0.02 m^2 (c) 3×10^{-2} m^2 (d) 10^{-4} m^2

7. Convert these **mass** measurements into **kilograms (kg)**:

(a) 2500 g (b) 350 g (c) 1020 g (d) 3×10^4 g

8. Convert these **mass** measurements into **grams (g)**:

(a) 6.70 kg (b) 3400 mg (c) 0.05 kg (d) 150 mg

9. Change these **times** into **seconds (s)**:

(a) 3 m (b) 2 h 30 m (c) 3.6 m (d) 4 m 30 s

10. How many **seconds** are there in a **minute**, an **hour**, a **day** and a **year**?

11. A ticker timer makes **50 dots per second** on a ticker tape.
What **fraction** of a second would be the following numbers of **spaces** between dots?

(a) 25 (b) 10 (c) 5 (d) 2

12. Calculate the **area**, in cm^2, of squares of side:

(a) 2 cm (b) 5 cm c) 10 cm.

13. Calculate the **volume**, in cm^3, of cubes of side:

(a) 2 cm (b) 5 cm (c) 10 cm.

14. Do these calculations using your **calculator**:

(a) $2500 \div 5000$ (b) 0.002×10000 (c) $^{3400}/_{8}$

(d) $(500 \times 600) \div 1000$ (e) $300 \div (40 \times 5)$

15. Do these calculations using your **calculator**:

(a) $(2 \times 10^3) \times (4 \times 10^2)$ (b) $(4 \times 10^5) \times (2 \times 10^{-2})$

(c) $(6 \times 10^3) \div (3 \times 10^2)$ (d) $(4 \times 10^5) \div (2 \times 10^2)$

16. Do these calculations using your **calculator**:

(a) $(8 \times 10^{-3}) \div (4 \times 10^2)$ (b) $(5 \times 10^3) \div (4 \times 10^{-2})$

(c) $(3.2 \times 10^6) \div (1.6 \times 10^2)$ (d) $(4.8 \times 10^{-5}) \div (1.6 \times 10^{-2})$

17. Do these calculations using your **calculator**:

(a) $2 \times 10^2 \times 10^3$ (b) $10^2 \times 10^3$ (c) $10^4 \times 10^{-3}$

(d) $10^3 \div (2 \times 10^2)$ (e) $10^6 \div 10^{-2}$ (f) $10^{-3} \div (2 \times 10^{-2})$

18. Do these calculations using your **calculator**:

(a) $(3.0 \times 10^8) \div (200 \times 10^3)$ (b) $(10^3)^2$ (c) $(10^2)^3$

(d) $10^6 \times 10^{-4}$ (e) $10^8 \div (2 \times 10^{-5})$ (f) $10^{-3} \div 10^{-5}$

19. Express the following as **percentages**:

(a) 10 out of 100 (b) 20 out of 500 (c) 300 out of 1000

(d) 35 out of 100 (e) 36 out of 200 (f) 0.2 out of 4.0

20. Calculate: (a) 10 % of 250 (b) 25 % of 840

(c) 12.5 % of 400 (d) 30 % of 10^3 (e) 25 % of 2.4×10^6

21. With your calculator, use the $^1/_x$ button (or x^{-1}) to calculate $\mathbf{^1/_x}$ for each of these values of **x**:

(a) 5 (b) 10 (c) 25 (d) 0.02 (e) 2×10^{-6}

Basic Algebra

1. Find the value of **x** in each example:

(a) $2x = 4$ (b) $3x = 15$ (c) $3x = 0.24$ (d) $5x = 45.5$ (e) $x/2 = 6$

(f) $x/3 = 3$ (g) $x/5 = 4$ (h) $2x/3 = 8$ (i) $3x/4 = 3$

2. Find the value of **x** in each example:

(a) $x^2 = 4$ (b) $x^2 = 16$ (c) $x^2 = 25$ (d) $x^2 = 100$ (e) $\sqrt{x} = 2$

(f) $\sqrt{x} = 3$ (g) $\sqrt{x} = 12$ (h) $x^3 = 125$ (j) $x^3 = 1000$ (k) $\sqrt[3]{x} = 2$

(l) $\sqrt[3]{x} = 3$ (m) $x^2 \div 2 = 50$ (n) $x^2 \div 4 = 16$

3. Find the value of **x** in each example:

(a) $2x + 3 = 7$ (b) $3x - 2 = 7$ (c) $2x - 2 = x - 1$ (d) $3x + 4 = 13$

(e) $3x + 2 = 2x - 3$ (f) $x^2 + 1 = 5$ (g) $x^2 + 4 = 13$ (h) $x^2 - 2 = 14$

(i) $2x^2 - 5 = 27$ (j) $2x^3 - 4 = 50$ (k) $3x^2 + 9 = 36$ (l) $2\sqrt{x} = 10$

4. Calculate the value of each of the following expression if x = 2, y = 4 and z = 5:

(a) x^2 (b) x^3 (c) x^5 (d) y^3 (e) $y^{1/2}$ (f) $y^{3/2}$ (g) z^2 (h) z^3

5. Some calculator screens display the 'answer' of a calculation as $2^{\,03}$ which should be interpreted as 2×10^3. (That is: 2 multiplied by 10, three times = 2000).
It must **not** be taken to mean the same as 2^3 which means 2 x 2 x 2 (= 8).
For each of the following, write down what **number** is shown by the calculator screen in 'normal' form, (e.g. $2^{\,03}$ = 2000).

(a) $2^{\,04}$ (b) $3^{\,03}$ (c) $4.3^{\,05}$ (d) 2.3^{-03} (e) 9.7^{-04} (f) $6.73^{\,06}$

6. For each of these physics equations, change the subject of the equation:

(a) **F = ma**, so **a** = ? (b) **F = ma**, so **m** = ? (c) **v = fλ**, so **f** = ? (d) **v = fλ**, so **λ** = ?

(e) **Q** = **It**, so **I** = ? (f) **Q** = **It**, so **t** = ? (g) **V** = E/Q, so **E** = ? (h) **V** = E/Q, so **Q** = ?

(i) **a =** $(v-u)/t$, so **v =** ? (j) **a =** $(v-u)/t$, so **t =** ? (k) **v** = d/t , so **d** = ? (l) **v** = d/t , so **t** = ?

(m) **E** = **mgh** , so **m =** ? (n) **E** = $\frac{1}{2}mv^2$, so **m** = ? (o) **E** = $\frac{1}{2}mv^2$, so **v** = ?

(p) pV/T = **R**, so **p** = ? (q) pV/T = **R**, so **V** = ? (r) pV/T = **R**, so **T** = ?

Errors and Uncertainties

1. For the following sets of measurements, calculate, in each case

   (i) the **mean** and

   (ii) the **approximate random uncertainty**:

   (a) 10 N, 15 N, 13 N, 13 N, 14 N, 17 N, 11 N, 16 N

   (b) 2.3 m, 2.6 m, 1.9 m, 2.3 m, 2.0 m, 2.2 m, 2.2 m, 1.8 m, 2.5 m, 2.4 m

   (c) 510 g, 522 g, 508 g, 496 g, 498 g, 519 g, 509 g, 515 g

2. In each case, the **absolute uncertainty** in a measurement is stated.
   Calculate the **percentage uncertainty**.

   (a) (3.2 $^+/_-$ 0.2) m　(b) (4.8 $^+/_-$ 0.4) volts　(c) (0.83 $^+/_-$ 0.05) cm

   (d) (2100 $^+/_-$ 25) cm^3　(e) (6.2 $^+/_-$ 0.3) x 10^3 Ω　(f) (2.01 $^+/_-$ 0.02) A

3. State which situations would give **systematic**, **reading, calibration** or **random uncertainties**:

   (a) a thermometer constantly reading two degrees too high

   (b) a spread of readings of radioactive background count

   (c) a newton balance with a sticky barrel

   (d) an experimenter reading the pointer of an analogue voltmeter from one side

   (e) making a measurement with a metre stick to half of one millimetre

   (f) a meter which the manufacturer states is accurate to $^+/_-$ 2%

   (g) bathroom scales which have not been zeroed

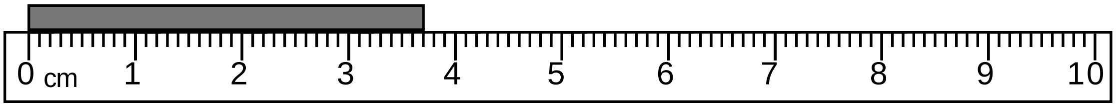
   (h) measurements, with the same digital balance, of the weight of a number of ‘identical’ peas

   (i) a pupil repeatedly reading the wrong scale on a dual scale meter

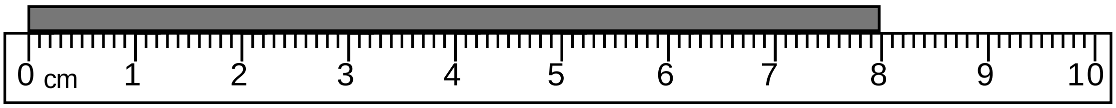
   (j) a class of pupils making individual measurements of the height of the room

4. State the **reading** and **uncertainty** in the form (reading $^{+}/_{-}$ uncertainty) for each of these measurements and calculate the **percentage uncertainty**:

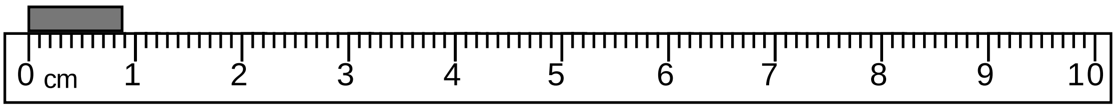
(a)



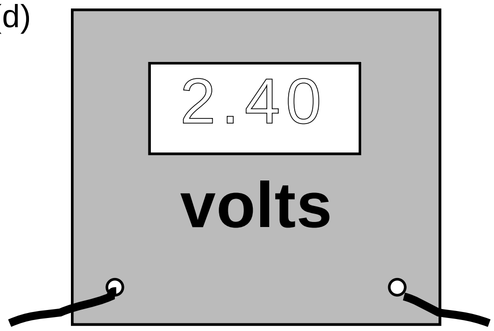
(b)



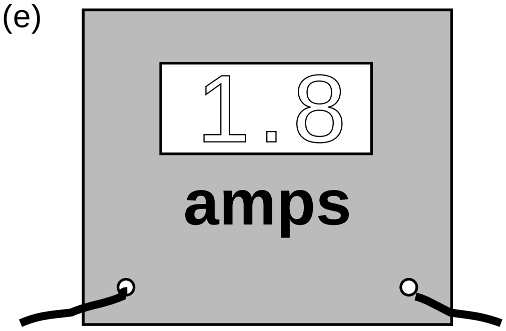
(c)



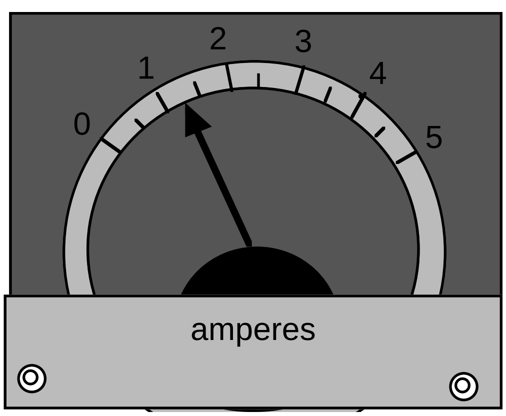
(d)



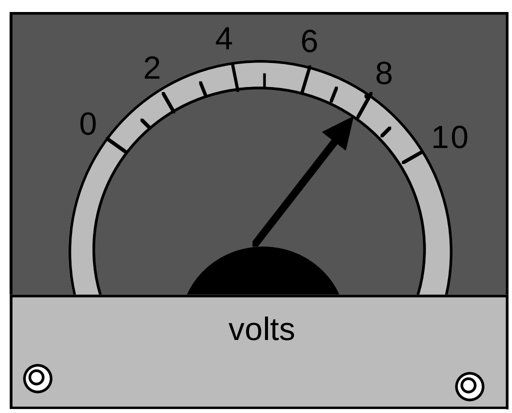
(e)



(f)



(g)



Answer File

Speed

1. 10; 330; 400; 3300; 1.5×10^9; 128; 300; 4; 50

2. 5.48 m/s 3. 105 m 4. 80 s 5. 10.8 km 6. 2 h 22 m

7. 3 h 6.3 m 8. 181 m/s 9. 18.8 m/s 10. 11 d 2 h

11. 12 h 12. 40 km/h 13. 37.5 km 14. 3 15. 0.05 s

16. (a) 0.1 m/s (b) 10 cm/s

17. 9.7 m/s 18. 19 m/s 19. 90 m 20. Yes, 61.6 m to stop 21. 10 h

22. 50 m/s 23. 1.54 m/s 24. 0.17 s 25. 9.46×10^{12} m

Acceleration

1. 4; -10; 25; 7.5; 2.0; 0.01

2. 5; 7; -2.5; -4; 0; 40; 12; 0; 10; 0; 5; 60; 40; 2; 10; 6; 7

3. 3.5 m/s^2 4. 5 m/s^2 5. 3 m/s^2 6. 22.5 m/s

7. (a) 4 mph/s (b) 1.8 m/s^2

8. -6 m/s^2 ; decelerating 9. 14 s 10. 10 m/s; no, initial speed not known

11. 17 m/s 12. 1.6 m/s^2 13. 250 cm/s^2; 2.5 m/s^2 14. 66.7 m/s^2

15. 9 s 16. - 17. 2500 m/s^2 18. 8×10^{-3} m/s^2

19. 2×10^{16} m/s^2 20. (a) 0.4 m/s (b) 3.4 m/s

Equations of motion

1. m/s 2. average velocity 3. 17 m/s 4. 12 m/s; 24 m

5. displacement; metre 6. 90 m 7. 16 m/s

8. initial velocity; extra velocity due to acceleration 9. 5 s

10. m/s 11. 20 m/s 12. 14 m/s 13. 4 s; back at starting position

14. 4 m/s^2 15. 6 s 16. 20 m 17. 40 m/s 18. velocity

19. 4 m further 20 8.9 m/s

21. 10.4 s; 38.5 m/s 22. 225 m 23. 75 m 24. displacement

25. 25 m/s; 125 m 26. 75 m 27. 9.5 m/s^2 28. 2 s 29. 12.2 m/s

30. 4 m/s^2 31. 250 m 32. 4 s; 50 m/s at 53^o to horizontal

33. 6.5 s 34. 27.5 m/s 35. 2.5 s 36. 10 m/s^2 down

37. 10 s; 3464 m 38. 900 m 39. 5 s; no 40. (a) 60 s (b) 60 s

Vertical Motion

1. (a) 10 m/s (b) 20 m/s (c) 30 m/s (d) 34 m/s (e) 6.0 m/s

2. (a) 5.0 m (b) 20 m (c) 45 m (d) 57.8 m (e) 1.8 m

3. (a) 3.0 s (b) 3.0 s

4. 16.2 m 5. 80 m 6. 1.4 s 7. 18 s; no

8. 3.75 m/s2 9. 2.6 m/s

10. (a) 20 m (b) 1.0 s

11. (a) 20 m/s (b) 30 m/s (c) 40 m/s (d) 44 m/s (e) 16 m/s

12. (a) 15 m (b) 40 m (c) 75 m (d) 91.8 m (e) 7.8 m

13. (a) 20 m/s up (b) 8.0 m/s down (c) 18 m/s down

(d) 22 m/s down (e) 6.0 m/s up

14. (a) 7.0 m up (b) 4.0 m up (c) 9.0 m down (d) 17 m down

(e) 5.4 m up

15. 3.0 s; 45 m 16. 39.2 m

17. (a) 44 m up; 12 m/s; up (b) 48 m up; 8.0 m/s; down

(c) 10 m/s2 down

18. (a) 10 m/s2 down (b) 2.0 s

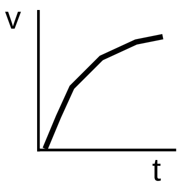
19. (a) 1.5 s (b) 11.25 m (c) 3.0 s (d) 20 m below top of well

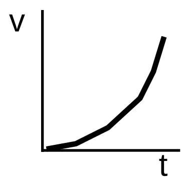
(e) 50 m

20. 16.2 m 21. 162 m 22. (a) 30 m/s (b) 45 m

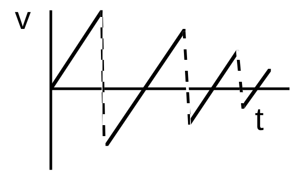
Graphs - straight line motion

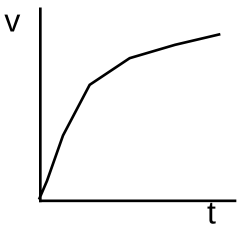
1. slope proportional to acceleration

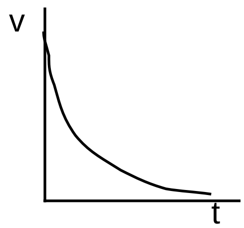
2. 

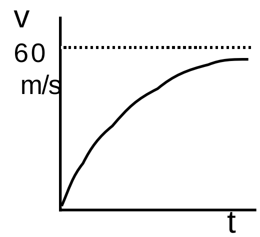
3. 

4. (a) distance
(b) displacement

5. 

6. 

7. 

8. 

9. straight line passing through origin

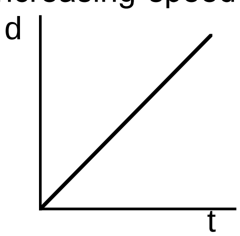
10. (a) change of momentum (b) change of velocity

11. (a) acceleration (b) speed

12. (a) force-time (b) speed-time (c) accel.-time

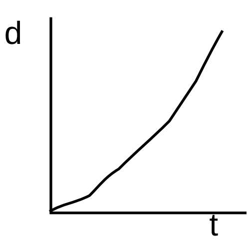
13. 2.5 m/s^2 14. not moving 15. constant speed

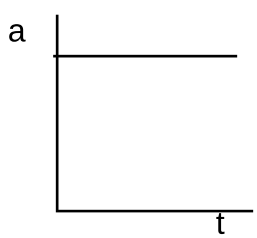
16. increasing speed 17. decreasing speed 18. constant velocity

19. 

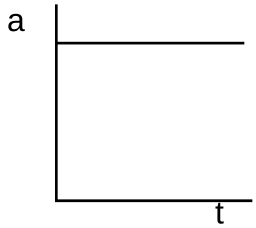
20. zero

21. constant acceleration from rest

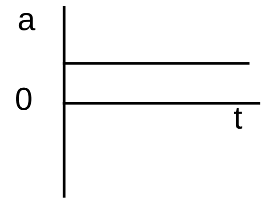
22. (a) 

(b) 

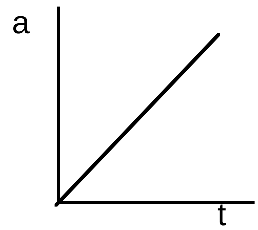
23. constant acceleration from a non-zero initial velocity

24. 

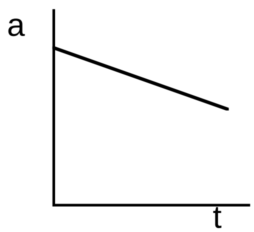
25. constant deceleration to rest

26. 

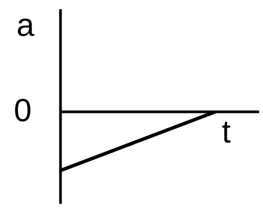
27. Increasing acceleration from rest

28. 

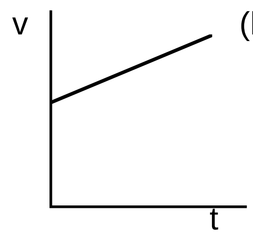
29. Decreasing acceleration from rest

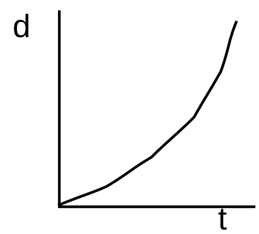
30. 

31. Decreasing deceleration to rest

32. 

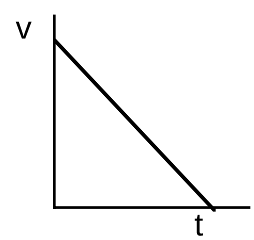
33. Constant acceleration

34. (a) 

(b) 

35. (a) A (b) A (c) A

36. both are uniform

37. 

38. Uniform acceleration for 5 seconds, then constant speed for 10 seconds followed by uniform deceleration over last 5 seconds.

39. (a) 50 m (b) 300 m (c) 15 m/s (d) 4 m/s^2

40. Uniform accel. for 5 s, then constant speed for 5 s, same accel. for further 5 s and finally uniform decel. to rest.

41. (a) 50 m (b) 150 m (c) 400 m (d) 20 m/s (e) 8 m/s^2

42. Uniform accel. for 10 s, then larger accel. for 5 s followed by uniform decel. to rest.

43. (a) 50 m (b) 125 m (c) 175 m (d) 8.75 m/s (e) 1 m/s^2 (f) 2 m/s^2

44. straight line; through origin 45. Kinetic energy against *square* of speed

46. velocity against time 47. distance against *square* of time

48. 3 m/s^2; 262.5 m

49. 2.5 m/s^2 ; 355 m; 11.8 m/s

50. (a) 2 m/s^2 (b) 100 m

51. (a) zero (b) 250 m

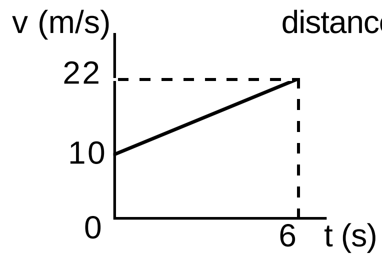
52. (a) -3 m/s^2 (b) 150 m

53. (a) 2.5 m/s^2 (b) 60 m

54. (a) -2 m/s^2 (b) 96 m

55. (a) 12 m/s (b) 22 m/s

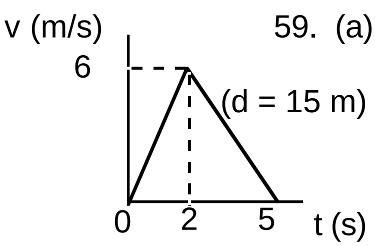
56.



distance = 96 m

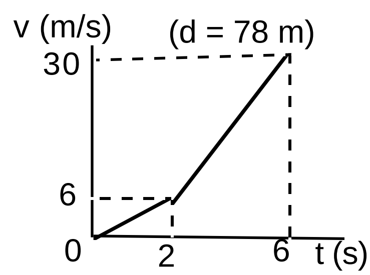
57. (a) zero
(b) zero

58.



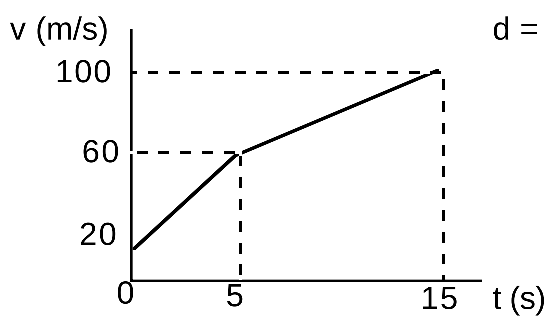
59. (a) 30 m/s (b) 30 m/s

60.



61. (a) 80 m/s (b) 100 m/s

62.



d = 1000 m

Using Vectors

1. -
2. weight & acceleration
3. speed & mass
4. -
5. -
6. (a) 7 km (b) 5 km 053^0
7. -
8. (a) 66 yards (b) 66 yards north
9. 3.2 m/s 18^0 to direction of rowing
10. 2.5 m/s 037^0
11. (a) 8.0 s (b) 3.6 m/s 56^0 to bank (c) 16 m west of B
    (d) 42 east of AB; 10.7 s

Resolving Vectors

1. -
2. (a) 0.50 (b) 0.87 (c) 0.87 (d) 0.50
   (e) 0 (f) 1.0 (g) 5.0 (h) 25
   (i) 42.4 (j) 42.4
3. (a) 7.4 N (b) 5.4 N (c) 2.7 m/s^2
4. A; vertical component of push adds to roller's weight
5. (a) 4.0 N (b) 9.0 N upwards
6. (a) 18 m/s at 30^0 to pitch (b) (i) 15.6 m/s (ii) 9.0 m/s upwards
7. (a) (i) 10 N (ii) 17.3 N (b) (i) 12 N (ii) 48.5 N
8. (a) (i) 18 m/s (ii) 24 m/s
9. 0 N (b); 71 N (a); 36 N (d); 134 N (c)

Projectiles

1. c; e; g; i; j (others all have at least one force, other than gravity acting)

2. horizontal 3. vertical 4. all 9.8 m/s^2 vertically

5. - 6. - 7. parabola 8. (a) 0.40 s (b) 24 cm

9. (a) 4.0 s (b) 15 m/s (c) 43 m/s at 69^0 below horizontal

10. 9.8 m/s^2 vertically down

11. (a) both 35.4 m/s (b) 0 m/s (c) 64 m

    (d) 9.8 m/s^2 vertically down (e) 7.2 s (f) 255 m

12. (a) 21 m/s at 29^0 below horizontal (b) 26 m/s at 45^0 below hor.

    (c) 30 m/s at 53^0 below horizontal (d) 35 m/s at 59^0 below hor.

    (e) 55 m/s at 71^0 below hor.

13. (a) 3.0 s (b) 50 m/s at 53^0 below hor. (c) 80 m

    (d) 120 m (e) 125 m (f) 10 m/s^2 vertically down

14. 60 m/s 15. 41 m/s at 56^0 below horizontal

16. (a) 7.0 m/s (b) 8.0 m/s at 29^0 below horizontal

17. (a) 34 m (b) 20 m/s at 41^0 below horizontal

    (c) 26 m above level of cliff (d) 8.1 s

    (e) 15 m/s horizontally; 9.8 m/s2 vertically down

18. (a) 37^0 (b) 2.4 s (c) 20 m/s

19. (a) 9.8 m/s^2 vertically down (b) 7.9 m

    (c) 14 m/s at 68^0 below horizontal 20. 65 m/s

21. (a) (i) 110 m (ii) 120 m (iii) 126 m (iv) 128 m

    (v) 126 m (vi) 120 m (b) 45^0

Unbalanced force

(a) 5 N right (b) 2 N right (c) 0 N (d) 2 N left (e) 6 N left

(f) 0 N (g) 3 N right (h) 0 N (i) 1 N left (j) 2 N right

(k) 2 N right (l) 1 N down (m) 8 N up (n) 0 N

F = ma (1)

(a) 2 m/s^2 right (b) 4 m/s^2 right (c) 0.5 m/s^2 left (d) 1 m/s^2 right

(e) 0 m/s^2 (f) 1 m/s^2 left (g) 2 m/s^2 right (h) 1.6 m/s^2 left

(i) 0 m/s^2 (j) 0 m/s^2 (k) 0.5 m/s^2 left (l) 10 m/s^2 down

(m) 1 m/s^2 up (n) 0.5 m/s^2 down

F = ma (2)

1. 0; 8; 1; 0; 10; 0.25; 2; 0.5   2. 112 N   3. 0   4. 800 N

5. 259 N   6. 3600 N   7. (a) 12 N (b) 12 N   8. 2.5 N

9. 4500 N; 2.5 m/s^2 10. 400 N   11. 3250 N   12. 550 N

13. 580 N   14. 30 kN   15. 450 N   16. (a) 0.3 m/s^2 (b) 420 N

17. (a) 1.6 m/s^2 ; 1920 N (b) 2370 N   18. 5 N; 2 m/s^2

19. (a) 0.75 m/s^2 ; 900 N (b) 900 N   20. 20 N   21. 0.5 m/s^2

22. -0.25 m/s^2 23. 600 N; 500 N   24. (a) 700 N (b) 0.7 m/s^2

25. (a) 0 N (b) constant velocity (c) acceleration of 0.5 m/s^2

26. (a) 5 N (b) deceleration of 0.05 m/s^2 (c) 10 s   27. 0.8 N   28. 8 N

29. 28 N   30. 2×10^4; 3000; 1000; 15; 800; 0.05; 10; 32

31. (a) 50 N up (b) 550 N   32. (a) 800 N (b) 800 N

33. 6.25×10^6 N   34. 100 N down   35. 875 N; 700 N

36. 630 N   37. (a) 60 N up (b) 460 N   38. (a) 120 N down (b) 680 N

39. (a) 120 N down (b) 480 N   40. (a) 80 N up (b) 1 m/s^2 up

41. (a) 60 N down (b) 1 m/s^2 down   42. 0.3 m/s^2 up

43. (a) 0 N (b) constant speed up or down or at rest   44. 600 N; 1.5 m/s^2 up

45. 510 N; 600 N   46. (a) 1 m/s^2 (b) 3 N   47. (a) 0.5 m/s^2 (b) 4 N

48. 3 m/s^2; 18 N   49. (a) 3 m/s^2 (b) 9 N (c) 9 N

50. (a) 1.5 m/s^2 (b) 6 N (c) 12 N (d) 9 N

51. (a) 0.5 m/s^2 (b) 2 N (c) 4 N

52. (a) 375 kN (b) 2.875 MN

53. (a) 6.9 kN (b) 10.6 kN   54. 30 tonnes   55. 1.4 N   56. 28000 N

Force diagrams

1. (normal) reaction; same size
2. lift; same size
3. -
4. (a) tension (b) difference between lengths of upthrust and weight vectors; downwards
5. upthrust; equal in size to weight
6. -
7. (a) three tensions (b) tension (up) and weight (down)
8. reaction (upwards)
9. tension
10. (a) tension in cords and reaction of wall (b) tension in cords

Blocks on Surfaces (1)

1. 2.5 m/s^2
2. 1.0 m/s^2; 2.0 N
3. 1.0 m/s^2; 3.0 N
4. 0.5 m/s^2; 2.0 N
5. 1.5 m/s^2; T_1 = 6.0 N; T_2 = 18 N
6. 4.0 m/s^2; 40 N
7. 2.0 m/s^2; m = 2.5 kg
8. 2.0 m/s^2; 4 kg
9. T_1 = 5.0 N; T_2 = 14 N
10. 0.5 m/s^2 left; T= 21 N
11. 2.0 m/s^2right; T_1 = 58 N; T_2 = 70 N

Blocks on Surfaces (2)

1. 1.0 m/s^2; 6.0 N
2. 4.0 m/s^2; 12 N
3. 2.0 m/s^2; 4.0 N
4. 1.0 m/s^2; 1.5 N
5. 1.0 m/s^2; 10 N
6. 2.0 m/s^2; 16 N
7. 1.0 m/s^2; 3.0 N
8. 1.0 m/s^2; 3.0 N
9. 3 kg; 10 N right
10. 6 kg; 6.0 N right

Blocks on Surfaces (3)

1. 0 m/s^2; 3.0 N
2. 1.0 m/s^2; 6.0 N
3. 2.0 m/s^2; 12 N
4. 2.0 m/s^2; 6.0 N
5. 0 m/s^2; 0 N
6. 1.0 m/s^2; 3.0 N
7. 2.0 m/s^2; 8.0 N
8. 2.0 m/s^2; 4.0 N
9. 0 m/s^2; 0 N

Hanging masses

1. 20 N   2. 50 N   3. 30 N each   4. 50 N each

5. T_1 = 60 N; T_2 = 40 N   6. T_1 = 80 N; T_2 = 60 N; T_3 = 40 N

7. T_1 = 25 N; T_2 = 25 N; T_3 = 20 N   8. T_1 = 40 N; T_2 = 15 N; T_3 = 15 N

9. T_1 = 80 N; T_2 = 20 N; T_3 = 40 N

Masses on surfaces

1. 27^o; 4.54 m/s^2 2. 20^o; 3.4 m/s^2 3. 38^o; 6.2 m/s^2

4. 50^o; 7.7 m/s^2 5. 27^o; 2.0 m/s^2 6. 20^o; 1.75 m/s^2

7. 38^o; 3.2 m/s^2 8. 50^o; 1.0 m/s^2

9. (a)(i) 38^o (ii) 42^o (iii) 18^o (b) no

10. 2.5 m/s^2; 7.5 N; 7.5 N   11. 0.33 m/s^2; 0.33 N; 0.33 N

12. 2.5 m/s^2; 5 N; 15 N   13. 1.5 m/s^2; 2.25 N; 4.25 N

Action and reaction

1. equal; opposite   2. same

3. should be “ force of apple on Earth”   4. force of gases on rocket

5. force on apple on Earth   6. cart pulling on horse

7. force of ball on foot   8. force exerted by Moon on Earth

9. force of water on compressed air

10. opposite to car’s motion; forward force of road on tyre

11. 250 N; opposite to direction of ball’s motion   12. 25 N down

Momentum

1. 20; 50; 20; 1500; 12; 500   2. 14000 kgm/s   3. 12 kgm/s

4. No loss of E_k 5. 2.4×10^8 kgm/s   6. 800 kgm/s   7. 2000 kgm/s

8. 1200 kg   9. 50 kg   10. 80 m/s   11. 28000 kgm/s   12. zero

13. 24 cm/s; 0.096 J   14. 10 cm/s to the right   15. 25 cm/s to the right

16. zero; zero   17. 2.4 m/s in direction of 1500 kg car

18. 20 cm/s; 0.35 J   19. (a) 0.5 kgm/s to right (b) 10 cm/s to right

20. (a) 0.5 kgm/s to left (b) 5 cm/s to left

21. (a) 2 m/s to right (b) 64000 J   22. 4 cm/s to right

23. (a) zero (b) 100 cm/s to right   24. (a) 12 cm/s (b) 0.054 J

25. 15 m/s up   26. 6 m/s to right   27. 0.6 m/s to left

28. 1 m/s to right   29. 2 m/s to left

30. (a) 4 kg (b) 6 J   31. 8 m/s; 192 kJ

Impulse and Momentum

1. - 2. kgm/s 3. vector; has direction

4. rate; change 5. newton-second (Ns) 6. vector; has direction

7. -

8. 1.0 & 1;0; 10 & 10; 10 & 10; 10 & 10; 0.10 & 0.10; 0.50 & 0.50; 1.0 & 2.0

   10 & 1.0; 50000 & 50; 5000 & 100; 0.005 & 0.20; 0.0002 & 5.0 $x10^{-4}$;

   2.0 $x10^{6}$ & 10

9. (a) 5.0 Ns (b) 5.0 kgm/s 10. (a) 8.0 Ns (b) mass

11. 5.0 Ns 12. (a) 2.0 kgm/s (b) 2.0 Ns

13. (a) 1.5 kgm/s (b) 1.5 Ns (c) time of contact not known

14. 1500 N 15. (a) 30 m/s (b) 450 N

16. impulse 17. -

18. (i) (a) 20 Ns (b) 10 m/s (c) 10 N

    (ii) (a) 10 Ns (b) 5.0 m/s (c) 5.0 N

    (iii) (a) 30 Ns (b) 15 m/s (c) 5.0 N

19. (a) 6.0 kgm/s left (b) (+) 9 kgm/s

Weight

1. 20; 45; 4.8; 33; 80; 300; 9.8; 3.7

2. (a) 15 N (b) 32 N (c) 5 N (d) 20000 N (e) 3.2×10^6 N (f) 10^5 N

(g) 0.35 N (h) 0.026 N (i) 3.5 N

3. 26 N/kg

4. 6.5 N/kg 5. 1.6 N/kg 6. 3 m/s^2

7. 26 N/kg; 3.7 N/kg; 9.8 N/kg; 11.3 N/kg

8. 90 kg; 144 N 9. 340 N; 85 kg 10. (a) 75 kg (b) 75 kg

11. (a) 80 kg (b) 784 N 12. 55 kg; 770 N 13. 0.23 N/kg

14. No; the craft and astronauts fall at same rate

15. (a) vertically down (b) vertically down (c) vertically down

16. (a) 800 N (b) 800 N (c) 800 N (d) 800 N 17. Child (4 N more)

18. (a) 90 kg (b) 90 kg (c) 3.7 N/kg 19. 60 N up; 3 m/s^2 up

20. 4.32 kg 21. (a) 2850 N (b) 5.7 m/s^2

Work

1. 50; 15000; 5; 30000; 200; 0.1; 900 2. 1000 J . 42 J

4. 24 N 5. None 6. 400 J 7. 3 kJ 8. direction 9. 20 m

10. 80 cm 11. 120 kg 12. 2 MJ 13. 10 km 14. heat

15. (gravitational) potential energy 16. kinetic energy

17. kinetic and potential energy 18. potential energy 19. 600 kJ

20. 45 J 21. 5 m 22. None; force not moved in its own direction

23. 225 kJ 24. 8000 N 25. 5700 N

Kinetic Energy

1. 1; 2; 25; 10; 4; 10; 0.02; 6; 10; 0.1 2. 157.5 kJ 3. 9 J 4. 5.3 m/s

5. 3 kg 6. 25 J 7. proportional; square 8. 180 kJ 9. 4 m/s

10. 20 m/s 11. 50 g 12. 12800 J 13. 4000 J 14. 1440 MJ

15. 1200 kg 16. 6 m/s 17. 10 m/s 18. 20 g

19. E_k increases by four times 20. 2000 J 21. 23 J 22. 1300 kg
23. 8.4×10^8 J 24. 60 kg 25. Energy against square of speed

26. (a) 10 m/s (b) 450 kJ (c) 75 kJ

Potential Energy

1. 60; 100; 1.2×10^7; 3; 2000; 10; 1.6; 50; 3.7 2. 6000 J 3. 2700 J

4. 2.45 m 5. 1200 J 6. 2400 J 7. approx. 48 kJ

8. (a) 6010 J (b) kinetic energy 9. 3 kg rock (18 J more) 10. 200 MJ

11. 30 J 12. 15 MJ 13. 15 m 14. 3.7 N/kg 15. 75 kg

16. 60 kg 17. 1800 J 18. 1.8 MJ 19 27 J

Potential Energy to and from Kinetic Energy

1. (a) 10 m/s (b) 10 m/s 2. (a) 15 J (b) 15 J (c) 10 m/s 3. 40 m/s

4. 0.45 m 5. (a) 2 m/s (b) 20 cm 6. 120 J 7. 100 J

8. 18 m/s 9. heat 10. 11.8 m/s 11. (a) 64 J (b) 8 m/s

12. 0.45 m 13. (a) 1.25 m (b) smaller; less E_p gained

14. (a) middle (b) highest point (c) elastic potential energy

Power

1. 50; 10000; 400; 10000; 2 x 10^8; 60; 0.002   2. 500 W   3. 450 kJ

4. 128 W   5. 1.5 kW   6. 300 s   7. 6 kW

8 (a) 2000 J (b) 400 W   9. 500 W   10. 50 mins   11. 18 kJ

12. (a) 12 N (b) 360 J (c) 72 J/s   13. T's = 4 x S's

14. 9 MJ   15. 0.2 W   16. 200 W   17. 3 m   18. 480 W

19. 30 s   20. 2 s   21. 25 W   22. 20 kW   23. 432 kJ

24. 150 W   25. 25 m   26. 31.5 kW

Efficiency

1. useful; total   2. output; total   3. heat

4. no; always some energy losses

5. can't get more energy out than put in   6. 60 %   7. 70 %   8. 8 %

9. 300 J   10. 720 J   11. (a) 6 % (b) 94 J   12. 3 mins.

13. 1.2 kW   14. (a) 120 kJ (b) heat   15. 250 W   16. 40 J

17. (a) 2 W (b) 67 %   18. 150 J   19. 7.5 W

20. (a) 2 J (b) 40 %   21. (a) 24 W (b) 18 W (c) 75%

22. 67 %   23. 63 %   24. 27 %

25. (a) 24 J (b) 20 J (c) 83 %   26. (a) 36 J (b) 20 N

27. 76 %   28. 50 kW   29. 84 %

Electrostatics

1. charge; gaining; losing   2. negative; positive   3. positive; negative

4. (a) pushed away (b) same (c) repel

5. (a) pulled towards rod (b) attract

6.

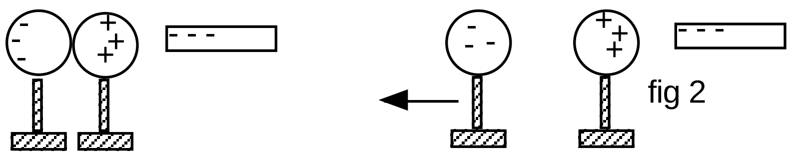


fig 1   fig 2

Charge = current x time

1. 30; 36; 30; 2400; 4; 5   2. 600 C   3. 36 C   4. 4 A   5. 50 s

6. 40 s   7. 1.35 C   8. 30 s   9. 45 mC   10. charge

11. 4320 C   12. 20 hours   13. 12 s   14. 0.72 C

15. 2.5 mA   16. 1800 C   17. (a) 7.5 C (b) 7.5 C

18. (a) lamp1: 10 C; lamp 2: 6 C (b) 16 C (c) 16 C   19. 20000 A

20. 300 mA   21. 6912 C   22. 1000 C   23. doubled

24. 150 C

Potential difference = energy ÷ charge

1. 12; 9; 12; 5000; 2025; 3450   2. voltage   3. work done; charge

4. 12 V   5. 25 V   6. 24 J   7. 3 V   8. 36 J   9. 15 J

10. 150 J   11. 18 mJ   12. 18 J   13. 2.5 C   14. volt

15. 6 V   16. 10^9 J   17. 1.2 V   18. 24 J   19. 3.2×10^{-16} J

20. 60 C   21. 9 V   22. 25 J   23. 2.4×10^{-4} J

24. 9.6×10^{-15} J   25. 7.5×10^6 m/s   26. 3×10^7 m/s

Ohm's Law

1. 6; 18; 20; 3; 0.05; 0.0036; 1.2; 230 2. 535 Ω 3. 2 A

4. 26.7 Ω 5. 1.33 A 6. 9 V

7. (a) 0.15 A (b) 0.75 mA (c) 1.5 mA 8. 12.5 Ω

9. 4.5 μA 10. resistance increases with temperature

11. current; proportional; temperature 12. straight line through origin

13. resistance 14. 20 Ω 15. increases 16. 24 Ω

$P = IV = I^2R = V^2/R$

1. 60; 2300; 20; 4; 12; 6 2. 8.7 A 3. approx. 60 W

4. 0.5 W 5. 12 V 6. 200 W 7. 10 Ω 8. 1000 W

9. 40 W 10. 9.1 A 11. 10 A 12. 192 W

13. 960 W 14. 100 W 15. power 16. 960 Ω 17. 500 W

18. 720 W 19. 8 % 20. 176 Ω 21. 4 x

22. watt 23. approx. 320 mA

24. (a) 30 W (b) 200W (c) 135 W 25. 1000 J 26. 690 W

27. 2.7 A 28. 26 Ω 29. 146 mA

Combinations of resistors

1. 9 Ω; series 2. 1350 Ω 3. 4 Ω 4. 480 Ω 5. 5 Ω; parallel

6. 2 Ω 7. (a) 1 kΩ (b) 3 Ω (c) 8 Ω

8. (a) 1 Ω (b) 5 Ω (c) 40 Ω

9. (a) 10 Ω (b) 2 Ω

10. (a) 10 Ω (b) 15 Ω

11. (a) 3 Ω (b) 4 Ω (c) 4 Ω

12. (a) 6 Ω (b) 12 Ω (c) 8 Ω

13. (a) 2 Ω (b) 3 Ω 14. (a) 20 Ω (b) 5 Ω

15. 60 Ω 16. less 17. 20 Ω 8. 0 Ω

19. (a) infinite (b) 0 Ω 20. 100 Ω 21. 20 Ω 22. 3 V; 3 V

23. 6 Ω in parallel with 3 Ω in parallel with two 1 Ω resistors in series

24. 60 Ω; 30 Ω 25. 2 Ω 26. 12 Ω; 4 Ω

27. 10 Ω in series with parallel combination of others

28. 10 Ω in series with parallel combination of other two

Circuit Rules

1. series with lamp; as low as possible

2. parallel with lamp; as large as possible

3. ammeter should be in between resistors and in series with them

4. voltmeter should be connected across both ends of resistor A

5. (a) P = 3 A; Q = 3 A (b) P = 1 A; Q = 3 A

6. (a) 2 V (b) 3 V

7. A_1: 2 A; A_2: 3 A; V_1: 2 V; V_2: 4 V

8. A_1: 0.3 A; A_2: 0.2 A; A_3: 0.6 A; V_1: 3 V; V_2: 1 V; V_3: 3 V

9. voltmeter used instead of ammeter

Circuits

1. (a) lamps light (b) both lamps off (c) series

2. (a) both lamps light (b) lamp B stays on (c) parallel

3. (a) none (b) none (c) all lamps lit (d) A

4. (a) resistor (b) fuse (c) earth (d) ammeter (e) cell

5. (a) S1 (b) S1 and S2 (c) not possible

6. (a) parallel (b) no (c) S1 and S2 *or* S3 (d) all switches

   (e) yes, either or both

7. (a) on (b) off then on again (c) off

8. (a) diode (b) microphone (c) voltmeter (d) battery (e) variable resistor

9. (a) no, diode blocks current (b) yes, diode conducts

10. speed increases because full 12 volts now across motor.

11 - 24 (answers not supplied)

General circuit problems

1. watt 2. ohm 3. 225 J 4. 0.5 mA

5. 7.5 Ω in series with parallel combination of 5 Ω and 2 Ω and 3 Ω in series

6. 1.2 kΩ 7. 2 Ω 8. 3.33 V 9. parallel; series 10. parallel

11. 0.1 A 12. 3.4 V 13. same at all points

14. yes, if two are in parallel 15. ampere 16. coulomb

17. 2 A; 12 V 18. 2.5 C 19. 8.2 V 20. 0 to 8 volts

21. 20 V; 1 A 22. 4 V

Internal Resistance

1. electromotive force 2. volt 3. ohm 4. volt

5. terminal potential difference

6. (a) drops (b) difference between voltmeter readings (c) current

7. open; no current drawn from cell

8. (a) 1.65 V (b) 0.13 V 9. -

10. (a) 1.55 V (b) 1.40 V (c) 1.32 V (d) 0.30 V
11. heat

12. (a) 4 V; 2 Ω (b) 6 V; 3 Ω (c) 2 V; 0.5 Ω (d) 6 V; 1.5 Ω

13. (a) 1.5 V; 0 A (b) 1.2 V; 0.3 A

14. (a) 2.0 V; 0 A (b) 1.9 V; 0.2 A

15. (a) 1.2 V; 0 A (b) 1.08 V; 0.6 A

16. (a) 0.20 V (b) 0.80 Ω (c) 5.20 Ω

17. (a) 0.40 A (b) 1.6 V (c) 9 Ω 18. 0.2 A; 1.2 V

19. (a) 1.5 V (b) 0.3 A; 1.2 V (c) 0.5 A; 1.0 V

20. (a) 0.20 A (b) 0.04 W (c) 1.8 V

21. (a) 0.50 A (b) 0.20 W (c) 1.1 V

22. (a) 1.02 A (b) 0.18 A

23. 0.89 Ω

24. Ammeter reading falls, voltmeter reading increases

25. (a) 1.0 W (b) 1.8 W (c) 720 W

26. (a) - (b) e.m.f. (c) (negative of) internal resistance

27. (a) - (b) (negative of) internal resistance (c) e.m.f.

28. (a) 6.0 V (b) 2.0 Ω 29. - 30. - 31. -

32. (a) - (b) - (c) - (d) e.m.f.

(d) (negative of) internal resistance

Voltage or Potential Dividers

1. -

2. (a) (Voltage across) R_1 is 5.0 V; R_2 is 5.0 V

   (b) R_1 is 8.0 V; R_2 is 2.0 V

   (c) R_1 is 3.0 V; R_2 is 9.0 V (d) R_1 is 20 V; R_2 is 30 V

   (e) R_1 is 4.0 V; R_2 is 1.0 V (f) R_1 is 14.4 V; R_2 is 5.6 V

3. (a) 0 - 8 V (b) 0 - 2.0 V (c) 0 - 3.0 V (d) 0 - 10 V

   (e) 0 - 4.0 V

4. (a) 6.0 V (b) drops; smaller resistance (c) 4.0 V

5. AB - 2 V BC - 4 V CD - 6 V AC - 6 V BD - 10 V AD - 12 V

6. (a) 0 V (b) 2.0 V (c) 1.5 V

7. (a) 6.0 V; 4.0 V (b) 5.0 V; 4.0 V (c) 9.6 V; 6.0 V

   (d) 4.0 V; 6.0 V

8. (a) 9 V; 7.2 V; 3.0 V (b) 600 Ω

Wheatstone Bridge

1. potential 2. potential difference

3. (a) 3.0 V (b) 3.0 V

4. (a) (+) 1.5 V (b) - 1.5 V 5. not equal 6. equal

7. P/Q = X/R 8. no change 9. adjust to balance bridge

10. - 11. 63(Ω); 102; 5; 125; 14; 41.5; 0.20; 8860

12. (i) yes (ii) yes (iii) no (iv) yes (v) yes

13. (a) P/R = Q/S (b) S/R = Q/P (c) PS = QR

(d) Q = PS/R (e) R = PS /Q (f) S = RQ/P

(g) P = RQ/S

14. (a) 200 Ω (b) 80 Ω (c) 125 Ω (d) 32.3 Ω

(e) 332 Ω (f) 5.23 Ω

15. unbalanced 16. zero 17. adjust to balance bridge

18. X/R = l/(100 - l) 19. 70.0cm,25.7Ω; 50.0 cm;120Ω; 40.0 cm, 36Ω;

54.5 cm, 419Ω; 43.6 cm,329Ω; 50.0 cm, 98Ω; 54.3 cm, 699Ω; 47.7 cm, 2289Ω

20. no change 21. - 22. - 23. direct proportion

24. yes 25. accurate 26. (a) temperature (b) light level

27. reverse reading (+ to - or vice versa)

Household Electricity

1. 6; 15; 1; 4; 80; 5; 500 W; 3 kW; 100 W 2. 4 kWh; 28 p

3. 40 hours 4. 800 W 5. 100 hours 6. 3 600 000 J

7. 2.5 kWh 8. lamp cheaper (7.2 kWh and fire 7.5 kWh) 9. 14 p

10. 100 hours 11. £76.44 12. 1 kW 13. 450 units; 150 hours

14. (a) 10 A (9.2 A) (b) 3 A (0.42 A) (c) 13 A (12. 5 A) (d) 5 A (4.2 A)

(e) 10 A (5.4 A)

15. protects wiring from overheating 16. melts

17. metal case; makes fuse melt if case becomes 'live'

18. brown and blue only

19. earth wire; plastic not conductor so cannot be 'earthed'

20. plastic not conductor so unsuitable for 'earthing' current

21. 23.3 A 22. 1200 W

23. thicker; carries larger current before melting

24. fuse becomes warm and is attached to live pin

25. live; cuts off high voltage if melts

26. live; cuts of live voltage when switch is 'off'

27. could electrocute person if casing touched

Alternating current and voltage

1. number of cycles in unit time (second)

2. (a) 60 (b) 300 (c) 600 (d) 30 (e) 7200

3. 50 Hz 4. 88 Hz

5. (a) (i) 2.5 V (ii) 5.0 V (iii) 12.5 V (iv) 25 V

   (b) (i) 25 Hz (ii) 50 Hz (iii) 250 Hz (iv) 500 Hz

6. (i) 50 Hz (ii) 100 Hz (iii) 500 Hz (iv) 1000Hz

7. 0 V 8. root mean square

9. (a) 3.5 V (b) 7.1 V (c) 110 V (d) 240 V (e) 230 V

10. (a) 2.1 V (b) 4.2 V (c) 10.6 V (d) 21 V

11. (a) 20 V (b) 300 V (c) 10 V (d) 282 V (e) 57 mV

12. 14.2 V 13. 20 V 14. 7.1 A 15. -

16. ‘height’ is 2..8 divisions; length of one whole cycle is 4 divisions

Electromagnetism

1. magnetic field 2. (a) - (b) reverses 3. decreases

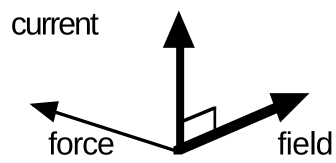
4. (a) switch closed (b) larger voltage *or* more coils wound on core

5. doesn't become permanently magnetised; magnet can be switched on and off

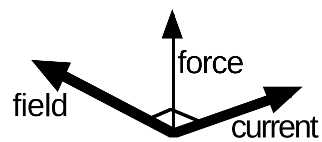
6. (a) 90° to both (b) reverse current *or* field (c) increase current *or* field strength

7.

(a)



(b)



8. (a) arrow same size; pointing downward (b) current in opposite directions (c) commutator

9. (a) electromagnets (b) magnetised core increases field (c) smoother running

10. change; magnetic; e.m.f.

11. (a) force pushes against opposing field set up by induced current

(b) force needs to be moved to do work

13. (a) B to A (b) deflect to other side (c) zero

(d) stronger field; faster motion; two or more loops of wire moved through field

14. magnets arranged with *same poles* facing 15. direction; e.m.f.; oppose

16. (a) north (b) north opposes motion of magnet etc.

(c) work done by force in moving magnet (d) south

17. would accelerate magnet, producing kinetic energy without any work being done

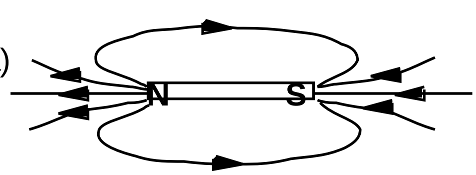
18. induced e.m.f. always acts against motion of pedals which produce it etc.

19. (a) changing flux in coil (b) none (c) none

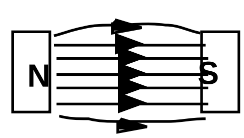
20. (a) changing field round left coil causes changing flux in second coil (b) transformer

21.

(a)



(b)



22. wind coil of conducting wire round core, supply current to it with batter

Transformers

1. 500; 200; 600; 20; 10; 240 2. 200 3. 5750

4. (a) 80 V (b) 12 V (c) 0 V (d) 10 V (e) 400 V (f) 120 V

5. equal 6. 24 W 7. 0.1 A 8. (a) 4 A (b) 0.21 A

9. 29; step-down 10. 479

11. (a) 72 V a.c. (b) 0 V (c) 1380 V a.c. 12. 12 V a.c.; 50 Hz

13. 5000 V a.c.; 50 Hz 14. 0 V 15. (a) 30 W; 24 W (b) 6 J

16. (a) 0.1 J (b) 83.3 % 17. 0.1 A, 0.4 A

Power Transmission

1. (a) 2 A; 4 W (b) 0.2 A; 0.04 W 2. low power loss

3. (a) 20 kW (b) 0.02 W

4. (a) 2 A (b) 8 J (c) 8 V (d) 16 W (e) first steps voltage *up* by factor of 10 from supply, second steps voltage *down* by factor of 10 at lamp end of wire

Electric fields

1. 20 V

2. (a) 40 V (b) 6.4×10^{-18} J (c) 3.8×10^{6} m/s

3. (a) 8.0×10^{-17} J (b) 1.3×10^{7} m/s 4. (a) 4.5×10^{7} m/s (b) 5800 V

Capacitance

1. 2.0×10^{-6} F; 2.0×10^{-3} F; 1.0×10^{-4} F; 0.6 C; 1.35×10^{-11} C; 12 V; 200 V

2. (a) 2.0 μF (b) 16 μF (c) 10 μF (d) 0.1 μF

3. - 4. 8.0 μF 5. (a) 10μF (b) 3.0×10^{-5} C

6. 9.0×10^{-4} C 7. 1.5×10^{-12} C

8. (a) 0.012 C (b) 0.012 C 9. (a) 5000 F (b) +0.06 C

10. 0.09 C 11. (a) right side circuit (b) - 12. - 13. 0.36 J

14. 3.24×10^{-4} J 15. 12 V 16. (a) 0.041 J (b) 0.041 J

17. 0.012 C 18. capacitance 19. energy (stored)

20. (A) (a) 1.0 μF (b) 5×10^{-5} J (B) (a) 20 μF (b) 1.44×10^{-3} J

21. (a) 9.0 mA (b) 12 mA 22. (a) 3.0 mA (b) 3.0 V

23. 1.0 mA 24. (a) 8.0 s (b) 4.0 kΩ 25. 0.072 J

26. (a) 5.8 V (b) 5.8×10^{-3} C (c) 8.4 mA 27. (a) 10 mA (b) 5.0 mA

28. charge 29. equal areas (same total charge) 30. -

31. (a) 9.0 V (battery voltage) (b) - (c) -

32. 12 V 33. (a) (i) 7.0 V (ii) 5.5 V (iii) 2.8 V (iv) 0.7 V

(b) 4.5 mA

(c) 9.0 V (d) 0 V (e) 0.0198 C (f) 1.5 mA

34. - 35. (a) reactance decreases as capacitance increases

(b) reactance decreases as frequency increases

36. straight line through origin

37. (a) increases (e.g. less opposition to current) (b) decreases

38. (a) position X (b) - (c) - 39. (a) - (b) 9.0 V

40. (a) - (b) $V/(R1 + R3)$ (c) $V/(R2 + R3)$

(d) no effect (e) 1.8×10^{-4} C (f) 8.1×10^{-4} J

Electronics

1. process 2. thermistor, microphone, LDR, pressure switch

3. (a) 7 V (b) 2 V (c) 10 mA (d) 200 Ω 4. 400 Ω 5. 5 V

6. battery *or* LED connected 'wrong way round' 7. value of 'R' too large

8. 50 μA 9. 500x 10. 20 μA 11. (a) (i) 0 V (ii) 6 V (b) (i) 6 V (ii) 0 V

12. (a) ON (b) ON (c) transistor and LED switch OFF 13. Reverse 'R' and 'S'

14. (a) increases (b) decreases (c) 2.6 V 15. No, would do opposite

16. (a) increases (b) decreases (c) 2.8 V 17. (a) - (b) value of 'R' increased

18. (a) zero (b) increases quickly then more slowly (c) 9 V

19. (a) value of 'R'; value of 'C' (b) increase value of 'R' or 'C'

20. (a) battery (b) curve should reach same voltage but take longer

21. (a) decreases (b) increases (c) 3.6 V 22. (a) - (b) increase value of 'R' or 'C'

23. 0; 0 24. 0; 1; 0; 1,1 25. 0; 1; 1,1; 1,1 26. (a) NOR (b) NAND

27.

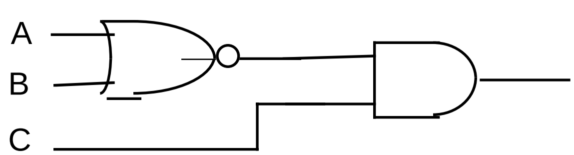
INPUTS			OUTPUTS	
A	B	C	D	Z
0	0	0	0	0
0	0	1	0	0
0	1	0	0	0
0	1	1	1	1
1	0	0	0	1
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

28.

INPUTS			OUTPUTS		
A	B	C	D	E	Z
0	0	0	1	0	0
0	0	1	1	1	1
0	1	0	1	1	1
0	1	1	1	1	1
1	0	0	0	0	0
1	0	1	0	1	0
1	1	0	0	1	0
1	1	1	0	1	0

29. use OR gate 30. NOT gate on sensor and AND gate

31.



Analogue Electronics

1. -   2. (a) 0 V (b) - 2.0 V (c) - 5.0 V (d) - 10 V (e) 4.0 V

(f) 12 V (g) 7.0 V (h) - 14 V approx. (saturation) (i) + 14 V (sat.)

3. (a) 0 V (b) - 2.0 V (c) - 5.0 V (d) - 9.5 V (e) 2.0 V

(f) 12 V (g) 7.0 V (h) - 14 V (saturation) (i) 14 V (sat.)

4. (a) (i) 0 V (ii) - 3.0 V (iii) - 5.4 V (iv) 3.6 V

(v) 8 V approx. (saturation) (vi) - 8 V (saturation) (b) (v) would be 12 V

5. 120 kΩ   6. (a) 0.20 V (b) - 0.15 V (c) - 3 mV (d) 0.05 V

(e) 0 V (f) 2 μV (g) - 0.24 V

7. (a) 10 kΩ (b) 20 kΩ (c) 50 kΩ (d) 5 kΩ (e) 100 kΩ (f) 1 kΩ

8. (a) 50 mV (b) 200 Ω

9. (a) 1 kΩ (b) 2 kΩ (c) 5 kΩ (d) 10 kΩ (e) 12 kΩ (f) - 14 V

10. (a) - 12 V (b) - 6.0 V

11. (a) 1 & 10 (b) 5 & 500 (c) 100 & 5 *or* 20 & 10 (d) 5 & 20

12. (a) - (b) square wave (due to saturation)   13. -   14.-   15. 0.08 V approx.

16. (a) 10 - 0 - 10 volts approx. (b) approx. 8 to 9 times

17. (a) 30 kΩ (b) inverted   18. (a) - (b) output is (inverse) sum of inputs

19. (a) 0 V (b) - 2.0 V (c) 2.0 V (d) 0 V

(e) - 9.0 V (f) - 1.0 V (g) - 6.0 V (h) 1.0 V

20. (a) 0 V (b) - 3.0 V (c) 3.0 V (d) - 1.0 V

(e) - 10 V (f) - 6.0 V (g) - 6.0 V (h) - 3.0 V   21. -

22. (a) - (b) (i) 2.0 V (ii) 0 V (iii) - 1.0 V (iv) 0 V

(v) 7.0 V (vi) - 8.0 V (vii) 6.6 V (viii) 14 V (sat.)

23. (a) (i) 1.0 V (ii) 2.0 V (iii) 0.50 V (iv) 1.0 V

(v) 5.0 V (vi) 0.20 V (vii) 10 V (viii) 14 V (saturation)

(b) all negative, same magnitudes

Speed of sound

1. (a) 340 m (b) 680 m (c) 3570 m (d) 170 m (e) 0.34 m 2. 1500 m/s

3. 4.5 s 4. (a) 2500 m (b) 2 ms 5. 5.1 km

6. (a) - (b) 850 m 7. 0.29 s 8. 238 m

9. 270 m/s 10. (a) 309 m/s (b) -

Speed of light

1. (a) 300 000 000 m/s (b) 300 000 km/s 2. 185 000 miles per second

3. (a) 6×10^8 m (b) 1.05×10^9 m (c) 3×10^7 m (d) 6×10^6 m

(e) 3000 m (f) 1230 m

4. (a) 4 s (b) 0.5 (c) 10^{-5} s (d) 2×10^{-6} s (e) 3.15×10^7 s

5. 2×10^8 m/s 6. 3.84×10^8 m 7. 0.24 s 8. -

9. 8.33 min 10. 6.3×10^{11} m 11. 3.25 ms

$V = f\lambda$

1. 25; 1; 100; 2; 150; 4.8; 620; 9×10^7 2. 45 3. 1280

4. 0.017 s 5. 1 kHz 6. 4 cm 7. 0.02 s; period

8. 1.33 Hz 9. 0.2 s 10. 0.25 s 11. 0.25 Hz 12. 512 Hz

13. 1.7 m 14. 0.05 m 15. 5 m 16. 5200 m/s

17. (a) 2.5×10^{-5} s (b) 8.5 mm 18. 7.5×10^{-4} m 19. 2.65 m

20. 10 cm/s 21. decreases 22. (a) 3.0 m/s (b) 1.5 s (c) 1.0 m

23. 18 mm; 7.3 cm 24. 4.4×10^{14} Hz 25. 1515 m

26. 3×10^{-11} m 27. 909 kHz 28. 261 m 29. 2.95 m

30. 200 kHz 31. 5×10^{14} Hz 32. 1.5×10^{-10} m

33. 3 mm; 10^{-11} s 34. - 35. 200 km

Wave properties

1. - 2. (a)-(d) no effect 3. (a)-(c) no effect (d) concave after reflection

4. focus *or* focal point 5. return after reflection as plane parallel waves

6. - 7. (a) emerge as circular waves (b) straight wave fronts with curved edges

8. -

9. refraction - change of wave *speed* in moving into different medium;
diffraction - bending round edge of obstacle, with *no change* in wave speed.

10. - 11. destructive interference 12. constructive interference

Waves and Interference

1. same 2. time for one cycle 3. f = 1 ÷ T

4. 0.5 Hz 5. (a) 10 Hz (b) 0.10 s 6. -

7. (a) D (b) D (c) D (d) A & C (e) A & B

8. Interference

9. same frequency (wavelength) and constant phase difference

10. (a) diagram A (b) destructive interference (c) diagram A
(d) diagram B

11. -

12. (a) constructive (b) constructive (c) destructive
(d) destructive (e) constructive (f) destructive
(g) constructive

13. (a) constructive (b) destructive (c) constructive
(d) destructive (e) constructive

14. (a) 8.0 cm (b) 4250 Hz (c) 50 cm

Properties of light

1. (a)-(c) reflected rays all at same angle to *normal* as incident rays

2. reflection 3. -

4. (a) diagram 'b' (b) diagrams 'a' (at infinity) and 'c'

5. same distance from mirror

6. (a) right side appears on left and vice versa (b) - 7. -

8. real image - mirror 'a'; virtual image - mirror 'b'

9. refracted ray should be parallel to first ray

10. bends *towards* the normal 11. -

12. ray refracted into air in 'left' diagram; other ray is totally internally reflected

13. total internal reflection (T.I.R.) 14. -

15. blue ray refracted through larger angle than red 16. blue 17. constant

18. decreases 19. 1.37 20. (a) reflected (b) refracted into air 21. 0.52^{o}

22. 2×10^{8} m/s 23. 48.7^{o} 24. 391 nm 25. 49.5^{o}

26. 42^{o} 27. 1.44 28. 24.6^{o} 29. 34.5^{o}

30. 1.33 31. 1.61 32. 1.95×10^{8} m/s 33. 1.58

34. 59^{o} ray refracted into water; 63^{o} ray totally internally reflected at surface

35. 66.2^{o} 36. 2.26×10^{8} m/s, 77^{o} to normal 37. 49.7^{o}

38. 1.97×10^{8} m/s; 286 nm 39. 1.48 40. 70.2^{o}

41. 4.9×10^{-7} m; 3.8×10^{14} Hz 42. 1.88×10^{8} m/s; 4×10^{14} Hz; 4.7×10^{-7} m 43. -

44. - 45. Lens B focal length shorter 46. Lens B

47. (a) 5 cm (b) 40 cm (c) 10 cm (d) 7.1 cm (e) 50 cm 48. +2.5 D 49. +5 D

50. 10 cm lens 51. does not really exist, just *appears* to 52. diverging 53. -

54. (a) 5 cm (b) - 55. - 56. - 57. - 58. - 59. - 60 -

Ray diagrams

1. (a) same size, distance, inverted, real

   (b) enlarged, further from lens, inverted, real

   (c) diminished,closer, inverted, real

   (d) enlarged, image at ‘infinity’, upright, virtual

   (e) diminished, closer, upright, virtual

2. infinity 3. (b) and (d) 4. (c) and (e)

5. twice focal length from lens 6. same orientation, enlarged, virtual

7. closer than principal focus

8. (a) same size, distance, inverted, real

   (b) enlarged, further from lens, inverted, real
   (c) enlarged, further from lens, on same side as object, upright, virtual

   (d) diminished, closer and on same side as object, upright, virtual

9. (a) 40 cm from lens, 2 cm tall, real (b) 60 cm from lens, 4 cm tall, real

   (c) 20 cm from lens, 4 cm tall, virtual (d) formed at ‘infinity’, virtual

   (e) 6.67 cm from lens, 2 cm tall, virtual (f) 40 cm from lens, 25 cm tall, virtual

10. - 11. 4.5 cm 12. half size 13. 8 cm from lens

14. upright, virtual

Grating equation

1. - 2. (a) 0.0033 mm (b) 3.33×10^{-6} m

3. (a) 0.0017 mm (b) 1.67×10^{-6} m

4. (a) 644 mm (b) 50.5^{0} 5. (a) 546 mm (b) 21.3^{0}

6. (a) 7.0^{0} (b) 14.1^{0} (c) yellow

7. (a) 1.25×10^{-6} m (b) 800 lines per mm

8. (a) 0.06^{0} (b) larger

Inverse square law

1. - 2. - 3. (a) 20; 3.2

4. (a) (i) 16000 (ii) 2560 (iii) 256 000 (b) 4.0 m

5. 4 m

6. (a) 128 μSvh^{-1} (b) 8 m (c) 11.3 m

Specific heat capacity

1. 84000; 84000; 20; 50; 20; 0.25; 4200; 450 2. 4400 J/kgK

3. 68040 J 4. (a) 240 kJ (b) 4 mins

5. (a) 9.24 MJ (b) 51 min 20 s 6. 2100 J/kgK 7. 440 J/kgK

8. 50^{o}C 9. 94.5 kJ 10. 42240 J 11. 819 J

12. 130 J/kgK 13. per unit mass 14. 40^{o}C 15. 10.5 mins

16. 24^{o}C 17. 3 min 9 s 18. 104^{o}C

19. (a) 16.6 MJ (b) 55 mins.

Specific latent heat

1. 668000; 167000; 10; 0.4; 835000; 452000; 130000; 290000

2. 1.17 x 10^{6}J 3. 200400 J 4. 904000J 5. 100^{o}C

6. 20.3 g 7. 50 g 8. (a) 55 g (b) 50 s

9. (a) 0^{o}C (b) in equilibrium with ice

10. (latent) heat in steam over and above heat in boiling water

11. (a) suspension of tiny water droplets in air (b) inside spout

12. 64000 J/kg 13. 294000 J/kg 14. melting ice (48090 J) > boiling water (45200 J)

15. vinegar (390 kJ/kg) > benzene (400 kJ/kg)

16. (a) cooling water - freezing water - cooling ice (b) 0^{o}C

(c) -18^{o}C, same as freezer 17. (a) - (b) 81^{o}C (c) 24^{o}C

Density

1. 1000; 1.43; 7500; 5; 50; 3.2×10^8 2. (a) 13.6 (b) 13600

3. (a) 13.6 (b) 13600; mercury   4. 1200 kg/m^3 5. 38 cm^3

6. 2.2 cm^3 7. 8900 kg/m^3 8. 34 N   9. 170 N; 17 litres

10. sinks; density = 1.22 g/cm^3 11. floats; density = 0.92 g/cm^3

12. 1.25 kg/m^3 13. 73.8 kg

14. (a) 1480 kg/m^3 ;1480 g/litre (b) 270 cm^3 15. 50 cm^3

16. 8.96 g/cm^3 17. 474 g   18. 0.24 g/cm^3 19. 11.5 g/cm^3

20. 19.3 g/cm^3 ; it *is* gold   21. 0.42   22. 562.5 tonnes

23. 5 cm

24. (a) 50 kg (b) 0.83 g/cm^3 (c) float; density less than that of water

25. 135 g   26. 35 cm^3

Pressure

1. 5; 25000; 4×10^{10}; 4×10^{-3}; 4×10^{-4}; 2; 5000; 10000

2. (a) pA (b) F ÷ p   3. (a) 10 kPa (b) 20 kPa

4. 3.75×10^7 N   5. (a) 0.1 (b) 1000

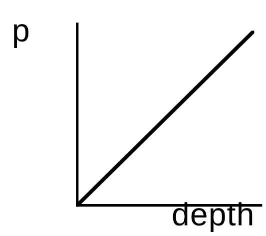
6. 900 N   7. (a) 670 Pa (b) 150 times smaller   8. 80 N

9. Shuffling; larger area in contact with ice, so less pressure exerted.

10. (a) 1550 Pa (b) 5128 Pa   11. 1.14×10^7 Pa   12. -

13. 10^5 Pa
]

14. 5 cm   15.



16. 4500 Pa   17. 1.5 m

18. 26 kPa above atmospheric pressure   19. 9804 m   20. newton

Buoyancy and Flotation

1. pressure directly proportional to depth   2. straight line through origin
3. pressure directly proportional to density   4. straight line through origin

5. upthrust; weight; displaced

6. (a) displaces 20000 t of water (b) 20000 tonnes

7. -   8. -   9. -   10. 15cm^3 11. -

12. (a) hot and low salinity (b) -   13. (a) no (b) -

14. (a) 6.4 N (b) - (c) 2.0 N (d) stays same

15. (a) and (c) only   16. (a) 12 N (b) 12 N

17. (a) 0.5 N (b) 50 cm^3 18. 1100 N

19. (a) - (b) (i) no change (ii) heavier (iii) downwards

20. carbon dioxide more dense than helium so weight of balloon is greatewr than the upthrust

Gas Laws

1. pressure against *inverse* of volume

2. 20, 300; 15, 300; 10, 300; 40, 300; 50, 300

3. 4.04×10^5 Pa 4. volume increases, pressure decreases

5. x = 120; y = 20 6. 3.2×10^5 Pa 7. (a) halved (b) doubled

8. 1.0×10^5 Pa 9. pressure; absolute 10. absolute temperature

11. add 273

12. (a) 273 K (b) 373 K (c) 293 K (d) 310 K (e) 0 K (f) 77 K (g) 600 K (h) 546 K

13. (a) -273^{o}C (b) 0^{o}C (c) 100^{o}C (d) 21^{o}C (e) -12^{o}C 14. 23260 m^3

15. 381 cm^3 16. 253^{o}C

17. 100^{o}C - *actual* temperature; 100C^o - *change* of temp. 18. volume; absolute

19. absolute temperature 20. 1.45×10^5 Pa 21. 16^{o}C

22. -11^{o}C 23. 1.37×10^5 Pa 24. 197^{o}C 25. 135^{o}C

26. 29.6 lb/in^2 27. 9.3 cm^3 28. 1603 kPa 29. 117 cm^3

30. 392^{o}C 31. 47C^o 32. 5.05×10^5 Pa

33. (a) 480 litres (b) 24 mins (c) 12 litres left in cylinder

34. 5 cm^3 35. 1.01×10^5 Pa 36. 44 lb/in^2

37. less weight of air above

38. 1.46 atmospheres 39. 540

Radioactivity

1. (a) 6p, 6n, carbon (b) 6p, 8n, carbon (c) 92p, 143n, uranium

   (d) 92p, 146n, uranium (e) 82p, 136n, lead (f) 88p, 140n, radium

   (g) 2p, 2n, helium

2. (a) 2 less (b) 2 less 3. (a) increases by 1 (b) decreases by 1

4. (a) no change (b) no change

5. (a) X = 234; Y = 90 (b) X = 234; Y = 91 (c) X 234; Y = 92; ? = U

   (d) X = 218; Y = 84 (e) X 83; Y = 0; ? = Pb (f) X = 14; Y = 7; ? = N

6. time for activity to decrease by one half

7. (a) one half (b) one quarter (c) one eighth

8. 6.25 % 9. 2 days 10. 16 years 11. approx. 6.5 mins

12. approx. 19 days 13. 15 mins 14. 22.2 days 15. 5.4×10^{9}

16. 7.5 decays per minute 17. 6 hours 18. 8 mins.

19. (a) 25 c.p.m. (b) 5 mins 20. approx 3 mins 21. approx. 6 hours

E = mc^2

1. slightly less 2. mass lost 3. $E = mc^2$; energy, mass, speed of light

4. two 5. X = 138; Y = 56 6. X = 100; Y = 42; Z = Mo

7. 3.3×10^{-11} J 8. 1.62×10^{-28} kg 9. nuclear fusion; energy

10. 3.6×10^{26} J

Nuclear reactions

1. $E = mc^2$ 2. 4.5×10^{-13} J   3. 9.8×10^{-30} kg

4. (a) Z - Kr; x - 36; y - 4   (b) Z - Xe; x - 54; y - 2

   (c) Z - Mo; x - 137; y - 42

5. (a) 3.0×10^{-28} kg   (b) $E = 2.7 \times 10^{-11}$ J

6. (a) 4.0×10^{-28} kg   (b) 3.6×10^{-11} J

7. (a) (i) 0.213 u (ii) 3.70×10^{-28} kg   (b) 3.33×10^{-11} J

8. (a) (i) 0.0972 u (ii) 1.63×10^{-28} kg   (b) 1.47×10^{-11} J

9. (a) 3.13×10^{19} per second   (b) 0.012 g/s (that is, the mass no longer *fissionable*; the *actual* mass loss is only 1.1×10^{-5} g/s)

10. (a) 1390 MW   (b) 4.38×10^{19} per second

11. (a) x - 1; 4 - 4; Z - He   (b) x - 2; y - 2; Z - H

12. (a) $m = 1.32 \times 10^{-28}$ kg; $E = 1.19 \times 10^{-11}$ J   (b) 4.2×10^{17} /s

13. (a) $m = 3.32 \times 10^{-30}$ kg; $E = 2.99 \times 10^{-13}$ J   (b) 6.7×10^{19} /s

E = hf (photons)

1. (a) 3.98×10^{-19} J   (b) 2.49×10^{-19} J   (c) 6.63×10^{-19} J

2. (a) 4.97×10^{-19} J   (b) 3.06×10^{-16} J   (c) 2.84×10^{-19} J

3. (a) 5.00×10^{-7} m   (b) 500 nm   4. 4.34×10^{14} Hz

5. 8.0×10^{-15} J

6. (a) 3.14×10^{-19} J   (b) 3.18 W/m^2 (c) 3.2×10^{15}

7. 6.3×10^{19} /s

Dosimetry and Safety

1. becquerel; Bq
2. (a) 1000 (b) 1000000
3. 2000 Bq; 6 x 10^4 Bq;185 kBq; 200 kBq; 75000; 370000; 1.5 x 10^7; 1.5 x 10^9; 5 s; 45 s
4. -
5. 32 cpm
6. gray; Gy
7. 0.2 Gy; 5 μGy; 1.0 J; 8.0 mJ; 70 kg; 80 kg
8. 2.5 μGy
9. 20 μGyh^{-1}
10. 4.0 μGy
11. 200 hours
12. sievert; Sv
13. quality factor
14. 1000 μSv or 1.0 mSv
15. 30 mSv
16. 10
17. 2.0 mSv
18. 5.0 μSvh^{-1}
19. 2.0 mSv
20. 0.57 μSvh^{-1}
21. 28 μSvh^{-1}
22. (a) 100 mGy (b) 600 mSv
23. -
24. (a) 150 μGyh^{-1} (b) 500 μSvh^{-1} (c) 2.5 mSv
25. 4.0 mm
26. (a) 11 mm (b) 750 cpm
27. 15 mm

Solar system and universe

1. planets; star; year; days; satellite; month; hours; day   2. Sun

3. other side of planet   4. No

5. Moon is much closer to Earth than Sun

6. Galaxy   7. planets relatively close to Earth, stars very far away

8. C; moved position compared to stars

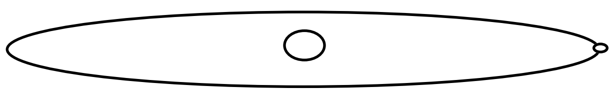
9. (a) Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto (Pluto occasionally closer than Neptune)   (b) Mercury   (c) increases

10. winter; northern hemisphere tilted *away* from Sun

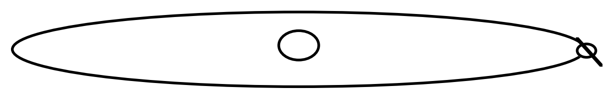
11. northern hemisphere should be tilted *towards* Sun

12. same tilt to Sun all year

13.



14.



15. (a) gravitational   (b) increases with mass   (c) decreases with distance

16. orbit would be closer to Sun   17. reflects sunlight

18. (a) E   (b) C and G   (c) -   (d) -   (e) May 14   (f) A

19. Lunar eclipse

20. (a) Moon should be directly between Earth and Sun (b) Moon's orbital plane tilted to Earth's orbital plane

21. - ; as Earth rotates once in 24 hours, a 'bulge' passes point once every 6 hours (progress of Moon round Earth makes it not exactly six hours)

22. Moon and Sun in line; *extra* gravitational pull of Sun

Measurements

1. (a) 2×10^{-3} m^3 (b) 6×10^{-5} m^3 (c) 3 m^3

2. (a) 2.5 l (b) 2000 l (c) 0.5 l

3. (a) 1600 cm^3 (b) 3×10^6 cm^3 (c) 65000 cm^3 (d) 80 cm^3

4. (a) 2 m (b) 15 m (c) 0.9 m (d) 70 m

5. (a) 0.4 m^2 (b) 5 m^2 (c) 2×10^6 m^2 (d) 0.001 m^2

6. (a) 10000 cm^2 (b) 200 cm^2 (c) 300 cm^2 (d) 1 cm^2

7. (a) 2.5 kg (b) 0.35 kg (c) 1.02 kg (d) 30 kg

8. (a) 6700 g (b) 3.4 g (c) 50 g (d) 0.15 g

9. (a) 180 s (b) 9000 s (c) 216 s (d) 270 s

10. 60; 3600; 86400 s; 31,536,000 s

11. (a) 0.5 s (b) 0.2 s (c) 0.1 s (d) 0.04 s

12. (a) 4 cm^2 (b) 25 cm^2 (c) 100 cm^2

13. (a) 8 cm^3 (b) 125 cm^3 (c) 1000 cm^3

14. (a) 0.5 (b) 20 (c) 425 (d) 300 (e) 1.5

15. (a) 8×10^5 (b) 8000 (c) 20 (d) 2000

16. (a) 2×10^{-5} (b) 1.25×10^5 (c) 2×10^4 (d) 3×10^{-3}

17. (a) 2×10^5 (b) 10^5 (c) 10 (d) 5 (e) 10^8 (f) 0.05

18. (a) 1500 (b) 10^6 (c) 10^6 (d) 100 (e) 5×10^{12} (f) 100

19. (a) 10% (b) 4 % (c) 30 % (d) 35% (e) 18 % (f) 5 %

20. (a) 25 (b) 210 (c) 50 (d) 300 (e) 6×10^5

21. (a) 0.2 (b) 0.1 (c) 0.04 (d) 50 (e) 500,000

Basic Algebra

1. (a) 2 (b) 5 (c) 0.08 (d) 9.1 (e) 12 (f) 9 (g) 20 (h) 12 (i) 4

2. (a) 2 (b) 4 (c) 5 (d) 10 (e) 4 (f) 9 (g) 144 (h) 5 (j) 10 (k) 8

   (l) 27 (m) 10 (n) 8

3. (a) 2 (b) 3 (c) 1 (d) 3 (e) -5 (f) 2 (g) 3 (h) 4 (i) 4 (j) 3

   (k) 3 (l) 25

4. (a) 4 (b) 8 (c) 32 (d) 64 (e) 2 (f) 8 (g) 25 (h) 125

5. (a) 20000 (b) 3000 (c) 430000 (d) 0.0023 (e) 0.00097 (f) 6730000

6. (a) $a = F/m$ (b) $m = F/a$ (c) $f = v/l$ (d) $l = v/f$ (e) $I = Q/t$ (f) $t = Q/I$ (g) $E = VQ$

(h) $Q = E/V$ (i) $v = u + at$ (j) $t = (v-u)/a$

   (k) $d = vt$ (l) $t = d/v$ (m) $m = E/gh$ (n) $m = 2E/v2$ (o) $v = \sqrt{2E/m}$

   (p) $p = RT/V$ (q) $V = RT/p$ (r) $T = pV/R$

Errors and Uncertainties

1. (a) (i) 13.6 (ii) 0.8 (b) (i) 2.22 (ii) 0.08 (c) (i) 510 (ii) 3

2. (a) 0.3% (b) 8.3% (c) 6.0 % (d) 1.2 %

   (e) 4.8% (f) 1.0%

3. (a) systematic (b) random (c) random (d) systematic

   (e) reading (f) calibration (g) systematic (h) random

   (i) systematic (j) random

4. (a) (3.72 $^{+}/_{-}$ 0.05) cm; 1.3% (b) (8.00 $^{+}/_{-}$ 0.05) cm; 0.63%

   (c) (0.90 $^{+}/_{-}$ 0.05) cm; 5.6% (d) (2.40 $^{+}/_{-}$ 0.01) V; 0.4%

   (e) (1.8 $^{+}/_{-}$ 0.1) A; 5.6%

   (f) (1.3 $^{+}/_{-}$ 0.25) cm; 19% [Note: large divisions suggests a large calibration error of half smallest division (0.25 here); it could be argued that smaller divisions could be 'judged by eye' at, say 0.1 but this may be too optimistic if the instrument is inherently inaccurate.]

   (g) (8.0 $^{+}/_{-}$ 0.5) V; 6.3% (Note: see (f))