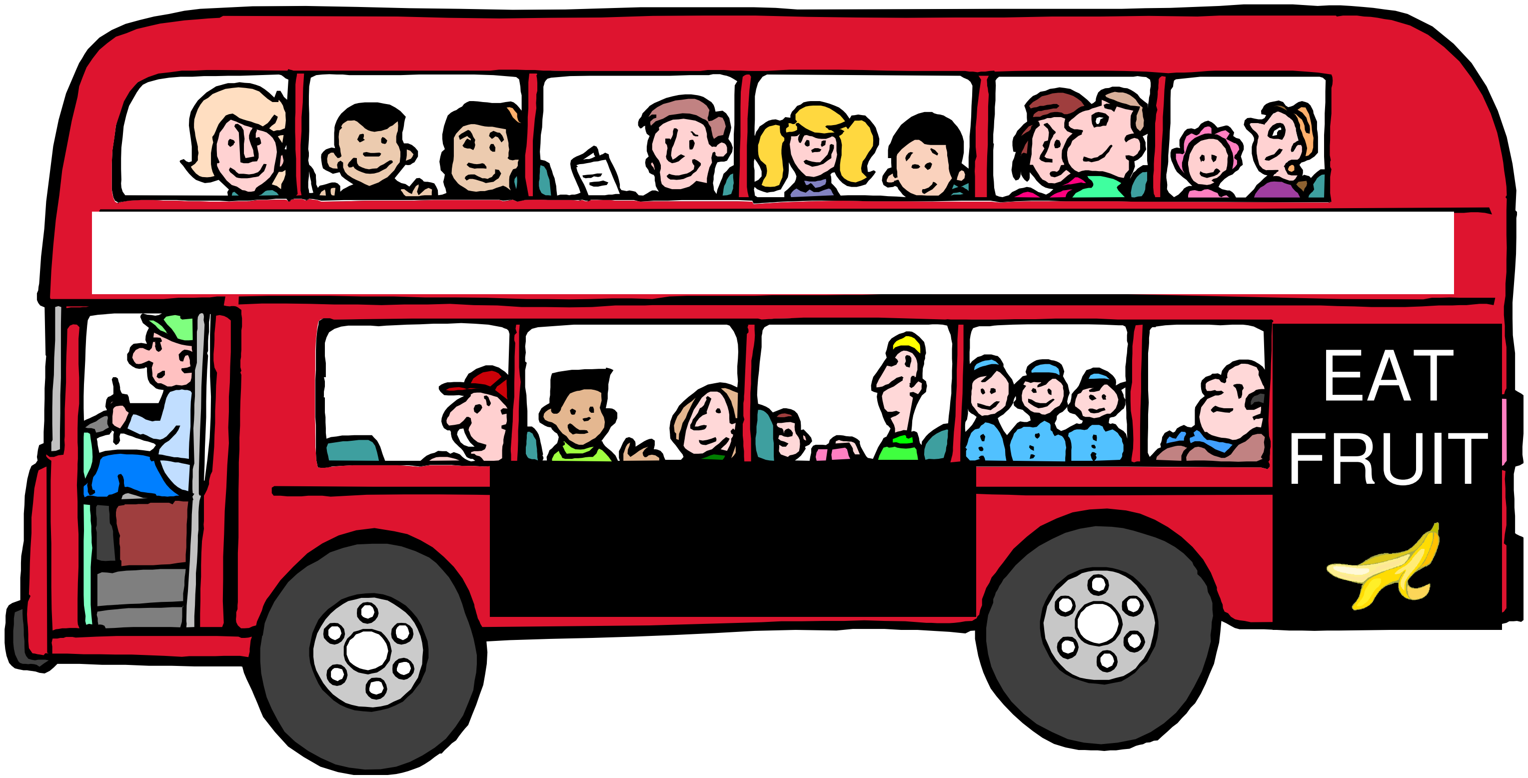
Standard Grade Physics

Measuring Motion



Name: ______________________________ **Class:** ______ **Teacher:** ______________________

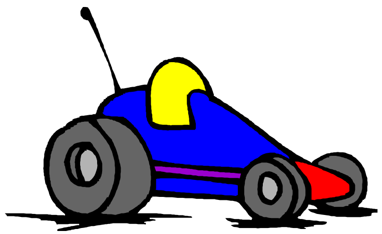
	BLUE = General RED = Credit										
1.	Define the term "speed".										
2.	Carry out calculations involving the relationship between distance, time and average speed.										
3.	Describe how to measure an average speed.										
4.	Describe how to measure instantaneous speed.										
5.	Explain how the method used to measure the time of travel can have an effect on the measured value of the instantaneous speed.										
6.	Identify situations where average and instantaneous speeds are different.										
7.	Define the term "acceleration".										
8.	Calculate acceleration from change of speed per unit time.										
9.	Carry out calculations involving the relationship between initial speed (u), final speed (v), time (t) and uniform acceleration (a).										
10.	Draw speed-time graphs showing steady speed, slowing down and speeding up.										
11.	Describe the motions represented by a speed-time graph.										
12.	Calculate acceleration, from speed-time graphs, for motion with a single constant acceleration.										
13.	Calculate distance gone and acceleration from speed-time graphs involving more than one constant acceleration.										

	BLUE = General RED = Credit										
1.	Describe the effects of forces in terms of their ability to change the shape, speed and direction of travel of an object.										
2.	State that the force of friction can oppose the motion of a body.										
3.	Describe and explain situations in which attempts are made to increase or decrease the force of friction.										
4.	Describe how to use a Newton balance to measure force.										
5.	Distinguish between mass and weight.										
6.	State that weight is a force and is the Earth's pull on an object.										
7.	State that the weight per unit mass (kilogram) is called the "gravitational field strength".										
8.	Use the approximate value of 10 N/kg to calculate weight.										
9.	State that equal forces acting in opposite directions on an object are called balanced forces and are equivalent to no force at all.										
10.	Explain the movement of objects in terms of Newton's first law.										
11.	State that when balanced forces or no forces act on an object, its speed remains the same.										
12.	Explain, in terms of forces, why seat belts are required in road vehicles.										
13.	Describe the qualitative effects of change of mass or of force on the acceleration of an object.										
14.	Carry out calculations involving the relationship between acceleration, unbalanced force and mass.										
15.	Carry out calculations using the relationship between acceleration, force and mass involving more than one force (in one dimension).										

Section 1: ON THE MOVE

• Why Use the Term "Average Speed"?

Even for objects which only travel a short distance (like a radio-controlled toy car), we still use the term **average speed** because the speed will change, even over the short distance travelled.



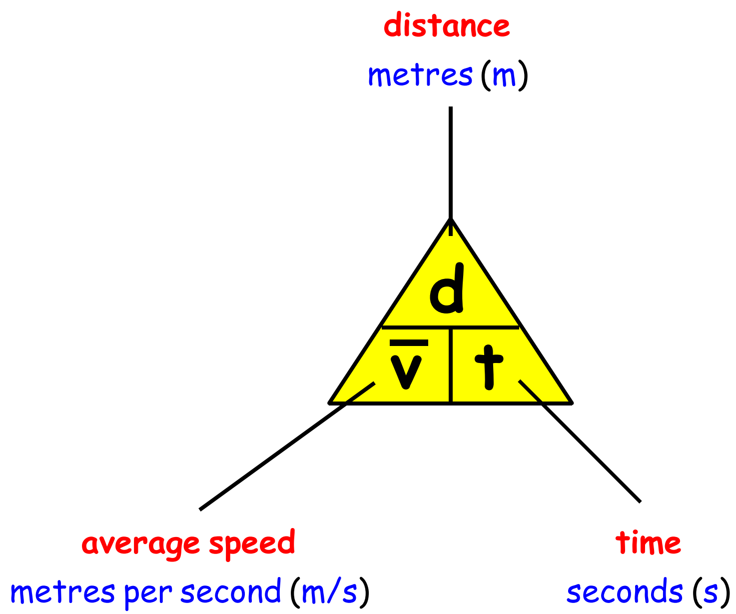
• Average Speed Calculations

The **average speed** ($\bar{v}$) of a moving object is the **distance** it travels in a given **time**.

Note the use of the bar (-) above the v to represent "average speed" . . . We pronounce this as "v bar" .

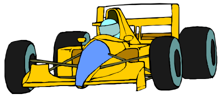
$$\text{average speed} = \frac{\text{distance}}{\text{time}}$$

$$\bar{v} = \frac{d}{t}$$

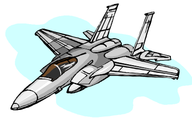


1) Calculate the missing quantity in each case:

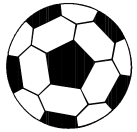
- average speed = ?
- distance = 500 metres
- time = 5 seconds



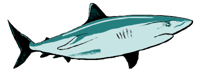
- average speed = ?
- distance = 15 000 metres
- time = 25 seconds



- average speed = ?
- distance = 10 metres
- time = 0.5 seconds



- average speed = ?
- distance = 45 metres
- time = 2.5 seconds

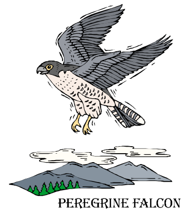


- average speed = ?
- distance = 59.5 metres
- time = 3.5 seconds

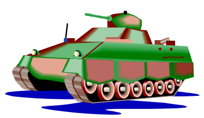
- average speed = ?
- distance = 1 440 metres
- time = 80 seconds

- average speed = ?
- distance = 750 metres
- time = 500 seconds

- average speed = ?
- distance = 540 metres
- time = 12 seconds

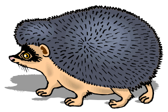


- average speed = 12 metres per second
- distance = ?
- time = 6 seconds



- average speed = 0.001 metres per second
- distance = ?
- time = 120 seconds

- average speed = 1.2 metres per second
- distance = 6 metres
- time = ?



- average speed = 10.2 metres per second
- distance = 100 metres
- time = ?

For very long journeys of **kilometres/miles** which take **hours** to complete, average speeds are quoted in units of **kilometres per hour** (**km/h**) or **miles per hour** (**mph**).

● You may have to solve problems involving these units in tests or in your Standard Grade Physics exam.

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2) Convert the following speeds from **kilometres per hour** to **metres per second**.

Hint - Convert **kilometres** to **metres** (by **multiplying by 1 000**), then **divide by 3 600** (since **1 hour = 3 600 seconds**).

$$\bar{v} = \frac{d}{t}$$

(a) 18 kilometres per hour.

(b) 72 kilometres per hour.

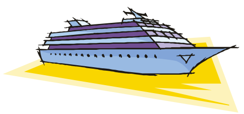
(c) 100 kilometres per hour.

3) Wendy takes 45 minutes to run a 10 kilometre race.

(a) What is Wendy's time in **hours** (expressed as a decimal)?

(b) Calculate Wendy's average speed in **kilometres per hour**.

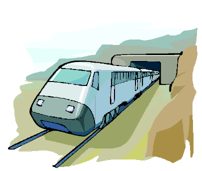
4) A cruise ship takes a time of 5 hours 30 minutes to sail 33 miles.



(a) Express the time in **hours** in decimal form.

(b) Calculate the average speed of the ship in **miles per hour**.

5) The Eurostar train service from London to Brussels takes 2 hours 45 minutes to cover the 340 kilometre track distance.



Calculate the average speed of the train in **kilometres per hour**.

6)

<u>**GNER Flying Scotsman service**</u>

Depart London Kings Cross 1000 hours.

Arrive Edinburgh Waverley 1415 hours.

Total distance = 400 miles

Using information from these timetable extracts, calculate the train's average speed in **miles per hour**.

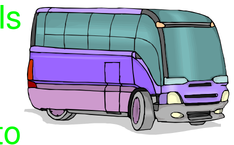
7) An extract from an express coach timetable is shown below.

Assuming the coach departs and arrives exactly on time, calculate the total distance travelled in **kilometres** if the average speed for the journey is 80 kilometres per hour.

Depart Aberdeen 1400 hours

Arrive Glasgow 1715 hours

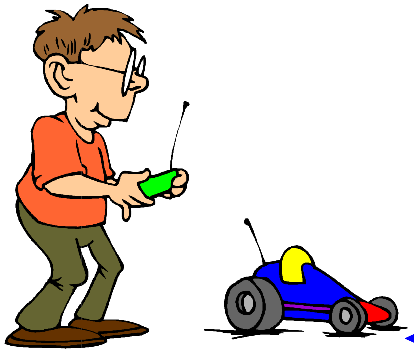
8) A coach travels the 157.5 mile road distance from Edinburgh to Inverness at an average speed of 45 miles per hour.

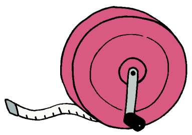


Calculate the time taken for the journey in **hours**.

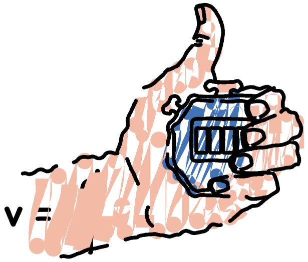
measured distance

start • **Measuring Average Speed: Human Timing** finish





v =



average speed = $\dfrac{\text{distance travelled}}{\text{time taken}}$

Sample Readings and Calculation

- distance travelled (d) = 6 metres
- time taken (t) = 1.5 seconds
- average speed ($\bar{v}$) = ?

$$\bar{v} = \frac{d}{t}$$

$$= \frac{6}{1.5}$$

= **4 metres per second**

9) The following readings were obtained during 3 runs of the radio-controlled car.

For each set of readings, calculate the **average speed** of the radio-controlled car:

Run 1

- distance travelled (d) = 9 metres
- time taken (t) = 1.8 seconds

Run 2

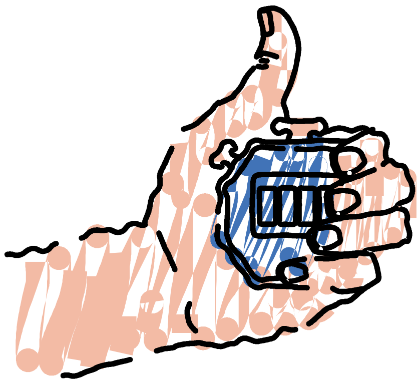
- distance travelled (d) = 12 metres
- time taken (t) = 2.5 seconds

Run 3

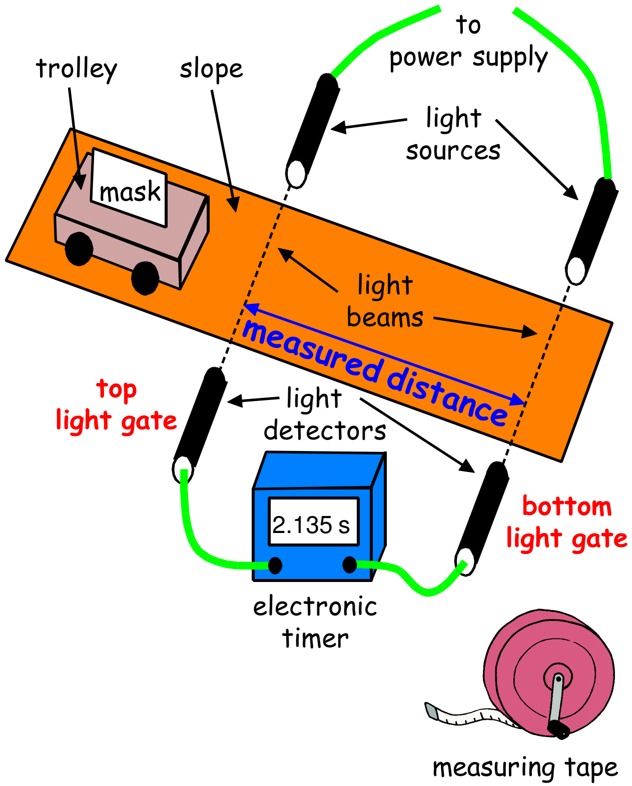
- distance travelled (d) = 15 metres
- time taken (t) = 6.0 seconds

• Measuring Average Speed: Electronic Timing

Stopwatches and Human Reaction Time



To measure the **average speed** ($\bar{v}$) of a moving object (for example, a **trolley** rolling down a slope) with **electronic timing**, we use a **measuring tape** and **2 light gates** connected to an **electronic timer**. A **mask** (**thick card**) is fixed on top of the trolley.



Sample Readings and Calculation

- distance travelled (d) between light gates = 1.25 metres
- time taken (t) to travel between light gates = 0.500 seconds
- average speed ($\bar{v}$) = ?

$$\bar{v} = \frac{d}{t}$$

$$= \frac{1.25}{0.500}$$

= **2.5 metres per second**

10) The following readings were obtained during 3 separate runs of the trolley down the slope.

For each set of readings, calculate the **average speed** of the trolley as it ran down the slope:

Run 1

- distance travelled (d) between light gates = 1.25 metres
- time taken (t) to travel between light gates = 0.250 seconds

Run 2

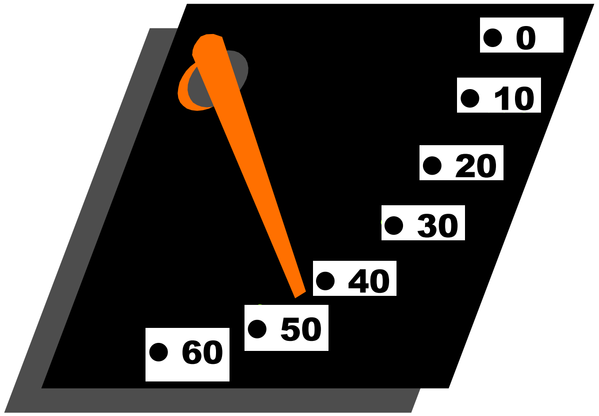
- distance travelled (d) between light gates = 0.80 metres
- time taken (t) to travel between light gates = 0.500 seconds

Run 3

- distance travelled (d) between light gates = 1.50 metres
- time taken (t) to travel between light gates = 0.750 seconds

• Instantaneous Speed

The **instantaneous speed** (**v**) of a moving object is its **speed** at a **particular instant of time**.

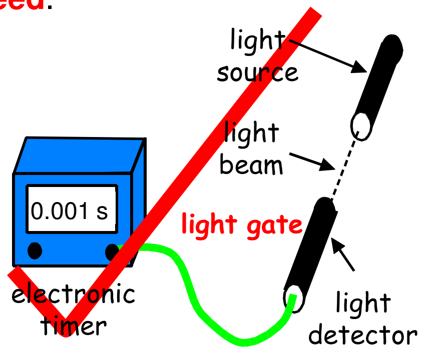


a car speedometer

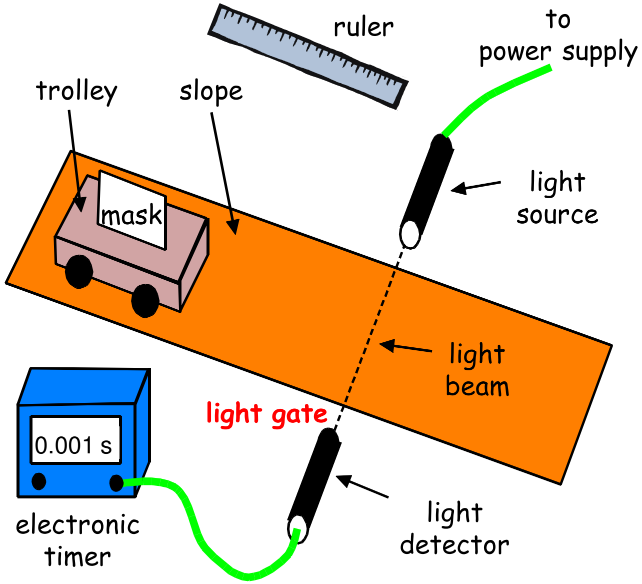
The method used to measure the **time of travel** has an effect on the estimated value for **instantaneous speed**.

A **stopwatch** cannot be used because we are not able to press the start and stop buttons quickly enough - Slow **human reaction time**.

We have to use **electronic timing** which can measure very small time intervals - For example, **0.001 seconds**.



• Measuring Instantaneous Speed: Electronic Timing



When the front edge of the **mask** enters the **light beam** of the **light gate**, the electronic timer is automatically switched **on**.

When the back edge of the **mask** leaves the **light beam** of the **light gate**, the electronic timer is automatically switched **off**.

The electronic timer shows the time the **mask** takes to travel through the **light gate**.

Sample Readings and Calculation

- distance (length of mask) = 0.01 metres
- time taken (t) for mask to travel through light gate = 0.002 seconds
- instantaneous speed (v) = ?

$$v = \frac{d}{t}$$

$$= \frac{0.01}{0.002}$$

= **5 metres per second**

11) The following readings were obtained during 3 separate runs of the trolley down the slope.

For each set of readings, calculate the **instantaneous speed** of the trolley as it passed through the light gate:

Run 1

- distance (length of mask) = 0.01 metres.
- time taken (t) for mask to travel through light gate = 0.001 seconds.

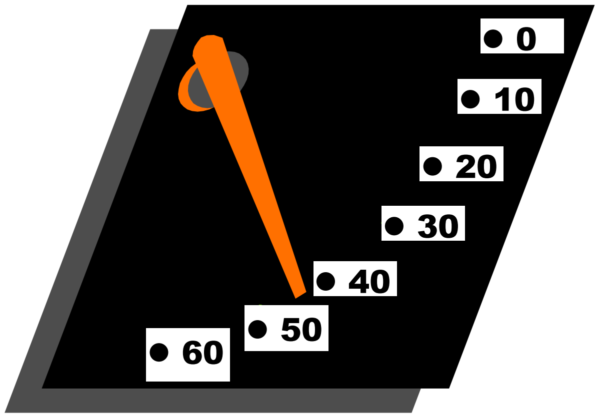
Run 2

- distance (length of mask) = 0.015 metres.
- time taken (t) for mask to travel through light gate = 0.003 seconds.

Run 3

- distance (length of mask) = 0.02 metres.
- time taken (t) for mask to travel through light gate = 0.005 seconds.

• Comparing Instantaneous and Average Speeds



12) (a) Why do we use the term **average speed** to describe the movement of objects which travel a large distance? ____

____

(b) Describe and explain the movement of a bus on a typical journey from Glenrothes to Kirkcaldy:

____

____

____

____

13) (a) What do we mean by the **instantaneous speed** of an object? ____________________

____

(b) What device in a car shows the **instantaneous speed** of the car? ____________________

(c) Explain whether we can use a **stopwatch** to determine the **instantaneous speed** of an object:

____

____

____

(d) Why is **electronic timing** used to determine the **instantaneous speed** of an object?

____

____

____

14) (a) In most cases, at any particular moment in time, does the **instantaneous speed** of an object have the ***same*** or a ***different*** value from its **average speed**? ____________________

(b) Explain why: ____

____

____

(c) Give **2** examples of when the **instantaneous** and **average speeds** of an object have ***the same*** value: ____

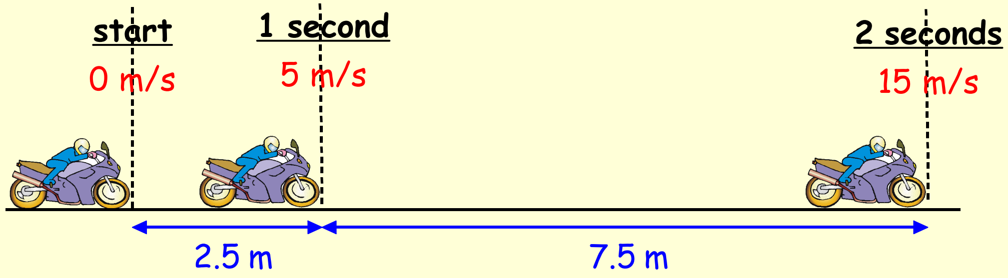
____

• Acceleration (and Deceleration)

This diagram shows a motorbike **accelerating** from a **stationary start** (**rest, 0 metres per second**).

After each second:

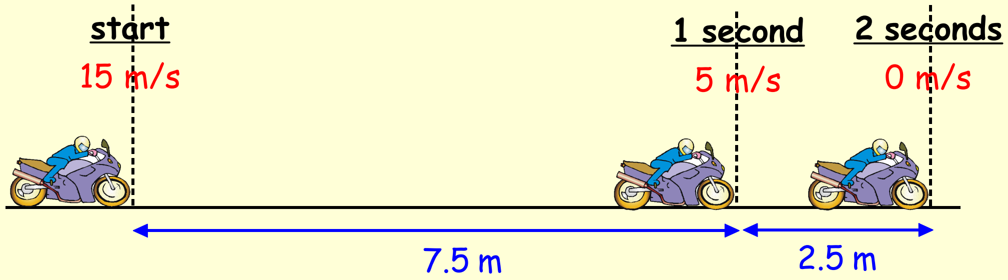
- Its **instantaneous speed** has **increased**.
- It has travelled **further** than it travelled the second before.



This diagram shows a motorbike **decelerating** from an **instantaneous speed** of **15 metres per second** to **rest** (**0 metres per second**).

After each second:

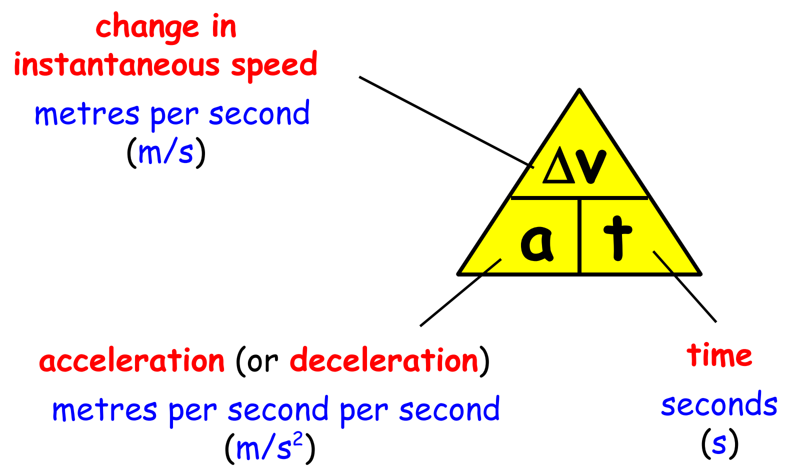
- Its **instantaneous speed** has **decreased**.
- It has travelled **less far** than it travelled the second before.



The **acceleration** (**a**) or **deceleration** of an object is its **change in instantaneous speed** over a **given time**.

$$\text{acceleration (or deceleration)} = \frac{\text{change in instantaneous speed}}{\text{time taken}}$$

$$a = \frac{\Delta v}{t}$$

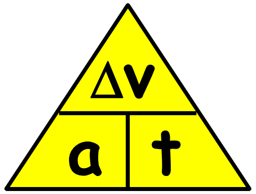


• Acceleration Calculations

Sample Acceleration Calculation

Calculate the **acceleration** of a go-kart which starts from **rest** (**0 metres per second**) and speeds up to **10 metres per second** in a time of **5 seconds**.

- Δv = 10 - 0 = 10 metres per second
- t = 5 seconds
- a = ?



$$a = \frac{\Delta v}{t}$$

$$a = \frac{\Delta v}{t}$$

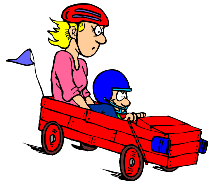
$$= \frac{10}{5}$$

= **2 metres per second per second**

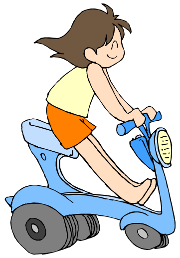
15) In each case, calculate the **acceleration** of the vehicle:

(a) Farmer Jones' tractor starts from rest and speeds up to 8 metres per second in 10 seconds.

(b) In their go-kart, Jill and her Mum speed up from rest to 6 metres per second in 12 seconds.

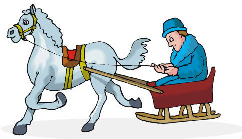


(c) In their golf cart, Tom and Sue speed up from 2 metres per second to 9 metres per second in 5 seconds.



(d) On her motor scooter, Milly takes 5 seconds to speed up from 3 metres per second to 13 metres per second.

(e) Sid's sleigh takes 20 seconds to speed up from 4 metres per second to 12 metres per second.



(f) Mike's motorbike takes 5 seconds to speed up from 10 metres per second to 30 metres per second.

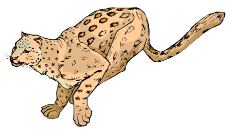
16) Barah's forklift truck accelerates at 0.25 metres per second per second while speeding up from rest to 5 metres per second.

Calculate the time this takes.

17) Sam somersaults across a gym floor. He starts from rest and speeds up to 2.4 metres per second, having accelerated at 0.3 metres per second per second.

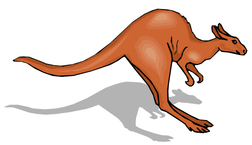
What time does this take?

18) Starting from rest, a cheetah accelerates at 3.6 metres per second per second for 7.5 seconds.



Calculate the Cheetah's change in speed during this time.

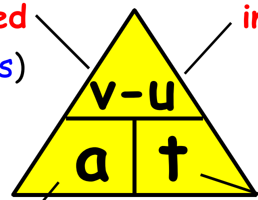
19) Starting from rest, a red kangaroo accelerates at 3 metres per second per second for 5.5 seconds.



By how much does the kangaroo's speed increase over this time?

• More Acceleration Calculations

$a = \dfrac{\Delta v}{t}$ can also be written in the form $a = \dfrac{v - u}{t}$



final instantaneous speed metres per second (m/s)

initial instantaneous speed metres per second (m/s)

acceleration (or **deceleration**) metres per second per second (m/s^2)

time seconds (s)

Sample Calculations

Acceleration

Calculate the **acceleration** of a walker who speeds up from **1 m/s** to **3 m/s** in a time of **4 s**.

- v = 3 m/s
- u = 1 m/s
- t = 4 s
- a = ?

$$a = \frac{v - u}{t} = \frac{3 - 1}{4}$$

$$= \frac{2}{4}$$

$$= \underline{0.5\ m/s^2}$$

Deceleration

Calculate the **deceleration** of a cyclist who slows down from **7 m/s** to **1 m/s** in a time of **3 s**.

- v = 1 m/s
- u = 7 m/s
- t = 2 s
- a = ?

$$a = \frac{v - u}{t} = \frac{1 - 7}{3}$$

$$= \frac{-6}{3}$$

$$= \underline{-2\ m/s^2}$$

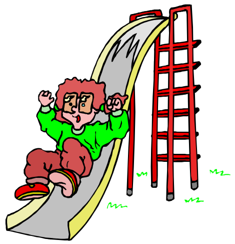
The - sign indicates "deceleration"

20) In each case: (a) Calculate the **acceleration** or **deceleration** over the stated time interval. (b) Tick the correct **acceleration** or **deceleration** box.

- initial speed (u) = 0 m/s
- final speed (v) = 6 m/s
- time = 12 s

acceleration ☐ **deceleration** ☐

- initial speed (u) = 0 m/s
- final speed (v) = 3 m/s
- time = 2 s



acceleration ☐ **deceleration** ☐

- initial speed (u) = 4.5 m/s
- final speed (v) = 0 m/s
- time = 2.5 s

acceleration ☐ **deceleration** ☐

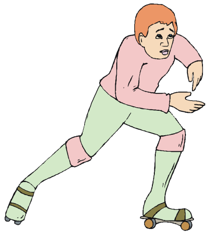
- initial speed (u) = 3.6 m/s
- final speed (v) = 0 m/s
- time = 6 s

acceleration ☐ **deceleration** ☐

- initial speed (u) = 1.5 m/s
- final speed (v) = 7.5 m/s
- time = 2 s

acceleration ☐ **deceleration** ☐

- initial speed (u) = 7.8 m/s
- final speed (v) = 2.3 m/s
- time = 2.5 s



acceleration ☐ **deceleration** ☐

- initial speed (u) = 5.5 m/s
- final speed (v) = 2.3 m/s
- time = 8 s

acceleration ☐ **deceleration** ☐

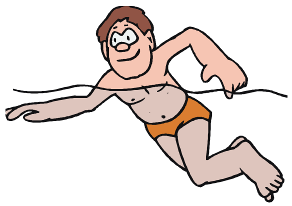
- initial speed (u) = 0.6 m/s
- final speed (v) = 6.8 m/s
- time = 4.1 s

acceleration ☐ **deceleration** ☐

- initial speed (u) = 12.3 m/s
- final speed (v) = 1.5 m/s
- time = 9 s

acceleration ☐ **deceleration** ☐

- initial speed (u) = 0.5 m/s
- final speed (v) = 2.5 m/s
- time = 20 s



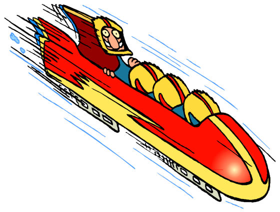
acceleration ☐ **deceleration** ☐

- initial speed (u) = 0.9 m/s
- final speed (v) = 2.1 m/s
- time = 6 s

acceleration ☐ **deceleration** ☐

- initial speed (u) = 6.7 m/s
- final speed (v) = 2.3 m/s
- time = 5.5 s

acceleration ☐ **deceleration** ☐



21) As a bobsleigh reaches a steep part of track, its speed increases from 24 m/s to 36 m/s. This happens in 0.4 s.

Calculate the acceleration of the bobsleigh during this time.

22) An arrow hits a stationary target at 50 m/s and comes to rest in 0.1 s.

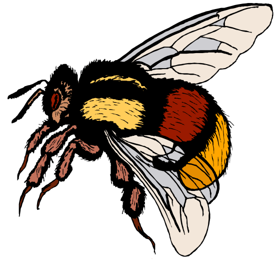
Calculate the deceleration of the arrow once it hits the target.

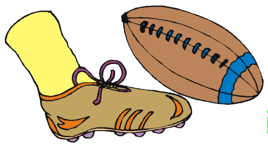
23) Starting from rest, a fireman slides down a pole with an acceleration of 1.2 m/s^2. His speed at the bottom of the pole is 3.6 m/s.

Calculate the time taken to slide down the pole.

24) A bee, decelerating at 0.7 m/s^2, slows down from 6.7 m/s to 2.5 m/s.

What time does this take?

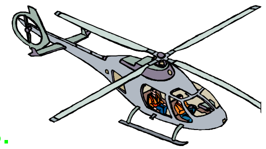




25) When a stationary rugby ball is kicked, it is in contact with a player's boot for 0.05 s. During this short time, the ball accelerates at 600 m/s^2.

Calculate the speed at which the ball leaves the player's boot.

26) A helicopter is flying at 35 m/s. It then decelerates at 2.5 m/s^2 for 12 s.

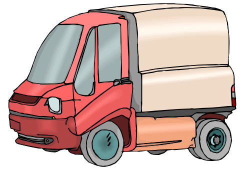


Calculate the speed of the helicopter after the 12 s.

27) A speed of a conveyor belt is increased to 2.8 m/s by accelerating it at 0.3 m/s^2 for 4 s.

Calculate the initial speed of the conveyor belt.

28) A van decelerates at 1.4 m/s^2 for 5 s. This reduces its speed to 24 m/s.



Calculate the van's initial speed.

• Car Performance

For example: A typical Ferrari road car can accelerate from rest (0 km/h or 0 mph) to 100 km/h (62 mph) in only 4 seconds !

Acceleration Calculation

- v = 100 kilometres per hour
- u = 0 kilometres per hour
- t = 4 seconds
- a = ?

$$a = \frac{v - u}{t}$$

$$= \frac{100 - 0}{4}$$

$$= \frac{100}{4}$$

= <u>25 kilometres per hour per second</u>

Acceleration Calculation

- v = 62 miles per hour
- u = 0 miles per hour
- t = 4 seconds
- a = ?

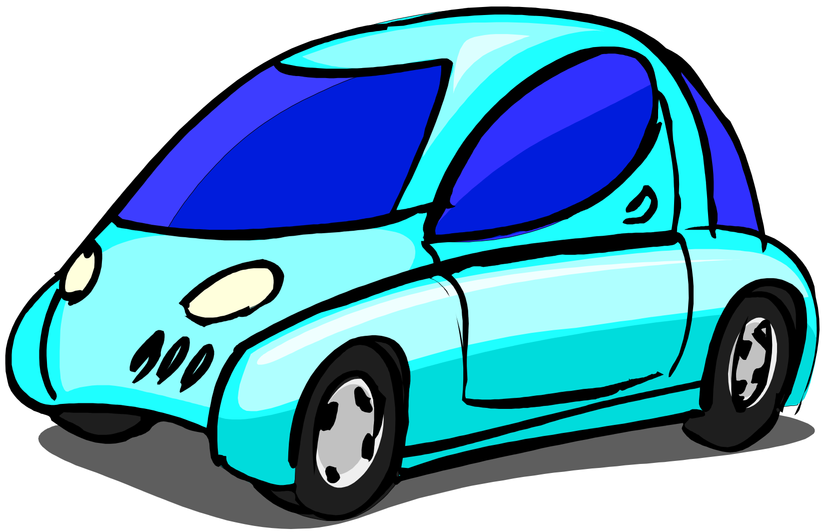
$$a = \frac{v - u}{t}$$

$$= \frac{62 - 0}{4}$$

$$= \frac{62}{4}$$

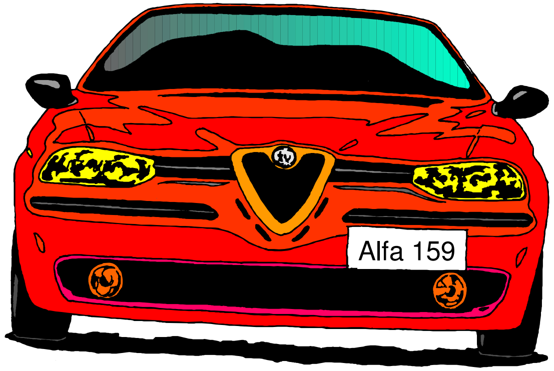
= <u>15.5 miles per hour per second</u>

29) In each case, calculate the **acceleration** of the car in **kilometres per hour per second** and in **miles per hour per second**:



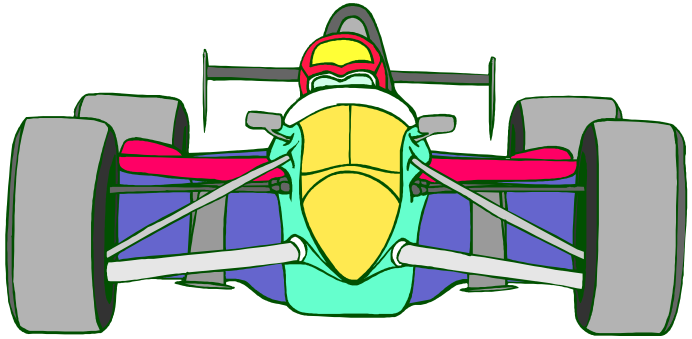
Volkswagen Beetle

0 - 100 km/h (0 - 62 mph) in 10.9 s



Alfa Romeo 159 3.2 V6 JTS

0 - 100 km/h (0 - 62 mph) in 7.0 s



Formula 1 Grand Prix car

0 - 100 km/h (0 - 62 mph) in 1.25 s

30) (a) Arrange the 4 cars shown on these 2 pages (16 + 17) in order of their **acceleration performance**:

1) ________________________ **(greatest acceleration)**

2) ________________________

3) ________________________

4) ________________________ **(least acceleration)**

(b) By just looking at the **time** a car takes to speed up from rest to 100 km/h or 62 mph, how can you tell whether the car has a small or large acceleration?

____

____

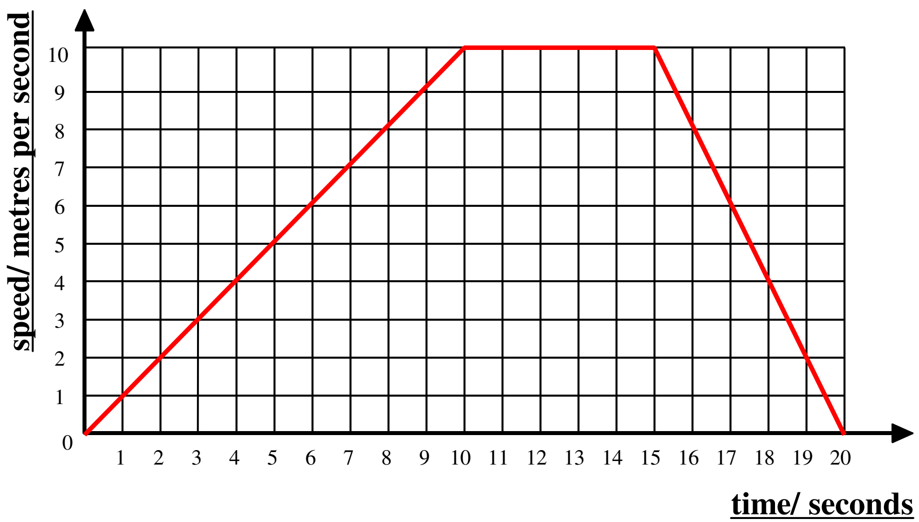
____

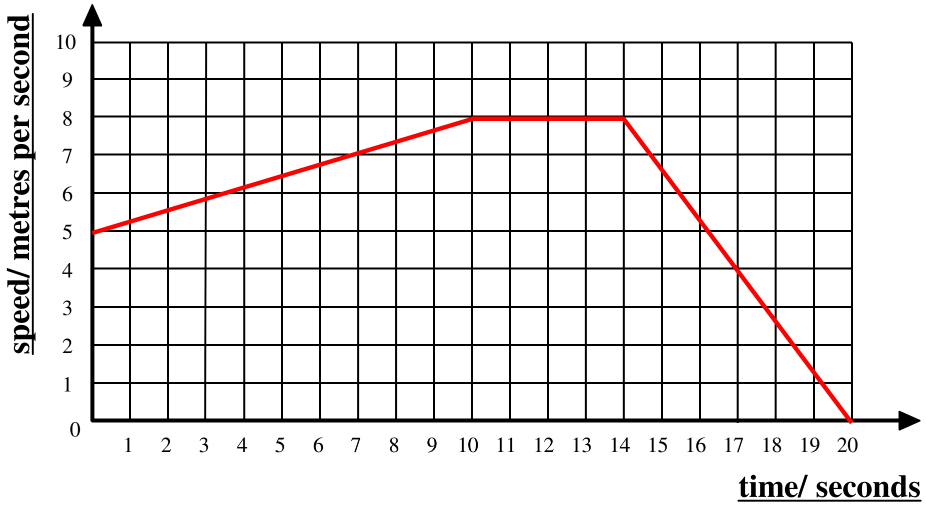
• Speed-Time Graphs

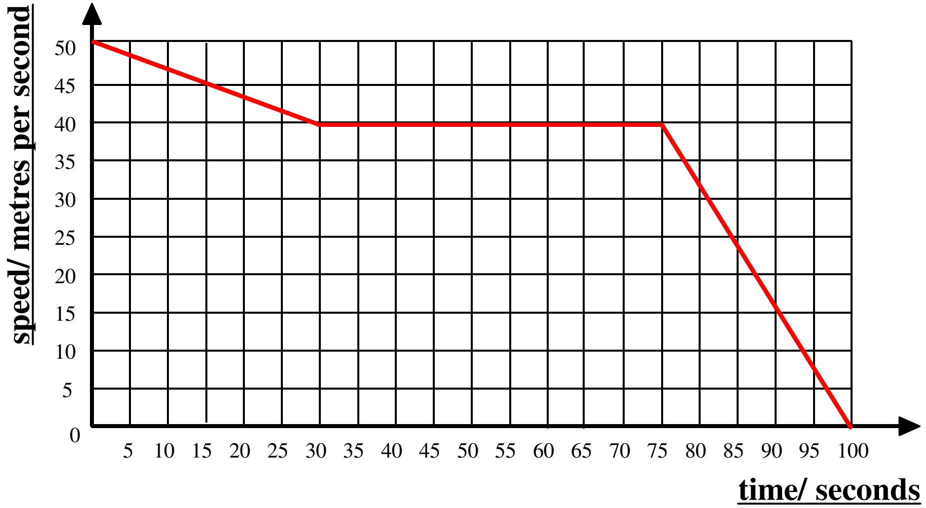
The motion of any object can be represented by a **line** drawn on a **speed-time graph**:

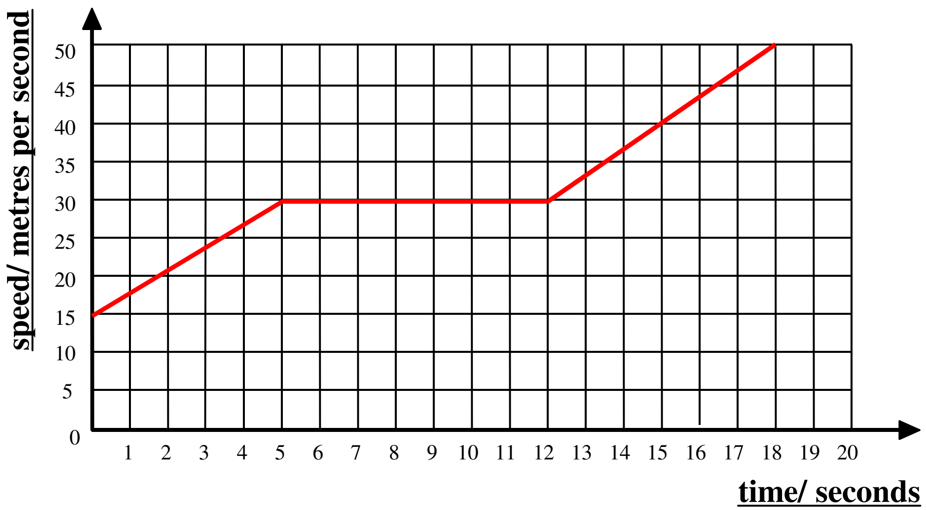
---

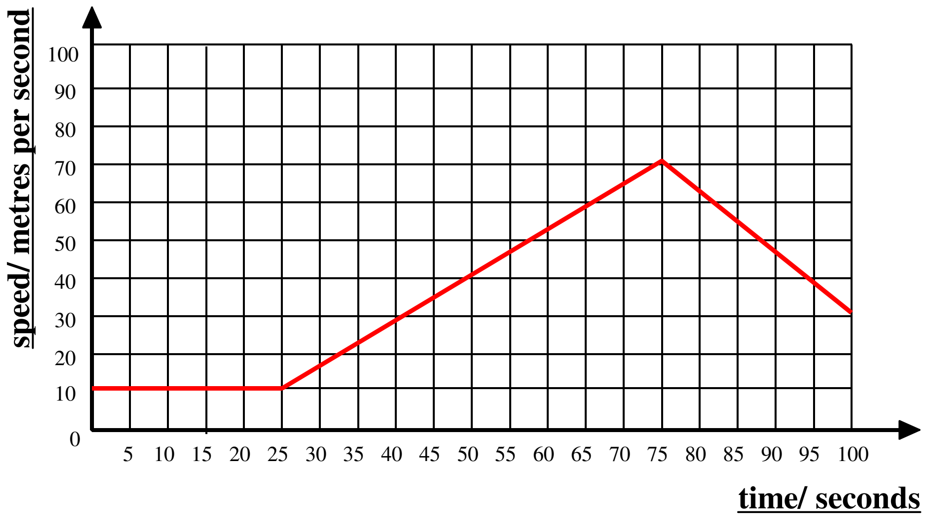
31) Describe the motion represented by the **line** on each **speed-time graph**:




speed/ metres per second
0
1
2
3
4
5
6
7
8
9
10
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
time/ seconds


speed/ metres per second
0
5
10
15
20
25
30
35
40
45
50
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
time/ seconds


speed/ metres per second
0
5
10
15
20
25
30
35
40
45
50
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
time/ seconds

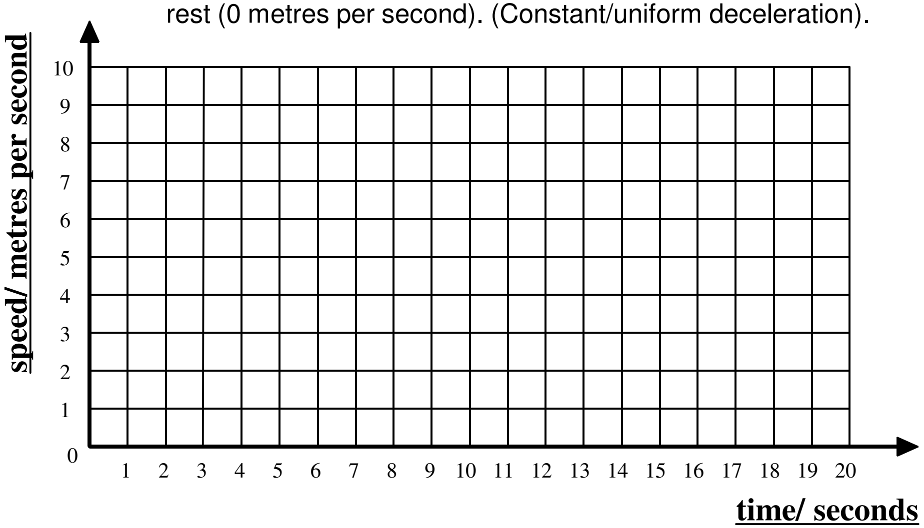

speed/ metres per second
0
10
20
30
40
50
60
70
80
90
100
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
time/ seconds

32) Draw the **line** on each **speed-time graph** to represent the motion described:

0 - 5 seconds: Speeding up from rest (0 metres per second) to 10 metres per second. (Constant/uniform acceleration).

5 - 15 seconds: Steady speed of 10 metres per second.

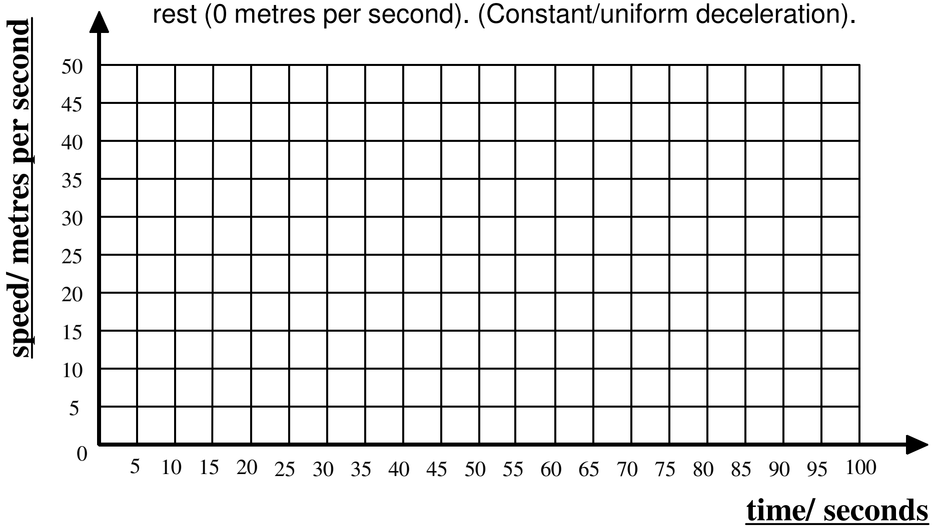
15 - 20 seconds: Slowing down from 10 metres per second to rest (0 metres per second). (Constant/uniform deceleration).



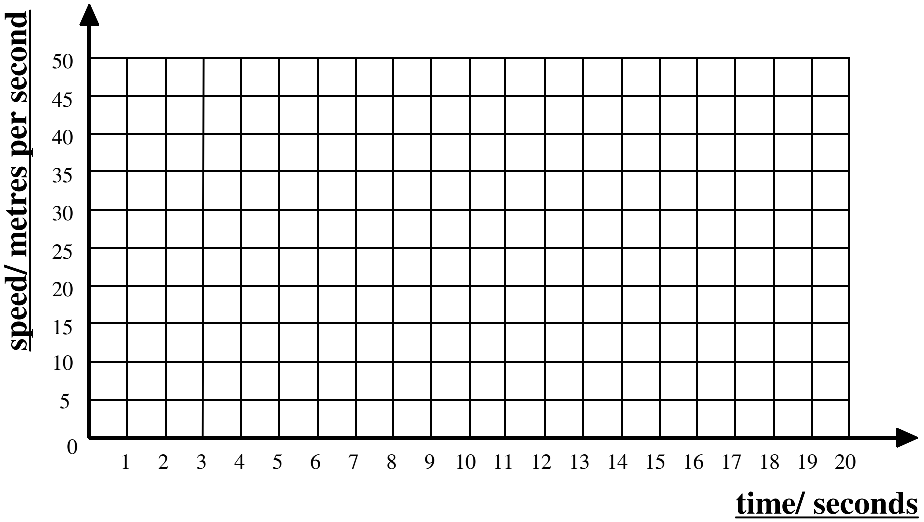
0 - 30 seconds: Speeding up from 25 metres per second to 40 metres per second. (Constant/uniform acceleration).

30 - 60 seconds: Steady speed of 40 metres per second.

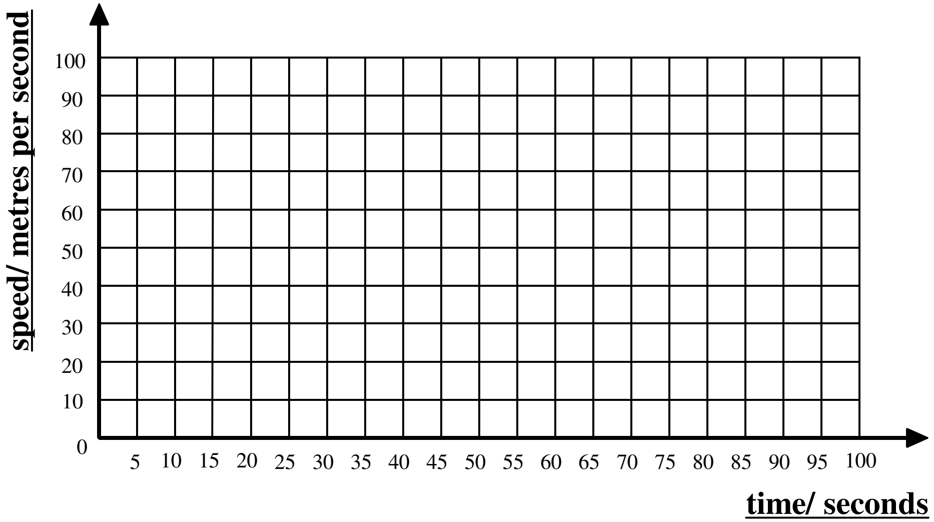
60 - 90 seconds: Slowing down from 40 metres per second to rest (0 metres per second). (Constant/uniform deceleration).



With uniform/constant acceleration, a motorcycle takes 8 seconds to speed up from rest to 20 metres per second. The motorcycle continues to travel at this steady speed for 4 seconds. It then increases its speed to 45 metres per second (constant/uniform acceleration) in 7 seconds.



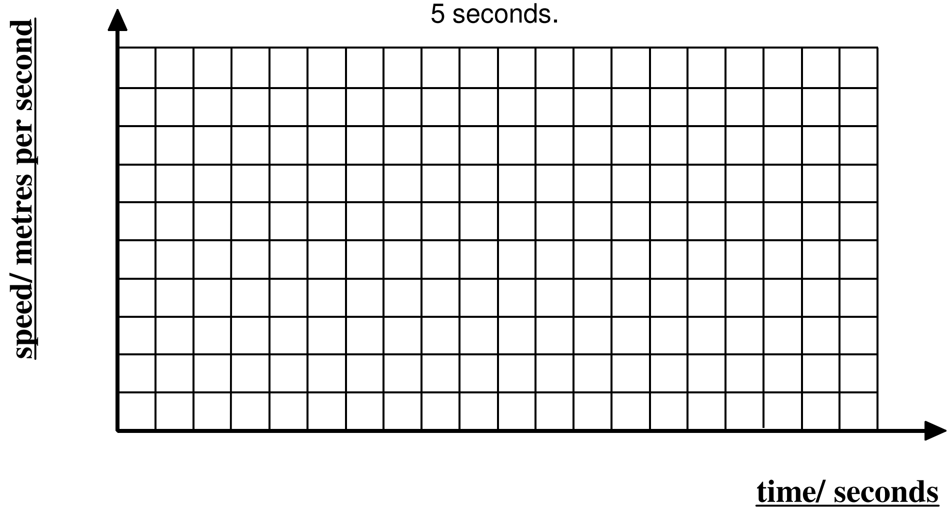
A helicopter, initially travelling at 80 metres per second, decelerates constantly/uniformly to a speed of 60 metres per second in 25 seconds. For the next 50 seconds, it continues to travel at this steady speed before decelerating constantly/uniformly to rest in a further 25 seconds.



Put numbers on each axis.

Maximum speed = 9 metres per second. Total time = 18 seconds.

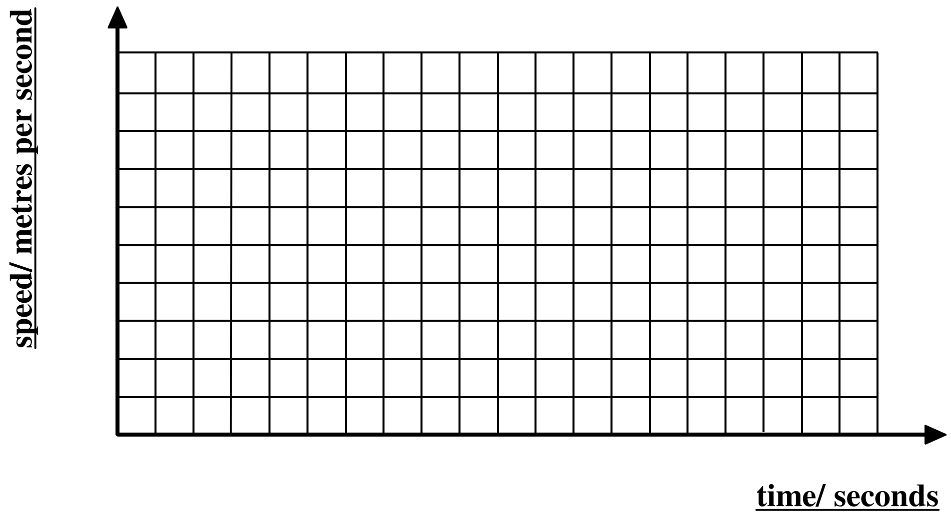
A cyclist travels at a steady speed of 9 metres per second for 6 seconds before decelerating constantly/uniformly to a speed of 2 metres per second in 7 seconds. She then travels at this steady speed for a further 5 seconds.



Put numbers on each axis.

Maximum speed = 90 metres per second. Total time = 20 seconds.

A racing car travels at a steady speed of 10 metres per second for 2 seconds before accelerating constantly/uniformly for 12 seconds to a speed of 90 metres per second. The car then immediately decelerates constantly/uniformly for 6 seconds to a speed of 70 metres per second.



• Calculating Acceleration (or Deceleration) From a Speed-Time Graph

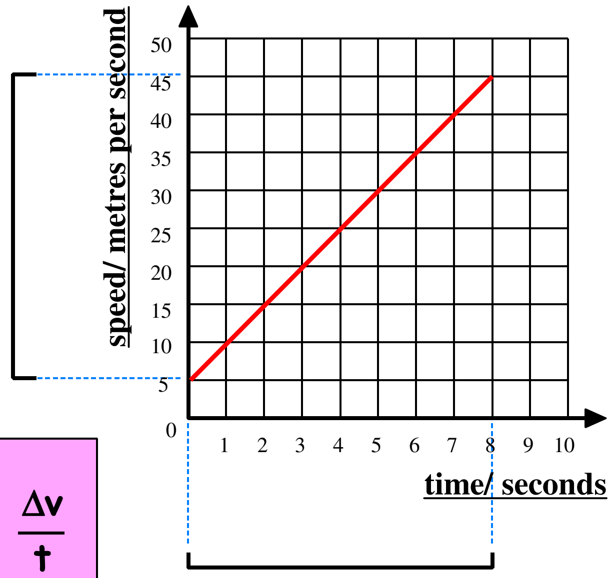
By taking **speed** and **time** values from a **speed-time graph**, we can calculate the **acceleration** or **deceleration** of the object which the graph represents.

For Example

Change in instantaneous speed (Δv)

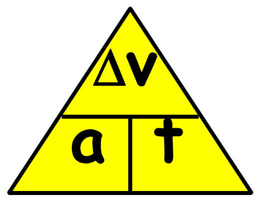
= 45 - 5

= 40 metres per second



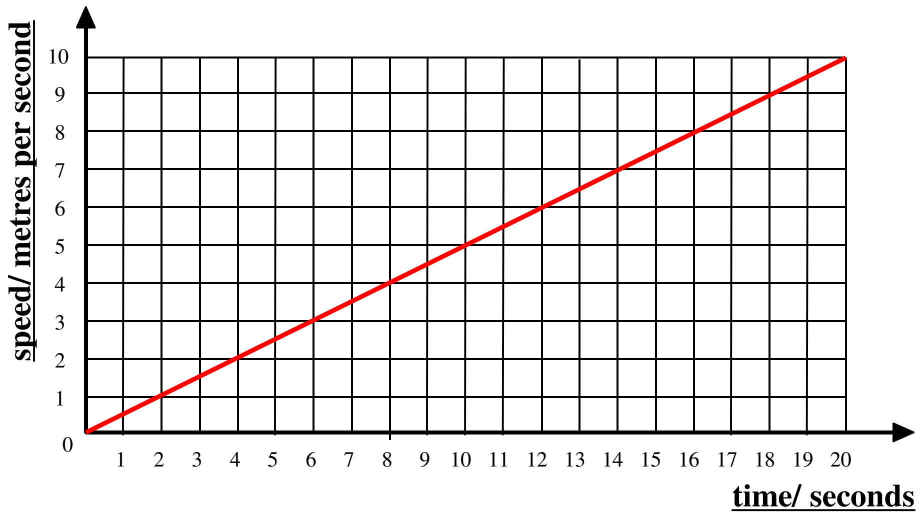
time (t) = 8 - 0

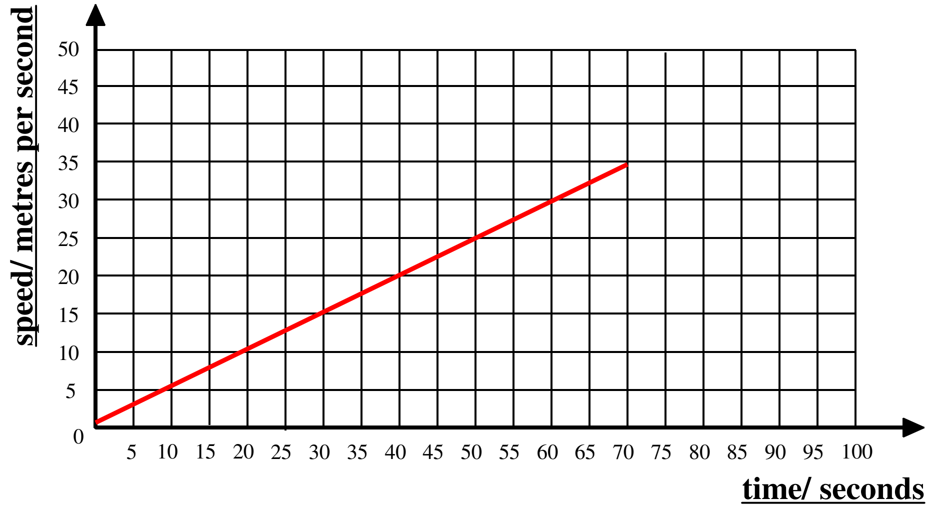
= 8 seconds

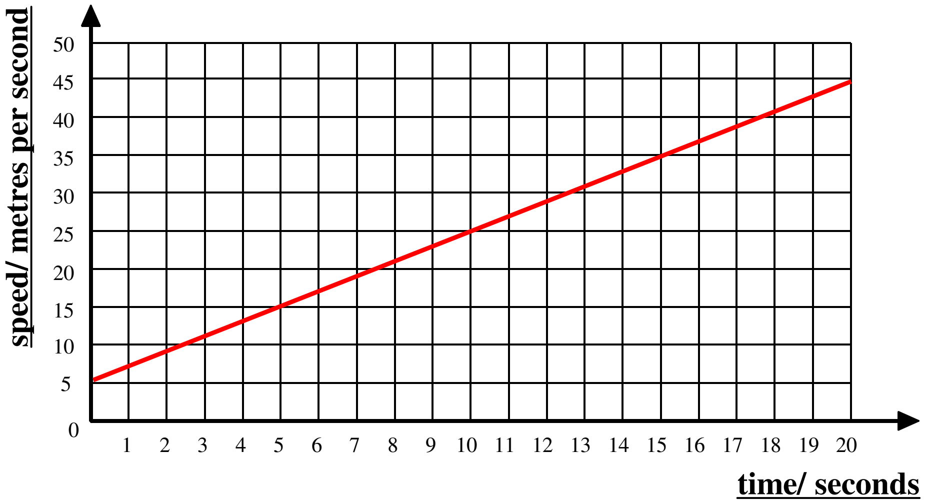


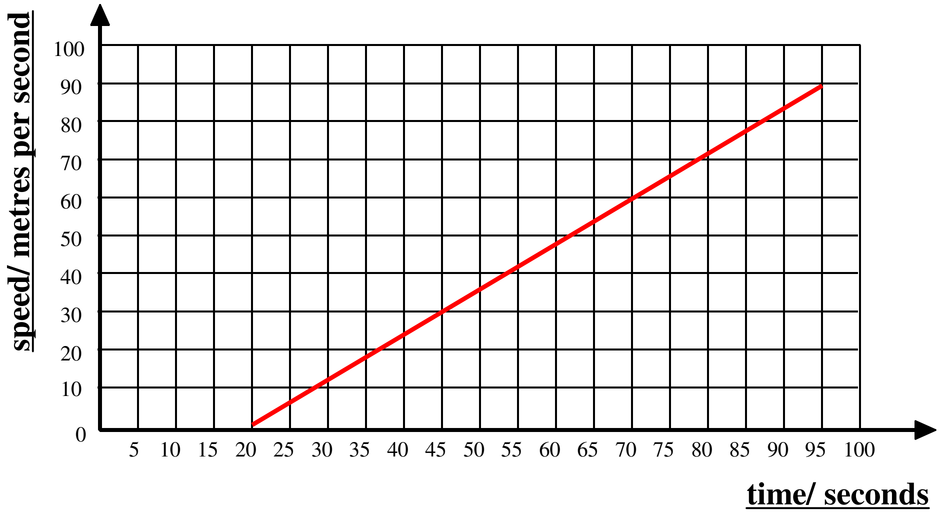
$$a = \frac{\Delta v}{t}$$

33) Calculate the **acceleration** represented by the **line** on each **speed-time graph**.









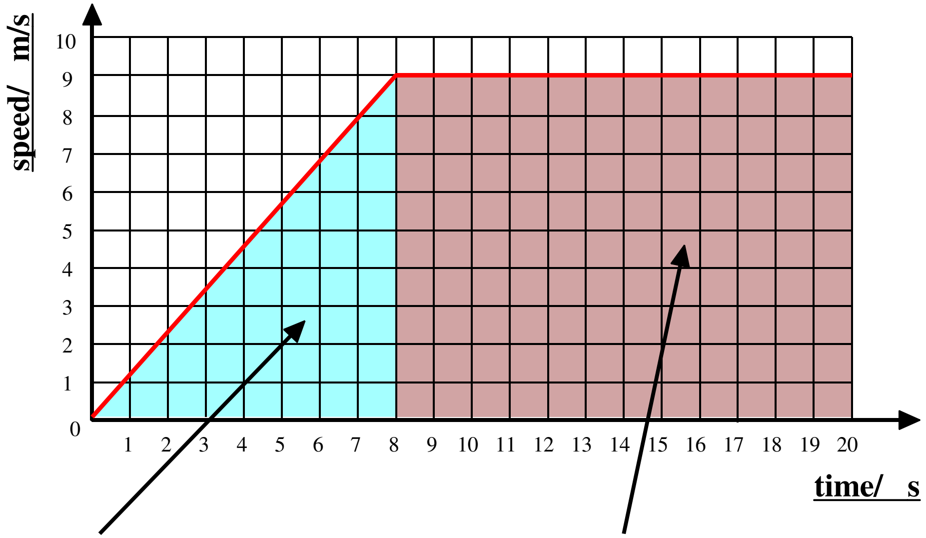
• Calculating Distance Gone From a Speed-Time Graph

The **area** under a **speed-time graph** representing the motion of an object gives the **distance** gone by the object.

For Example

This **speed-time graph** represents the motion of a go-kart for the first 20 seconds of its journey.

Determine the **distance** gone by the go-kart during these 20 seconds.

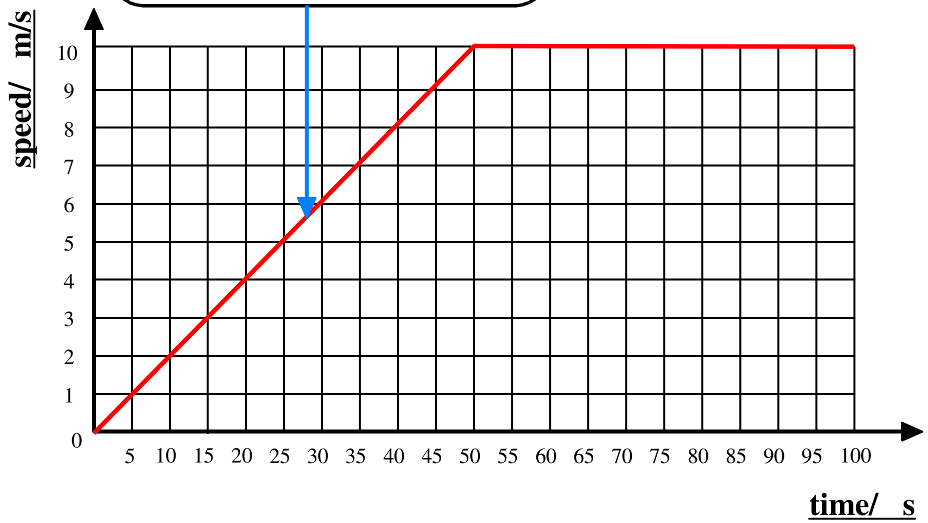


• Distance and Acceleration Calculations

34) Each of the following **speed-time graphs** represent the motion of a vehicle.

For each graph, calculate any **accelerations** and **decelerations** of the vehicle, plus the **distance** gone:

Acceleration Calculation



Distance Calculation

Acceleration Calculation

Deceleration Calculation

Distance Calculation

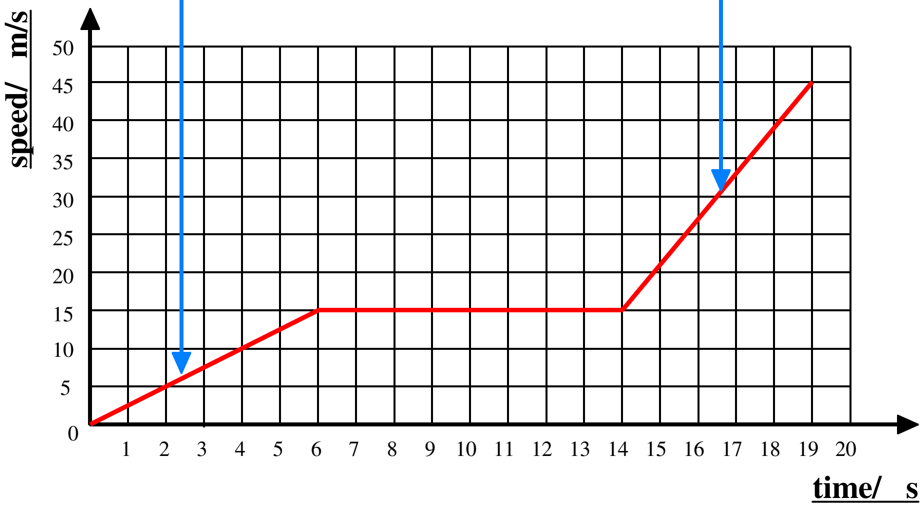
Acceleration Calculation

Deceleration Calculation

Distance Calculation

Acceleration Calculation

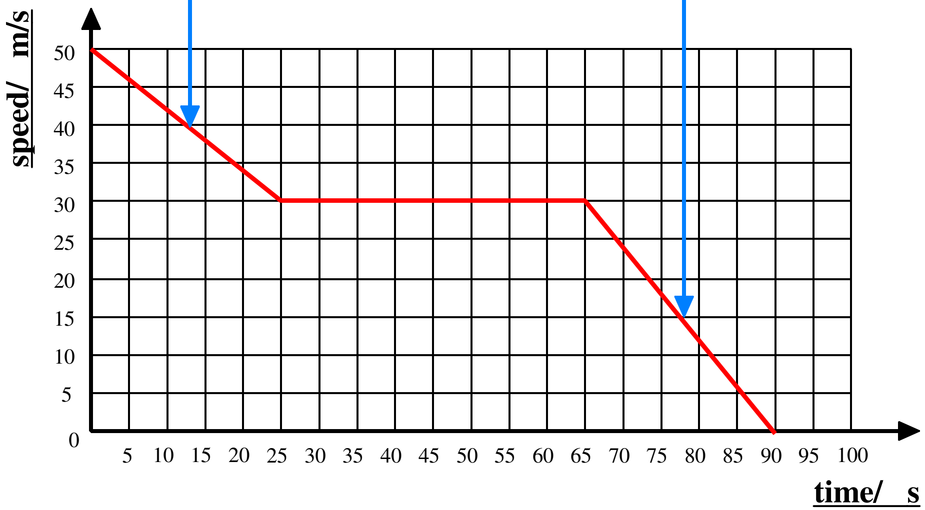
Acceleration Calculation



Distance Calculation

Deceleration Calculation

Deceleration Calculation



Distance Calculation

Section 2: FORCES AT WORK

• Forces and Their Effects

• **s** _ _ _ _ _

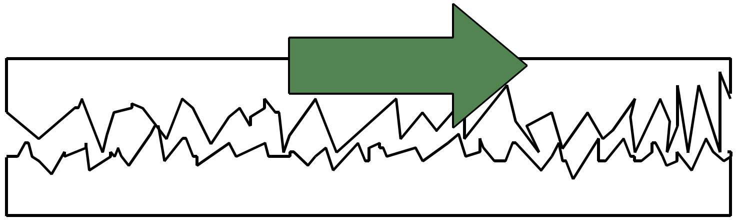
• **s** _ _ _ _ _

• **d** _ _ _ _ _ _ _ _ _ of travel

• The Force of Friction

No surface is **perfectly smooth**.

Every surface has **rough**, **uneven** parts.



• Increasing and Decreasing Friction

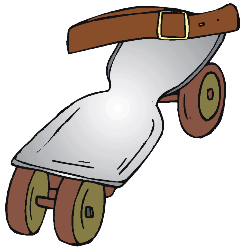
The force of **friction** plays a vital part in our everyday lives - Sometimes we need to **increase** it, other times we need to **decrease** it.

1) These diagrams show **"friction in everyday life"**.

In each case, tick the correct box to show whether **friction** is being **increased** or **decreased**.

Write a brief note to explain the situation:

☐ increased friction
☐ decreased friction

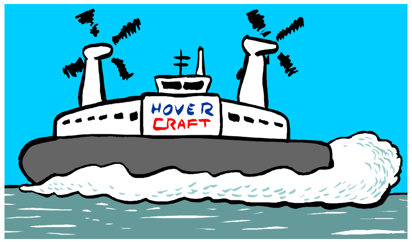


☐ increased friction
☐ decreased friction

☐ increased friction
☐ decreased friction

☐ increased friction
☐ decreased friction

☐ increased friction
☐ decreased friction



☐ increased friction
☐ decreased friction

• Air Friction/Resistance and Streamlining

When an object moves through the **air**, the **air** rubs against the object, **slowing it down**.

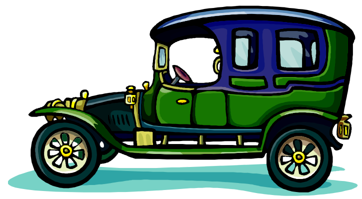
This effect is known as **air f** _ _ _ _ _ _ _ or **air r** _ _ _ _ _ _ _ _ _ .

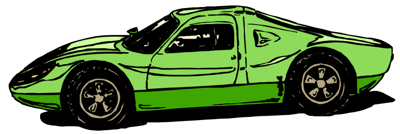
2) Explain how a **parachute** works:

3) (a) What is meant by **"streamlining"** an object? ______

(b) Draw lines to represent the **air flow** over these 2 cars :

(b) Explain which car is most **"streamlined"**:





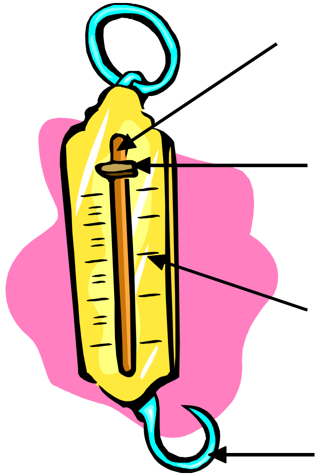
• Measuring Force

Force is measured in units called
n _ _ _ _ _ _ _ (symbol __).

We can measure **force** using a **Newton balance**.

4) (a) Label the diagram of a **Newton balance** using the words in the word bank:

hook	internal spring	pointer
	scale	



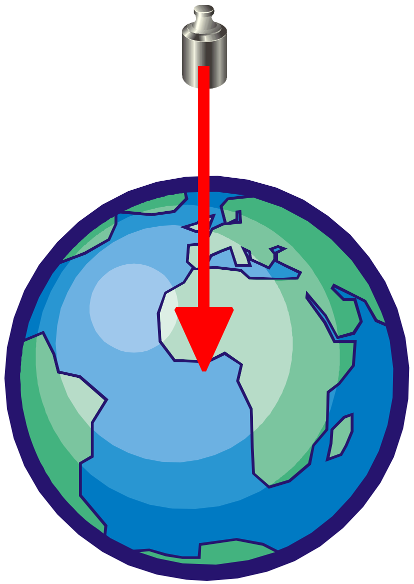
(b) Explain how a **Newton balance** works: ______________________________

(c) Explain how you would use a **Newton balance** to measure the **force** required to pull open a drawer: ______________________________

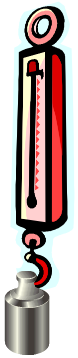
• Mass and Weight

Mass

Weight



5) When an object is hung from a **Newton balance**, what quantity does the **force reading** on the **Newton balance** represent?



____

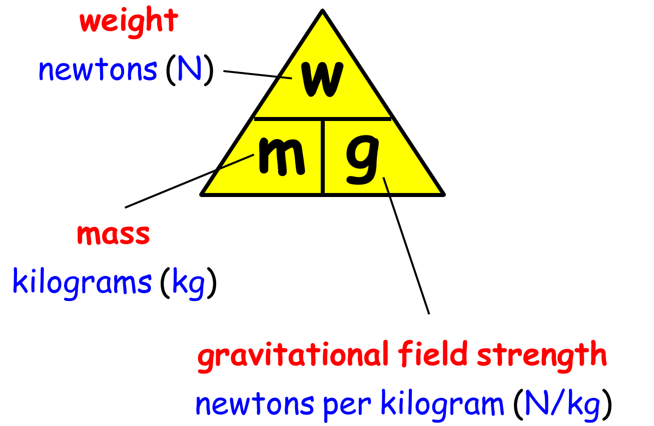
____

• Mass and Weight Calculations

For any object:

$$\boxed{\text{weight} = \text{mass} \times \text{gravitational field strength}}$$

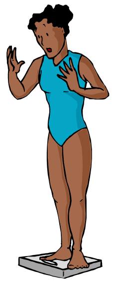
$$\boxed{w = m\,g}$$



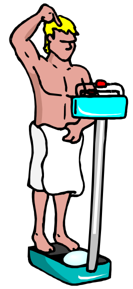
Near Earth's surface, g = 10 N/kg

6) Each person is standing on a set of scales on the Earth's surface.
Calculate the **weight** of each person:

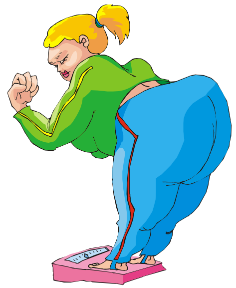
Harry
(mass 80 kilograms)



Mary
(mass 55 kilograms)

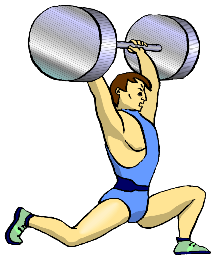


David
(mass 62 kilograms)



Bertha
(mass 110 kilograms)

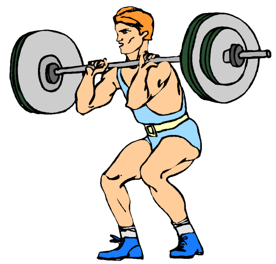
7) Each weightlifter is working out in a gym on the Earth's surface.
Calculate the **mass** being lifted by each weightlifter:



Dwayne
(lifting 1 000 newtons)

Sonya
(lifting 150 newtons)

Tanya
(lifting 320 newtons)



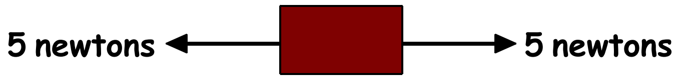
Victor
(lifting 1 600 newtons)

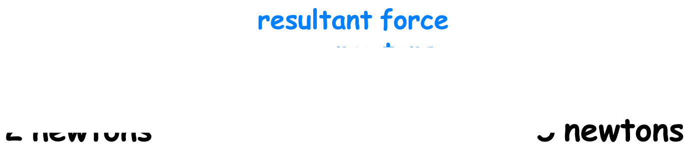
• Balanced and Unbalanced Forces

We can show the **direction** of a **force** using an ***arrow***.

Balanced Forces

For example:

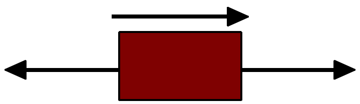




For example:

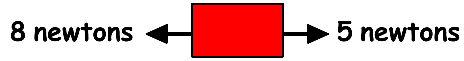
Unbalanced Forces

If the forces acting on an object are **not equal in size**, the forces are said to be **u** _ _ _ _ _ _ _ _ _ _.

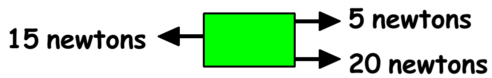


8) In each case, calculate the **size** of the **resultant force** and state any **direction**. Tick the correct box to show whether the forces acting on the object are **balanced** or **unbalanced**.

☐ balanced forces ☐ unbalanced forces

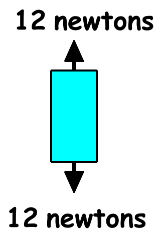


☐ balanced forces ☐ unbalanced forces

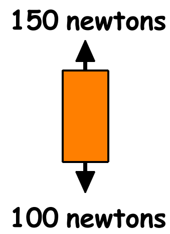


☐ balanced forces ☐ unbalanced forces

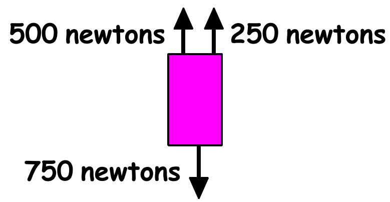
☐ balanced forces ☐ unbalanced forces



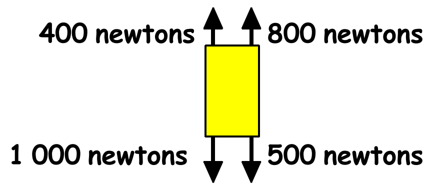
☐ balanced forces ☐ unbalanced forces



☐ balanced forces ☐ unbalanced forces



☐ balanced forces ☐ unbalanced forces



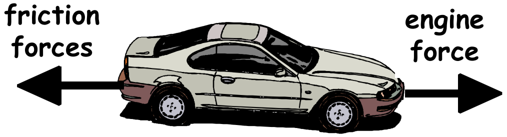
☐ balanced forces ☐ unbalanced forces

• Newton's First Law of Motion

Sir Isaac Newton
- a famous 17th century physicist

For example:

The diagram shows the forces which act on a car in the horizontal direction:



- The car is stationary at a set of traffic lights.

The forces acting on it are ____________.
The engine force and friction forces equal ___ newtons.

- As the traffic lights change to green, the car accelerates forwards.

The forces acting on it **are now** _______________.
The engine force is ________ than the friction forces.

- After a few seconds, the car reaches a constant speed (known as its **t** _ _ _ _ _ _ _ _ speed).

The forces acting on it are now __________ again.
(During these few seconds, the size of the friction forces ___________ until they are the _______ size as the engine force).

9) The diagram shows the horizontal forces acting on a motorbike during a race.

How does the size of these forces compare:

(a) Just before the start of the race when the motorbike is **not moving**? ____

____

(b) One second after the start of the race when the motorbike is **accelerating forwards**? ____

____

(c) A few seconds later when the motorbike has reached a **constant** (**terminal**) **speed**? ____

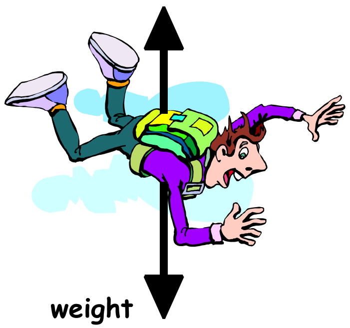
____

(d) Just before the end of the race when the motorbike is **decelerating**? ____

____

---

10) The vertical forces acting on a skydiver are shown in the diagram.



(a) As soon as the skydiver jumps from an aeroplane, he **accelerates downwards**. Explain why:

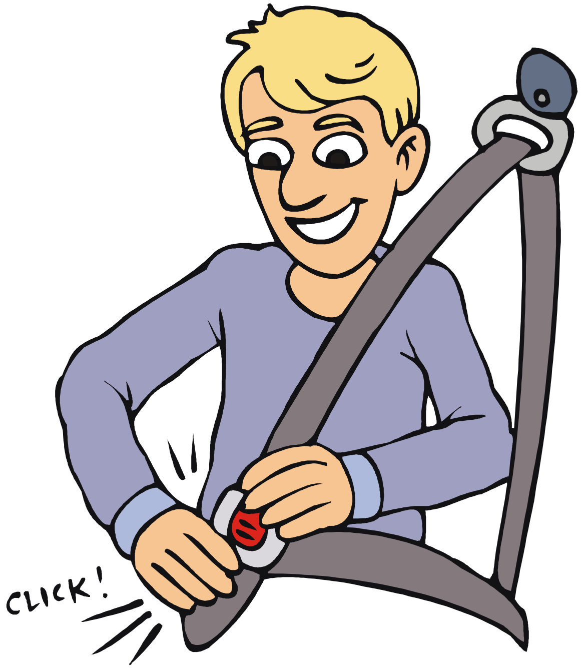
____
____
____
____
____

(b) After a few seconds, the skydiver reaches a **constant** (**terminal**) **speed**. Explain why:

____
____
____
____

• Seat Belts

Seat belts are a vital **safety feature** in road vehicles. Every year, thousands of people's lives are saved because, during a vehicle crash, they were wearing a **seat belt**.

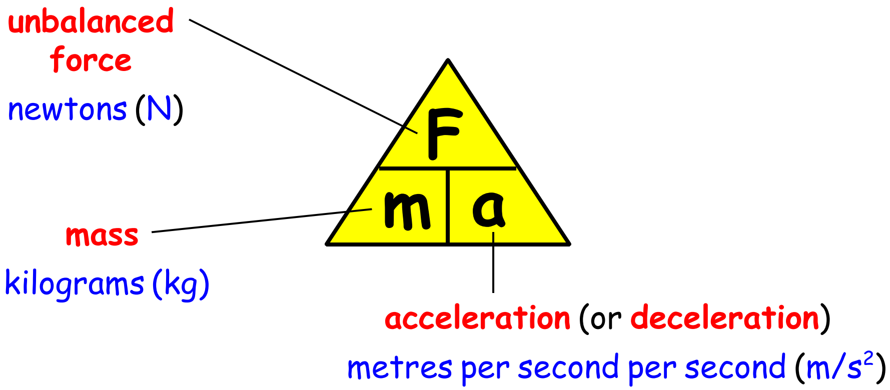


Explain, in terms of **forces**, how a **seat belt** works:

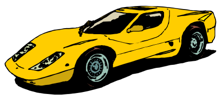
• Newton's Second Law of Motion

unbalanced force = mass x acceleration

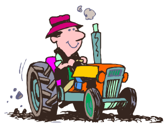
$$F = m\,a$$



• F = ma Calculations

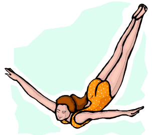


11) Calculate the **acceleration** of a car of mass 1 500 kilograms which is acted upon by an unbalanced force of 4 500 newtons.

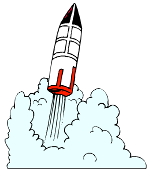


12) A tractor and its driver have a combined mass of 1 700 kilograms. An unbalanced force of 2 040 newtons drives the tractor forward. Calculate the tractor's **acceleration**.

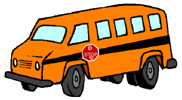
13) An unbalanced force of 91 newtons acts on Simon and his skateboard which have a combined mass of 65 kilograms. Calculate the **acceleration** of Simon and his skateboard.



14) Daisy the diver has a mass of 50 kilograms. After jumping from a diving board, she accelerates downwards towards a swimming pool at 10 metres per second per second. Calculate the **unbalanced force** acting on her.



15) Calculate the **unbalanced force** acting on a rocket of mass 5 000 kilograms if it accelerates upwards from the ground at 0.8 metres per second per second.

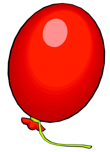


16) A minibus of mass 2 500 kilograms accelerates at 0.75 metres per second per second. Calculate the **unbalanced force** acting on the minibus.

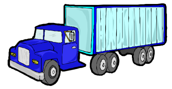
17) Sally the snow boarder accelerates at 0.5 metres per second per second when an unbalanced force of 30 newtons acts on her. Calculate the combined **mass** of Sally and her snow board.

18) When an unbalanced force of 780 newtons acts on a skydiver, he accelerates towards the ground at 10 metres per second per second. Calculate the **mass** of the skydiver and his equipment.

19) A speed skater accelerates at 1.5 metres per second per second when an unbalanced force of 96 newtons acts on him. Calculate the **mass** of the speed skater.



20) A balloon of mass 0.001 kilograms accelerates upwards when acted upon by an unbalanced force of 0.002 newtons. Calculate the **acceleration** of the balloon.



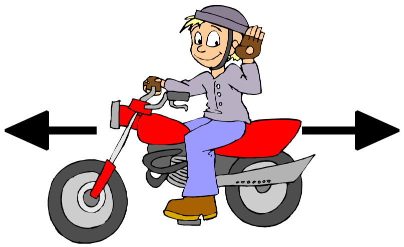
21) A 10 000 kilogram truck accelerates at 0.2 metres per second per second. Calculate the size of the **unbalanced force** acting on the truck.

22) A mini hovercraft accelerates at 1.6 metres per second per second when an unbalanced force of 1 840 newtons acts on it. Calculate the **mass** of the hovercraft.

• More F = ma Calculations

Example: The diagram shows the horizontal forces acting on a motorbike:

thrust from engine = 1 500 N



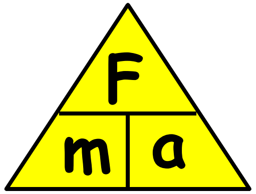
air resistance = 800 N

mass = 250 kg

Determine:

(a) The **size** and **direction** of the **unbalanced force** acting on the motorbike.

(b) The **size** and **direction** of the motorbike's **acceleration**.



F = m a

(a) Unbalanced force = 1 500 N - 800 N

= **700N to the left**

(b) $a = \frac{F}{m}$

$= \frac{700}{250}$

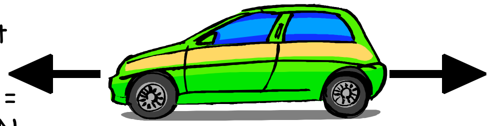
= **2.8 m/s² to the left**

23) In each case, determine:

(a) the **size** and **direction** of the **unbalanced force** acting on the object;

(b) the **size** and **direction** of the object's **acceleration**.

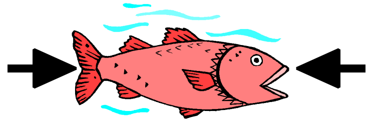
thrust from engine = 5 000 N



air resistance = 2 000 N

mass = 1 200 kg

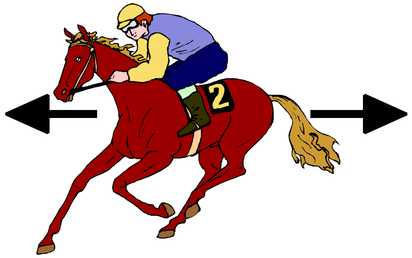
thrust from tail = 15.0 N



resistive forces = 14.4 N

mass = 0.4 kg

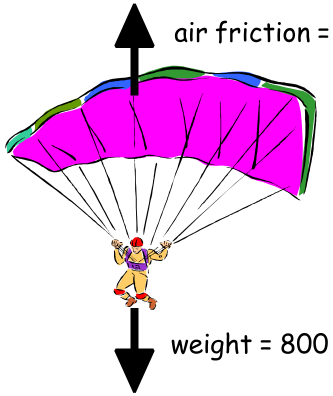
thrust from hooves = 3 000 N



resistive forces = 800 N

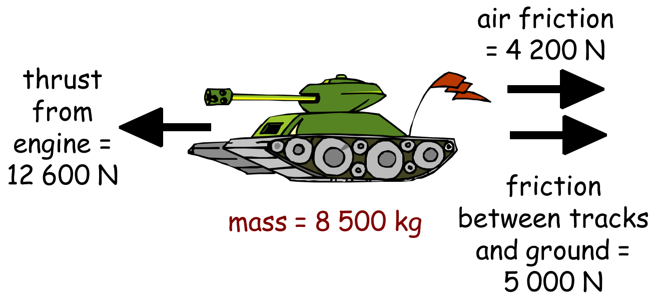
mass = 1 000 kg

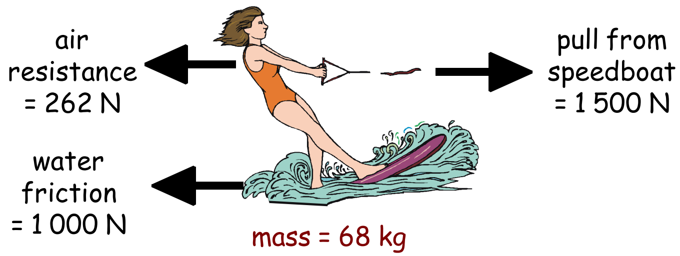
air friction = 704 N

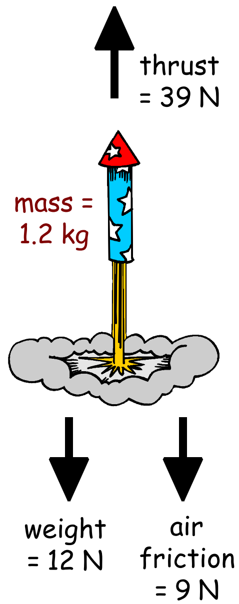


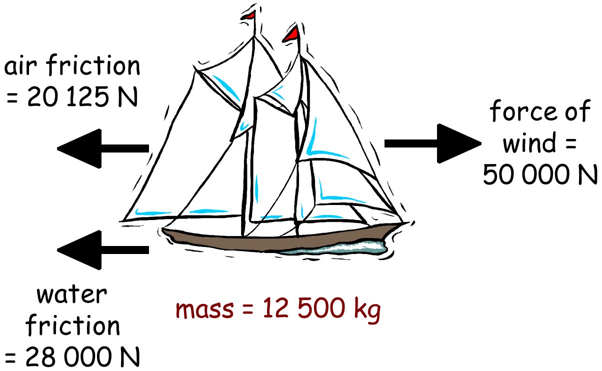
mass = 80 kg

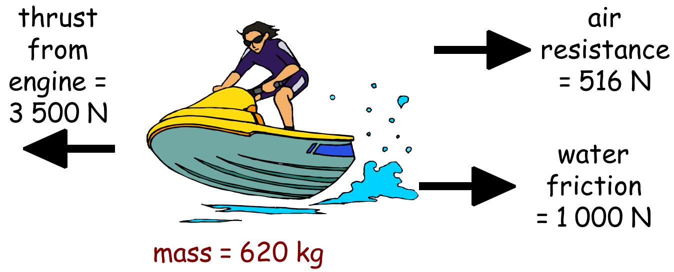
weight = 800 N

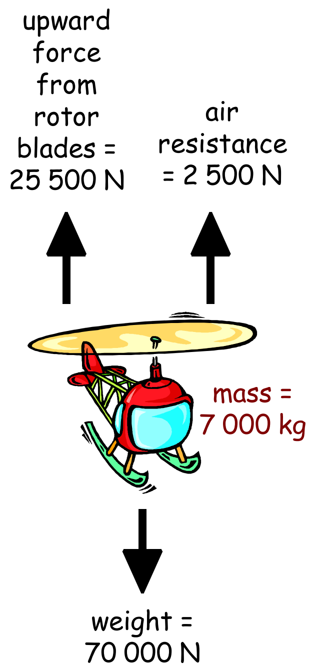

thrust from engine = 12 600 N
air friction = 4 200 N
friction between tracks and ground = 5 000 N
mass = 8 500 kg


air resistance = 262 N
water friction = 1 000 N
pull from speedboat = 1 500 N
mass = 68 kg


thrust = 39 N
mass = 1.2 kg
weight = 12 N
air friction = 9 N


air friction = 20 125 N
force of wind = 50 000 N
water friction = 28 000 N
mass = 12 500 kg


thrust from engine = 3 500 N
air resistance = 516 N
water friction = 1 000 N
mass = 620 kg


upward force from rotor blades = 25 500 N
air resistance = 2 500 N
mass = 7 000 kg
weight = 70 000 N