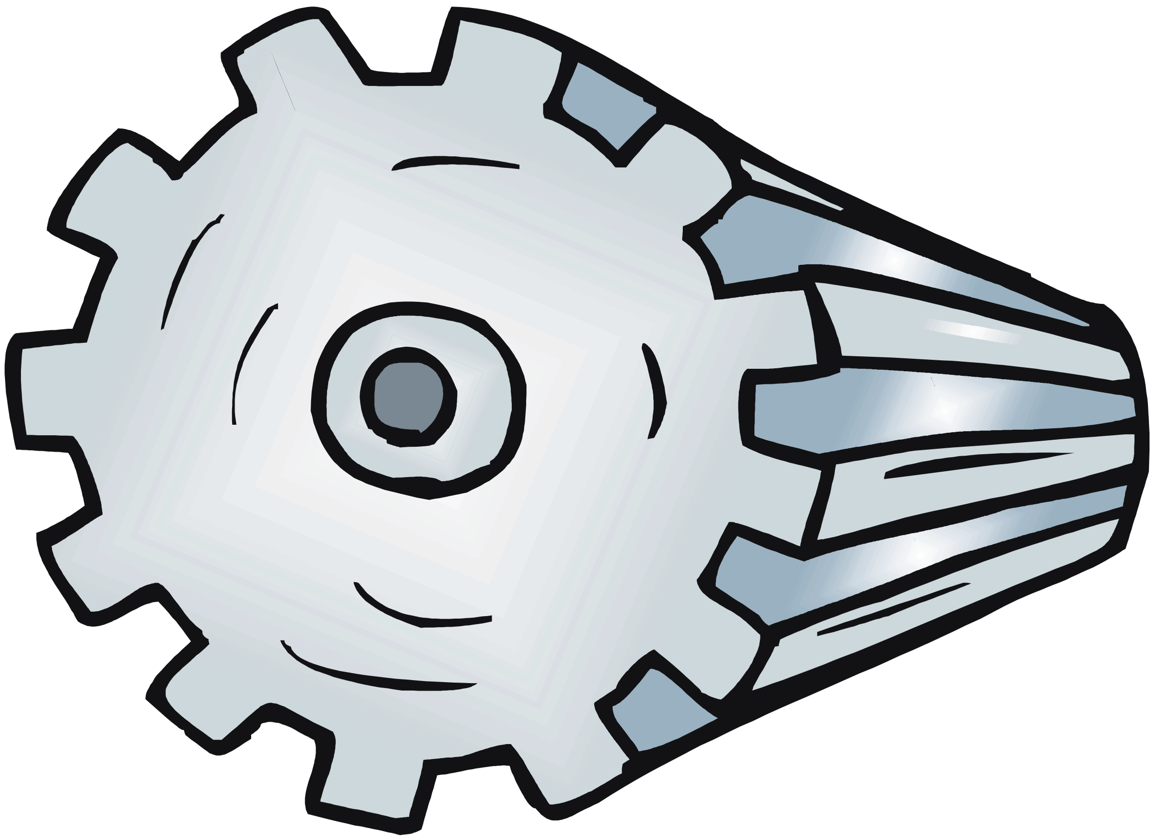
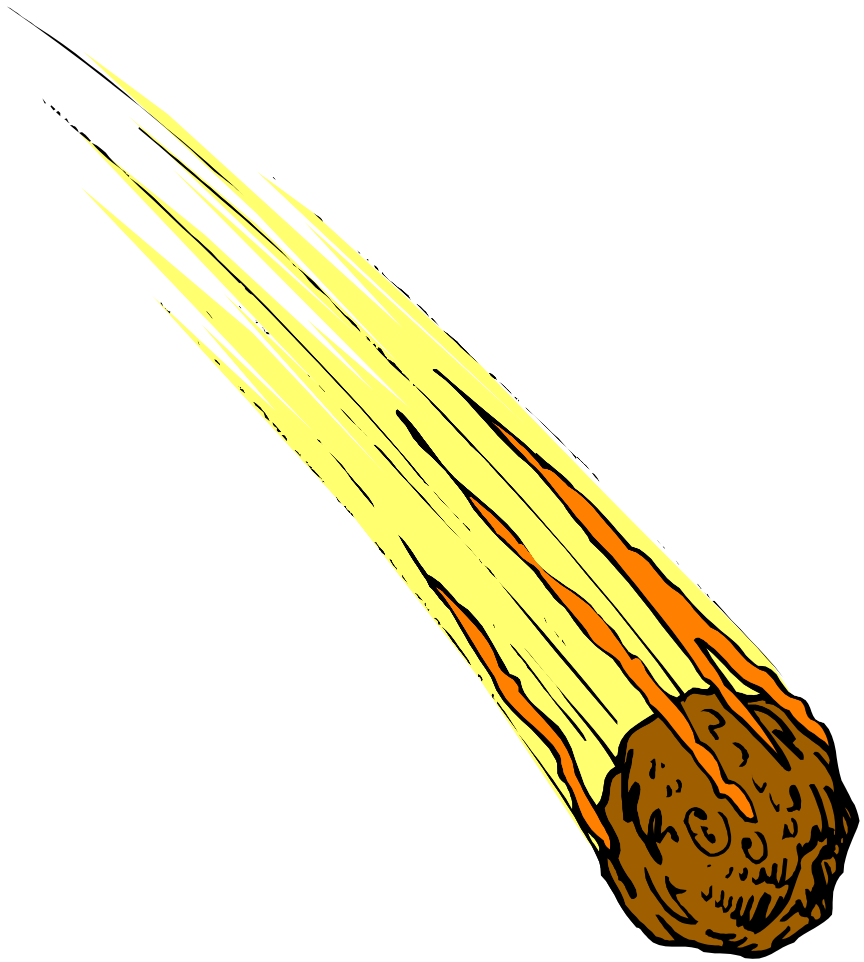
Intermediate 2

MECHANICS and HEAT





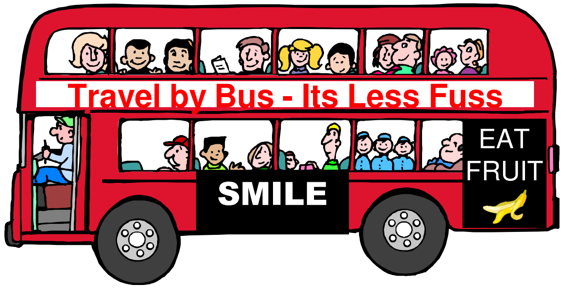
Name: ______________________________ Class: ______ Teacher: ____________________

Section 1: Kinematics

• Why Use the Term "Average Speed"?

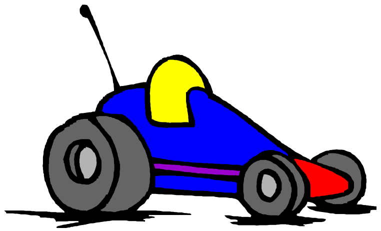
When an object moves over a large distance, its speed rarely stays the same.

For example, a bus travelling from Edinburgh to Glasgow will change its speed many times during its journey as it negotiates traffic and stops/starts to collect and drop off passengers.



This is why we use the term **average speed** when describing the movement of objects which travel a large distance.

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.



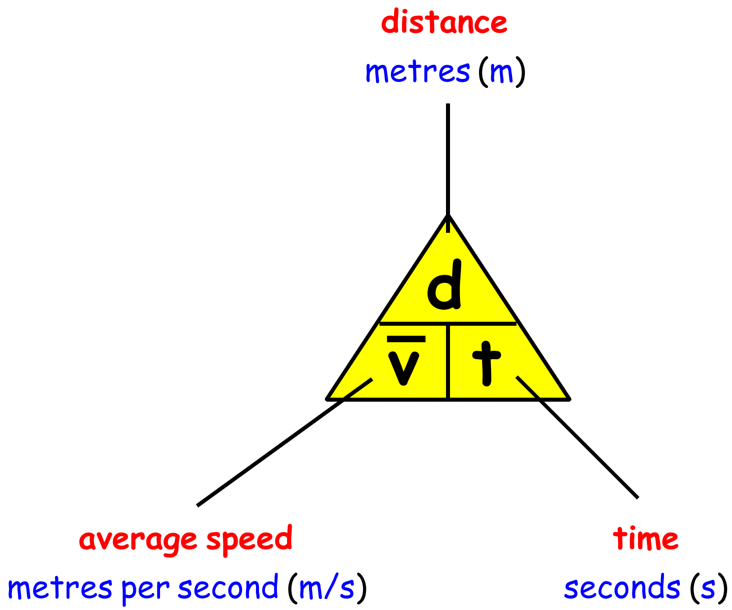
• Average Speed Calculations

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".

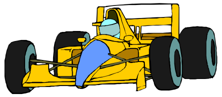
$$\text{average speed} = \frac{\text{distance}}{\text{time}}$$

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

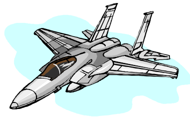


1) Calculate the missing quantity in each case:

- average speed = ?
- distance = 500 m
- time = 5 s

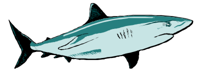


- average speed = ?
- distance = 15 000 m
- time = 25 s



- average speed = ?
- distance = 10 m
- time = 0.5 s

- average speed = ?
- distance = 45 m
- time = 2.5 s

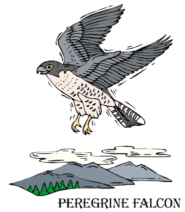


- average speed = ?
- distance = 59.5 m
- time = 3.5 s

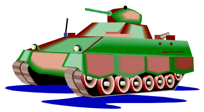
- average speed = ?
- distance = 1 440 m
- time = 80 s

- average speed = ?
- distance = 750 m
- time = 500 s

- average speed = ?
- distance = 540 m
- time = 12 s



- average speed = 12 m/s
- distance = ?
- time = 6 s



- average speed = 0.001 m/s
- distance = ?
- time = 120 s

- average speed = 1.2 m/s
- distance = 6 m
- time = ?

- average speed = 10.2 m/s
- distance = 100 m
- 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 Intermediate 2 Physics exam.

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.

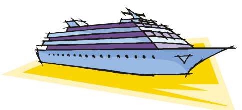
(c) 100 kilometres per hour.

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**.

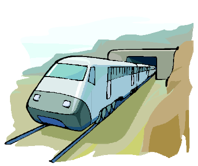
4) A cruise ship takes a time of 5 hours 30 minutes to sail 33 miles.



(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)

East Coast Flying Scotsman service

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**.

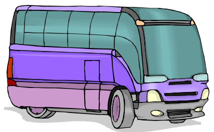
7) An express coach timetable is shown below.

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

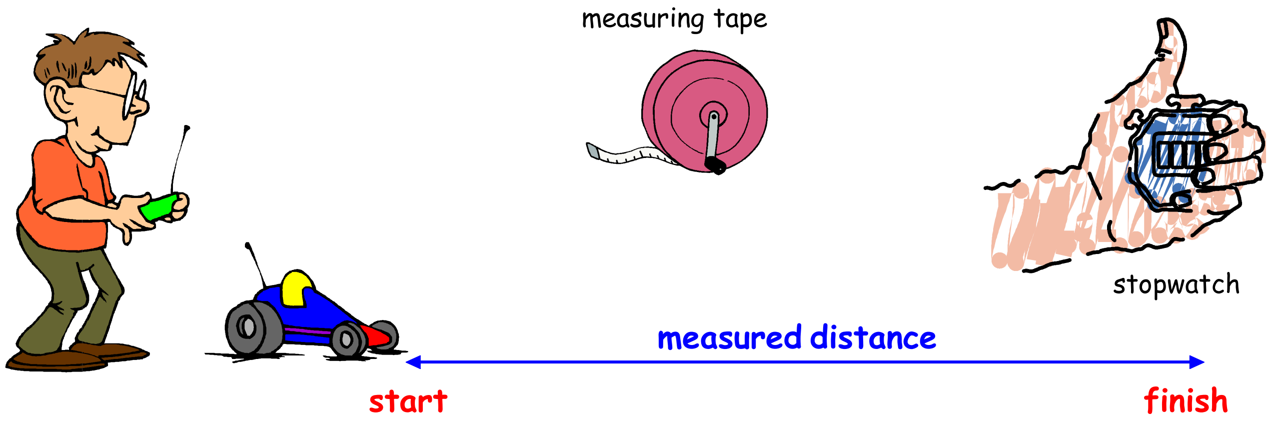
8) A coach travels the 157.5 mile road distance from Edinburgh to Inverness at an average speed of 45 miles per hour.



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

• Measuring Average Speed: Human Timing

To measure the **average speed** ($\bar{v}$) of a moving object (for example, a **radio-controlled toy car**), we can use a **measuring tape** and **stopwatch**:



1) With a **m** _ _ _ _ _ _ _ _ _ **t** _ _ _ , measure (and mark with chalk) a distance of several metres on the ground.

2) With a **s** _ _ _ _ _ _ _ _ _ , time how long it takes the radio-controlled toy car to travel this distance.

3) Calculate the **average speed** of the toy car using the formula:

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

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

Sample Readings and Calculation

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

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

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

$$= \underline{4\ m/s}$$

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 m
- time taken (t) = 1.8 s

Run 2

- distance travelled (d) = 12 m
- time taken (t) = 2.5 s

Run 3

- distance travelled (d) = 15 m
- time taken (t) = 6.0 s

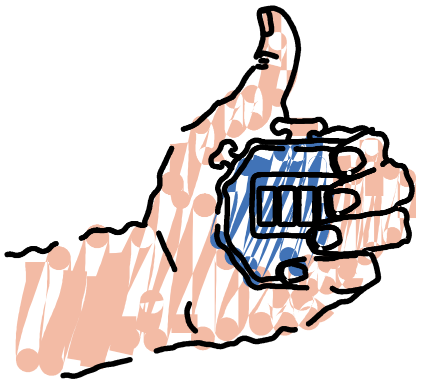
• Measuring Average Speed: Electronic Timing

Stopwatches and Human Reaction Time

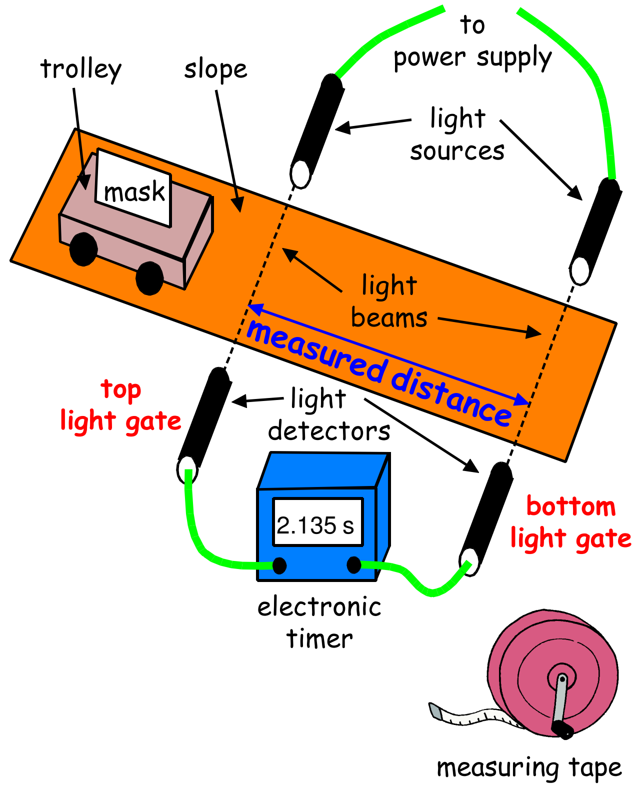
Using a **stopwatch** to time moving objects does **not** give us a very **accurate** value for the time taken. This is due to **human reaction time**.

For example, imagine you are timing a radio-controlled toy car from the moment it starts to the moment it has travelled 5 metres. When your eyes see the car start to move, they send a message to your brain. Your brain processes this message then sends another message to your finger telling it to press the **start button** on the stopwatch - but it takes a fraction of a second for all this to happen, so the car is **already moving** before the **start button** is pressed. When the car reaches the 5 metre mark, the same signalling/reaction process takes place in your body - the car will have **travelled past** the 5 metre mark before the **stop button** is pressed. Because of this, the timing of the car journey is **not accurate**.

This is particularly important when timing sprint races where a difference of less than 0.001 seconds can mean the difference between first and second place! In cases like this, **electronic timing** is used - This does not involve humans pressing buttons (no **human reaction time**) so is far **more accurate** than **human timing**.



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 - No light can pass through the mask.



When the **mask** breaks the **light beam** of the **top light gate**, the electronic timer is automatically switched **on**.

When the **mask** breaks the **light beam** of the **bottom light gate**, the electronic timer is automatically switched **off**.

The electronic timer shows the time the trolley takes to travel from the **top light gate** to the **bottom light gate**.

1) With a **m** _ _ _ _ _ _ _ _ **t** _ _ _ , measure the distance between the 2 light gates.

2) Put the trolley at the top of the slope and let it run down the slope (so that the mask passes through the **l** _ _ _ _ **b** _ _ _ of both **l** _ _ _ _ **g** _ _ _ _).

3) Read the **time** taken for the trolley to travel from the top light gate to the bottom light gate from the **e** _ _ _ _ _ _ _ _ _ **t** _ _ _ _ .

3) Calculate the **average speed** of the trolley using the formula:

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

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

Sample Readings and Calculation

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

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

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

$$= \underline{2.5 \text{ m/s}}$$

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 m
- time taken (t) to travel between light gates = 0.250 s

Run 2

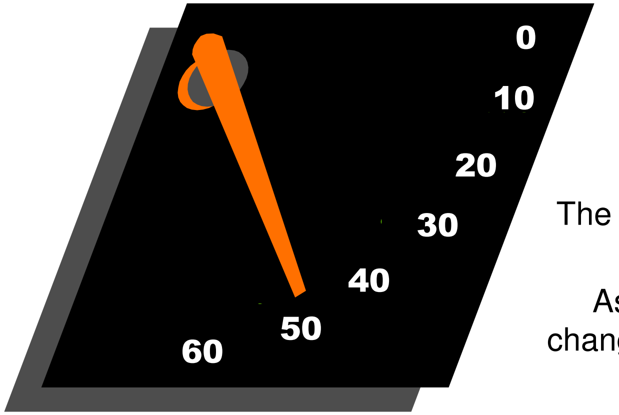
- distance travelled (d) between light gates = 0.80 m
- time taken (t) to travel between light gates = 0.500 s

Run 3

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

• Instantaneous Speed

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



a car speedometer

Note that for " instantaneous speed ", there is NO bar (-) above the v.

The **instantaneous speed** of a car is shown on its **speedometer**.

As the **instantaneous speed** of the car changes, the **speedometer reading** changes.

The **instantaneous speed** of a moving object is estimated by measuring the **distance** the object travels in a **very short time** - Much less than **1 second**.

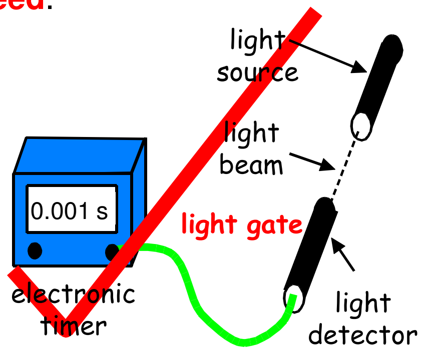
The **smaller** the **measured time**, the better will be the estimate for the object's **instantaneous speed**.

For times **longer than** about **0.005 seconds**, the **speed** determined is really the **average speed**.

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

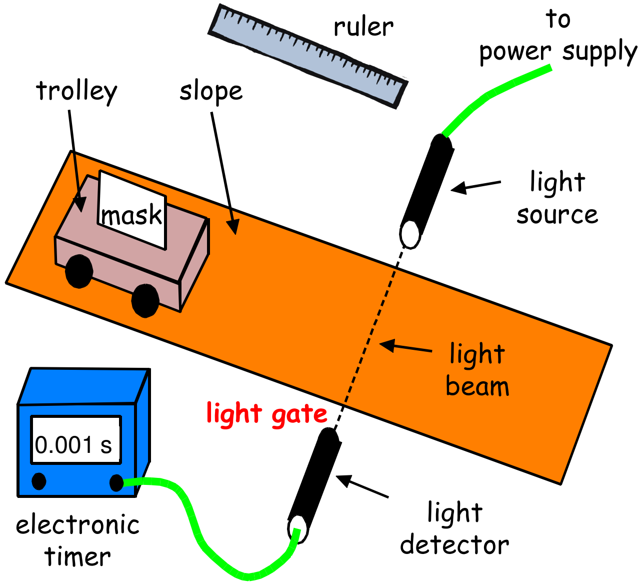
A **stopwatch** cannot be used because we are not able to press the start and stop buttons quickly enough - Slow **human reaction time**.

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



• Measuring Instantaneous Speed: Electronic Timing

To measure the **instantaneous speed** (**v**) of a moving object (for example, a **trolley** rolling down a slope) at a **particular point** on the slope, we employ **electronic timing** - **1 light gate** is connected to an **electronic timer**. A **short mask** (about a 1 or 2 cm length of **thick card**) is fixed on top of the trolley - No light can pass through the mask.



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**.

1) With a **r** _ _ _ _ , measure the **l** _ _ _ _ _ of the short mask.

2) Place the **l** _ _ _ _ **g** _ _ _ at the particular point on the slope where you want to measure the trolley's **i** _ _ _ _ _ _ _ _ _ _ _ _ _ **speed**.

3) Put the trolley at the top of the slope and let it run down the slope (so that the short mask passes through the **l** _ _ _ _ **b** _ _ _ of the **l** _ _ _ _ **g** _ _ _.)

3) Calculate the **instantaneous speed** of the trolley using the formula:

$$\text{instantaneous speed} = \frac{\text{distance (length of mask)}}{\text{time taken for mask to travel through light gate}}$$

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

Sample Readings and Calculation

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

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

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

$$= \underline{5 \text{ m/s}}$$

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 m
- time taken (t) for mask to travel through light gate = 0.001 s

Run 2

- distance (length of mask) = 0.015 m
- time taken (t) for mask to travel through light gate = 0.003 s

Run 3

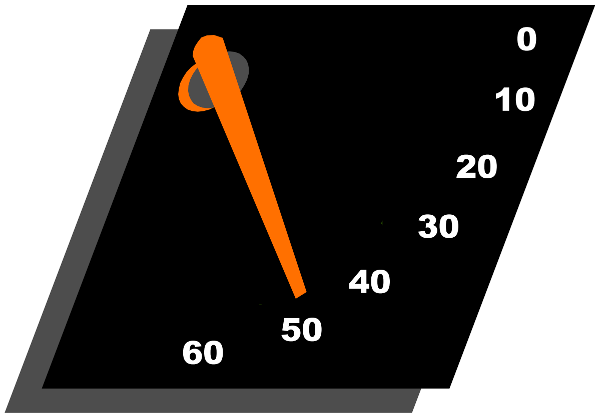
- distance (length of mask) = 0.02 m
- time taken (t) for mask to travel through light gate = 0.005 s

• Comparing Instantaneous and Average Speeds

In most cases, at any **particular instant of time**, the **instantaneous speed** of a moving object will have a **different value** from its **average speed** - because most objects **speed up** and **slow down** during their journey.

The **instantaneous** and **average speeds** will only have the **same value** over a **long period of time** if the object:

- does not **move**.
- does not **speed up** or **slow down**.



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 Edinburgh to Glasgow: ____________________

____

____

____

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: ____________________

____

• Scalar and Vector Quantities

The following are *some* of the **quantities** you will meet in the Intermediate 2 Physics course:

distance displacement

speed velocity

force

time

Quantities can be divided into 2 groups:

SCALARS

These are specified by stating their **magnitude** (**size**) only, with the correct unit.

VECTORS

These are specified by stating their **magnitude** (**size**), with the correct unit, and a **direction**.

Some **scalar** quantities have a corresponding **vector** quantity. Other **scalar** and **vector** quantities are independent. For example:

corresponding scalar quantity	corresponding vector quantity
distance (e.g., 25 m)	displacement (e.g., 25 m North)
speed (e.g., 10 m/s)	velocity (e.g., 10 m/s East)
time (e.g., 12 s)	NONE
NONE	force (e.g., 10 N to the right)

DISTANCE and DISPLACEMENT

- **Distance** (a **scalar** quantity) is **the total length of path travelled**.

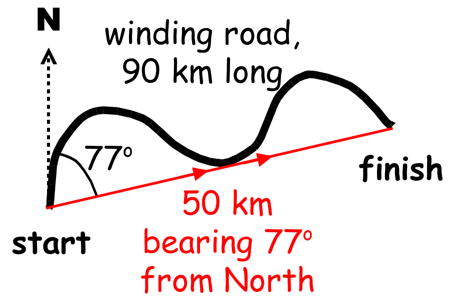
[A **unit** must always be stated].

- **Displacement** (a **vector** quantity) is **the length and direction of a straight line drawn from the starting point to the finishing point**.

[A **unit** and **direction** must always be stated, unless the **displacement is zero**, in which case there is **no direction**].

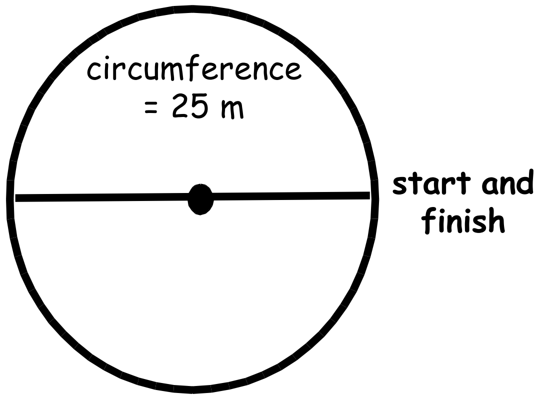
For example:

1) Bill drives 90 km along a winding road.



- Distance travelled = 90 km
- Displacement = 50 km bearing 77° from North

2) Ben jogs once around the centre circle of a football pitch.



- Distance travelled = 25 m
- Displacement = 0 m. (He is back where he started, so the length of a straight line drawn from his starting point to his finishing point is 0 m).

SPEED and VELOCITY

- **Speed** (a **scalar** quantity) is **the distance travelled every second**.

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

[A **unit** must always be stated].

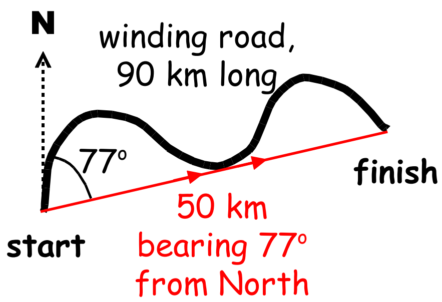
- **Velocity** (a **vector** quantity) is **the change of displacement every second**.

$$\text{velocity} = \frac{\text{displacement}}{\text{time}}$$

[A **unit** and **direction** must always be stated, unless the **velocity is zero**, in which case there is **no direction**].

For example:

Bill drives 90 km along a winding road in a time of 2 hours:



- Distance travelled = 90 km
- Displacement = 50 km bearing 77° from North

$$\text{average speed} = \frac{\text{distance}}{\text{time}} = \frac{90}{2} = 45 \text{ km/h}$$

$$\text{velocity} = \frac{\text{displacement}}{\text{time}} = \frac{50}{2} = 25 \text{ km/h}$$

bearing 77° from North

15) (a) How would you specify a **scalar** quantity? ______________________________

____

(b) Give three examples of **scalar** quantities: ______________________________

____

16) (a) How would you specify a **vector** quantity? ______________________________

____

(b) Give three examples of **vector** quantities: ______________________________

____

17) State the difference between **distance** and **displacement**:

____

18) Explain the terms **speed** and **velocity**: ______________________________

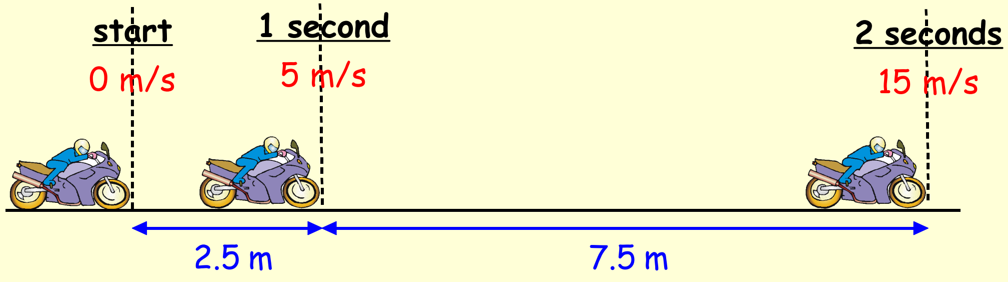
____

● Acceleration (and Deceleration)

This diagram shows a motorbike **accelerating** from a **stationary start** (**rest, 0 m/s**) to a **velocity** of **15 m/s to the right**.

After each second:

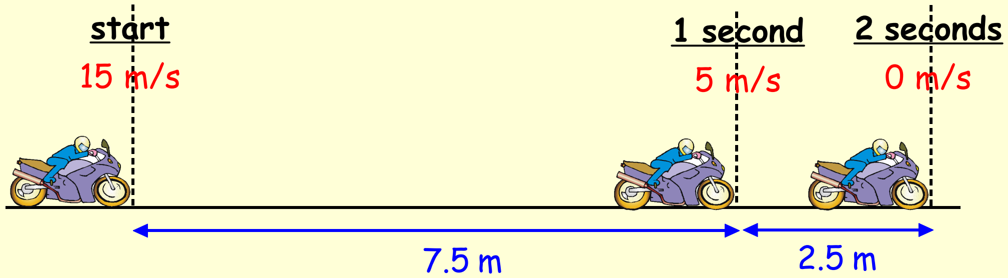
- Its **velocity** has **increased**.
- It has travelled **further** than it travelled the second before.



This diagram shows a motorbike **decelerating** from a **velocity** of **15 m/s to the right** to **rest** (**0 m/s**).

After each second:

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



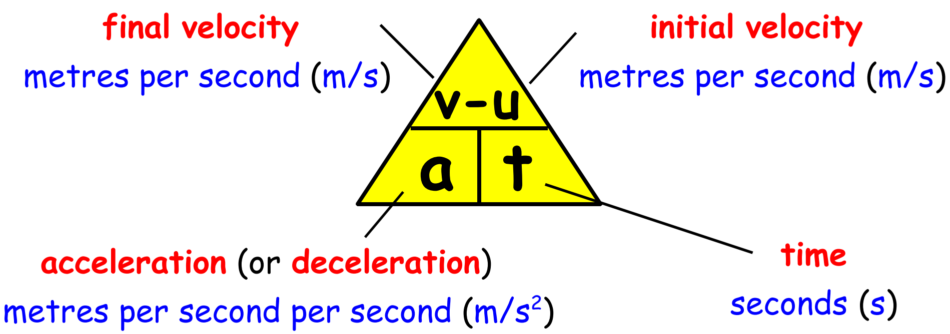
- When an object's **velocity increases** with time, the object is **a** _ _ _ _ _ _ _ _ _ _ _ _ _.
- When an object's **velocity decreases** with time, the object is **d** _ _ _ _ _ _ _ _ _ _ _ _ _.

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

Acceleration (or **deceleration**) is a **vector** quantity.

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

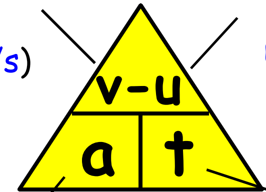
$$a = \frac{v - u}{t}$$



• Acceleration Calculations

final velocity
metres per second (m/s)

initial velocity
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 increases their velocity from **1 m/s** to **3 m/s** **to the right** in a time of **4 s**.

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

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

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

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

<u>to the right</u>

Deceleration

Calculate the **deceleration** of a cyclist who decreases their velocity from **7 m/s** to **1 m/s** **to the right** in a time of **3 s**.

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

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

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

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

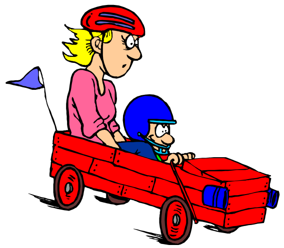
<u>to the right</u>

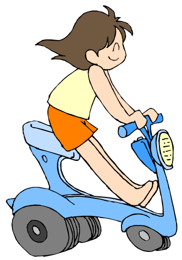
The - sign indicates "<u>deceleration</u>"

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

(a) Farmer Jones' tractor starts from rest and increases its velocity to 8 m/s to the right in 10 s.

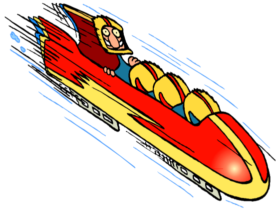
(b) In their go-kart, Jill and her Mum increase their velocity from rest to 6 m/s to the right in 12 s.





(c) On her motor scooter, Dominique takes 5 s to increase her velocity from 3 m/s to 13 m/s to the right.

(d) Mike's motorbike takes 5 s to increase in velocity from 10 m/s to 30 m/s to the right.



20) As a bobsleigh reaches a steep part of track, its velocity increases from 24 m/s to 36 m/s down the slope. This happens in 0.4 s.

Calculate the acceleration of the bobsleigh during this time.

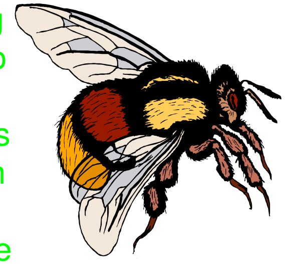
21) An arrow hits a stationary target with a velocity of 50 m/s to the right and comes to rest in 0.1 s.

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

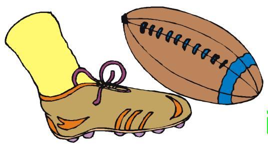
22) Starting from rest, a fireman slides down a pole with an acceleration of 1.2 m/s^2 downwards. His velocity at the bottom of the pole is 3.6 m/s downwards.

Calculate the time taken to slide down the pole.

23) A bee, decelerating at 0.7 m/s^2 to the right, decreases its velocity from 6.7 m/s to 2.5 m/s to the right.



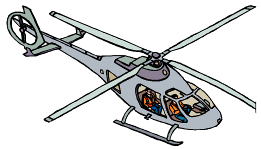
What time does this take?



24) 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 at 45° above the horizontal ground.

Calculate the velocity with which the ball leaves the player's boot.

25) A helicopter is flying at 35 m/s to the right. It then decelerates at 2.5 m/s^2 to the right for 12 s.

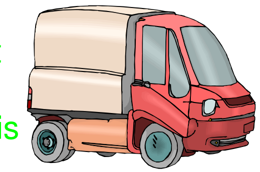


Calculate the velocity of the helicopter after the 12 s.

26) The velocity of a conveyor belt which is moving to the right is increased to 2.8 m/s by accelerating it at 0.3 m/s^2 to the right for 4 s.

Calculate the initial velocity of the conveyor belt.

27) A van decelerates at 1.4 m/s^2 to the right for 5 s. This reduces its velocity to 24 m/s to the right.



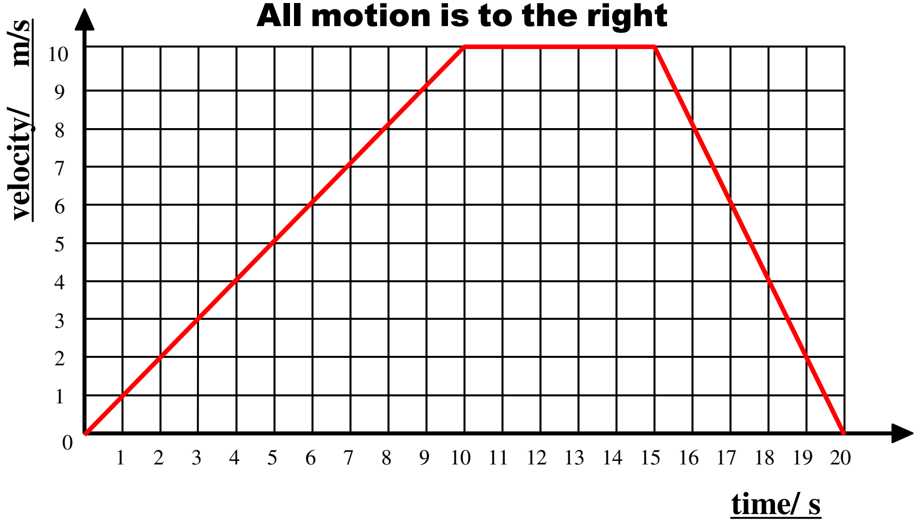
Calculate the van's initial velocity.

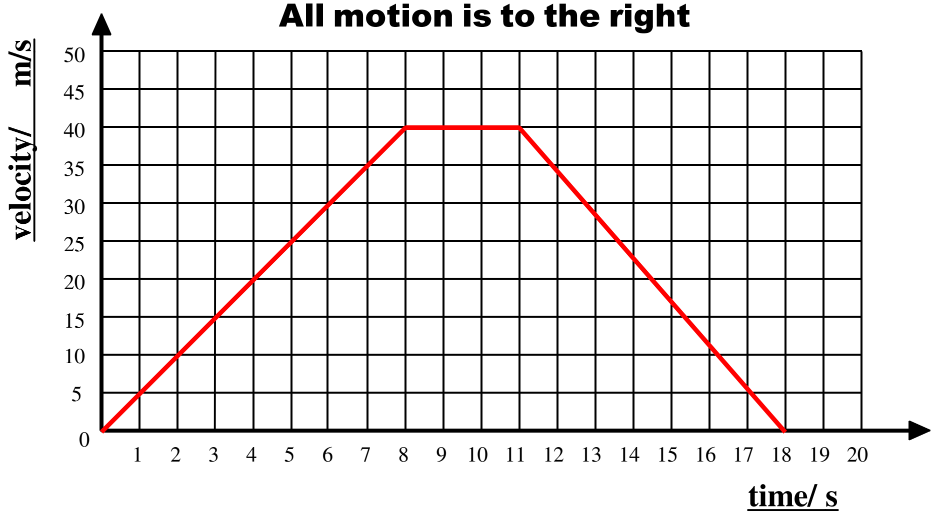
• Velocity-Time Graphs

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

---

28) Describe the motion represented by the **line** on each **velocity-time graph**:





0 - 10 seconds: ____________ ____________ from ____ m/s to ____ m/s.
(Constant/uniform ________________).

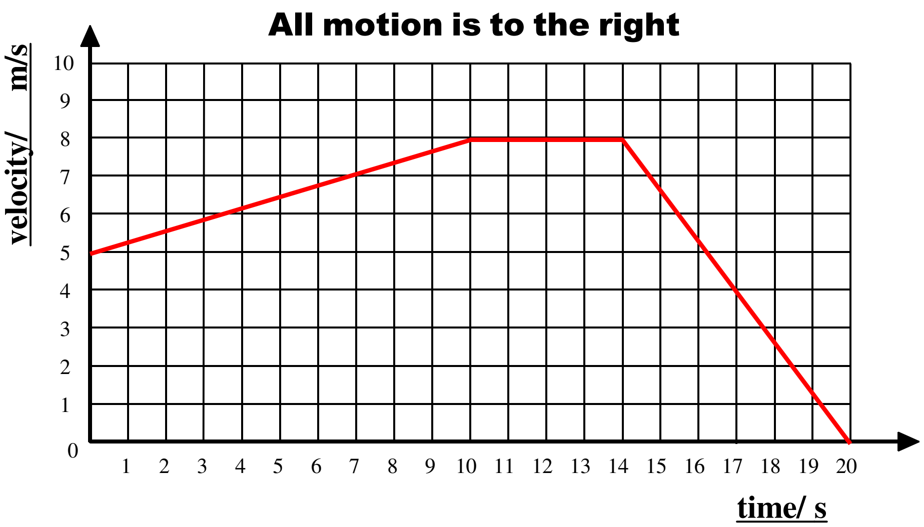
10 - 15 seconds: ___________ __________ of ____ m/s.

15 - 20 seconds: ____________ ______________ from ____ m/s to ____ m/s.
(Constant/uniform ________________).

0 - 8 seconds: ____________ ____________ from ____ m/s to ____ m/s.
(Constant/uniform ________________).

8 - 11 seconds: ___________ __________ of ____ m/s.

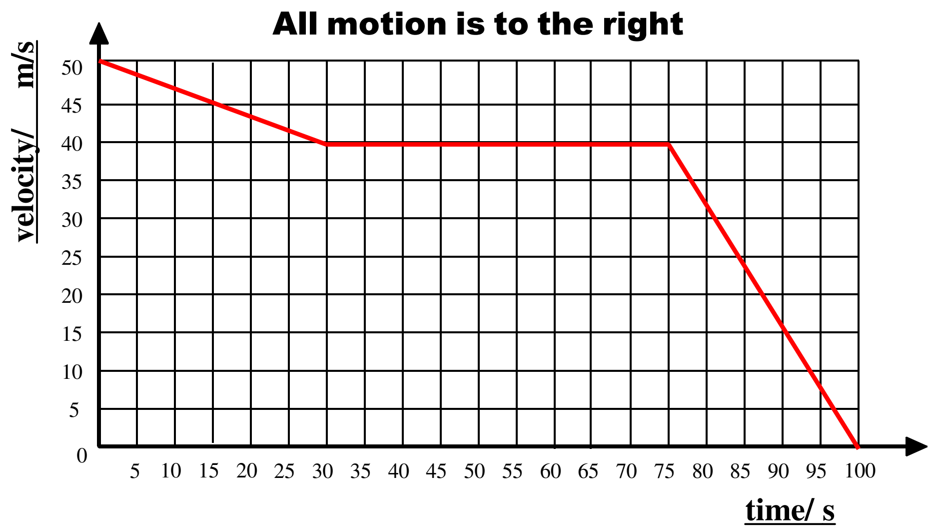
11 - 18 seconds: ____________ ______________ from ____ m/s to ____ m/s.
(Constant/uniform ________________).



0 - 10 seconds: ____________ ____________ from ____ m/s to ____ m/s.
(Constant/uniform __________________).

10 - 14 seconds: ____________ ___________ of ____ m/s.

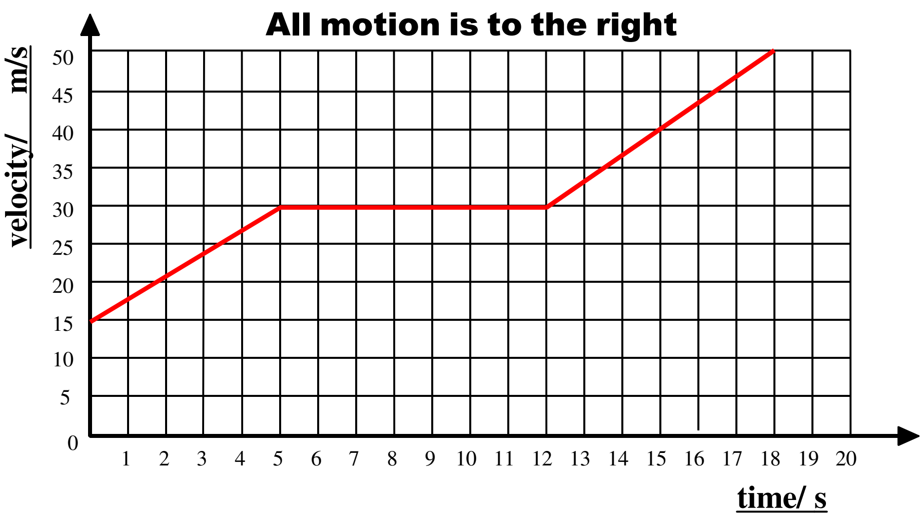
14 - 20 seconds: ____________ ______________ from ____ m/s to ____ m/s.
(Constant/uniform ____________________).



0 - 30 seconds: _____________ ______________ from ____ m/s to ____ m/s.
(Constant/uniform ____________________).

30 - 75 seconds: ____________ ___________ of ____ m/s.

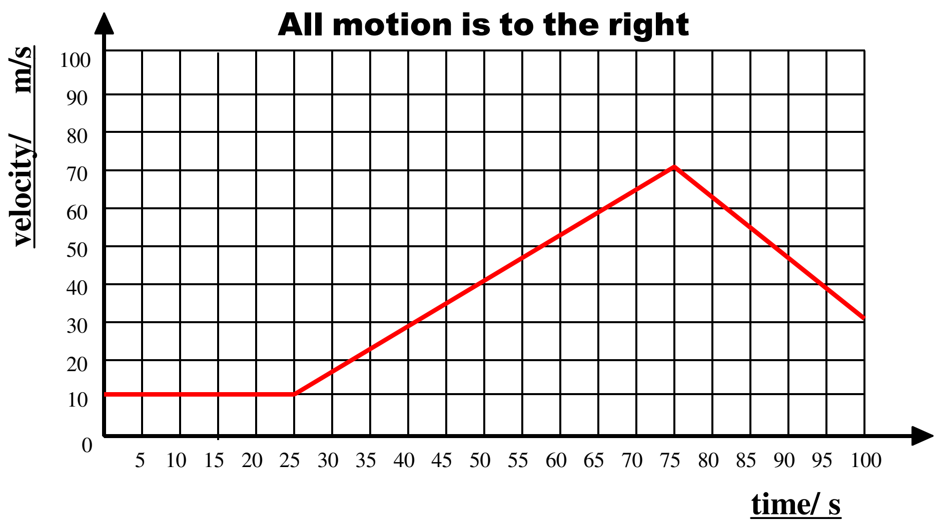
75 - 100 seconds: _____________ _____________ from ____ m/s to ____ m/s.
(Constant/uniform ____________________).



0 - 5 seconds: _____________ _____________ from ____ m/s to ____ m/s.
(Constant/uniform __________________).

5 - 12 seconds: ____________ ___________ of ____ m/s.

12 - 17 seconds: _____________ _____________ from ____ m/s to ____ m/s.
(Constant/uniform __________________).



0 - 25 seconds: ____________ ___________ of ____ m/s.

25 - 75 seconds: _____________ _____________ from ____ m/s to ____ m/s.
(Constant/uniform ________________).

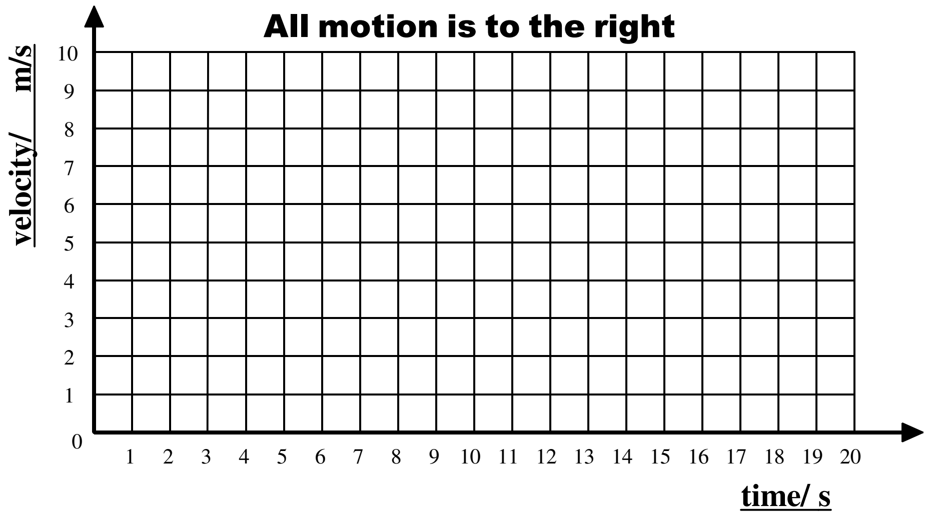
75 - 100 seconds: _____________ ______________ from ____ m/s to ____ m/s.
(Constant/uniform ____________________).

29) Draw the **line** on each **velocity-time graph** to represent the motion described:

0 - 5 seconds: Increasing velocity from rest (0 m/s) to 10 m/s to the right. (Constant/uniform acceleration).

5 - 15 seconds: Constant velocity of 10 m/s to the right.

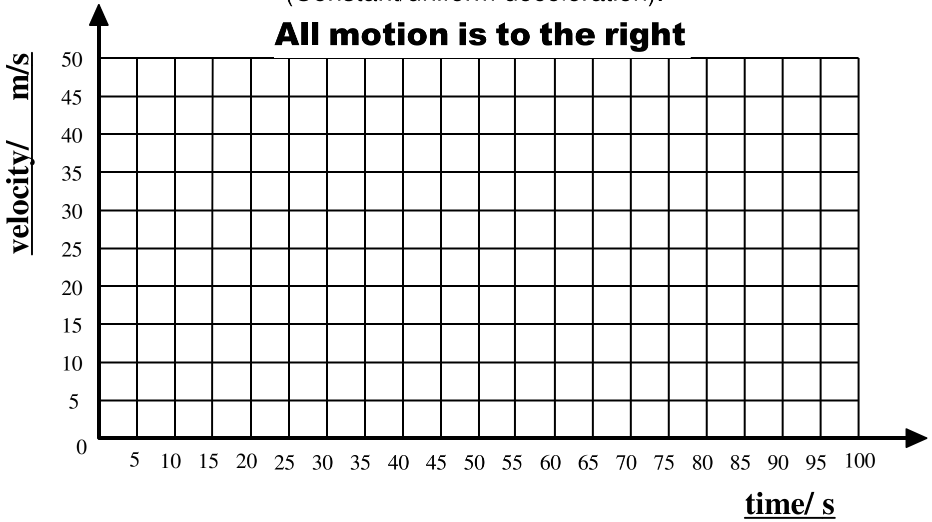
15 - 20 seconds: Decreasing velocity from 10 m/s to the right to rest (0 m/s). (Constant/uniform deceleration).



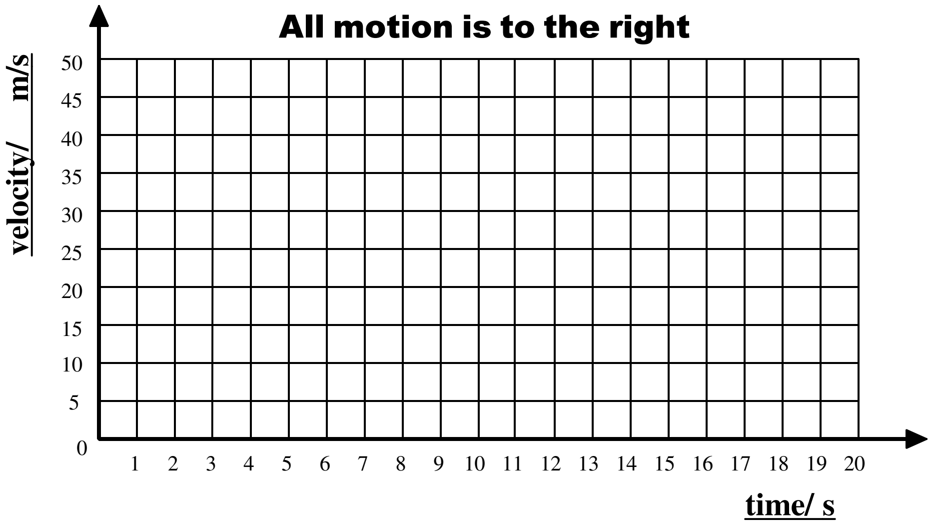
0 - 30 seconds: Increasing velocity from 25 m/s to 40 m/s to the right. (Constant/uniform acceleration).

30 - 60 seconds: Constant velocity of 40 m/s to the right.

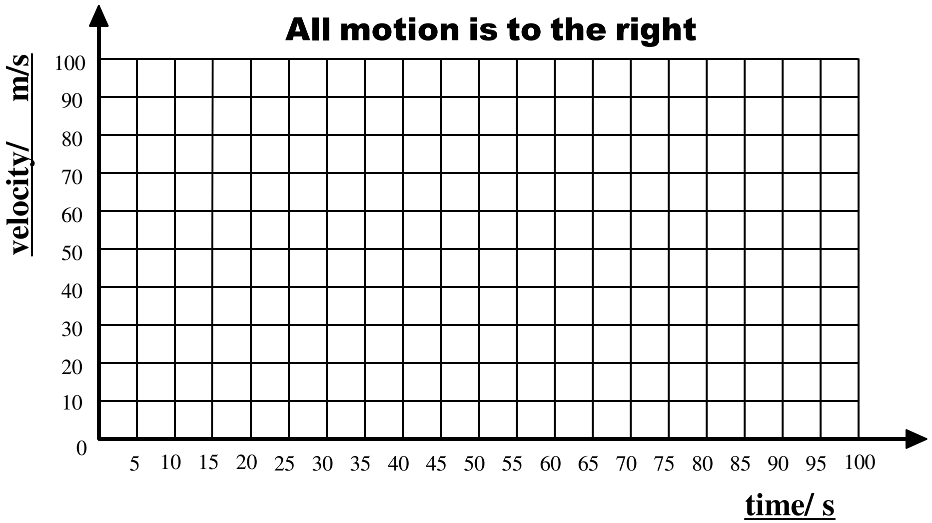
60 - 90 seconds: Decreasing velocity from 40 m/s to the right to rest (0 m/s). (Constant/uniform deceleration).



With uniform/constant acceleration, a motorcycle takes 8 s to increase its velocity from rest to 20 m/s to the right. The motorcycle continues to travel at this steady velocity for 4 s. It then increases its velocity to 45 m/s to the right (constant/uniform acceleration) in 7 s.



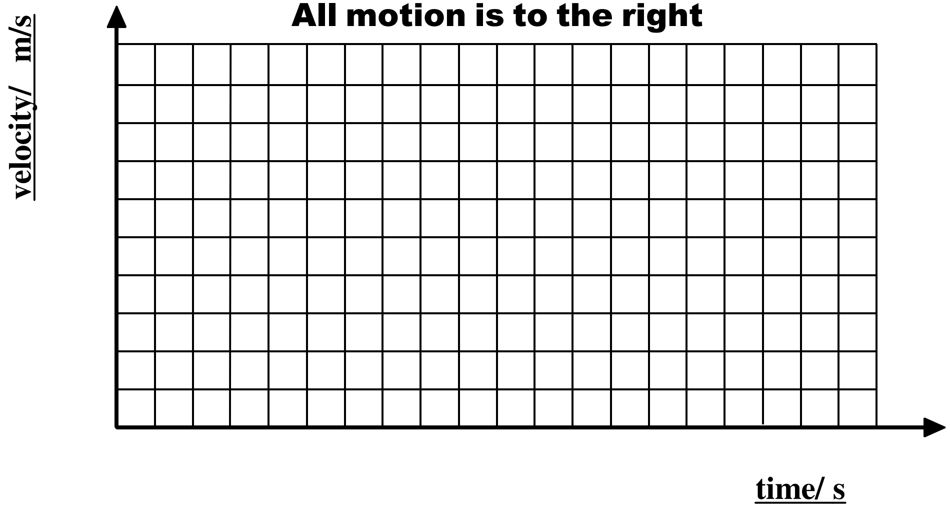
A helicopter, initially travelling at 80 m/s to the right, decelerates constantly/uniformly to a velocity of 60 m/s to the right in 25 s. For the next 50 s, it continues to travel at this steady velocity before decelerating constantly/uniformly to the right to rest in a further 25 s.



30) Put numbers on each axis.

Maximum velocity = 9 m/s. Total time = 18 s.

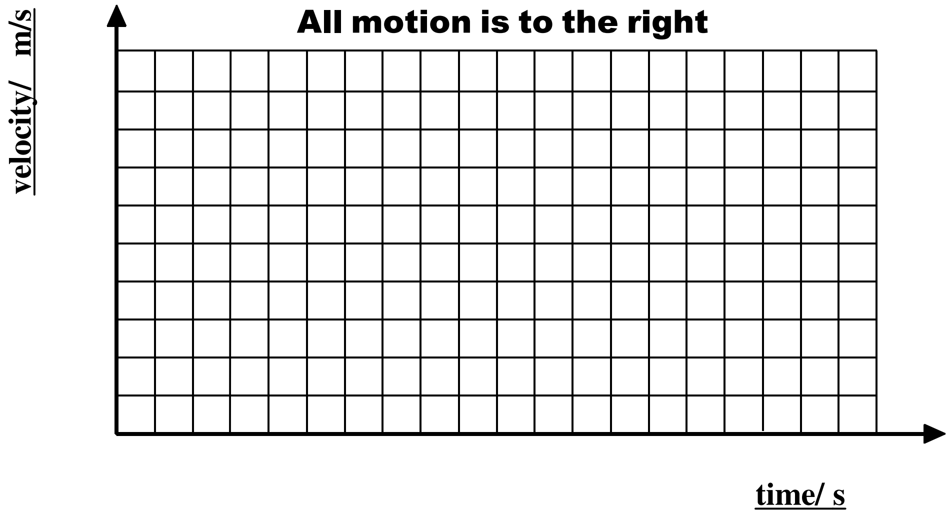
A cyclist travels at a steady velocity of 9 m/s to the right for 6 s before decelerating constantly/uniformly tothe right to a velocity of 2 m/s in 7 s. She then travels at this steady velocity to the right for a further 5 s.



31) Put numbers on each axis.

Maximum velocity = 90 m/s. Total time = 20 s.

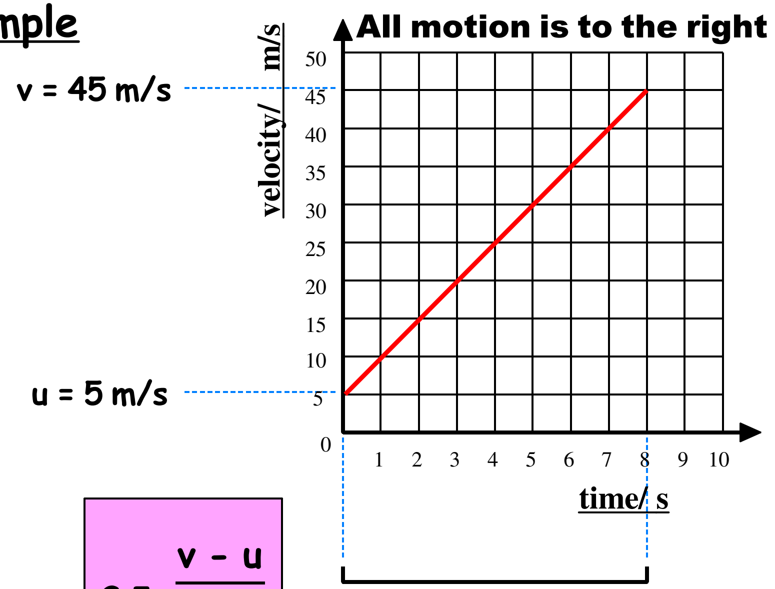
A racing car travels at a constant velocity of 10 m/s to the right for 2 s before accelerating constantly/uniformly for 12 s to a velocity of 90 m/s to the right. The car then immediately decelerates constantly/uniformly to the right for 6 s to a velocity of 70 m/s.

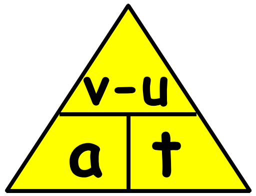


• Calculating Acceleration (or Deceleration) From a Velocity-Time Graph

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

For Example





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

time (t) = 8 - 0

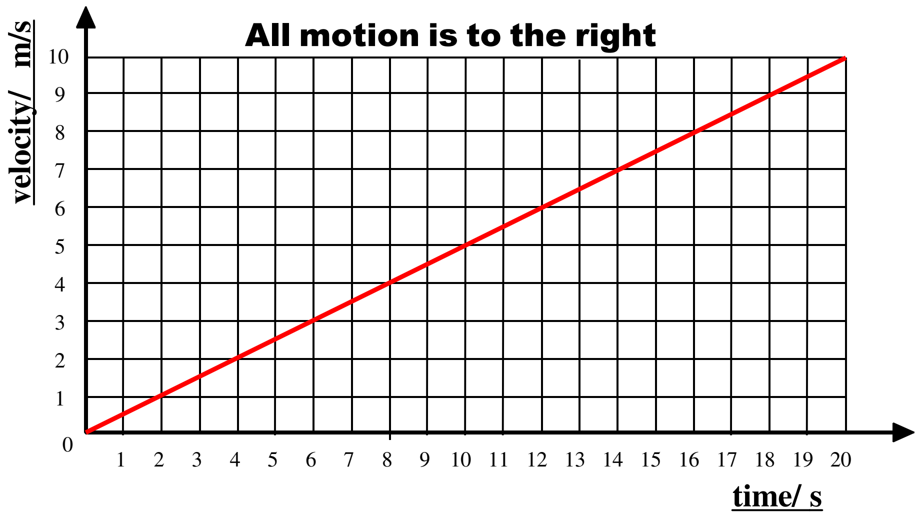
= 8 s

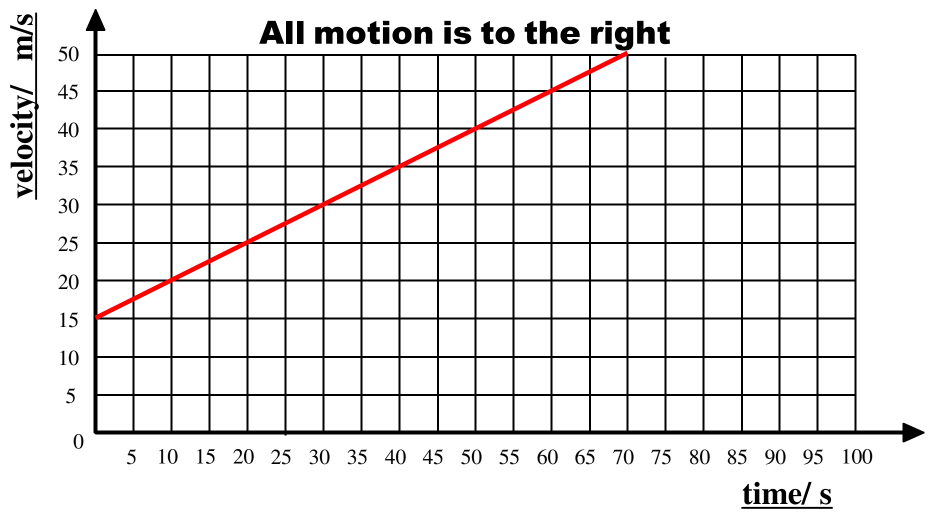
$$\text{acceleration (a)} = \frac{v - u}{t}$$

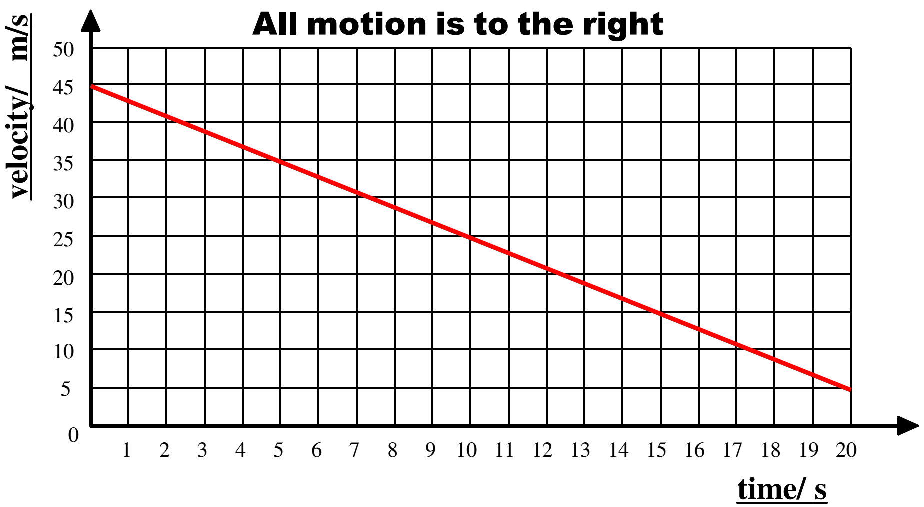
$$= \frac{45 - 5}{8}$$

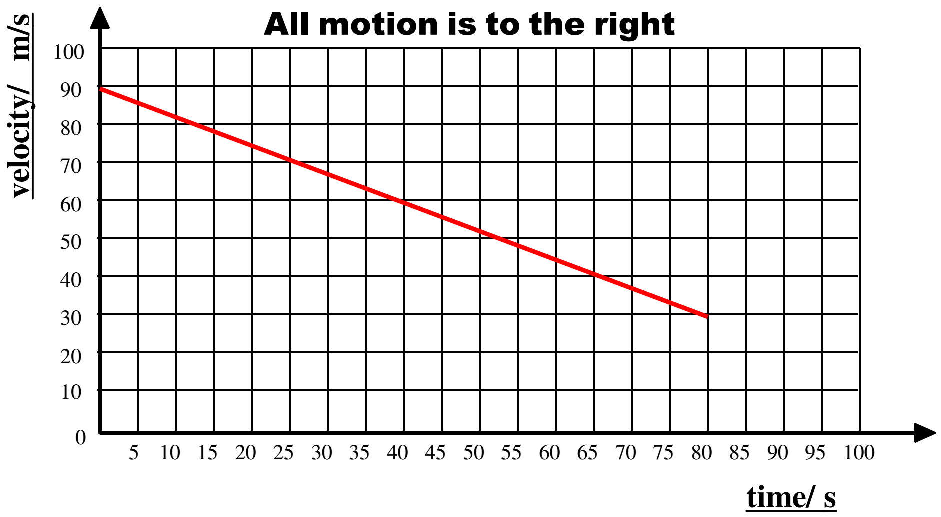
$$= \underline{5\ m/s^2\ \text{to the right}}$$

32) Calculate the **acceleration** or **deceleration** represented by the **line** on each **velocity-time graph**.









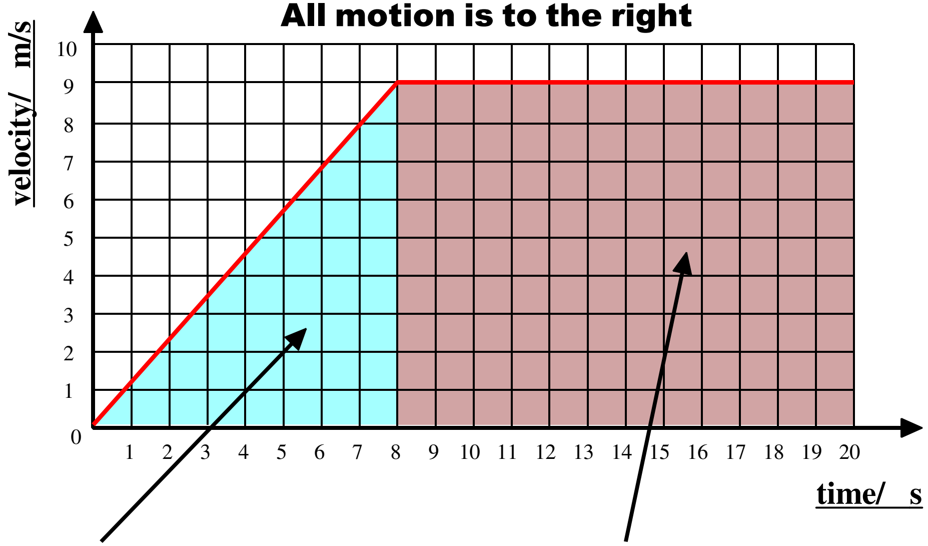
• Calculating Displacement From a Velocity-Time Graph

The **area** under a **velocity-time graph** representing the motion of an object gives the **displacement** of the object.

For Example

This **velocity-time graph** represents the motion of a go-kart travelling to the right for the first 20 s of its journey.

Determine the **displacement** of the go-kart during these 20 s.



Area of triangle = 1/2 x base x height
= 1/2 x 8 x 9
= 36

Area of rectangle = base x height
= 12 x 9
= 108

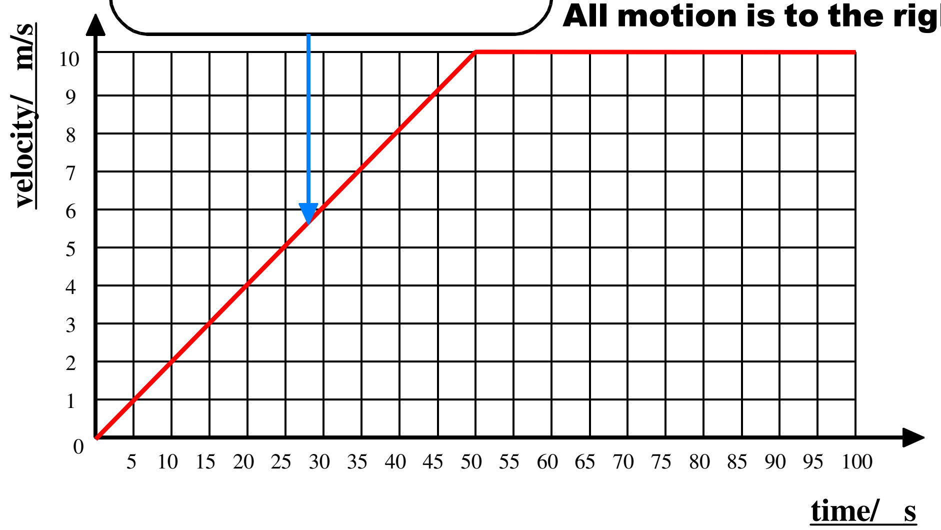
Displacement = Area under velocity-time graph
= 36 + 108
= 144 m to the right

• Displacement and Acceleration Calculations

33) Each of the following **velocity-time graphs** represent the motion of a vehicle.

For each graph, calculate any **accelerations** and **decelerations** of the vehicle, plus the vehicle's **displacement**:

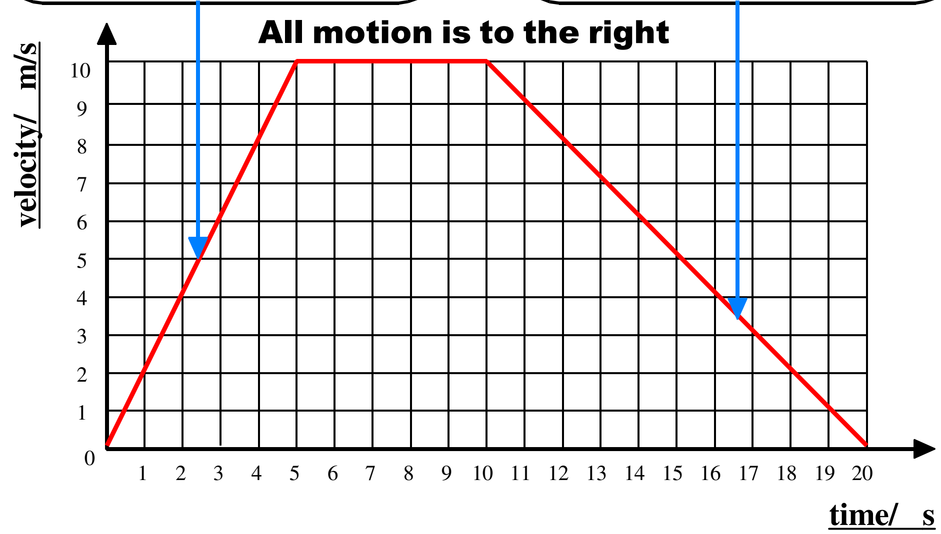
Acceleration Calculation



Displacement Calculation

Acceleration Calculation

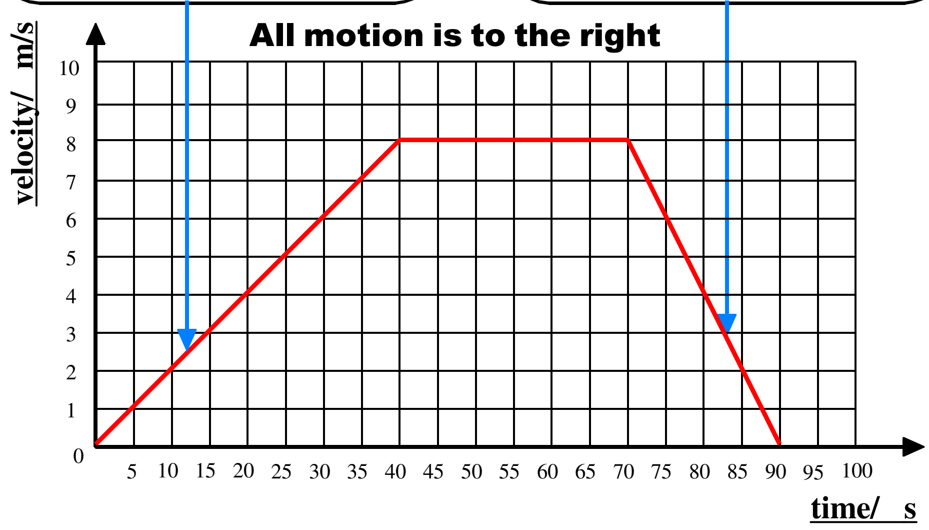
Deceleration Calculation



Displacement Calculation

Acceleration Calculation

Deceleration Calculation

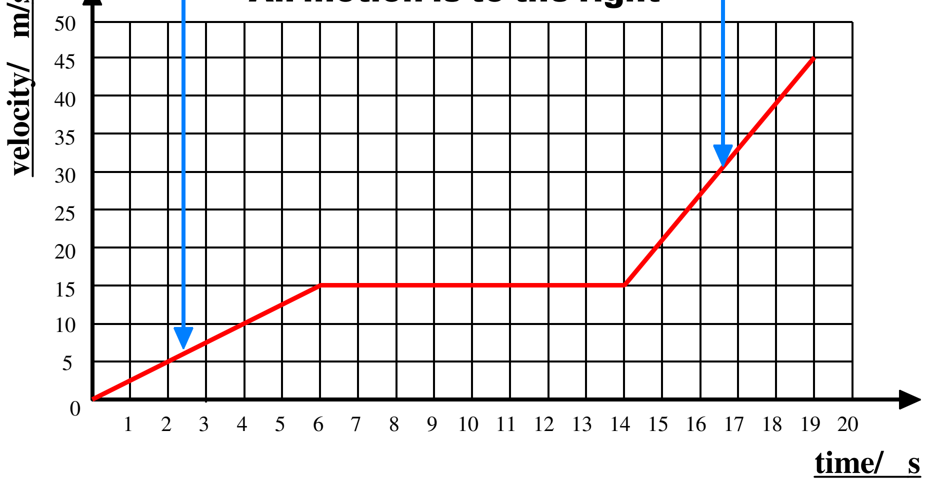


Displacement Calculation

Acceleration Calculation

Acceleration Calculation

All motion is to the right

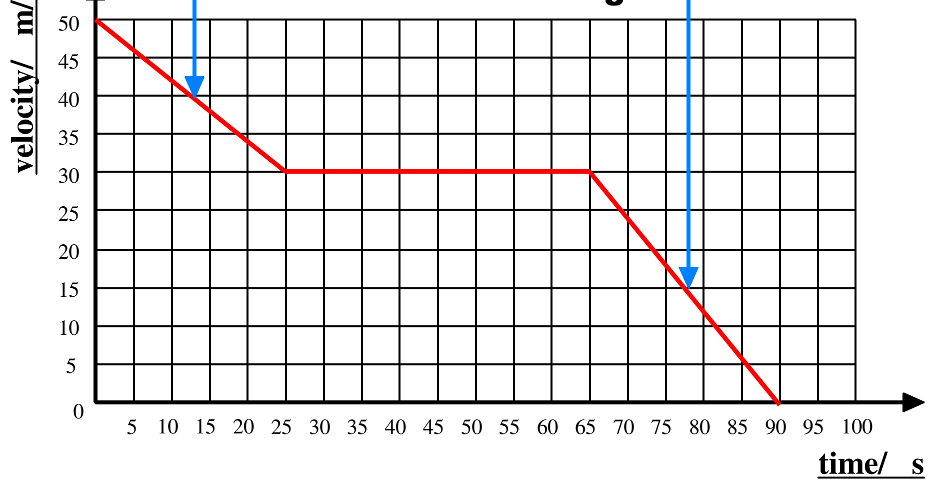


Displacement Calculation

Deceleration Calculation

Deceleration Calculation

All motion is to the right



Displacement Calculation

Section 2: Dynamics

• Forces and Their Effects

A **force** can be thought of as a
p _ _ _ or **p** _ _ _ or **t** _ _ _ _ on an object.

A **force** can change an object's:

• **s** _ _ _ _

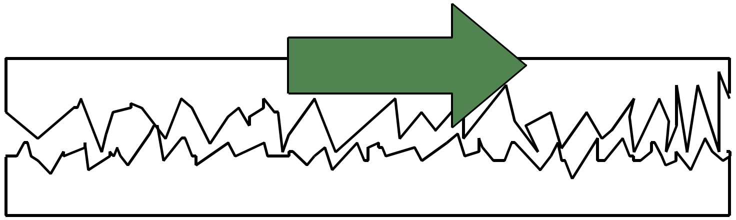
• **s** _ _ _ _

• **d** _ _ _ _ _ _ _ _ of travel

• The Force of Friction

No surface is **perfectly smooth**.
Every surface has **rough**, **uneven** parts.

When we **move** one surface over another, the **rough**, **uneven** parts **rub together**.



This creates a **force** which tries to **slow down** or **stop** the **movement**.

This **force** is called **friction**.

The **smoother** the surfaces rubbing together, the **l** _ _ _ _ the **friction** - Movement is **e** _ _ _ _ _.

The **rougher** the surfaces rubbing together, the **h** _ _ _ _ _ the **friction** - Movement is **more d** _ _ _ _ _ _ _ _.

• 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.

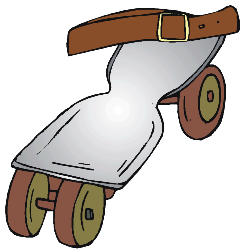
34) These diagrams show **"friction in everyday life"**.

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

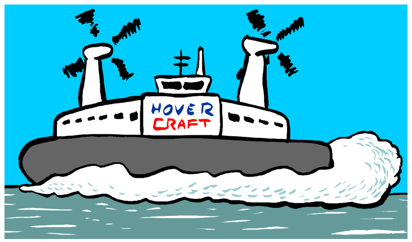
☐ decreased friction

☐ 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**.

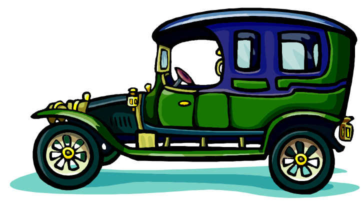
This effect is known as **air f** _ _ _ _ _ _ _ _ or **air r** _ _ _ _ _ _ _ _ _ _ _.

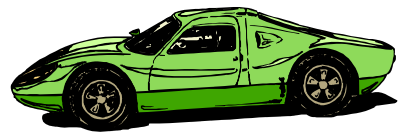
35) Explain how a **parachute** works:

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

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

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





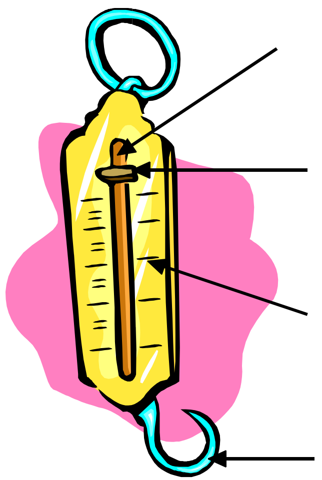
• Measuring Force

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

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

37) (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

The **mass** of an object is the **amount of material** in the object.

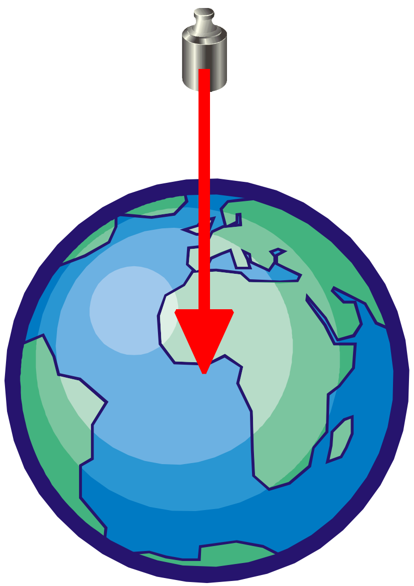
The unit of **mass** is the **k** _ _ _ _ _ _ _ _ (_ _).

Weight

All objects attract (pull one another together) - This attraction (pull) is known as the **force of g** _ _ _ _ _ _.

Weight is a **force**. It is the **Earth's gravitational pull** on an object.

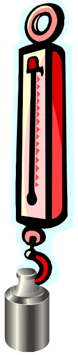
The unit of **weight** is the **n** _ _ _ _ _ (__).



The **force of gravity** pulls every object near or on the Earth's surface down towards the centre of the Earth with a **force** of **10 newtons for every kilogram of mass**.

This **downwards force** (**weight**) **per kilogram of mass** is called the **g** _ _ _ _ _ _ _ _ _ _ _ _ _ **f** _ _ _ _ **s** _ _ _ _ _ _ _ _. (Symbol __).

Near the Earth's surface,
g = ___ newtons per kilogram (**N/kg**).



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

____

____

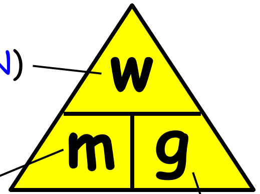
• Mass and Weight Calculations (On Earth)

For any object:

weight = mass × gravitational field strength

$w = m\,g$

weight
newtons (N)



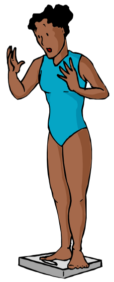
mass
kilograms (kg)

gravitational field strength
newtons per kilogram (N/kg)

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

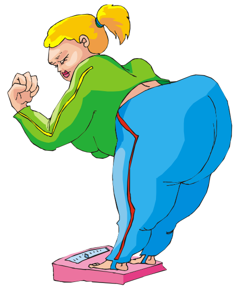
39) Each person is standing on a set of scales on the Earth's surface.
Calculate the **weight** of each person:

Harry
(mass 80 kilograms)



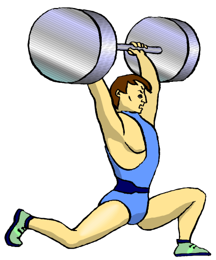
Mary
(mass 55 kilograms)

David
(mass 62 kilograms)



Bertha
(mass 110 kilograms)

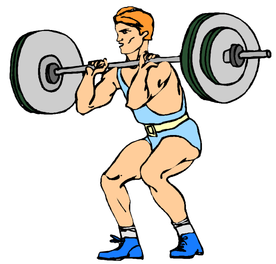
40) Each weightlifter is working out in a gym on the Earth's surface.
Calculate the **mass** being lifted by each weightlifter:



Dwayne
(lifting 1 000 newtons)

Sonya
(lifting 150 newtons)

Tanya
(lifting 320 newtons)



Victor
(lifting 1 600 newtons)

• Mass and Weight Calculations (Not on Earth)

PROVIDED NO MATERIAL IS ADDED TO OR REMOVED FROM AN OBJECT, ITS MASS WILL NOT CHANGE ..... NO MATTER WHERE THE OBJECT IS MOVED TO IN THE UNIVERSE.

ON DIFFERENT PLANETS (OR MOONS OR STARS), THE FORCE OF GRAVITY PULLING DOWN ON EVERY KILOGRAM OF AN OBJECT WHICH IS NEAR ITS SURFACE IS DIFFERENT ..... SO THE GRAVITATIONAL FIELD STRENGTH NEAR THE SURFACE OF DIFFERENT PLANETS (OR MOONS OR STARS) IS DIFFERENT.

Some examples of gravitational field strength:

PLACE IN UNIVERSE	gravitational field strength (N/kg)
Near surface of Earth	10
Near surface of the Moon	1.6
Near surface of Mars	4
In deep outer space	0

41) Calculate the **weight** of a 2.5 kg metal block when it is:

(a) Near the surface of Earth.

(b) Near the surface of the Moon.

(c) Near the surface of Mars.

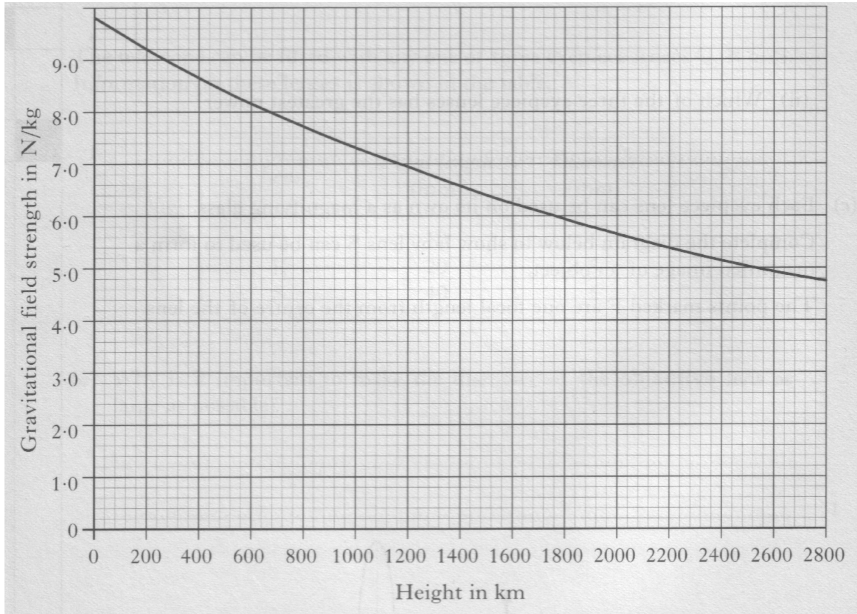
(d) In deep outer space.

Gravitational Field Strength and Distance From a Planet/Moon/Star

As you move further away from the surface of a planet/moon/star, the value for the **gravitational field strength** **decreases**.

This means that the **weight** of an object **decreases** as its distance from a planet/moon/star increases.

42) The graph below shows how the gravitational field strength of the Earth decreases as you move further away from its surface:



Use the graph to help you calculate the **weight** of a 15 kg object when it is at each of the following heights above the Earth's surface.

(a) 200 km

(b) 1 400 km

(c) 2 200 km

• Balanced and Unbalanced Forces

Force is a **vector** quantity - It has ***magnitude*** (***size***) and ***direction***.

Balanced Forces

If the forces acting on an object are **equal in size** but **act in opposite directions**, the forces are said to be **b** _ _ _ _ _ _ _ _.

For example:

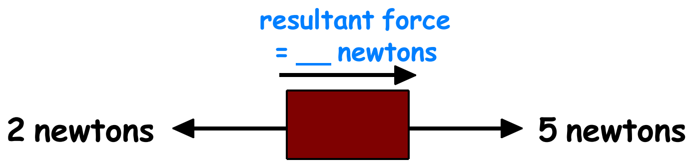
The forces **cancel out**.
They are equivalent to **no force at all**.

We say: **"The resultant force is zero"**.

Unbalanced Forces

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

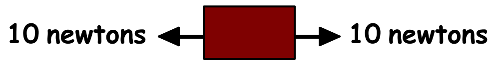
For example:



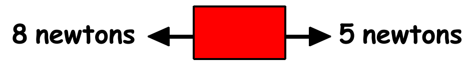
The forces **do not cancel out**.
We could replace the forces with **<u>one</u> force** (called a **resultant** force) which would have exactly the same affect on the object.

For the forces shown in the diagram above, we can say:
"The resultant force is __ newtons to the ________".

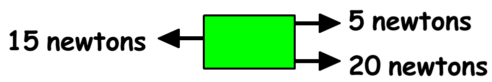
43) In each case, calculate the **size** of the **<u>resultant</u> force** and state any **direction**. Tick the correct box to show whether the forces acting on the object are **balanced** or **unbalanced**.



☐ balanced forces ☐ unbalanced forces

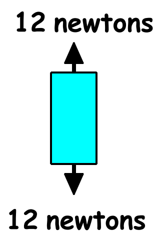


☐ balanced forces ☐ unbalanced forces

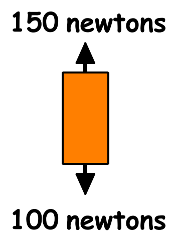


☐ balanced forces ☐ unbalanced forces

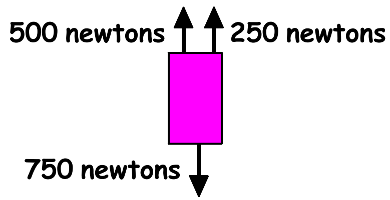
☐ balanced forces ☐ unbalanced forces



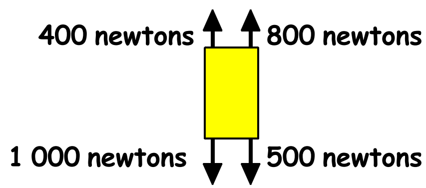
☐ balanced forces ☐ unbalanced forces



☐ balanced forces ☐ unbalanced forces



☐ balanced forces ☐ unbalanced forces



☐ balanced forces ☐ unbalanced forces

• Newton's First Law of Motion

Sir Isaac Newton
- a famous 17th and 18th century physicist

If the **forces** acting on an object are **balanced** (or **no forces act**), the object's **speed** remains the same.

The object:

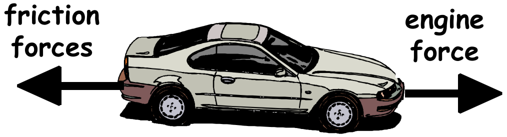
- remains **s** _ _ _ _ _ _ _ _ _ _ **or**
- continues to move at **c** _ _ _ _ _ _ _ _ **s** _ _ _ _ in a **s** _ _ _ _ _ _ _ _ **l** _ _ _.

If the forces acting on an object are **unbalanced**, the object:

- **a** _ _ _ _ _ _ _ _ _ _ _ in the direction of the **u** _ _ _ _ _ _ _ _ _ _ **f** _ _ _ _.

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 horizontal forces acting on it are ________________.
The engine force and friction forces have the __________ size.

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

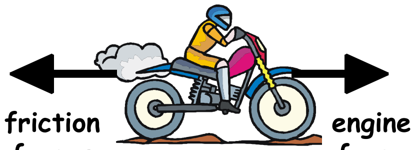
The horizontal forces acting on it **are now** ___________________.
The engine force is ____________ than the friction forces.

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

The horizontal 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).

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

How does the size of these forces compare:



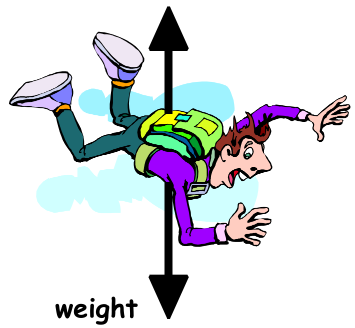
(a) Just before the start of the race when the motorbike is **not moving**? ____
____

(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 after the finish of the race when the motorbike is **decelerating**? ____
____

45) 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:

____
____
____
____

• Newton's Second Law of Motion

An object **accelerates** (or **decelerates**) when an **unbalanced force** acts on it.

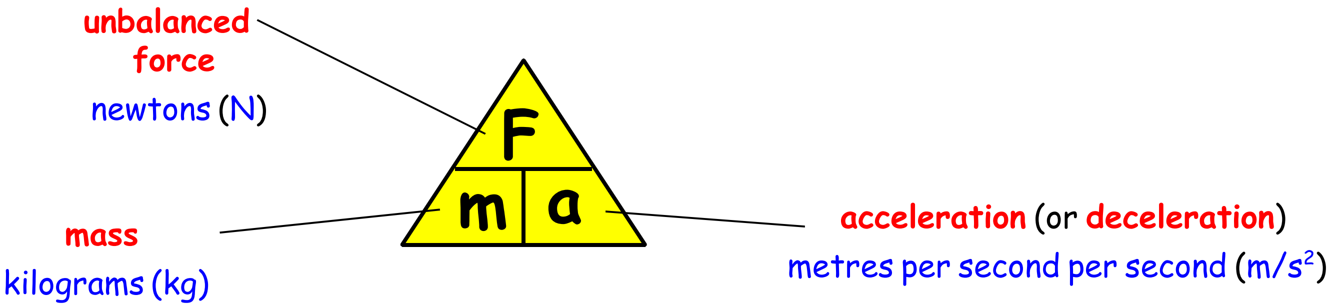
The **acceleration** of the object depend on the **mass** of the object and the **size** of the **unbalanced force** acting on it.

- If you increase the **mass** of the object, the **acceleration** ___________.
- If you increase the size of the **unbalanced force**, the **acceleration** ___________.

Acceleration, **unbalanced force** and **mass** are related by the formula:

$$\boxed{\text{unbalanced force} = \text{mass} \times \text{acceleration}}$$

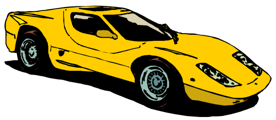
$$\boxed{F = m\,a}$$



A force of 1 newton causes an object of mass 1 kg to accelerate at 1 m/s^2.

• F = ma Calculations

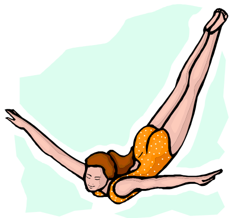
46) Calculate the **acceleration** of a car of mass 1 500 kg which is acted upon by an unbalanced force of 4 500 N to the right.



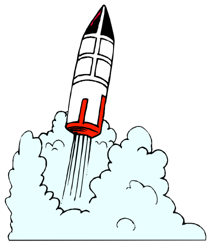
47) A tractor and its driver have a combined mass of 1 700 kg. An unbalanced force of 2 040 N drives the tractor forward. Calculate the tractor's **acceleration**.

48) An unbalanced force of 91 N acts to the right on Simon and his skateboard which have a combined mass of 65 kg. Calculate the **acceleration** of Simon and his skateboard.

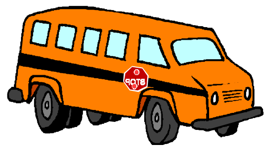
49) Daisy the diver has a mass of 50 kg. After jumping from a diving board, she accelerates downwards towards a swimming pool at 10 m/s^2. Calculate the **unbalanced force** acting on her.



50) Calculate the **unbalanced force** acting on a rocket of mass 5 000 kg if it accelerates upwards from the ground at 0.8 m/s^2.



51) A minibus of mass 2 500 kg accelerates to the right at 0.75 m/s^2. Calculate the **unbalanced force** acting on the minibus.

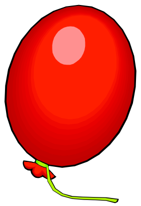


52) Sally the snow boarder accelerates at 0.5 m/s^2 down a slope when an unbalanced force of 30 N acts on her down the slope. Calculate the combined **mass** of Sally and her snow board.

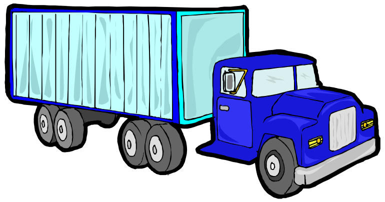
53) When an unbalanced force of 780 N acts downwards on a skydiver, he accelerates towards the ground at 10 m/s^2. Calculate the **mass** of the skydiver and his equipment.

54) A speed skater accelerates at 1.5 m/s^2 when an unbalanced force of 96N acts on him to the right. Calculate the **mass** of the speed skater.

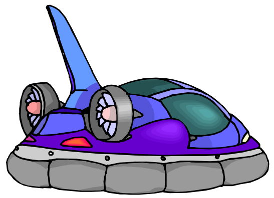
55) A balloon of mass 0.001 kg accelerates upwards when acted upon by an unbalanced force of 0.002 N. Calculate the **acceleration** of the balloon.



56) A 10 000 kg truck accelerates at 0.2 m/s^2 to the right. Calculate the size of the **unbalanced force** acting on the truck.



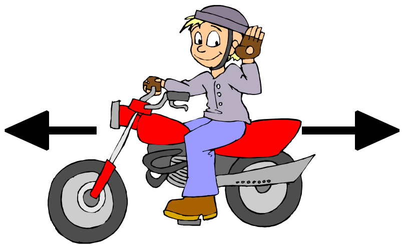
57) A mini hovercraft accelerates at 1.6 m/s^2 to the right when an unbalanced force of 1 840 N acts on it. Calculate the **mass** of the hovercraft.



• More F = ma Calculations

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

thrust from engine = 1 500 N



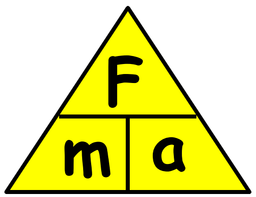
resistive forces = 800 N

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

$= \frac{700}{250}$

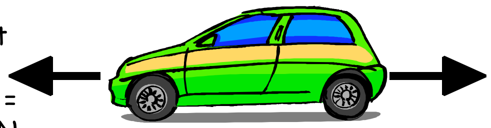
= 2.8 m/s^2 to the left

58) 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**.

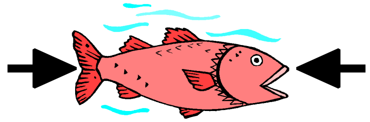
thrust from engine = 5 000 N



resistive forces = 2 000 N

mass = 1 200 kg

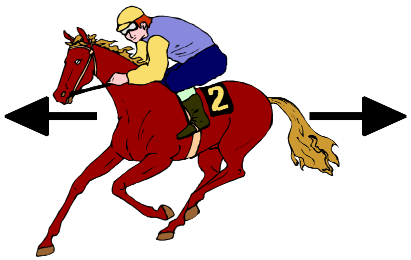
thrust from tail = 15.0 N



resistive forces = 14.4 N

mass = 0.4 kg

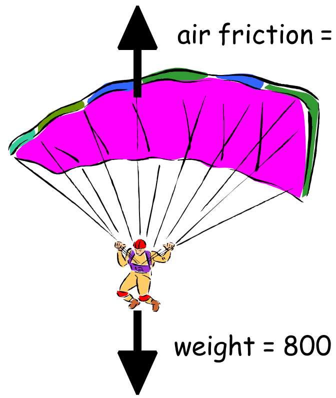
thrust from hooves = 3 000 N



resistive forces = 800 N

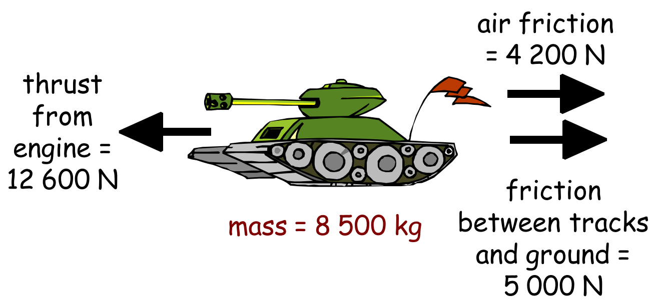
mass = 1 000 kg

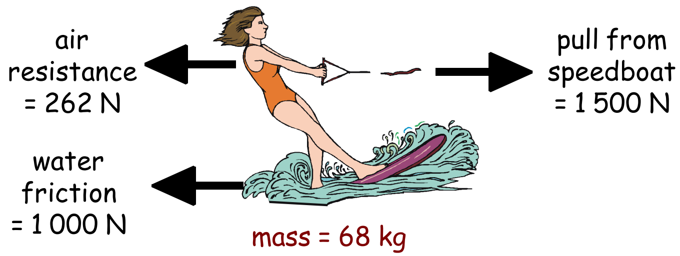
air friction = 704 N

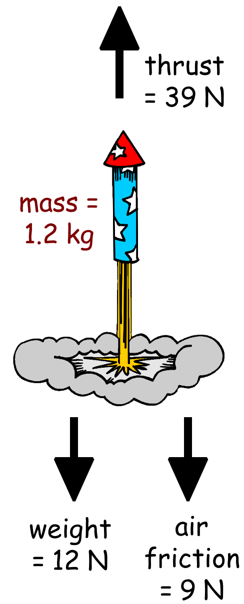


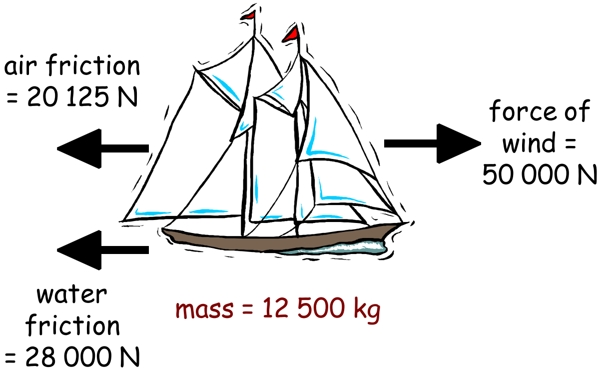
mass = 80 kg

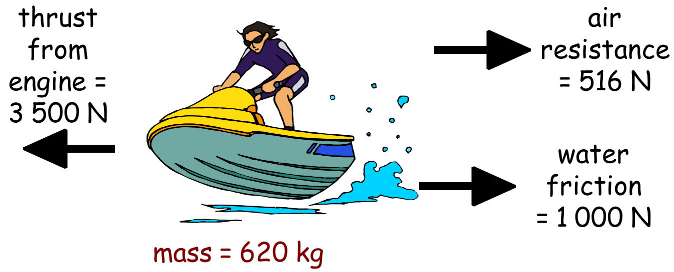
weight = 800 N

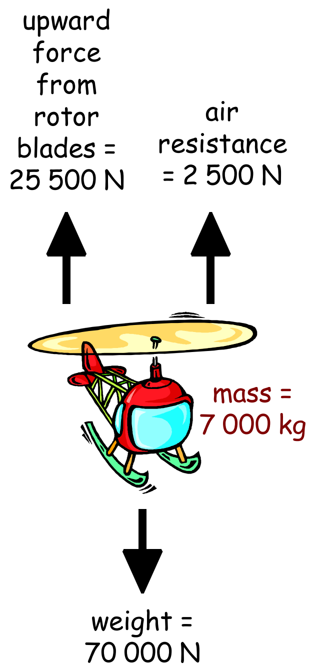

thrust from engine = 12 600 N
air friction = 4 200 N
friction between tracks and ground = 5 000 N
mass = 8 500 kg


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

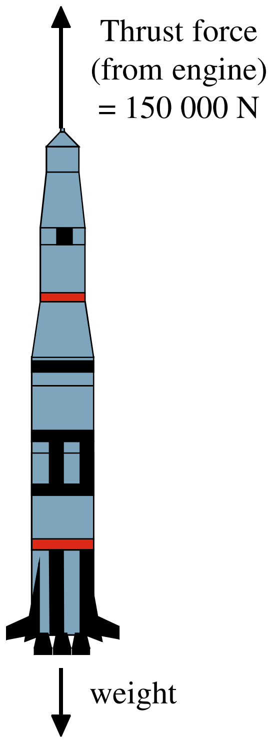

thrust = 39 N
mass = 1.2 kg
weight = 12 N
air friction = 9 N


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

59) The diagram shows the vertical forces acting on a rocket of mass 12 000 kg which is being launched from the earth's surface, where g = 10 N/kg (Air friction has been ignored).



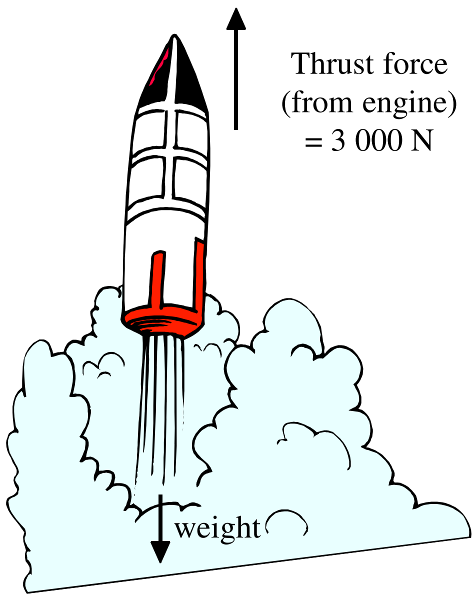
Determine:

(a) The **weight** of the rocket.

(b) The size and direction of the **unbalanced force** acting on the rocket as it is launched.

(c) The size and direction of the rocket's **acceleration** as it is launched.

60) A spacecraft of mass 1 500 kg "blasts off" from the surface of the moon where g = 1.6 N/kg. The forces acting on the spacecraft at the instant it "blasts off" are shown on the diagram.



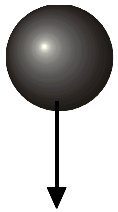
Calculate:

(a) The **weight** of the spacecraft on the moon's surface.

(b) The size and direction of the **unbalanced force** acting on the spacecraft as it "blasts off".

(c) The size and direction of the spacecraft's **acceleration** as it "blasts off".

• Gravitational Field Strength and Acceleration Due to Gravity



Gravitational field strength of 10 N/kg acts on an object, causing it to accelerate downwards towards the Earth's surface at 10 m/s^2.

The **force of gravity** pulls every object near or on the Earth's surface down towards the centre of the Earth with a **force** of **10 newtons for every kilogram of mass**.

This **downwards force** (**weight**) **per kilogram of mass** is called the **g _ _ _ _ _ _ _ _ _ _ _ _** **f _ _ _ _** **s _ _ _ _ _ _ _**. (Symbol __).
Near the Earth's surface,
g = ___ Newtons per kilogram (**N/kg**).

$$\text{acceleration} = \frac{\text{Force}}{\text{mass}}$$

The **force of gravity** acting on all objects with **mass** which are close to the Earth's surface, causes the objects to **accelerate** towards the Earth's surface - The objects have **"acceleration due to gravity"**.

The objects all have the **same value of acceleration** (if the effects of air resistance are negligible [very small]):

acceleration due to gravity (g) = 10 m/s^2.

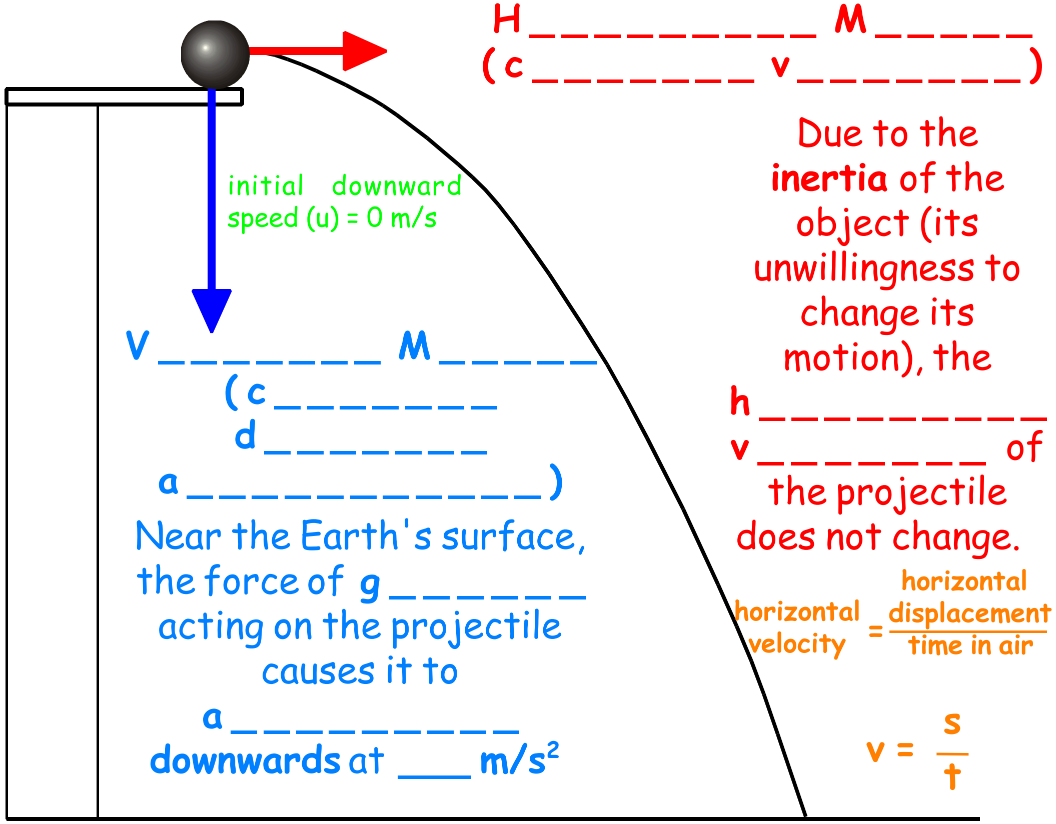
GRAVITATIONAL FIELD STRENGTH and ACCELERATION DUE TO GRAVITY are "*EQUIVALENT TERMS*".

• Projectile Motion

Any object which is projected (fired) through the air is known as a **projectile**.

An object which is originally projected (fired) in a **horizontal** direction, follows a **c** _ _ _ _ _ _ **p** _ _ _ known as a **t** _ _ _ _ _ _ _ _ _ _.

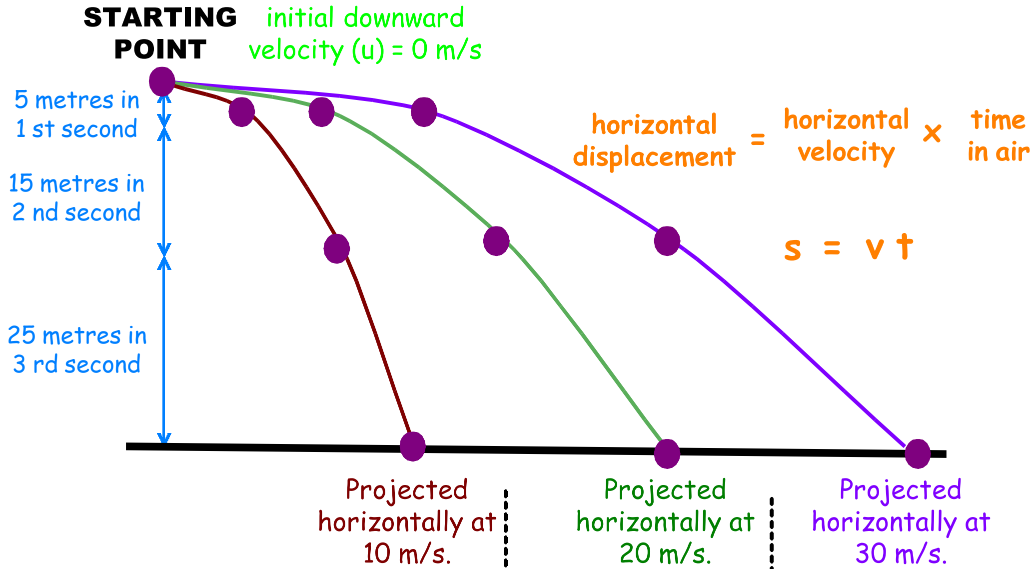
The **c** _ _ _ _ _ _ **p** _ _ _ is due to a combination of **2 separate motions** in the **h** _ _ _ _ _ _ _ _ _ _ and **v** _ _ _ _ _ _ _ _ directions:



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

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

The diagram below shows the position of a ball projected horizontally at three different velocities. In each case, the ball takes exactly 3 seconds to reach the ground.



Projected horizontally at 10 m/s.	Projected horizontally at 20 m/s.	Projected horizontally at 30 m/s.
horizontal displacement = v t	horizontal displacement = v t	horizontal displacement = v t
= 10 m/s × 3 s	= 20 m/s × 3 s	= 30 m/s × 3 s
= <u>30 m</u>	= <u>60 m</u>	= <u>90 m</u>

- The greater the **horizontal velocity** of a projectile, the **f** _ _ _ _ _ _ it travels horizontally before landing.
- Every second, the **downward vertical distance** travelled by a projectile **i** _ _ _ _ _ _ _ _ _ because the force of **g** _ _ _ _ _ _ _ acting on it causes it to **a** _ _ _ _ _ _ _ _ _ _.

We can use this acceleration equation to calculate the **downward vertical velocity** of the ball in the above diagram as it lands:

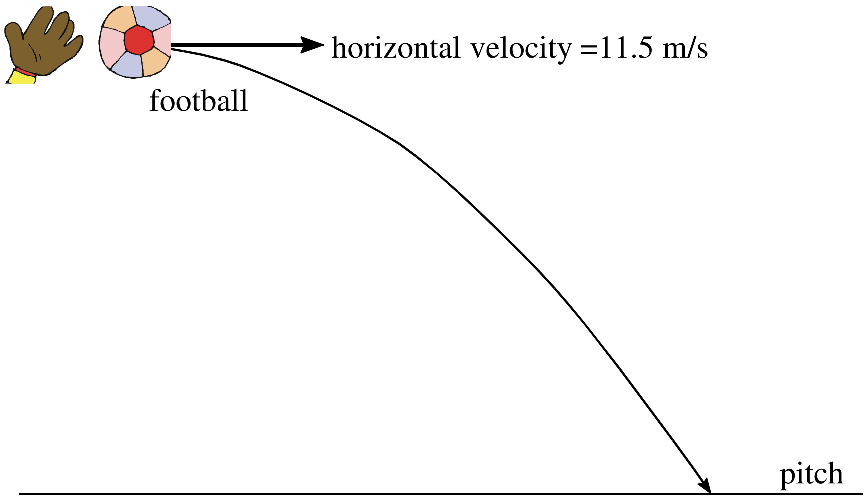
$$a = \frac{v - u}{t} \quad \therefore 10 = \frac{v - 0}{3} \quad \therefore 10 = \frac{v}{3} \quad \therefore v = 10 \times 3$$

$$= \underline{30\ m/s}$$

downward acceleration (a) due to gravity = 10 m/s²

initial downward velocity (u) = 0 m/s

61) Jordan the goalkeeper punches a football which has been kicked across his goal mouth. The football leaves his glove with a horizontal velocity of 11.5 m/s to the right and takes 0.80 s to land on the pitch.



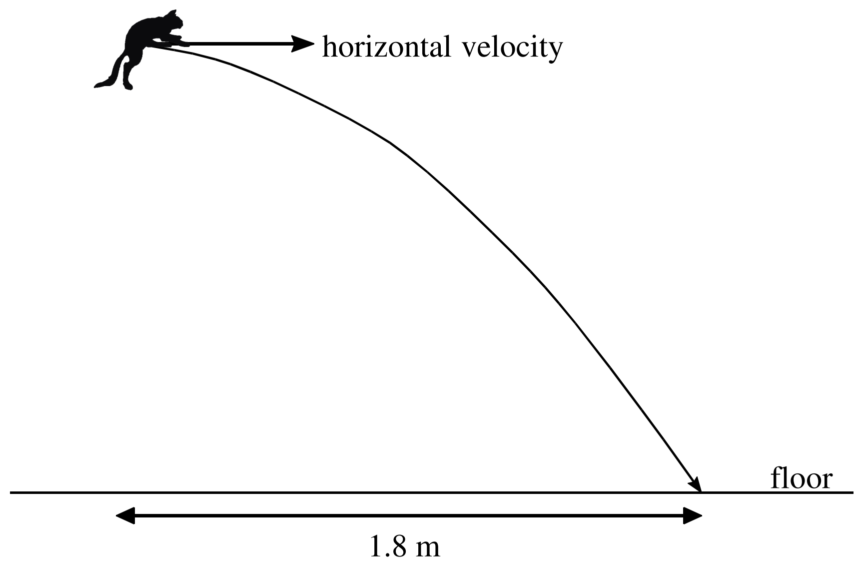
(a) Describe the **horizontal velocity** of the football from the instant it is punched to the instant it lands.

(b) Show, by calculation involving horizontal motion, that the **horizontal displacement** travelled by the football during the 0.8 s is 9.2 m to the right.

(c) At the instant the football leaves Jordan's hand, the downward vertical velocity of the football is 0 m/s.

Calculate the **downward vertical velocity** of the football as it lands.

62) The Physics Department's pet cat jumps horizontally to the right from a window ledge. The cat lands on the floor 0.36 s later. Its horizontal displacement is 1.8 m to the right.



(a) During the jump, does the **horizontal velocity** of the cat increase, decrease or remain constant?

(b) Show, by calculation involving horizontal motion, that the **horizontal velocity** of the cat just before landing is 5 m/s to the right.

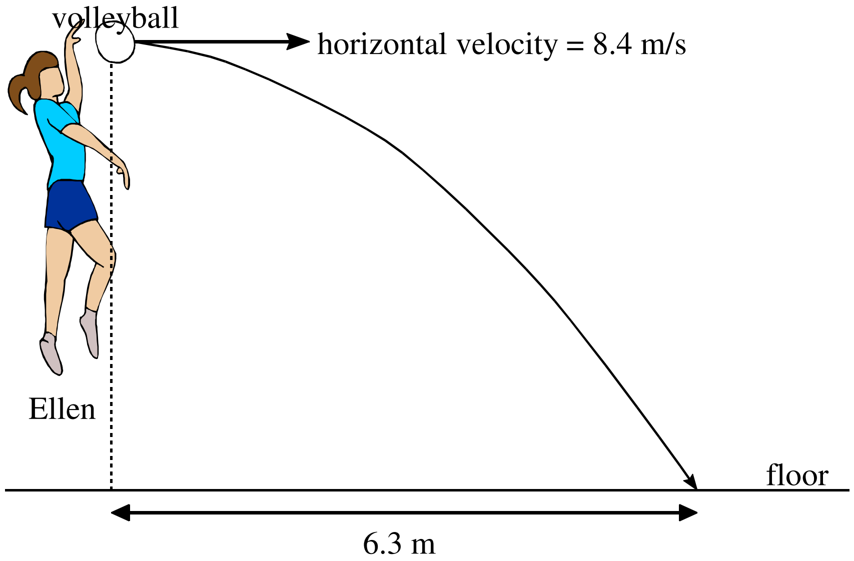
(c) At the instant the cat jumps from the window ledge, its downward vertical velocity is 0 m/s.

Calculate the **downward vertical velocity** of the cat as it lands.

63) Ellen's hand hits a volleyball from a point directly above the central net.

The volleyball leaves Ellen's hand with a horizontal velocity of 8.4 m/s to the right.

On leaving her hand, the volleyball follows a curved path, hitting the floor when its horizontal displacement is 6.3 m to the right.



(a) Show, by calculation involving horizontal motion, that the **time** taken for the volleyball to travel from Ellen's hand to the floor is 0.75 s.

(b) At the instant the volleyball leaves Ellen's hand, the downward vertical velocity of the volleyball is 0 m/s.

Calculate the **downward vertical velocity** of the volleyball as it reaches the floor.

64) A rocket is fired horizontally from a cliff top at 40 m/s to the right. The rocket hits the sea below after 4 s.

(a) What will be the rocket's **horizontal component of velocity** just before it hits the sea?

(b) What will be the rocket's **range** (**horizontal displacement**)?

(c) What will be the rocket's **vertical component of velocity** just before it hits the sea?

(d) Sketch the **velocity-time graph** for the rocket's **vertical motion**.

(e) Use the graph to determine the rocket's **vertical displacement** (the **height of the cliff**).

65) Fred kicks a football off a cliff with a horizontal velocity of 5 m/s to the right. The football lands on ground below the cliff 2.5 s later.

(a) What will be the ball's **horizontal component of velocity** just before it hits the ground?

(b) What will be the ball's **range** (**horizontal displacement**)?

(c) What will be the ball's **vertical component of velocity** just before it hits the ground?

(d) Sketch the **velocity-time graph** for the ball's **vertical motion**.

(e) Use the graph to determine the ball's **vertical displacement** (the **height of the cliff**).

66) Barney pushes a coin off a staircase. The coin's initial horizontal velocity is 0.5 m/s to the right. It hits the floor after 1.2 s.

(a) What will be the coin's **horizontal component of velocity** just before it hits the floor?

(b) What will be the coin's **range** (**horizontal displacement**)?

(c) What will be the coin's **vertical component of velocity** just before it hits the floor?

(d) Sketch the **velocity-time graph** for the coin's **vertical motion**.

(e) Use the graph to determine the coin's **vertical displacement** (the **height of the staircase**).

67) Wilma throws a dart horizontally at 8 m/s to the right.
The dart hits the floor after 0.6 s.

(a) What will be the dart's **horizontal component of velocity** just before it hits the floor?

(b) What will be the dart's **range** (**horizontal displacement**)?

(c) What will be the dart's **vertical component of velocity** just before it hits the floor?

(d) Sketch the **velocity-time graph** for the dart's **vertical motion**.

(e) Use the graph to determine the dart's **vertical displacement** (the **height it was thrown from**).

68) Betty fires an arrow horizontally at 25 m/s to the right.
The arrow hits the ground after 0.4 s.

(a) What will be the arrow's **horizontal component of velocity** just before it hits the ground?

(b) What will be the arrow's **range** (**horizontal displacement**)?

(c) What will be the arrow's **vertical component of velocity** just before it hits the ground?

(d) Sketch the **velocity-time graph** for the arrow's **vertical motion**.

(e) Use the graph to determine the arrow's **vertical displacement** (the **height it was fired from**).

• Finding the Resultant of Two Forces Acting At Right-Angles To Each Other

The magnitude (size) and direction of the resultant of two forces (vectors) acting at right-angles to each other can be obtained using the **"tip to tail" rule**.

The "TIP TO TAIL" RULE

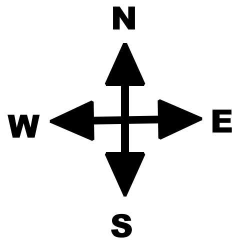
- Each vector must be represented by a straight line of suitable scale. The straight line must have an arrow head to show its direction.
- The vectors must be joined so that the tip of the first vector touches the tail of the second vector.
- A straight line is drawn from the starting point to the finishing point. The scaled-up length and direction of this straight line is the resultant vector. It should have 2 arrow heads to make it easy to recognise.

YOU SHOULD BE ABLE TO ADD THE TWO FORCES USING A SCALE DIAGRAM OR MATHEMATICS - Pythogoras theorem and SOHCAHTOA.

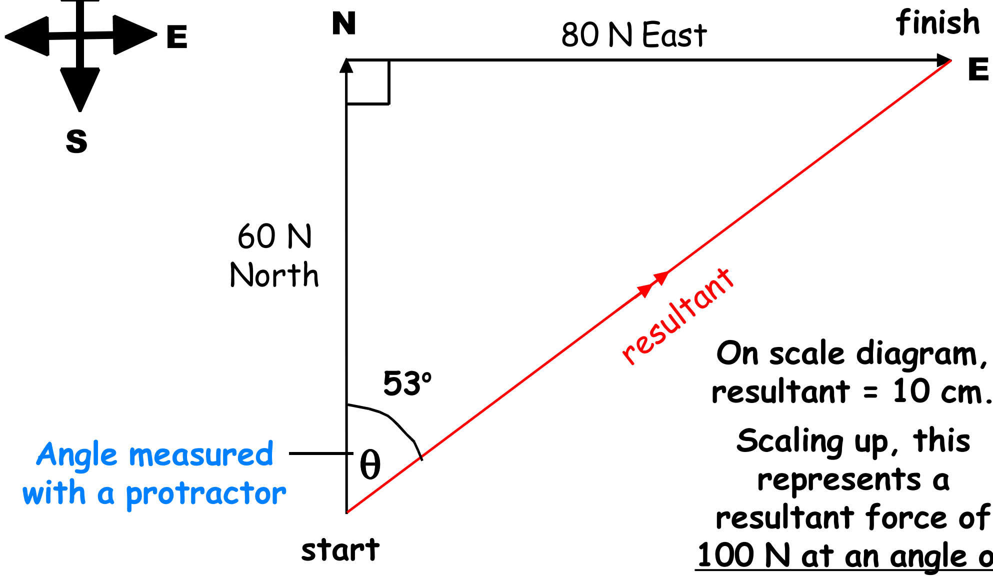
LARGE SCALE DIAGRAMS GIVE MORE ACCURATE RESULTS THAN SMALLER ONES! - ALWAYS USE A SHARP PENCIL!

Example

A force of 60 N pushes a football along the ground to the North. A second force of 80 N pushes the football along the ground to the East. Determine the ***magnitude*** (***size***) and ***direction*** of the **resultant force** acting on the football.



Method 1 - by scale diagram   Scale: 1 cm = 10 N



On scale diagram, resultant = 10 cm.

Scaling up, this represents a resultant force of 100 N at an angle of 53° to the 60 N force.

Method 2 - Using mathematics

A rough sketch of the vector diagram (NOT to scale) should be made if you solve such a problem using mathematics.

First, Using PYTHAGORAS THEOREM

$$\text{resultant}^2 = 60^2 + 80^2 = 3600 + 6400 = 10\,000$$

$$\text{so, resultant} = \sqrt{10\,000} = \underline{100}\ \text{N}$$

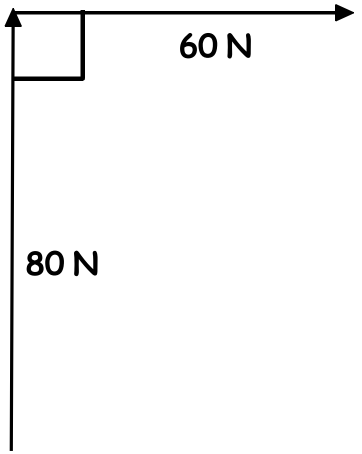
Next, Using SOHCAHTOA

$$\tan\theta = \frac{O}{A} = \frac{80}{60} = 1.33$$

$$\text{so, } \theta = \tan^{-1} 1.33 = \underline{53^\circ}$$

Resultant force = 100 N at an angle of 53° to the 60 N force.

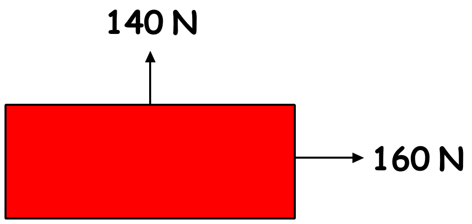
69) Two forces act on an object at right-angles to each other, as shown in the diagram below:



Find the ***magnitude*** (***size***) and direction of the resultant force relative to the 80 N force.

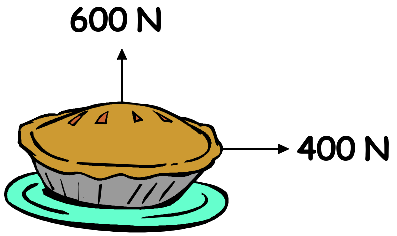
70) Two teachers are both trying to grab the last box of Physics Department pencils. The diagram shows the size and direction of the 2 forces being exerted on the pencil box. (The forces act at right-angles to each other).

Using either **mathematics** or a **scale drawing**, determine the ***magnitude*** (***size***) and ***direction*** of the **resultant force** acting on the pencil box relative to the 140 N force.



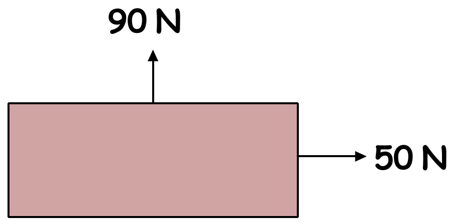
71) In the school dinner hall, two pupils both grab the last pie at the same time. The diagram shows the size and direction of the 2 forces being exerted on the pie. (The forces act at right-angles to each other).

Using either **mathematics** or a **scale drawing**, determine the ***magnitude (size)*** and ***direction*** of the **resultant force** acting on the pie, relative to the 600 N force.



72) The diagram shows the size and direction of 2 forces being exerted on a wooden block. (The forces act at right-angles to each other).

Using either **mathematics** or a **scale drawing**, determine the ***magnitude*** (***size)*** and ***direction*** of the **resultant force** acting on the wooden block, relative to the 90 N force.



• Newton's Third Law (Newton Pairs)

Forces occur in pairs - Newton pairs - The "action" and the "reaction".

If object A exerts a force on object B, then object B exerts an equal but opposite force on object A.

PUPILS OFTEN CONFUSE BALANCED/UNBALANCED FORCES WITH NEWTON PAIRS.

YOU MUST LEARN THAT:

- **BALANCED/UNBALANCED FORCES ACT ON THE S _ _ _ OBJECT.**
- **NEWTON PAIRS ACT ON D _ _ _ _ _ _ _ _ OBJECTS.**

73) Six **NEWTON PAIRS** are shown in the diagrams below.

Complete each diagram to identify the "action" and "reaction" forces:

ACTION

Force of brush on floor.

REACTION

____

____

____

ACTION

Force of goalkeeper gloves on football.

REACTION

____

____

____

ACTION

Force of drumstick on drum.

REACTION

____

____

____

ACTION

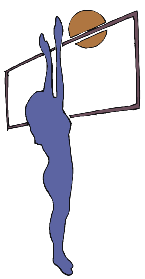
____

____

____

REACTION

Force of football on boot.



ACTION

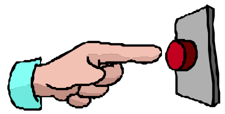
____

____

____

REACTION

Force of volleyball on hand.



ACTION

____

____

____

REACTION

Force of button on finger.

Rocket propulsion can be explained in terms of "Newton pairs":

The **rocket engine** produces **exhaust gases**.

- The **rocket engine** pushes the **exhaust gases** (the "propellant") **b** _ _ _ _ _ _ _ _ _ _ - This is the **a** _ _ _ _ _ _ **force**.

- At the same time, the **exhaust gases** push the **rocket engine** (and therefore the rocket) **f** _ _ _ _ _ _ _ _ - This is the **r** _ _ _ _ _ _ _ _ **force**.

74) Complete the diagram below to show the "action" and "reaction" forces:

ACTION

R _ _ _ _ _ _ e _ _ _ _ _ _
pushes
e _ _ _ _ _ _ _ g _ _ _ _ _
b _ _ _ _ _ _ _ _ _ _.

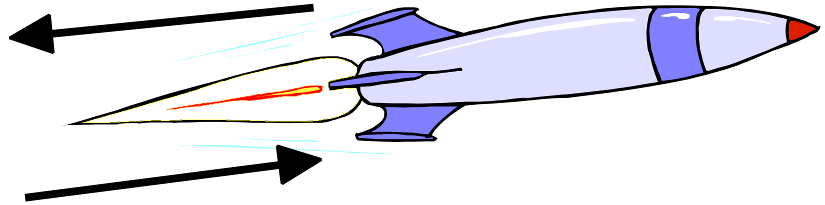
REACTION

E _ _ _ _ _ _ _ g _ _ _ _ _
push
r _ _ _ _ _ _ e _ _ _ _ _ _
f _ _ _ _ _ _ _ _ _ .

75) Complete the diagram to show the "action" and "reaction" forces which cause the rocket to be propelled forward:

ACTION

____
____
____

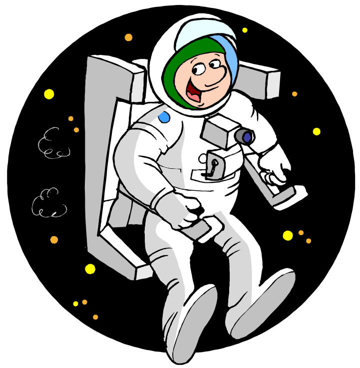


REACTION

____
____
____

76) On his back, an astronaut wears a 'jet pack'. This contains a small rocket engine which, when fired, emits exhaust gases away from the astronaut's back.

Label the diagram with "arrows" and "words" to explain how the 'jet pack' can propel the astronaut forwards through space.



• Momentum

The **momentum** of a moving object gives an indication of the amount of "**damage**" the object can do when it collides with something.

The larger the momentum, the greater the damage.

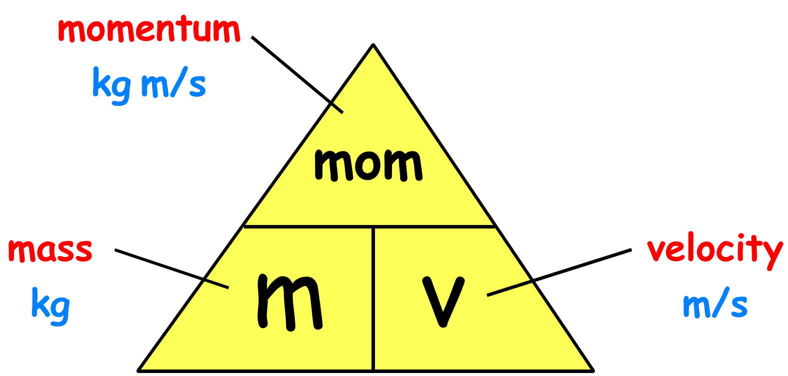
The **momentum** of an object is the product of its **mass** and **velocity**.

Unit: **kg m/s**.

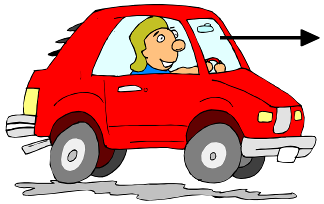
Momentum is a **vector** quantity - It requires a **size** (**number**) and **direction** to describe if fully.

$$\text{momentum} = \text{mass} \times \text{velocity}$$

kg m/s   kg   m/s

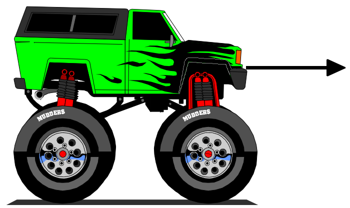


77) Calculate the momentum of each of these moving vehicles:



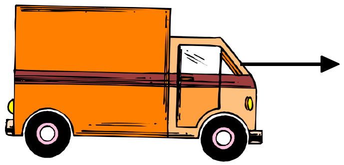
15 m/s

1 000 kg



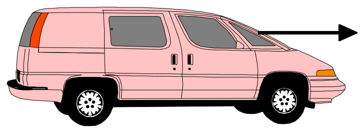
5 m/s

2 500 kg



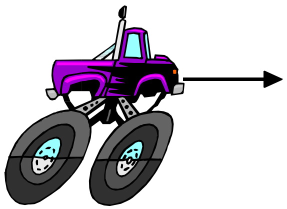
12 m/s

7 500 kg



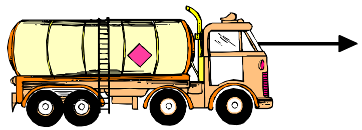
9 m/s

4 200 kg



2.5 m/s

1 800 kg



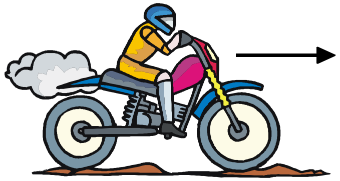
7.5 m/s

10 000 kg

78) Calculate the **momentum** of each of these moving objects:

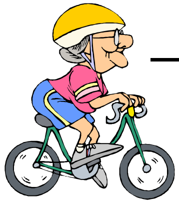
7 m/s

25 kg



11 m/s

270 kg

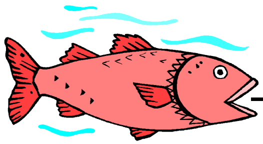


3.2 m/s

85 kg

8.5 m/s

400 kg



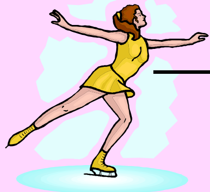
0.25 m/s

1.5 kg

4.5 m/s

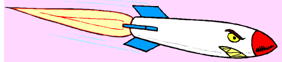
65 kg

79) Calculate the **mass** of each of these moving objects:



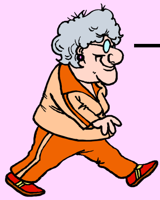
3 m/s

momentum =
180 kg m/s
to the right



100 m/s

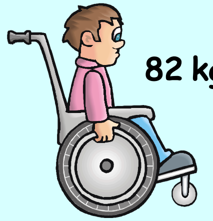
momentum =
35 000 kg m/s
to the right



1.8 m/s

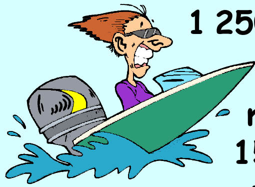
momentum =
117 kg m/s
to the right

80) Calculate the **velocity** of each of these moving objects:



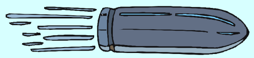
82 kg

momentum =
123 kg m/s
to the right



1 250 kg

momentum =
15 625 kg m/s
to the right



0.0015 kg

momentum =
0.3 kg m/s
to the right

● The Law of Conservation of Linear Momentum

In the absence of net external forces, the total momentum just before a collision is equal to the total momentum just after the collision.

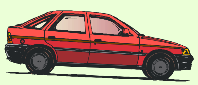
This is a very useful concept. It can be applied to the interaction (collision) of two objects moving in one direction.

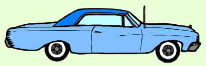
Example

The diagrams below represent a red car (moving at 15 m/s to the right) crashing into the back of a stationary blue car. The two cars join together and move off to the right. Calculate the velocity at which the joined cars move off after the collision.

BEFORE COLLISION

15 m/s ⟶ 0 m/s





1 200 kg 800 kg

Total momentum before collision = momentum of red car

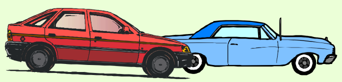
= mv

= 1 200 x 15

= 18 000 kg m/s

AFTER COLLISION

v = ? m/s ⟶



Total mass = 1 200 + 800

= 2 000 kg

Total momentum after collision = momentum of joined cars

= mv

= 2 000 x V

= 2 000 V kg m/s

Total momentum before collision = Total momentum after collision

18 000 = 2 000 V

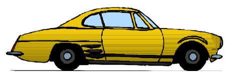
V = 18 000/2 000

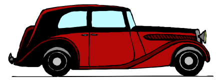
V = 9 m/s

81) A car (which is moving to the right) collides with a stationary car. The cars join together and move off to the right, as shown in the diagrams below. Calculate the velocity at which the joined cars move off.

BEFORE COLLISION

9 m/s ⟶ 0 m/s

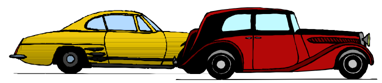




500 kg 1 000 kg

AFTER COLLISION

v = ? m/s ⟶

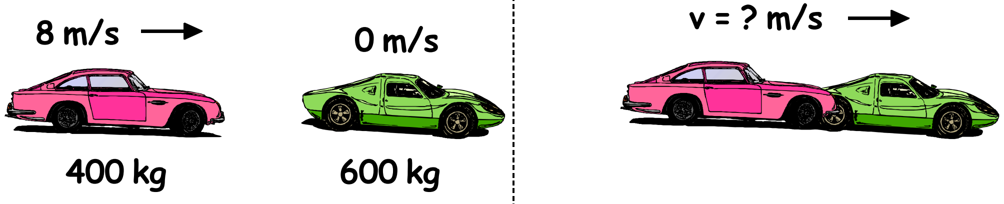


Total mass = 500 + 1 000

= 1 500 kg

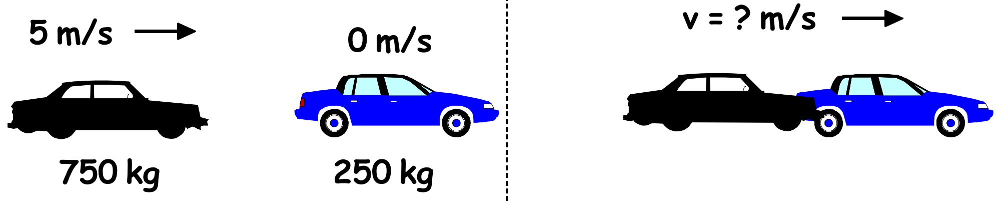
82) A car (which is moving to the right) collides with a stationary car. The cars join together and move off to the right, as shown in the diagrams below. Calculate the velocity at which the joined cars move off.

BEFORE COLLISION | AFTER COLLISION



83) A car (which is moving to the right) collides with a stationary car. The cars join together and move off to the right, as shown in the diagrams below. Calculate the velocity at which the joined cars move off.

BEFORE COLLISION | AFTER COLLISION



84) A car (which is moving to the right) collides with a stationary truck. The vehicles join together and move off to the right, as shown in the diagrams below. Calculate the original velocity of the car.

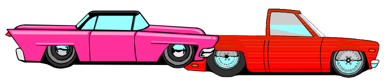
BEFORE COLLISION

v = ? m/s → 0 m/s

800 kg 400 kg

AFTER COLLISION

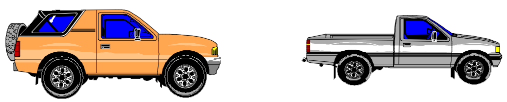
8 m/s →



85) A truck (which is moving to the right) collides with a stationary truck. The trucks join together and move off to the right, as shown in the diagrams below. Calculate the original velocity of the truck which was moving to the right.

BEFORE COLLISION

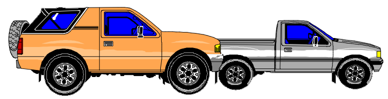
v = ? m/s → 0 m/s



900 kg 600 kg

AFTER COLLISION

3 m/s →

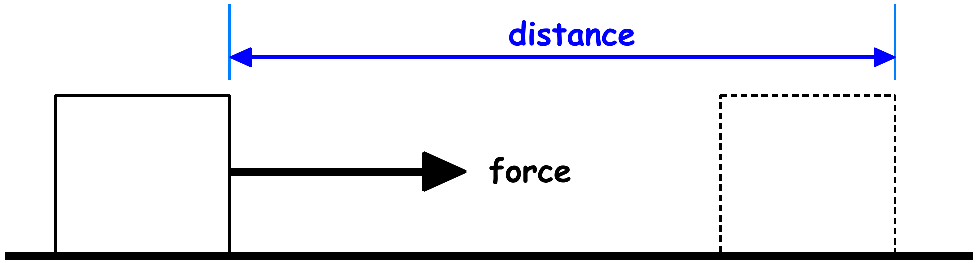


86) A car (mass 800 kg) which is travelling to the right at 15 m/s, crashes into the back of a stationary minibus (mass 1 200 kg). The vehicles stick together and move off to the right. Calculate the velocity at which they do so.

87) A 900 kg van, which is travelling to the right, collides with a stationary motorbike of mass 350 kg. The vehicles join together and move off to the right at 7.2 m/s. Calculate the original velocity of the van.

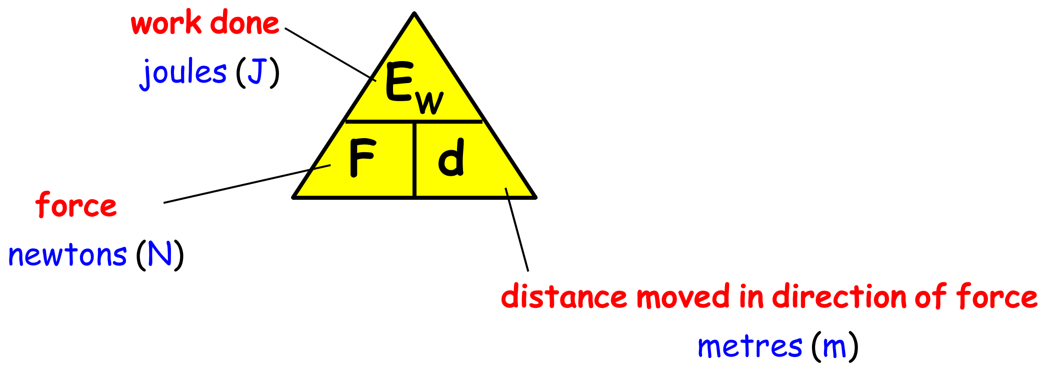
• Work Done = Energy Transferred

When a **force** moves an object through a **distance**, the **force** does **work** on the object:



work done = force × distance moved in direction of force

$E_W = F\ d$



The **work done** by the **force** on the object leads to a **transfer of energy**.

One form of **energy** is transformed (changed) to other forms of **energy**.

work done = energy transferred

• E_W = Fd Calculations

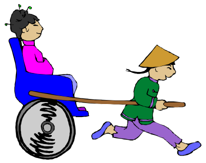
88) Calculate the **work done** by Matthew when he pulls a barrow full of sand with a constant force of 2 000 N over a distance of 15 m.

89) Charlene pushes her baby cousin's pram 50 m along the road by applying a constant force of 200 N. Calculate the **work done**.

90) In order to pull a sledge 75 m across the snow, a dog must exert a constant force of 1 000 N. How much **work** must the dog do?

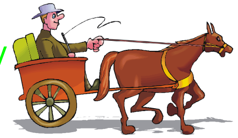
91) Calculate the **energy transferred** by Tony when he pushes his luggage 30 m with a constant force of 230 N.

92) Calculate the **energy transferred** by Lee when he pulls a rickshaw 200 m with a constant force of 1 200 N.

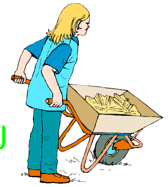


93) How much **energy** is **transferred** by Michael when he pushes his car 15 m with a constant force of 1 500 N.

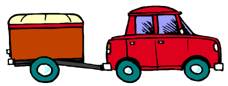
94) A horse does 75 000 J of work by pulling a cart 25 m with a constant force. Calculate the size of the **force** applied by the horse.



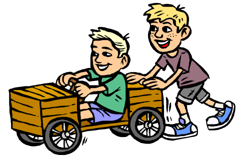
95) When Rianne pushes a wheelbarrow 12 m with a constant force, she does 13 800 J of work. Calculate the size of the **force** applied by Rianne.



96) A car pulls a trailer 500 m along the road with a constant force. The car transfers 1 800 000 J of energy. Calculate the size of the **force** applied.

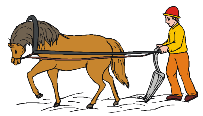


97) Sean pushes Stefan in his go-kart with a constant force of 700 N, doing 5 600 J of work. Calculate the **distance** travelled.



98) Darren does 3 870 J of work when he pulls his golf trolley with a constant force of 215 N. Calculate the **distance** Darren pulls the trolley.

99) A horse transfers 360 000 J of energy when it pulls a plough with a constant force of 4 000 N. Calculate the **length** of the furrow produced.



• Power

work done = energy transferred

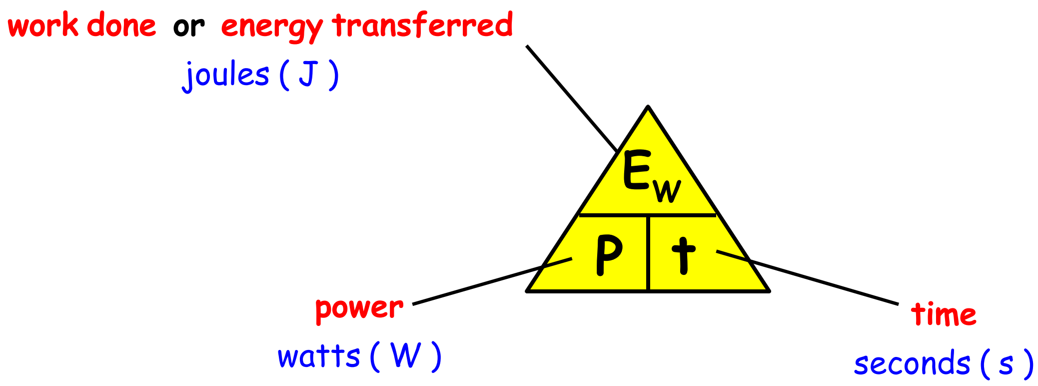
Power is the amount of **work done** (or the amount of **energy transferred**) every second.

$$\text{power} = \frac{\text{work done (or energy transferred)}}{\text{time}}$$

$$P = \frac{E_w}{t}$$

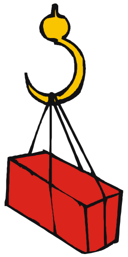
Power is measured in **w** _ _ _ _ (__).

1 w _ _ _ = 1 j _ _ _ _ per s _ _ _ _ _ _.

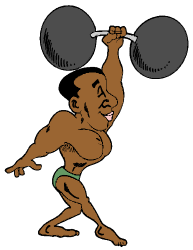


• $E_W = Pt$ Calculations

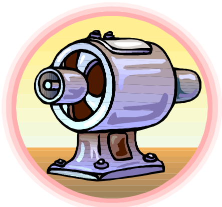
100) A crane does 30 000J of work when it lifts a load for 6 s. Calculate the **power** of the crane engine.



101) A weightlifter does 3 800 J of work in 1.6 s when he lifts a set of weights. Calculate the **power** developed by the weightlifter.



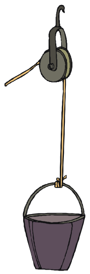
102) An electric motor does 30 J of work in 1.5 s when it lifts a small load. Calculate the **power** of the motor.



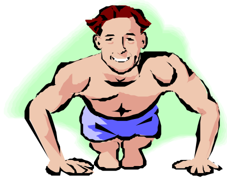
103) When Lewis pulls a loaded sledge across the snow, he transfers 24 000 J of energy in 60 s. Calculate the **power** developed by Lewis.

104) Simon transfers 1 125 J of energy when he moves his wheelchair for 15 s. Calculate the **power** developed by Simon.

105) When a bucket is hoisted off the ground, 390J of energy is transferred in 6.5 s. Calculate the **power** of the hoist.



106) Murray develops 375 W of power while working out for 45 s.
Calculate the **work done**.

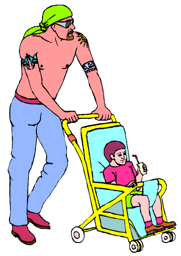


107) A food blender has a power rating of 500 W. Calculate the **work done** by the blender in 15 s.

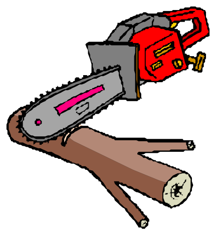
108) During a tug-of-war contest, Gillian develops 380 W of power as she tugs for 12.5 s. Calculate the **energy transferred** by Gillian.

109) An electric drill (power rating 1 250 W) transfers 18 125 J of energy. For what **time** was the drill operated?

110) For what **time** does Mr. Smith push his young son's pushchair if Mr. Smith develops a power of 65 W while transferring 7 800 J of energy?



111) A chain saw develops 1 350 W of power while doing 19 170 J of work. Calculate the operating **time** of the chain saw.



• Gravitational Potential Energy

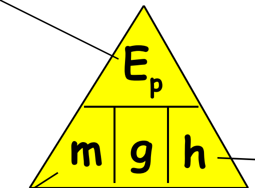
Any object which is above the ground has **gravitational potential energy**.

gravitational potential energy	=	mass	×	gravitational field strength	×	height

$E_p = mgh$

gravitational potential energy

joules (J)



mass of object

kilograms (kg)

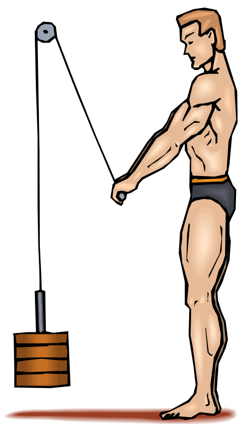
gravitational field strength

newtons per kilogram (N/kg)

height of object above ground

metres (m)

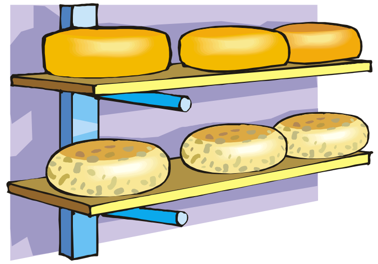
Near Earth's surface, $g = 10$ N/kg



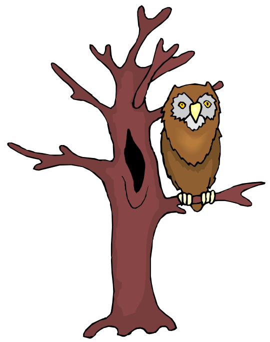
- When an object is lifted up off the ground, **work** is done **against** gravity - The work done is equal to the **i** _ _ _ _ _ _ _ _ in the object's **gravitational potential energy**.
- When an object is lowered down towards the ground, **work** is done **by** gravity - The work done is equal to the **d** _ _ _ _ _ _ _ _ in the object's **gravitational potential energy**.

• $E_p = mgh$ Calculations

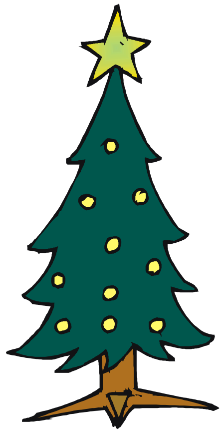
112) Calculate the **gravitational potential energy** of a 15 kg cheese which is sitting on a 1.5 m high shelf.



113 'Hoot' the owl has a mass of 2.8 kg. Calculate her **gravitational potential energy** when she is sitting 9.5 m up a tree.



114) A star (mass 0.75 kg) sits on top of a 12 m high Christmas tree. Calculate the **gravitational potential energy** of the star.



115) Calculate the **gravitational potential energy** of Graham's golf ball (mass 0.045 kg) which is stuck 1.8 m up a tree.

116) When Boris holds a set of weights 1.9 m above the floor, the weights have a gravitational potential energy of 3 800 J. Calculate the **mass** of these weights.

117) During a 'strong man' competition, Hamish holds a 150 kg boulder above the ground. If the boulder has a gravitational potential energy of 1 650 J, calculate its **height** above the ground.

118) Kayleigh has a mass of 62 kg. She climbs 2.5 m up a ladder. Determine:

(a) Kayleigh's ***increase*** in **gravitational potential energy**;

(b) the **work done** against gravity.

119) Ally the abseiler descends 35 m down a rope. His mass is 70 kg. Determine:

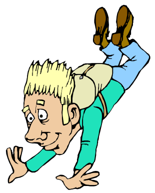
(a) Ally's ***decrease*** in **gravitational potential energy**;

(b) the **work done** by gravity.

120) A helicopter (mass 6 200 kg) increases its height above the ground by 115 m. Determine:

(a) the ***increase*** in **gravitational potential energy**;

(b) the **work done** against gravity.

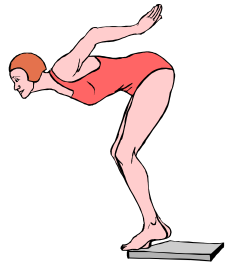


121) A skydiver (mass 68 kg) falls 350 m through the air. Determine:

(a) the ***decrease*** in **gravitational potential energy**;

(b) the **work done** by gravity.

122) When Alana climbs 8.5 m up a rope, she does 4 675 J of work against gravity. Determine Alana's **mass**.



123) When Shona, mass 66 kg, dives from a high board into a swimming pool, 16 500 J of work is done by gravity. Determine the distance Shona falls through.

• Kinetic Energy

Kinetic energy is **movement energy**.

A moving object's **kinetic energy** depends on its **mass** and **velocity**:

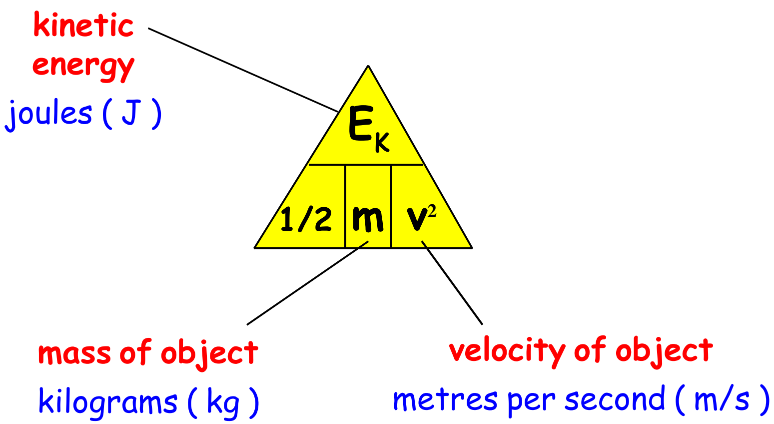
● The greater the **mass** of a moving object, the ______________ is the value of its **kinetic energy**.

● The greater the **velocity** of a moving object, the ______________ is the value of its **kinetic energy**.

Kinetic energy, **mass** and **velocity** are related by the formula:

$$\boxed{\text{kinetic energy} = 1/2 \times \text{mass} \times \text{velocity}^2}$$

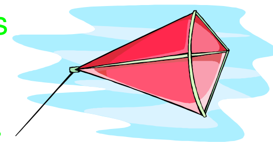
$$\boxed{E_K = 1/2\, m\, v^2}$$



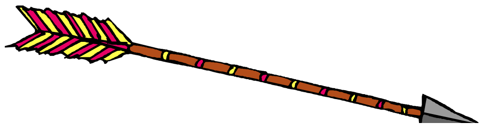
• $E_K = 1/2\ mv^2$ Calculations

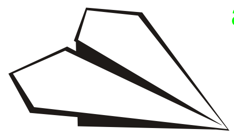
124) Quasim, who has a mass of 60 kg, is jogging with a velocity of 5 m/s to the right. Calculate Quasim's **kinetic energy**.

126) Kevin's kite has a mass of 0.02 kg. It is travelling through the air with a velocity of 3 m/s to the right. Calculate the **kinetic energy** of the kite.



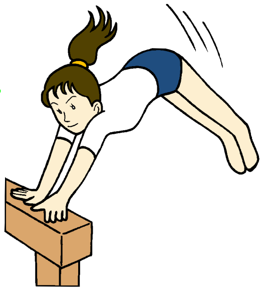
125) Calculate the **kinetic energy** of a 0.12 kg arrow which is travelling through the air with a velocity of 50 m/s to the right.





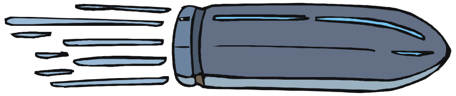
127) Ryan throws a paper aeroplane of mass 0.001 kg. The plane leaves his hand with a velocity of 5 m/s to the right. Calculate the **kinetic energy** of the plane at this instant.

128) Dominique has a mass of 55 kg. During her gymnastics display, she springs off the end of a beam with a velocity of 4 m/s upwards. Calculate the **kinetic energy** of Dominique at this instant.

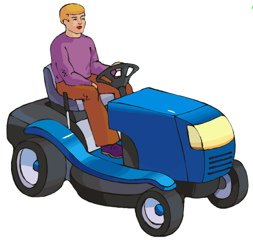


129) Ross fires a 0.002 kg stone from a catapult. If the stone leaves the catapult with a velocity of 10 m/s to the right, calculate the **kinetic energy** of the stone at this instant.

130) A bullet, travelling through the air with a velocity of 1 200 m/s to the right, has 11 520 J of kinetic energy. Calculate the **mass** of the bullet.

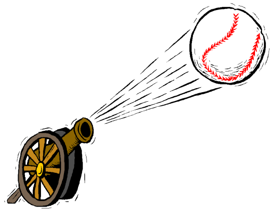


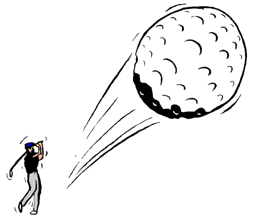
131) Duncan (mass 64 kg) has 72 J of kinetic energy while swimming the butterfly stroke in a forwards direction. Calculate Duncan's **velocity** at this instant.



132) When driven with a velocity of 2.5 m/s to the right, Graeme's grass cutting machine and Graeme have a kinetic energy of 3 750 J. Calculate the combined **mass** of Graeme and the machine.

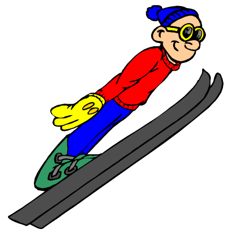
133) A 1.25 kg cannonball is fired from a cannon to the right with 6 250 J of kinetic energy. Calculate the **velocity** at which the cannonball leaves the cannon.





134) A golf ball leaves the face of a golf club with a velocity of 40 m/s to the right. At this instant, the golf ball has 36.8 J of kinetic energy. Calculate the **mass** of the golf ball.

135) Daniel and his skis have a combined mass of 60 kg. Daniel takes off from a ski jump to the right with a kinetic energy of 18 750 J. Calculate his take off **velocity**.



• Typical Energy Transformation Calculations

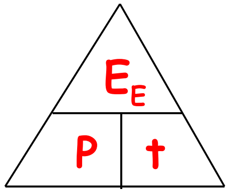
We cannot make or destroy energy - but we can transform (change) it from one type to another.

You will need these **formulae** to solve the following problems. The problems involve the **transformation** (**change**) of energy from one type to another:

An electric motor transforms (changes) electrical energy to mainly kinetic energy.

Electrical Energy (E_E) = Power (P) x time (t)

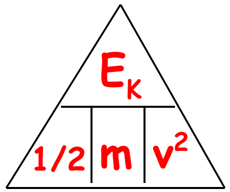
- Electrical Energy: joules (J)
- Power: watts (W)
- time: seconds (s)



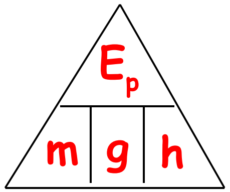
Kinetic energy is movement energy - It depends on the mass and velocity of the moving object.

Kinetic Energy (E_K) = 1/2 x mass (m) x velocity (v)^2

- Kinetic Energy: joules (J)
- mass: kilograms (kg)
- velocity: metres per second (m/s)



Any object which is above ground level has gravitational potential energy - As the object falls to the ground, its gravitational potential energy is transformed (changed) to mainly kinetic energy.



Gravitational potential energy (E_P) = mass (m) x gravitational field strength (g) x height (h)

- Gravitational potential energy: joules (J)
- mass: kilograms (kg)
- gravitational field strength: newtons/kilogram (N/kg)
- height: metres (m)

g = 10 N/kg near Earth's surface

136) An electric motor has a power of 40 W. It takes 5 s for the motor to pull a mass of 16 kg across a frictionless floor to the right at constant velocity.

(a) Calculate the electrical energy transformed by the motor during the 5 s.

(b) Assuming that all the electrical energy is transformed to kinetic energy, calculate the velocity at which the motor pulls the mass across the floor.

137) A radio-controlled toy car is powered by an electric motor. The car has a mass of 0.8 kg and travels across the floor to the right for 6 s.

(a) If the car travels across the floor with a constant velocity of 3 m/s to the right, calculate its kinetic energy.

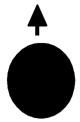
(b) All of the electrical energy supplied to the electric motor is transformed to kinetic energy. Calculate the power rating of the motor.

138) Kelly drops her handbag, which has a mass of 0.5 kg, 200 m down a cliff.

(a) Calculate the gravitational potential energy of the handbag before it is dropped.

(b) Assuming that all the gravitational potential energy has been transformed to kinetic energy at the instant just before the handbag reaches the bottom of the cliff, calculate the downward velocity of the handbag at this instant.

139) A 1.5 kg cannonball is fired straight up in the air from ground level with a velocity of 30 m/s upwards.



(a) Calculate the kinetic energy of the cannonball at the instant it leaves the ground.

(b) When the cannonball reaches its maximum height, all of the kinetic energy has been transformed to gravitational potential energy. Calculate the maximum height the cannonball reaches.

140) A teacher sets up a model pumped storage hydro-electric power station in her lab. The model uses a small electric motor (power rating 20 W) to raise 5 kg of water upwards through a small height. This takes a time of 8 s.

(a) Calculate the electrical energy transformed by the electric motor while lifting the water.

(b) If all the electrical energy is transformed to gravitational potential energy, calculate the height the water is raised to.

141) During the night, surplus electrical energy produced by nuclear power stations is used to pump 50 000 kg of water every minute a height of 300 m up a dam.

(a) Calculate the gravitational potential energy gained by the 50 000 kg of water.

(b) Assuming all the electrical energy supplied to the electric motor of the pump is transferred to gravitational potential energy of the water, calculate the power rating of the motor.

• Typical Efficiency of Energy Transformation Calculations

In the previous energy transformation calculations, it was assumed that no energy was transformed into unwanted types - The transformations were **100% efficient**.

In reality, during any energy transformation, as well as the useful type of energy given out, some energy is also transformed into unwanted types, usually heat - The transformations are **not 100% efficient**.

We say that, during the energy transformation, energy is **degraded**.

- Describe why **kinetic energy** is transformed into usually unwanted **heat energy** by any working machine:

____

____

____

The **efficiency** of any machine/device indicates how good it is at transforming the energy supplied to it into another useful type of energy.

Efficiency is expressed as a percentage.

$$\text{Efficiency} = \frac{\text{Useful Energy Output}}{\text{Energy Input}} \times 100\ \%$$

OR

$$\text{Efficiency} = \frac{\text{Useful Power Output}}{\text{Power Input}} \times 100\ \%$$

142) In each case, calculate the efficiency of the machine/device:

(a) food mixer

Energy input = 200 J

Useful energy output = 140 J

(b) electric fan

Energy input = 5 000 J

Useful energy output = 4 000 J

(c) colour television

Energy input = 1 600 J

Useful energy output = 1 400 J

(d) electric drill

Power input = 10 000 W

Useful power output = 6 000 W

(e) electric light bulb

Power input = 525 W

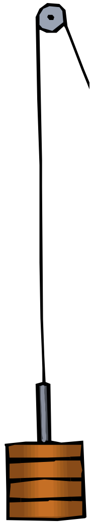
Useful power output = 25 W

(f) computer

Power input = 900 W

Useful power output = 300 W

143) A 100 W electric motor lifts a mass of 2.5 kg upwards through a height of 3.5 m. This takes 5 s.

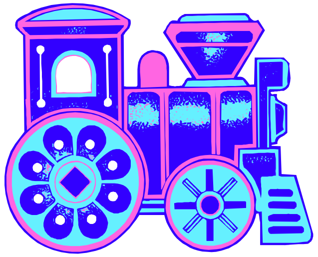


(a) Calculate the energy input - The electrical energy supplied to the motor during the 5 s.

(b) Calculate the energy output - The gravitational potential energy gained by the mass.

(c) Calculate the efficiency of the electric motor during the lifting process.

144) A 2 W electric motor moves a 0.5 kg toy train 15 m across a floor with a constant velocity of 6 m/s to the right. This takes a time of 10 s.



(a) Calculate the electrical energy supplied to the motor during the 10 s - The energy input.

(b) Calculate the kinetic energy the motor supplies to the toy train - The energy output.

(c) Calculate the efficiency of the electric motor.

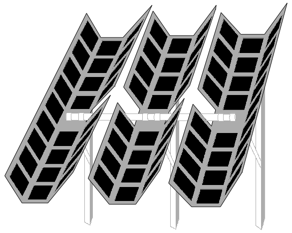
145) A conveyor belt at a supermarket check out counter is powered by a 20 W electric motor. Every 3 s, the motor can move groceries with a mass of 15 kg at a constant velocity of 1.2 m/s to the right.

(a) Calculate the electrical energy supplied to the electric motor during the 3 s.

(b) Calculate the kinetic energy the motor supplies to the food on the conveyor belt.

(c) Calculate the efficiency of the electric motor.

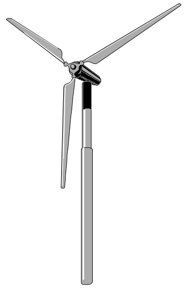
146) A 1 m^2 area of solar cells receives 1 500 W of solar power in a given time.



(a) Calculate the solar power which would be received by solar cells with an area of 3 m^2 in the same time.

(b) If the output power from this 3 m^2 area of solar cells is 1 500 W, calculate the efficiency of the solar cells.

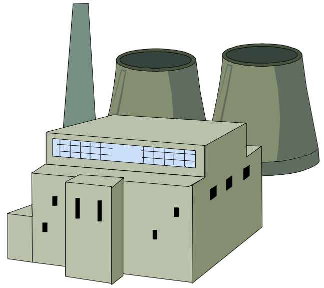
147) A wind turbine receives 9×10^6 J of energy every second.



(a) Calculate the power input to the wind turbine.

(b) If the power output from the wind turbine is 6×10^6 W, calculate the efficiency of the turbine.

148) Every second, 2.5×10^8 J of heat energy is input to a thermal power station.



(a) Calculate the power input to the power station.

(b) If the power station outputs 1.1×10^8 W of power, calculate its efficiency.

• Heat and Temperature

Temperature tells us how h _ _ or c _ _ _ an object is.

Temperature is measured in units of
d _ _ _ _ _ _ C _ _ _ _ _ _ (° _).

Heat is a form of energy which flows from places at h _ _ _ _ _ temperature to places at l _ _ _ _ temperature.

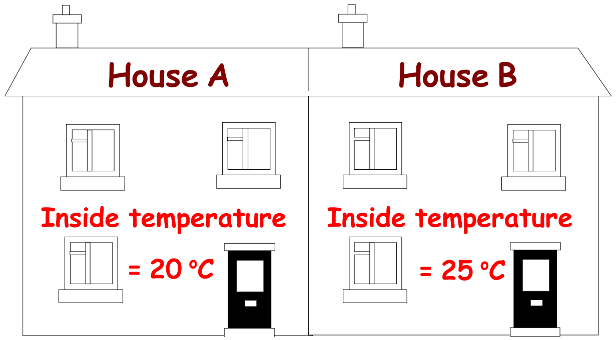
• Heat Loss From a House

The heat energy lost from a house in a given time depends on the temperature difference between the inside and outside of the house.
(The inside is usually warmer than the outside).

The h _ _ _ _ _ the temperature difference,
the m _ _ _ heat energy is lost.

149) Explain which house (A or B) loses most heat energy to the air outside in a given time:

Outside air temperature = 10 °C.



Heat energy can be lost from a house by:

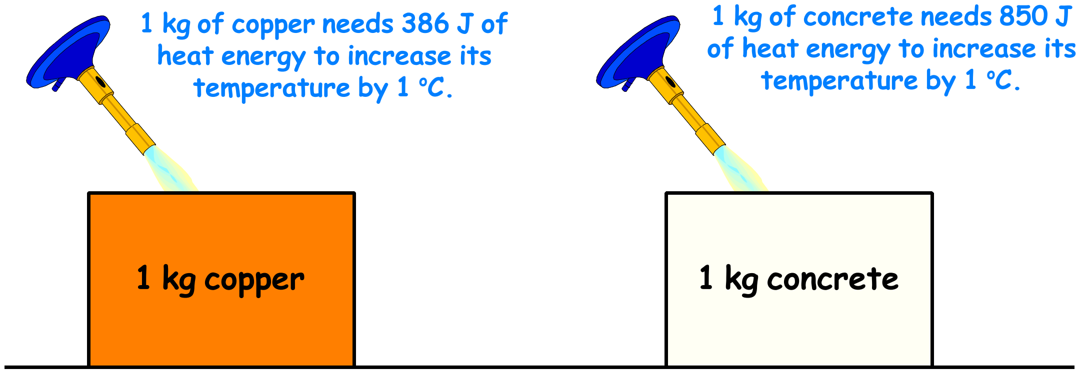
- **Conduction** - Happens mainly in solids. Particles vibrate against each another, passing heat energy from one particle to the next.
- **Convection** - Happens in liquids and Gases. Hot particles move up while cold particles move down. This creates a convection current.
- **Radiation** - Does not involve particles. Infra-red heat energy travels through gases and liquids as waves.

To reduce the amount of heat energy escaping from a house by conduction, convection and radiation we can:

conduction	
convection	
radiation	

• Specific Heat Capacity

Different substances need different amounts of heat energy to increase the temperature of 1 kg of them by 1 °C.



The s _ _ _ _ _ _ _ _ h _ _ _ c _ _ _ _ _ _ _ _ of a substance is the amount of h _ _ _ energy needed to change the temperature of 1 kg of the substance by 1 °C
- Each substance has a different value of s _ _ _ _ _ _ _ _ h _ _ _ c _ _ _ _ _ _ _ _.

This formula applies to any substance, so long as it does not melt, freeze, evaporate or condense while heat energy is being added to it or taken away from it:

$$E_h = m\,c\,\Delta T$$

heat energy added to or taken away from substance (J)

mass of substance (kg)

specific heat capacity of substance (J/ kg °C)

change in temperature of substance (°C)

substance	specific heat capacity
alcohol	2 350 J/ kg °C
aluminium	902 J/ kg °C
concrete	850 J/ kg °C
copper	386 J/ kg °C
glass	500 J/ kg °C
water	4 180 J/ kg °C

Use the values given in the table to solve these problems:

150) How much heat energy would you need to add to 3 kg of copper to increase its temperature by 2 °C?

151) How much heat energy would you need to add to 5 kg of concrete to increase its temperature by 3 °C?

152) How much heat energy does 1.5 kg of alcohol need to take in to increase its temperature by 5 °C?

153) How much heat energy is given out by a 4 kg sheet of glass when its temperature falls by 4 °C?

154) How much heat energy is given out by a 2.5 kg aluminium sheet when its temperature falls by 12 °C?

155) How much heat energy does 0.75 kg of alcohol need to give out to decrease its temperature by 1.8 °C?

156) Amy puts 0.8 kg of water with a temperature of 20 °C in an electric kettle. How much heat energy must the kettle supply in order to increase the temperature of the water to boiling point (100 °C)?

157) During a chemistry lesson, Jack was asked to heat 0.05 kg of alcohol up to its boiling point of 79 °C. If the temperature of the alcohol just before heating was 19°C, how much heat energy was needed?

158) Melissa measured the temperature of water in an electric kettle and found it to be 25 °C. When the kettle was switched on, it increased the water temperature to 95 °C by supplying 175 560 J of heat energy. Calculate the mass of water in the kettle.

159) Kevin put 0.25 kg of hot water in a beaker. As the water cooled, it gave out 36 575 J of heat energy to the surroundings. Calculate the decrease in water temperature.

• Change of State

When a substance melts, freezes, evaporates or condenses, we say it is changing its physical s _ _ _ _.

For a substance to melt or evaporate, it must g _ _ _ h _ _ _ energy.

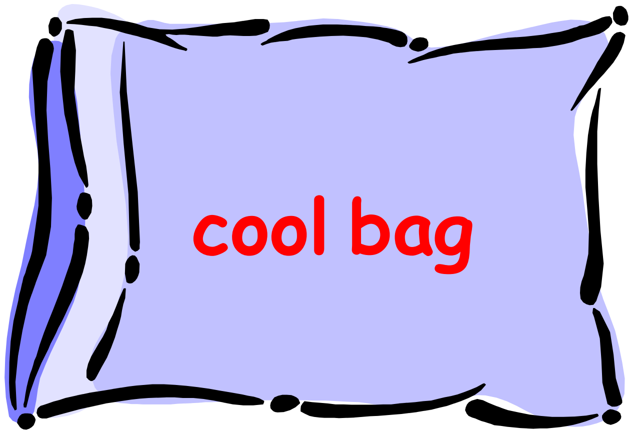
For a substance to freeze or condense, it must l _ _ _ h _ _ _ energy.

When melting, freezing, evaporating or condensing takes place, the t _ _ _ _ _ _ _ _ _ _ _ of the substance does not change.

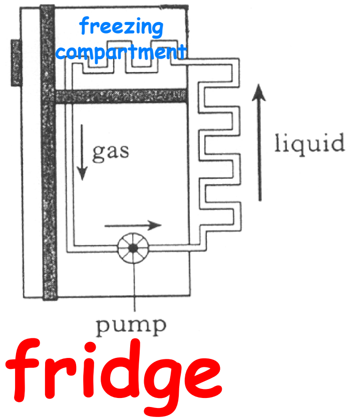
This is very useful. For example:

1) <u>A cool bag/box for food</u> - This contains a special block containing ice or other frozen material. The frozen material takes h _ _ _ energy away from the food in the bag/box and m _ _ _ _, turning into a liquid.

As a result, the t _ _ _ _ _ _ _ _ _ _ _ of the material and the food does not increase.



2) <u>A fridge</u> - A special liquid is pumped through the walls of the freezing compartment. The liquid takes h _ _ _ energy away from the food in the compartment and e _ _ _ _ _ _ _ _ _ _, turning into a gas - As a result, the t _ _ _ _ _ _ _ _ _ _ _ of the food d _ _ _ _ _ _ _ _.



The gas is pumped to the back of the fridge where it gives out the heat energy into the room. The gas c _ _ _ _ _ _ _ _ _, turning back to liquid, which is pumped into the freezing compartment again.

• Specific Latent Heat

• The <u>specific latent heat of fusion</u> is the amount of heat energy taken in to change 1kg of a solid at its melting point temperature to a liquid (or the amount of heat energy given out when 1 kg of a liquid at its freezing point temperature changes to a solid).

• The <u>specific latent heat of vaporisation</u> is the amount of heat energy taken in to change 1 kg of a liquid at its boiling point temperature to a gas (or the amount of heat energy given out when 1 kg of a gas at its condensing point temperature changes to a liquid).

$$E_h = m\,l$$

E_h: heat energy added to or taken away from substance (J)

m: mass of substance (kg)

l: specific latent heat of fusion or vaporisation of substance (J/kg)

160) Calculate how much heat energy 2 kg of ice (frozen water) at its melting point temperature must take in so that it all changes to liquid water. (Specific latent heat of fusion for water = 3.34×10^5 J/kg).

161) 0.5 kg of liquid alcohol at its freezing point temperature freezes, thereby turning into a solid. How much heat energy does the alcohol give out to the surroundings? (Specific latent heat of fusion for alcohol = 0.99×10^5 J/kg).

162) Calculate how much heat energy 1.5 of liquid water at its boiling point temperature must take in so that it all changes to steam. (Specific latent heat of vaporisation for water = 22.6×10^5 J/kg).

163) 0.4 kg of gaseous alcohol at its condensing point temperature changes into liquid alcohol. How much heat energy does the alcohol give out to the surroundings? (Specific latent heat of vaporisation for alcohol = 11.2×10^5 J/kg).

164) How much heat energy is needed to completely melt a 5 kg block of solid copper which is at its melting point temperature? (Specific latent heat of fusion for copper = 2.05×10^5 J/kg).

165) When a mass of liquid water at its freezing point temperature freezes, it gives out 5.01×10^6 J of heat energy to the surroundings. Calculate the mass of water. (Specific latent heat of fusion for water = 3.34×10^5 J/kg).

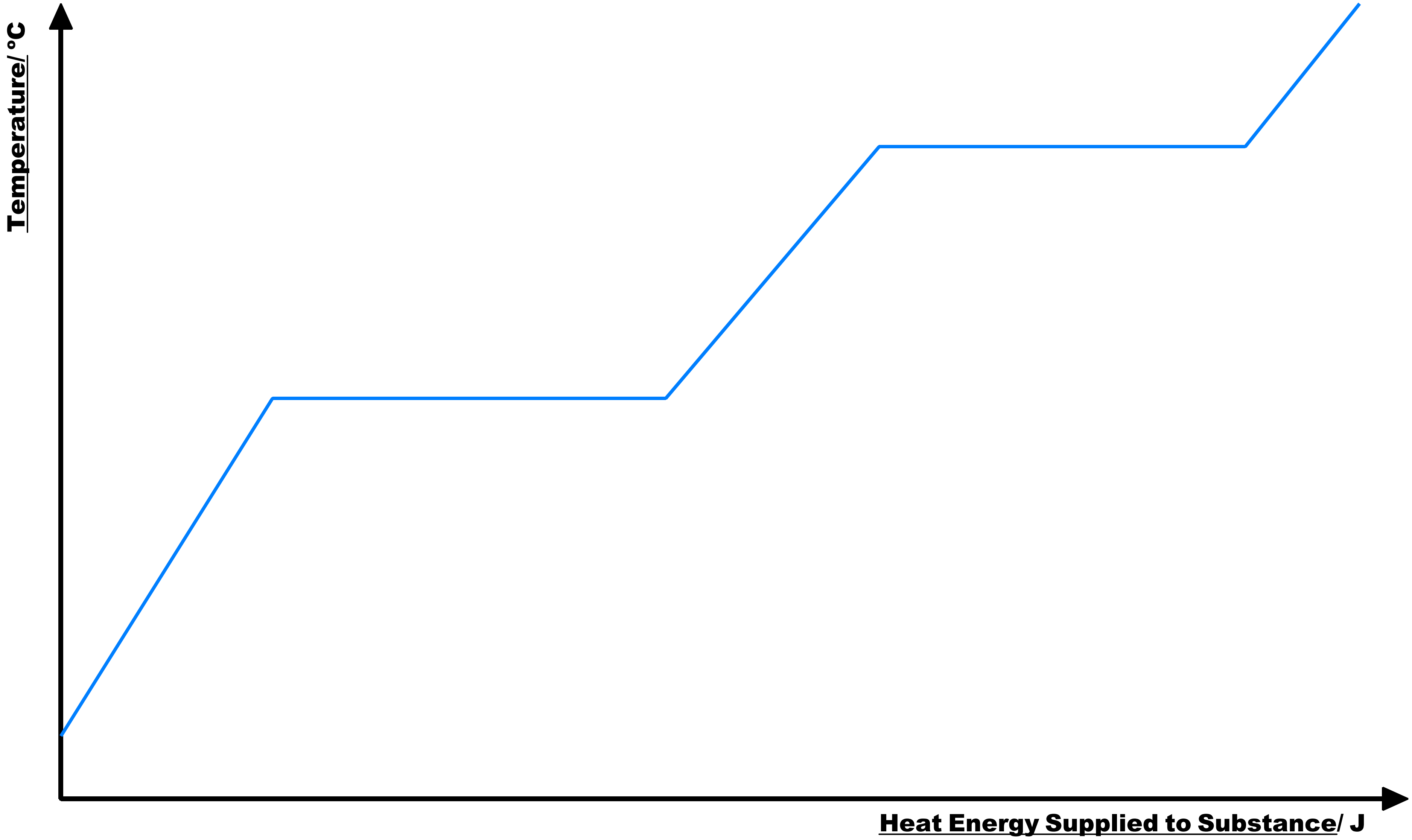
166) How much heat energy is needed to completely turn 0.6 kg of liquid turpentine at its boiling point temperature into turpentine gas? (Specific latent heat of vaporisation for turpentine = 2.90×10^5 J/kg).

167) When a mass of gaseous glycerol at its condensing point temperature condenses, it gives out 1.245×10^6 J of heat energy to the surroundings. Calculate the mass of glycerol. (Specific latent heat of vaporisation for glycerol = 8.30×10^5 J/kg).

• Temperature-Heat Energy Graph

This is a typical graph showing how the **temperature** of a **solid substance** changes as **heat energy** is supplied to it:

Label the graph to explain the various changes in its slope:

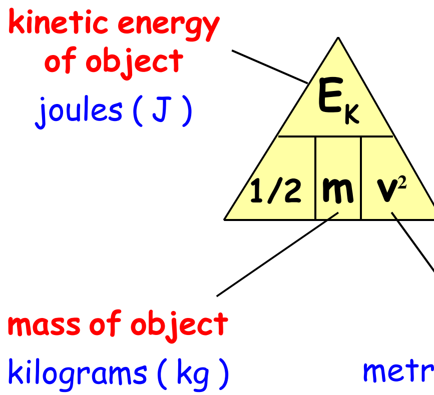


• Entry (or Re-Entry) of Objects into the Earth's Atmosphere

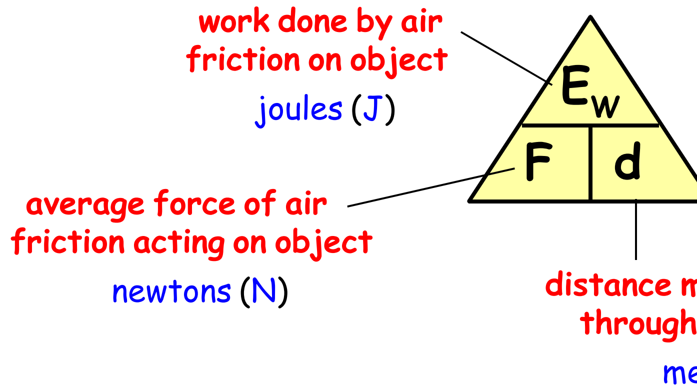
When a moving object enters (or re-enters) the Earth's atmosphere from outer space, an **air friction force** acts on the object, causing the object to **decelerate**.

The **air friction force** does **work** on the object, changing some of the object's **k** _ _ _ _ _ _ **energy** to **h** _ _ _ **energy** - The **t** _ _ _ _ _ _ _ _ _ _ _ of the object **increases**. Often the **t** _ _ _ _ _ _ _ _ _ _ _ increase is so large that the object **g** _ _ _ _ .

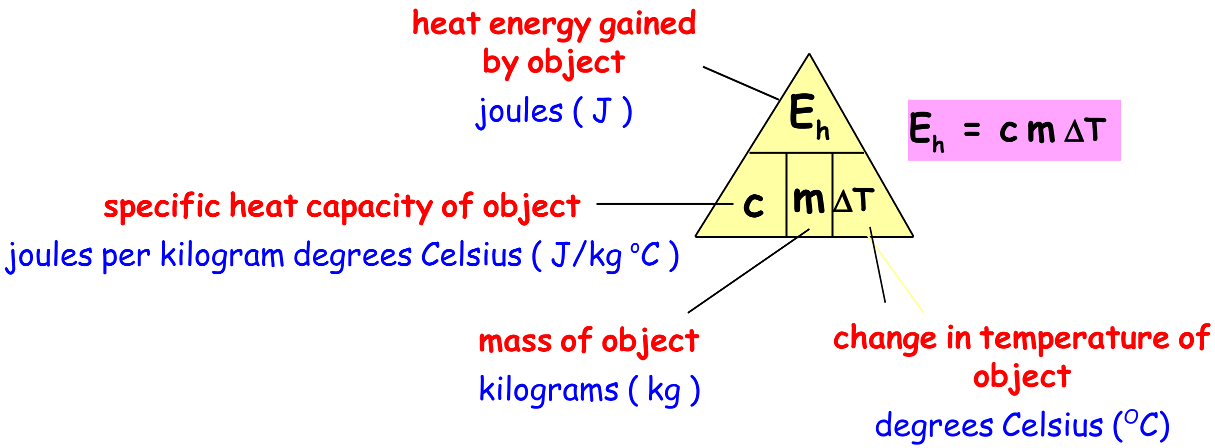
Not all of the **heat energy** causes an increase in **temperature** - Some **e** _ _ _ _ _ _ to the surroundings and some causes part of the object to **m** _ _ _. When the object is **m** _ _ _ _ _ _ , its **t** _ _ _ _ _ _ _ _ _ _ _ does not **c** _ _ _ _ _.



$$E_K = 1/2\, m\, v^2$$



$$E_W = F\, d$$

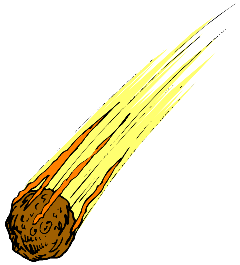


$$E_h = c\, m\, \Delta T$$

• Entry (or Re-Entry) Calculations

Example:

(a) A meteorite of mass 120 kg enters the Earth's atmosphere with a velocity of 15 000 m/s downwards.
Calculate the kinetic energy of the meteorite.



$E_k = 1/2\ m\ v^2$

$= 0.5 \times 120 \times 15\,000^2$

$= 1.35 \times 10^{10}$ J

(b) The force of air friction acting on the meteorite changes 1.5×10^9 J of the meteorite's kinetic energy to heat energy as the meteorite travels a distance of 25 000 m through the Earth's atmosphere.

Calculate the average force of the air friction acting on the meteorite.

$E_w = F\ d$

$\therefore F = \dfrac{E_w}{d}$

$= \dfrac{1.5 \times 10^9}{25\,000} = 60\,000$ N

(c) 1.5×10^9 J of the meteorite's kinetic energy is changed to heat energy as the 120 kg meteorite travels through the Earth's atmosphere. The material from which the meteorite is made has a specific heat capacity of 1 500 J/kg °C.

Calculate the rise in temperature of the meteorite. (Assume no other energy changes take place and that no heat energy is lost to the surroundings).

$E_h = c\ m\ \Delta T$

$\therefore \Delta T = \dfrac{E_h}{c\ m}$

$= \dfrac{1.5 \times 10^9}{1\,500 \times 120} = 8\,333$ °C

168) (a) A meteorite, mass 250 kg, is travelling at a velocity of 12 000 m/s downwards when it enters the Earth's atmosphere.

Calculate the **kinetic energy** of the meteorite at this instant.

(b) As the meteorite travels 30 000 m through the Earth's atmosphere, the force of air friction changes 1.8×10^{10} J of the meteorite's kinetic energy to heat energy.

Calculate the **average force** of the air friction acting on the meteorite.

(c) 1.8×10^{10} J of the meteorite's kinetic energy is changed to heat energy as the 250 kg meteorite travels through the Earth's atmosphere. The material from which the meteorite is made has a specific heat capacity of 1 600 J/kg °C.

Calculate the **rise in temperature** of the meteorite. (Assume no other energy changes take place and that no heat energy is lost to the surroundings).

169) (a) An 800 kg mass of space debris is travelling at a velocity of 15 000 m/s downwards when it enters the Earth's atmosphere.

Calculate the **kinetic energy** of the space debris as it enters the Earth's atmosphere.

(b) As the space debris travels 170 000 m through the Earth's atmosphere, the force of air friction changes 8.5×10^{10} J of the kinetic energy of the space debris to heat energy.

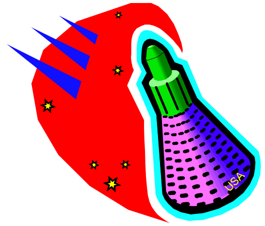
Calculate the **average force** of the air friction acting on the space debris as the debris travels through the Earth's atmosphere.

(c) 8.5×10^{10} J of the kinetic energy of the 800 kg space debris is changed to heat energy as the debris travels through the Earth's atmosphere. The space debris has a specific heat capacity of 2 500 J/kg °C.

Calculate the **rise in temperature** of the debris. (Assume no other energy changes take place and that no heat energy is lost to the surroundings).

170) (a) At the instant a space capsule of mass 1 200 kg enters the Earth's atmosphere in a horizontal direction, the capsule has 7.26×10^{10} J of kinetic energy.

Calculate the **velocity** of the space capsule at this instant.



(b) As the space capsule travels 3000 m through the Earth's atmosphere, the average force of air friction acting on the capsule is 2×10^{7} N.

Calculate the **work done** by the atmosphere on the capsule as the capsule travels this distance.

(c) A 'heat shield' on the space capsule has a mass of 5 000 kg. The heat shield absorbs 5×10^{10} J of heat energy as the space capsule travels through the Earth's atmosphere, causing the temperature of the heat shield to increase by 15 000 °C.

Calculate the **specific heat capacity** of the material from which the heat shield is made. (Assume no other energy changes take place and that no heat energy is lost to the surroundings).

Notes