Speed, Velocity and Acceleration

24th Jan

The SPEED of an object is the DISTANCE it travels in EACH UNIT OF TIME.

The standard unit of speed is 'metres per second' which is written as 'm/s'.

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

- speed in metres per second, m/s
- distance in metres, m
- time in seconds, s

LEARN

The SPEED of an object always has two components: a size (that's the number that goes with it – also called the MAGNITUDE)
· a unit (the thing it is measured in)

It does NOT depend on direction. This means it is a SCALAR quantity.

Examples of scalar quantities; energy, mass, volume, time, distance

If, to fully describe a quanitity, you need to give a MAGNITUDE, A DIRECTION and usually a unit then that quantity is a VECTOR.

Examples of vectors include; velocity, any force, acceleration, momentum

Velocity is SPEED IN A GIVEN DIRECTION.

If an object SPEEDS UP, SLOWS DOWN or CHANGES DIRECTION then its VELOCITY CHANGES.

An object is ACCELERATING whenever ITS VELOCITY IS CHANGING.

ACCELERATION is the RATE OF CHANGE OF VELOCITY (it tells us how much the velocity changes by each second).

$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time}}$$

Where we can find 'change in velocity' by using:

change in velocity = final velocity – initial velocity

The units of acceleration are 'metres per square second' or m/s^2

LEARN

Spelling test: FRICTION, PRESSURE, SPEED, VELOCITY, CENTRE OF MASS, STREAMLINING, AIR RESISTANCE, MOMENT, STOPPING DISTANCE, ACCELERATION.

Please put one or two worked examples in your BBL notes.

1. Speed Questions

(a) Mr Sutherland walks stylishly across his classroom. He covers 9 m in 6 s. What is his speed?

$speed = \frac{9}{6} = 1.5$ m/s

(1 mark)

(b) A car travels along a road at 18 m/s. How far does it travel in 7 minutes?

7 mins = 420s, (7×60) | $18 = \frac{distance}{420}$ substitution | 18 × 420 = distance; distance = 7560 m

(2 marks)

(c) A high speed train travels at 56 m/s. Assuming it can do this speed throughout the journey, how long would it take to go from London to Manchester (260.4 km)?

260.4 km = 260400 m ✓ | $56 = \frac{260400}{time}$ | $time = \frac{260400}{56}$ = 4650 s ✓

(2 marks)

2. Acceleration Questions

(a) When a golf ball is hit off the tee, it accelerates from zero to 45 m/s in a time of just 0.005 s. Calculate its acceleration.

$a = \frac{45-0}{0.005} = 9000$ m/s²

(1 mark)

(b) A car slows down as it enters a town from 25 m/s to 13 m/s in a time of 5 s. Calculate its acceleration.

$a = \frac{-12}{5} = -2.4$ m/s²

(1 mark)

(c) A fighter jet can accelerate at 30 m/s². How long does it take to go from a speed of 90 m/s to 225 m/s?

$30 = \frac{225-90}{t}$ | $t = \frac{225-90}{30}$ = 4.5 s

(2 marks)

Forces and Newton's First Law

30th Jan

A force is a push or a pull. Forces can either act a distance (NON-CONTACT FORCES) or occur when objects touch (CONTACT FORCES).

Examples of contact forces: friction, air resistance, water resistance, upthrust, drag, reaction/normal contact force

Examples of non-contact forces: gravity (weight), magnetism, electrostatic

Often objects have multiple forces acting on them. If we are to know the effect these forces would have we need to find the RESULTANT FORCE.

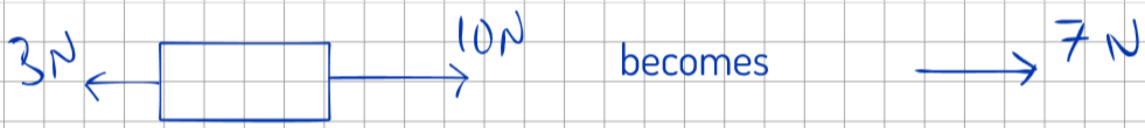
The resultant force is a SINGLE FORCE that has THE SAME EFFECT as ALL OF THE FORCES acting on an object.

Resultant Forces

Once we have drawn a diagram to show all of the forces acting on a single object, we can find out the resultant force:

If two forces are coplanar (acting along the same line) and in the same direction, they add together.

If they are coplanar but in opposite directions, we subtract the smaller force from the larger one.



Newton's First Law of motion states that an object will REMAIN AT REST or CONTINUE AT A CONSTANT VELOCITY unless it is acted on by A RESULTANT FORCE.

In simple terms: if there is no resultant force (forces are balanced) an object will just keep doing whatever it was doing.

If there is a resultant force an object will ACCELERATE. It can speed up/slow down/change direction.

The acceleration is always in the same direction as the resultant force.

Newton's Second Law

Newton's Second Law of motion states that the ACCELERATION of an object is DIRECTLY PROPORTIONAL to the RESULTANT FORCE. It is INVERSELY PROPORTIONAL to the MASS OF THE OBJECT.

So if, for the same object, the resultant force doubles so would the acceleration.

And, for the same resultant force, an object with twice the mass would have half the acceleration.

Resultant Force = Mass x Acceleration

$$F = ma$$

Stopping Distances

5th Feb

When a driver sees a hazard in the road they would use the brakes to stop the vehicle.

The total distance the driver travels after seeing the hazard before coming to a stop is called the STOPPING DISTANCE.

stopping distance = thinking distance + braking distance

Thinking distance: the distance travelled during reaction time

Braking distance: the distance travelled after pressing the brakes, until the vehicle stops

The THINKING DISTANCE is affected by factors that affect the driver's reaction time.

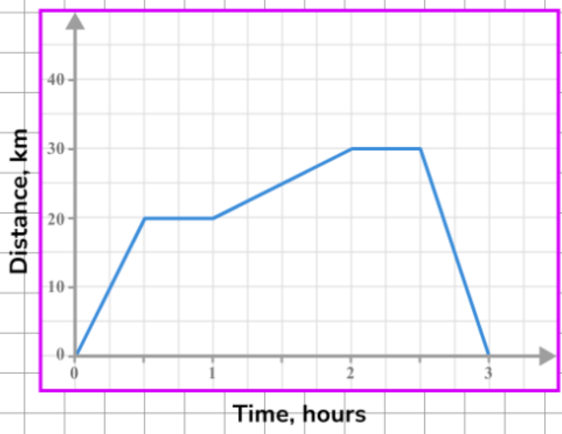
PHYSICAL FACTORS affect the braking distance and usually involve changing the amount of friction (between tyres and the road or in the brakes).

The only factor that changes both is the SPEED.

A typical human reaction time is between 0.2 seconds and 0.5 seconds. This can be measured using the 'ruler drop test' or with computer software.

Distance-Time Graphs

6th Feb



The motion of an object can be represented by plotting a distance-time graph.

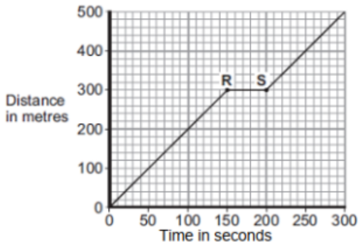
The GRADIENT of the graph shows how fast the object is moving.

The STEEPER THE LINE, the GREATER THE SPEED.

If the graph shows a HORIZONTAL LINE, it means the object is NOT MOVING.

Q1. (a) **Figure 1** shows the distance–time graph for a person walking to a bus stop.

Figure 1



(i) Which **one** of the following statements describes the motion of the person between points **R** and **S** on the graph?

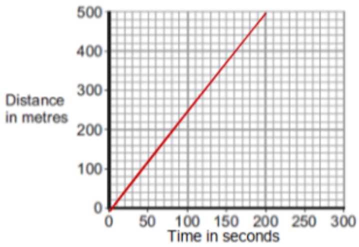
- Not moving ✓
- Moving at constant speed
- Moving with increasing speed

(1)

(ii) Another person, walking at constant speed, travels the same distance to the bus stop in 200 seconds.

Complete **Figure 2** to show a distance–time graph for this person.

Figure 2



(1)

(b) A bus accelerates away from the bus stop at 2.5 m/s².

The total mass of the bus and passengers is 14 000 kg.

Calculate the resultant force needed to accelerate the bus and passengers.

$F = ma$

$= 14000 \times 2.5$ ✓

Resultant force = 35000 N ✓

(2)

Terminal Velocity

7th Feb

As an object falls through a fluid (a gas or a liquid) it initially accelerates.

This is a skydiver the instant they step out of a plane.

There is a LARGE RESULTANT FORCE DOWNWARDS.

This causes a LARGE ACCELERATION DOWNWARDS.

A few seconds later....

As their SPEED INCREASES the force of DRAG INCREASES.

This DECREASES the RESULTANT FORCE.

This means ACCELERATION DECREASES.

Eventually....

The DRAG = WEIGHT

There is now NO RESULTANT FORCE

The skydiver now moves at a CONSTANT VELOCITY called the TERMINAL VELOCITY.

When the skydiver opens their parachute, drag will increase. This will create a resultant force upwards, causing them to slow down. This means they eventually reach a new, lower terminal velocity.

Pressure

19th Feb

The PRESSURE exerted by a FORCE tells us how much force acts on each unit of area. It tells us how 'spread out' a force is over an area.

We can calculate the pressure a force exerts using:

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} \quad \text{or} \quad P = \frac{F}{A}$$

Force is ALWAYS measured in newtons, N.

Area is USUALLY measured in square metres, m^2, but may also be given in square centimetres, cm^2.

This means pressure has units of newtons per square metre, or newtons per square centimetre.

Note: you may see pressure with a unit of Pa (pascals), but 1 Pa = 1 N/m^2.

1. A box has a weight of 200N. It sits on a base which has an area of 8 cm^2. What pressure does it exert on the floor?

$P = \frac{200}{8} = 25\ N/cm^2$ ✓ ✓

(2 marks)

2. A car sits on four tyres, each of which has an area in contact with the road of $70cm^2$. If the car weighs 14,000 N, calculate the pressure it applies to the road.

$P = \frac{14{,}000}{4 \times 70} = 50\ N/cm^2$

(2 marks)

3. A book measures 20cm by 10cm and has a weight of 5 N. What pressure does it apply to the table that it is sitting on?

$P = \frac{5}{20 \times 10} = 0.025\ N/cm^2$

(2 marks)

4. What force is needed to apply a pressure of 3 N/m^2 to an area of 6 m^2?

$3 = \frac{F}{6}$ ✓ $F = 6 \times 3$ ✓ $= 18\ N$ ✓✓✓

(3 marks)

5. A person whose weight is 400 N applies a pressure to the floor (when standing on both feet) of 1.6 N/cm^2. What is the total area of their feet?

$1.6 = \frac{400}{A}$, $A = \frac{400}{1.6} = 250\ cm^2$ ✓✓✓

↑ substitution

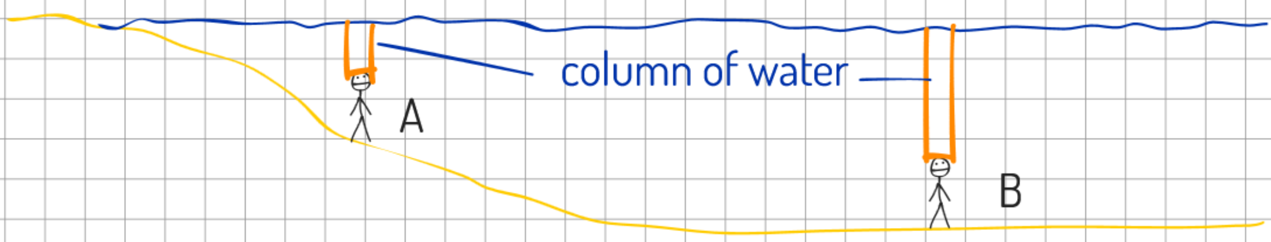
(3 marks)

Pressure in Fluids

20th Feb

Particles in liquids and gases are constantly moving and collide with the walls of their containers. This creates a pressure.

Also the pressure in any fluid increase with depth in the fluid.



There is a greater weight of fluid on person B, than person A. So they experience a greater pressure.

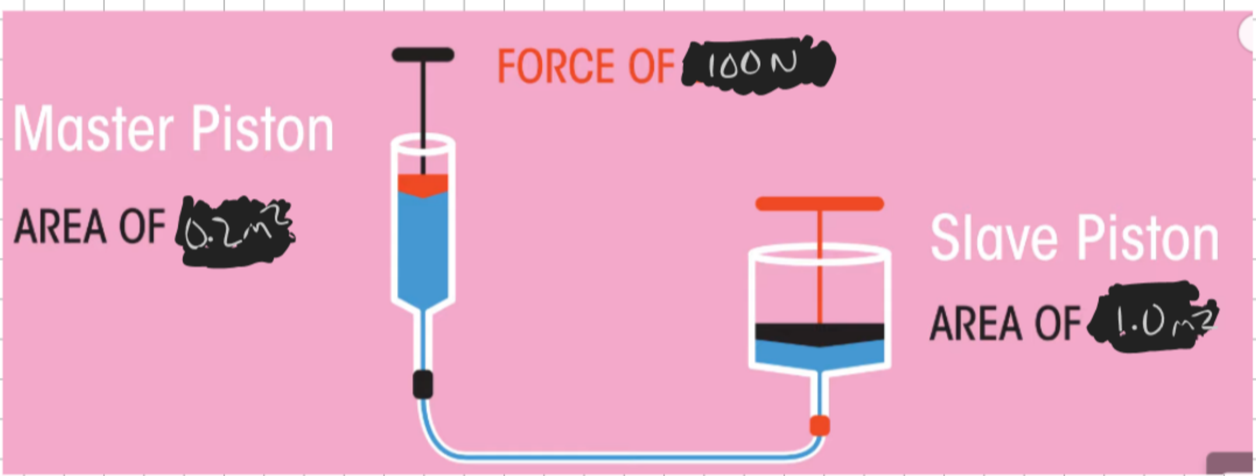
This is also why atmospheric pressure decreases with altitude.

The atmosphere also becomes less dense as altitude increases, which also lowers the pressure.

Hydraulics

Liquids are incompressible. This means when we exert a force on them, the change in pressure is transferred in all directions through the liquid.

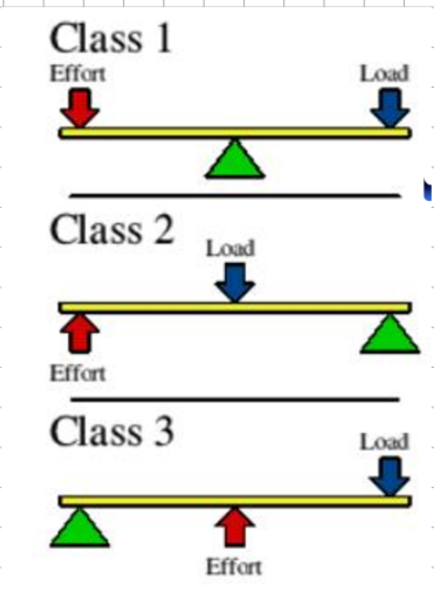
We can take advantage of this in hydraulic systems which act as FORCE MULTIPLIERS.



LEVERS are another example of FORCE MULTIPLIERS.

A lever always has three things: the effort (input force), pivot/fulcrum (turning point) and a load (output force).

The CLASS of a LEVER is determined by the positions of these three things.



See saw, using a screwdriver to open a paint can

Wheelbarrow, nutcracker

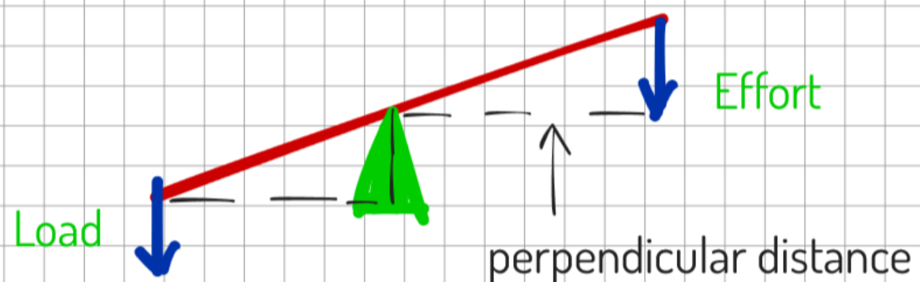
Tweezers

The TURNING EFFECT of a force is called the MOMENT.

To calculate the moment of a force we use the following equation:

Moment = Force x perpendicular distance from the force to the point

The unit of moment is the newton metre, or N m.



The PRINCIPLE OF MOMENTS:

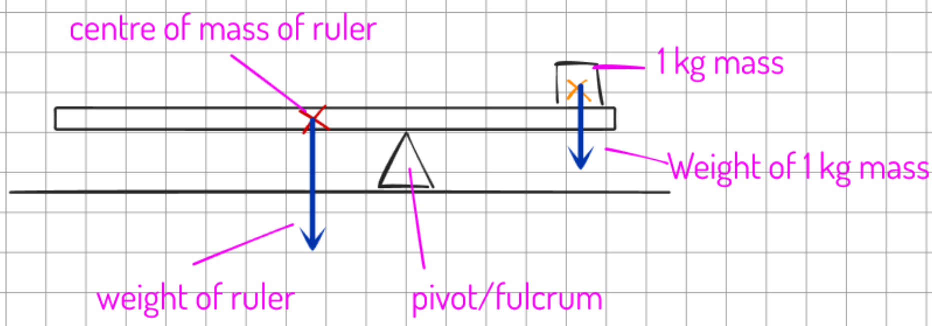
For an object to be in ROTATIONAL EQUILIBRIUM (i.e. balanced) the SUM OF THE ANTICLOCKWISE MOMENTS must EQUAL the SUM OF THE CLOCKWISE MOMENTS around the same point.

Centre of Mass

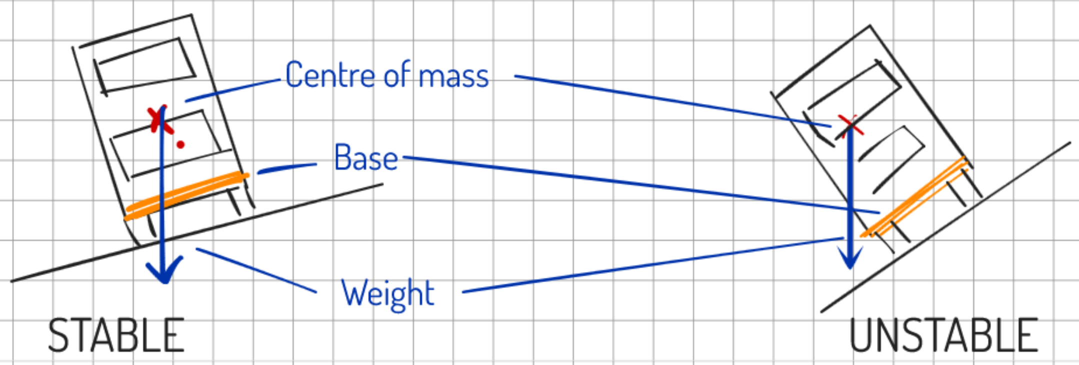
26th Feb

The CENTRE OF MASS of an object is the point at which all of its mass can be considered to be concentrated.

It is also the point through which the object's weight can be treated to act.



An object will be stable (not topple over) if the line of action of its weight lies inside its base.



To increase stability: make the base wider or lower the centre of mass