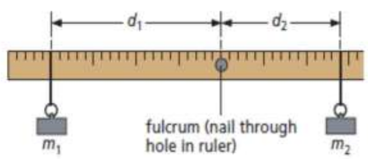
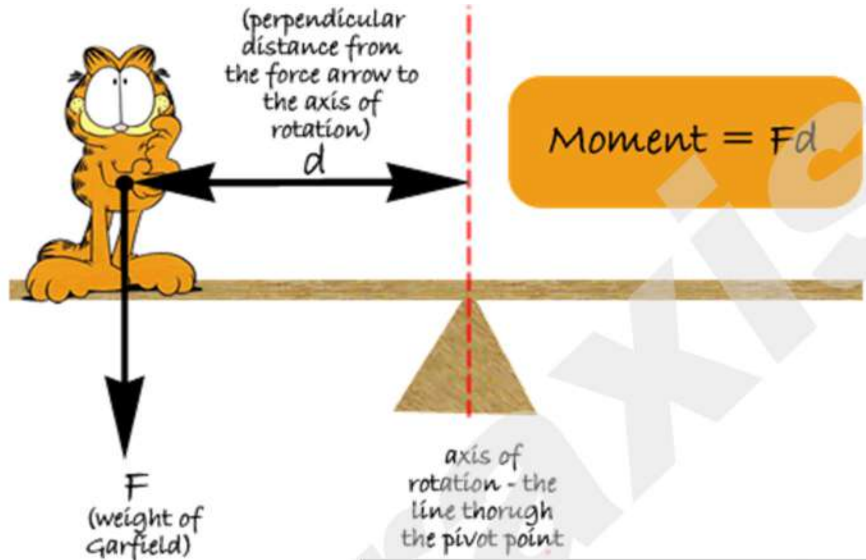
Turning Effect

Moment of a force is the turning effect of a force.

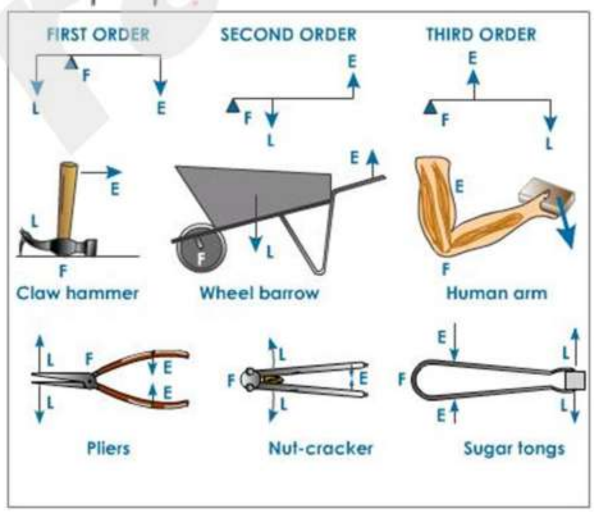
Unit is Newton meter N m.

Balancing a beam
The weigh must be moved so that the clockwise turning effect equals to the anticlockwise turning effect in order to balance the beam.





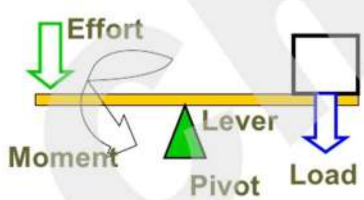
Law of moments (Law of levers)
When an object is balanced (in equilibrium) the sum of the clockwise moments is equal to the sum of the anticlockwise moments.
-There is no net moment on a body which is in equilibrium

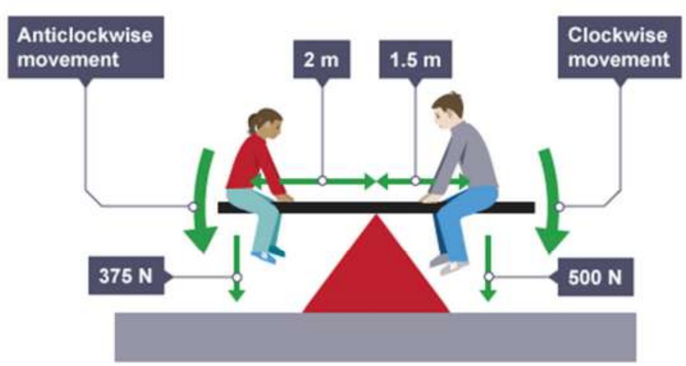


Lever

-Any device which can turn about a pivot

-Effort is used to overcome a resisting force known as load and the pivotal point is called fulcrum/ pivot.





A satellite close to the Earth (at a height of about 200 km) has an orbital speed of 8 km/s. Taking the radius of the orbit as approximately equal to the Earth's radius of 6400 km, calculate the time it takes to make one orbit.

Moment of a Force: A measure of its turning effect (e.g. pushing a door open/close, turning a tap on/off)

- Moments occur when forces cause objects to rotate about some pivot
- The size of the moment depends upon:
  - The size of the force
  - The distance between the force and the pivot
- Moment = force × perpendicular distance from the pivot
- Unit: Newton centimetres (**N cm**) or newton metres (**N m**)

The principle of moments states that:

- For a system to be balanced, the sum of clockwise moments must be equal to the sum of anticlockwise moments

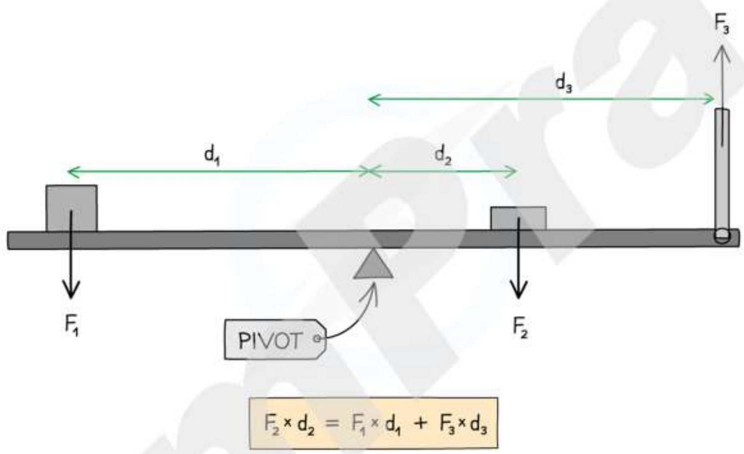


Diagram showing the moments acting on a balanced beam

- In the above diagram:
  - Force F_2 is supplying a clockwise moment;
  - Forces F_1 and F_3 are supplying anticlockwise moments
- Hence:

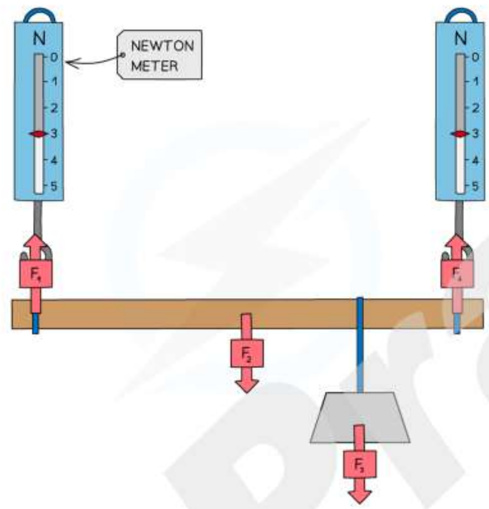
$F_2 \times d_2 = (F_1 \times d_1) + (F_3 \times d_3)$

Equilibrium

- When there is no resultant force and no resultant moment, an object is in equilibrium
- equilibrium" means that an object keeps doing what it's doing, without any change
- Therefore:
  - If the object is moving it will continue to move (in a straight line)
  - If it is stationary it will remain stationary
  - The object will also not start or stop turning

- Conditions of Equilibrium:
  - The forces on the object must be balanced (there must be no resultant force)
  - The sum of clockwise moments on the object must equal the sum of anticlockwise moments (the principle of moments)

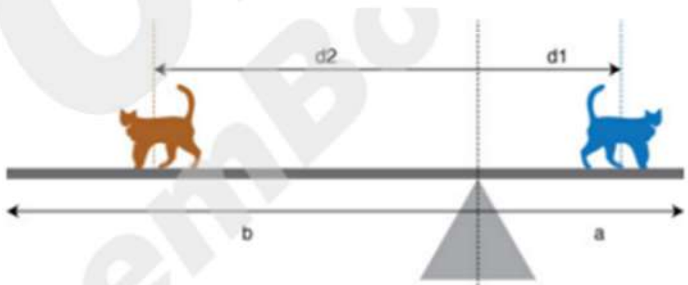
A simple experiment to demonstrate that there is no net moment on an object in equilibrium involves taking an object, such as a beam, and replacing the supports with newton (force) meters:



- The beam is in equilibrium
- The various forces acting on the beam can be found either by taking readings from the newton meters or by measuring the masses (and hence calculating the weights) of the beam and the mass suspended from the beam
- The distance of each force from the end of the ruler can then be measured, allowing the moment of each force about the end of the ruler to be calculated
- It can then be shown that the sum of clockwise moments (due to forces F_2 and F_3) equal the sum of anticlockwise moments (due to forces F_1 and F_4)

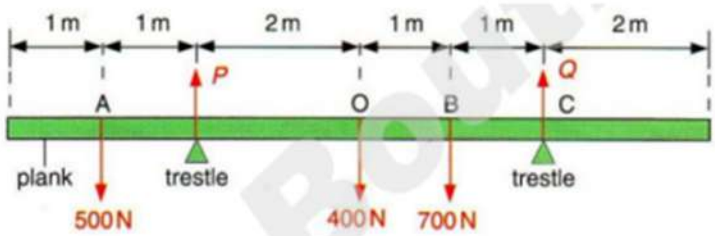
Exercises:

1. Two cats, Mr. Orange and Ms. Blue are on a see saw which is a 3 metre long wood plank having a mass of 4kg. The system in equilibrium when a = b/2, d1 = 50cm and d2 = 105cm. If Ms. Blue has a mass of 12kg, what is the mass of Mr. Orange?



2. 2 painter/decorators weighing 500N and 700N respectively stand on a plank of wood at positions A and B. The plank is resting on 2 trestles (supports) and weighs 400N. The trestles exert upward forces, P and Q, on the plank (known as reactions).

Calculate the upward forces P and Q.



Past Year Topical Questions

Oct/Nov 2019 (43)

2 **(a)** **(i)** State, in words, the equation that defines the *moment of a force*.

....

.... [2]

(ii) State what is meant by the *moment of a force*.

.... [1]

(iii) *Force* is a vector quantity.

Explain what is meant by the term *vector*.

....

.... [1]

(b) Fig. 2.1 shows a tower crane used to lift a load on a construction site.

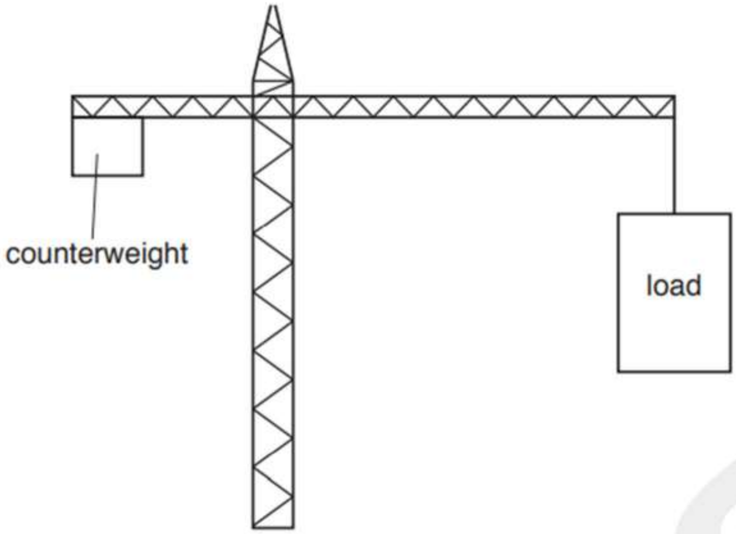


Fig. 2.1

Explain how the counterweight prevents the crane from toppling over.

....

....

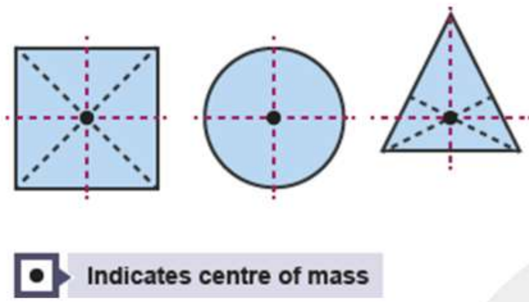
.... [2]

[Total: 6]

Centre of Gravity

A point representing the mean position of the matter in a body or system as if its whole mass is concentrated in one point though the Earth's gravity attracts every part of it.

For simple rigid objects with uniform density, the centre of mass is located at the *centroid.*

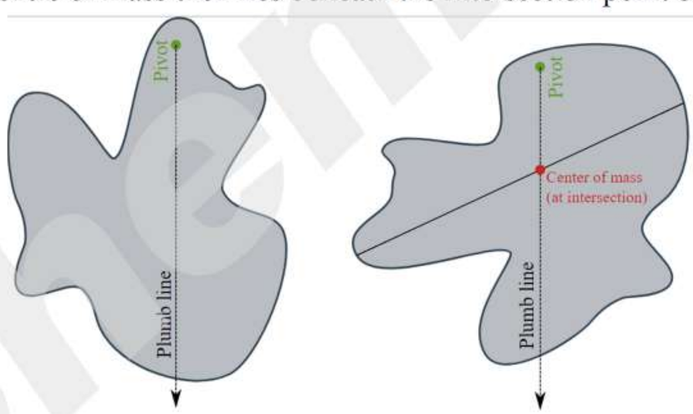


COM of irregular body

An irregularly shaped piece of cardboard suspended on a pin-board is a good example of this. The cardboard pivots freely around the pin under gravity and reaches a stable point.

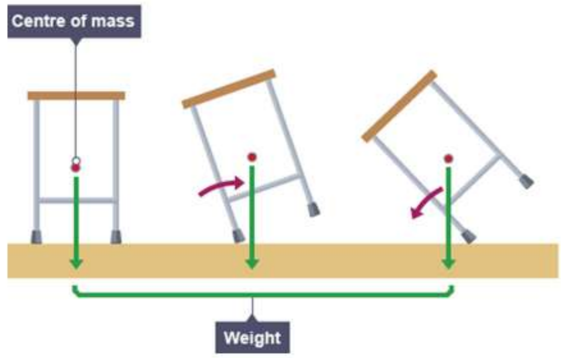
A *plumb line* is hung from the pin and used to mark a line on the object. The pin is moved to another location and the procedure repeated.

The centre of mass then lies beneath the intersection point of the two lines.



Toppling

A body will topple if the vertical line through its COM falls outside its base.



Stability

Stability of a body can be increased by:

a.) Lowering its centre of mass

b.) Increasing its area of base

STABLE EQUILIBRIUM

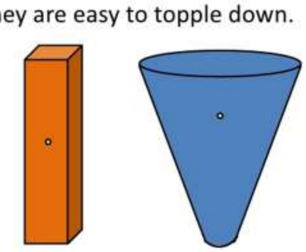
For stable objects:

- the C.G. is at lowest possible position.
- the C.G. needs to be raised in order to topple the object.
- they are difficult to topple over.

UNSTABLE EQUILIBRIUM

For unstable objects:

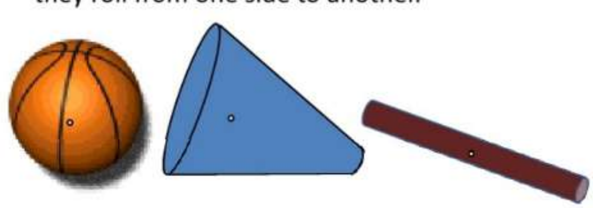
- the C.G. is at the highest possible position.
- the C.G. is lowered in order to topple the object.
- They are easy to topple down.



NEUTRAL EQUILIBRIUM

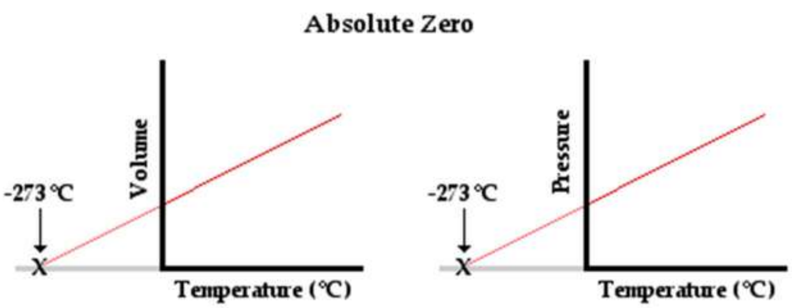
For objects with neutral equilibrium:

- the C.G. is neither lowered nor raised when the object is toppled.
- they roll from one side to another.



Gases and the Absolute Scale of Temperature

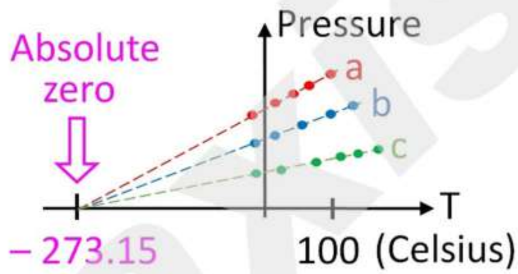
The Gas Law

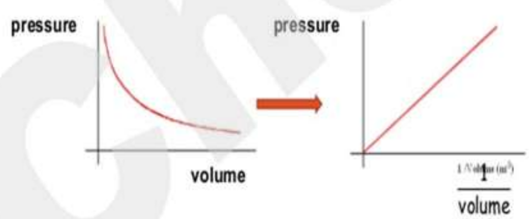
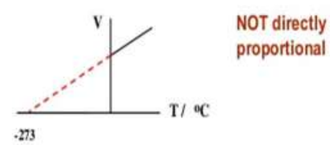
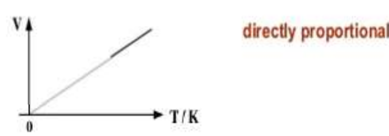


A volume vs. temperature and a pressure vs. temperature plot will each have an x-intercept of -273 C. The volume and the pressure of a gas seem to reduce to 0 at a very specific temperature (assuming the gas remains as a gas).

Unit Conversions
Celsius to Kelvin

$$T_K = T_C + 273.15$$



Boyle's law	Charles' law
What is Boyle's Law? Boyle's Law states that for a fixed mass of gas at constant temperature the pressure varies inversely as the volume (pV = k). $P \propto \frac{1}{V}$ This is used in the form: $P_1 V_1 = P_2 V_2$ — pressure (Pa – Pascal); volume (m³) **Graphs of Boyle's Law:**  **Application of Boyle's Law** A bicycle pump is a good example of Boyle's law. As the volume of the air trapped in the pump is reduced, its pressure goes up, and air is forced into the tire. 	**What is Charles' Law?** Charles' Law states that the volume of a constant mass of gas is directly proportional to the absolute temperature if the pressure remains constant. $V \propto T$ $\frac{V}{T} = \text{constant}$ This is used in the form: $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ — volume (m³); temperature (K) When using this equation you must use **temperature** as **kelvin (K)**. **Graphs of Charles' Law**  When the graph is extended back (the dotted line) until the volume reaches zero, it crosses the axis at -273°C. If the graph is volume against temperature in kelvin, the graph will show volume to be directly proportional to temperature as shown below. 

2.2 Thermal Properties and Temperature

Thermal Expansion of Solids, Liquids and Gases

Pressure law

What is Pressure Law?

Pressure Law states that the pressure of a constant mass of gas is directly proportional to the absolute temperature if the volume remains constant.

$P \propto T$ $\frac{P}{T} = \text{constant}$

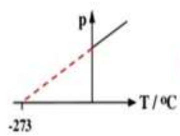
This is used in the form:

pressure (Pa – Pascal) $\frac{P_1}{T_1} = \frac{P_2}{T_2}$ temperature (K)

When using this equation you must use **temperature** as **kelvin (K)**.

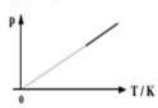
Graphs of Pressure Law

The straight line graph does not pass through the origin.



If the graph is extended back until the pressure reaches zero, it will cross the axis at **-273°C**. This is known as **absolute zero**.

If the pressure against temperature in kelvin graph is drawn, the graph will show pressure being directly proportional to temperature.



Example 2.1

60 cm³ of a gas is at 27 °C. Calculate the volume of this gas at 10 °C, if the pressure is unchanged. SHOW ME

$V_1 = 60\ cm^3$

$T_1 = 27\ °C = 27 + 273 = 300\ K$

$T_2 = 10\ °C = 10 + 273 = 283\ K$

$V_2 = ?$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\frac{60}{300} = \frac{V_2}{283}$$

$$300 \times V_2 = 283 \times 60$$

$$V_2 = \frac{16{,}980}{300}$$

$$V_2 = 56.6\ cm^3$$

What would the volume be if you did not convert to Kelvin?

22.2cm³

WRONG

Combined Gas law

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

Example 1.1

A sample of gas has a volume of 30 cm³ at a pressure of 2x10⁵ Pa. Calculate the new volume of gas when the pressure is increased to 4x10⁵ Pa, assuming the temperature remains constant. SHOW ME

$P_1 = 2\times10^5\ Pa$

$V_1 = 30\ cm^3$

$P_2 = 4\times10^5\ Pa$

$V_2 = ?$

$$P_1 V_1 = P_2 V_2$$

$$(2\times10^5)\times30 = (4\times10^5)\times V_2$$

$$6\times10^6 = (4\times10^5)\times V_2$$

$$V_2 = \frac{6\times10^6}{4\times10^5}$$

$$V_2 = 15\ cm^3$$

Example 3.1

A quantity of gas has a pressure of 2.5x10⁴ Pa at a temperature of 20 °C. Calculate the new pressure when the temperature reaches 37 °C assuming the volume remains constant. To see solution, click SHOW ME

$P_1 = 2.5\times10^4\ Pa$

$T_1 = 20\ °C = 20 + 273 = 293\ K$

$T_2 = 37\ °C = 37 + 273 = 310\ K$

$P_2 = ?$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \qquad \frac{2.5\times10^4}{293} = \frac{P_2}{310}$$

$$293\times P_2 = 310\times(2.5\times10^4)$$

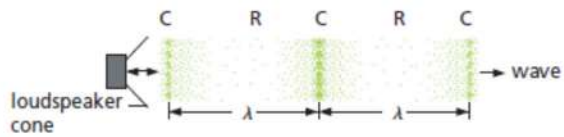
$$P_2 = \frac{77.5\times10^5}{293}$$

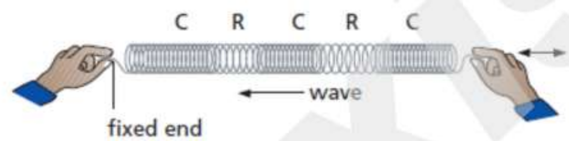
$$P_2 = 2.65\times10^4\ Pa$$

3.4 Sound

Sound

-Longitudinal wave
- Air particles vibrate backward and forward as the wave passes.





-Sound waves are reflected well on hard and flat surface.
-Reflected sounds forms an echo
-Reverberation formed as the result of the echo joins up with the original sound due to the near reflecting surface (within 15 meter)

Material	air (0 °C)	water	concrete	steel
Speed/m/s	330	1400	5000	6000

$$\text{speed of sound in air} = \frac{\text{distance travelled by the sound}}{\text{time taken}} = \frac{d}{t}$$

-Human could hear only sounds with frequencies from 20 Hz to 20,000 Hz
-Musical Notes:
a) Pitch = higher if frequency of sound is higher
b) Loudness = higher if amplitude of sound is higher
c) Quality = better if lesser and weaker overtones (notes apart from fundamental frequency)

Speed of sound in air is approx. 330-350 m/s. Sound generally travels faster in solids than in liquids and faster in liquids than in gases.

Ultrasound

A sound with a frequency that is higher than 20kHz.

Uses: non-destructive testing of materials, medical scanning of soft tissue and sonar including calculation of depth or distance form time and wave speed.

Past Year Topical Questions

Feb/Mar 2021 (22)

20 What is the approximate wavelength in air of the highest frequency sound that can be heard by a normal healthy person?

A 0.02 m **B** 60 m **C** 20 000 m **D** 7 000 000 m

21 What causes the change in direction when light travels from air into glass?

A The amplitude of the light changes.

B The colour of the light changes.

C The frequency of the light changes.

D The speed of the light changes.

22 Light from a torch is incident on a plane mirror. The angle of incidence is 38°.

What is the angle of reflection?

A 38° **B** 52° **C** 76° **D** 142°

23 Two rays with an angle of incidence of 60° pass into dilute and concentrated sugar-water solutions. The refractions are shown.

Which row is correct?

	refractive index as concentration increases	speed through solution as concentration increases
A	decreases	decreases
B	decreases	increases
C	increases	decreases
D	increases	increases