Get Better At PHYSICS Resources

THE FREE PHYSICS LAW BOOK

Contents

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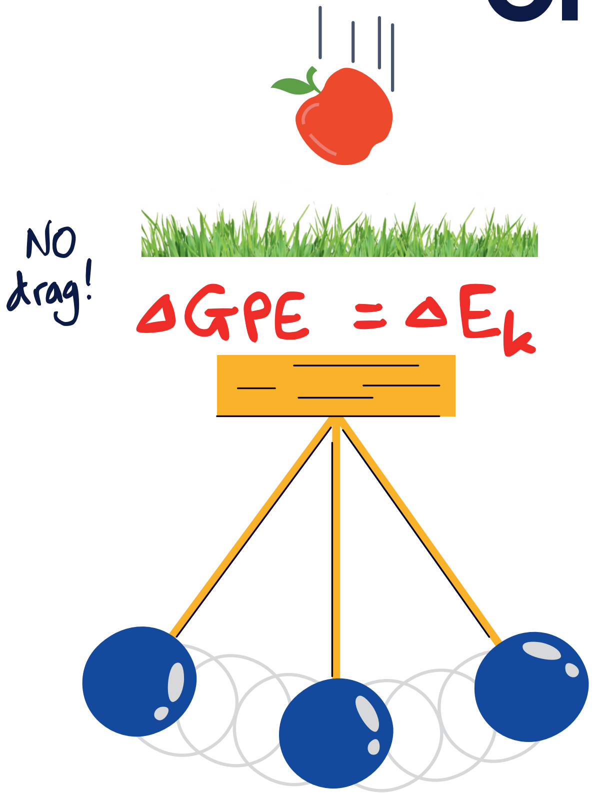
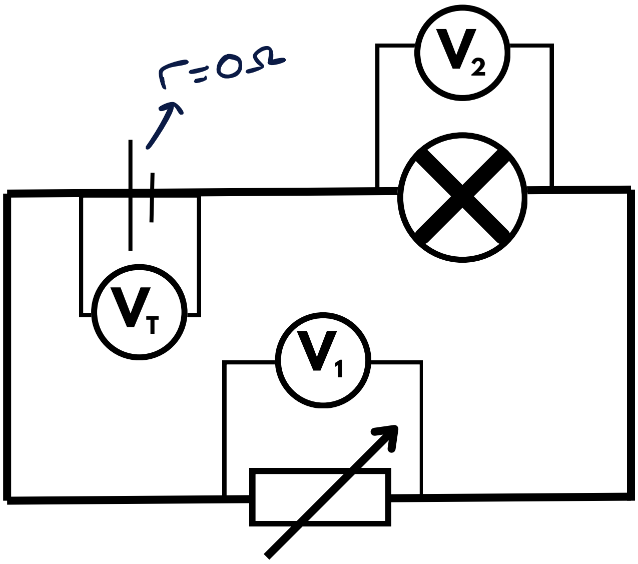
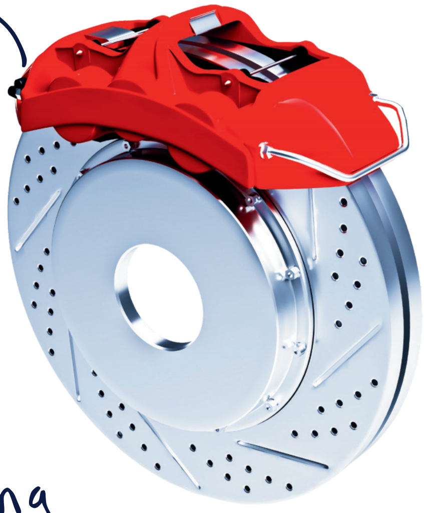
PRINCIPLE OF CONSERVATION OF ENERGY



$\Delta GPE = \Delta E_k$



$$V_T = V_1 + V_2$$



$$\Delta W = \Delta E_k$$

$$Fs = \frac{1}{2}mv^2$$

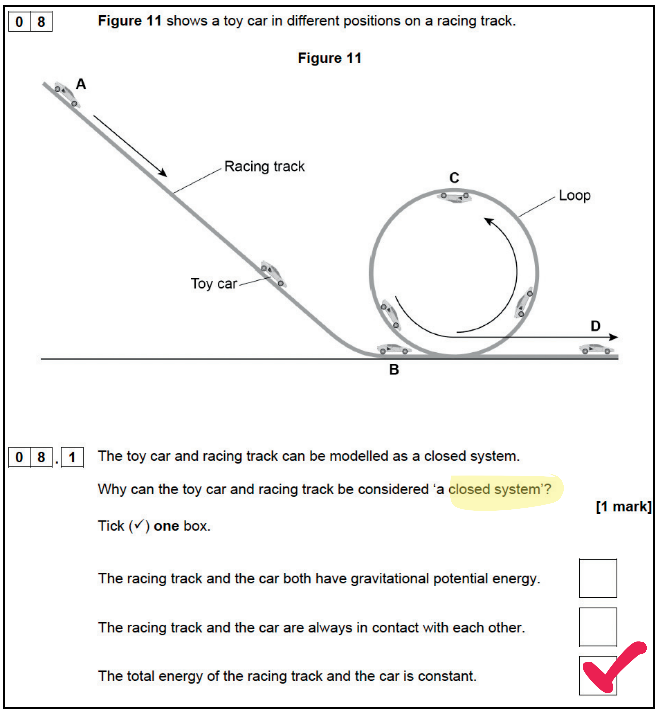
Decelerating Force

Braking Distance

Energy cannot be created or destroyed, only transferred from one store to another

Total Energy in a closed system is constant

PRINCIPLE OF CONSERVATION OF ENERGY



0 8 **Figure 11** shows a toy car in different positions on a racing track.

Figure 11

0 8 . 1 The toy car and racing track can be modelled as a closed system.

Why can the toy car and racing track be considered 'a closed system'?

[1 mark]

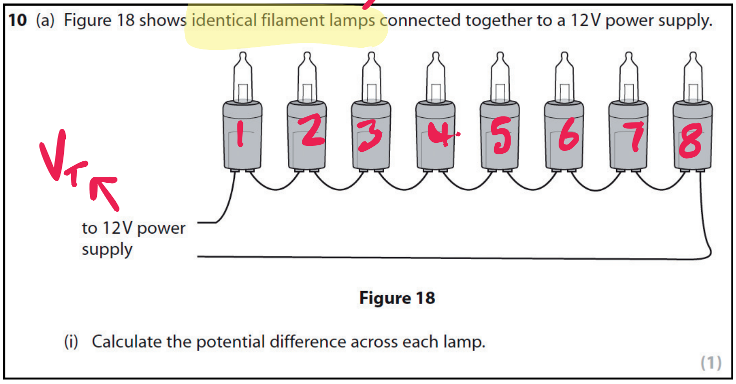
Tick (✓) **one** box.

The racing track and the car both have gravitational potential energy. ☐

The racing track and the car are always in contact with each other. ☐

The total energy of the racing track and the car is constant. ☑

$V_1 = V_2 = V_3 \dots = V$



10 (a) Figure 18 shows identical filament lamps connected together to a 12V power supply.

Figure 18

(i) Calculate the potential difference across each lamp.

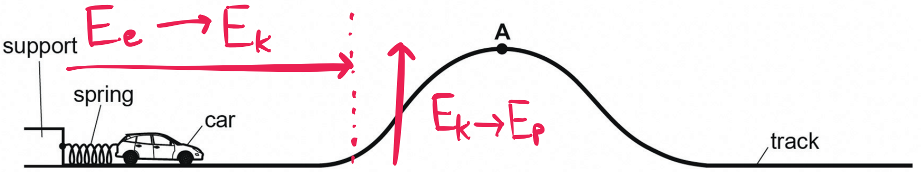
(1)

$$V_T = V_1 + V_2 + \dots$$

$$\text{so } V_T = 8V \Rightarrow 12 = 8V$$

$$\therefore \underline{\underline{V = 1.5V}}$$

(b) The arrangement in **(a)** is used to propel the toy car along a smooth track.



$E_k = 0J$

(i) Point **A** is at the top of the track.
The launch speed of the car is now adjusted until the car just reaches **A** with zero speed.
The height of **A** is 0.20 m above the horizontal section of the track.

h

All the elastic potential energy of the spring is transferred to gravitational potential energy of the car.

Calculate the initial compression x of the spring.

- mass of car m = 80 g → 0.08kg
- force constant k of the spring = 60 N m^{-1}.

$$E_e = E_p \Rightarrow \frac{1}{2}kx^2 = mgh$$

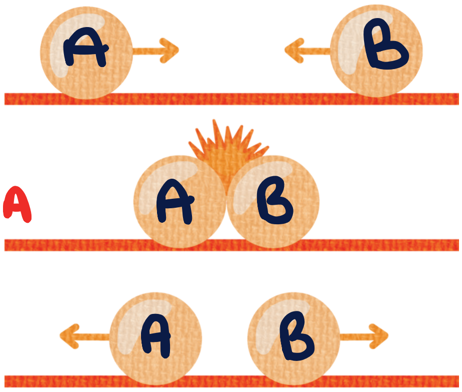
$$x = \sqrt{\frac{2mgh}{k}}$$

$$\therefore \underline{\underline{x = 0.072m}}$$

Energy cannot be created or destroyed, only transferred from one store to another

Total Energy in a closed system is constant

PRINCIPLE OF CONSERVATION OF MOMENTUM



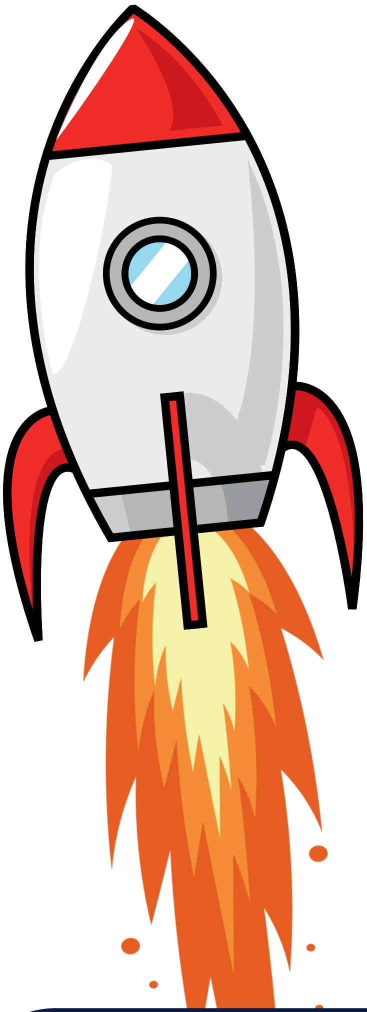
$$p_T = m_A u_A + m_B(-u_B)$$

$$F_{A\to B} = -F_{B\to A}$$

$$p_T = m_A(-V_A) + m_B V_B$$

$$p_c = p_D$$

$$m_c V_c = m_D V_D$$

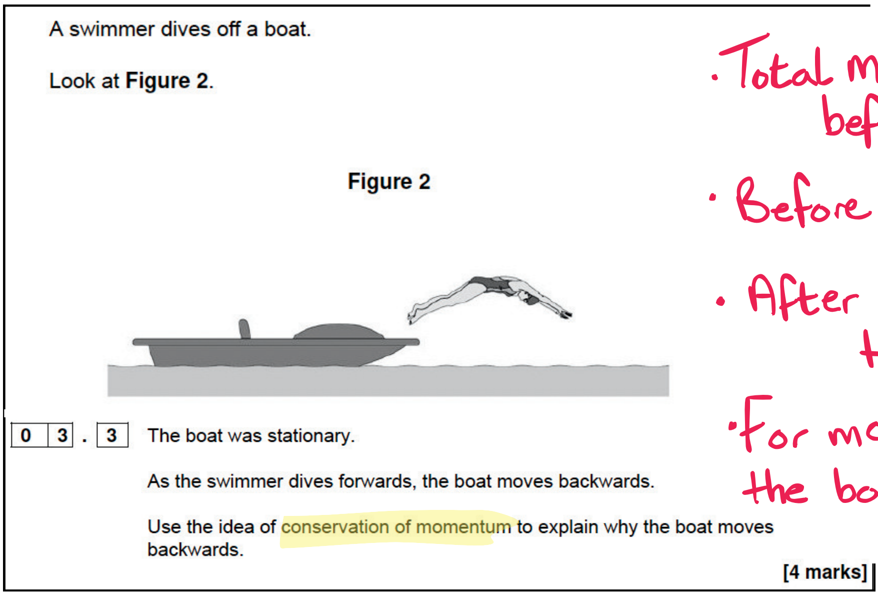


- As the fuel is forced out of the rocket at high speed, its momentum increases.
- Before take-off, the rocket and fuel were at rest: $p_T = 0$; so after take-off $p_T = 0$ also.
- The rocket and fuel have equal & opposite momentums.

Total momentum before an event is equal to Total momentum after the event

Collision OR explosion

PRINCIPLE OF CONSERVATION OF MOMENTUM



A swimmer dives off a boat.

Look at **Figure 2**.

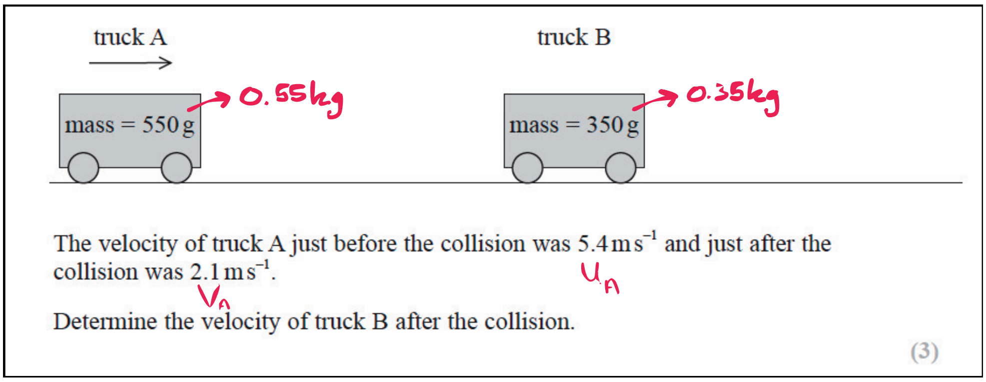
0 3 . 3 The boat was stationary.

As the swimmer dives forwards, the boat moves backwards.

Use the idea of conservation of momentum to explain why the boat moves backwards.

[4 marks]

- Total momentum before = Total Momentum after
- Before diving, total momentum = 0
- After diving, diver gains momentum to the right
- For momentum to be conserved, the boat must gain momentum to the left.



The velocity of truck A just before the collision was 5.4 m s^{-1} and just after the collision was 2.1 m s^{-1}.

u_A V_A

Determine the velocity of truck B after the collision.

(3)

Total momentum before = Total Momentum after

$$p_A + p_B = p_A' + p_B'$$

$$m_A u_A + 0 = m_A V_A + m_B V_B$$

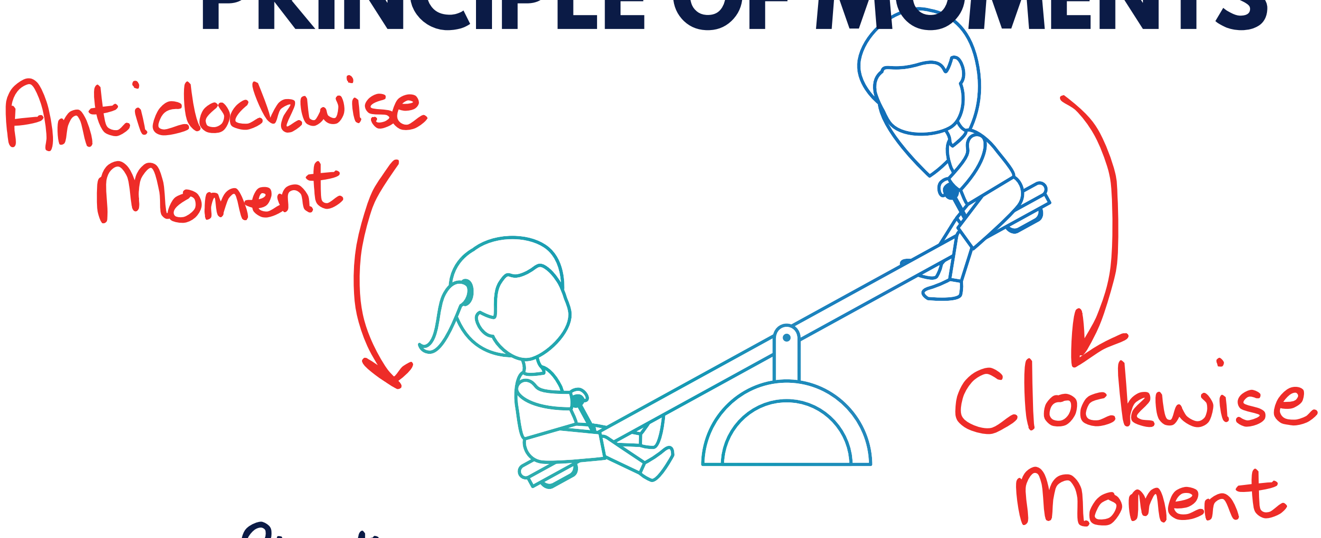
$$(0.55 \times 5.4) + 0 = (0.55 \times 2.1) + 0.35 V_B$$

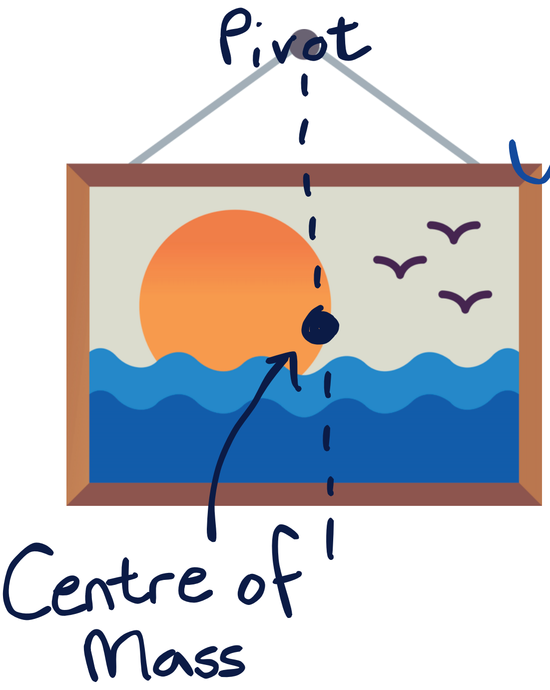
$$\therefore \underline{\underline{V_B = 5.19 \, ms^{-1}}}$$

Total momentum before an event is equal to Total momentum after the event

Collision OR explosion

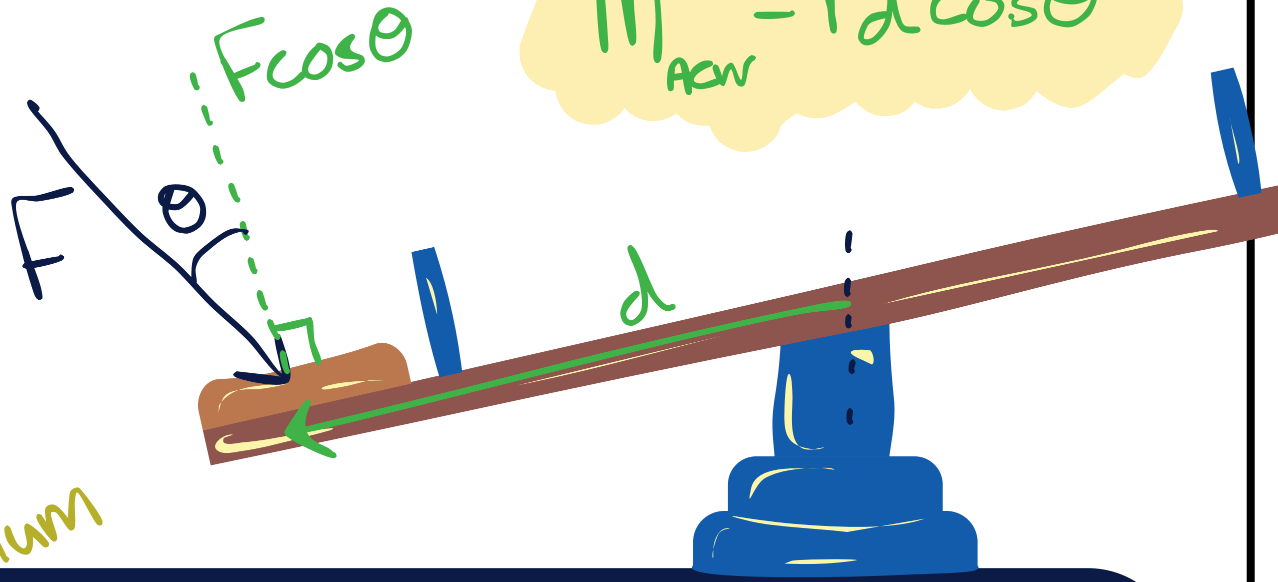
PRINCIPLE OF MOMENTS





When the CoM of an object is directly over the pivot, the resultant moment = 0.

$$M_{ACW} = Fd\cos\theta$$



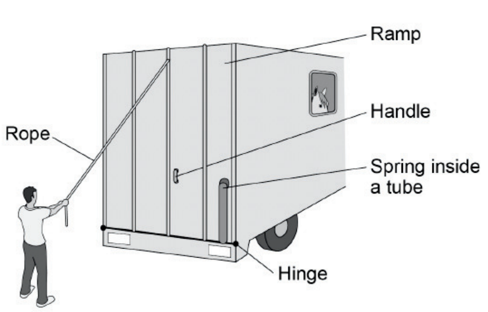
In Equilibrium

Total Anticlockwise Moment is equal to Total Clockwise Moment

PRINCIPLE OF MOMENTS

1 0 **Figure 19** shows the back of a lorry. The lorry is used to carry horses.

Figure 19



The ramp is lowered by pulling on the rope or by pulling on the handle.

The hinge acts as a pivot.

1 0 . 1 Explain why it is easier to lower the ramp by pulling on the rope rather than pulling on the handle.

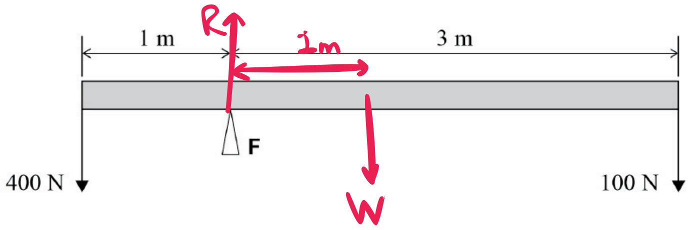
[2 marks]

- The distance, from where the rope is attached to the door, to the hinge (pivot) is greater...
- So a smaller force is needed (to produce the required moment)

CoM is in the centre

in equilibrium

2 4 A uniform rod is balanced horizontally about a support **F**. Forces of 400 N and 100 N act at the ends of the rod, as shown.



What is the reaction force acting on the rod at support **F**?

[1 mark]

A 100 N ○

B 500 N ○

C 550 N ○

D 600 N ●

- $M_{Acw} = M_{cw}$

$(400\times1) = (W\times1) + (100\times3)$

$\therefore W = 100N$

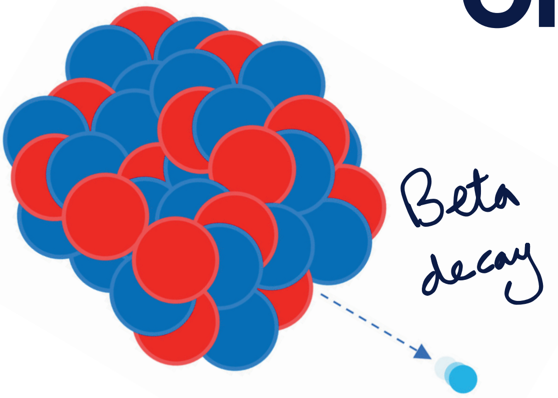
- $F_{up} = F_{down} \Rightarrow R = 400 + 100 + 100$

$\underline{R = 600N}$

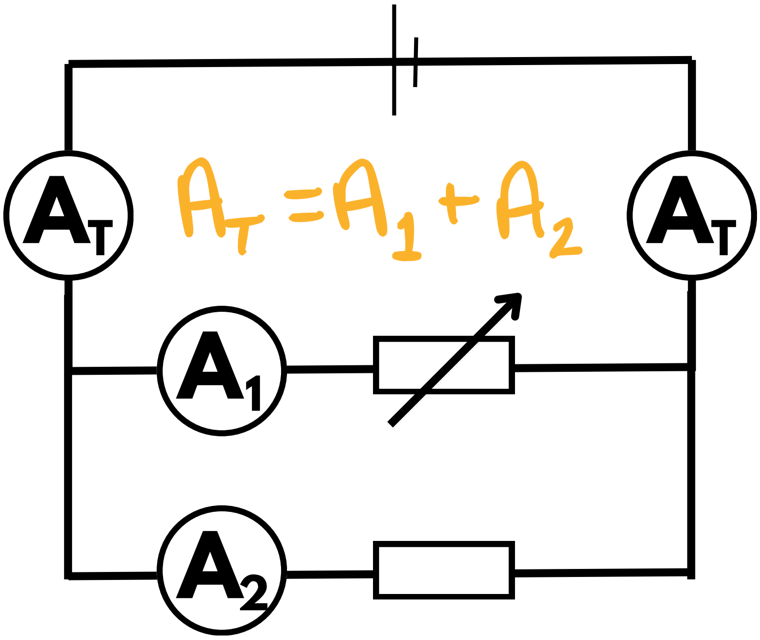
In Equilibrium

Total Anticlockwise Moment is equal to Total Clockwise Moment

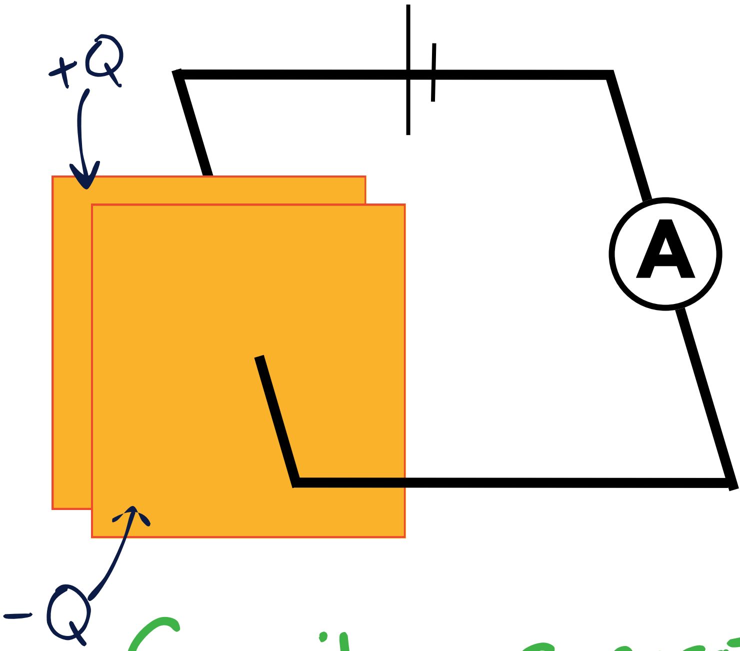
PRINCIPLE OF CONSERVATION OF CHARGE



$$n \rightarrow p + \beta^- + \bar{\nu}_e$$



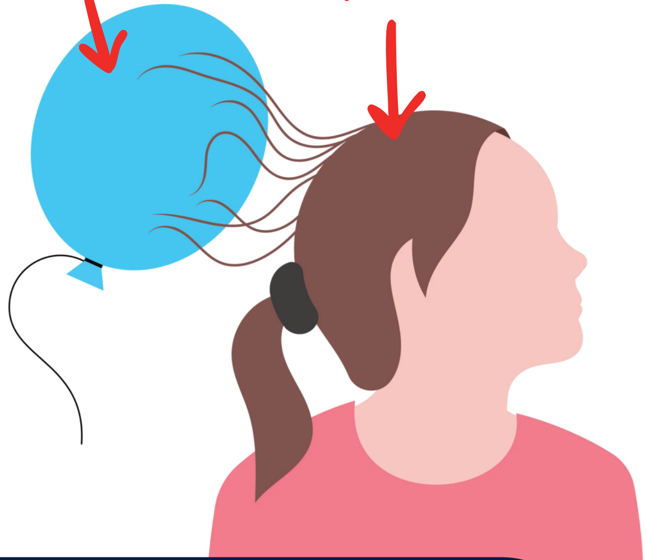
$$A_T = A_1 + A_2$$



Capacitors separate charge.

Magnitude of charge on each plate is equal.

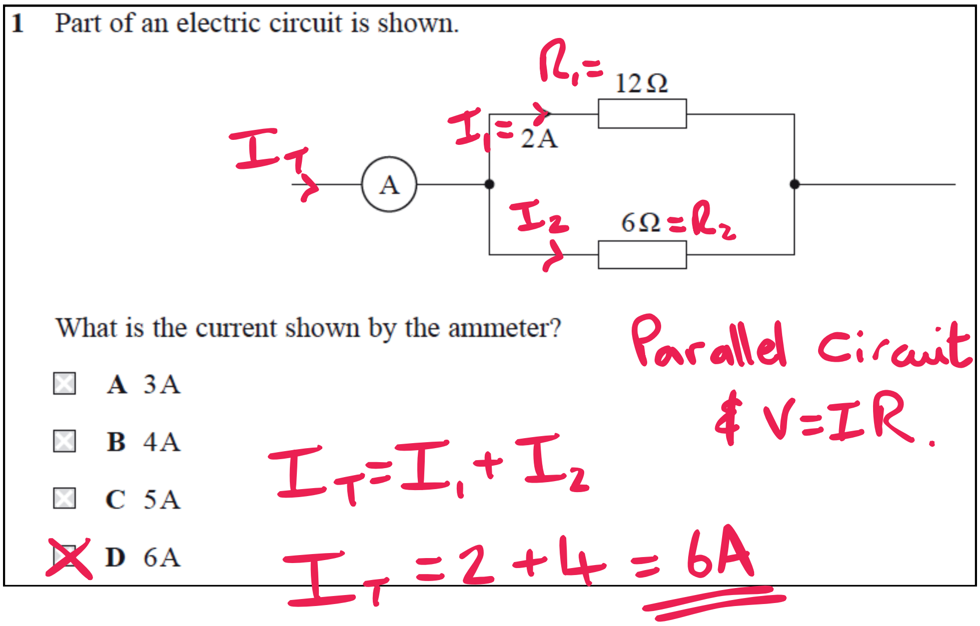
Electrons Gained = Electrons Lost



Total amount of charge in a closed system remains constant over time

$$\Delta Q = 0$$

PRINCIPLE OF CONSERVATION OF CHARGE



1 Part of an electric circuit is shown.

What is the current shown by the ammeter?

☒ **A** 3A

☒ **B** 4A

☒ **C** 5A

☒ **D** 6A

$I_T = I_1 + I_2$

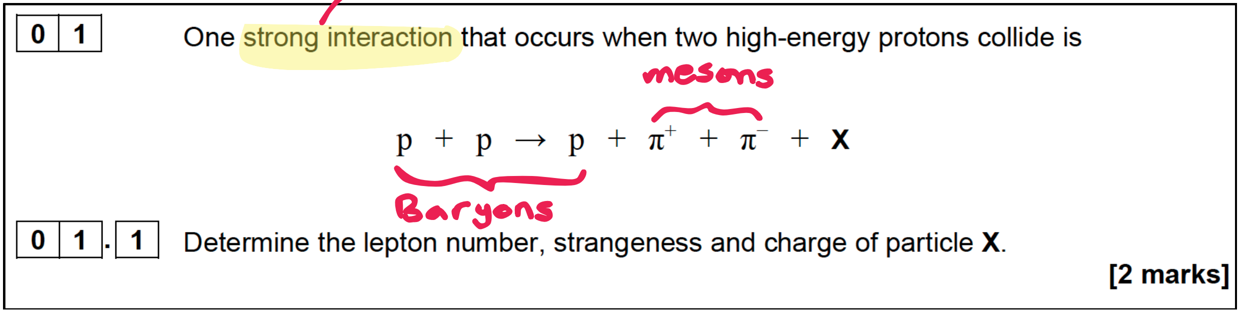
$I_T = 2 + 4 = \underline{\underline{6A}}$

Parallel circuit, so $V_1 = V_2$ & $V = IR$. ∴ $I_1R_1 = I_2R_2$

$2 \times 12 = I_2 \times 6$

$\Rightarrow \underline{I_2 = 4A}$

Strangeness conserved



0 1 One strong interaction that occurs when two high-energy protons collide is

$$\underbrace{p + p \rightarrow p}_{\text{Baryons}} + \overbrace{\pi^+ + \pi^-}^{\text{mesons}} + \mathbf{X}$$

0 1 . 1 Determine the lepton number, strangeness and charge of particle **X**.

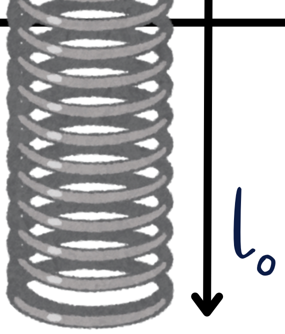
[2 marks]

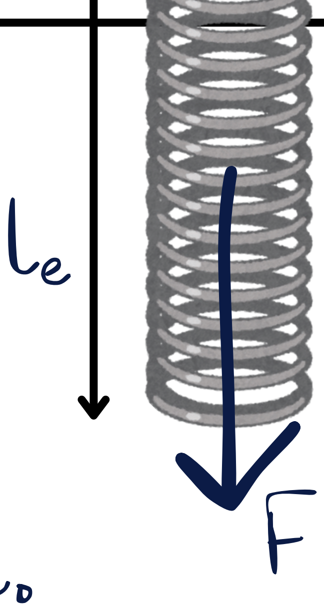
$$p + p \longrightarrow p + \pi^+ + \pi^- + \boxed{X}$$

$$\text{conserved}\left\{\begin{array}{lcccccccccccccc} Q & +1 & + & +1 & = & +1 & + & +1 & + & -1 & + & +1 \\ S & 0 & + & 0 & = & 0 & + & 0 & + & 0 & + & 0 \\ L & 0 & + & 0 & = & 0 & + & 0 & + & 0 & + & 0 \end{array}\right.$$

Total amount of charge in a closed system remains constant over time

HOOKE'S LAW





$$F = ke$$

Spring Constant (stiffness)

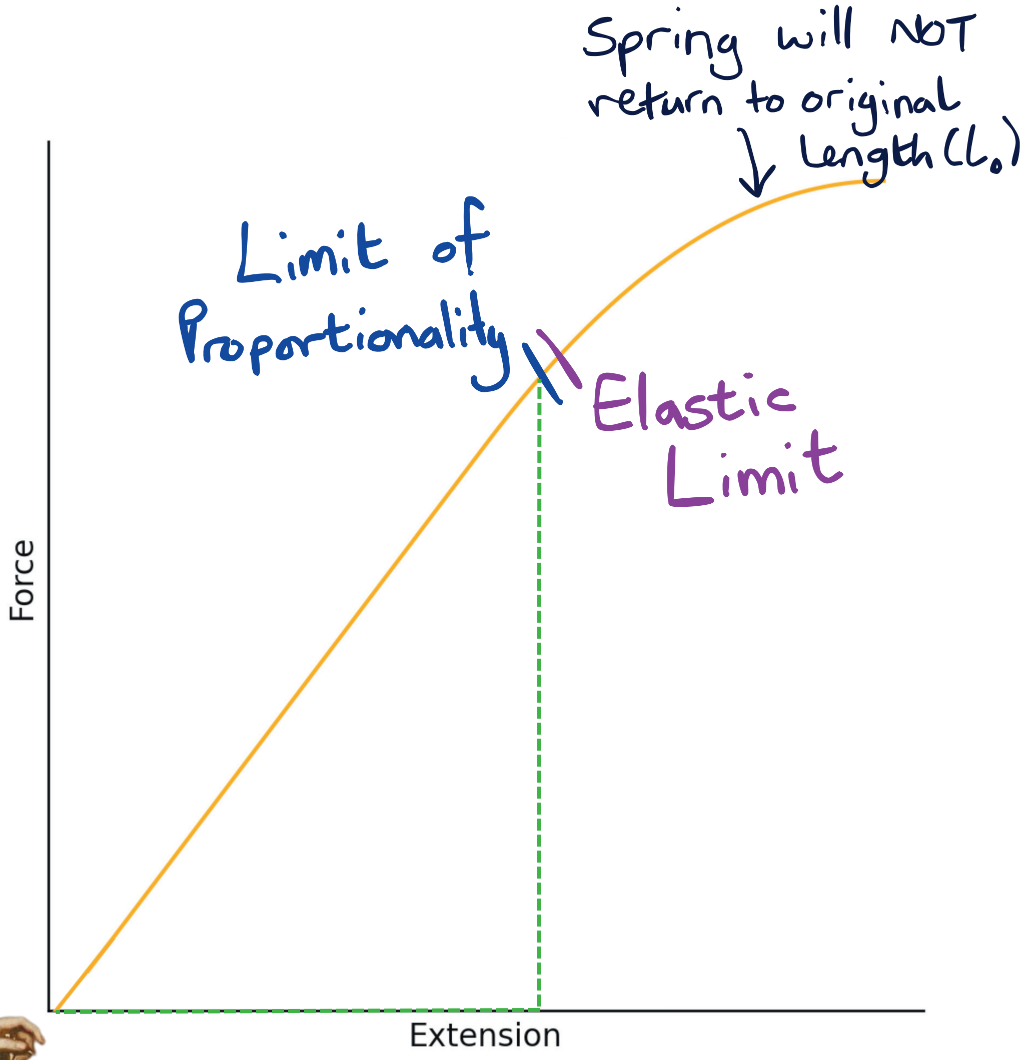
$e = l_e - l_0$

gradient

$$\frac{\Delta y}{\Delta x} = \frac{\Delta F}{\Delta e} = k$$

Area (of ◿)

$$\Delta y \Delta x = \frac{1}{2}Fe = E_e$$

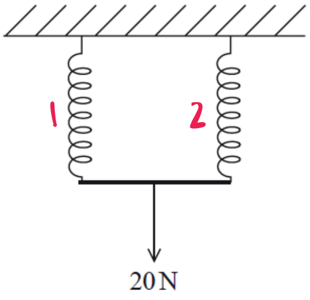


Provided the limit of proportionality is not exceeded, the force applied to an object is directly proportional to the extension of the object.

HOOKE'S LAW

Same k

2 Two identical springs are arranged side by side as shown.



$$k_{Total} = k_1 + k_2 = 2k = \frac{F}{e}$$

$$2k = \frac{20}{8} = 2.5\,Ncm^{-1}$$

$$\therefore \underline{k = 1.25\,Ncm^{-1}}$$

When a force of 20 N is applied, an extension of 8 cm is obtained.

A force of 5 N is applied to one of the springs on its own.

Which of the following is the extension obtained?

☐ **A** 2 cm

☒ **B** 4 cm

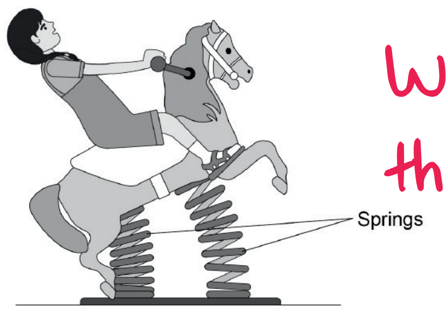
☐ **C** 8 cm

☐ **D** 16 cm

$$e = \frac{F}{k} = \frac{5}{1.25} = \underline{\underline{4\,cm}}$$

0 2 **Figure 3** shows a child on a playground toy.

Figure 3



When the force is removed, the spring will return to its original shape.

0 2 . 1 The springs have been elastically deformed.

Explain what is meant by 'elastically deformed'.

[2 marks]

Provided the limit of proportionality is not exceeded, the force applied to an object is directly proportional to the extension of the object.

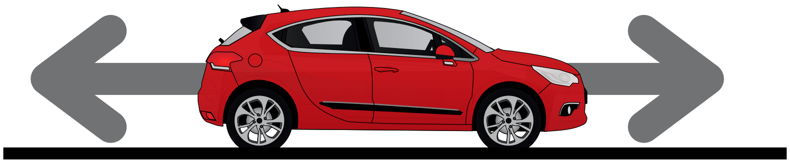
NEWTON'S 1ST LAW OF MOTION

Drag = Weight

$F_R = 0$

Terminal velocity

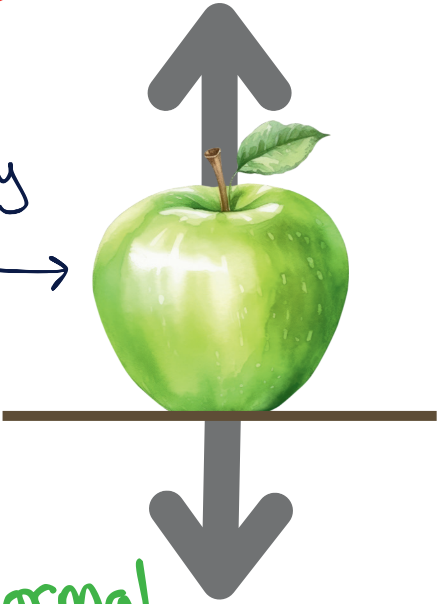
Constant speed



Drag = Friction

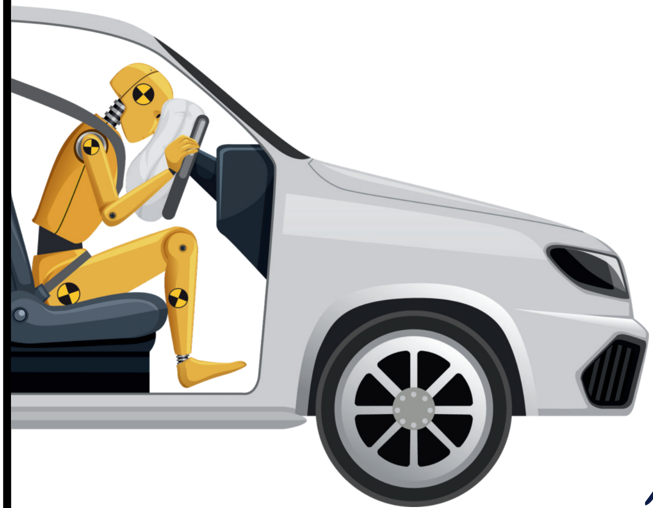
$F_R = 0$

Stationary



Normal Contact Force = Weight

$F_R = 0$



inertia

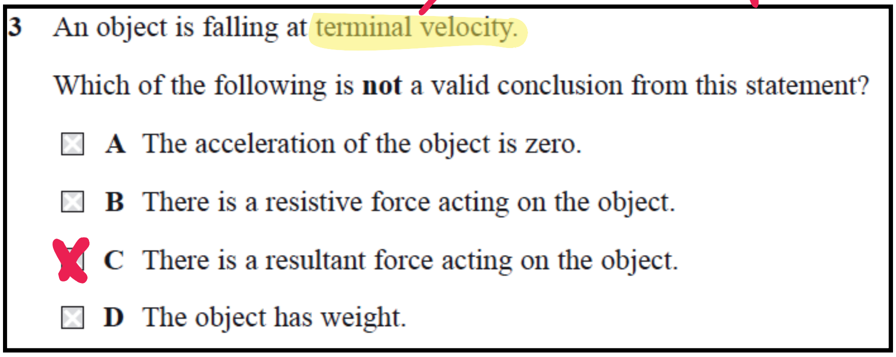
An object will continue in motion until a resultant force brings it to a stop.

F_R

When the resultant force acting on an object equals zero, the object will either stay still or travel at constant speed.

NEWTON'S 1ST LAW OF MOTION

→ constant speed



3 An object is falling at terminal velocity.

Which of the following is **not** a valid conclusion from this statement?

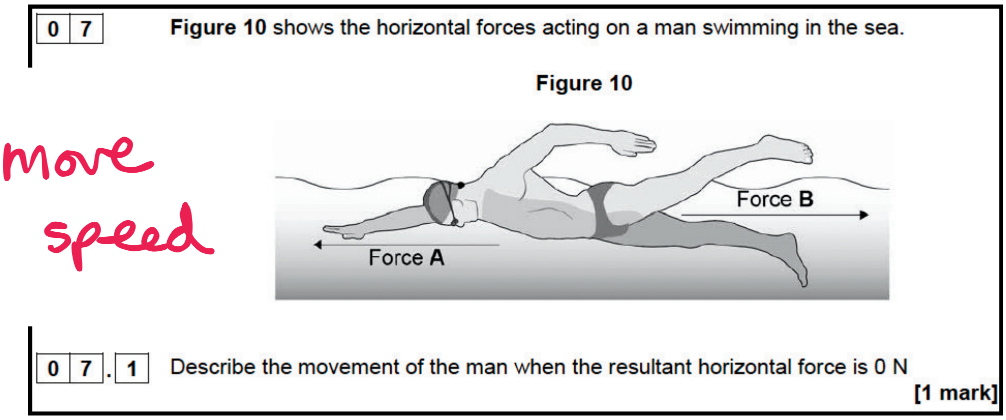
☒ **A** The acceleration of the object is zero.

☒ **B** There is a resistive force acting on the object.

☒ **C** There is a resultant force acting on the object.

☒ **D** The object has weight.

The man will move with constant speed

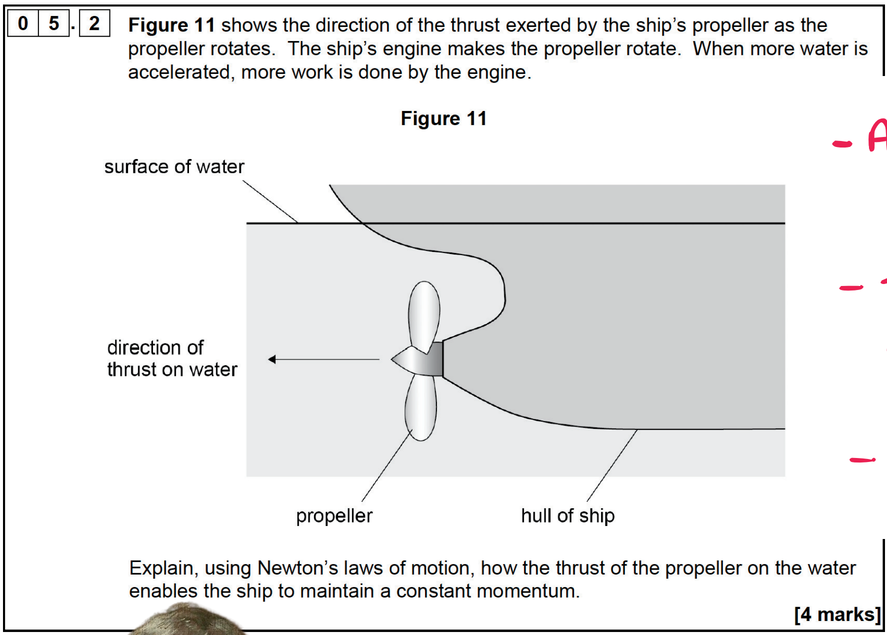


0 7 **Figure 10** shows the horizontal forces acting on a man swimming in the sea.

Figure 10

0 7 . 1 Describe the movement of the man when the resultant horizontal force is 0 N

[1 mark]



0 5 . 2 **Figure 11** shows the direction of the thrust exerted by the ship's propeller as the propeller rotates. The ship's engine makes the propeller rotate. When more water is accelerated, more work is done by the engine.

Figure 11

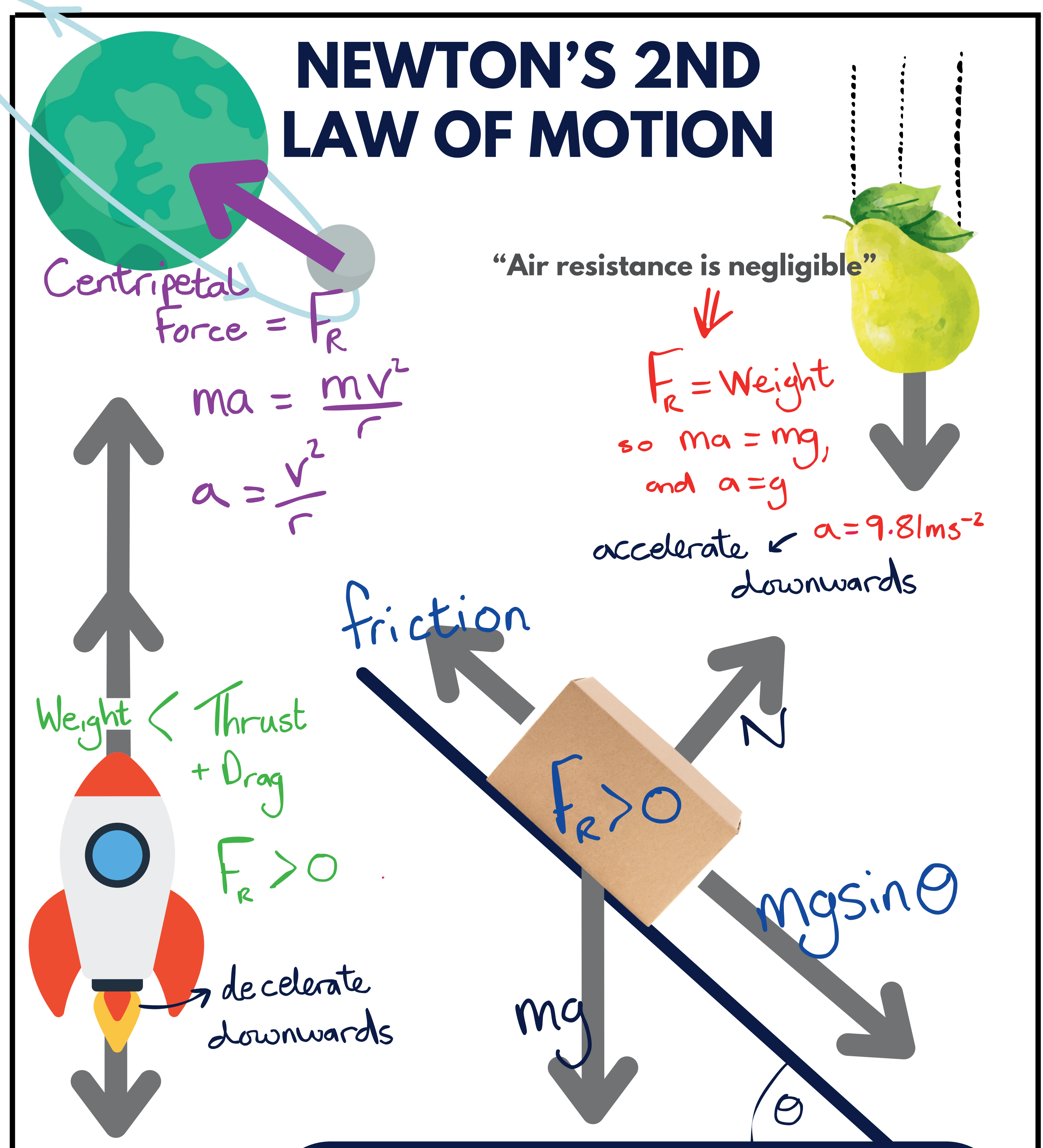
Explain, using Newton's laws of motion, how the thrust of the propeller on the water enables the ship to maintain a constant momentum.

[4 marks]

- A resultant force is needed to Change the momentum of the water.
  ↳ Newton's 2nd Law
- The force on the water produces an equal & opposite force on the Propeller ⇒ Newton's 3rd Law
- The force on the ship is equal to the drag force on the ship
  ↳ Newton's 1st Law

When the resultant force acting on an object equals zero, the object will either stay still or travel at constant speed.

NEWTON'S 2ND LAW OF MOTION



Centripetal Force = F_R

$$ma = \frac{mv^2}{r}$$

$$a = \frac{v^2}{r}$$

"Air resistance is negligible"

F_R = Weight

so $ma = mg$, and $a = g$

$a = 9.81ms^{-2}$ accelerate downwards

$F_R > 0$

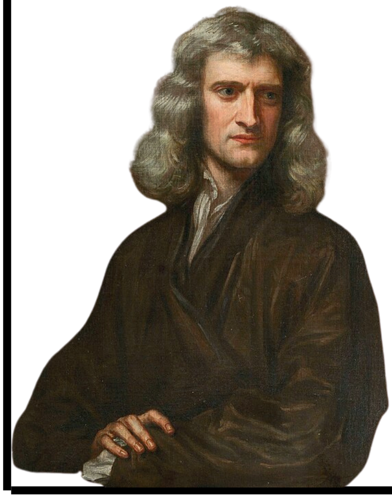
mgsinθ

Weight < Thrust + Drag

$F_R > 0$

decelerate downwards

When there is a resultant force acting on an object, the object will accelerate in the direction of the resultant force.

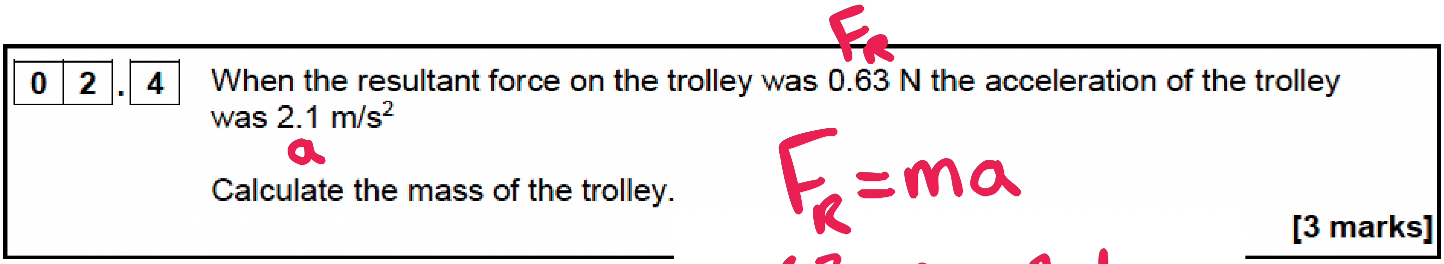


$$a \propto \frac{1}{m}$$

$$a \propto F_R$$

$$F_R = ma = \frac{m\Delta v}{\Delta t}$$

NEWTON'S 2ND LAW OF MOTION



0 2 . 4 When the resultant force on the trolley was 0.63 N the acceleration of the trolley was 2.1 m/s^2

Calculate the mass of the trolley.

[3 marks]

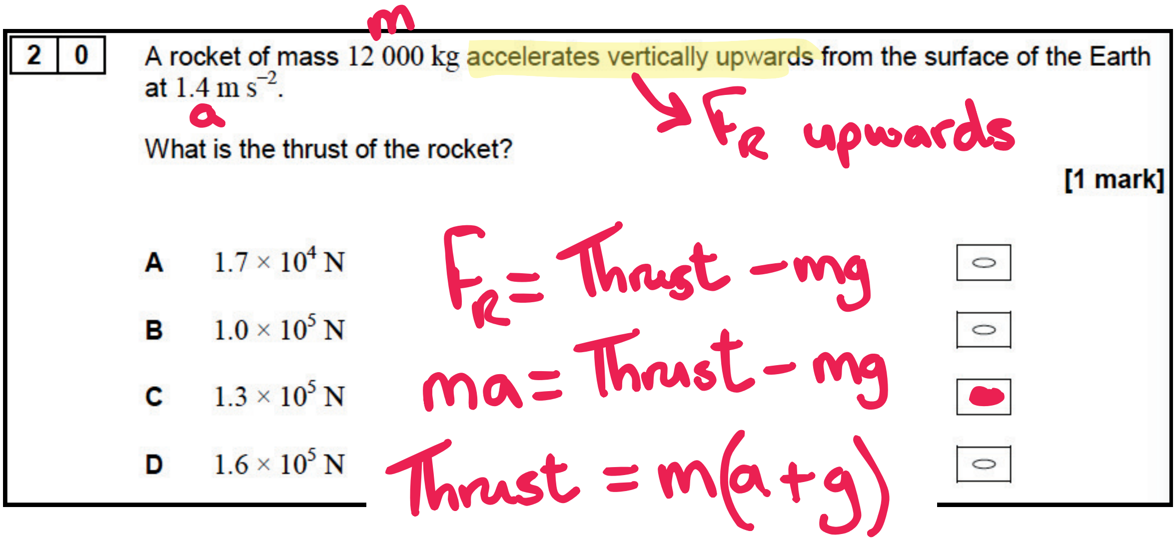
F_R

a

$F_R = ma$

$0.63 = m \times 2.1$

$\therefore m = \frac{0.63}{2.1} = \underline{\underline{0.3kg}}$



2 0 A rocket of mass 12 000 kg accelerates vertically upwards from the surface of the Earth at 1.4 m s^{-2}.

What is the thrust of the rocket?

[1 mark]

A 1.7 × 10^4 N ○

B 1.0 × 10^5 N ○

C 1.3 × 10^5 N ●

D 1.6 × 10^5 N ○

m

a

$\rightarrow F_R$ upwards

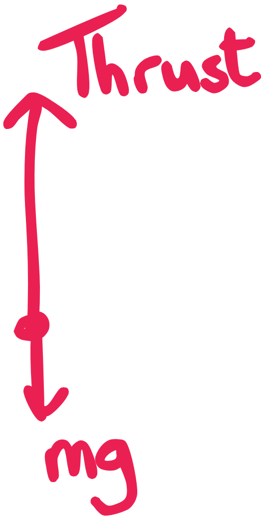
$F_R = Thrust - mg$

$ma = Thrust - mg$

$Thrust = m(a+g)$

$= 1200(1.4+9.81)$

$Thrust = \underline{\underline{134,520N}}$



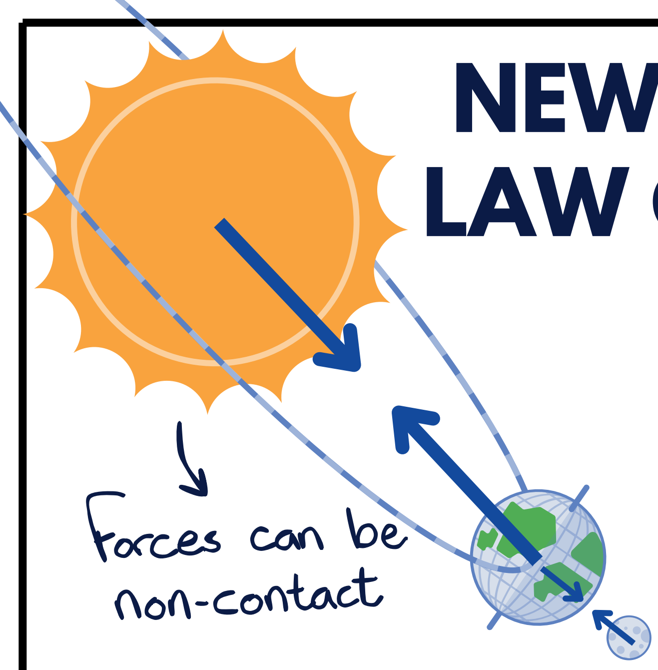
When there is a resultant force acting on an object, the object will accelerate in the direction of the resultant force.

$a \propto \frac{1}{m}$

$a \propto F_R$

$$F_R = ma = \frac{m\Delta v}{\Delta t}$$

NEWTON'S 3RD LAW OF MOTION



Forces can be non-contact

Total force is zero

$$F_{A\to B} = -F_{B\to A}$$

so $$F_{A\to B} + F_{B\to A} = 0$$

Force of bird on the perch

Electrostatic

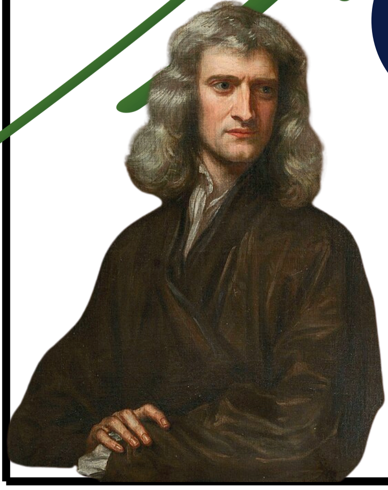
Force of perch on the bird

Gravitational

Force of bird on the Earth

Force of Earth on the bird

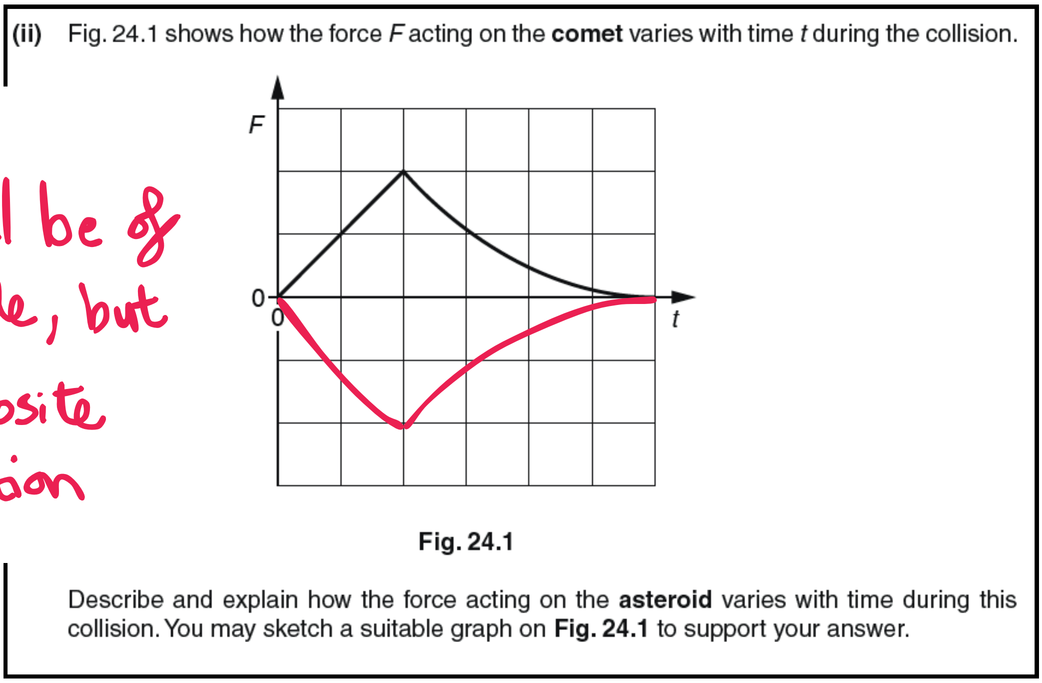
When 2 objects interact, the force of object A on object B will be equal and opposite to the force of object B on object A



2 conditions must be met:

- ☑ Forces act on 2 objects
- ☑ Forces are the same type

NEWTON'S 3RD LAW OF MOTION

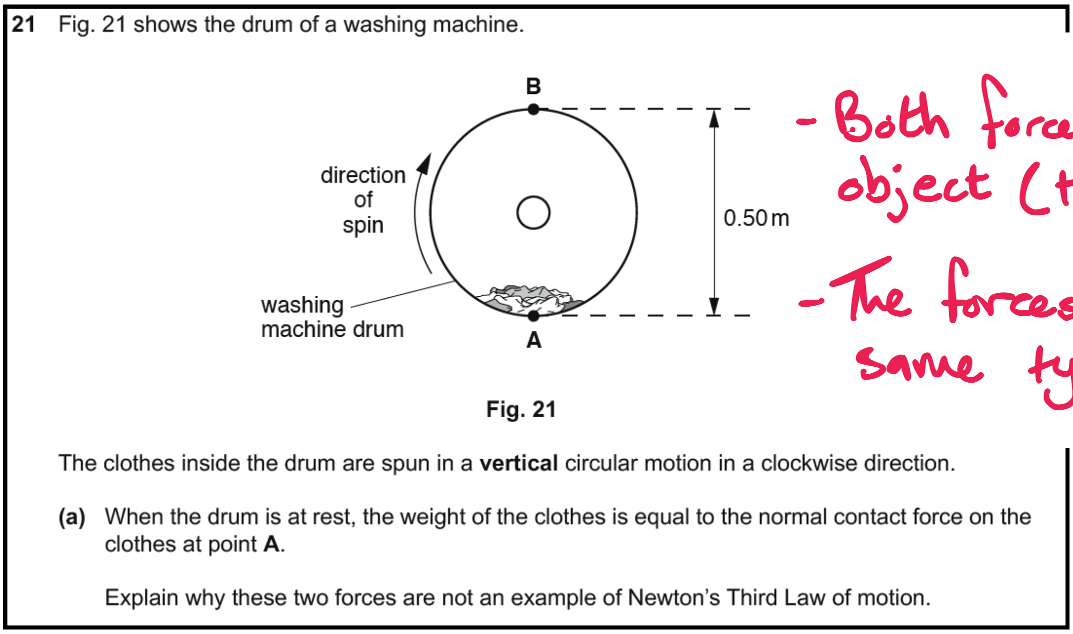


(ii) Fig. 24.1 shows how the force *F* acting on the **comet** varies with time *t* during the collision.

Fig. 24.1

Describe and explain how the force acting on the **asteroid** varies with time during this collision. You may sketch a suitable graph on **Fig. 24.1** to support your answer.

The force will be of equal magnitude, but act in the opposite (negative) direction



21 Fig. 21 shows the drum of a washing machine.

Fig. 21

The clothes inside the drum are spun in a **vertical** circular motion in a clockwise direction.

(a) When the drum is at rest, the weight of the clothes is equal to the normal contact force on the clothes at point **A**.

Explain why these two forces are not an example of Newton's Third Law of motion.

- Both forces act on one object (the clothes)
- The forces are not the same type

When 2 objects interact, the force of object A on object B will be equal and opposite to the force of object B on object A

2 conditions must be met:

☑ Forces act on 2 objects

☑ Forces are the same type