



Rewarding Learning

ADVANCED SUBSIDIARY (AS)
General Certificate of Education
2024

Centre Number

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Candidate Number

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Physics

StemUp Model Solution

Assessment Unit AS 1

assessing

Forces, Energy and Electricity



[SPH11]

SPH11

WEDNESDAY 15 MAY, MORNING

TIME

1 hour 45 minutes.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.

You must answer the questions in the spaces provided.

Do not write outside the boxed area on each page or on blank pages.

Complete in black ink only. **Do not write with a gel pen.**

Answer **all nine** questions.

INFORMATION FOR CANDIDATES

The total mark for this paper is 100.

Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question.

Your attention is drawn to the Data and Formulae Sheet which is inside this question paper.

You may use an electronic calculator.



- 1 (a) An electric car is powered by a battery which can store 270 MJ of energy when fully charged. The battery is charged by attaching a cable that transfers 7 kW of power at a voltage of 240 V.

- (i) After a journey, there is 60 MJ of energy remaining in the battery. Calculate the time taken to fully charge the battery, assuming the charging process is 100% efficient. Give your answer in hours.

$$\text{Energy needed} = 270 - 60 = 210 \text{ MJ} = 210 \times 10^6 \text{ J}$$

$$P = W \div t \quad \text{so} \quad t = W \div P$$

$$t = 210 \times 10^6 \div 7 \times 10^3$$

$$t = 30000 \text{ s}$$

$$t = 30000 \div 3600 = 8.33 \text{ h}$$

$$\text{Charging time} = \underline{8.33} \text{ h}$$

[6]

- (ii) Calculate the current that flows through the charging cable when the battery is being charged.

$$P = IV \quad \text{so} \quad I = P \div V$$

$$7 \times 10^3 = I \times 240$$

$$I = 7000 \div 240 = 29.2 \text{ A}$$

$$\text{Current} = \underline{29.2} \text{ A}$$

[3]



- (b) The wire in the charging cable has a circular cross-section and is 3.0 m long. It is made of copper, of resistivity $1.7 \times 10^{-8} \Omega \text{ m}$, and resistance $1.1 \text{ m}\Omega$.

Calculate the diameter of the wire.

$$R = \rho l \div A \quad \text{so} \quad A = \rho l \div R$$

$$1.1 \times 10^{-3} = 1.7 \times 10^{-8} \times 3.0 \div A$$

$$A = (1.7 \times 10^{-8} \times 3.0) \div 1.1 \times 10^{-3} = 4.64 \times 10^{-5} \text{ m}^2$$

$$A = \pi d^2 \div 4 \quad \text{so} \quad d = \sqrt{4A \div \pi}$$

$$d = \sqrt{4 \times 4.64 \times 10^{-5} \div \pi} = \sqrt{5.90 \times 10^{-5}}$$

$$d = 7.7 \times 10^{-3} \text{ m}$$

Diameter = 7.7×10^{-3} m

[6]

[Turn over]



- 2 A student connects a cell of e.m.f. 5.00 V in series with a resistor and variable resistor causing current I to flow, as shown in **Fig. 2.1**.

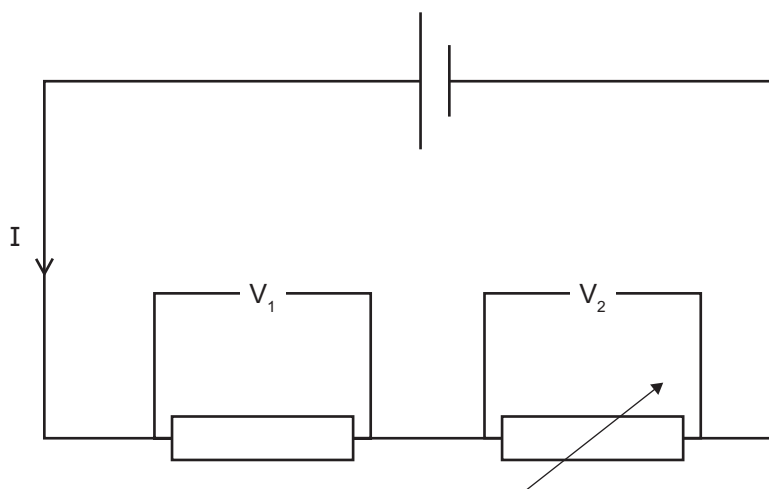


Fig. 2.1

- (i) The student measures the voltages as $V_1 = 1.21 \text{ V}$ and $V_2 = 3.62 \text{ V}$. Calculate the total voltage across the two resistors and explain any difference between this value and the e.m.f. of the cell.

$V_1 + V_2 = 1.21 + 3.62 = 4.83 \text{ V}$, which is less than the e.m.f. of 5.00 V.

This is because the cell has an internal resistance, so 0.17 V is dropped across the cell itself (lost volts, $V = E - Ir$).

[3]



- (ii) The resistance of the variable resistor is then increased. Place a tick (✓) in each row of **Table 2.1** to state how this will affect the quantities listed in the table.

[4]

Table 2.1

Quantity	Increases	Decreases	Remains the same
I		✓	
V_1		✓	
V_2	✓		
$V_1 + V_2$	✓		

[Turn over



- 3 A drone takes off from ground level and remains directly above the take off point for the duration of its flight. The graph in **Fig. 3.1** shows how the upwards vertical velocity of the drone changes with time after taking off.

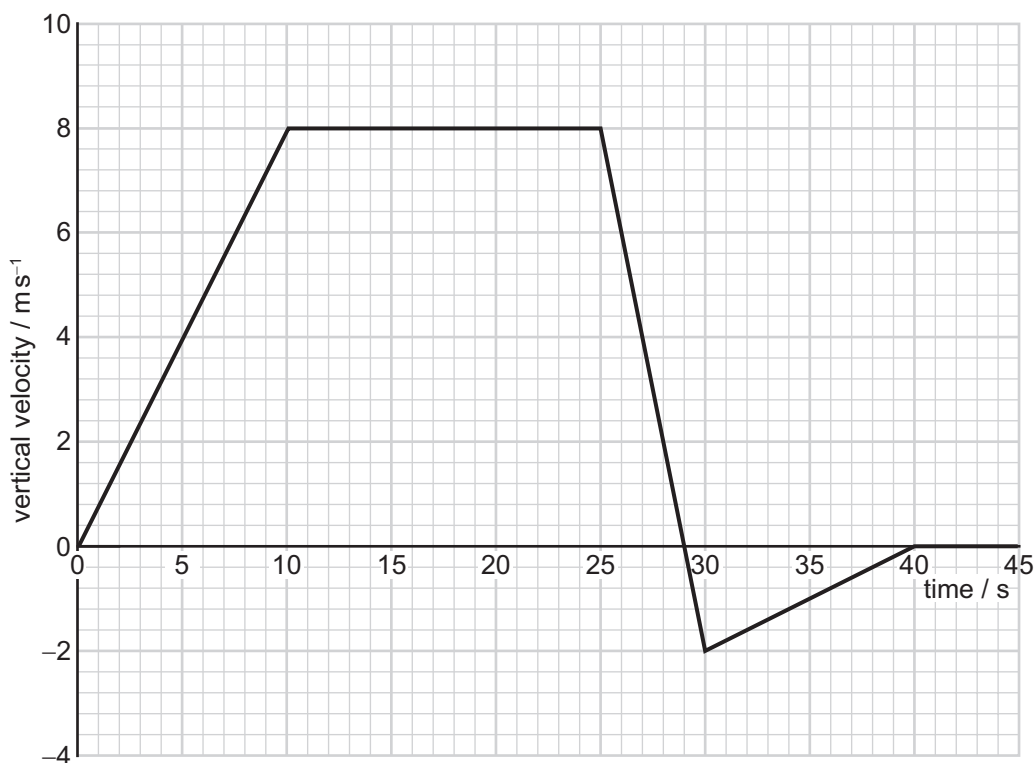


Fig. 3.1

- (i) By examining **Fig. 3.1**, complete **Table 3.1** to show how the height and speed of the drone changes during the time periods by placing **two** ticks in each row.

Table 3.1

Time Period / s	Height increasing	Height decreasing	Height constant	Speed increasing	Speed decreasing	Speed constant
0–10	✓			✓		
10–25	✓					✓
25–29	✓				✓	
30–40		✓			✓	

[4]



(ii) Calculate the initial acceleration of the drone.

Acceleration = gradient of the velocity-time graph

$$a = (v - u) \div t = (8 - 0) \div 10$$

$$a = 0.8 \text{ m s}^{-2}$$

Acceleration = 0.8 m s⁻² [3]

(iii) Calculate the final height of the drone above its initial starting position.

Displacement = area under the velocity-time graph

Upwards (0 to 29 s, trapezium): $\frac{1}{2} \times (29 + 15) \times 8 = 176 \text{ m}$

Downwards (29 to 40 s, triangle): $\frac{1}{2} \times 11 \times 2 = 11 \text{ m}$

Final height = $176 - 11 = 165 \text{ m}$

Height = 165 m [4]

[Turn over]



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- 4 The pilot of a glider places it into a shallow dive so that it travels at a constant velocity of 60 m s^{-1} at a constant angle of 5° to the horizontal, as shown in **Fig. 4.1**. The three forces that act on the glider, lift, weight, and drag are shown on the diagram.

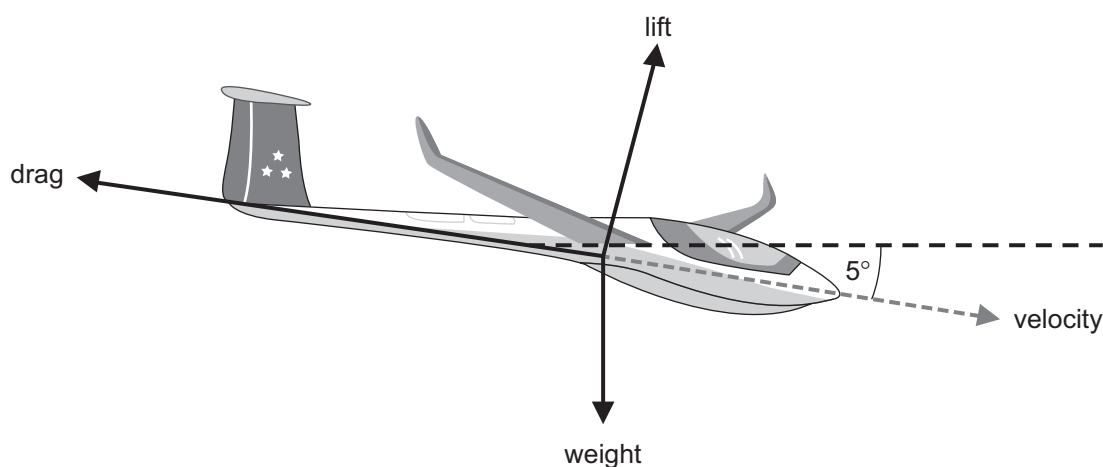


Fig. 4.1

- (a) Explain how Newton's first law applies in this situation.

Newton's first law: a body stays at rest or moves with constant velocity

unless a resultant force acts on it.

The glider travels at a constant velocity, so the resultant of the lift, weight and drag must be zero (the forces are balanced).

[2]

[Turn over]



- (b) The pilot then increases the angle of the glider's dive, causing it to move with a constant acceleration. The velocity and acceleration are now both in a direction of 30° to the horizontal. The lift on the glider from the wings is $50\,000\text{ N}$ and is perpendicular to the direction of travel. The drag on the glider is 6000 N . The forces acting on the glider are shown in **Fig. 4.2**.

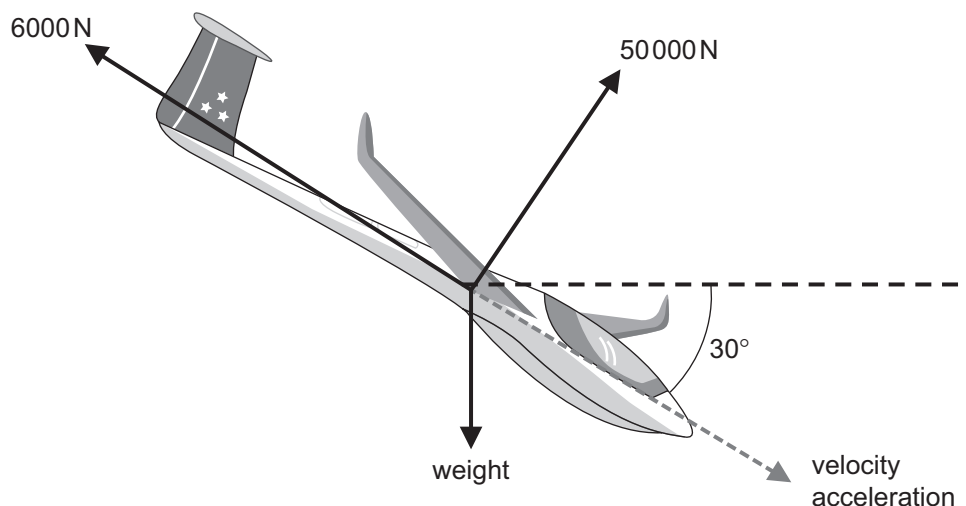


Fig. 4.2

- (i) Calculate the mass of the glider.

Lift is perpendicular to the direction of travel, and there is no acceleration perpendicular to the velocity, so forces balance there:

$$W \cos 30^\circ = 50000$$

$$W = 50000 \div \cos 30^\circ = 57735\text{ N}$$

$$W = mg \quad \text{so} \quad m = W \div g = 57735 \div 9.81$$

$$m = 5885\text{ kg}$$

Mass = 5885 kg

[4]



(ii) Calculate the acceleration of the glider.

Along the direction of travel:

Resultant force = $W \sin 30^\circ$ – drag

$$RF = 57735 \times \sin 30^\circ - 6000$$

$$RF = 28868 - 6000 = 22868 \text{ N}$$

$$RF = ma$$

$$22868 = 5885 \times a$$

$$a = 22868 \div 5885 = 3.89 \text{ m s}^{-2}$$

Acceleration = 3.89 m s⁻²

[5]



5 (a) State the principle of moments.

When a body is in equilibrium, the sum of the clockwise moments about any point equals the sum of the anticlockwise moments about the same point.

[3]

- (b) A non-uniform beam of length 6.2m rests on two supports, A and B, a distance of 0.90m from each end as shown in **Fig. 5.1**. A weight of 420 N is placed 0.40m from the end of the beam.

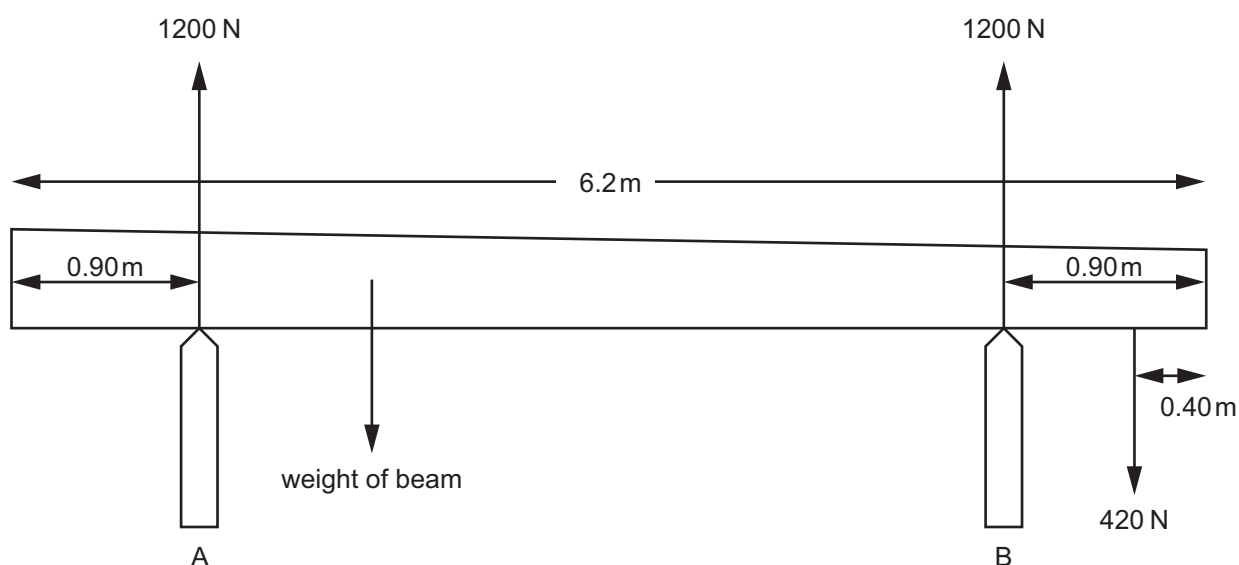


Fig. 5.1

- (i) Given that the reaction at each of the supports is 1200 N, show that the weight of the beam is 1980 N.

The beam is in equilibrium, so resultant force = 0:

sum of upward forces = sum of downward forces

$$1200 + 1200 = 420 + W \quad \text{so} \quad W = 2400 - 420 = 1980 \text{ N}$$

[2]



(ii) Calculate the distance of the centre of gravity of the beam from the support A.

Take moments about A (beam in equilibrium):

B is $6.2 - 0.90 - 0.90 = 4.4$ m from A

420 N is $4.4 + 0.90 - 0.40 = 4.9$ m from A

Clockwise moments = anticlockwise moments

$$1980 \times d + 420 \times 4.9 = 1200 \times 4.4$$

$$1980d + 2058 = 5280$$

$$d = 3222 \div 1980 = 1.63 \text{ m}$$

Distance = 1.63 m

[4]



- 6 (a) The graph in **Fig. 6.1** shows how the resistance of a resistor and a negative temperature coefficient (n.t.c.) thermistor change with temperature.

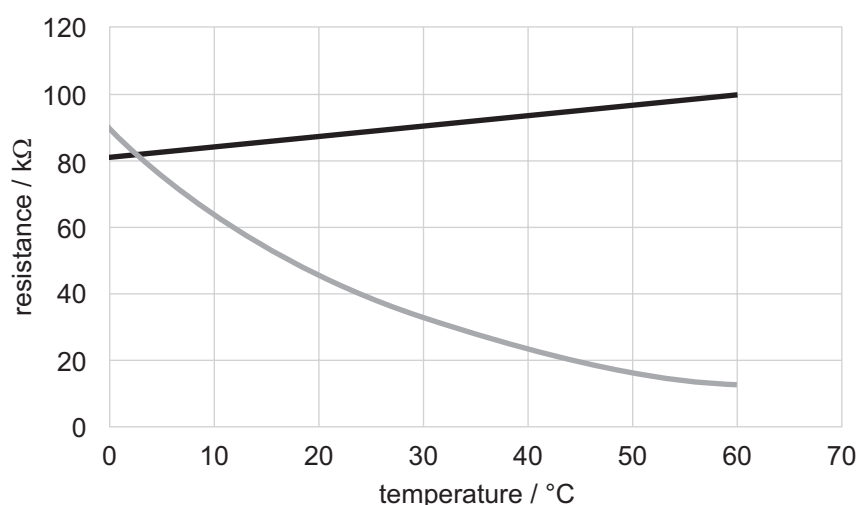


Fig. 6.1

- (i) With reference to **Fig. 6.1** compare how the resistance of the two components changes as the temperature is increased. Explain the causes of this behaviour in both components.

Resistor:

The resistance of the resistor increases (slowly, roughly linearly) as temperature increases. The ions/atoms in the lattice vibrate more, so there are more collisions between the free electrons and the ions.

n.t.c. thermistor:

The resistance of the thermistor decreases (rapidly) as temperature increases. The atoms also vibrate more, giving more collisions as in the resistor, but this is less dominant: as temperature increases many more electrons become free (delocalised) charge carriers, so resistance falls.

[6]



- (ii) Sketch the current–voltage characteristic of the n.t.c. thermistor on **Fig. 6.2**.

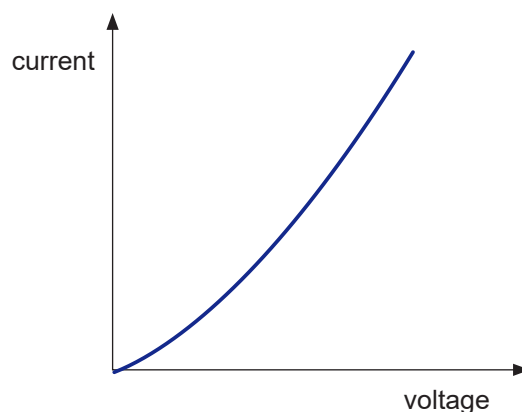


Fig. 6.2

[1]

- (iii) Explain how the current-voltage characteristic you have sketched in **Fig. 6.2** is related to the graph in **Fig. 6.1**.

As the voltage increases the current increases, so more power is

dissipated and the temperature of the thermistor increases.

From Fig. 6.1 a higher temperature means a lower resistance, so the

graph gets steeper (curves upwards) because $I \div V$ increases, i.e. less

resistance.

[3]

- (b) In terms of a temperature change, describe how a new alloy could be tested to determine if it is a superconducting material.

Cool the alloy to a very low temperature, close to absolute zero, while

measuring its resistance. If at a certain (critical) temperature the resistance

suddenly drops to zero, the alloy is a superconductor.

[2]

[Turn over



- 7 An archer fired an arrow from his bow. The arrow was released with a horizontal velocity and hit the bullseye of a target 10.0 m away from the archer, 1.20 m below the point that the arrow was released from, as shown in Fig. 7.1.

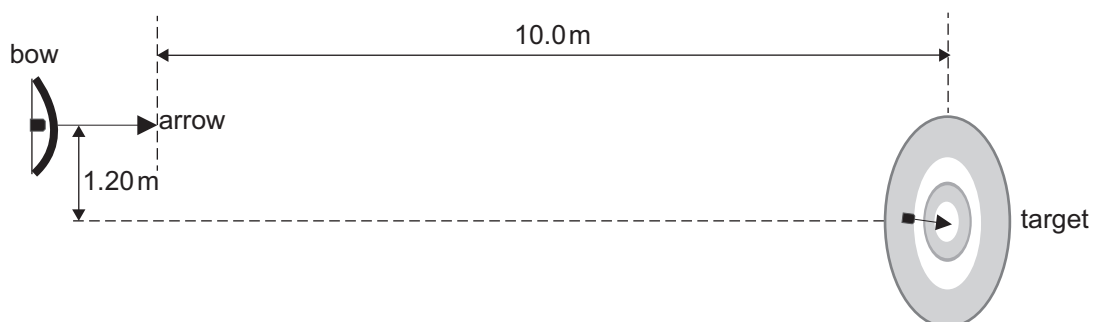


Fig. 7.1

- (i) By considering the vertical motion of the arrow, calculate the time taken for the arrow to reach the target.

Vertically: $s = ut + \frac{1}{2}at^2$, with $u = 0$ (released horizontally)

$$1.20 = 0 + \frac{1}{2} \times 9.81 \times t^2$$

$$t^2 = 2 \times 1.20 \div 9.81 = 0.2446$$

$$t = 0.495 \text{ s}$$

Time = 0.495 s

[4]



(ii) Calculate the horizontal velocity of the arrow when it was released.

Horizontal velocity is constant:

$$v = s \div t = 10.0 \div 0.495$$

$$v_H = 20.2 \text{ m s}^{-1}$$

Horizontal velocity = 20.2 m s⁻¹ [3]

(iii) Calculate the magnitude of the velocity when the arrow hit the target.

Vertically: $v = u + at$

$$v_V = 0 + 9.81 \times 0.495 = 4.85 \text{ m s}^{-1}$$

$$v^2 = v_H^2 + v_V^2 = 20.2^2 + 4.85^2$$

$$v = \sqrt{(408 + 23.5)} = \sqrt{432}$$

$$v = 20.8 \text{ m s}^{-1}$$

Magnitude of velocity = 20.8 m s⁻¹ [5]

[Turn over]



- 8 Two blocks, A and B, are connected by a string placed over a pulley as shown in Fig. 8.1.

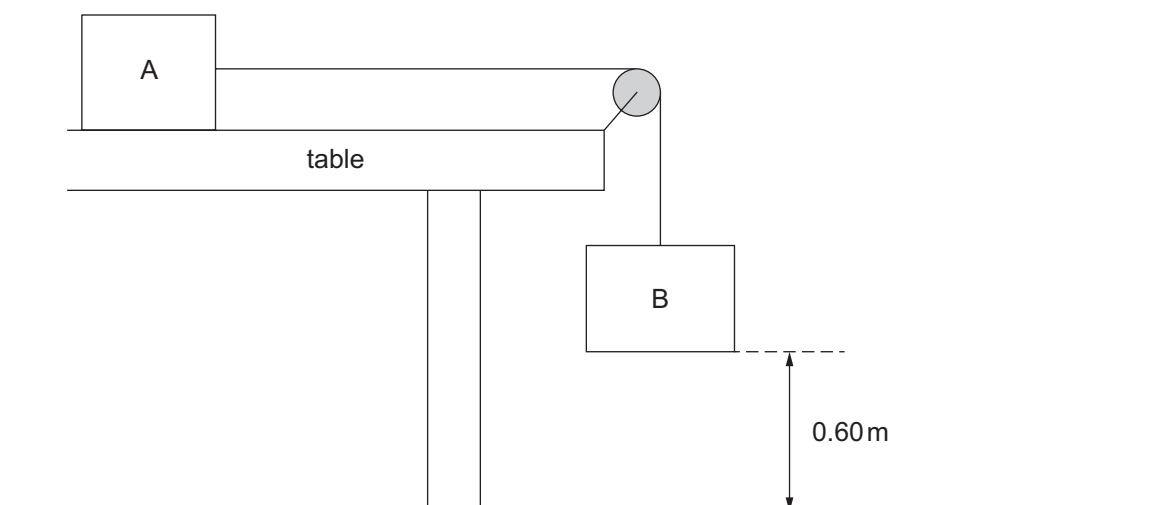


Fig. 8.1

Block A has a mass of 4.3 kg and is placed on a table with a rough surface. Block B has a mass of 3.1 kg and is initially held a height of 0.60 m above the ground. When block B is released both blocks accelerate.

- (a) Calculate the loss in gravitational potential energy GPE of block B when it falls to the ground.

$$GPE = mgh$$

$$GPE = 3.1 \times 9.81 \times 0.60$$

$$GPE = 18.2 \text{ J } (18 \text{ J})$$

$$GPE = \underline{18} \text{ J}$$

[3]



(b) Blocks A and B are travelling at a speed of 1.4 m s^{-1} when block B hits the ground.

(i) Calculate the energy lost due to friction between block A and the table when block B falls to the ground.

$$KE \text{ gained by both blocks} = \frac{1}{2}mv^2$$

$$KE = \frac{1}{2} \times (4.3 + 3.1) \times 1.4^2$$

$$KE = 7.3 \text{ J}$$

$$\text{Energy lost to friction} = GPE \text{ lost} - KE \text{ gained}$$

$$W = 18.2 - 7.3 = 11 \text{ J}$$

Energy lost = 11 J [5]

(ii) Calculate the average value of the force of friction on block A as it moves across the table.

Block A moves 0.60 m across the table.

$$\text{Work done against friction } W = F \times s$$

$$11 = F \times 0.60$$

$$F = 11 \div 0.60 = 18 \text{ N}$$

Friction = 18 N [3]

[Turn over]



- 9 (a) A neon atom of mass 3.4×10^{-26} kg moves at a speed of 720 m s^{-1} directly towards a stationary helium atom of mass 6.7×10^{-27} kg. After the collision the neon and helium atoms move in the same direction but at different speeds.

- (i) Calculate the momentum of the neon atom before the collision and state the unit.

$$p = mv$$

$$p = 3.4 \times 10^{-26} \times 720$$

$$p = 2.45 \times 10^{-23} \text{ kg m s}^{-1}$$

Momentum = 2.45×10^{-23}

Unit = kg m s^{-1}

[4]

- (ii) State the principle of the conservation of momentum.

In a system of colliding objects, the total momentum before the
collision equals the total momentum after the collision, provided no
external forces act (isolated system).

[2]



(b) The speed of the helium atom after the collision is 1203 m s^{-1} .

(i) Calculate the speed of the neon atom after the collision.

Total momentum before = total momentum after

$$2.45 \times 10^{-23} = (6.7 \times 10^{-27} \times 1203) + (3.4 \times 10^{-26} \times v_{\text{Ne}})$$

$$2.45 \times 10^{-23} = 8.06 \times 10^{-24} + 3.4 \times 10^{-26} \times v_{\text{Ne}}$$

$$3.4 \times 10^{-26} \times v_{\text{Ne}} = 1.64 \times 10^{-23}$$

$$v_{\text{Ne}} = 1.64 \times 10^{-23} \div 3.4 \times 10^{-26} = 483 \text{ m s}^{-1}$$

Speed = 483 m s⁻¹

[4]

(ii) Describe how you would determine whether the collision is elastic or inelastic.

Calculate the total kinetic energy ($\frac{1}{2}mv^2$) of both atoms before the

collision and after it. If they are equal, kinetic energy is conserved and

the collision is elastic; if KE after is less, it is inelastic.

[2]

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SPH11/7
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Rewarding Learning

ADVANCED SUBSIDIARY
General Certificate of Education

Physics

Assessment Units AS 1 and AS 2

[SPH11/SPH21]

DATA AND FORMULAE SHEET

Data and Formulae Sheet for AS 1 and AS 2

Values of constants

speed of light in a vacuum	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
the Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
mass of electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
mass of proton	$m_p = 1.67 \times 10^{-27} \text{ kg}$
acceleration of free fall on the Earth's surface	$g = 9.81 \text{ m s}^{-2}$
electron volt	$1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$
the Hubble constant	$H_0 \approx 2.4 \times 10^{-18} \text{ s}^{-1}$

Useful formulae

The following equations may be useful in answering some of the questions in the examination:

Mechanics

conservation of energy	$\frac{1}{2} mv^2 - \frac{1}{2} mu^2 = Fs$ for a constant force
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Waves

two-source interference	$\lambda = \frac{ay}{d}$
diffraction grating	$d \sin \theta = n\lambda$

Light

lens equation

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

Electricity

terminal potential difference

$$V = E - Ir \text{ (e.m.f., } E; \text{ Internal Resistance, } r)$$

potential divider

$$V_{\text{out}} = \frac{R_1 V_{\text{in}}}{R_1 + R_2}$$

Particles and photons

Einstein's equation

$$\frac{1}{2} m v_{\text{max}}^2 = hf - hf_0$$

de Broglie equation

$$\lambda = \frac{h}{p}$$

Astronomy

red shift

$$z = \frac{\Delta\lambda}{\lambda}$$

recession speed

$$z = \frac{v}{c}$$

Hubble's law

$$v = H_0 d$$

