

AS Level Physics A

H156/02 Depth in physics

Time allowed: 1 hour 30 minutes

You must have:

- the Data, Formulae and Relationships Booklet
- a ruler (cm/mm)

You can use:

- a scientific or graphical calculator



Please write clearly in black ink. **Do not write in the barcodes.**

Centre number

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Candidate number

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First name(s)

Last name

StemUp Model Solution

INSTRUCTIONS

- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

INFORMATION

- The total mark for this paper is **70**.
- The marks for each question are shown in brackets [].
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **24** pages.

ADVICE

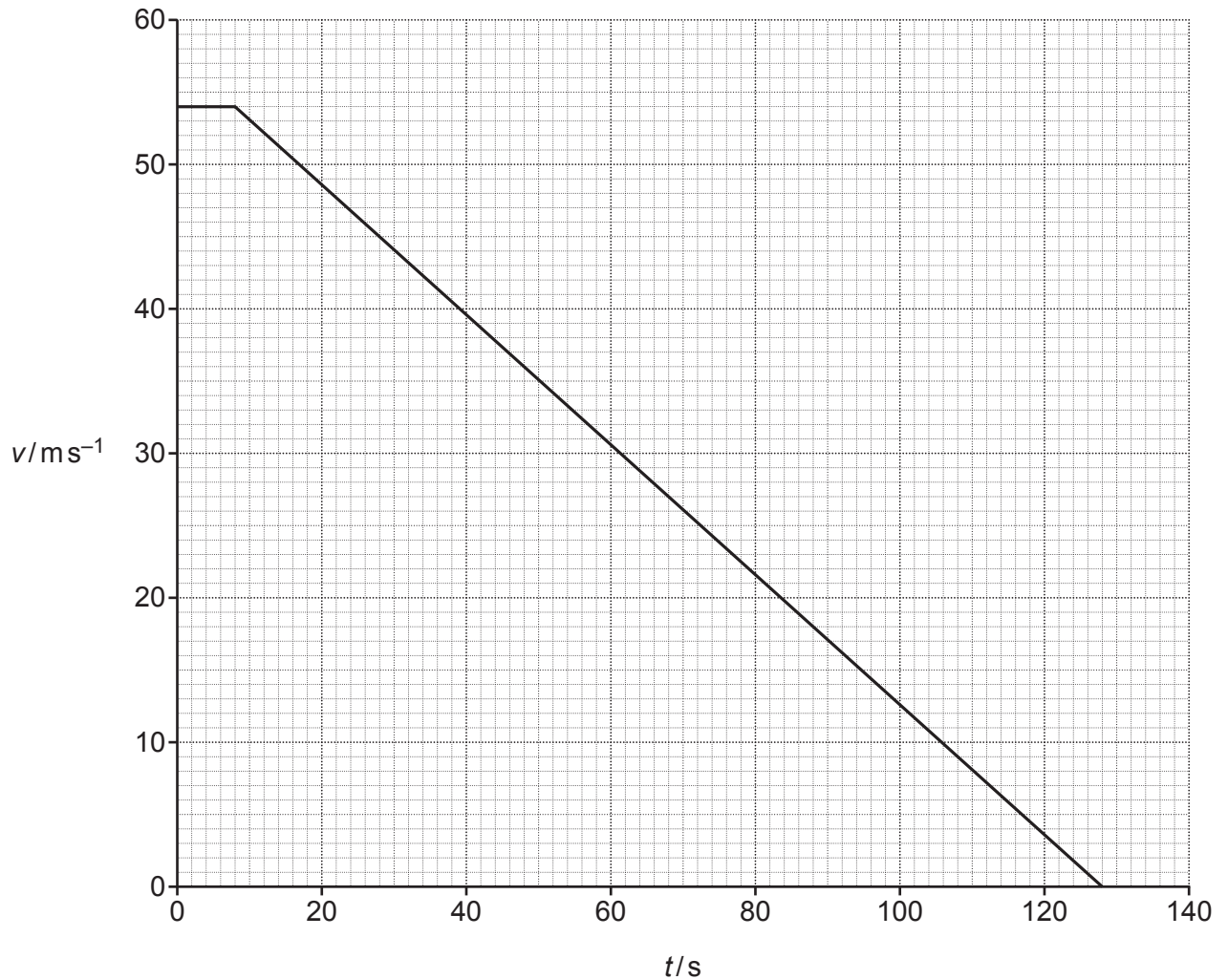
- Read each question carefully before you start your answer.

2

Answer **all** the questions in this section.

- 1 A high speed passenger train is travelling at a velocity of 54 ms^{-1} .

The simplified graph shows the variation with time t of the velocity v of the train until it stops.
At $t = 0$ the driver starts to think about applying the brakes.



- (a) Use the graph to determine the acceleration a of the train while the driver applies the brakes.

$$a = \Delta v \div \Delta t = (0 - 54) \div (128 - 8)$$

$$a = -54 \div 120$$

$$a = \text{---} -0.45 \text{ ms}^{-2} \text{ [1]}$$

- (b) Use the graph to determine the total stopping distance d of the train from $t = 0$.

$$d = \text{area under graph} = (8 \times 54) + (\frac{1}{2} \times 120 \times 54)$$

$$d = 432 + 3240 = 3672 \text{ m}$$

$$d = \text{---} 3700 \text{ m [2]}$$

- (c) Suggest why the graph does **not** show the real motion of the train.

The deceleration would not be constant, so the line would be curved, not straight.

Brakes cannot be applied at maximum instantly, so the deceleration increases gradually.

and the braking force changes as the speed changes. [2]

2

- (a) A student has six similar metal spherical balls. To determine the mean mass of a ball, the student measures the diameters of the balls.

The table shows the measurements.

Diameter/cm	0.565	0.562	0.555	0.561	0.562	0.556
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The density of the metal is $(8.9 \pm 0.1) \text{ g cm}^{-3}$.

- (i) Show that the mean mass m of each of the balls is approximately 0.82 g.

$$\text{mean diameter} = 3.361 \div 6 = 0.5602 \text{ cm, so } r = 0.2801 \text{ cm}$$

$$V = \frac{4}{3} \pi r^3 = \frac{4}{3} \times \pi \times (0.2801)^3 = 0.0920 \text{ cm}^3$$

$$m = \rho V = 8.9 \times 0.0920 = 0.819 \text{ g} \approx 0.82 \text{ g}$$

[2]

- (ii) Calculate the percentage uncertainty in m .

$$\Delta d = (0.565 - 0.555) \div 2 = 0.005 \text{ cm}$$

$$\% \text{ in } d = 0.005 \div 0.560 \times 100 = 0.89\%, \text{ so } \% \text{ in } V = 3 \times 0.89 = 2.7\%$$

$$\% \text{ in } \rho = 0.1 \div 8.9 \times 100 = 1.1\%$$

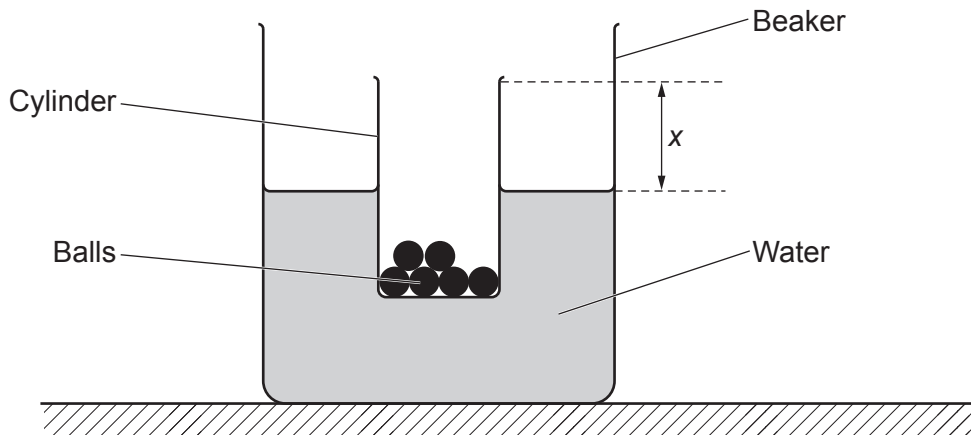
$$\% \text{ in } m = 2.7 + 1.1 = 3.8\%$$

percentage uncertainty = ...3.8..... % [2]

- (b) A hollow cylinder of mass 18 g has height 7.1 cm and cross-sectional area 6.2 cm^2 .

The six balls from part (a) are placed in the cylinder.

The cylinder is placed into a beaker of tap water. It floats upright as shown in the diagram.



The top of the cylinder is a distance x above the surface of the water.

The density of tap water is 1.0 g cm^{-3} .

- (i) Calculate x .

$$\text{mass of cylinder + balls} = 18 + 6 \times 0.82 = 22.9 \text{ g}$$

$$\text{floats: mass of water displaced} = 22.9 \text{ g, so volume} = 22.9 \text{ cm}^3$$

$$\text{depth under water} = 22.9 \div 6.2 = 3.7 \text{ cm}$$

$$x = 7.1 - 3.7 = 3.4 \text{ cm}$$

$$x = \underline{3.4} \text{ cm [3]}$$

- (ii) The student repeats the experiment using sea water.

State how the value of x changes.

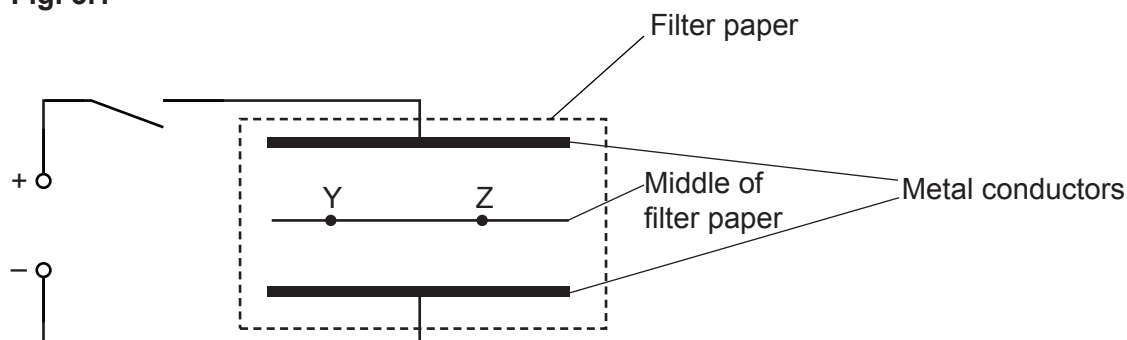
Explain your answer.

x increases. Sea water has a greater density than tap water (1.0 g cm^{-3}), so a smaller volume of sea water needs to be displaced to give an upthrust equal to the weight (Archimedes' principle), so the cylinder floats higher. [2]

3

- (a) To investigate mobile charge carriers, a student soaks a sheet of filter paper in a solution of salt. They fix metal conductors to the filter paper and connect the conductors to a power supply as shown in **Fig. 3.1**.

Fig. 3.1

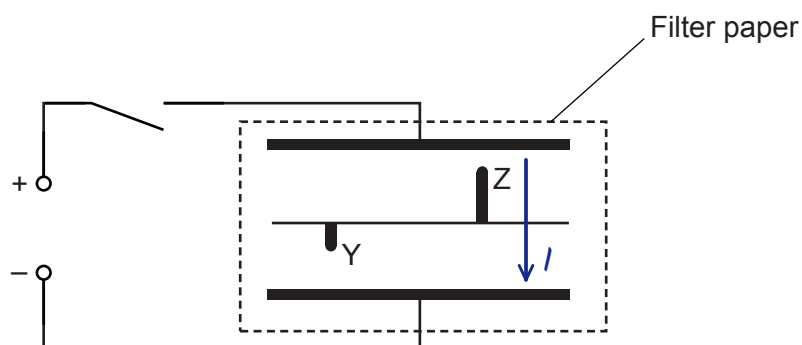


The student places two different soluble coloured crystals, Y and Z, on the middle of the filter paper as shown.

They close the switch.

After 20 s, due to the movement of the mobile charge carriers in crystals Y and Z, the filter paper appears as shown in **Fig. 3.2**.

Fig. 3.2



- (i) On the filter paper shown in **Fig. 3.2**, draw an arrow to indicate the conventional current I for the visible charge carriers of crystal Z. Label the arrow I . [1]
- (ii) Compare the visible charge carriers of crystal Y with the visible charge carriers of crystal Z.

Explain your answer.

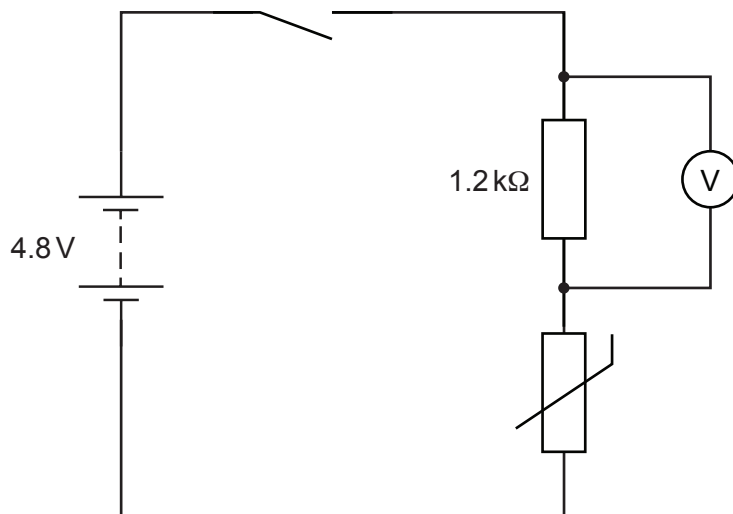
Y has moved towards the negative terminal: the visible charge carriers of Y are attracted to the negative, so they are positive.

Z has moved towards the positive terminal: the visible charge carriers of Z are attracted to the positive, so they are negative.

In the same 20 s, Y has travelled a smaller distance than Z, so the speed (drift velocity) of the charge carriers of Y is smaller than that of Z. [4]

- (b) A student sets up the circuit shown in Fig. 3.3.

Fig. 3.3



The battery has an electromotive force (e.m.f.) of 4.8 V and negligible internal resistance.

The voltmeter measures the potential difference (p.d.) across the resistor of resistance 1.2 kΩ.

- (i) At a temperature of 20 °C, the resistance of the thermistor is 2.6 kΩ.

Calculate the voltmeter reading V .

$$V = 1.2 \div (1.2 + 2.6) \times 4.8$$

$$V = 1.52 \text{ V}$$

$$V = \dots\dots\dots 1.5 \dots\dots\dots \text{ V [2]}$$

- (ii) The student places the thermistor in hot water.

At a temperature of 60 °C, the voltmeter reads 3.2 V.

Calculate the resistance R of the thermistor.

$$\text{p.d. across thermistor} = 4.8 - 3.2 = 1.6 \text{ V}$$

$$I = 3.2 \div 1200 = 2.67 \times 10^{-3} \text{ A}$$

$$R = 1.6 \div 2.67 \times 10^{-3} = 600 \text{ } \Omega$$

$$R = \dots\dots\dots 600 \dots\dots\dots \text{ } \Omega \text{ [2]}$$

- (iii) The student replaces the resistor of resistance $1.2\text{ k}\Omega$ with a resistor of resistance $120\text{ k}\Omega$.

Suggest why $120\text{ k}\Omega$ is **not** a sensible value to use to measure the temperature of a sample of water between 0°C and 100°C .

*The resistance of the thermistor (a few $\text{k}\Omega$) is very small compared with $120\text{ k}\Omega$,
so most of the p.d. is across the $120\text{ k}\Omega$ resistor: the voltmeter reads almost 4.8 V
(about 4.7 V to 4.8 V) at every temperature. So there is very little change in the
voltmeter reading between 0°C and 100°C .* [2]

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4 A student has a battery of electromotive force (e.m.f.) 2.2 V.

(a) The quantities e.m.f. and potential difference (p.d.) are both measured in volts, V.

Describe **one** other similarity and **one** difference between e.m.f. and p.d.

similarity ...both are the work done (energy transferred) per unit charge (joules per coulomb).....

difference ...e.m.f.: energy transferred from chemical to electrical (work done on the charges);
...p.d.: energy transferred from electrical to heat (work done by the charges).....

[2]

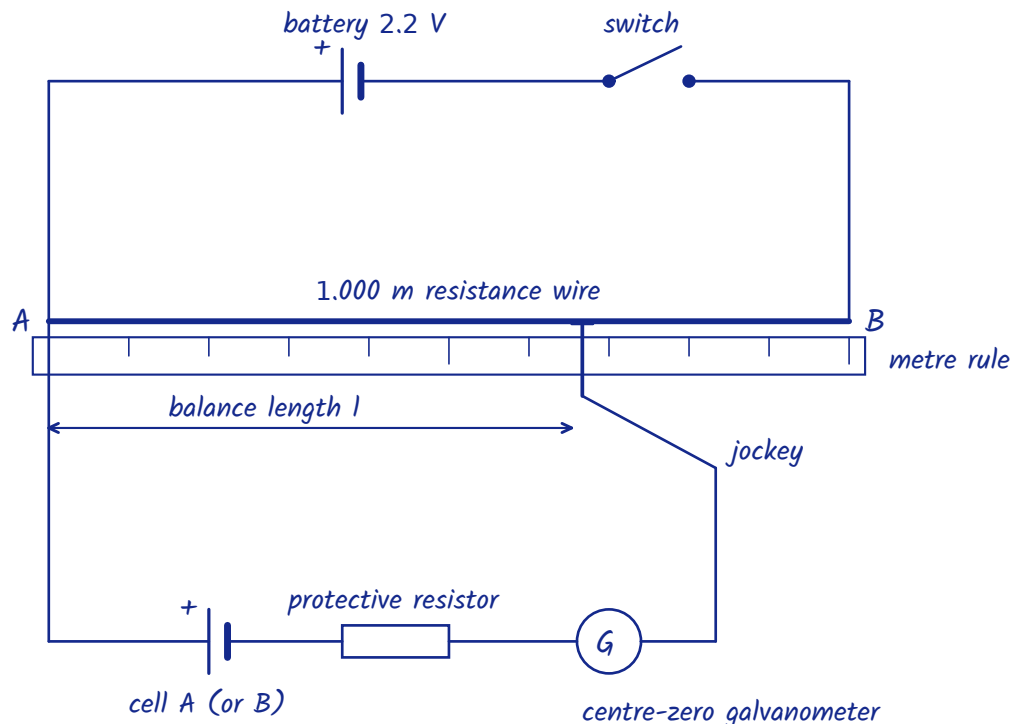
(b)* The student has two cells **A** and **B**, the battery of e.m.f. 2.2 V and a potentiometer. The potentiometer is constructed using 1.000 m of resistance wire.

Describe, with the aid of a suitable diagram, how the student can safely conduct an experiment to compare the e.m.f. of cell **A** with the e.m.f. of cell **B**.

The student uses the potentiometer. Include any other equipment they need.

[6]

Diagram



Set up the circuit as shown: the 2.2 V battery and a switch are connected across the 1.000 m wire AB, fixed along a metre rule. Cell A is connected with its positive terminal to A (the same side as the battery's positive terminal), in series with a protective resistor and a centre-zero galvanometer, to a jockey.

Close the switch and tap the jockey at different points on the wire until the galvanometer reads zero. Then short out the protective resistor and adjust the jockey to find the exact balance point, where the galvanometer shows no deflection. At balance no current flows through the cell, so its e.m.f. equals the p.d. across the length l of wire.

Measure the balance length l_A from A to the jockey with the metre rule. Repeat to find a mean l_A . Replace cell A with cell B and find the mean balance length l_B in the same way.

The p.d. per unit length along the wire is constant (2.2 V across 1.000 m), so e.m.f. is proportional to balance length:

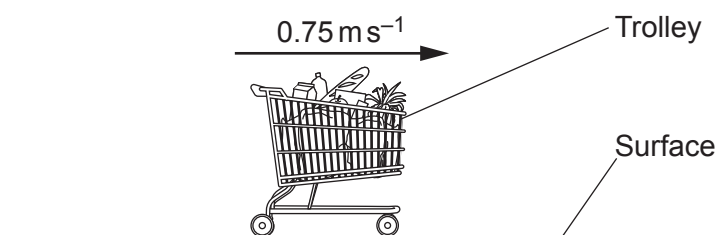
$$E_A \div E_B = l_A \div l_B, \text{ and } E_A = 2.2 \times l_A \div 1.000 \text{ m}, E_B = 2.2 \times l_B \div 1.000 \text{ m}.$$

Additional answer space if required

Safety: open the switch when not taking readings so that the wire does not heat up (and its resistance does not change); tap the jockey rather than sliding it so the wire is not damaged; the protective resistor stops a large current through the galvanometer.

- 5 A shopper pushes a trolley loaded with shopping at a constant speed of 0.75 ms^{-1} along a horizontal surface as shown in **Fig. 5.1**.

Fig. 5.1



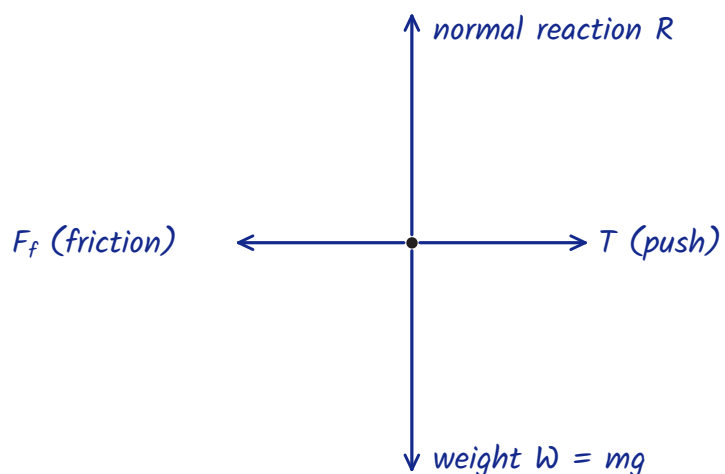
The mass of the loaded trolley is 49 kg .

The force pushing the trolley is T .

The force of friction F_f between the trolley and the surface is 24 N .

- (a) The loaded trolley is represented by $\bullet$ in **Fig. 5.2**.

Fig. 5.2



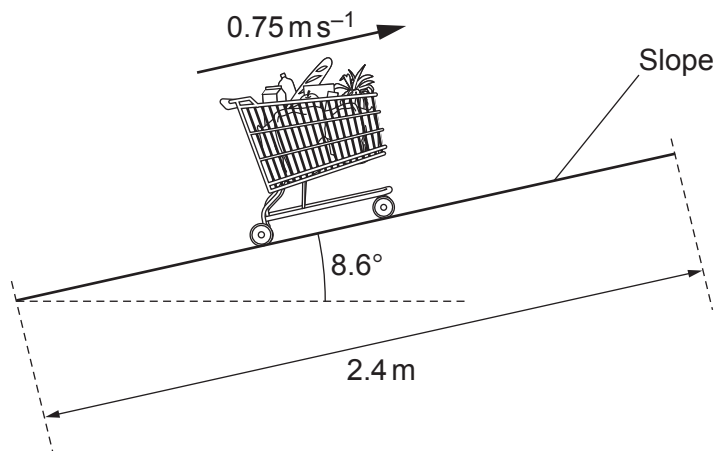
- (i) On **Fig. 5.2** draw a free-body diagram representing **all** the forces acting on the loaded trolley. Label the forces. [4]

- (ii) State the value of T .

$T = \dots\dots\dots 24 \dots\dots\dots \text{ N}$ [1]

- (b) The shopper now pushes the loaded trolley up a slope made from the same surface, as shown in Fig. 5.3.

Fig. 5.3



The angle between the horizontal and the slope is 8.6° and the trolley travels a distance of 2.4 m along the slope.

The force of friction F_f between the trolley and the surface is 24 N .

- (i) The equation relating power P to force F and velocity v is $P = Fv$.

Derive this equation from first principles.

$$P = \text{work done} \div \text{time} = W \div t, \text{ and } W = Fx$$

$$\text{so } P = Fx \div t, \text{ and } x \div t = v, \text{ so } P = Fv$$

[2]

- (ii) Calculate the work done W against the force of gravity in moving the trolley along the slope.

$$W = mgh = 49 \times 9.81 \times 2.4 \sin 8.6^\circ$$

$$W = 49 \times 9.81 \times 0.359 = 172.5 \text{ J}$$

$$W = \dots\dots\dots 170 \dots\dots\dots \text{ J [2]}$$

- (iii) Calculate the **total** power P needed to push the trolley up the slope at a constant speed of 0.75 ms^{-1} .

$$\text{total force} = 172.5 \div 2.4 + 24 = 71.9 + 24 = 95.9 \text{ N}$$

$$P = Fv = 95.9 \times 0.75 = 72 \text{ W}$$

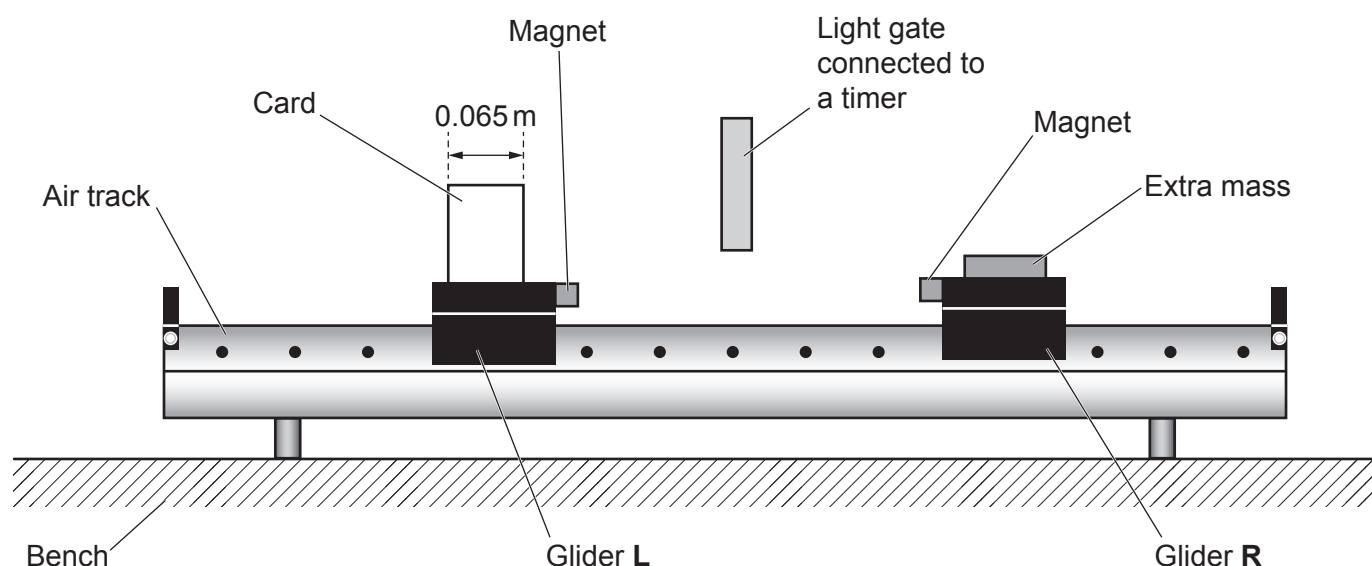
$$P = \dots\dots\dots 72 \dots\dots\dots \text{ W [2]}$$

Turn over

- 6 A teacher uses a linear air track to investigate collisions.

Fig. 6.1 shows the arrangement of apparatus.

Fig. 6.1



The teacher connects the light gate to a timer. The timer records the time for the card on glider **L** to pass through the light gate. The length of the card is 0.065 m.

The mass of glider **L** is 0.18 kg and the mass of glider **R** and the extra mass is 0.27 kg.

The two magnets are positioned so that they will repel each other.

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

The total momentum of a system before a collision is equal to the total momentum after the collision, provided that no external force acts (closed system).

[2]

- (b) Glider **R** is stationary. Glider **L** moves at velocity u from left to right and collides with **R**. After the collision **L** rebounds and passes back through the light gate and **R** moves to the right.

The table records the time taken t for the card to pass through the light gate.

	t/s
L moving to the right before the collision	0.26
L moving to the left after the collision	1.30

- (i) Show that the momentum of **L** before the collision is $0.045 \text{ kg m s}^{-1}$.

$$u = 0.065 \div 0.26 = 0.25 \text{ m s}^{-1}$$

$$p = mu = 0.18 \times 0.25 = 0.045 \text{ kg m s}^{-1}$$

[1]

- (ii) Determine the impulse of the force acting on **R**.

$$L \text{ after: } v = 0.065 \div 1.30 = 0.050 \text{ m s}^{-1} \text{ to the left}$$

$$\text{momentum of } L \text{ after} = -0.18 \times 0.050 = -0.0090 \text{ kg m s}^{-1}$$

$$\text{impulse on } R = -\Delta p \text{ of } L = 0.045 - (-0.0090) = 0.054 \text{ N s}$$

$$\text{impulse} = \dots\dots\dots 0.054 \dots\dots\dots \text{ N s} \quad [2]$$

- (iii) Calculate the velocity v of **R** after the collision.

$$v = \text{impulse} \div m = 0.054 \div 0.27 = 0.20 \text{ m s}^{-1}$$

$$v = \dots\dots\dots 0.20 \dots\dots\dots \text{ m s}^{-1} \quad [1]$$

- (c) The teacher changes one of the magnets to a cork and the other magnet to a pin and repeats the experiment.

Glider **L** moves from left to right. The time for the card to pass through the light gate is 0.26 s.

Glider **L** collides and sticks to glider **R**. After the collision **L** and **R** move together to the right.

Show, using energy considerations and the principle of conservation of momentum, that the collision is **inelastic**.

Include relevant calculations in your answer.

$$KE \text{ before} = \frac{1}{2} \times 0.18 \times 0.25^2 = 5.625 \times 10^{-3} \text{ J}$$

$$\text{momentum conserved: } 0.045 = (0.18 + 0.27)v, \text{ so } v = 0.10 \text{ m s}^{-1}$$

$$KE \text{ after} = \frac{1}{2} \times 0.45 \times 0.10^2 = 2.25 \times 10^{-3} \text{ J}$$

*The kinetic energy after ($2.25 \times 10^{-3} \text{ J}$) is less than before ($5.625 \times 10^{-3} \text{ J}$),
so kinetic energy is not conserved: the collision is inelastic.*

[4]

7 A laser emits green light of wavelength $5.32 \times 10^{-7} \text{ m}$.

(a) The power of the laser is 1.0 mW.

Calculate the number of photons N emitted per second.

$$E = hc \div \lambda = 6.63 \times 10^{-34} \times 3.00 \times 10^8 \div 5.32 \times 10^{-7} = 3.74 \times 10^{-19} \text{ J}$$

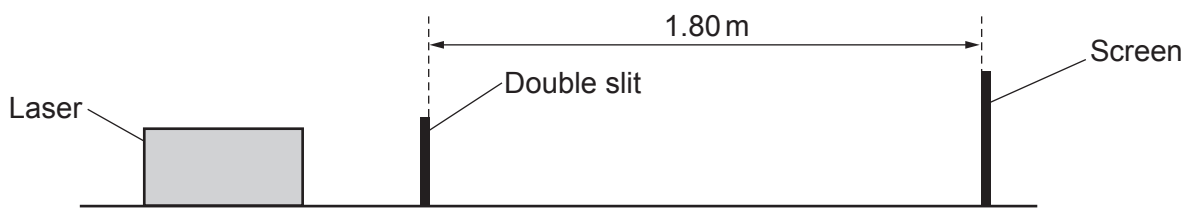
$$N = P \div E = 1.0 \times 10^{-3} \div 3.74 \times 10^{-19} = 2.7 \times 10^{15}$$

$$N = \dots\dots\dots 2.7 \times 10^{15} \dots\dots\dots \text{ s}^{-1} \text{ [2]}$$

(b) A student uses the laser to look at the interference pattern through a double slit.

The student arranges the apparatus as shown in Fig. 7.1.

Fig. 7.1 (not to scale)



The width of the screen is about 6 cm.

The distance between the double slit and the screen is 1.80 m.

The student determines that the fringe width is $3.82 \pm 0.02 \text{ mm}$.

(i) The light from the laser that falls on the double slit is coherent.

State the meaning of the term coherent.

The waves have a constant phase difference (and the same frequency).
 [1]

(ii) Explain how the student determined the fringe width.

Use vernier calipers to measure the distance across several (n) fringe spacings on the screen, e.g. 10 fringes.
Divide this distance by n to get the fringe width (this reduces the percentage uncertainty).
 [2]

- (iii) Calculate the separation a of the slits.

Give your answer to 3 significant figures.

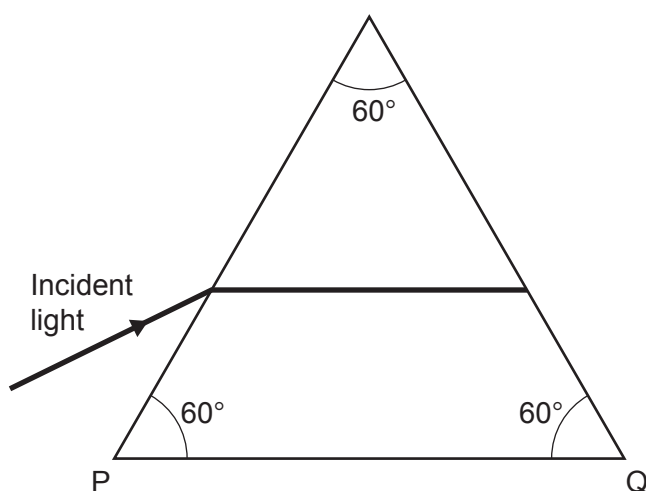
$$\lambda = ax \div D, \text{ so } a = \lambda D \div x$$

$$a = 5.32 \times 10^{-7} \times 1.80 \div 3.82 \times 10^{-3} = 2.507 \times 10^{-4} \text{ m}$$

$$a = \dots\dots\dots 2.51 \times 10^{-4} \dots\dots\dots \text{ m [2]}$$

- (c) Light from the laser is incident on an equilateral triangular glass prism as shown in **Fig. 7.2**.

Fig. 7.2



The refracted ray in the prism is parallel to PQ.

The refractive index of the glass is 1.48.

Calculate:

- (i) the wavelength λ of the light in the glass

$$\lambda = 5.32 \times 10^{-7} \div 1.48 = 3.59 \times 10^{-7} \text{ m}$$

$$\lambda = \dots\dots\dots 3.59 \times 10^{-7} \dots\dots\dots \text{ m [1]}$$

- (ii) the angle of incidence i of the incident ray.

$$\text{ray parallel to PQ, so angle of refraction } r = 30^\circ$$

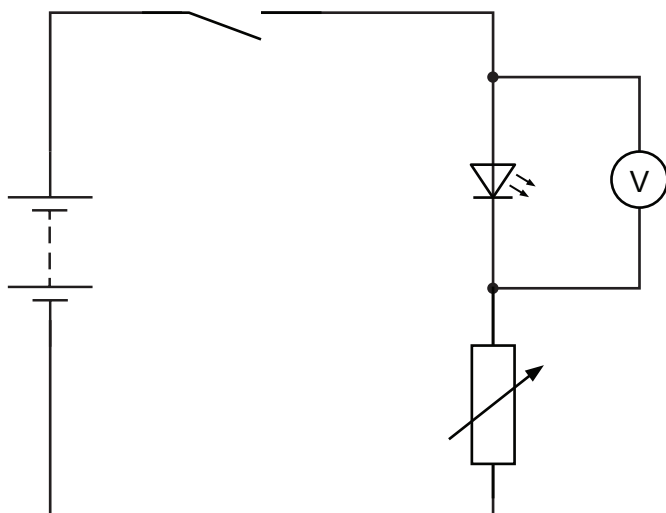
$$\sin i = n \sin r = 1.48 \times \sin 30^\circ = 0.74, \text{ so } i = 48^\circ$$

$$i = \dots\dots\dots 48 \dots\dots\dots^\circ \text{ [2]}$$

18
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- 8* A student carries out an experiment to determine the Planck constant. They use the circuit shown.



The frequency of the emitted light from the LED is f and the potential difference for the LED to just light is V .

The student repeats the experiment for LEDs that emit light of different frequency.

The table shows their results.

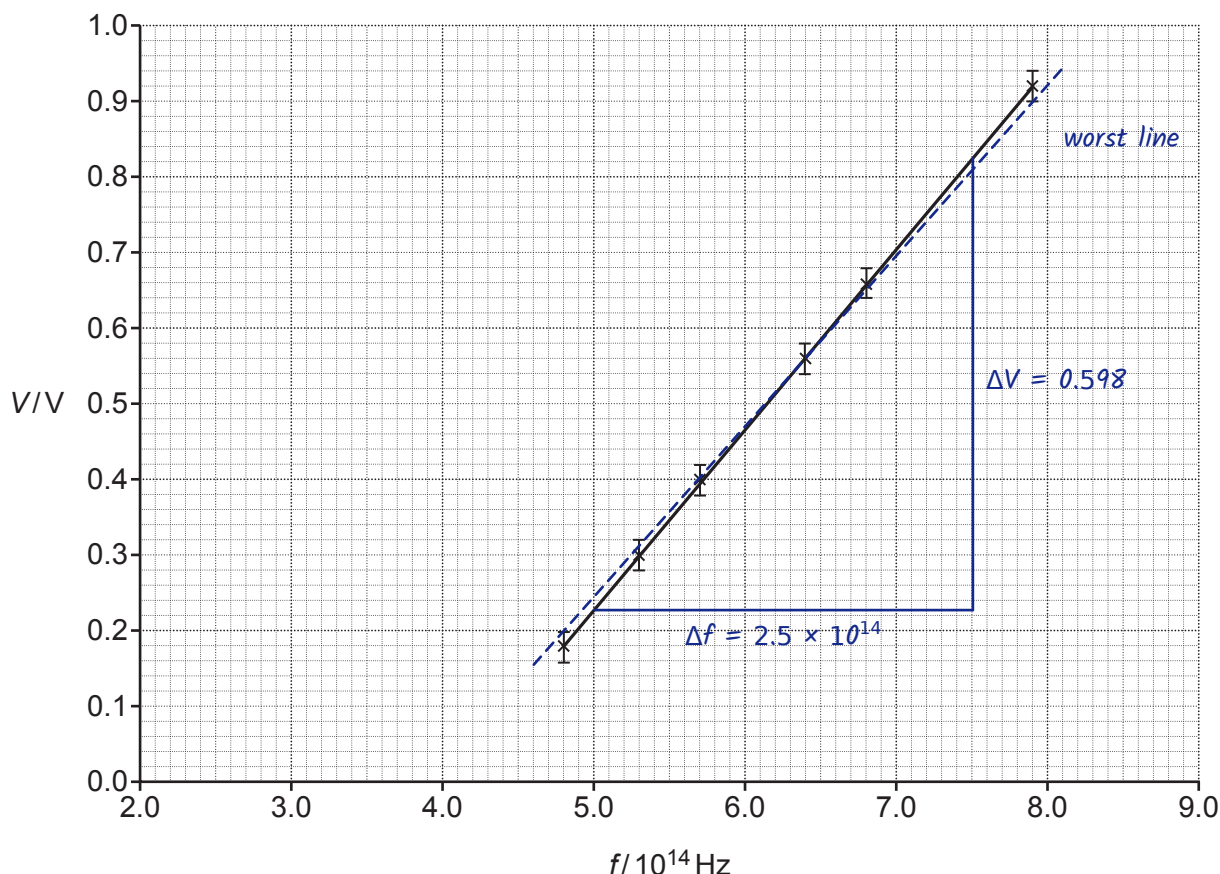
$f/10^{14}\text{Hz}$	V/V
4.8	0.18 ± 0.02
5.3	0.30 ± 0.02
5.7	0.40 ± 0.02
6.4	0.56 ± 0.02
6.8	0.66 ± 0.02
7.9	0.92 ± 0.02

It is suggested that the relationship between V and f is

$$V = \frac{h}{e}f - \frac{K}{e}$$

where e is the charge on an electron, h is the Planck constant and K is a constant.

The student plots a graph of V/V on the y-axis against $f/10^{14}$ Hz on the x-axis is plotted.



Describe how to measure V accurately **and** use the graph to determine h and K .

Include the percentage uncertainty in your value of h .

[6]

Measuring V : use a voltmeter across the LED. Start with the variable resistor at maximum and slowly decrease its resistance until the LED just lights; record V .
 Darken the room and look at the LED through a black tube to shield background light. Then increase the resistance until the LED just goes off; repeat and take a mean V for each LED.
 Comparing $V = (h/e)f - K/e$ with $y = mx + c$: gradient = h/e , intercept = $-K/e$.
 Gradient (large triangle) = $0.598 \div 2.5 \times 10^{14} = 2.39 \times 10^{-15} \text{ V s}$
 $h = \text{gradient} \times e = 2.39 \times 10^{-15} \times 1.60 \times 10^{-19} = 3.8 \times 10^{-34} \text{ J s}$
 $f = 0$ is off the graph, so use $y = mx + c$ with the point (7.9, 0.92):
 $c = 0.92 - (2.39 \times 10^{-15} \times 7.9 \times 10^{14}) = -0.97 \text{ V}$
 $K = -ce = 0.97 \times 1.60 \times 10^{-19} = 1.55 \times 10^{-19} \text{ J}$

Worst acceptable line (dashed) through (4.8, 0.20) and (7.9, 0.90):

$$\text{worst gradient} = 0.70 \div 3.1 \times 10^{14} = 2.26 \times 10^{-15} \text{ V s}$$

$$\% \text{ uncertainty in gradient} = (2.39 - 2.26) \div 2.39 \times 100 = 5.4\%$$

$$e \text{ is a constant, so \% uncertainty in } h = 5.4\%: h = (3.8 \pm 0.2) \times 10^{-34} \text{ J s}$$

Additional answer space if required

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END OF QUESTION PAPER

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