



Oxford Cambridge and RSA

AS Level Physics A

H156/02 Depth in physics

Thursday 8 June 2017 – Afternoon

Time allowed: 1 hour 30 minutes



You must have:

- the Data, Formulae and Relationships Booklet (sent with general stationery)

You may use:

- a scientific or graphical calculator
- a ruler (cm/mm)



First name										
Last name	StemUp Model Solution									
Centre number						Candidate number				

INSTRUCTIONS

- Use black ink. HB pencil may be used for graphs and diagrams.
- Complete the boxes above with your name, centre number and candidate number.
- Answer **all** the questions.
- Write your answer to each question in the space provided. If additional space is required, you should use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the barcodes.

INFORMATION

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

Answer **all** the questions.

- 1 (a) Define what is meant by the *stopping distance* of a vehicle.

The stopping distance is the sum of the thinking distance and the braking distance; the total distance travelled from when the driver sees a hazard to when the vehicle stops. [1]

- (b) Fig. 1.1 shows a train of mass $1.9 \times 10^5 \text{ kg}$ travelling at 61 km h^{-1} along a level track.



Fig. 1.1

- (i) Show that the train is travelling at about 17 m s^{-1} .

$$v = (61 \times 1000) / 3600 = 16.9 \text{ m s}^{-1} \approx 17 \text{ m s}^{-1}$$

[1]

- (ii) The brakes of the train are applied and the train is brought to rest in a distance of 310 m. Calculate

1. the initial kinetic energy E_k of the train

$$E_k = \frac{1}{2}mv^2 = \frac{1}{2} \times 1.9 \times 10^5 \times 17^2$$

$$E_k = 2.7(5) \times 10^7 \text{ J}$$

$$E_k = \dots\dots\dots 2.7 \times 10^7 \dots\dots\dots \text{ J [2]}$$

2. the average deceleration a of the train

$$v^2 = u^2 + 2as: 0 = 17^2 + 2 \times a \times 310$$

$$a = -289 / 620 = -0.47 \text{ m s}^{-2}$$

$$\text{deceleration} = 0.47 \text{ m s}^{-2}$$

$$a = \dots\dots\dots 0.47 \dots\dots\dots \text{ ms}^{-2} \text{ [3]}$$

3. the average braking force F on the train.

$$F = ma = 1.9 \times 10^5 \times 0.47$$

$$F = 8.9 \times 10^4 \text{ N}$$

$$F = \dots\dots\dots 8.9 \times 10^4 \dots\dots\dots \text{ N [2]}$$

- (iii) Fig. 1.2 shows a similar train travelling at 61 km h^{-1} up an incline.

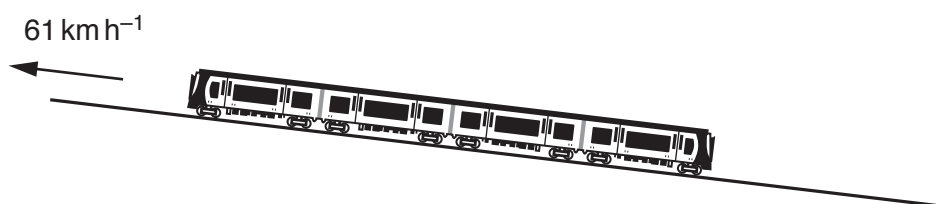


Fig. 1.2

The brakes of the train are applied with the **same** average braking force. State and explain how the distance that the train travels, from when the brakes are applied until the train stops, compares with when the train is travelling on level track.

The distance is smaller. A component of the train's weight acts down the incline, against the motion (in the same direction as the braking force), so the opposing (net) force and the deceleration are greater. [2]

PLEASE DO NOT WRITE ON THIS PAGE

- 2 Fig. 2.1 shows an experiment in the laboratory to investigate the extension of two identical springs connected end to end. A student initially measures the length L of the two-spring combination without a load attached.

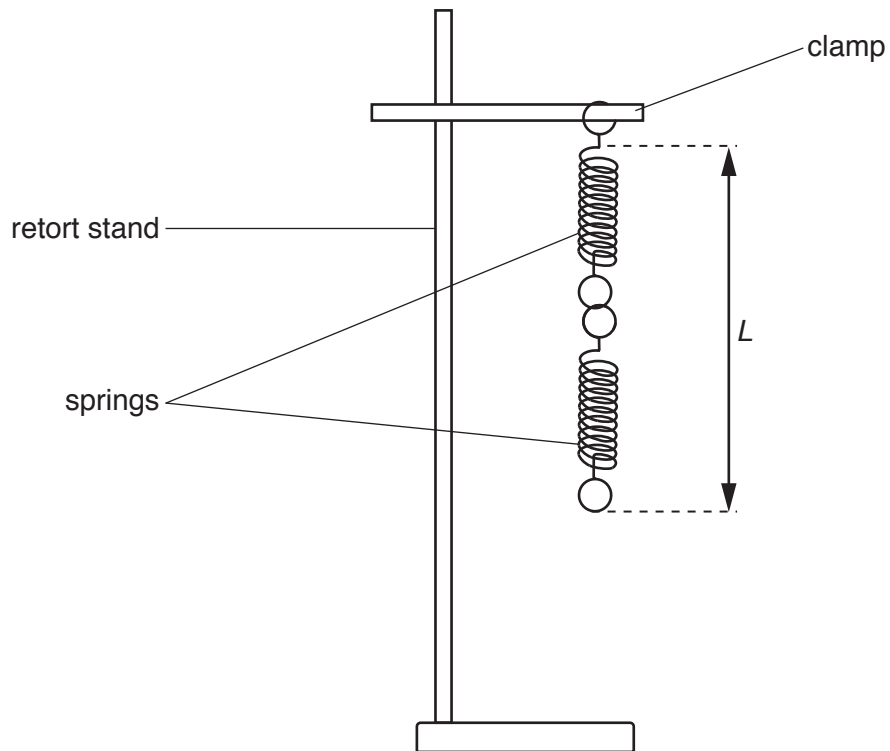


Fig. 2.1

Question 2 continues on page 6

The student adds mass m to the lower spring and measures the new length L of the two-spring combination.

The student determines the weight F of the mass added to the spring.

The student's results are shown in Fig. 2.2.

m/g	F/N	L/cm	e / cm
0	0	12.0	0.0
50	0.49	13.0	1.0
100	0.98	13.8	1.8
150	1.47	14.8	2.8
200	1.96	15.6	3.6
250	2.45	16.6	4.6

Fig. 2.2

- (a) Complete the table shown in Fig. 2.2 by calculating and recording values of the extension e/cm of the spring combination. [1]
- (b) On Fig. 2.3 plot a graph of e/cm (y -axis) against F/N (x -axis). Draw the straight line of best fit. [4]
- (c) Determine the gradient of the straight line of best fit.

$$\text{gradient} = \Delta e / \Delta F = (4.48 - 0.40) / (2.40 - 0.20)$$

$$\text{gradient} = 4.08 / 2.20 = 1.85 \text{ cm N}^{-1}$$

$$\text{gradient} = \dots\dots\dots 1.85 \dots\dots\dots [1]$$

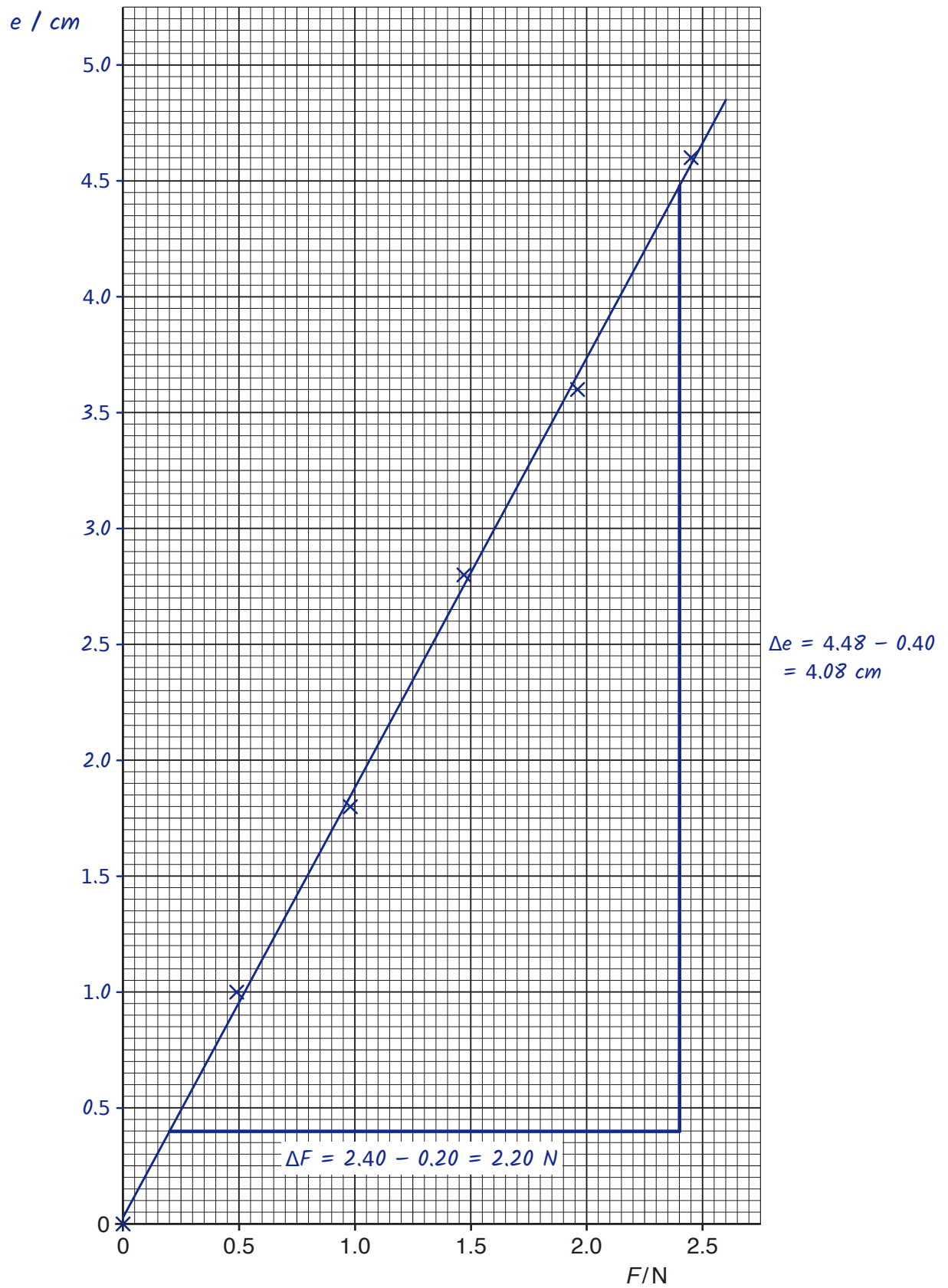


Fig. 2.3

- (d) Use your answer to (c) to determine the experimental value for the force constant k_2 of the two-spring combination. Include an appropriate unit.

$$k_2 = F / e = 1 / \text{gradient} = 1 / 1.85$$

$$k_2 = 0.54 \text{ N cm}^{-1} (= 54 \text{ N m}^{-1})$$

$$k_2 = \dots\dots\dots 0.54 \text{ N cm}^{-1} \dots\dots\dots [2]$$

- (e) State and explain whether your graph shows that the spring combination obeys Hooke's law.

*Hooke's law: the extension is directly proportional to the load (force),
provided the elastic limit is not exceeded.*

*My graph is a straight line passing through the origin, so the spring
combination obeys Hooke's law.* [2]

- (f) The experiment is repeated with a third identical spring added to the bottom of the two springs. The force constant of this new three-spring combination is k_3 .

Determine the ratio

$$\frac{k_3}{k_2}$$

*For identical springs of force constant k in series, each spring has
the same tension F :*

$$F = k_2 \times 2e = k_3 \times 3e, \text{ so } k_2 = k/2 \text{ and } k_3 = k/3$$

$$k_3 / k_2 = (k/3) / (k/2) = 2/3$$

$$\frac{k_3}{k_2} = \dots\dots\dots 2/3 (= 0.67) \dots\dots\dots [2]$$

3 (a) A solid wooden sphere of density 650 kg m^{-3} has a diameter of 2.8 cm.

(i) Describe and explain how the student can measure precisely the diameter of the sphere.

Use a micrometer (screw gauge) or vernier calliper, which has a resolution of 0.01 mm (or 0.1 mm), to measure the diameter. Repeat the reading in different directions across the sphere and take the average. [2]

(ii) Show that the mass of the sphere is 0.0075 kg.

$$V = \frac{4}{3}\pi r^3 = \frac{4}{3} \times \pi \times (0.014)^3 = 1.15 \times 10^{-5} \text{ m}^3$$

$$m = \rho V = 650 \times 1.15 \times 10^{-5} = 7.47 \times 10^{-3} \text{ kg}$$

$$m \approx 0.0075 \text{ kg}$$

[2]

(iii) The sphere is pushed below the surface of water as shown in Fig. 3.

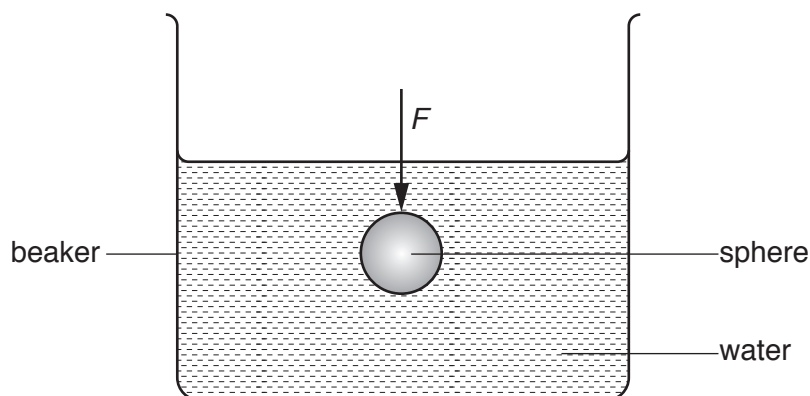


Fig. 3

Determine the force F that needs to be applied to the sphere to keep the wooden sphere stationary in this position.

density of water = 1000 kg m^{-3}

$$\text{upthrust} - \text{weight: } F = Vg(\rho_{\text{water}} - \rho_{\text{wood}})$$

$$F = 1.15 \times 10^{-5} \times 9.81 \times (1000 - 650)$$

$$F = 0.039 \text{ N}$$

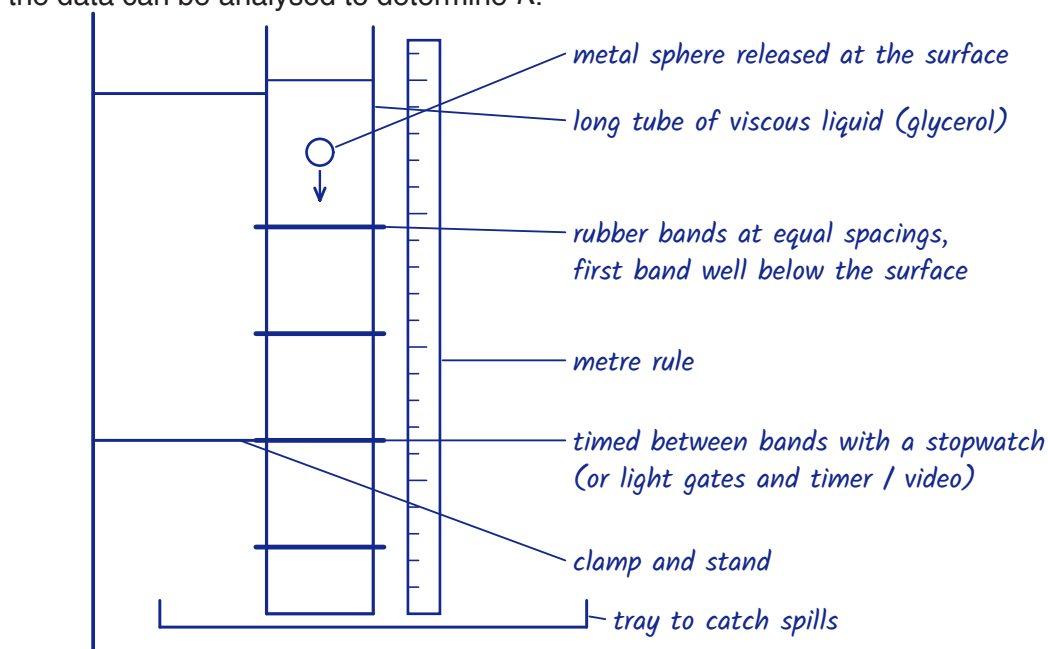
$$F = \dots\dots\dots 0.039 \dots\dots\dots \text{ N [2]}$$

- (b)* A student wishes to investigate how the terminal velocity v of a metal sphere varies with the radius r of the sphere as it travels through a liquid. It is suggested that

$$v = Kr^2$$

where K is a constant.

Describe with the aid of a suitable diagram how an experiment can be safely conducted, and how the data can be analysed to determine K .



Procedure: a long vertical tube (about 1 m) is filled with a viscous liquid such as glycerol, clamped firmly to a stand and placed in a tray, as in my diagram. Rubber bands are placed round the tube at equal spacings (e.g. every 10 cm), the first one well below the surface so that the sphere has reached terminal velocity.

Measurements: measure the diameter d of each sphere with a micrometer (or vernier calliper), repeated in different directions and averaged, so $r = d/2$. Release the sphere gently at the surface along the centre of the tube. Measure the distance between the bands with a metre rule and use a stopwatch to time the sphere between each pair of bands (or use light gates connected to a timer, or film it with a video camera against a ruler and step through frame by frame).

Terminal velocity: if the times for successive equal distances are the same,

the sphere is travelling at terminal velocity and $v = \text{distance} / \text{time}$. Repeat 3 times for the same r and find the mean v , then repeat for at least five spheres of different radius.

Safety: the tray catches any spills, gloves are worn because glycerol is slippery, the tube is clamped so it cannot topple, and the spheres are removed from the bottom using a strong magnet rather than by hand.

Analysis: calculate $r = d/2$ and r^2 for each sphere and plot a graph of v (y-axis) against r^2 (x-axis). If $v = Kr^2$ the graph is a straight line through the origin, so draw the line of best fit and find its gradient using a large triangle: $K = \text{gradient}$.

[6]

- 4 Some houses are heated by “night storage heaters” which use cheap electricity between the hours of midnight and 7.00 am.

Fig. 4.1 shows a circuit diagram of three identical 230 V, 3.5 kW storage heaters connected to a 230 V mains power supply of negligible internal resistance.

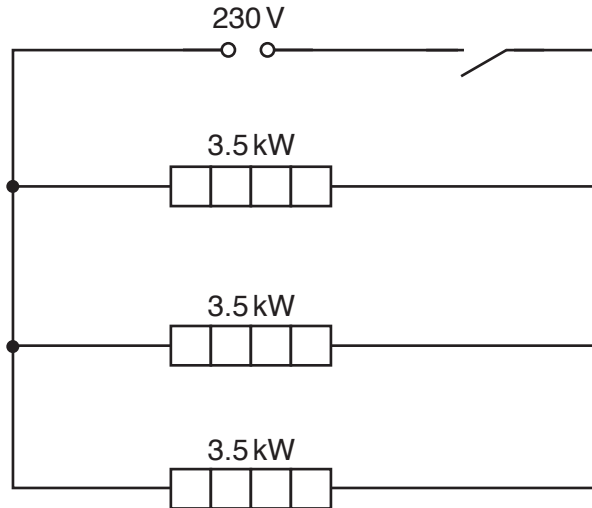


Fig. 4.1

- (a) (i) Show that the resistance of each heating element is about $15\ \Omega$ when the heater is operating at 230 V.

$$P = V^2/R, \text{ so } R = V^2/P = 230^2 / 3500$$

$$R = 15.1\ \Omega \approx 15\ \Omega$$

[1]

- (ii) The heating element is constructed from a metallic wire of resistivity $1.6 \times 10^{-6}\ \Omega\text{ m}$. The radius of the wire is 0.55 mm. Determine the length L of the metallic wire in one heating element.

$$A = \pi r^2 = \pi \times (0.55 \times 10^{-3})^2 = 9.5 \times 10^{-7}\ \text{m}^2$$

$$R = \rho L/A, \text{ so } L = RA/\rho = (15 \times 9.5 \times 10^{-7}) / 1.6 \times 10^{-6}$$

$$L = 8.9\ \text{m}$$

$$L = \dots\dots\dots 8.9 \dots\dots\dots \text{ m [3]}$$

- (iii) State and explain whether the heater obeys Ohm's law.

Ohm's law: the current is directly proportional to the p.d. ($V \propto I$)

provided the physical conditions (temperature) remain constant.

The temperature of the element is not constant, it heats up, so its

resistance changes and it does not obey Ohm's law. [2]

- (b) The cost of 1 kWh of energy is 7.6 pence.

Calculate the cost of using the three storage heaters between midnight and 7.00am every night for one week.

$$\text{energy per night} = 3 \times 3.5 \text{ kW} \times 7 \text{ h} = 73.5 \text{ kW h}$$

$$\text{energy per week} = 73.5 \times 7 = 514.5 \text{ kW h}$$

$$\text{cost} = 514.5 \times 7.6 \text{ p} = 3910 \text{ p} = \text{£}39.10$$

$$\text{cost} = \text{£} \dots\dots\dots 39.10 \dots\dots\dots [2]$$

Question 4 continues on page 14

- (c) A student monitors the temperature in a room by using a potential divider circuit containing a negative temperature coefficient (NTC) thermistor. The student sets up the circuit shown in Fig. 4.2.

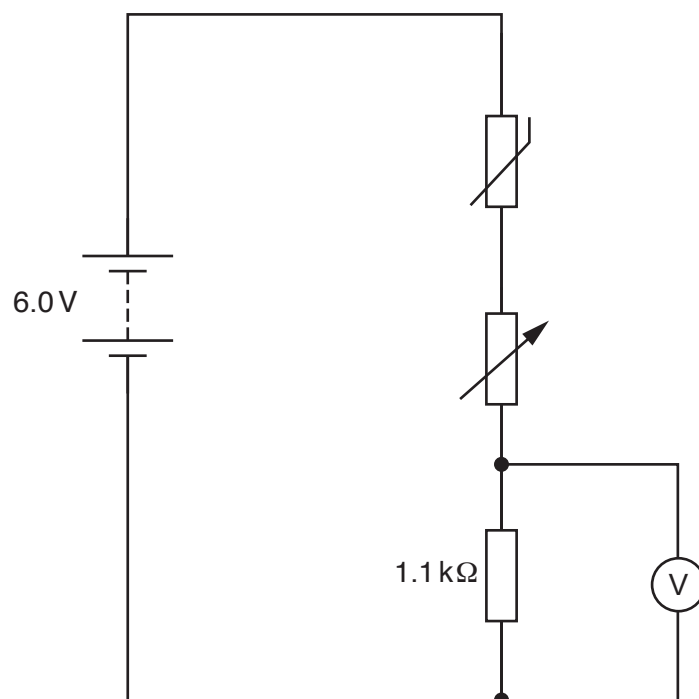


Fig. 4.2

The battery has an e.m.f. of 6.0V and negligible internal resistance.

- (i) When the temperature of the thermistor is 12 °C the thermistor has a resistance of 6.8 kΩ. The resistance of the variable resistor is set to a value of 1.4 kΩ. Calculate the reading V on the voltmeter.

$$V = (1.1 / (6.8 + 1.4 + 1.1)) \times 6.0$$

$$V = (1.1 / 9.3) \times 6.0 = 0.71 \text{ V}$$

$$V = \dots\dots\dots 0.71 \dots\dots\dots \text{ V [2]}$$

- (ii) Explain how the reading on the voltmeter will change when the temperature of the thermistor increases.

As the temperature of the thermistor increases, the resistance of the (NTC) thermistor decreases.

So the total resistance of the circuit decreases and the current increases.

A greater proportion of the 6.0 V is across the fixed 1.1 k Ω resistor, so the p.d. across the fixed resistor increases ($V = IR$ with I larger).

The reading on the voltmeter will increase. [4]

Question 5 begins on page 16

5 This question is about a laser pen.

(a) Define the terms *phase difference* and *coherence*.

phase difference the difference in angle (degrees or radians) by which one wave leads or lags another, between similar points on two waves.

coherence the waves have a constant (fixed) phase difference.

[2]

(b) Green light from the laser pen passes through a pair of narrow slits S_1 and S_2 as shown in Fig. 5.1.

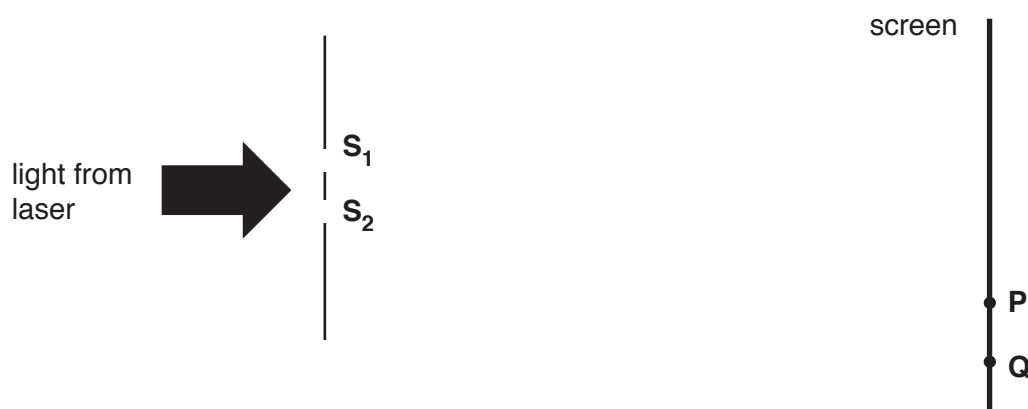


Fig. 5.1

A pattern is produced on a screen consisting of regularly spaced bright and dark lines as shown in Fig. 5.2.

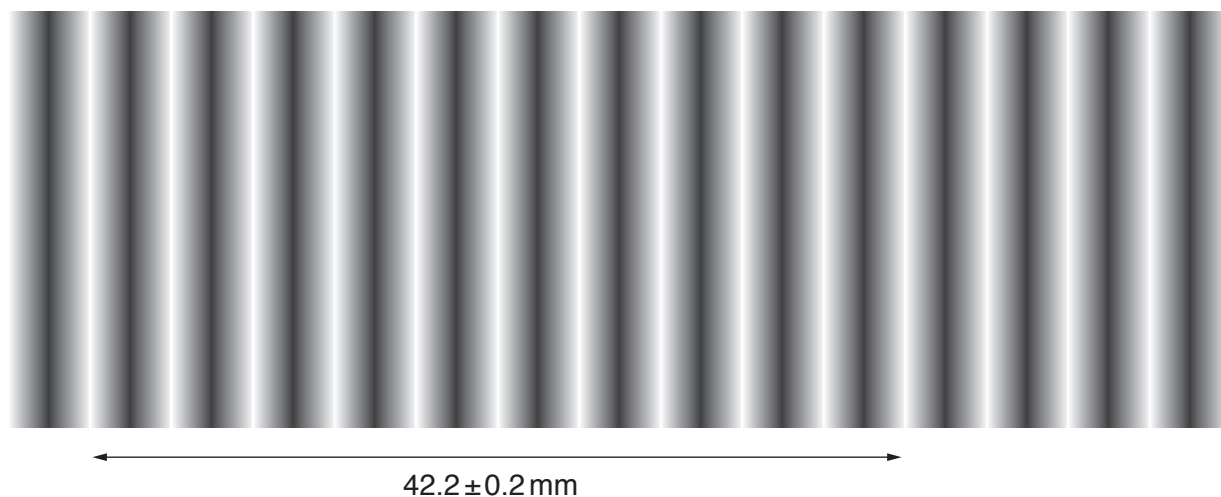


Fig. 5.2

- (i) Fig. 5.1 shows two points, **P** and **Q**, on the screen. Explain in terms of path difference why point **P** is a bright line and point **Q** is a dark line.

At P the path difference $S_2P - S_1P$ is a whole number of wavelengths

$(n\lambda)$: the waves arrive in phase, constructive interference, bright line.

At Q the path difference is an odd number of half wavelengths, $(n +$

$\frac{1}{2})\lambda$: the waves arrive in antiphase, destructive interference, dark line.

[2]

- (ii) The screen is at a distance of $4.50 \pm 0.02\text{m}$ from the slits and the slit separation is $0.56 \pm 0.02\text{mm}$.

1. Use Fig. 5.2 to determine the wavelength λ of the light.

42.2 mm is 10 fringe spacings: $x = 42.2 / 10 = 4.22\text{ mm}$

$$\lambda = ax / D = (0.56 \times 10^{-3} \times 4.22 \times 10^{-3}) / 4.50$$

$$\lambda = 5.25 \times 10^{-7}\text{ m}$$

$$\lambda = \dots\dots\dots 5.25 \times 10^{-7} \dots\dots\dots \text{ m [3]}$$

2. Determine the percentage uncertainty in λ .

$$\% \text{ uncertainty in } D = (0.02 / 4.50) \times 100 = 0.44 \%$$

$$\% \text{ uncertainty in } a = (0.02 / 0.56) \times 100 = 3.57 \%$$

$$\% \text{ uncertainty in } x = (0.2 / 42.2) \times 100 = 0.47 \%$$

$$\% \text{ uncertainty in } \lambda = 0.44 + 3.57 + 0.47 = 4.5 \%$$

$$\text{percentage uncertainty} = \dots\dots\dots 4.5 \dots\dots\dots \% [2]$$

- (c) The power of the green light from the laser pen is 50.0 mW. It is now used in a demonstration of the photoelectric effect.

- (i) Calculate the number of photons n that the laser emits per second.

$$\text{photon energy } E = hc/\lambda$$

$$E = (6.63 \times 10^{-34} \times 3.00 \times 10^8) / 5.25 \times 10^{-7}$$

$$E = 3.79 \times 10^{-19} \text{ J}$$

$$n = P / E = 50.0 \times 10^{-3} / 3.79 \times 10^{-19} = 1.3 \times 10^{17}$$

$$n = \dots\dots\dots 1.3 \times 10^{17} \text{ s}^{-1} \dots\dots\dots [2]$$

- (ii) The green light falls on a negatively charged metal plate with a work function of 2.6 eV. Explain whether photoelectrons will be emitted.

$$\text{Work function} = 2.6 \times 1.60 \times 10^{-19} = 4.16 \times 10^{-19} \text{ J. Each photon}$$

$$\text{has energy } 3.79 \times 10^{-19} \text{ J (2.37 eV).}$$

The photon energy is less than the work function, so no photoelectrons

will be emitted.

[2]

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Question 6 begins on page 20

- 6 (a) Describe how a stationary wave is different from a progressive wave.

A progressive wave transfers energy in the direction of the wave and all points have the same amplitude. A stationary wave has no net energy transfer (energy is stored) and has nodes where the amplitude is always zero, so points have different amplitudes. [2]

- (b)* A student is investigating stationary waves in a hollow tube. The tube is open at one end and closed at the other end. The student connects a signal generator to a loudspeaker which is placed just above the tube as shown in Fig. 6.

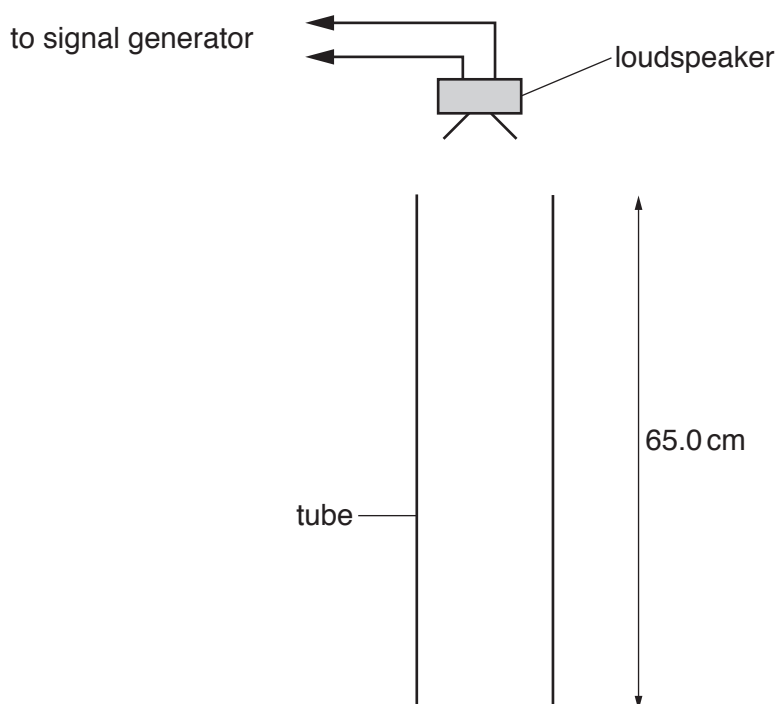


Fig. 6

The length of the tube is 65.0 cm.

As the frequency of the signal generator is slowly increased from 0 Hz the student observes sound that varies in loudness. The loudest sound occurs at frequencies 130 Hz, 390 Hz and 650 Hz.

The experiment is then repeated with a hollow tube of the **same** length but open at both ends. The loudest sound now occurs at frequencies 260 Hz, 520 Hz and 780 Hz.

Using your knowledge and understanding of stationary waves explain these observations. Include in your answer how you could determine an experimental value for the speed of sound in air.

The sound wave from the loudspeaker travels down the tube and is reflected at the end. The incident and reflected waves, with the same frequency and speed, superpose (interfere) to form a stationary wave. At

certain frequencies a stationary wave fits the tube exactly (resonance) and the sound is loudest.

The air particles oscillate longitudinally, parallel to the length of the tube.

At nodes the amplitude is zero and at antinodes it is a maximum. There must be a node at a closed end (the air cannot move) and an antinode at an open end.

Closed tube: the fundamental frequency (1st harmonic) has a node at the closed end and an antinode at the open end, so $L = \lambda/4$ and $\lambda = 4 \times 0.650 = 2.60$ m at 130 Hz. The next resonances have $L = 3\lambda/4$ and $L = 5\lambda/4$, so only odd harmonics occur: $3 \times 130 = 390$ Hz and $5 \times 130 = 650$ Hz.

Open tube: there is an antinode at each end, so the fundamental (1st harmonic) has $L = \lambda/2$ and $\lambda = 2 \times 0.650 = 1.30$ m at 260 Hz. All harmonics occur: $2 \times 260 = 520$ Hz and $3 \times 260 = 780$ Hz.

Speed of sound: $v = f\lambda$. Closed tube: $v = 130 \times 2.60 = 338$ m s⁻¹, and $390 \times (4 \times 0.650 / 3) = 338$ m s⁻¹. Open tube: $v = 260 \times 1.30 = 338$ m s⁻¹. To find v experimentally, measure L with a metre rule, find the frequencies of the loudest sounds on the signal generator, work out λ from L for each harmonic and calculate $v = f\lambda$ for each and average; or plot f against $1/\lambda$, where the gradient = v . This gives $v = 338$ m s⁻¹.

[6]

END OF QUESTION PAPER

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