



AS Level Physics B (Advancing Physics)

H157/02 Physics in depth

Time allowed: 1 hour 30 minutes

You must have:

- the Data, Formulae and Relationships Booklet

You can use:

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



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

Centre number

--	--	--	--	--

Candidate number

--	--	--	--

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 a correct method, even if your answer is wrong.

INFORMATION

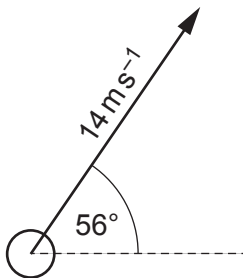
- The total mark for this paper is **70**.
- The marks for each question are shown in brackets [].
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **20** pages.

ADVICE

- Read each question carefully before you start your answer.

Section A

- 1 A ball is thrown with an initial speed of 14 ms^{-1} at an angle of 56° to the horizontal, as shown in the diagram. The ball leaves the thrower's hand at a vertical distance of 1.7 m above the ground.



- (a) Write down the horizontal and vertical components of velocity of the ball at the instant it is thrown.

horizontal component, $u_H = \dots 7.83 \dots \text{ ms}^{-1}$

vertical component, $u_V = \dots 11.6 \dots \text{ ms}^{-1}$ [2]

- (b) Calculate the maximum height above the ground reached by the ball. You can assume that air resistance is negligible.

$$\text{At max height } v_V = 0: v_V^2 = u_V^2 + 2as$$

$$s = u_V^2 \div 2g = 11.6^2 \div (2 \times 9.81) = 6.86 \text{ m}$$

$$\text{height} = 6.86 + 1.7 = 8.56 \text{ m}$$

height = $\dots 8.6 \dots \text{ m}$ [2]

- (c) Calculate the horizontal distance between the point where the ball is thrown and the point where it reaches its maximum height.

$$\text{time to max height } t = u_V \div g = 11.6 \div 9.81 = 1.18 \text{ s}$$

$$\text{distance} = u_H \times t = 7.83 \times 1.18 = 9.24 \text{ m}$$

distance = $\dots 9.2 \dots \text{ m}$ [2]

- 2 A light-emitting diode (LED) emits monochromatic blue light of wavelength 470 nm. Each photon emitted is produced by a single electron crossing the LED.

(a) Calculate the work done by an electron in the LED as one photon of blue light is emitted.

$$f = c/\lambda = 3.0 \times 10^8 \div 470 \times 10^{-9} = 6.38 \times 10^{14} \text{ Hz}$$

$$W = E = hf = 6.63 \times 10^{-34} \times 6.38 \times 10^{14} = 4.23 \times 10^{-19} \text{ J}$$

$$\text{work done} = \dots 4.23 \times 10^{-19} \dots \text{ J [2]}$$

(b) Explain why a p.d. of 2.60 V across the LED would **not** result in the emission of light.

*To emit a photon the p.d. must be at least $V = W/Q = 4.23 \times 10^{-19} \div 1.60 \times 10^{-19} = 2.64 \text{ V}$.
2.60 V is less than 2.64 V, so it does not supply each electron with enough energy (eV) to emit a photon.* [2]

(c) In use, the LED draws an electric current of 30 mA.

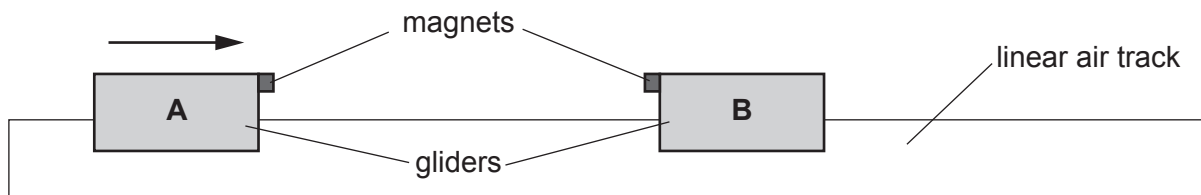
Calculate the number of photons emitted each second, assuming that the energy efficiency of a blue LED is 93%.

$$\text{electrons per second} = I/e = 30 \times 10^{-3} \div 1.60 \times 10^{-19} = 1.875 \times 10^{17} \text{ s}^{-1}$$

$$\text{photons per second} = 0.93 \times 1.875 \times 10^{17} = 1.74 \times 10^{17} \text{ s}^{-1}$$

$$\text{number per second} = \dots 1.74 \times 10^{17} \dots \text{ s}^{-1} \text{ [2]}$$

- 3 The diagram shows a linear air track with two gliders **A** and **B**, with different masses, which move on the track with negligible friction. The gliders each carry a magnet arranged to repel the other glider when they approach. Initially, glider **A** moves towards glider **B**, which is stationary, as shown.



The velocity V_A of glider **A** varies with time t as shown in the graph.



- (a) Calculate the velocity v_B of glider **B** after the impact.

Mass of glider **A** = 160 g

Mass of glider **B** = 120 g

$$\text{momentum before} = p_A = 0.160 \times 1.5 = 0.24 \text{ N s}$$

$$\text{after: } 0.24 = 0.160 \times 0.4 + p_B = 0.064 + p_B$$

$$p_B = 0.24 - 0.064 = 0.176 \text{ N s}$$

$$v_B = 0.176 \div 0.120 = 1.47 \text{ m s}^{-1}$$

$$v_B = \dots 1.47 \dots \text{ ms}^{-1} \text{ [3]}$$

- (b) Calculate the mean force exerted on glider **B** by glider **A** during the impact.

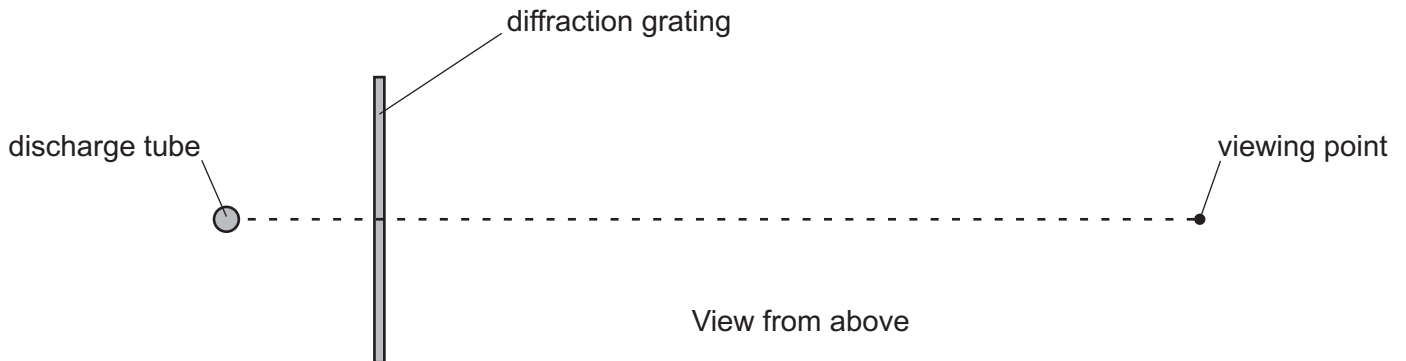
$$\text{impact lasts from } t = 2.8 \text{ s to } 3.0 \text{ s, } \Delta t = 0.2 \text{ s}$$

$$F = \Delta p / \Delta t = 0.176 \div 0.2 = 0.88 \text{ N}$$

$$\text{mean force} = \dots 0.88 \dots \text{ N [1]}$$

- 4 A diffraction grating has 300 lines per mm. It is to be used to measure the wavelengths of light emitted by a discharge tube, where a high voltage causes a low-pressure gas to emit light.

The diagram shows a plan view of the diffraction grating (the grating lines run down into the plane of the diagram) mounted near the discharge tube perpendicular to the light emitted by the tube.



A student looking towards the discharge tube from the viewing point sees several vertical bright lines. In the direction of the tube there is the zero-order spectral line. To left and right of the zero-order there are also several red- and blue-coloured lines.

- (a) (i) State why the zero-order spectral line is a different colour from the other lines.

At the zero order there is no path difference between waves from adjacent slits, so all wavelengths arrive in phase (constructive superposition) at the same place. So the zero-order line is the combination of all the wavelengths emitted by the tube, whereas in the other orders the path difference for a maximum depends on wavelength, so the colours are separated. [2]

- (ii) State why the first-order blue spectral lines are closer to the zero-order line than the first-order red lines.

Blue light has a shorter wavelength than red, and from $n\lambda = d \sin \theta$ a smaller λ gives a smaller $\sin \theta$, so a smaller angle θ . [1]

- (b) Describe how the student could determine the wavelength of the blue light emitted by the discharge tube.

Measure the angle θ between the first-order blue line and the zero-order line; e.g. mark the apparent positions of the zero-order line and the blue line on a screen or bench, measure the distances with a ruler and use trigonometry ($\tan \theta = x/L$), or use a protractor.

$d = 1 \div 300\,000 \text{ lines per m} = 3.33 \times 10^{-6} \text{ m}$.

Then use $n\lambda = d \sin \theta$ with $n = 1$ to find $\lambda = d \sin \theta$ (repeat for the lines on both sides and average).

[3]

- 5 Wirewound resistors are used where a high level of power has to be dissipated. A typical wirewound resistor consists of a coil of nichrome wire of uniform cross-section wound on a ceramic core.

- (a) Calculate the length L of nichrome wire of diameter 0.508 mm required to give a resistance of 15 Ω .

electrical resistivity of nichrome = $1.10 \times 10^{-6} \Omega \text{ m}$

$$A = \pi r^2 = \pi \times (0.254 \times 10^{-3})^2 = 2.03 \times 10^{-7} \text{ m}^2$$

$$R = \rho L / A \text{ so } L = RA / \rho$$

$$L = 15 \times 2.03 \times 10^{-7} \div 1.10 \times 10^{-6} = 2.76 \text{ m}$$

$$L = \dots 2.76 \dots \text{ m [2]}$$

- (b) The resistance of the resistor must be accurate to within $\pm 0.1 \Omega$.

Calculate the maximum uncertainty ΔL which can be allowed in the length measurement.

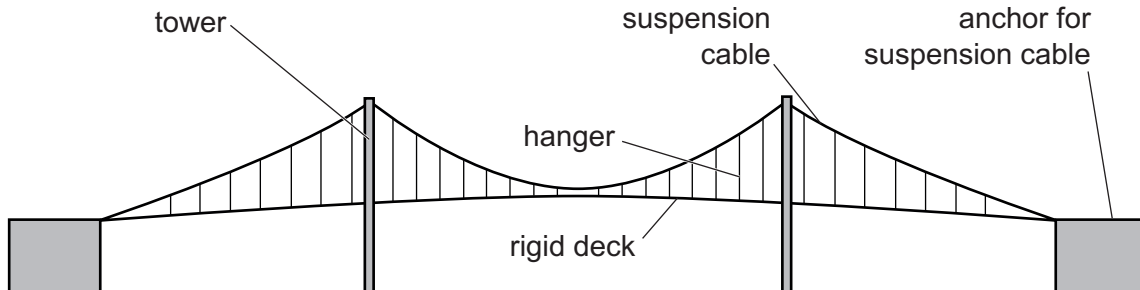
$$\Delta L / L = \Delta R / R = 0.1 \div 15 = 6.67 \times 10^{-3}$$

$$\Delta L = 6.67 \times 10^{-3} \times 2.76 = 0.018 \text{ m}$$

$$\Delta L = \dots 0.018 \dots \text{ m [2]}$$

Section B

- 6 This question is about the stresses in vertical cables ('hangers') used to support the rigid deck of a suspension bridge and the vehicles it carries. The hangers are attached to suspension cables which are firmly anchored at each end of the bridge and pass over two supporting towers as shown below.



- (a)* The suspension cables and the hangers are made from steel, but the towers of suspension bridges are made from concrete. The rigid deck is made from steel covered with concrete and is stiffened by steel girders.

Give reasons for these choices in terms of the behaviour of steel and of concrete under tensile and compressive stress and other factors which may affect the material choices.

The hangers, the suspension cables and the deck are under tension (tensile stress), while the towers are under compression (compressive stress), as they carry the weight pushing down on them.

Steel is strong and tough: it behaves similarly under tension and compression, so it can be used for the hangers and cables. Being tough (ductile) it does not fail suddenly; cracks do not spread easily.

Concrete is strong under compression but weak under tension because it is brittle; under tension cracks propagate through it and it fails suddenly. Brittle failure could make the bridge collapse, so concrete is only used where it is under compression, i.e. the towers.

Concrete is relatively cheap and can be poured into moulds in situ, which suits the large towers, while steel is expensive and must be made to fit. The deck uses concrete on steel, stiffened by steel girders (reinforced), so the steel takes the tension, keeping the deck rigid, stable and safe. [6]

- (b) A suspension bridge has a rigid deck supported by 500 steel hangers of circular cross-section.

Length of bridge between the two anchors = 2.7 km

Diameter of each hanger = 0.32 m

Mass of rigid deck = 1.4×10^8 kg

Yield stress of steel in hangers = 2.7×10^9 Pa

Young modulus of steel, $E = 2.1 \times 10^{11}$ Pa

- (i) Use the data above to show that the tensile stress in the hangers is less than 2 % of their yield stress. You can assume the load is evenly shared between the hangers.

$$\text{weight per hanger } F = mg/500 = 1.4 \times 10^8 \times 9.81 \div 500 = 2.75 \times 10^6 \text{ N}$$

$$A = \pi(0.32/2)^2 = 0.0804 \text{ m}^2$$

$$\text{stress } \sigma = F/A = 2.75 \times 10^6 \div 0.0804 = 3.42 \times 10^7 \text{ Pa}$$

$$\sigma / \text{yield stress} = 3.42 \times 10^7 \div 2.7 \times 10^9 = 0.0127 = 1.27 \%$$

1.27 % is less than 2 % of the yield stress.

[3]

- (ii) The maximum number of vehicles allowed on this bridge at any one time would give an additional load of 6000 kg per metre length of the suspended deck.

Calculate the ratio $\frac{\text{mean hanger stress with the maximum load on the bridge}}{\text{mean hanger stress with no vehicles on the bridge}}$ to an

appropriate number of significant figures.

$$\text{additional weight} = 2700 \times 6000 \times 9.81 = 1.59 \times 10^8 \text{ N}$$

$$\text{weight per hanger} = 2.75 \times 10^6 + 1.59 \times 10^8 \div 500 = 3.07 \times 10^6 \text{ N}$$

$$\sigma_{\text{max}} = 3.07 \times 10^6 \div 0.0804 = 3.82 \times 10^7 \text{ Pa}$$

$$\text{ratio} = 3.82 \times 10^7 \div 3.42 \times 10^7 = 1.117$$

2 s.f., as in the raw data, so ratio = 1.1

ratio = ...1.1..... [3]

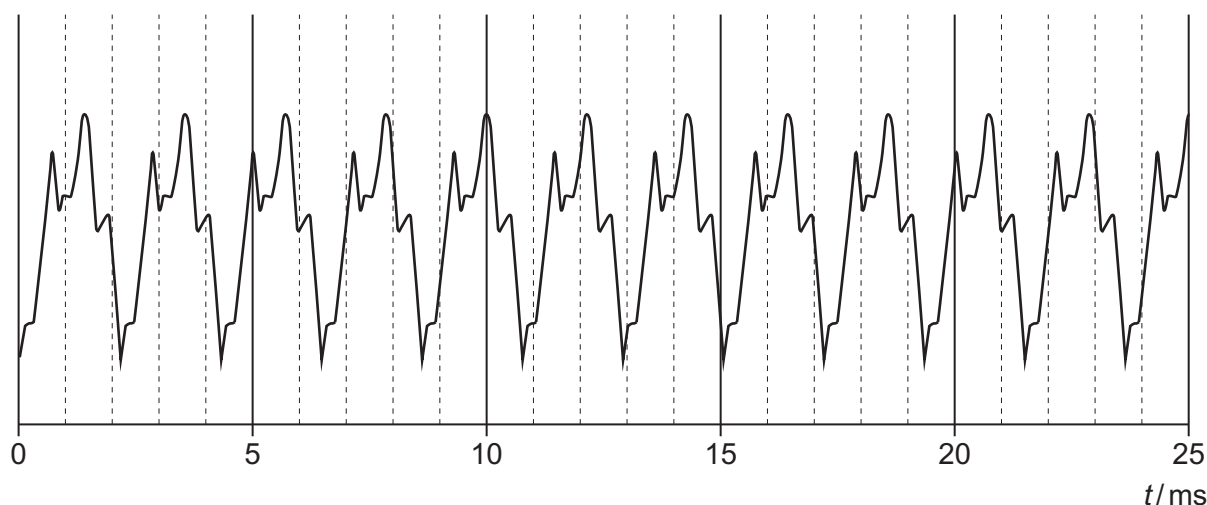
- (iii) Suggest **two** reasons why the maximum number of vehicles allowed on the bridge is less than the theoretical number based on calculations of stress.

1. Some lorries may be very heavily loaded, much more than the average load assumed.....
2. Wind loading may put an additional force on the hangers (or traffic may stop and queue closer together)..... [2]

7 This question is about recording music.

(a) Fig. 7.1 shows an oscilloscope trace of a musical note played by a clarinet.

Fig. 7.1



- (i) Use data from Fig. 7.1 to make as accurate an estimate as possible of the frequency f of the musical note together with the uncertainty Δf of the value. Show your working clearly.

$$11 \text{ complete cycles take } 23.7 \text{ ms, so } T = 23.7 \div 11 = 2.15 \times 10^{-3} \text{ s}$$

$$f = 1/T = 1 \div 2.15 \times 10^{-3} = 465 \text{ Hz}$$

$$\text{uncertainty in reading } 11T = \pm 0.1 \text{ ms, so } T_{\max} = 23.8 \div 11 = 2.163 \text{ ms}$$

$$f_{\min} = 1 \div 2.163 \times 10^{-3} = 462 \text{ Hz, } \Delta f = 465 - 462 = 3 \text{ Hz}$$

frequency, $f \pm \Delta f = \dots\dots\dots 465 \dots\dots\dots \pm \dots\dots\dots 3 \dots\dots\dots \text{ Hz [4]}$

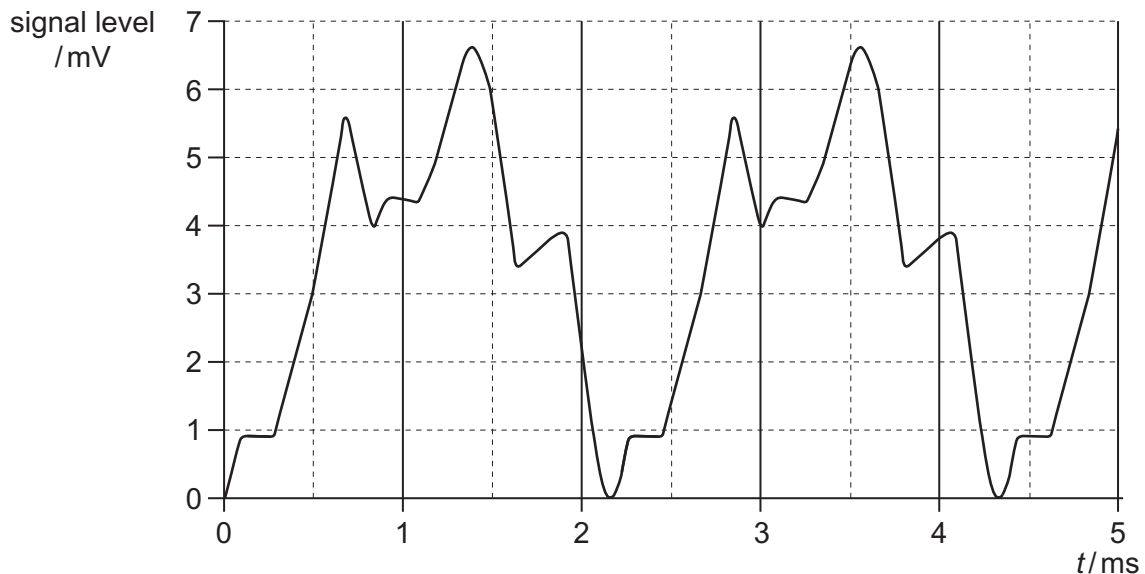
- (ii) Describe and explain the feature of Fig. 7.1 which shows that this musical note contains more than one frequency.

*A single frequency gives a sine wave, but this trace has repeating
irregularities (peaks of different heights), so harmonics are present: the
irregularities fluctuate at a greater frequency than the pattern repeats.*

[2]

- (b) The analogue signal of Fig. 7.1 is to be recorded and stored digitally. Fig. 7.2 shows the beginning of the signal in greater detail.

Fig. 7.2



It is suggested that this signal should be digitised using eight voltage-levels (0 – 7 mV) with the signal being sampled every 0.25 ms.

- (i) Explain how the eight voltage levels illustrated can be encoded with a three-bit binary number and give the binary code which would represent a value of 3 mV.

3 bits give $2^3 = 8$ different codes (000 to 111), one for each 1 mV level from 0 to 7 mV. At each sampling time the value recorded is the level nearest below the true value.

binary code: 011 [3]

- (ii) Explain why the audio signal produced from this code will sound different from the original clarinet note.

Only 8 distinct levels and samples every 0.25 ms, so the curve is smoothed and detail is lost; the signal will have different harmonics (high frequencies are missed). [2]

- (c) A piece of music for solo clarinet lasts for 1 minute and 39 seconds. Assuming that it is digitised with eight voltage levels (3-bit coding) sampled every 0.25 ms, calculate the number of bytes of memory required to store the piece.

$$\text{number of samples} = 99 \text{ s} \div 0.25 \times 10^{-3} \text{ s} = 396\,000$$

$$\text{bits} = 396\,000 \times 3 = 1\,188\,000 \text{ bits}$$

$$\text{bytes} = 1\,188\,000 \div 8 = 148\,500$$

$$\text{number of bytes} = \dots 148\,500 \dots [2]$$

- (d) A commercial download of the music described in (c) is a stereophonic (two-channel) recording sampled at 44.1 kHz with 8-bit coding. Calculate the time taken to download the piece of music at a download rate of 65 Mbits⁻¹.

$$\text{samples} = 99 \times 44\,100 = 4.37 \times 10^6 \text{ per channel}$$

$$\text{bits} = 2 \times 8 \times 4.37 \times 10^6 = 6.99 \times 10^7 \text{ bits}$$

$$t = 6.99 \times 10^7 \div 65 \times 10^6 = 1.07 \text{ s}$$

$$\text{time} = \dots 1.07 \dots \text{ s } [2]$$

15
BLANK PAGE

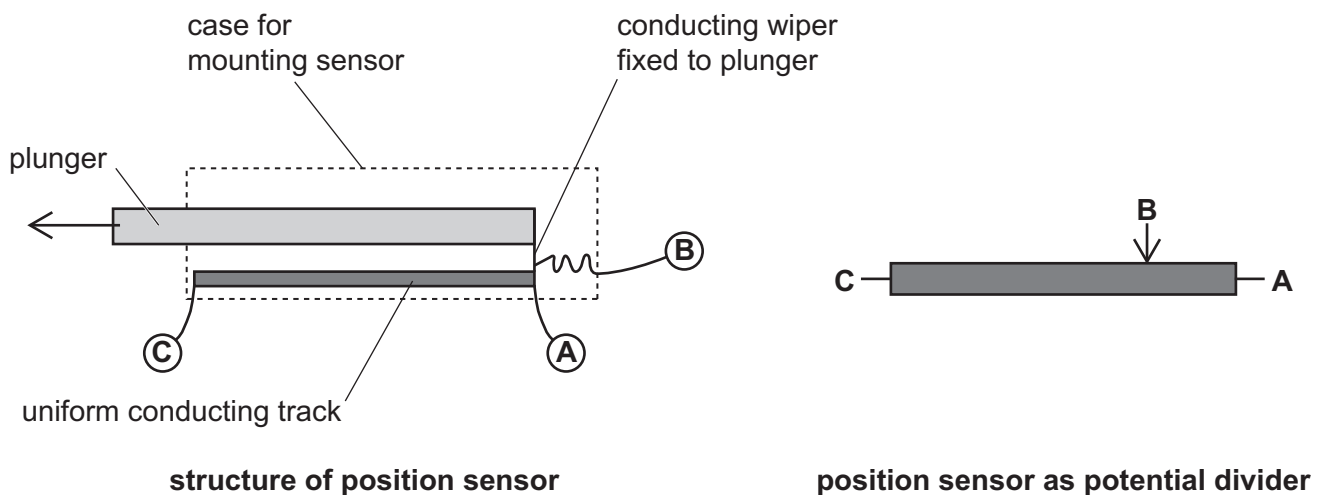
PLEASE DO NOT WRITE ON THIS PAGE

Section C

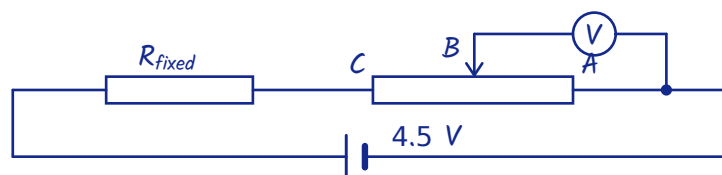
- 8 Alex is planning an investigation which requires measurement of position which changes slowly with time.

Alex decides to use a position sensor to monitor the changes. This sensor is a linear potential divider as shown in **Fig. 8.1**. As the plunger moves through its complete range, the conducting wiper moves from **A** to **C**.

Fig. 8.1



- (a) The position sensor is connected in series with a fixed resistor R_{fixed} and a battery of emf 4.5V and negligible internal resistance. The p.d. V_{AB} across the portion of the position sensor between the end **A** of position sensor and the conducting wiper **B** is measured with a voltmeter of very high resistance. The total resistance of the track **AC** is 10 k Ω .
- (i) Draw and label fully the circuit diagram described above.



[2]

- (ii) The p.d. V_{AB} is to be used to calculate the resistance of the active length **AB** of the sensor. Explain why the voltmeter should have a resistance much higher than R_{fixed} .

The voltmeter is in parallel with AB, so the resistance between A and B is a parallel combination; a lower resistance meter would draw a significant current and make the response non-linear.

[2]

- (b) Alex calibrates the sensor using a 30 cm metal rule with divisions every 1 mm and a voltmeter of resolution 1 mV.

He records the reading V_{AB} at various displacements d of the plunger from its position of minimum resistance and obtains the following readings.

d/mm	0	2	5	8	11	15	20	25	32	40	48
V_{AB}/V	0.00	0.82	1.61	2.12	2.47	2.81	3.10	3.31	3.51	3.68	3.80

- (i) Alex did not take readings of V_{AB} at uniform intervals of d .
By referring to the data in the table, explain why this was an appropriate decision.

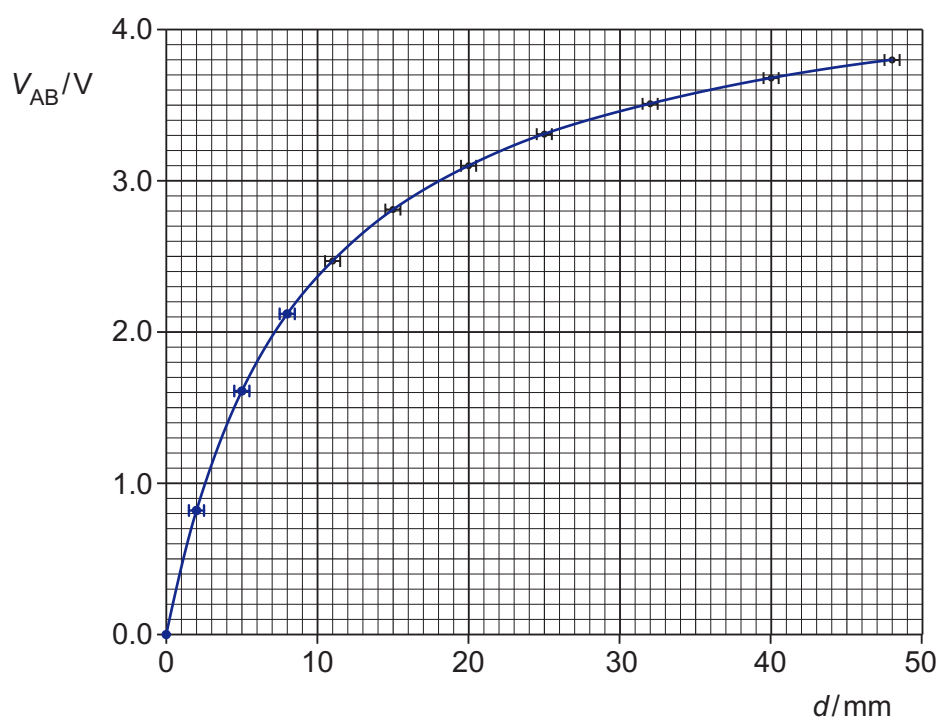
The relationship between d and V_{AB} is non-linear. V_{AB} changes rapidly for small d and slowly for large d , so more readings at small d show the trend better (ΔV_{AB} between readings is similar). [2]

- (ii) Alex rounded the p.d. values to the nearest 10 mV. By comparing the precision available in the two measuring instruments, state why this was appropriate.

The ruler's uncertainty is about 0.5 mm in 150 mm (1/300), whereas even rounded to 10 mV the voltmeter gives 10 mV in 3.5 V (1/350), so it is still more precise than the ruler. [1]

- (c) Use data from the table in (b) to complete the graph of Fig. 8.2 below.

Fig. 8.2



[2]

- (d)* Alex repeats the calibration, using the same position sensor and the same battery, and obtains the data in the following table.

d/mm	0	2	5	8	11	15	20	30	50
V_{AB}/V	0.00	0.30	0.68	1.00	1.27	1.57	1.88	2.33	2.88

Explain the difference from the circuit which gave the data used in **Fig. 8.2**, and evaluate the change in the performance of the sensor circuit produced.

The same sensor and battery were used, so the difference is the value of R_{fixed} : the repeat used a higher resistance. When $V_{AB} = 2.25 \text{ V}$ (half the 4.5 V emf), R_{fixed} equals the resistance of segment AB.

First set: $V_{AB} = 2.25 \text{ V}$ at about $d = 9 \text{ mm}$, so $R_{\text{fixed}} \approx (9/50) \times 10 \text{ k}\Omega = 1800 \Omega$. Repeat: 2.25 V at a bit under 30 mm, so $R_{\text{fixed}} \approx (29/50) \times 10 \text{ k}\Omega = 5800 \Omega$.

In the first set V_{AB} changes rapidly near $d = 0$ and then very slowly near $d = 50 \text{ mm}$ (from 40 to 48 mm only 0.12 V), so the graph is very non-linear. The sensitivity (gradient dV/dd) is very small at large d , so small movements there are hard to resolve.

In the repeat V_{AB} changes much more uniformly with d (about 0.15 V per mm at first and still about 0.03 V per mm near 50 mm), giving a greater range of useful p.d.s across the movement.

Evaluation: a more linear response of V_{AB} with d means the position can be identified with more consistent resolution over the whole range and calibration is easier, so the higher value of R_{fixed} produced a better sensor circuit, although the sensitivity near $d = 0$ is lower.

[6]

END OF QUESTION PAPER

This image shows a blank sheet of white paper designed for handwriting practice. It features a solid vertical line on the left side, creating a narrow margin. The rest of the page is filled with evenly spaced horizontal dashed lines, providing guides for letter height and placement. There are no other markings or text on the page.

Copyright Information

If OCR has unwittingly failed to correctly acknowledge or clear any third-party content in this assessment material, OCR will be happy to correct its mistake at the earliest possible opportunity.

OCR is part of Cambridge University Press & Assessment, which is itself a department of the University of Cambridge.

stemup.co.uk