

SAMPLE

This is a real A Level Paper 4 I marked for a student, shown as they got it back, in their own handwriting. The only change is that their name is removed. Every mark and note is what they received.

YOUR OWN PAPER

Want yours marked like this? It's from £25 a paper at cieinsider.com/marked. The last page explains how it works.

Here's your Paper 4.

9702/44, May/June 2026 (Paper 4, Variant 4). Marked against Cambridge's published mark scheme for that paper, the way I marked scripts for Cambridge.

61 / 100

YOUR MARK

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
8/10	3/10	5/9	10/13	7/9	8/9	9/14	3/11	3/8	5/7

The one thing I'd fix before your next Paper 4

Answer every part, and take the quick marks first. You left 12 marks blank, and they weren't at the end of the paper. You skipped them and carried on:

- **2(a)(ii)**, 2 marks: two properties of a geostationary orbit. Recall, about 30 seconds. (note 3)
- **3(c)**, 2 marks: a better way to measure the water's temperature. (note 8)
- **8(a)(iii)** and **8(b)(i)**, 6 marks: the photon model and the Planck constant. (notes 16, 17)
- **9(b)(ii)**, 2 of the 3 conclusions. (note 20)

On this paper the grade boundaries were 10 marks apart, so the blanks alone were worth more than a grade. On a 2-hour paper, do a first pass that collects every definition and recall mark, then go back for the long calculations.

The second pattern is **the last step**. In 2(c) the orbit radius is $R + h$, in 8(b)(ii) you still had to convert J to eV, in 10(b)(iii) you needed the square root, and in 4(c)(i) Q is the *change* in U. You knew the physics each time and stopped one line short.

Where the other marks went

The blue numbers match the blue circles on your script.

1 **1(c)** 2 MARKS

The radius is right. Once the potential energy decreases, the electron is closer to the proton. The force goes as $1/r^2$, so a smaller r means a bigger force and the acceleration **increases**. And because $a = \omega^2 r$, $\omega^2 = a/r$, which also goes up, so the angular speed **increases** too.

2 **2(a)(i)** 1 MARK

What you wrote is a property of the orbit: its period matches the Earth's rotation. That's what 2(a)(ii) asks for. The meaning is what the matching period gives you: the satellite **stays above the same point on the Earth's surface**.

3 **2(a)(ii)** 2 MARKS

Left blank. Any two of: the orbit is **equatorial**, it goes **west to east** (the same way the Earth turns), and its **period is 24 hours**. Your answer to 2(a)(i) was one of these, so it would have scored here.

4 **2(b)(ii)** 1 MARK

In a show-that, the step the mark is on has to be written down. You went from $GM/R^2 = \omega^2 R$ straight to $GM = 4\pi^2 R^3/T^2$. Write $\omega = 2\pi/T$, substitute it, then rearrange.

5 2(c) 3 MARKS

The orbit radius is measured from the centre of the Earth, so $R = 6370 + 35\,900 = \mathbf{42\,270\text{ km}}$. The 35 900 km is the height above the surface. With that R the density comes out at $\mathbf{5530\text{ kg m}^{-3}}$. Your arithmetic from your own numbers was right: 3390 follows from $R = 35\,900\text{ km}$.

The volume mark needs the Earth's radius in metres: $V = \frac{4}{3}\pi(6.37 \times 10^6)^3$. Working in km happened to cancel in your final division, but the volume you wrote down is not the Earth's volume in m^3 , and that is what the mark is for. Convert to SI at the start and every intermediate value earns its mark.

6 3(a) 1 MARK

Zero net energy transfer earned one mark. The other is for saying the two objects are at the **same temperature**.

7 3(b)(i) 1 MARK

You said where the energy goes, but not what that does to the water. The thermistor takes thermal energy from the water, so **the water cools**. That's why the reading is $76.8\text{ }^\circ\text{C}$ and not $78.0\text{ }^\circ\text{C}$: the thermistor is measuring a temperature it has lowered itself.

8 3(c) 2 MARKS

Left blank. Use a **thermocouple** or a smaller thermistor. It has less mass, so it takes less thermal energy from the water. Or **warm the thermistor** to about $78\text{ }^\circ\text{C}$ before you put it in. Both marks have to come from the same method.

9 4(c)(i) 1 MARK

You're right that no work is done. But the first law gives $Q =$ the **change** in U , not U . At constant volume U is proportional to T , and T is proportional to p , so $U_B = (5.84/1.84)U_A$ and $Q = U_B - U_A = \mathbf{2.2U_A}$.

10 4(c)(ii) 2 MARKS

In BC there is no *thermal energy transfer*. That doesn't mean there's no change in internal energy. With no heat in or out, the change in U equals the work done on the gas. At C the pressure is back to $1.84 \times 10^5\text{ Pa}$ and the volume has doubled (0.160 against 0.0800 m^3), so $U_C = 2U_A$. From note 9, $U_B = 3.2U_A$, so $W = 2U_A - 3.2U_A = \mathbf{-1.2U_A}$. No heat transfer is not the same thing as a constant temperature.

11 5(a)(ii) 2 MARKS

A show-that needs numbers, and you only gave symbols. Use $v_0 = \omega x_0$ with $\omega = 2\pi f$: $f = v_0/(2\pi x_0) = 4.4/(2\pi \times 2.5) = \mathbf{0.28\text{ Hz}}$. Your rearrangement $f = vr/2\pi$ also has the r on the wrong line.

12 6(b) 1 MARK

The flat sections and the minimum at about 0.53 V are right. But a capacitor discharging through a resistor doesn't fall in a straight line. It's an **exponential curve**, steep at first and getting less steep.

13 7(a) 1 MARK

The mark needs the direction to reverse **regularly** (periodically, repeatedly). Switching direction once doesn't make an alternating current.

14 7(b) 2 MARKS

Your field shape is good. The direction is reversed, though. Apply the right-hand grip rule to the current shown and the field inside points **from right to left**. So every arrow goes the other way, and **N is on the left**, S on the right. One reversed rule cost both marks.

15 7(d)(ii) 2 MARKS

Faraday's law is right, and it earned a mark. What's missing is the method. Draw a **tangent at the steepest part** of the curve to get the largest rate of change of B . Then maximum e.m.f. = **steepest gradient $\times$ area $\times$ number of turns**. Watch the wording as well: the e.m.f. depends on the gradient itself, not on a change in the gradient.

16 8(a)(iii) 3 MARKS

Left blank. Any three of: an electron needs a minimum energy to leave the surface; the photon it absorbs must have at least that much energy; a photon's energy is proportional to its frequency ($E = hf$); so a minimum energy means a **minimum frequency**.

17 8(b)(i) 3 MARKS

$E = hc/\lambda$ is where to start, but you're given two wavelengths and two kinetic energies. Write $hc/\lambda = \Phi + E_K$ for each one, then subtract to get rid of Φ : $h \times 3.00 \times 10^8 \times (1/178 \times 10^{-9} - 1/254 \times 10^{-9}) = (5.27 - 1.91) \times 10^{-19}$. That gives $h = \mathbf{6.66 \times 10^{-34} \text{ J s}}$. Quoting 6.63 from the data sheet earns nothing here.

18 8(b)(ii) 2 MARKS

Your working is right up to 5.92×10^{-19} , but that value is in joules. The question asks for eV, so divide by 1.60×10^{-19} to get **3.7 eV**.

19 9(a) 2 MARKS

You got the mark for the supply being **alternating**. The first mark is for a **p.d.** (a voltage) across the crystal making it change shape. You wrote current, and it's the p.d. across the crystal that makes it distort, not a current through it. The last mark is for what the crystal then does: it vibrates at ultrasound frequency and makes the medium next to it oscillate. "Pulses sent into the body" doesn't explain how the wave is made.

20 9(b)(ii) 3 MARKS

The gradient changes at $x = 5.0 \text{ cm}$ and $x = 7.0 \text{ cm}$, so Y is **2.0 cm** thick, not 1 cm. The gradients give you two more conclusions: attenuation coefficients of **3.2 cm^{-1}** for X and **1.5 cm^{-1}** for Y . Each conclusion needs a value and a unit.

21 10(a)(ii) 1 MARK

Radiant flux is a power. What's measured here is the **radiant flux intensity** (power per unit area), and the mark needs it named correctly.

22 10(b)(iii) 1 MARK

$L = 4\pi r^2 \sigma T^4$ is right, but your expression is r^2 . The radius needs the **square root**: $r = \sqrt{(L / 4\pi \sigma T_{\text{star}}^4)}$.

Marks you got, but I'd tighten the wording

These scored, but only just. Here's the version that makes each one safe.

A 5(a)(i)

Your loop comes to points at $x = \pm 2.5 \text{ cm}$. The mark scheme didn't penalise that, but for simple harmonic motion the v - x graph is an **ellipse**: $v = \pm \omega \sqrt{(x_0^2 - x^2)}$, so the curve meets the x -axis vertically. Draw it smooth and rounded at both ends.

B 7(d)(i)

You wrote $NB \times 2\pi r^2$, then substituted πr^2 . The substitution is what scored. Had you used the $2\pi r^2$ you'd written, the answer would have been double and the mark gone. The coil's area is **πr^2** , so write the formula you actually use.

C 7(d)(ii)

Your Faraday's law sentence scored, and it stood because the wrong sentence after it didn't contradict it. Don't rely on that. Write only the correct version:

Draw a tangent to Fig. 7.2 where the curve is steepest and find its gradient: this is the maximum rate of change of B. Maximum e.m.f. = steepest gradient $\times$ area $\times$ number of turns, because by Faraday's law the e.m.f. equals the rate of change of flux linkage.

D 9(a)

You scored one of three. The full answer is three short sentences, one per mark:

A p.d. applied across the piezoelectric crystal makes it change shape. The p.d. is alternating, so the crystal vibrates. It vibrates at ultrasound frequency, and its vibrations make the medium next to it oscillate.

Reading the marks on your script

- ✓ Mark awarded, placed where you earned it
- ✓ In a calculation, all the ticks go by the final answer
- ✗ Not awarded
- ^ Something the mark needed is missing here
- 2/2 Your mark for that part

Good luck with the real one.

Rich

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DFD

CAMBRIDGE
International Education

Cambridge International AS & A Level

CANDIDATE
NAMECENTRE
NUMBER

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CANDIDATE
NUMBER

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PHYSICS

9702/44

Paper 4 A Level Structured Questions

May/June 2026

2 hours

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen. Do **not** use correction fluid or tape.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 100.
- The number of marks for each question or part question is shown in brackets [].

This document has **24** pages. Any blank pages are indicated.

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2

Data

acceleration of free fall	$g = 9.81 \text{ m s}^{-2}$
speed of light in free space	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
unified atomic mass unit	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27} \text{ kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $(\frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ m F}^{-1})$
Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
Stefan–Boltzmann constant	$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
hydrostatic pressure	$\Delta p = \rho g \Delta h$
upthrust	$F = \rho g V$
Doppler effect for sound waves	$f_o = \frac{f_s v}{v \pm v_s}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \dots$
resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$



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gravitational potential

$$\phi = -\frac{GM}{r}$$

gravitational potential energy

$$E_p = -\frac{GMm}{r}$$

pressure of an ideal gas

$$p = \frac{1}{3} \frac{Nm}{V} \langle c^2 \rangle$$

simple harmonic motion

$$a = -\omega^2 x$$

velocity of particle in s.h.m.

$$v = v_0 \cos \omega t$$

$$v = \pm \omega \sqrt{(x_0^2 - x^2)}$$

electric potential

$$V = \frac{Q}{4\pi\epsilon_0 r}$$

electrical potential energy

$$E_p = \frac{Qq}{4\pi\epsilon_0 r}$$

capacitors in series

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \dots$$

capacitors in parallel

$$C = C_1 + C_2 + \dots$$

discharge of a capacitor

$$x = x_0 e^{-\frac{t}{RC}}$$

Hall voltage

$$V_H = \frac{BI}{ntq}$$

alternating current/voltage

$$x = x_0 \sin \omega t$$

radioactive decay

$$x = x_0 e^{-\lambda t}$$

decay constant

$$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$$

intensity reflection coefficient

$$\frac{I_R}{I_0} = \frac{(Z_1 - Z_2)^2}{(Z_1 + Z_2)^2}$$

Stefan-Boltzmann law

$$L = 4\pi\sigma r^2 T^4$$

Doppler redshift

$$\frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}$$

- 1 (a) State Coulomb's law.

Force is directly proportional to the product of charges ✓
and inversely proportional to the square of their
separation ✓ [2]

- (b) In a model of an atom, an electron is in a circular orbit around a proton, as shown in Figure 1.1.

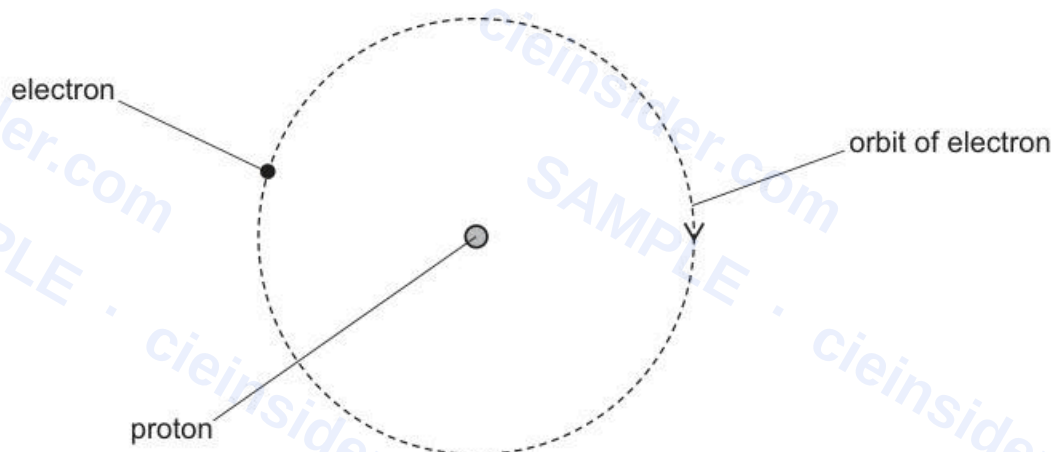


Figure 1.1

The electric potential energy of the electron is $-1.09 \times 10^{-18} \text{ J}$.

- (i) Show that the radius of the orbit is $2.11 \times 10^{-10} \text{ m}$.

$$E = \frac{Qq}{4\pi\epsilon_0 r}$$

$$-1.09 \times 10^{-18} = \frac{-1.6 \times 10^{-19} \times 1.6 \times 10^{-19}}{4\pi(8.85 \times 10^{-12})(r)}$$

$$r = 2.11 \times 10^{-10} \text{ m} \quad \checkmark$$

[1]

- (ii) Use the information in 1(b)(i) to determine the magnitude of the electric force between the electron and the proton.

$$F = \frac{E}{r}$$

$$F = \frac{1.09 \times 10^{-18}}{2.11 \times 10^{-10}} = 5.17 \times 10^{-9}$$

force = $5.17 \times 10^{-9} \text{ N}$ [1]

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5

(iii) Calculate the centripetal acceleration of the electron.

$$F = ma$$

$$5.17 \times 10^{-9} = 9.11 \times 10^{-31} \times a$$

$$a = 5.67 \times 10^{21}$$

acceleration = $5.67 \times 10^{21} \text{ ms}^{-2}$ [1] 1/1

(iv) Use your answer in 1(b)(iii) to determine the period of the orbit of the electron.

$$a = \omega^2 r$$

$$a = \frac{(2\pi)^2}{T^2} r$$

$$T = \sqrt{\frac{(2\pi)^2 r}{a}}$$

$$T = \sqrt{\frac{(2\pi)^2 \times 2.11 \times 10^{-10}}{5.67 \times 10^{21}}}$$

$$= 1.21 \times 10^{-15}$$

period = $1.21 \times 10^{-15} \text{ s}$ [2] 2/2

(c) The electron in 1(b) emits a photon so that the electric potential energy of the electron decreases. The electron remains in a circular orbit around the proton.

By placing **one** tick (✓) in each row, complete Table 1.1 to show how the quantities indicated for the electron change when the potential energy decreases.

Table 1.1

	decreases	stays the same	increases
radius of orbit	✓ ✓		
centripetal acceleration	✓ ✗		
angular speed		✓ ✗	

1 1/3

[3]

[Total: 10]



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DFD

6

2 A satellite is in geostationary orbit around the Earth. The orbit is circular.

(a) (i) State what is meant by a geostationary orbit.

The satellite has the same period of orbit around Earth is equal to the period of rotation of Earth. X 2 [1]

0/1

(ii) State **two** properties of the orbit.

1 3

2 [2]

0/2

(b) The orbit has radius R and period T .

(i) Determine an expression, in terms of R and T , for the speed v of the satellite in its orbit.

$$v = \omega R$$

$$v = \frac{2\pi R}{T}$$

$$v = \frac{2\pi R}{T} \checkmark [1]$$

1/1

(ii) Use Newton's law of gravitation to show that the mass M of the Earth is given by

$$M = \frac{4\pi^2 R^3}{GT^2}$$

where G is the gravitational constant.

$$F = \frac{GMm}{R^2}$$

$$F = m\omega^2 R$$

$$\frac{GMm}{R^2} = m\omega^2 R \checkmark$$

$$GM = \frac{4\pi^2 R^3}{T^2}$$

$$M = \frac{4\pi^2 R^3}{GT^2}$$

1/2





7

- (c) The Earth may be considered to be a sphere of radius 6370 km.
Geostationary satellites orbit at a height of 35 900 km above the surface of the Earth.

Determine a value, to three significant figures, for the mean density of the Earth.

$$\rho = \frac{M}{V} \quad \checkmark$$

$$M = \frac{4\pi^2 R^3}{GT^2}$$

$$V = \frac{4}{3}\pi r^3$$

$$\rho = \frac{\left[\frac{4\pi^2 (35900)^3}{6.67 \times 10^{-11} (24 \times 60 \times 60)^2} \right]}{\frac{4}{3}\pi (6370)^3} \quad \times$$

$$\rho = 3388.3$$

$$\approx 3390$$

density = 3390 $\times$ 1/4 kg m^{-3} [4]

[Total: 10]

- 3 (a) State what is meant by two objects being in thermal equilibrium.

Zero net thermal energy transfer between the two objects in contact. ✓ ^ 6

1/2

[2]

- (b) An insulated container with negligible specific heat capacity contains a mass of 63 g of water at an initial temperature of 78.0 °C.

A thermistor with a mass of 8.5 g is at an initial temperature of 25.0 °C. The thermistor is connected into a circuit containing an ammeter that is accurately calibrated to give readings of temperature in °C.

The thermistor is immersed in the water. When thermal equilibrium is reached, the ammeter indicates a temperature of 76.8 °C.

- (i) Explain why the thermistor does not measure the temperature as 78.0 °C.

Thermal energy is transferred from the water to the thermistor to increase the thermistor's temperature from 25.0 °C to 76.8 °C. ✓ ^ 7

1/2

[2]

- (ii) The specific heat capacity of water is 4.2 J g⁻¹ K⁻¹.

Calculate a value for the specific heat capacity, in J g⁻¹ K⁻¹, of the material of the thermistor.

Energy gain = Energy lost

$$E = mc\Delta T$$

$$8.5 \times c \times (76.8 - 25) = 63 \times 4.2 \times (78 - 76.8)$$

$$c = 0.72$$

✓✓✓

specific heat capacity = 0.72 J g⁻¹ K⁻¹ [3]

3/3



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9

- (c) Suggest, with a reason, how the initial temperature of the water in 3(b) could be measured more accurately than using the thermistor in 3(b).

8

0/2

[2]

[Total: 9]

- 4 (a) State the first law of thermodynamics.

Increase in internal energy is equal to the sum
of thermal energy supplied to the system and
work done on the system. ✓✓

2/2

[2]



- (b) A sample of an ideal gas contains 3.58×10^{24} molecules. The sample is at a temperature of 298 K and a pressure of 1.84×10^5 Pa.

- (i) Show that the volume of the gas is 0.0800 m^3 .

$$pV = NkT$$

$$1.84 \times 10^5 \times V = 3.58 \times 10^{24} \times 1.38 \times 10^{-23} \times 298$$

$$V = 0.08001$$

$$\approx 0.0800 \text{ m}^3 \checkmark \checkmark$$

2/2

[2]

- (ii) Calculate the amount of gas n in the sample.

$$N = \text{mol} \times N_A$$

$$\text{mol} = \frac{3.58 \times 10^{24}}{6.02 \times 10^{23}} = 5.95$$

$$n = 5.95 \checkmark \text{ mol [1]}$$

1/1

- (iii) Determine the average translational kinetic energy E_K of one molecule of the gas.

$$E_K = \frac{3}{2} kT$$

$$= \frac{3}{2} (1.38 \times 10^{-23}) (298)$$

$$= 6.17 \times 10^{-21} \checkmark \checkmark$$

$$E_K = 6.17 \times 10^{-21} \text{ J [2]}$$

2/2

- (iv) Explain why the average potential energy of one molecule of the gas is zero.

There are no intermolecular forces acting between molecules of the gas. $\checkmark$

1/1

[1]

- (v) Calculate the internal energy U_A of the gas.

$$U_A = \frac{3}{2} NkT$$

$$= 3.58 \times 10^{24} \times 6.17 \times 10^{-21}$$

$$= 22100$$

$$U_A = 22100 \checkmark \text{ J [1]}$$

1/1



(c) The gas in 4(b) undergoes two changes AB and BC, as shown in Figure 4.1.

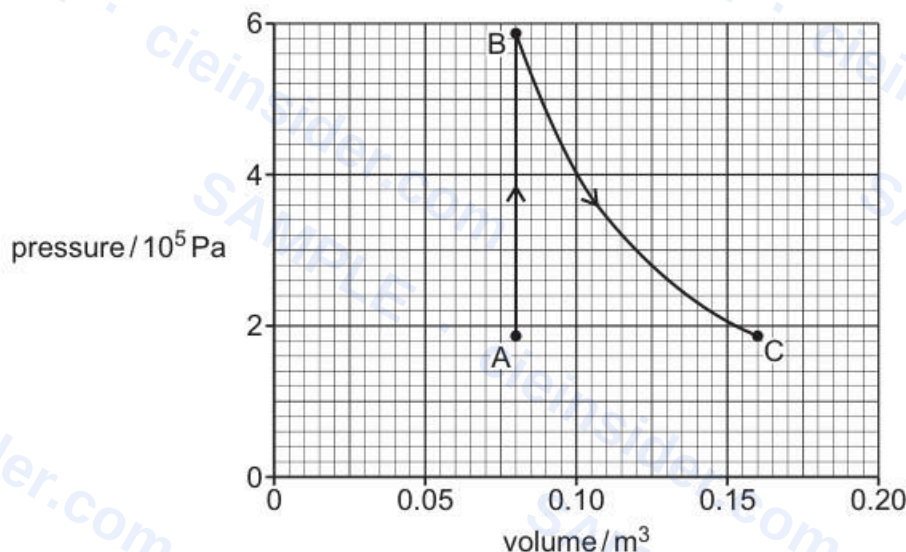


Figure 4.1

In change AB, the gas is heated at constant volume from its initial pressure of $1.84 \times 10^5 \text{ Pa}$ to a pressure of $5.84 \times 10^5 \text{ Pa}$.

In change BC, the gas rapidly expands and returns to its original pressure with no transfer of thermal energy. The volume of the gas after this expansion is 0.160 m^3 .

- (i) Determine an expression, in terms of U_A , for the thermal energy Q supplied to the gas during change AB. Explain your reasoning.

No change in volume so work done is zero ✓

$$\Delta U = Q + 0$$

$$Q = U \quad \times \quad 9$$

$$Q = \dots\dots\dots U_A \dots\dots\dots [2]$$

1/2

- (ii) Determine an expression, in terms of U_A , for the work W done on the gas during change BC. Explain your reasoning.

No change in internal energy ✗ 10

$$W = \dots\dots\dots [2]$$

0/2

[Total: 13]

- 5 A metal ball is attached to the lower end of a spring, as shown in Figure 5.1.

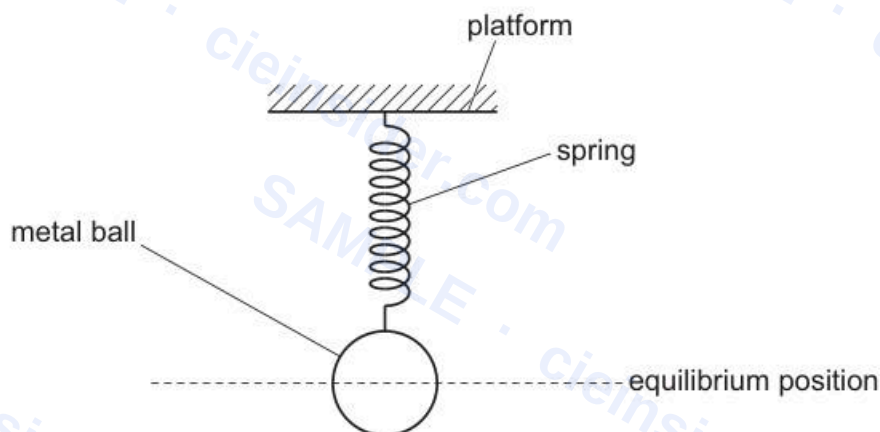


Figure 5.1

The upper end of the spring is attached to a platform that is initially stationary.

- (a) The ball is pulled down by a small distance and released so that it oscillates with simple harmonic motion. The oscillations have an amplitude of 2.5 cm and a maximum speed of 4.4 cm s^{-1} .
- (i) On Figure 5.2, sketch the variation of the velocity v of the ball with the displacement x from its equilibrium position as the ball undergoes one full oscillation.

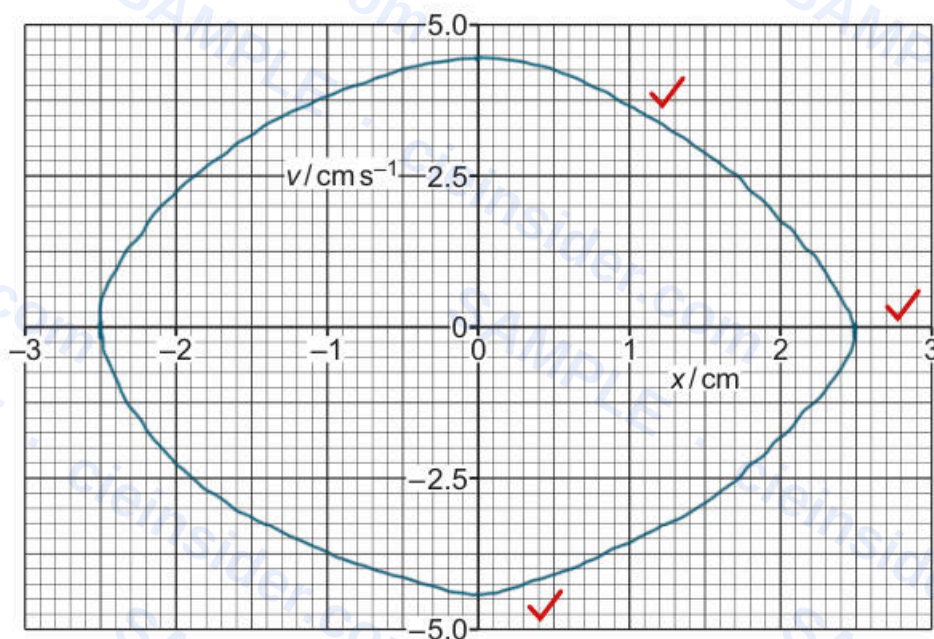


Figure 5.2

3/3

[3]

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13

(ii) Show that the frequency of the oscillations is 0.28 Hz.

$$v = \omega r$$

$$v = \frac{2\pi}{T} r$$

$$\frac{2\pi}{v r} = T$$

$$f = \frac{1}{T}$$

$$f = \frac{v r}{2\pi}$$

X 11

0/2

[2]

(b) The ball is returned to rest at its equilibrium position.

The platform is now moved up and down by a motor so that it oscillates vertically with simple harmonic motion of constant amplitude but variable frequency. The oscillating platform causes the ball to oscillate.

(i) State what is meant by resonance.

Resonance is when maximum amplitude is forced when natural frequency equals to forced frequency.

2/2

[2]

(ii) The frequency f of the oscillations of the platform slowly increases from 0 to 0.40 Hz.

On Figure 5.3, sketch the variation with f of the amplitude of the oscillations of the ball.

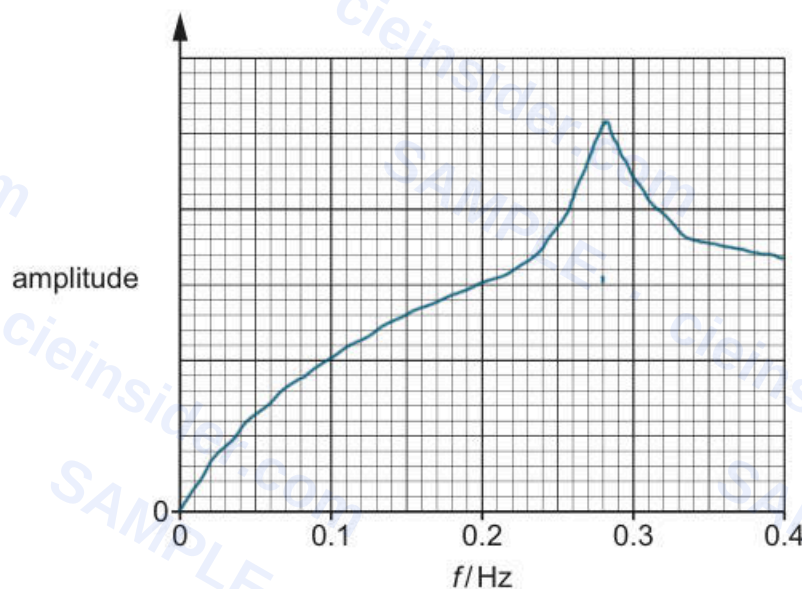


Figure 5.3

2/2

[2]

[Total: 9]

- 6 A capacitor of capacitance $47\ \mu\text{F}$, a cell of electromotive force (e.m.f.) 1.50 V and a resistor R are connected into the circuit of Figure 6.1.

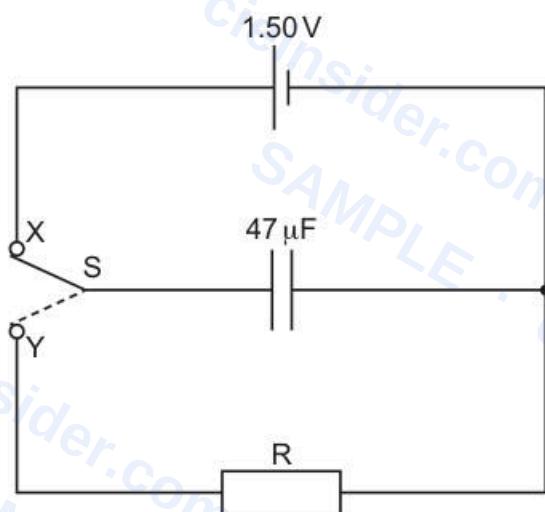


Figure 6.1

The two-way switch S alternates between terminals X and Y with a frequency of 0.20 Hz , as shown in the variation of switch position with time t in Figure 6.2.

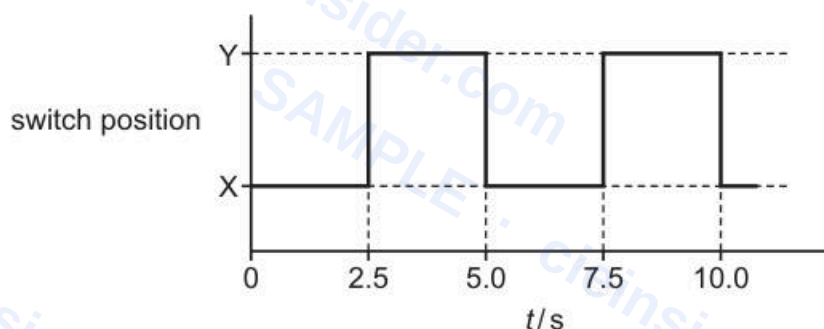


Figure 6.2

The time constant of the discharge circuit is 2.4 s .

- (a) (i) Calculate the resistance, in $\text{k}\Omega$, of R .

$$\tau = RC$$

$$2.4 = R(47 \times 10^{-6})$$

$$R = 51000\ \Omega$$

$$= 51\ \text{k}\Omega$$

resistance = 51 $\text{k}\Omega$ [2]

2/2

* 0000800000015 *

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15

(ii) Show that the minimum potential difference (p.d.) across the capacitor is 0.53 V.

$$V = V_0 e^{-\frac{t}{\tau}}$$

$$V = 1.5 e^{-\frac{2.5}{2.4}}$$

$$V = 0.529$$

$$\approx 0.53 \text{ V}$$

✓✓

2/2

[2]

(b) On Figure 6.3, sketch the variation of the p.d. V_C across the capacitor with t between $t = 0$ and $t = 10.0$ s.

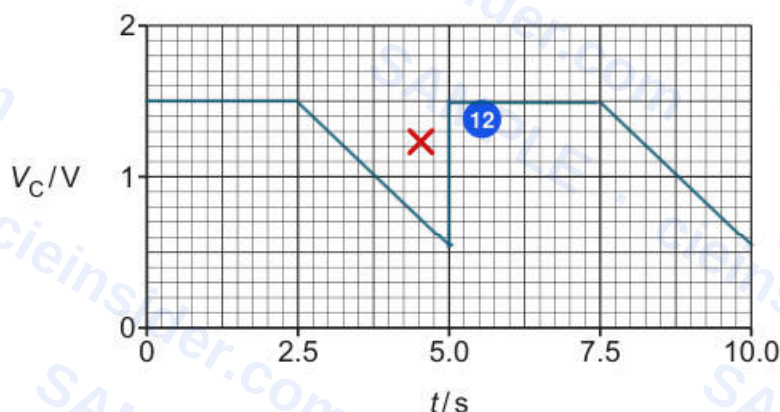


Figure 6.3

2/3

[3]

(c) The frequency at which the switch alternates is now doubled.

Explain, without calculation, whether the minimum p.d. across the capacitor is now less than, equal to or greater than 0.53 V.

The minimum p.d. across the capacitor increase as the time the capacitor discharges for is halved when frequency is doubled. ✓✓

2/2

[2]

[Total: 9]

- 7 (a) State what is meant by an alternating current.

Current the switches direction in the circuit. X 13

0/1

[1]

- (b) A coil of wire is wound onto a hollow insulating tube to form a solenoid, as shown in Figure 7.1.

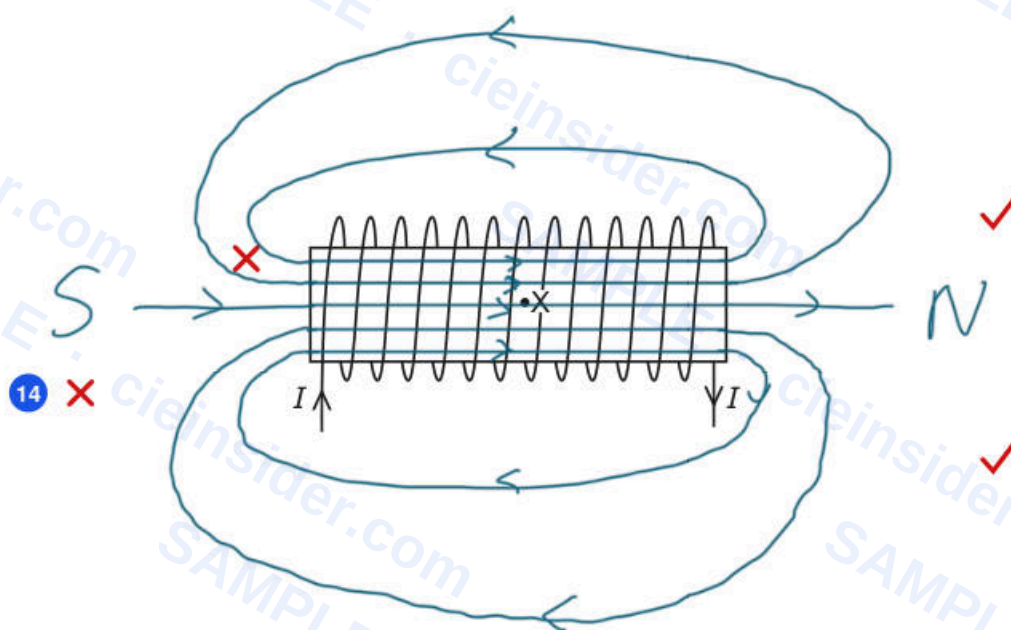


Figure 7.1

There is a constant current I in the solenoid in the direction indicated. There is a magnetic field inside and outside the solenoid due to this current.

- (i) On Figure 7.1, draw five field lines to represent the magnetic field inside and outside the solenoid. 2/3 [3]

- (ii) On Figure 7.1, indicate, with the letters N and S, the magnetic poles of the solenoid. 0/1 [1]

- (c) The current I in the solenoid in 7(b) now varies sinusoidally so that the flux density B of the magnetic field at point X varies with time t according to

$$B = 2.0 \cos 200\pi t$$

where B is in mT and t is in s.

- (i) Show that the period of the alternating magnetic field is 0.010 s.

$$\omega = 200\pi \quad T = \frac{2\pi}{200\pi} = 0.010 \text{ s} \quad \checkmark$$

1/1

[1]

- (ii) On Figure 7.2, sketch the variation of B with t between $t = 0$ and $t = 0.020$ s.

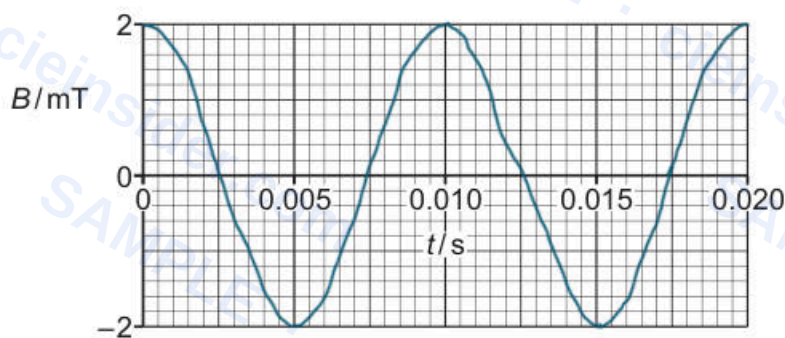


Figure 7.2

2/2

[2]

- (d) A small coil is placed at point X inside the solenoid in 7(c), so that its axis is parallel to the axis of the solenoid.

The small coil has 45 turns, each with a radius of 2.8×10^{-3} m.

- (i) Calculate the maximum magnetic flux Φ linked by the small coil. Give a unit with your answer.

$$\begin{aligned}\Phi &= NBA \\ &= NB \times 2\pi r^2 \\ &= 45 \times 2 \times 10^{-3} \times \pi (2.8 \times 10^{-3})^2 \\ &= 2.2 \times 10^{-6} \quad \checkmark \checkmark \checkmark\end{aligned}$$

$$\Phi = 2.2 \times 10^{-6} \text{ unit } \text{T.m}^2 \quad [3]$$

3/3

- (ii) Describe and explain how the variation of B with t in Figure 7.2 may be used to determine the maximum electromotive force (e.m.f.) induced in the small coil. No calculations are required.

E.m.f. induced is equal to the rate of change of magnetic flux linkage. Change in magnetic flux linkage is directly proportional to change in B . Rate of change of magnetic flux linkage is proportional to change in gradient of Fig 7.2. $\checkmark$ $\wedge$ [3]

1/3

15

[Total: 14]

- 8 (a) When a clean metal surface is illuminated by electromagnetic radiation, electrons may be emitted from the surface.

(i) State the name of this phenomenon.

Photoelectric effect ✓

1/1

[1]

(ii) State what is meant by the threshold frequency of the metal.

Minimum frequency of photon incident on metal surface to cause electron emission. ✓

1/1

[1]

(iii) Explain why the existence of the threshold frequency provides evidence for the photon model of electromagnetic radiation.

16

0/3

[3]

- (b) When a clean metal sheet is illuminated by radiation of wavelength 254 nm, electrons are emitted with a maximum kinetic energy of 1.91×10^{-19} J.

When the same metal sheet is illuminated by radiation of wavelength 178 nm, the maximum kinetic energy of the emitted electrons is 5.27×10^{-19} J.

(i) Use these data to calculate a value, to three significant figures, for the Planck constant.

$$E = \frac{hc}{\lambda} \quad 17$$

0/3

Planck constant = Js [3]



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- (ii) Determine a value, in eV, for the work function energy of the metal. Give your answer to two significant figures.

$$\frac{hc}{\lambda} = \phi + KE_{\max}$$

$$\frac{6.63 \times 10^{-34} \times 3 \times 10^8}{2.54 \times 10^{-9}} = \phi + 1.91 \times 10^{-19} \quad \checkmark$$

$$\phi = 5.92 \times 10^{-19} \quad \times \quad 18 \quad 5.92 \times 10^{-19} \quad \boxed{1/3}$$

work function energy = eV [3]

[Total: 11]

- 9 (a) Explain how ultrasound waves are generated by a piezoelectric transducer.

Piezoelectric crystal is connected to an alternating current power source. The AC causes the crystal to extend and contract generating ultrasound pulses. The are sent into the body.

1/3

[3]

- (b) Ultrasound waves are used to obtain information about a structure that consists of two materials, as shown in Figure 9.1.

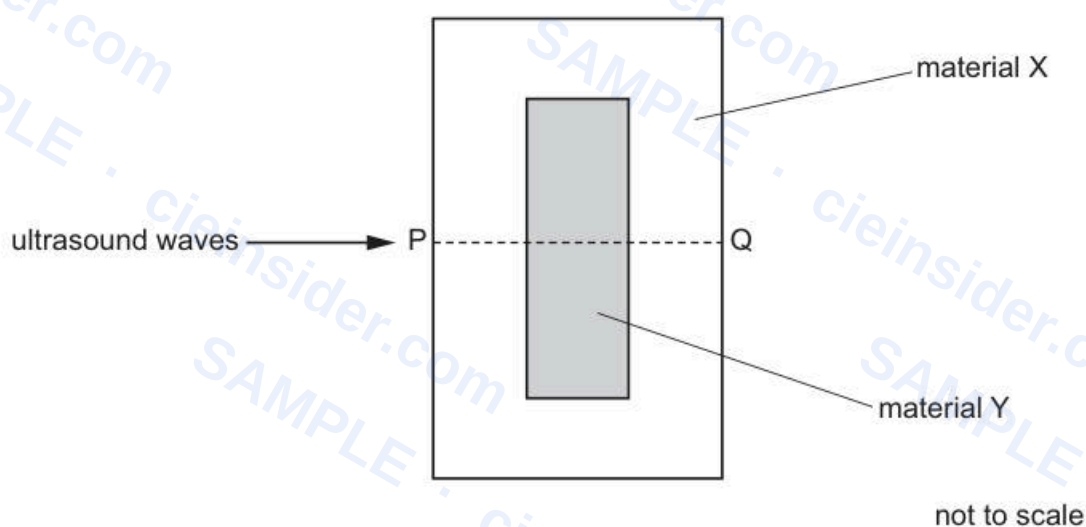


Figure 9.1

The waves enter the structure at point P and travel through the structure to point Q.

Material Y has a density of 8960 kg m^{-3} . The speed of sound in material Y is 4720 m s^{-1} .

- (i) Calculate the specific acoustic impedance Z of material Y. Give a unit with your answer.

$$\begin{aligned} Z &= \rho c \\ &= 8960 \times 4720 \\ &= 4.23 \times 10^7 \end{aligned}$$

$$Z = 4.23 \times 10^7 \text{ unit } \text{kg m}^{-2} \text{ s}^{-1} [2]$$

2/2

- (ii) The intensity of ultrasound entering the structure at point P is I_0 .
The transmitted intensity of the ultrasound between P and Q at distance x from P is I .

Figure 9.2 shows the variation with x of the value of $\ln(I/I_0)$.

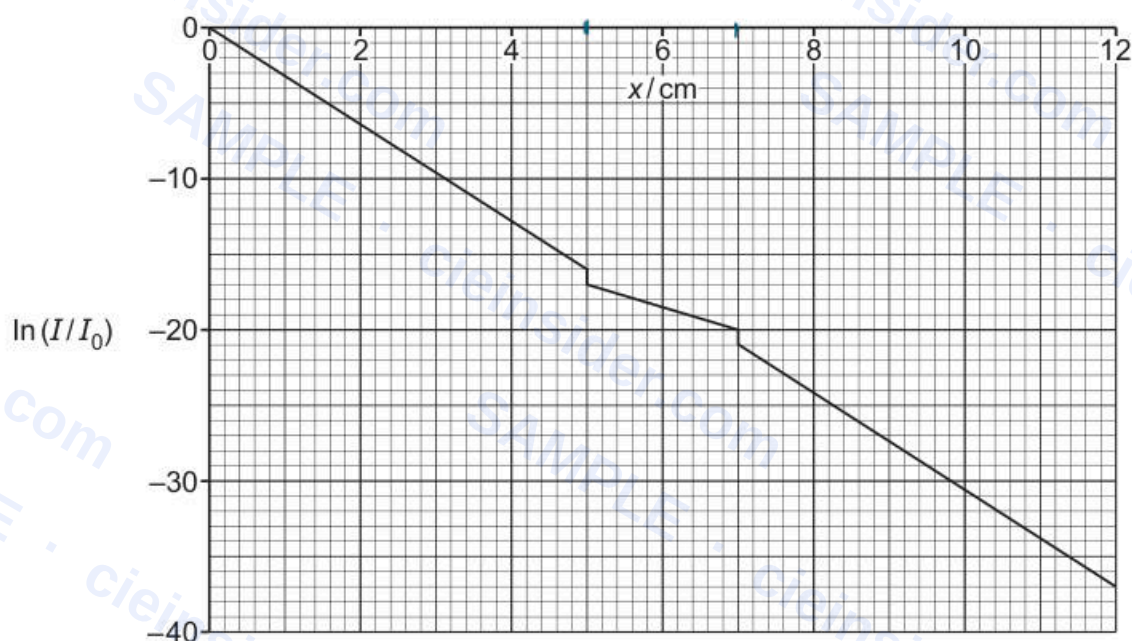


Figure 9.2

Determine **three** conclusions about the structure and the materials from which it is made that may be drawn from Figure 9.2. The conclusions may be qualitative or quantitative. Use the space for any working.

1 Material X is 1 cm thick in the path of the ultrasound. X 20

2

3

0/3

[3]

[Total: 8]

[Turn over]

- 10 (a) (i) State what is meant by a standard candle.

A star of known luminosity. ✓

1/1

[1]

- (ii) Explain how standard candles may be used to determine the distance of a galaxy from an observer.

21 Radiant flux of the standard candle is measured by observer. Use $F = \frac{L}{4\pi d^2}$, where d is distance to find distance of galaxy from observer. ✓

1/2

[2]

- (b) A star in a distant galaxy has luminosity L .

The star emits radiation that has maximum intensity at a wavelength that is known to be λ_{star} after correcting for redshift.

The Sun has surface temperature T_0 and emits radiation that has maximum intensity at wavelength λ_0 .

- (i) Explain why the wavelength of the radiation observed from the star has to be corrected for redshift.

The star is moving away from the observer so its light is redshifted causing wavelength to be longer than its true wavelength. ✓

2/2

[2]

- (ii) State an expression, in terms of λ_{star} , λ_0 and T_0 , for the surface temperature T_{star} of the star.

$$\lambda_s T_s =$$

$$T_{\text{star}} = \frac{\lambda_0 T_0}{\lambda_{\text{star}}} \quad \checkmark$$

1/1

[1]

- (iii) Determine an expression, in terms of L and T_{star} , for the radius of the star. Identify any other symbols that you use.

$$I = \sigma T^4$$

$$L = 4\pi r^2 \sigma T^4$$

$$I = \frac{P}{A}$$

$$P = IA = L$$

$$\sigma T^4 \times 4\pi r^2$$

' σ ' is Stefan-Boltzmann constant

$$\text{radius} = \frac{L}{4\pi \sigma (T_{\text{star}})^4}$$

0/1

[1]

[Total: 7]



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