OCR
Oxford Cambridge and RSA

Friday 9 June 2023 – Morning

A Level Physics A

H556/02 Exploring physics

Time allowed: 2 hours 15 minutes

ALevelPhysicsOnline.com
/ocr-a-exploring-physics

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 8 4 5 9 0 Candidate number 4 5 2 3

First name(s) Lewis

Last name Matheson

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 **100**.
- 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 **28** pages.

ADVICE
- Read each question carefully before you start your answer.

Section A

You should spend a **maximum** of **30 minutes** on this section.

Write your answer to each question in the box provided.

1 Which of these units is a base unit?

A A ←

B J kg m² s⁻¹

C m^2 m²

D N kg m s⁻²

Your answer A ✓ **[1]**

2 The accepted value of g is 9.81 ms^{-2}. In an experiment to verify the value of g, students obtained a value of 10.20 ms^{-2}.

What is the percentage difference between the students' value and the accepted value of g?

$$\frac{10.20 - 9.81}{9.81} \times 100 = 3.98\%$$

A 1%

B 2%

C 4%

D 8%

Your answer C ✓ **[1]**

3 Which of these statements is/are true?

1 Antiprotons are hadrons so are subject to the strong nuclear and weak nuclear forces. ✓
2 Neutrons are subject to the weak nuclear force only. hadrons ∴ strong ✗
3 The weak nuclear force is the only force that causes a change of quark type. ✓

A 1, 2 and 3

B Only 1 and 2

C Only 1 and 3

D Only 3

Your answer C ✓ **[1]**

4 A 200 W heater is used for 90 minutes. The cost per kWh is 13 pence.

How much did it cost to use the heater?

A 3.9p

B 39p

C £2.34

D £23.40

E = Pt = 0.200 kW × 1.5 h = 0.300 kWh

£ = 13p × 0.300 = 3.9p

Your answer A ✓ **[1]**

5 The diagram shows the path of a nucleus entering a magnetic field.

In which direction does the force on the nucleus act as it enters the magnetic field?

A down the page

B into the page

C out of the page

D up the page

Fleming's LHR, thumb points down

Your answer A ✓ **[1]**

6 Technetium-99m (Tc-99m) is a metastable isotope used in medical diagnosis.

Which ionising radiation does Tc-99m emit?

A alpha

B beta-minus

C beta-plus

D gamma

Tc-99m → Tc-99 + γ

Your answer D ✓ **[1]**

7 The power dissipated across a 1 kΩ resistor is 20 W.

What is the potential difference across the resistor?

A 0.02 V

B 50 V

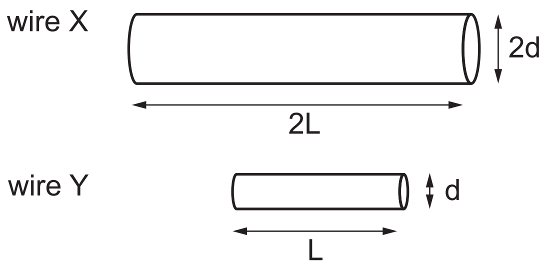
C 140 V

D 20 000 V

$P = \frac{V^2}{R}$ $V = \sqrt{PR} = \sqrt{20 \times 1000} = 141$

Your answer C ✓ **[1]**

8 The diagram shows the relative lengths and diameters of two copper wires, labelled wire X and wire Y.



What is the ratio of the resistivity of wire Y to wire X?

A 1 : 1

B 1 : 2

C 1 : 4

D 1 : 8

Resistivity is a property of the material the wire is made from, which is the same for both wires ∴ 1 : 1

Your answer A ✓ **[1]**

9 The centres of a positron and a helium nucleus are separated by 2 mm.

What is the electrostatic force between them?

A 1.15×10^{-28} N

B 2.30×10^{-25} N

C 5.75×10^{-23} N

D 1.15×10^{-22} N

$$F = \frac{Qq}{4\pi\varepsilon_0 r^2} = \frac{1.60\times10^{-19} \times (2\times1.60\times10^{-19})}{4\pi\times8.85\times10^{-12}\times(2\times10^{-3})^2}$$

$$= 1.151\times10^{-22}$$

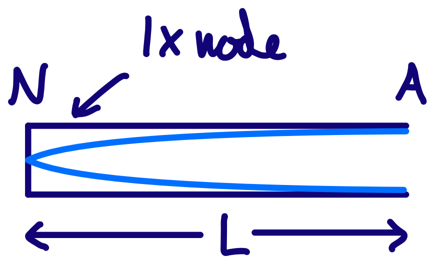
Your answer: D ✓

[1]

10 A column of air in a tube of length *L*, closed at one end, is forced to vibrate at its fundamental frequency. A standing wave is set up inside the tube.

Which row in the table is correct for this standing wave?

	Number of nodes inside the tube	**Wavelength / m**
A	1	L
B	1	2L
C	1	4L
D	2	2L

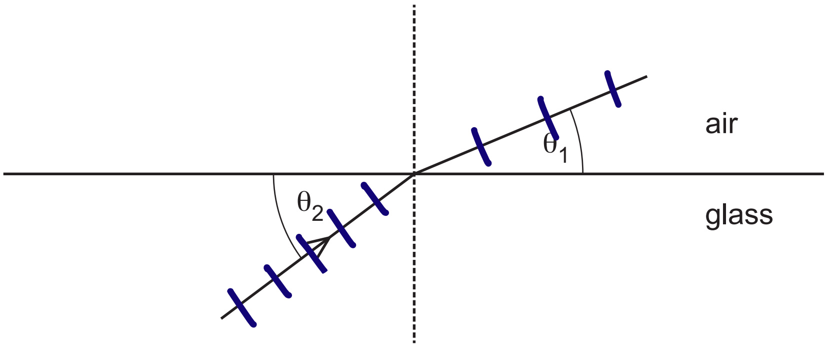


$L = \frac{\lambda}{4}$ $\lambda = 4L$

Your answer: C ✓

[1]

11 A ray of light is travelling through glass with refractive index n = 1.51. The diagram (not to scale) shows light incident on a glass / air interface.



Which of these statements is/are true?

1 wavelength of light in glass < wavelength of light in air ✓

2 $n_{glass} = 2n_{air}$ ✗

3 $\theta_2 > 48°$ ✓

$n_{air} = 1$

$\frac{n_{air}}{n_{glass}} = \frac{1}{1.51}$

$n_{glass} = 1.51\, n_{air}$

A 1 only

B 1 and 2

C 3 only

D 1 and 3

Your answer D ✓ **[1]**

$\sin C = \frac{1}{n}$

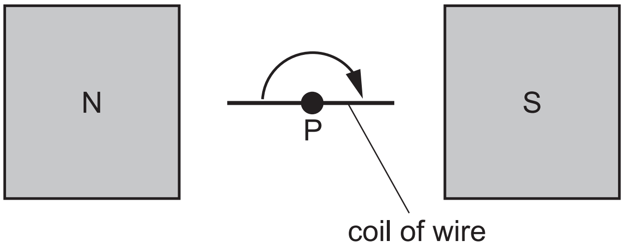
$C = \sin^{-1}\left(\frac{1}{1.51}\right) = 41.47°$

$\theta_2 > 90 - 41.47$

$\theta_2 > 48°$ (because no TIR occurs)

12 The diagram shows a coil of wire rotating between two permanent magnets in a model generator.

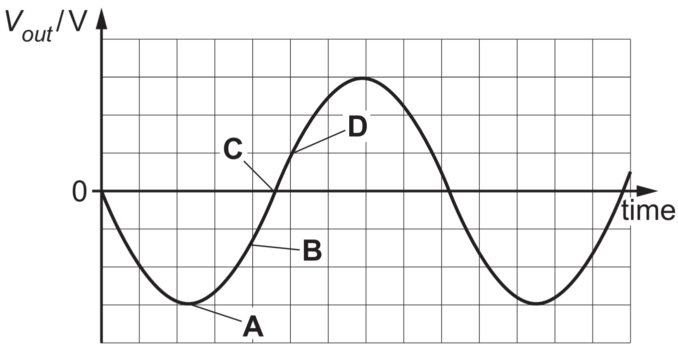
The coil is rotating clockwise about point P at constant angular velocity.



$N\phi = 0$

$\mathcal{E} = \frac{\Delta N\phi}{\Delta t} = \text{max}$

Which letter represents the output of the generator at the instant in the diagram?



Your answer A ✓ **[1]**

13 In the Rutherford scattering experiment alpha particles are directed at a gold foil.

Gold nuclei have 79 protons. The distance of closest approach is 47.0 fm.

Which is the best estimate of the work done on an alpha particle as it moves from 53.0 fm to the point of closest approach?

A 10^{-18} J

B 10^{-16} J

C 10^{-15} J

D 10^{-13} J

$\Delta E_e = \frac{Qq}{4\pi\varepsilon_0}\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$

$= \frac{79 \times 2 \times (1.60\times10^{-19})^2}{4\pi \times 8.85\times10^{-12}} \times \left(\frac{1}{47.0\times10^{-15}} - \frac{1}{53.0\times10^{-15}}\right)$

$= 8.76\times10^{-14} \approx 10^{-13}$

Your answer D ✓ **[1]**

14 A step-down transformer has an input potential difference of 200 V. There are 250 turns on the primary coil and 50 turns on the secondary coil. The secondary coil is connected to a 1.0 kΩ resistor.

What is the current through the resistor?

A 2×10^{-4} A

B 0.04 A

C 1 A

D 40 A

$V_s = \frac{n_s}{n_p} V_p = \frac{50}{250} \times 200 = 40\ V$

$I = \frac{V}{R} = \frac{40}{1.0 \times 10^3} = 0.040\ A$

Your answer B ✓ **[1]**

15 Which statement is Faraday's law?

A The direction of electric current induced by a changing magnetic field is such that the magnetic field created by the induced current opposes changes in the initial magnetic field. ✗ Lenz's law

B The magnitude of the electrostatic force between two point charges is directly proportional to the product of the magnitudes of charges and inversely proportional to the square of the separation. ✗ Coulomb's law

C The magnitude of induced EMF is proportional to the rate of change of the magnetic flux linkage. ✓

D The total energy of an isolated system remains constant. ✗ Law of conservation of energy

Your answer C ✓ **[1]**

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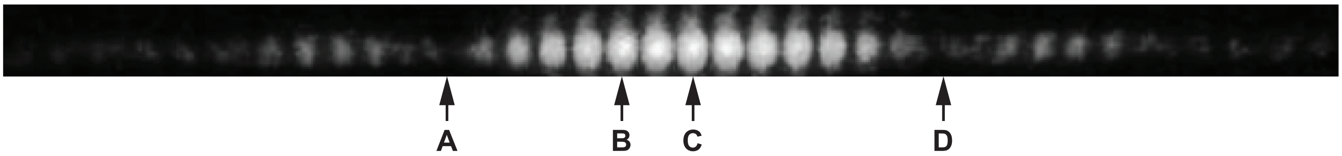
Section B

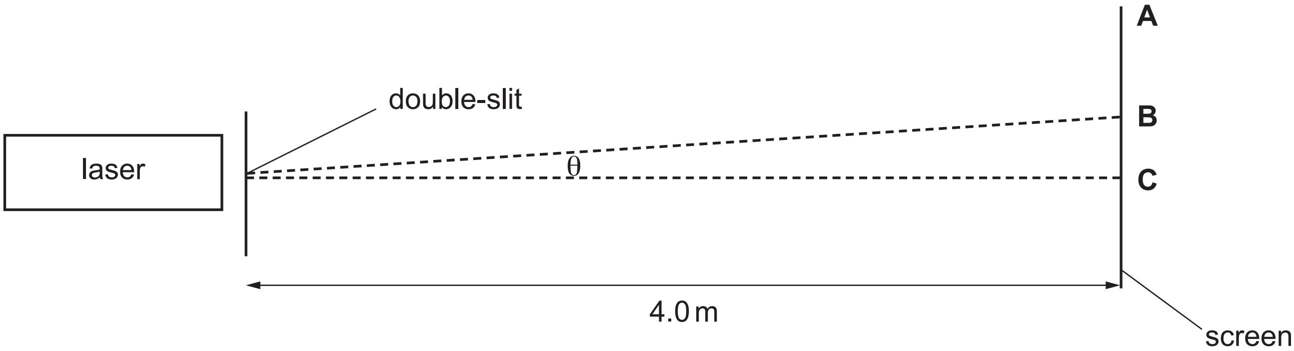
16 **Fig. 16.1** shows the pattern obtained in a Young double-slit experiment. The pattern is **not** to scale. Three regions of the pattern are labelled **A**, **B** and **D**. The central maximum is labelled **C**.

Fig. 16.1



Red light of wavelength 640 nm was used in the experiment. The distance between the centres of the two slits was 1.00×10^{-5} m. The distance from the double-slit to the screen was 4.0 m.

Fig. 16.2



(a) Name the physical processes that cause the features labelled **A**, **D** and **B**, **C** in **Fig. 16.1**.

A and **D** Destructive interference ✓

B and **C** Constructive interference ✓ **[2]**

(b) The Young double-slit experiment uses **coherent** waves. State what **coherent** means.

Waves with a constant phase difference. ✓

[1]

(c) Explain how the part of the pattern labelled **B** is formed.

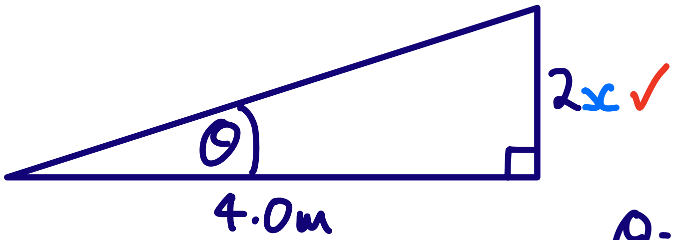
Waves arrive at the screen with a path difference of 2λ ✓ ∴ phase difference of 4π so they are in phase. ✓

[2]

(d) Calculate the angle θ from the central maximum **C** to the maximum labelled **B** as shown in **Fig. 16.2**.

$$\lambda = \frac{ax}{D} \qquad x = \frac{D\lambda}{a} = \frac{4.0 \times 640 \times 10^{-9}}{1.00 \times 10^{-5}} = 0.256\ m ✓$$

θ = 7.3 ✓ ° **[3]**



$$\theta = \tan^{-1}\left(\frac{2x}{4.0}\right) = \tan^{-1}\left(\frac{0.256}{2.0}\right)$$

$$\theta = 7.29°$$

17 Ultrasound B-scans can be used to image unborn babies.

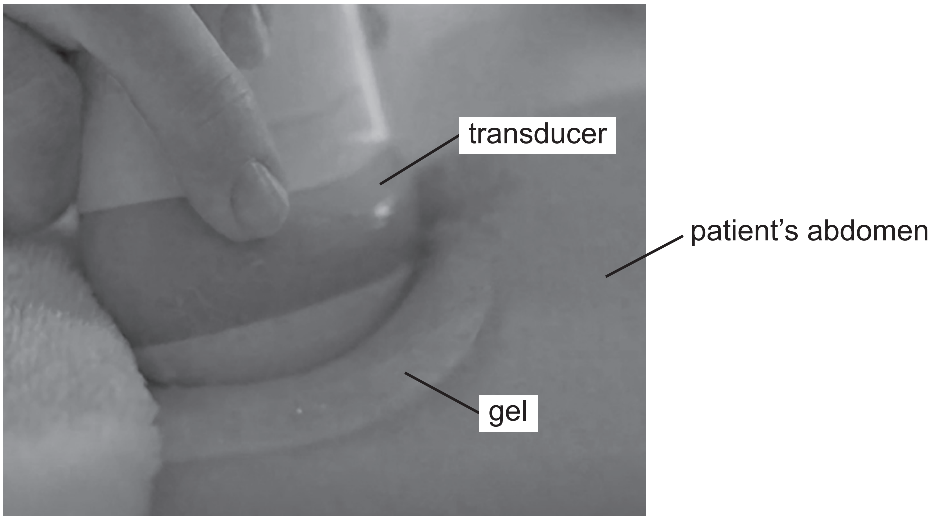
(a) Explain what is meant by ultrasound.

Longitudinal ✓ sound waves with a frequency greater than 20 kHz. ✓

[2]

(b)* **Fig. 17.1** is a labelled photograph of an ultrasound examination of a patient.

Fig. 17.1



Explain how the transducer both produces and receives ultrasound waves.

Explain the purpose of the gel. **[6]**

Transducer: High frequency alternating p.d. applied to faces of a piezoelectric crystal which causes it to stretch and compress at the same frequency ✓, producing ultrasonic waves which are sent in pulses. ✓

Between pulses, reflected ultrasound incident on the crystal causes it to resonate, inducing an alternating p.d. ✓

Gel: Acoustic impedance of air is different to the body tissue. The gel has an acoustic impedance similar to the body ✓ allowing a greater transmission of ultrasound as less is reflected ∴ a stronger signal. ✓

Additional answer space if required

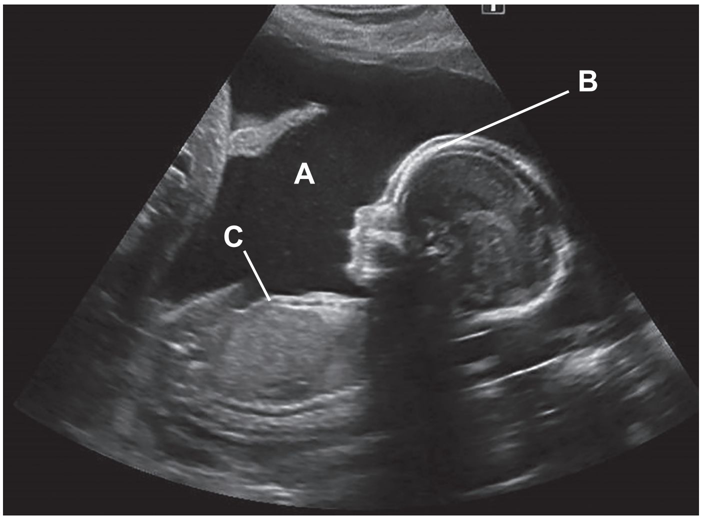
$$\frac{I_r}{I_0} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$$

When $Z_2 = Z_1$, $Z_2 - Z_1 = 0$ ∴ $I_r / I_0 = 0$ and none is reflected. ✓

Question 17 continues on page 14

(c) **Fig. 17.2** shows a B-scan of an unborn baby.

Fig. 17.2



(i) Explain why no signal is received back from **A**.

No change in acoustic impedance. ✓

.... **[1]**

(ii) Explain why a greater signal is received back from **B** than **C**.

Acoustic impedance of B is different to C, ✓ and the change at B is greater than C so more of the ultrasound is reflected. ✓ **[2]**

(d) Doppler ultrasound can be used to measure the speed of blood flow through blood vessels.

The speed of ultrasound in blood is 1600 ms^{-1}.

A transducer emitting ultrasound of frequency 10.0000 MHz is placed at 50° to the blood vessel.

The reflected ultrasound has a frequency of 9.9987 MHz.

Calculate the speed *v* of the blood flow.

$$\frac{2v\cos\theta}{c} = \frac{\Delta f}{f} \qquad v = \frac{\Delta f\, c}{2\cos\theta\, f} = \frac{(10.0 - 9.9987) \times 1600}{2 \times \cos 50 \times 10.0} ✓$$

$v = 0.1618$

v = 0.16 ✓ ms^{-1} **[2]**

18 **Fig. 18** represents a tube open at both ends.

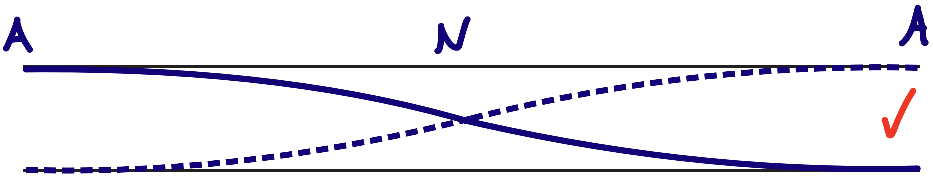
Air inside the tube is forced to oscillate by a speaker and produces a standing wave.

The length of the tube is 30.0 cm.

The wave speed inside the tube is 340 m s^{-1}.

(a) On **Fig. 18** sketch the standing wave for the fundamental mode of vibration.

Fig. 18



[1]

(b) Calculate the frequency f_0 of the speaker that is producing the standing wave inside the tube.

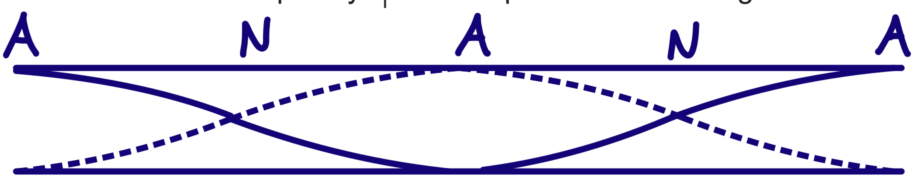
$L = \frac{\lambda}{2}$ $f_0 = \frac{v}{\lambda} = \frac{v}{2L} = \frac{340}{2 \times 0.300} = 566.7$

$\lambda = 2L$

f_0 = ...567...... Hz **[1]**

(c) The frequency of the speaker is increased.

Calculate the next frequency f_1 that will produce a standing wave in this tube.

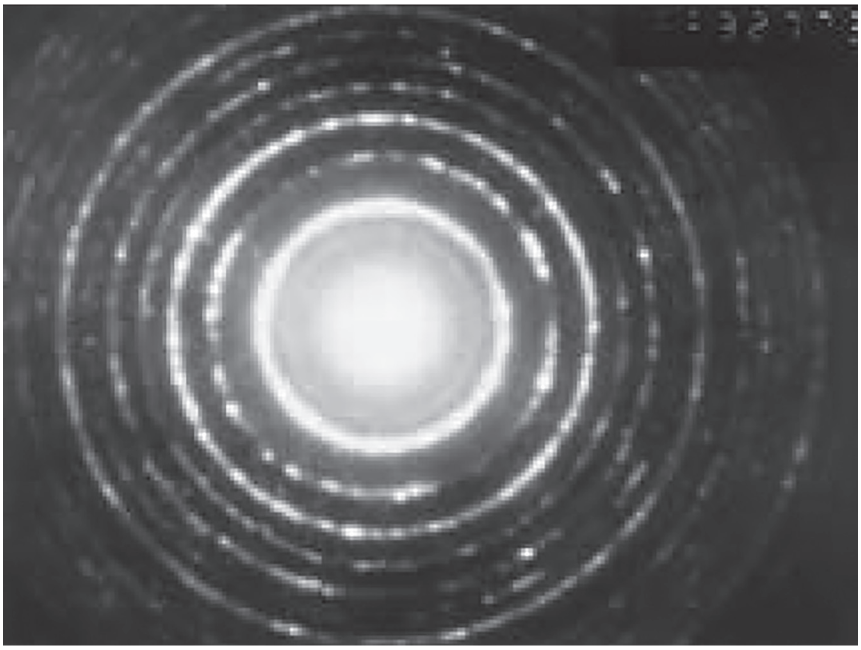


$\lambda = L$

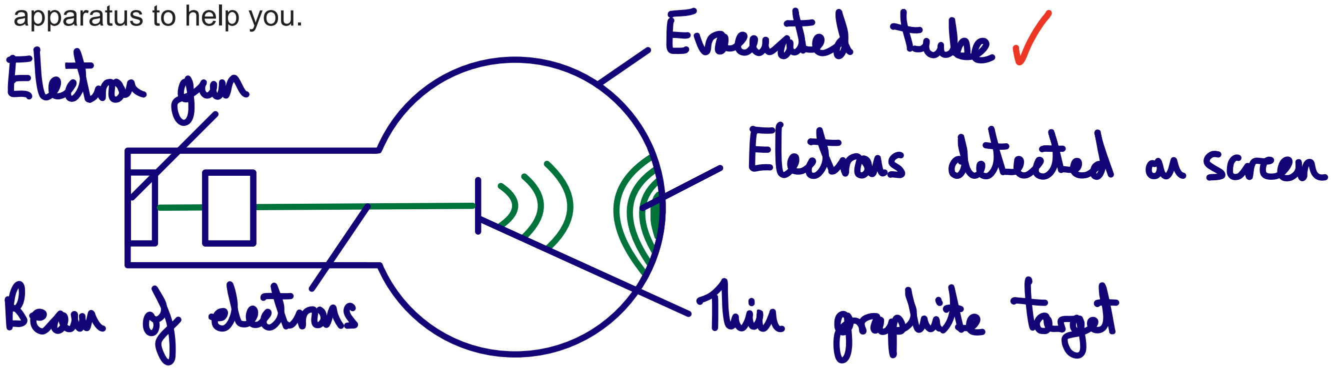
f_1 = ...1130...... Hz **[2]**

$f = \frac{v}{\lambda} = \frac{v}{L} = 2 \times f_0 = 2 \times 566.7 = 1133$

19 The picture shows an electron diffraction pattern produced by graphite in a cathode-ray tube.



(a) Describe the experiment that produces this pattern. Draw a labelled diagram of the apparatus to help you.



In an evacuated tube, electrons are accelerated ✓ by a high p.d then emitted from an electron gun and directed at a thin graphite target ✓. The diffracted electrons are detected on a screen. **[4]** ✓

(b) Explain why light and dark circles as shown in the picture are produced, stating what this evidence provides about electron behaviour.

Light circles caused by constructive interference, ✓ dark circles caused by destructive interference ✓ ∴ evidence of wave like behaviour of electrons. ✓

[3]

(c) A potential difference (p.d.) 5 kV is used to accelerate the electrons.

(i) Calculate the work done W on the electrons.

$W = qV = 1.60 \times 10^{-19} \times 5 \times 10^{3}$

1 sf

∴ answer could also be given to 1 sf

$W =$ 8.0×10^{-16} ✓ J **[1]**

(ii) Calculate the de Broglie wavelength λ of the accelerated electrons.

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

$E_K = \frac{1}{2}mv^2$ $\quad v = \sqrt{\frac{2E_K}{m}}$

$v = \sqrt{\frac{2 \times 8 \times 10^{-16}}{9.11 \times 10^{-31}}}$

$v = 4.19 \times 10^{7}$

$\lambda = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 4.19 \times 10^{7}}$ ✓

$\lambda = 1.7365 \times 10^{-11}$

$\lambda =$ 1.7×10^{-11} ✓ m **[2]**

(iii) Suggest a value for the spacing between the graphite atoms.
Justify your answer.

Greatest diffraction when λ = gap

∴ spacing of $\approx 1.7 \times 10^{-11}$ ✓

[1]

20 In an experiment a circuit is set up so that a capacitor with a resistor in series can be charged and at some later time discharged through the same resistor without changing the positions of the components. This process can be repeated.

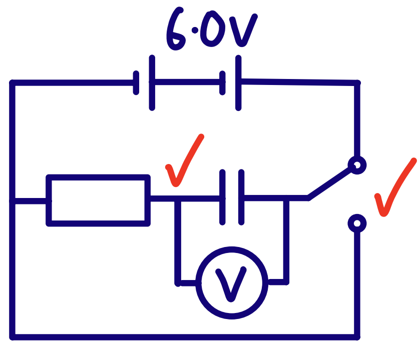
The supply has a potential difference (p.d.) 6.0 V d.c.

The capacitor has capacitance 1.0 μF.

The resistor has resistance 10 kΩ.

A voltmeter is used to measure the p.d. across the capacitor.

(a) Draw a circuit diagram for this experiment.



[2]

(b) Calculate the charge *Q* stored on the capacitor when it is fully charged.

$Q = CV = 1.0\times10^{-6} \times 6.0$

Q = 6.0×10^{-6} C **[1]**

(c) Use a calculation to explain why it will not be possible to measure the variation of p.d. across the capacitor with time, using a stop watch.

$\tau = RC = 10\times10^{3} \times 1.0\times10^{-6} = 1.0\times10^{-2} = 0.010\,s$

0.010s is the time taken for the p.d to fall to 37% of its initial value, this is much shorter than human reaction time. **[4]**

(d) State how this experiment can be modified to measure the variation of p.d. across the capacitor with time as the capacitor charges.

Use a datalogger with a voltage probe. ✓

.... **[1]**

(e) The capacitor was completely charged and then discharged to 4.12 V.

(i) Calculate the time t required for the p.d. across the capacitor to reach 4.12 V when discharging.

$V = V_0 e^{\frac{-t}{RC}}$ $\ln \frac{V}{V_0} = \frac{-t}{RC}$ $t = RC \ln \frac{V_0}{V}$ ✓

$t = 10\times10^{-3} \times 1.0\times10^{-6} \times \ln(6.0/4.12) = 3.759\times10^{-3}$

t = 3.8×10^{-3} ✓ s **[2]**

(ii) Calculate the average rate at which energy is lost by the capacitor as it discharges from 6.0 V to 4.12 V.

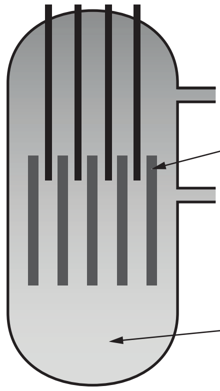
$W = \frac{1}{2}V^2C$ $\Delta W = \frac{1}{2}C\Delta(V^2) = \frac{1}{2}\times1.0\times10^{-6}\times(6.0^2 - 4.12^2)$ ✓

$W = 9.5128\times10^{-6}$ J ✓

$P = E/t = 9.5128\times10^{-6} / 3.759\times10^{-3} = 2.5306\times10^{-3}$

average rate at which energy is lost = 2.5×10^{-3} ✓ $J\,s^{-1}$ **[3]**

21 The diagram shows a simplified layout of a nuclear fission reactor used in a nuclear power station.



Fuel rods ✓

Moderator ✓

(a) Complete the labels on the diagram **[2]**

(b)* Describe how fission of nuclei is induced and controlled in the nuclear reactor.

Show how fission leads to the release of large amounts of energy.

The following masses may be useful.

Particle	Mass / u
U-235 nucleus	235.04395
Ba-141 nucleus	140.91440
Kr-92 nucleus	91.92617
$^1_0$n neutron	1.00867

[6]

U-235 nucleus absorbs a neutron to become U-236 which is unstable. This undergoes fission and splits into two smaller daughter nuclei and several fast moving neutrons. Moderator slows neutrons so other U-235 nuclei absorb these, causing a chain reaction, the rate of which is controlled by control rods which absorb excess neutrons. ✓✓✓

$U\text{-}235 + {}^1_0n \rightarrow Ba\text{-}141 + Kr\text{-}92 + 3\,{}^1_0n$

Mass defect $= 140.91440 + 91.92617 + 3 \times 1.00867$
$- 235.04395 - 1.00867 = 0.18604\,u$
$= 0.18604 \times 1.661 \times 10^{-27} = 3.09 \times 10^{-28}$ kg

Additional answer space if required

$E = mc^2 = 3.09 \times 10^{-28} \times (3.00 \times 10^8)^2$
$= 2.78 \times 10^{-11}$ J ← energy released per fission event.

Mass of products < mass of reactants ∴ energy is released. ✓✓✓

(c) The energy released from the fusion of 1 kg of hydrogen is more than seven times the energy released by the fission of 1 kg of uranium.

Compare the practicalities of using nuclear fusion of hydrogen with using nuclear fission of uranium to meet our energy needs.

Fission technology is established but fusion is not viable yet. ✓ Fission fuel (uranium) is finite whereas the fuel for fusion is readily available ✓ Fission is self sustaining but fusion requires high temperatures and pressures ✓ Fission products are also highly radioactive with very long half-lives. ✓ **[4]**

22 Radiographers commonly use molecules containing fluorine F-18 as tracers in positron emission tomography (PET) scanning.

Fluorine has a proton number of 9.

F-18 decays to oxygen (O) by β^+ decay.

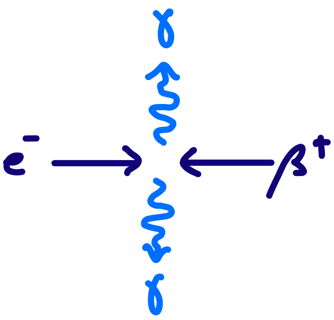
(a) Write the equation for the decay of a nucleus of F-18 using nuclear notation.

$${}^{18}_{9}F \rightarrow {}^{18}_{8}O + {}^{0}_{1}\beta^+ + {}^{0}_{0}\nu_e$$

[2]

(b) The β^+ particle (positron) produced travels only a short distance in the patient before it meets an electron and is annihilated.

Calculate the wavelength λ of gamma photons produced.



$2 \times E_e = 2 \times E_\gamma$

$E_e = E_\gamma$

c^2

$E = mc^2 = 9.11 \times 10^{-31} \times 9.00 \times 10^{16}$

$E = 8.119 \times 10^{-14}$ J

$E = \frac{hc}{\lambda}$ $\quad \lambda = \frac{hc}{E} = \frac{6.63 \times 10^{-34} \times 3.00 \times 10^{8}}{8.119 \times 10^{-14}}$

λ = 2.43×10^{-12} m **[3]**

(c) X-rays and gamma-rays are produced by different physical processes.

Briefly describe both processes.

X-rays: electrons in atoms de-excite

Gamma: nuclei decay

[2]

(d) F-18 has a half-life of 109.7 minutes.

Explain the advantage that this has for the patient but the disadvantage that this has for the radiographers.

Short half-life ∴ exposure of patient to ionising radiation is low, but it is not a long time to scan and diagnose the patient.

[3]

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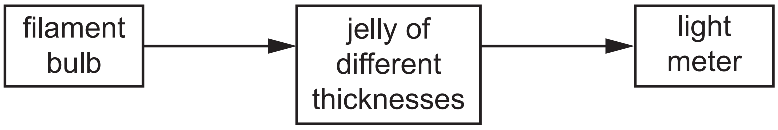
23 As light passes through a substance its intensity decreases exponentially with distance.

$I_x = I_0 e^{-\mu x}$

I_x is the intensity of light at a given thickness of jelly
I_0 is the intensity of light immediately before it enters the jelly
μ is the constant of proportionality
x is the thickness of the jelly that the light has passed through.

Some students are studying the absorption of visible light by red jelly. They set up the experiment below.



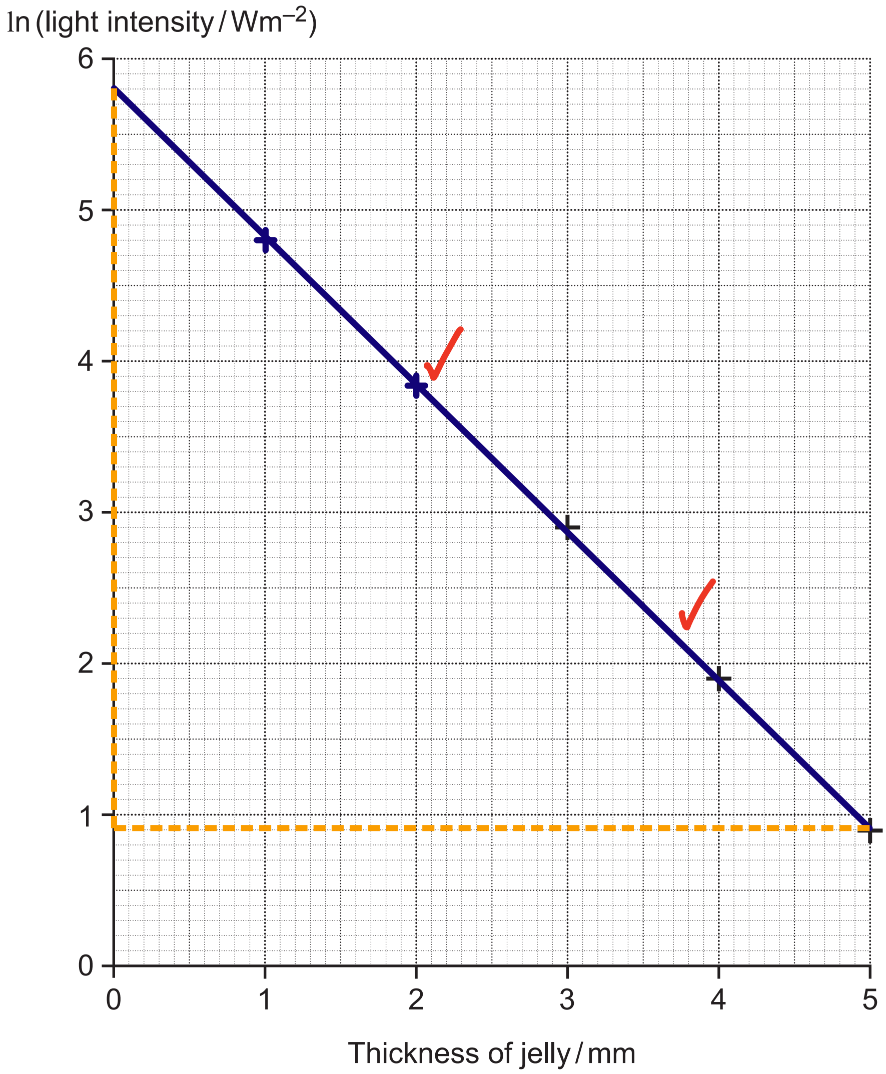
- The power to the bulb is kept constant.
- The distance between the bulb and the light meter is kept constant.
- Blocks of jelly of different thickness are used.
- They measure the intensity of light using a light meter.

(a) The table below shows their results and the natural log of the light intensity.

Thickness of jelly / mm	Light intensity / Wm^{-2}	ln (light intensity / Wm^{-2})
1	122	4.80
2	46.5	3.84
3	17.8	2.88
4	6.82	1.92
5	2.62	0.960

(i) Complete the last column of the results table for the 1 mm and 2 mm thicknesses of jelly. **[1]**

(ii) Plot the results from the table on the graph. Three points have already been plotted. **[1]**



(iii) Draw a best-fit straight line through your data points. **[1]**

(b) (i) Show how the equation for exponential absorption of light can give a straight line graph with a negative gradient.

$I_x = I_0 e^{-\mu x}$ $\ln I_x = \ln I_0 - \mu x$ ✓

$\ln I_x = -\mu x + \ln I_0$ ✓

$y = m x + c$ **[2]**

(ii) Use your graph to determine the intensity of the light I_0 before it enters the jelly.

$\ln I_0 = c = 5.8$ ✓

$I_0 = e^{5.8} = 330.3$

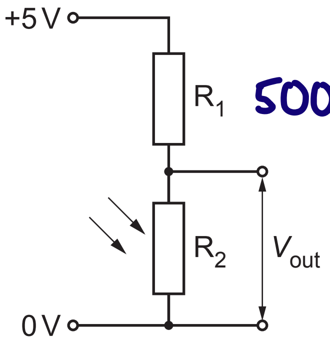
I_0 = 330 ✓ Wm^{-2} **[2]**

(iii) Use your graph to determine the constant of proportionality μ in units of mm^{-1}.

$-\mu = m = \frac{\Delta y}{\Delta x} = \frac{0.9 - 5.8}{5.0 - 0} = -0.98$ ✓

μ = + 0.98 ✓ mm^{-1} **[2]**

(c) The students decide to make their own light meter using this circuit.



The value of R_1 is 5 kΩ. The value of R_2 was 100 Ω when 1 mm jelly was used and 8 kΩ when 5 mm jelly was used.

$V_{range} = V_{max} - V_{min} = 2.979$

(i) Calculate the output voltage range obtained in this experiment.

$100 \leq R_2 \leq 8000$

$V_{out} = V_T \frac{R_2}{R_T}$

$V_{min} = 5 \times \frac{100}{5100} = 0.0980V$ ✓

$V_{max} = 5 \times \frac{8000}{13000} = 3.077$ V

range = 3.0 ✓ V **[2]**

(ii) Describe **two** ways the output voltage range could be increased.

1 Increase input voltage ✓

2 Decrease resistance of fixed resistor R_1 ✓

[2]

(iii) Explain how the circuit responds to a change in light intensity.

As the light intensity increases, R_2 decreases so V_{out} also decreases. ✓

[1]

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).