OCR
Oxford Cambridge and RSA

Thursday 14 October 2021 – Morning

A Level Physics A

H556/02 Exploring physics

Time allowed: 2 hours 15 minutes

You must have:
- the Data, Formulae and Relationships Booklet

You can use:
- a scientific or graphical calculator
- a ruler (cm/mm)

8334364570

H556/02

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

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

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 responses will be assessed in questions marked with an asterisk (*).
- This document has **32** 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.

Answer **all** the questions.

1 Faraday's law of electromagnetic induction is written below with **two** terms missing.

The ..... induced in a circuit is directly proportional to the rate of change of magnetic flux ..... .

What are the **two** missing terms?

A current, density

B current, linkage

C electromotive force, density

D electromotive force, linkage

Your answer ☐ **[1]**

2 Monochromatic light from a laser is incident normally on a diffraction grating.
A series of bright dots are formed on a distant screen.

Which **two** terms can be used to explain these bright dots?

A diffraction, interference

B reflection, interference

C refraction, diffraction

D refraction, reflection

Your answer ☐ **[1]**

3 The current in a lamp is 2.0 mA. The potential difference across the lamp is 6.0 V.

What is the energy transfer in the lamp over a period of 3.0 hours?

A 0.012 J

B 0.036 J

C 2.16 J

D 130 J

Your answer ☐ **[1]**

4 The diagram below shows two oppositely charged spheres.

The magnitude of the charge on each sphere is the same.
The point **P** is on the line joining the centres of the spheres and is the same distance from the centre of each sphere.

Which statement is correct?

A A negatively charged particle at **P** will move to the right.

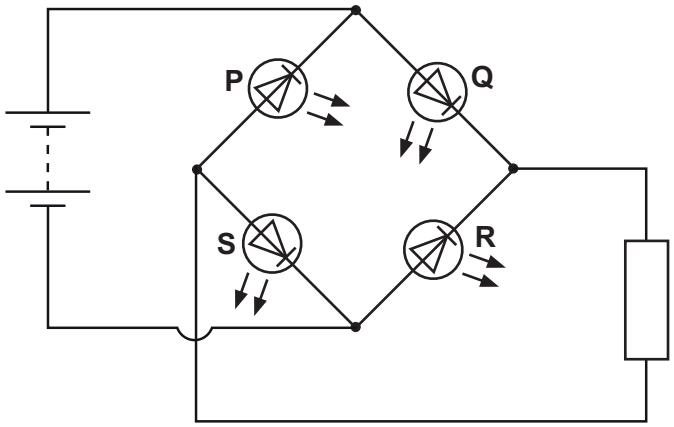
B The direction of the electric field at **P** is to the left.

C The electric potential at **P** is zero.

D The magnitude of the electric field strength at **P** is zero.

Your answer ☐ **[1]**

5 A circuit with four light-emitting diodes (LEDs) **P**, **Q**, **R** and **S** is shown below.



Two LEDs are lit in this circuit. Which **two** LEDs are lit?

A **P** and **Q**

B **P** and **R**

C **Q** and **R**

D **Q** and **S**

Your answer ☐ **[1]**

6 A student is modelling the decay of charge for a capacitor discharging through a resistor using the equation $\frac{\Delta Q}{\Delta t} = -0.2Q$.
The student decides to use $\Delta t = 0.5\,\text{s}$.
The initial charge on the capacitor is $1000\,\mu\text{C}$.

Part of the modelling spreadsheet from the student is shown below.

t/s	Charge Q left on capacitor at time t/μC	Charge ΔQ decaying in the next 0.5 s/μC
0	1000	100
0.5	900	
1.0		
1.5		

What is the value of Q in μC at $t = 1.5\,\text{s}$?

A 700

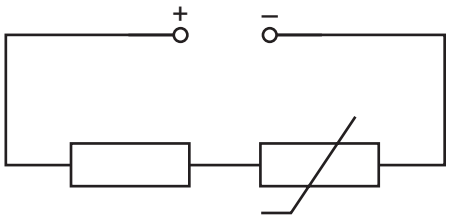
B 720

C 729

D 800

Your answer ☐ **[1]**

7 A circuit with a thermistor is shown below.



The resistance of the resistor is R and the resistance of the thermistor is $2.5R$.
The potential difference (p.d.) across the thermistor is 5.0 V.

What is the total p.d. across both components?

A 2.0 V

B 7.0 V

C 12.5 V

D 17.5 V

Your answer ☐ **[1]**

8 A double-slit is used in an interference experiment to independently investigate the light from two sources **K** and **L**. The light from the sources have different wavelengths.
The table below shows some data.

Light source	Wavelength of light	Separation between adjacent bright fringes	Distance between screen and double-slit
K	λ	1.2 mm	D
L	0.80λ		$0.50D$

What is the separation between adjacent bright fringes for source **L**?

A 0.48 mm

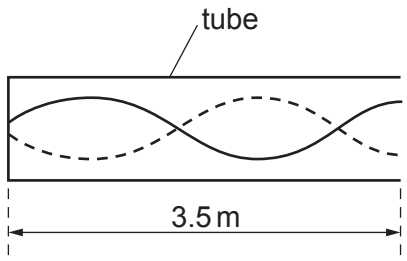
B 1.2 mm

C 1.9 mm

D 3.0 mm

Your answer ☐ **[1]**

9 A stationary sound wave formed in a tube is shown below.



The tube is closed at one end. The length of the tube is 3.5 m.
The speed of sound is 340 m s^{-1}.

What is the frequency of the sound wave?

A 97 Hz

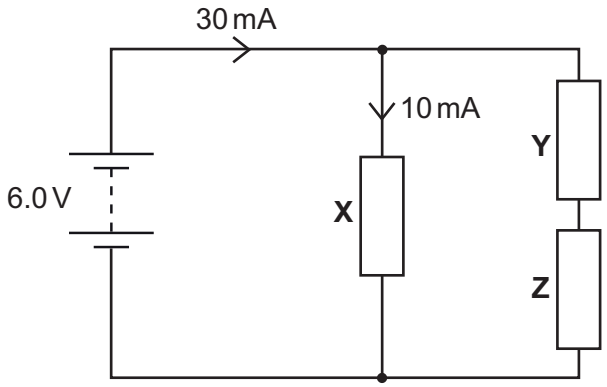
B 120 Hz

C 240 Hz

D 486 Hz

Your answer ☐ **[1]**

10 A battery of electromotive force (e.m.f) 6.0 V and of negligible internal resistance is used in the circuit below.



The current from the battery is 30 mA. The current in the resistor **X** is 10 mA.
The resistors **Y** and **Z** are identical.

What is the power dissipated in the resistor **Z**?

A 30 mW

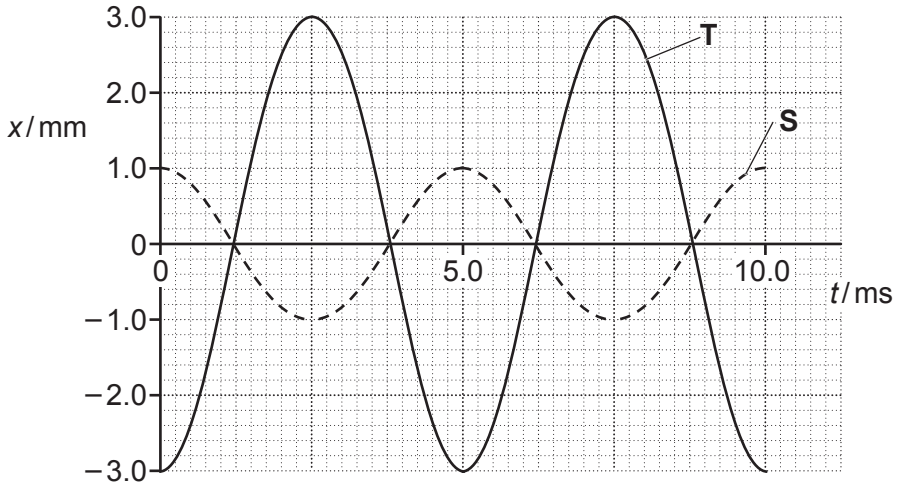
B 60 mW

C 120 mW

D 180 mW

Your answer ☐ **[1]**

11 The diagram below shows the graphs of displacement x against time t for two waves **S** and **T**.



The waves meet at a point in space.
The superposition of these two waves produces a resultant wave.

What is the frequency f and the amplitude A of the resultant wave?

A $f = 100\,\text{Hz}$, $A = 2.0\,\text{mm}$

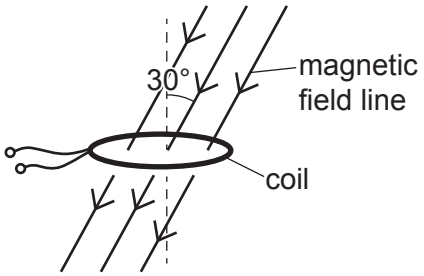
B $f = 100\,\text{Hz}$, $A = 4.0\,\text{mm}$

C $f = 200\,\text{Hz}$, $A = 2.0\,\text{mm}$

D $f = 200\,\text{Hz}$, $A = 4.0\,\text{mm}$

Your answer ☐ **[1]**

12 A flat coil has 200 turns and a cross-sectional area of $1.20 \times 10^{-4}\,m^2$.



The coil is placed horizontally in a uniform magnetic field. The magnetic flux density is 0.050 T. The magnetic field is at an angle of 30.0° to the vertical.

What is the magnetic flux linkage for this coil?

A 3.00×10^{-6} Wb

B 5.20×10^{-6} Wb

C 6.00×10^{-4} Wb

D 1.04×10^{-3} Wb

Your answer ☐ **[1]**

13 The nucleus of thorium-232 $\left({}^{232}_{90}\text{Th}\right)$ emits two alpha particles and two beta-minus particles to become a nucleus of an isotope of radium.

What is the nucleon number A and the proton number Z for the nucleus of this radium isotope?

A $A = 224$, $Z = 88$

B $A = 228$, $Z = 86$

C $A = 224$, $Z = 84$

D $A = 228$, $Z = 88$

Your answer ☐ **[1]**

14 A beam of ultrasound is incident normally at a boundary between two tissues **F** and **G**.

The table below shows some data on the two tissues.

	Tissue F	**Tissue G**
Density of tissue	ρ	1.2ρ
Speed of ultrasound in tissue	c	$1.5c$

What percentage of the intensity of the ultrasound is reflected at the boundary?

A 0.83%

B 8.2%

C 9.1%

D 29%

Your answer ☐ **[1]**

15 A radiation detector is placed in front of a beta-emitting source.
The count-rate is measured and recorded every 10 minutes.
The results are shown below.

$311\,s^{-1}$ $309\,s^{-1}$ $299\,s^{-1}$ $307\,s^{-1}$ $321\,s^{-1}$

What term can be used to describe the data shown?

A exponential

B linear

C random

D spontaneous

Your answer ☐ **[1]**

SECTION B

Answer **all** the questions.

16 (a) The normal frequency range of hearing for young people is from 20 Hz to 20 kHz.

(i) The speed of sound in air is 340 m s^{-1}.

Calculate the **shortest** wavelength a young person can hear.

wavelength = ... m **[2]**

(ii) Describe how you can use an oscilloscope, and other additional laboratory equipment, to determine the actual upper limit of the frequency range for a young person.

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(b) State **one** difference and **one** similarity between the **oscillations** of a stationary sound wave and a progressive sound wave.

Difference: .....

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Similarity: .....

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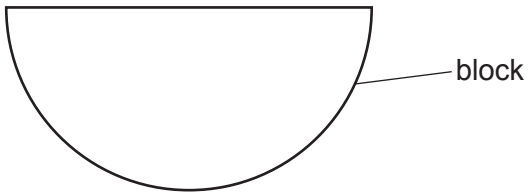
[2]

(c) You are provided with a ray-box, a semi-circular block of plastic and other normal laboratory equipment.
The outline of the block is shown below.



Describe how you could measure the refractive index *n* of the block using the critical angle method. Draw on the diagram and label it to make your answer clear.

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..... **[3]**

17 **(a)** Define the **work function** of a metal.

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..... **[1]**

(b) The work function of potassium is 2.3 eV.

(i) Potassium emits electrons from its surface when blue light is incident on it. Extremely intense red light produces no electrons.

Explain these observations in terms of photons and their energy.

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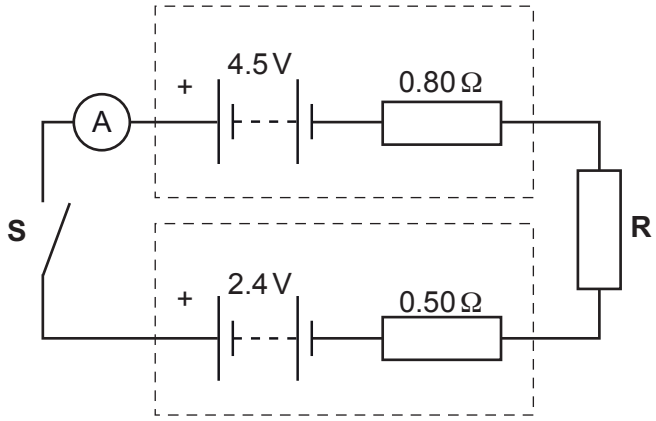
..... **[4]**

(ii) Light from a laser is incident on some potassium in a vacuum. Electrons are emitted. The wavelength of the light is 320 nm.

Calculate the shortest de Broglie wavelength of the emitted electrons.

de Broglie wavelength = ... m **[4]**

18 (a) The circuit diagram of an electrical circuit is shown below.



The positive terminals of the batteries are connected together.
One battery has electromotive force (e.m.f.) 4.5 V and internal resistance 0.80 Ω.
The other battery has e.m.f. 2.4 V and internal resistance 0.50 Ω.
R is a coil of insulated wire of resistance 1.2 Ω at room temperature.

The switch **S** is closed.

(i) On the diagram, draw an arrow to show the direction of the conventional current. **[1]**

(ii) Calculate the current I shown by the ammeter.

I = ... A **[3]**

(iii) The insulated wire has diameter 4.6×10^{-4} m.
The number density of charge carriers in **R** is 4.2×10^{28} m^{-3}.

Calculate the mean drift velocity v of the charge carriers in **R**.

v = ... m s^{-1} **[2]**

(iv) The current measured by the ammeter is smaller than that calculated in **(ii)**. This is because the temperature of **R** increased due to heating by the current.

Without any changes to the circuit itself, state and explain what practically can be done to make the measured current the same as the calculated current..

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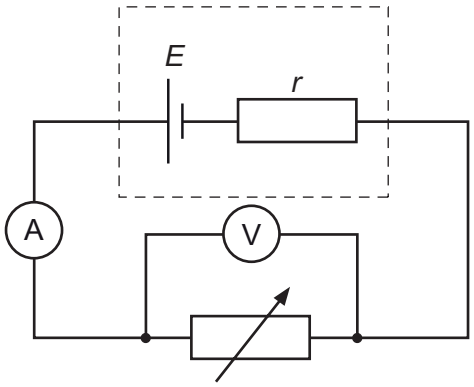
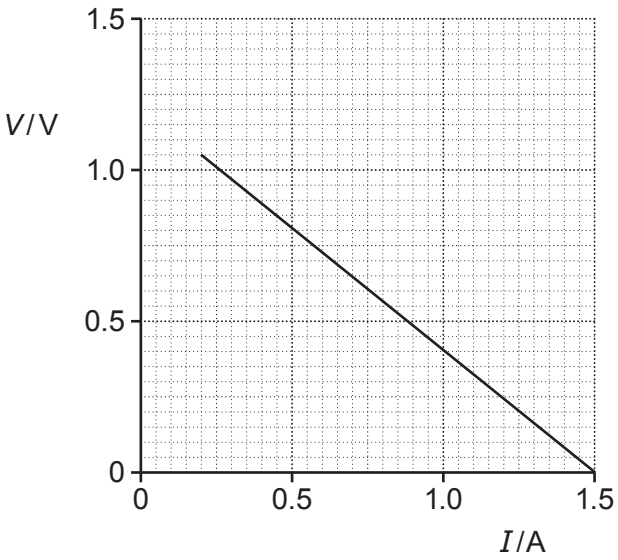
(b)* A student is doing an experiment to determine the e.m.f. E of a cell and its internal resistance r. The circuit diagram of the arrangement is shown below.



The student changes the resistance of the variable resistor. The potential difference V across the variable resistor and the current I in the circuit are measured.

The V against I graph plotted by the student is shown below.



V/V	I/A	R/Ω	P/W
0.20	1.25		
0.40	1.00		
0.60	0.75		
0.80	0.50		
1.00	0.25		

There is an incomplete table next to the graph.
R is the resistance of the variable resistor and P is the power dissipated by the variable resistor.

- Use the graph to determine E and r. Explain your reasoning.
- Calculate R and P to complete the table. Describe how P depends on R.

[6]

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Additional answer space if required

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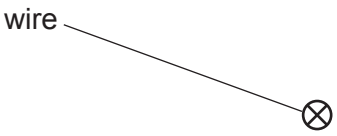
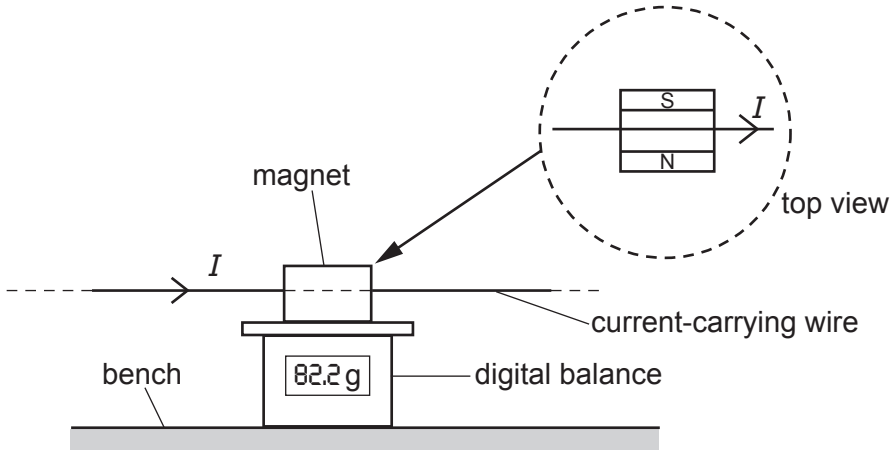
19 (a) The diagram below shows the top-view of a long current-carrying wire.



The direction of the current in the wire is into the plane of the paper.

Draw at least **three** field lines to indicate the magnetic field pattern around this wire. **[2]**

(b) The arrangement shown in the diagram below is used to determine the magnetic flux density between the poles of a permanent magnet.



The magnet is placed on the digital balance. The current-carrying wire is horizontal and at right angles to the magnetic field between the poles of the magnet. The wire is fixed.

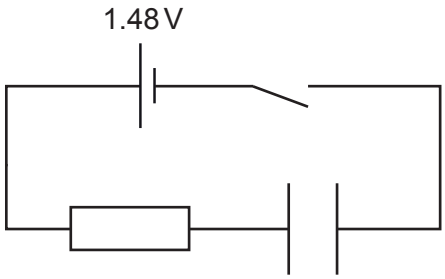
The following results are collected.

- length of the wire in the uniform field of the magnet = 6.0 ± 0.2 cm
- balance reading with no current in wire = 80.0 g
- balance reading with current in wire = 82.2 g
- current in wire = 5.0 ± 0.1 A

Calculate the magnetic flux density B, including the absolute uncertainty.
Ignore the absolute uncertainty in the balance readings.
Write your value for B to **2** significant figures and the absolute uncertainty to **1** significant figure.

B = ... ± ..... T **[4]**

20 (a) The diagram below shows a circuit to charge a capacitor.

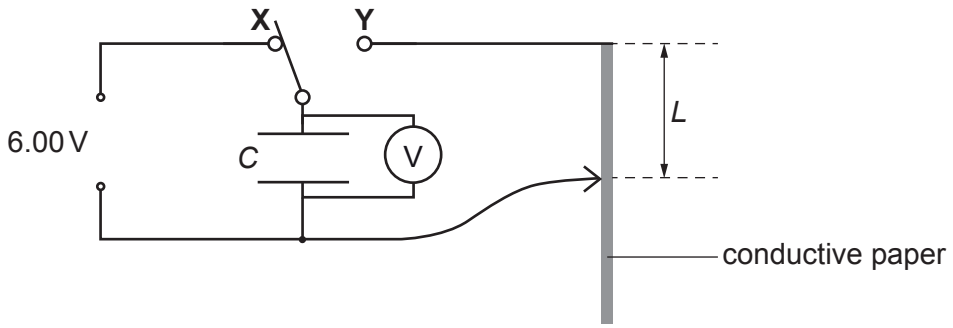


The electromotive force (e.m.f.) E of the cell is 1.48 V and it has negligible internal resistance.
The resistance of the resistor is 120 kΩ and the capacitance of the capacitor is 2000 μF.
At time t = 0 the capacitor is uncharged.
The switch is closed at time t = 0.

Calculate the time t when the potential difference across the capacitor is 1.00 V.

t = ... s **[4]**

(b) A capacitor of capacitance *C* is connected across a strip of conductive paper.



The switch is moved from **X** to **Y**, and the time *t* for the potential difference across the capacitor to halve is measured.

The time *t* is given by the expression

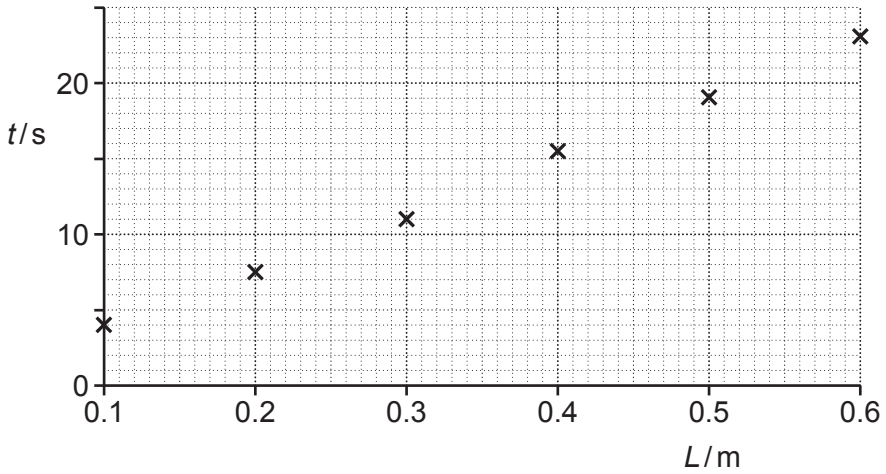
$t = (Ck \ln 2) \times L$

where *k* is the resistance of the conductive paper per unit length and *L* is the length of the conductive paper.

The value of *C* is 1.2×10^{-3} F.

In an experiment, *L* is changed and *t* measured.

The data points are plotted on a *t* against *L* grid as shown below.



Draw a straight line of best fit through the data points, and use the gradient of this line to determine k.

k = ... $\Omega\ m^{-1}$ **[4]**

21 **(a)** A high-energy X-ray photon interacts with an electron of an atom through the **Compton effect**.

Describe this effect.

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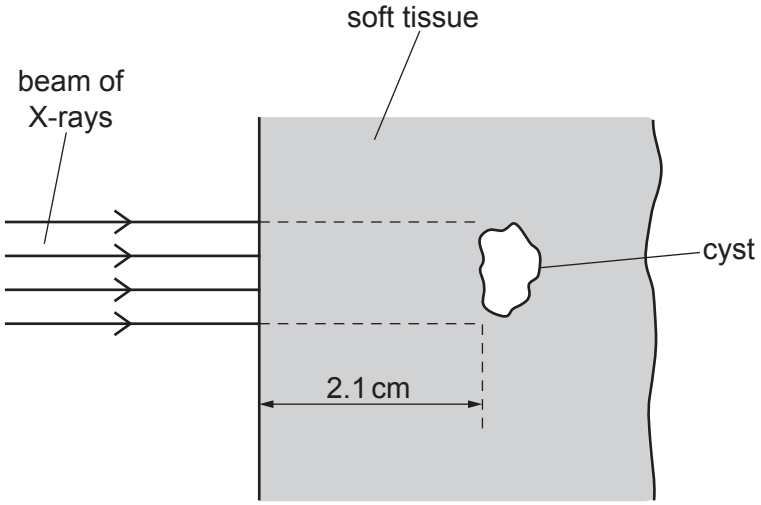
..... **[2]**

(b) The diagram below shows a beam of X-rays incident normally on some soft tissue.



The attenuation (absorption) constant of the soft tissue is $0.85\,\text{cm}^{-1}$.
The intensity of the beam is $4.6 \times 10^{3}\,\text{W m}^{-2}$.
There is a small cyst 2.1 cm from the surface of the soft tissue. The cross-sectional area of the cyst normal to the beam is $3.4 \times 10^{-4}\,\text{m}^{2}$.

The beam is switched on for 30 s.

Calculate the X-ray energy incident on the cyst in a period of 30 s.

energy = ... J **[4]**

(c) The attenuation coefficients of the cyst and the soft tissues in **(b)** were similar. This prevented imaging the cyst using a two-dimensional X-ray image.

Name a different X-ray technique that could be used to image the cyst. Explain the advantage of this technique.

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..... **[2]**

22 The medical tracer fluorine-18 is used in positron emission tomography (PET).
Fluorine-18 is a beta-plus emitter with a short half-life.

Describe how the fluorine-18 nuclei are located in a patient using a PET scanner.

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..... **[4]**

23 (a) Explain the function of the control rods and the moderator in a nuclear fission reactor.

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..... **[2]**

(b)* Some nuclear fission reactors use uranium-235 as fuel. In the future, there is possibility of using hydrogen-2 as fuel in fusion reactors.

Here is some information and data on fission and fusion reactions.

	Fission reactor	**Fusion reactor**
Typical reaction	${}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{144}_{56}Ba + {}^{89}_{36}Kr + 3{}^{1}_{0}n$	${}^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{1}H + {}^{1}_{1}H$
Approximate energy produced in each reaction	200 MeV	4 MeV
Molar mass of fuel material	uranium-235: $0.235\,kg\,mol^{-1}$	hydrogen-2: $0.002\,kg\,mol^{-1}$

- Describe the similarities and the differences between fission and fusion reactions.
- Explain with the help of calculations, which fuel produces more energy per kilogram.

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Additional answer space if required

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24 (a) **Fig. 24** shows two horizontal metal plates in a vacuum.

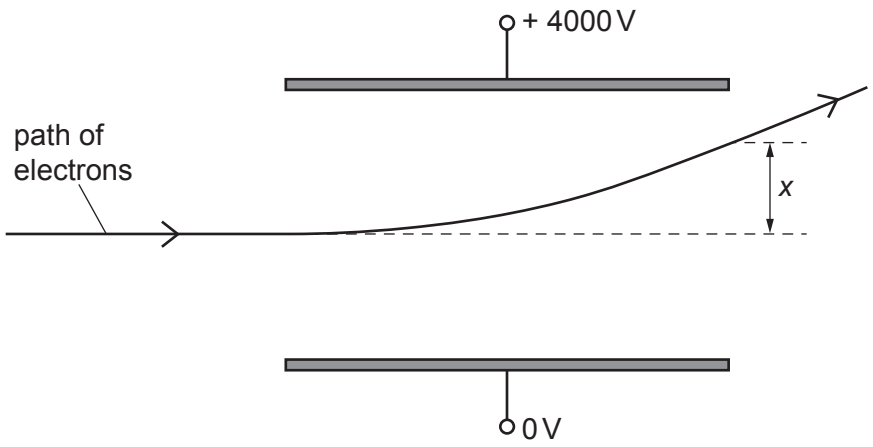

Fig. 24

The diagram is **not** drawn to scale.
Electrons travelling horizontally enter the space between the charged plates and are deflected vertically.

The potential difference between the plates is 4000 V.
The distance between the plates is 0.08 m.
The initial speed of the electrons is $6.0 \times 10^{7}\,\text{m s}^{-1}$.
The vertical deflection of the electrons at the far end of the plates is x.

(i) Show that the vertical acceleration a of an electron between the plates is $8.8 \times 10^{15}\,\text{m s}^{-2}$.

[3]

(ii) The length of each plate is 0.12 m.

Show that the time t taken by the electron to travel this length is $2.0 \times 10^{-9}\,\text{s}$.

[1]

(iii) Calculate the vertical deflection x of the electron.

x = ... m **[2]**

(b) The arrangement shown in **Fig. 24** is now used to investigate positrons emitted from a radioactive source.
The speed of the positrons is also $6.0 \times 10^7\,\text{m s}^{-1}$.

The initial path of the positrons is the same as that of the electrons in **Fig. 24**.

On **Fig. 24**, sketch the path of the positrons between the plates. **[2]**

(c) Beta-minus particles (electrons) emitted from a radioactive source have a range of speeds.

Describe and explain how a uniform magnetic field can be applied in the space between the charged plates to select beta-minus particles with a specific speed. No calculations are required.

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25 **(a)** A researcher is doing an experiment on a radioactive solution in a thin **glass** tube.
The solution has two radioactive materials **X** and **Y**.
The table below shows some data on these two materials.

	Material X	**Material Y**
Half-life	10 minutes	10 hours
Particles emitted	Alpha	Beta-minus
Daughter nuclei	Stable	Stable

The solution has the same number of nuclei of **X** and **Y** at the start.

(i) State and explain which material has the greatest activity at the start.

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..... **[1]**

(ii) State why it is dangerous for the researcher to handle the test tube with bare hands.

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..... **[1]**

(b) Carbon-14 ($^{14}_{6}C$) is produced in the upper atmosphere of the Earth by collisions between nitrogen nuclei and fast-moving neutrons.
The nuclear transformation equation below shows the formation of a single carbon-14 nucleus.

$$^{14}_{7}N + {}^{1}_{0}n \longrightarrow {}^{14}_{6}C + X$$

(i) State the proton number of particle X.

proton number = ... **[1]**

(ii) Use the data below to determine the binding energy per nucleon of the $^{14}_{6}C$ nucleus. Write your answer to **3** significant figures.

- mass of neutron = 1.675×10^{-27} kg
- mass of proton = 1.673×10^{-27} kg
- mass of $^{14}_{6}C$ nucleus = 14.000 u
- 1 u = 1.66×10^{-27} kg

binding energy per nucleon = ... J per nucleon **[4]**

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).

OCR
Oxford Cambridge and RSA

Friday 10 June 2022 – Afternoon

A Level Physics A

H556/02 Exploring physics

Time allowed: 2 hours 15 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 _____

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

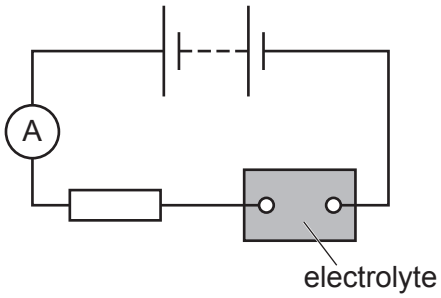
SECTION A

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

Write your answer to each question in the box provided.

Answer **all** the questions.

1 A current is present in the circuit below.



The resistor is made from a length of wire.

Which row gives the correct charge carriers in the resistor and in the electrolyte?

	Charge carriers in the resistor	**Charge carriers in the electrolyte**
A	Electrons	Electrons
B	Electrons	Ions
C	Electrons and protons	Ions and electrons
D	Electrons and ions	Ions and protons

Your answer ☐ **[1]**

2 The half-life of fluorine-18 isotope is T.
After time $t = 4T$ the number of fluorine-18 nuclei in a source is N.

How many fluorine-18 nuclei have decayed in the time interval from $t = 0$ to $t = 4T$?

A $3N$

B $4N$

C $15N$

D $16N$

Your answer ☐ **[1]**

3 The activity of an alpha-emitting source is 120 kBq. The kinetic energy of each alpha-particle is 4.0 MeV.

What is the rate of energy released by the source?

A 6.4×10^{-13} W

B 4.8×10^{-8} W

C 7.7×10^{-8} W

D 1.2×10^{5} W

Your answer ☐ **[1]**

4 Which of the following statement(s) correctly describe radioactive decay?

1 Radioactive decay can be modelled using dice.
2 Radioactive decay of nuclei is random.
3 Radioactive decay of nuclei is spontaneous.

A Only 1

B Only 2

C 2 and 3

D 1, 2 and 3

Your answer ☐ **[1]**

5 A gamma-ray photon of frequency 6.76×10^{22} Hz creates a particle-antiparticle pair. The particle-antiparticle pair have zero kinetic energy.

What is the mass of the particle?

A 2.49×10^{-28} kg

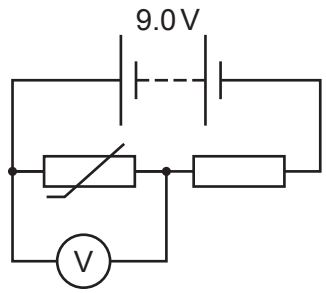
B 4.98×10^{-28} kg

C 7.47×10^{-20} kg

D 4.48×10^{-11} kg

Your answer ☐ **[1]**

6 A potential divider circuit is shown below.



The battery has electromotive force (e.m.f.) 9.0 V and negligible internal resistance.
At room temperature the potential difference (p.d.) across the thermistor is 4.5 V.
The temperature of the thermistor is increased and its resistance decreases by 20% from its previous value.

What is the p.d. across the thermistor now?

A 3.6 V

B 4.0 V

C 5.0 V

D 5.4 V

Your answer ☐ **[1]**

7 A particle is moving at right angles to a uniform magnetic field of flux density *B*. The particle has mass *m*, charge *q* and moves in a circular arc of radius *r* in the region of the magnetic field.

What quantities are required to determine the momentum of this particle?

A *B*, *q* and *r*

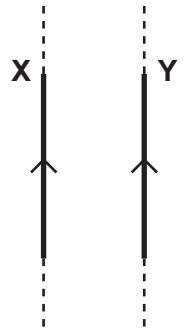
B *B*, *q* and *m*

C *B*, *q*, *r* and *m*

D *q*, *r* and *m*

Your answer ☐ **[1]**

8 The diagram below shows two long current-carrying conductors **X** and **Y**.



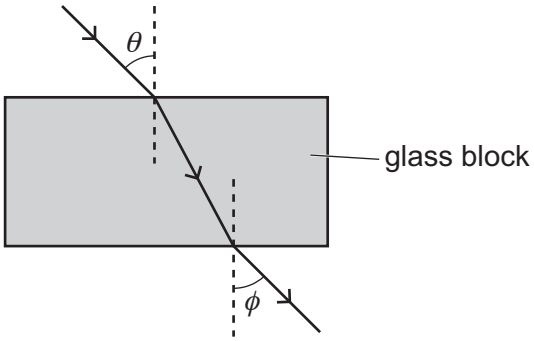
The conductors are parallel to each other.
Y experiences a force because it is in the magnetic field of **X**.

Which row gives the correct direction of the magnetic field at **Y** due to **X**, and the direction of the force experienced by **Y** due to this field?

	Direction of magnetic field	**Direction of force**
A	Down into the plane of paper	To the right
B	Up from the plane of paper	To the right
C	Down into the plane of paper	To the left
D	Up from the plane of paper	To the left

Your answer ☐ **[1]**

9 A student is investigating the refraction of light by a rectangular glass block. The glass block is surrounded by air.
The diagram below shows the path of the light as it enters the block, when it is refracted within the block and when it exits the block.



Which statement is correct?

A The angles θ and ϕ are the same because the glass block is surrounded by air.

B The product of $\sin\theta$ and the refractive index of glass is a constant.

C The refractive index of glass is less than the refractive index of air.

D The speed of light is the same in both air and glass.

Your answer ☐ **[1]**

10 A proton of mass 1.67×10^{-27} kg is travelling at a speed of $2.0 \times 10^{5}\,m\,s^{-1}$.

The table below shows the mass and speed of four particles **A**, **B**, **C** and **D**.

Particle	Mass / kg	Speed / $10^5\,m\,s^{-1}$
A	9.11×10^{-30}	5.0
B	8.80×10^{-28}	3.0
C	2.49×10^{-28}	2.0
D	3.34×10^{-27}	1.0

Which particle has the same de Broglie wavelength as the proton?

Your answer ☐ **[1]**

11 A beam of sound of intensity I_0 is reflected off the surface of water.
The amplitude of the reflected sound is $\frac{1}{4}$ the amplitude of the incident sound.

What is the intensity of the reflected sound in terms of I_0?

A $\frac{I_0}{16}$

B $\frac{I_0}{8}$

C $\frac{I_0}{4}$

D I_0

Your answer ☐ **[1]**

12 A small sample of muscle has volume 1.0 cm^3 and mass 1.10 g.
The speed of ultrasound in the muscle is 1600 m s^{-1}.

What is the acoustic impedance of the muscle?

A 1.76×10^3 kg m^{-2} s^{-1}

B 1.76×10^4 kg m^{-2} s^{-1}

C 1.76×10^6 kg m^{-2} s^{-1}

D 1.76×10^{12} kg m^{-2} s^{-1}

Your answer ☐ **[1]**

13 The mass of a proton is m_p, the mass of a neutron is m_n, and the mass of a hydrogen-3 ($^3_1$H) nucleus is M. The speed of light in a vacuum is c.

Which expression is correct for the binding energy (B.E.) of the hydrogen-3 nucleus?

A B.E. = $M \times c^2$

B B.E. = $(m_n + m_p - M) \times c^2$

C B.E. = $(m_n + 2m_p - M) \times c^2$

D B.E. = $(2m_n + m_p - M) \times c^2$

Your answer ☐ **[1]**

14 A wire in a circuit obeys Ohm's law.

Which statement about the wire is linked to this law?

A The current in the wire is directly proportional to the potential difference across it.

B The current in the wire is inversely proportional to its resistance.

C The resistance of the wire is directly proportional to its length.

D The resistance of the wire is inversely proportional to its cross-sectional area.

Your answer ☐ **[1]**

15 An electron has both mass and charge. The electron has a gravitational field and an electric field around it.

Which statement is **not** correct?

A Both field patterns look the same.

B Both field patterns show parallel field lines around the electron.

C Both field strengths obey an inverse square law with distance from the electron.

D The direction of both fields is the same at any point around the electron.

Your answer ☐ **[1]**

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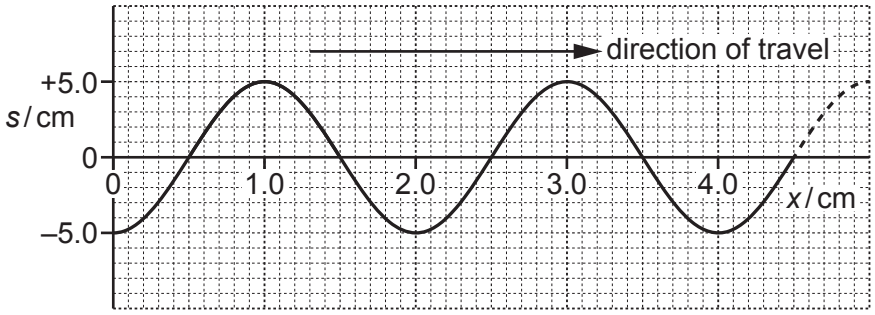
SECTION B

Answer **all** the questions.

16 (a) A graph of displacement s against distance x for a **progressive** wave at time $t = 0$ is shown below.



Determine:

(i) the phase difference ϕ in radians between the points on the wave at $x = 1.5\,\text{cm}$ and $x = 2.5\,\text{cm}$

ϕ = ... rad **[1]**

(ii) the displacement s at time $t = \frac{3}{4}T$ at $x = 1.5\,\text{cm}$, where T is the period of the oscillations of the wave.

s = ... cm **[1]**

(b) A beam of coherent light of wavelength λ is incident normally at two parallel slits (double-slit). A series of bright and dark fringes are formed on a distant screen placed parallel to the line joining the slits.
The location of some of these fringes is shown in **Fig. 16.1**.

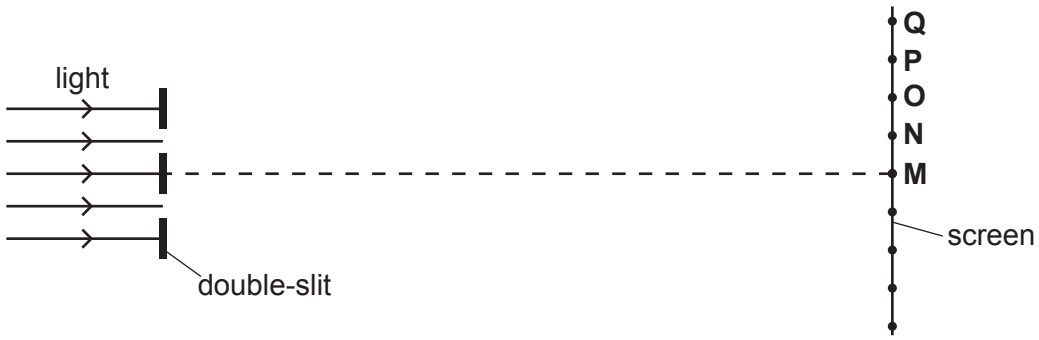


Fig. 16.1 (not to scale)

The bright fringes are seen at points **M**, **O** and **Q**. The dark fringes are seen at points **N** and **P**.

State the phase difference ϕ in degrees, and the path difference d in terms of wavelength λ, for the waves from the two slits meeting at point **P**.

ϕ = ... ° **[1]**

d = ... λ **[1]**

(c) A student is doing an experiment to determine the speed of sound in air by producing stationary waves inside a horizontal glass tube.

Fine powder is sprinkled inside the tube. A loudspeaker is placed close to the open end of the tube. The other end of the tube is closed. The loudspeaker is connected to a signal generator producing a frequency of 2.72 kHz.
The powder inside the tube forms piles at certain locations inside the tube, see **Fig. 16.2**.

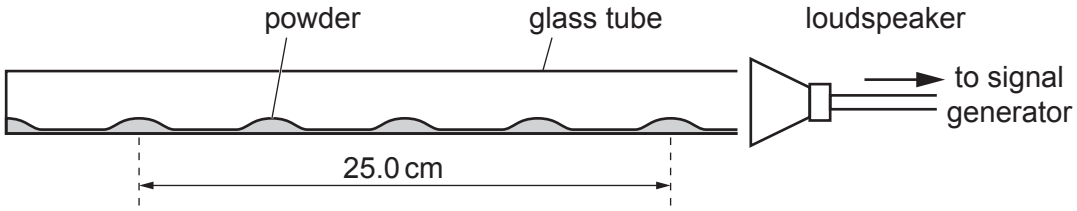


Fig. 16.2 (not to scale)

(i) Suggest why the powder piles up at the nodes within the tube.

.....

..... **[1]**

(ii) Use **Fig. 16.2** to determine the speed of sound v.

v = ... $m\,s^{-1}$ **[3]**

(iii) Determine the fundamental (minimum) frequency f_0 of the stationary wave that can be formed within this tube.

f_0 = ... Hz **[2]**

17 A light-emitting diode (LED) can be used to determine the Planck constant h. When the LED just starts to emit light, the equation below is valid

$$eV = \frac{hc}{\lambda}$$

where V is the potential difference (p.d.) across the LED, λ is the wavelength of the light emitted, c is the speed of light in vacuum and e is the elementary charge.

(a) In the equation above, $\frac{hc}{\lambda}$ is the energy of a photon emitted from the LED.

Determine the S.I. base units for h.

base units = ... **[2]**

(b)* Describe how an experiment can be carried out in the laboratory to determine h from a graph. Your description must include how V and λ are accurately determined. Assume that the values of e and c are known. **[6]**

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Additional answer space if required

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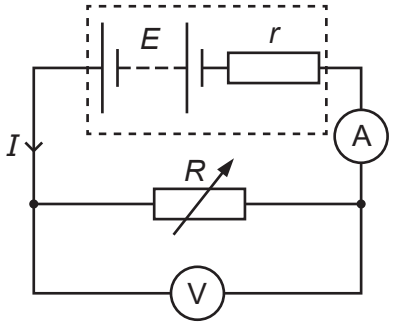
18 A battery is connected to a variable resistor.



The variable resistor is made from a length of wire. The resistance of the variable resistor is R. The battery has electromotive force (e.m.f.) E and internal resistance r. The current in the circuit is I.

(a) Compare the e.m.f. of the battery and the potential difference (p.d.) across the variable resistor in terms of energy transfers or changes.

.....

..... **[1]**

(b) State which physical quantity of the variable resistor is changed to alter its resistance.

..... **[1]**

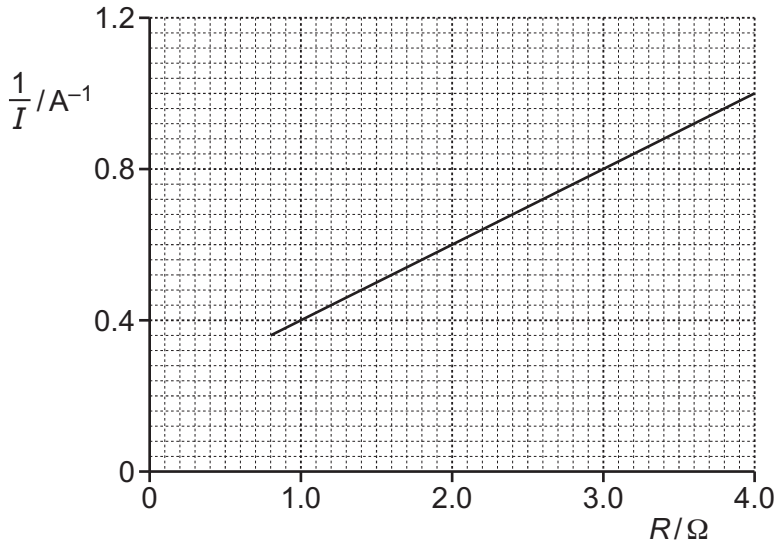
(c) A student connects up the circuit above to determine r.

(i) Show that $\frac{1}{I} = \frac{R}{E} + \frac{r}{E}$.

[2]

(ii) The student varies R and measures the current I.

The student plots a graph of $\frac{1}{I}$ against R.



1 Use the graph to determine the power dissipated in the variable resistor when $R = 3.0\,\Omega$.

power = ... W **[2]**

2 The e.m.f. E of the battery is 5.0 V.

Determine r from the intercept of the line with the vertical axis.

r = ... Ω **[2]**

19 The diagram below shows two parallel plates, **E** and **C**, in an evacuated glass tube.

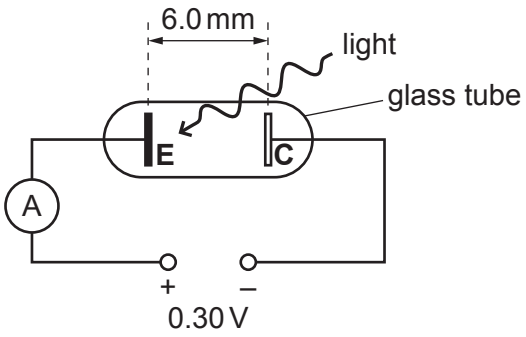


Plate **E** is made from potassium, which is sensitive to light. Plate **C** is not sensitive to light.

The separation between the plates is 6.0 mm and the potential difference between the plates is 0.30 V.

Light of frequency 6.3×10^{14} Hz is incident on plate **E**. The photoelectrons emitted from this plate have **maximum** kinetic energy 0.30 eV (4.8×10^{-20} J). The photoelectrons are repelled by the negative plate **C**. The ammeter reading is zero because these photoelectrons reach plate **C** with zero kinetic energy.

(a) Calculate the work function of potassium in eV.

work function = ... eV **[3]**

(b) This question is about a photoelectron emitted perpendicular to plate **E** and with an initial kinetic energy of 4.8×10^{-20} J.

(i) Show that the magnitude of deceleration of this photoelectron is 8.8×10^{12} m s^{-2}.

[3]

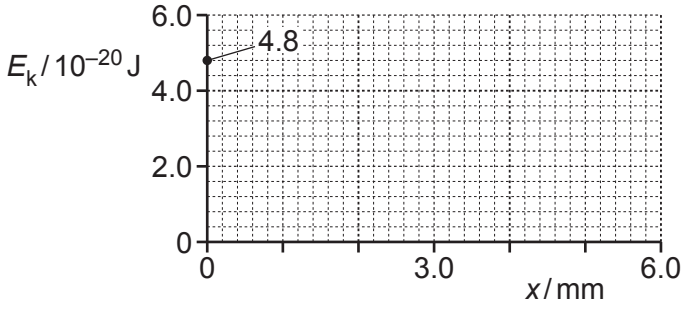
(ii) Show that the initial speed of the photoelectron is about $3 \times 10^5\,\text{m s}^{-1}$.

[2]

(iii) Calculate the time t taken by the photoelectron to travel from plate **E** to plate **C**.

t = ... s **[2]**

(iv) Using the axes shown below, sketch a graph of kinetic energy E_k against distance x from plate **E**.



[2]

(c) Explain, in terms of photons, what happens to the ammeter reading when light of frequency greater than $6.3 \times 10^{14}\,\text{Hz}$ is now incident on plate **E**.

.....

.....

..... **[2]**

20 (a) Deuterium is an isotope of hydrogen.
A nucleus of deuterium has a proton and a neutron.

Describe the nature and range of the **two** forces acting between these two hadrons.

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..... **[4]**

(b)* Here is some data for a nucleus of carbon-14 ($^{14}_{6}C$) and a nucleus of uranium-235 ($^{235}_{92}U$).

	Carbon-14 nucleus	**Uranium-235 nucleus**
Decay mode	Beta-minus decay	Alpha decay
Mass of nucleus / u	14.0	235.0
Radius of nucleus / 10^{-15} m	2.9	7.4

Use the data to:
- describe the composition of the nuclei before and after the decay in terms of hadrons and quarks
- show that both nuclei have the same density. **[6]**

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Additional answer space if required

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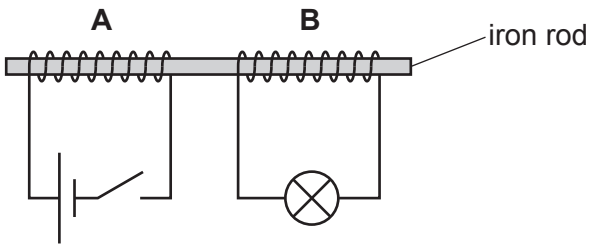
21 **(a)** The diagram below shows two insulated-copper coils **A** and **B** connected in circuits.



Both coils are individually wrapped around the same iron rod.
Coil **A** is connected to a cell and a switch. Coil **B** is connected to a filament lamp.

The switch is initially closed and the lamp is off.

The switch is then opened. The lamp flashes on for a brief time, and then remains off.

Explain these observations in terms of magnetic flux.

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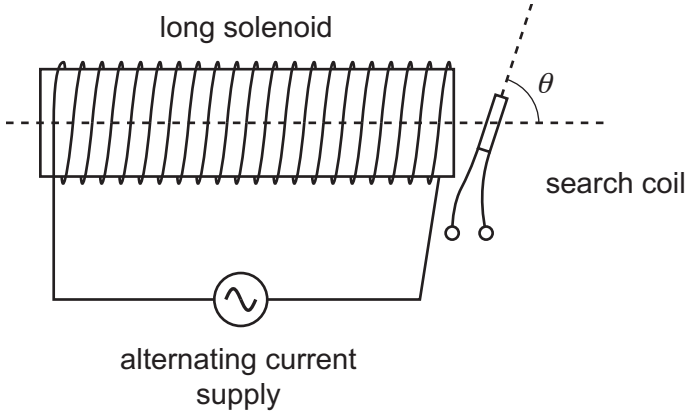
..... **[3]**

(b) A student is carrying out an experiment using a search coil.



A long solenoid is connected to an alternating current supply.

The search coil is placed at one end of the solenoid. The plane of the search coil is tilted such that it makes an angle θ with the central axis of the solenoid. The maximum alternating induced electromotive force (e.m.f.) across the ends of the search coil is E_0.

(i) Name an instrument that can be used to determine E_0.

..... **[1]**

(ii) The equation for E_0 is:

$E_0 = KI_0ANf\sin\theta$

where I_0 = maximum current in the solenoid, A = cross-sectional area of the search coil, N = number of turns of the search coil, f = frequency of the alternating current in the solenoid and $K = 4.0 \times 10^{-3}\,\text{VA}^{-1}\,\text{m}^{-2}\,\text{s}$.

The magnitude of the induced e.m.f. in the search coil can be determined using Faraday's law of electromagnetic induction:

e.m.f. = rate of change of magnetic flux linkage

In the experiment, angle θ is changed and E_0 measured.

Suggest the quantity, or quantities, in the equation $E_0 = KI_0ANf\sin\theta$ linked to

1 the 'rate' part of the law

..... **[1]**

2 the 'change of magnetic flux linkage' part of the law.

..... **[1]**

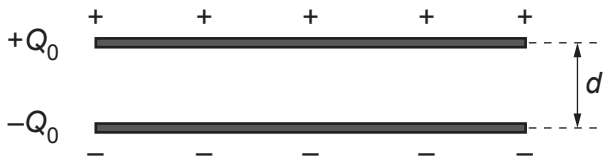
(iii) The student plots a straight-line graph of E_0 against $\sin\theta$.

Determine f, including the absolute uncertainty. Write your value of f to **2** significant figures.

$I_0 = (8.0 \pm 0.2)\text{A}$
$A = (7.8 \pm 0.1) \times 10^{-5}\,\text{m}^2$
$N = 5000$
gradient of line $= KI_0ANf = (0.62 \pm 0.03)\,\text{V}$

f = ... ± ..... Hz **[4]**

22 **(a)** The diagram below shows a simple capacitor.



The capacitor consists of two horizontal metal plates in a vacuum. The magnitude of the charge on each plate is Q_0. The potential difference (p.d.) between the plates is V_0. The capacitor plates have capacitance C_0. The separation between the plates is d. The energy stored by the capacitor is E_0.

The top plate is moved vertically upwards. The new separation between the plates is $2d$. The charge on each plate remains the **same**.
The energy stored by the capacitor **increases**.

(i) Determine the new:

1 capacitance in terms of C_0

capacitance = ... C_0 **[1]**

2 p.d. between the plates in terms of V_0

p.d. = ... V_0 **[1]**

3 energy stored in terms of E_0.

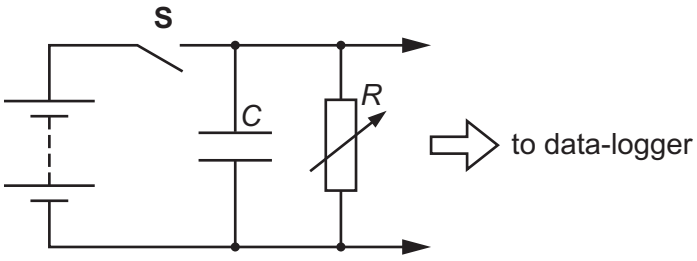
energy = ... E_0 **[1]**

(ii) Explain, in terms of forces between the plates, why the energy stored increases.

.....

..... **[1]**

(b) A student discharges a capacitor of capacitance C through a variable resistor of resistance R using the arrangement below.



The capacitor is made from two parallel metal plates separated by a sheet of paper of thickness 8.0×10^{-5} m. The area of overlap between the plates is 3.1×10^{-2} m^2.

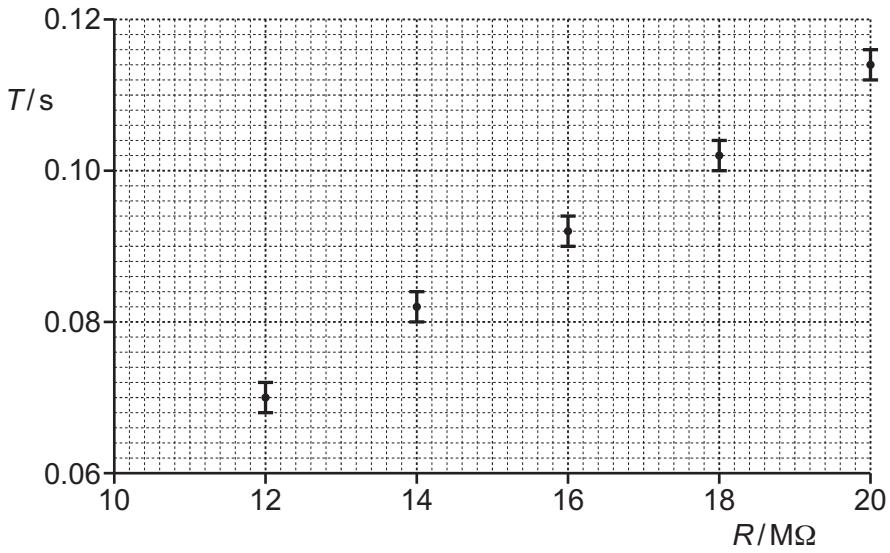
The capacitor is charged fully by closing switch **S**. At time $t = 0$, **S** is opened and the capacitor discharges through the resistor. After $t = T$, the potential difference across the capacitor is halved. The student repeats this for several values of R.

(i) The student decides to plot T against R to obtain a straight-line graph.

Show that the line has gradient = $C\ln 2$.

[2]

(ii) The data points plotted by the student are shown below.



1 Draw a best-fit straight line through the data points and use the gradient of this line to determine C.

C = ... F **[3]**

2 Use your answer in **(ii)1** to calculate the permittivity ε of the paper.

ε = ... F m^{-1} **[2]**

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23 A gamma camera has several important components including a collimator, scintillator and photomultiplier tubes.

(a) Suggest why the collimator needs to be long and narrow.

.....

..... **[1]**

(b) State the function of the scintillator.

.....

..... **[1]**

(c) In a single photomultiplier tube, a photon of light produces a $0.32\,\mu A$ pulse of current for a duration of $1.2\,ns$.

Calculate the number of electrons responsible for this pulse of current.

number of electrons = ... **[2]**

(d) State one diagnostic application of a gamma camera.

.....

..... **[1]**

Question 24 is on the next page

24 **(a)** Describe, in terms of X-ray photons, the attenuation mechanism of Compton scattering.

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..... **[2]**

(b) A parallel beam of X-rays is incident normally on a tissue as shown in **Fig. 24.1**.

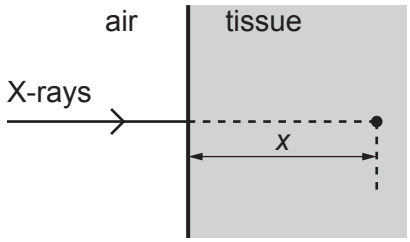

Fig. 24.1

The variation of the intensity I of the X-rays with depth x in the tissue is shown in **Fig. 24.2**.

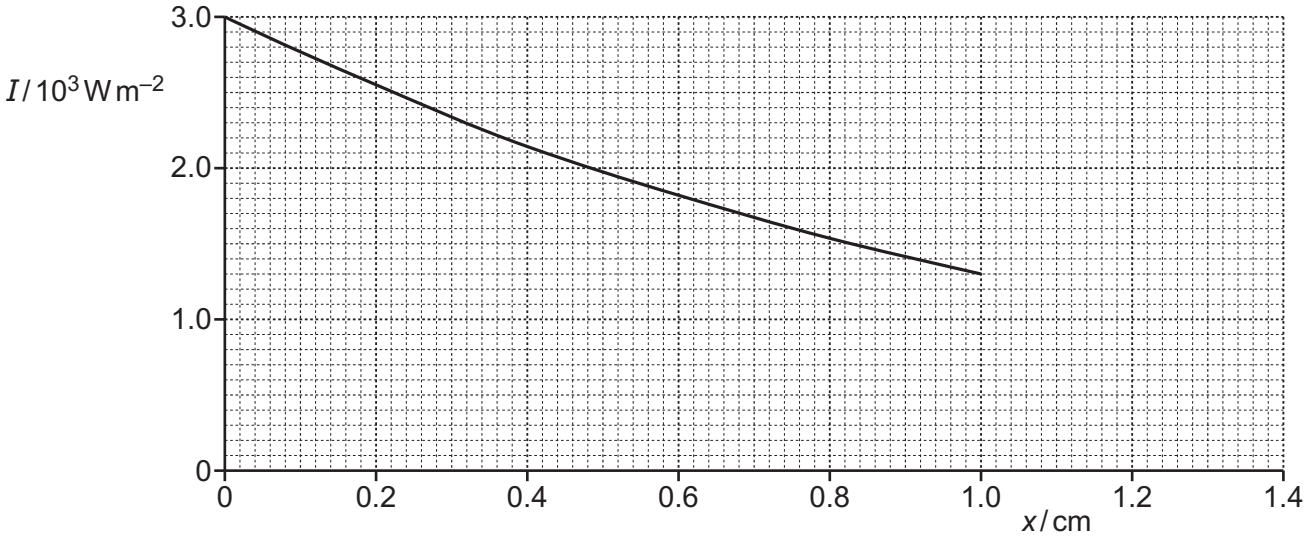

Fig. 24.2

The tissue has uniform structure between $x = 0$ and $x = 1.0$ cm.

(i) Use the graph to determine the attenuation (absorption) coefficient μ in cm^{-1} of the tissue.

μ = ... cm^{-1} **[2]**

(ii) Use the graph to determine the exposure time t for the total radiant energy incident per cm^2 at a depth of 1.0 cm to be 2.6 J.

t = ... s **[3]**

(iii) Beyond x = 1.0 cm, the tissue has a larger attenuation coefficient than the value calculated in **(i)**.

On **Fig. 24.2**, sketch the variation of I with x beyond x = 1.0 cm. **[2]**

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).

OCR
Oxford Cambridge and RSA

Friday 9 June 2023 – Morning

A Level Physics A

H556/02 Exploring physics

Time allowed: 2 hours 15 minutes

You must have:
- the Data, Formulae and Relationships booklet

You can use:
- a scientific or graphical calculator
- a ruler (cm/mm)

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H556/02

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

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

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

C m^2

D N

Your answer ☐ **[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?

A 1%

B 2%

C 4%

D 8%

Your answer ☐ **[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.
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 ☐ **[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

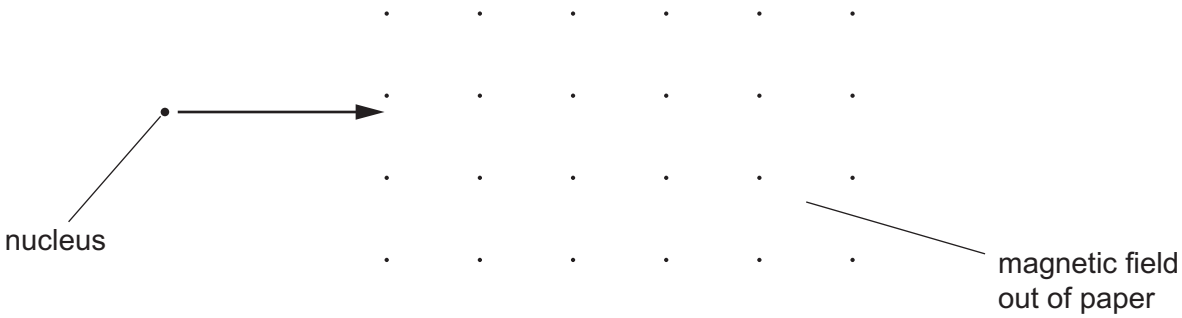
B 39p

C £2.34

D £23.40

Your answer ☐ **[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

Your answer ☐ **[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

Your answer ☐ **[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

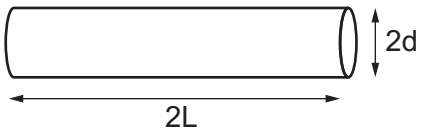
C 140 V

D 20 000 V

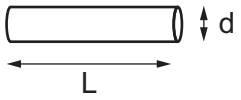
Your answer ☐ **[1]**

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

wire X



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

Your answer ☐ **[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

Your answer ☐ **[1]**

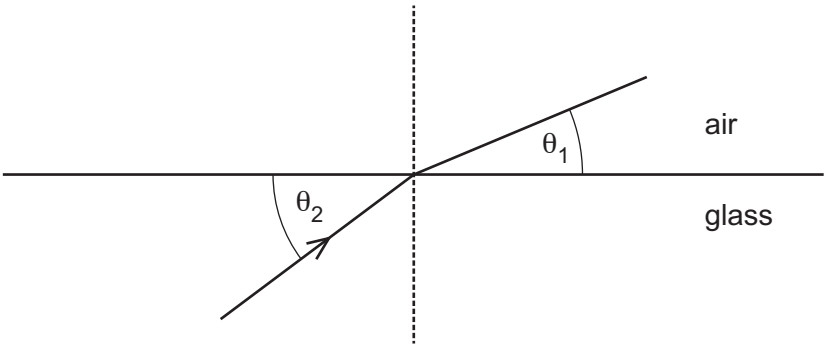
10 A column of air in a tube of length *L*, closed at one end, is forced to vibrate at its fundamental frequency. A standing wave is set up inside the tube.

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

Your answer ☐ **[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 $\theta_2 > 48°$

A 1 only

B 1 and 2

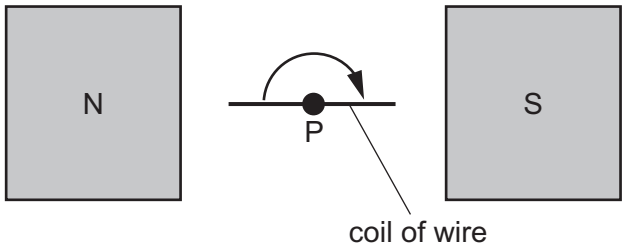
C 3 only

D 1 and 3

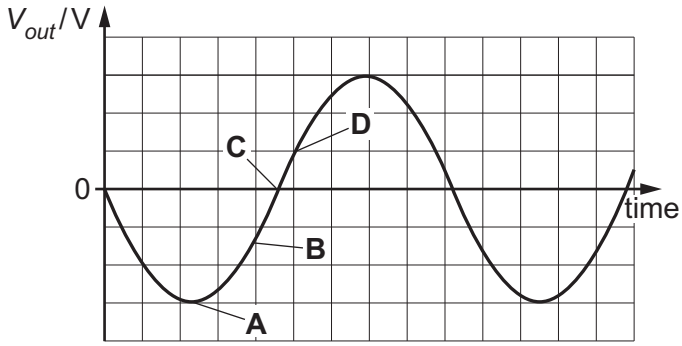
Your answer ☐ **[1]**

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.



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



Your answer ☐ **[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

Your answer ☐ **[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

Your answer ☐ **[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.

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.

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.

Your answer ☐ **[1]**

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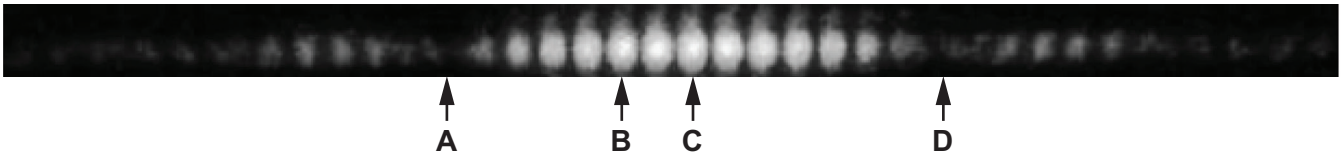
Section B

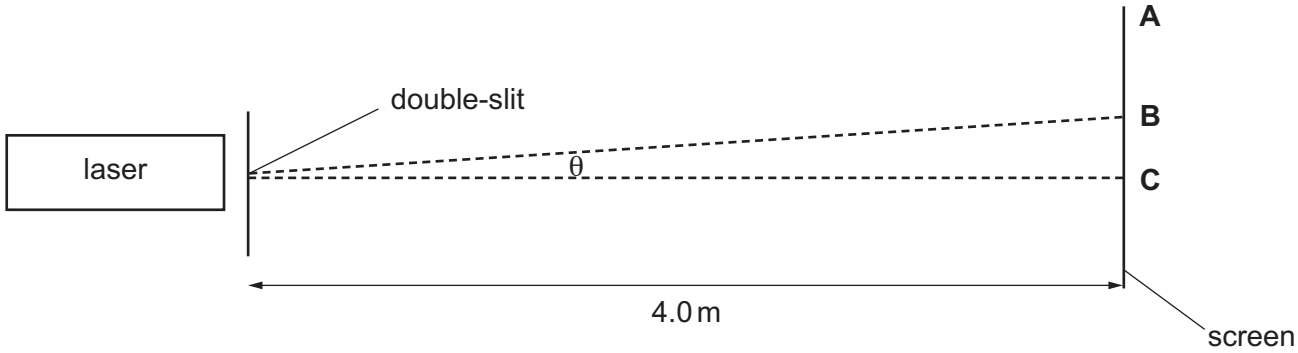
16 **Fig. 16.1** shows the pattern obtained in a Young double-slit experiment. The pattern is **not** to scale. Three regions of the pattern are labelled **A**, **B** and **D**. The central maximum is labelled **C**.

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** .....

B and **C** ..... **[2]**

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

.....

..... **[1]**

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

.....

.....

..... **[2]**

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

θ = ... ° **[3]**

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

(a) Explain what is meant by ultrasound.

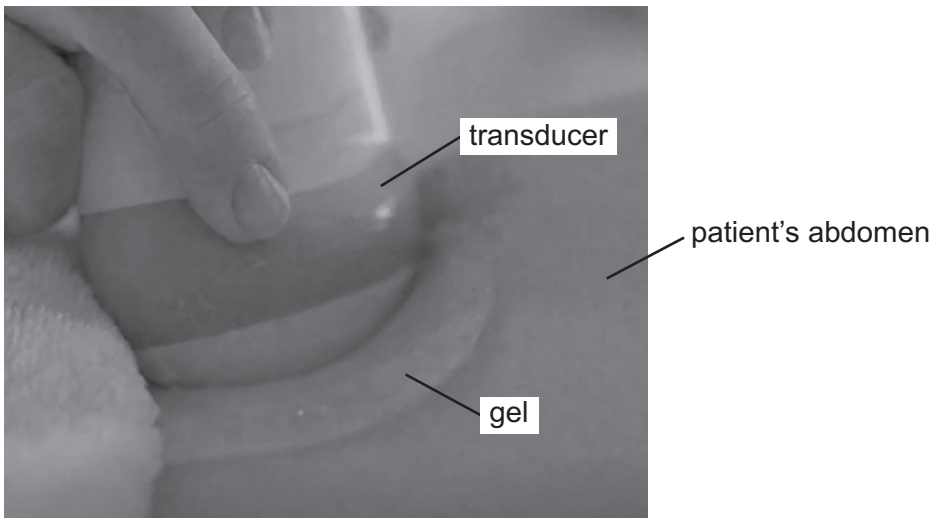
.....

.....

..... **[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]**

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Additional answer space if required

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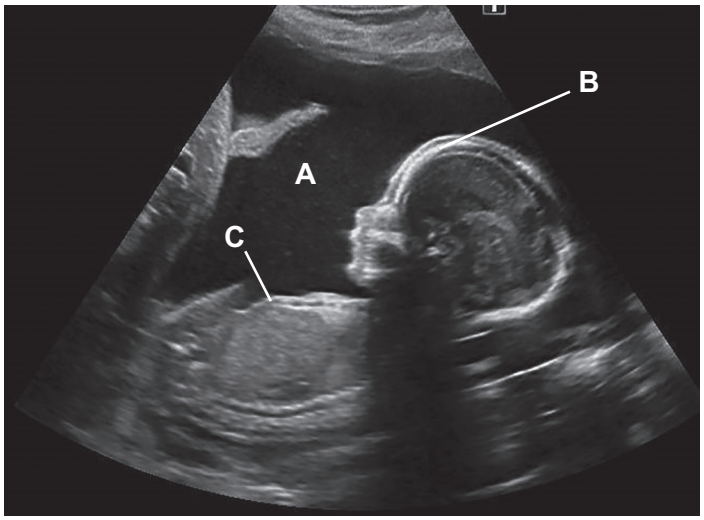
Question 17 continues on page 14

(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**.

.....

..... **[1]**

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

.....

.....

..... **[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.

v = ... 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 ms^{-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.

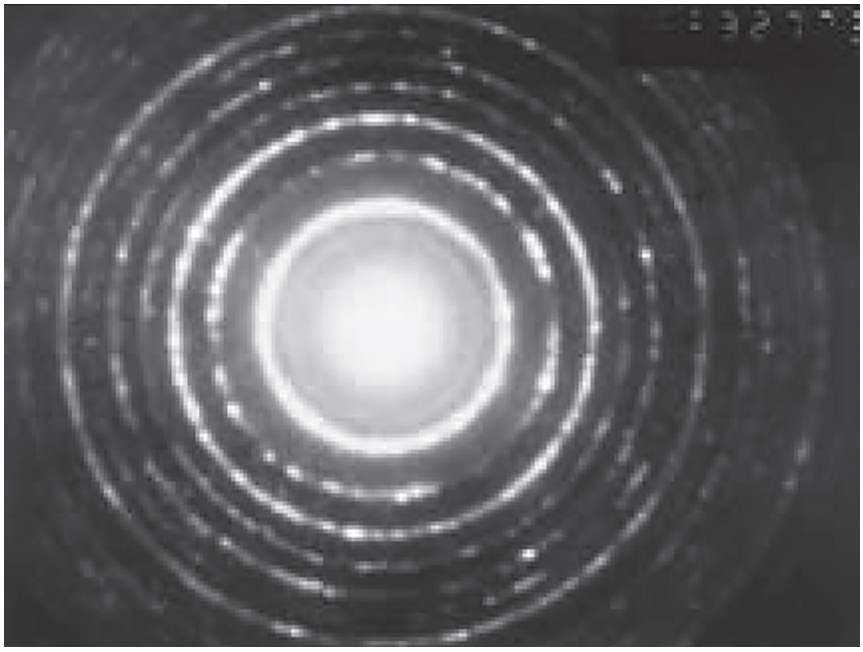
f_0 = ... Hz **[1]**

(c) The frequency of the speaker is increased.

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

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

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.

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..... **[4]**

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

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..... **[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 = ... J **[1]**

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

λ = ... m **[2]**

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

.....

.....

..... **[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 = ... 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.

.....

..... **[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.

.....

..... **[1]**

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

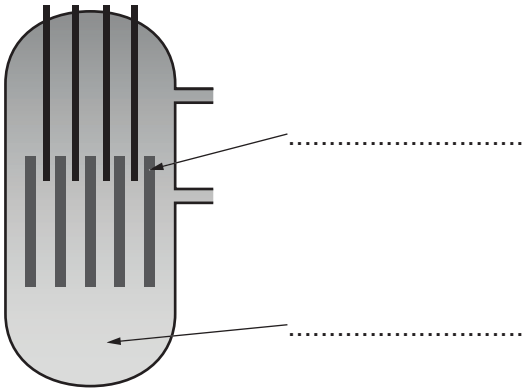
(i) Calculate the time *t* required for the p.d. across the capacitor to reach 4.12 V when discharging.

t = ...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.

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

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



(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]

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Additional answer space if required

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(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.

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..... **[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.

[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.

λ = ... m **[3]**

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

Briefly describe both processes.

.....

.....

..... **[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.

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..... **[3]**

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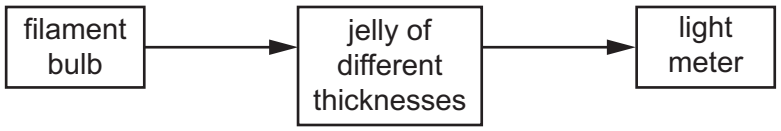
23 As light passes through a substance its intensity decreases exponentially with distance.

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

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.



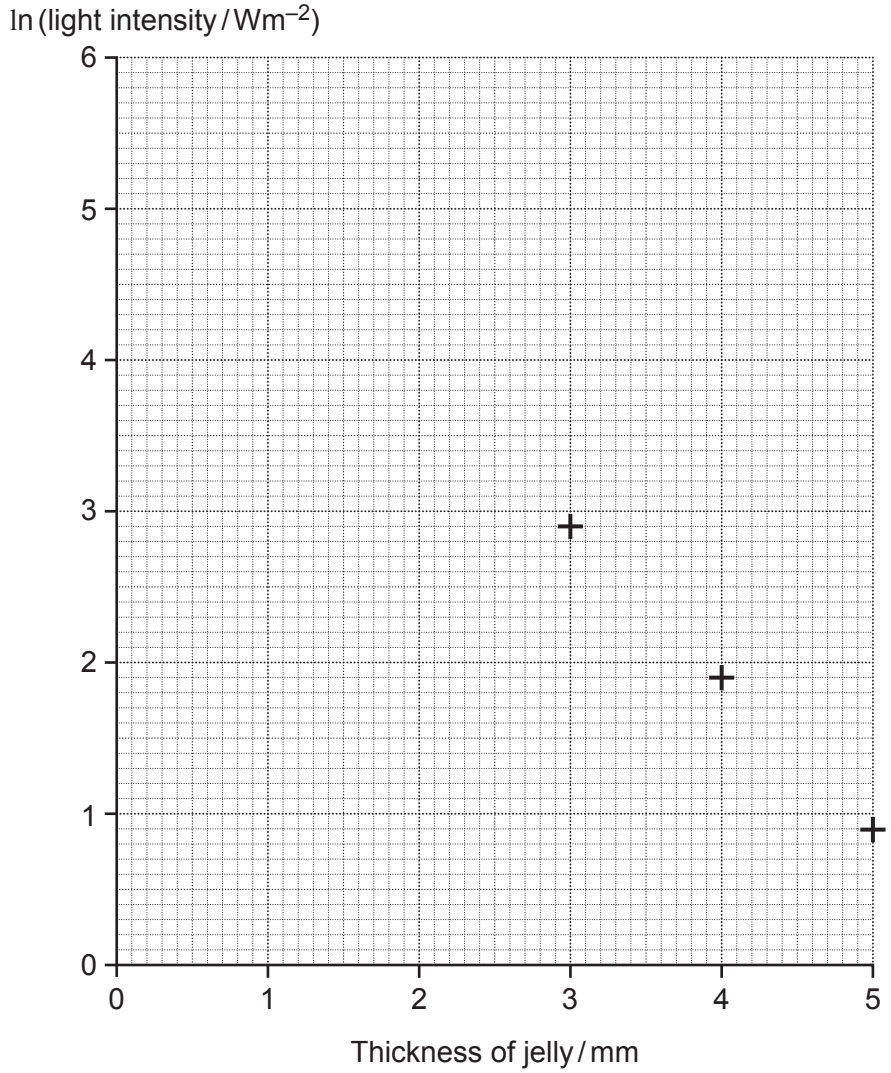
- The power to the bulb is kept constant.
- The distance between the bulb and the light meter is kept constant.
- Blocks of jelly of different thickness are used.
- They measure the intensity of light using a light meter.

(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	
2	46.5	
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.

[2]

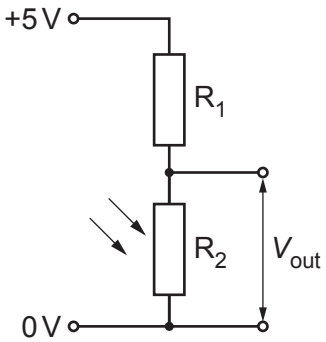
(ii) Use your graph to determine the intensity of the light I_0 before it enters the jelly.

I_0 = ... Wm^{-2} **[2]**

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

μ = ... 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.

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

range = ... V **[2]**

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

1 .....

.....

2 .....

.....

[2]

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

.....

.....

..... **[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).

OCR
Oxford Cambridge and RSA

Thursday 6 June 2024 – Morning

A Level Physics A

H556/02 Exploring physics

Time allowed: 2 hours 15 minutes

You must have:
- the Data, Formulae and Relationships booklet

You can use:
- a scientific or graphical calculator
- a ruler (cm/mm)

H55602

135977818 2

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

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

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 **32** pages.

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

DC (CJ/SG) 343112/7

Section A

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

Write your answer to each question in the box provided.

1 What are the base units of a kilowatt-hour?

A J

B $kg\,m^2\,s^{-1}$

C $kg\,m^2\,s^{-2}$

D W s

Your answer ☐ **[1]**

2 A neutrino is a fundamental particle.

Which row of the table correctly describes a neutrino?

	Classification	Force felt
A	hadron	strong nuclear
B	hadron	weak nuclear
C	lepton	strong nuclear
D	lepton	weak nuclear

Your answer ☐ **[1]**

3 Which one of these non-invasive medical scans does **not** expose the patient to ionising radiation?

A CAT

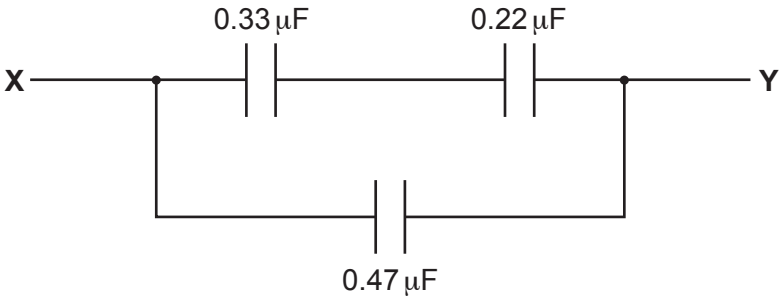
B PET

C Ultrasound

D X-ray

Your answer ☐ **[1]**

4 Three capacitors are arranged in a circuit.



The capacitance of each capacitor is shown.

What is the total capacitance between **X** and **Y**?

A 0.25 μF

B 0.60 μF

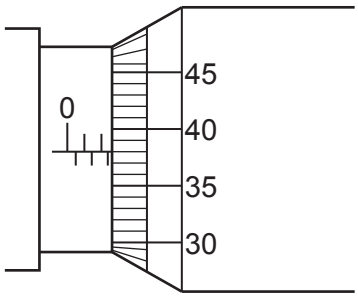
C 1.02 μF

D 8.0 μF

Your answer ☐ **[1]**

5 The image shows a micrometer that is being used to measure the diameter of a wire.

The micrometer has a zero error of +0.07 mm. The measured value of the diameter from the micrometer scale is 2.88 mm.



What is the correct area of cross-section of the wire?

A $2.21 \times 10^{-6}\,m^2$

B $6.20 \times 10^{-6}\,m^2$

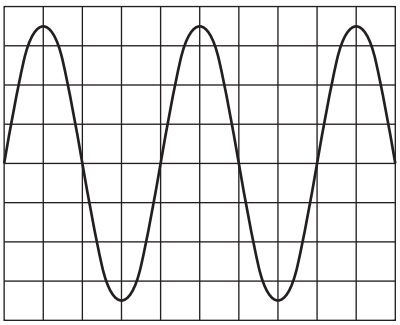
C $6.51 \times 10^{-6}\,m^2$

D $6.84 \times 10^{-6}\,m^2$

Your answer ☐ **[1]**

6 The image shows a display of an oscilloscope which is measuring an alternating voltage. The time base is set at 0.1 s / division. The voltage scale (y-sensitivity) is set at 0.5 V / division.

Which row of the table shows the correct amplitude and correct frequency?



	amplitude / V	frequency / Hz
A	1.75	0.4
B	1.75	2.5
C	3.50	0.4
D	3.50	2.5

Your answer ☐ **[1]**

7 This question is about the rate of decay of a radioactive source.

Which of the following statements is/are true?

The rate of decay is

1 dependent on the decay constant.
2 independent of the mass of the source.
3 dependent on time.

A 1 only

B 1 and 3

C 2 only

D 2 and 3

Your answer ☐ **[1]**

8 A student is using a spreadsheet to model the decay of charge on a capacitor.

They are using the equation $\frac{\Delta Q}{\Delta t} = -\frac{Q}{2.5}$.

The student chooses a time interval of 0.5 s. At time t = 0.0 s the charge on the capacitor is 600 μC.

Part of the modelling spreadsheet is shown below.

t / s	Charge Q left on capacitor after time t / μC	Charge ΔQ decaying in the next 0.5 s / μC
0.0	600	120
0.5	480	
1.0		
1.5		
2.0		

What is the charge on the capacitor at t = 1.5 s?

A 130 μC

B 240 μC

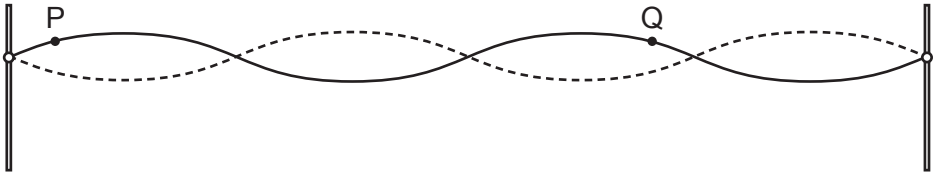
C 246 μC

D 307 μC

Your answer ☐ **[1]**

9 The diagram shows a string stretched between two posts.

The string is plucked and a stationary wave is set up.



What is the phase difference between P and Q?

A 0 rad

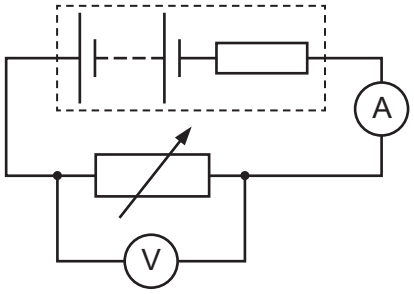
B $\frac{\pi}{4}$ rad

C $\frac{\pi}{2}$ rad

D π rad

Your answer ☐ **[1]**

10 A student uses the circuit below to determine the electromotive force (e.m.f.) and internal resistance of a battery.



They measure the current and potential difference (p.d.) across the variable resistor for different resistor values.

A graph is drawn with p.d. on the *y*-axis and current on the *x*-axis.

Which row is correct for calculating the e.m.f. and the internal resistance of the battery?

	e.m.f	**internal resistance**
A	magnitude of gradient	intercept on *y*-axis
B	magnitude of $\frac{1}{\text{gradient}}$	intercept on *y*-axis
C	intercept *y*-axis	magnitude of $\frac{1}{\text{gradient}}$
D	intercept *y*-axis	magnitude of gradient

Your answer ☐ **[1]**

11 At the Earth's equator the magnetic flux density B is approximately 25 μT.

What is the magnitude of the force on an electron with velocity $v = 100\,\text{km s}^{-1}$ as it is moving perpendicular to the Earth's magnetic field at the equator?

A $4.0 \times 10^{-25}\,\text{N}$

B $4.0 \times 10^{-22}\,\text{N}$

C $4.0 \times 10^{-19}\,\text{N}$

D $4.0 \times 10^{-16}\,\text{N}$

Your answer ☐ **[1]**

12 What is the radius of a carbon nucleus that has 6 protons and 7 neutrons?

Assume that the average radius of a nucleon r_0 is 1.2 fm.

A 2.2 fm

B 2.3 fm

C 2.8 fm

D 1.6 fm

Your answer ☐ **[1]**

13 A sub-atomic particle has a positive charge.

Which type of particle is it?

A anti-proton

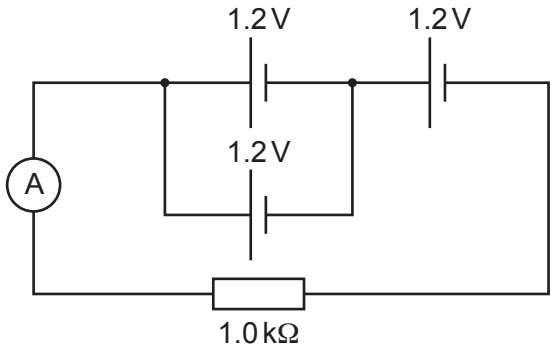
B down quark

C neutrino

D positron

Your answer ☐ **[1]**

14 A 1.0 kΩ resistor is connected in series to a battery made of three 1.2 V cells connected as shown. The cells have negligible internal resistance.



What is the reading on the ammeter?

A 1.2 mA

B 1.8 mA

C 2.4 mA

D 3.6 mA

Your answer ☐ **[1]**

15 Which sequence shows the energies below in **increasing** order of magnitude?

1 The change in kinetic energy of an electron accelerated through a potential difference of 1 V.
2 The kinetic energy of a proton with a velocity of 1000 m s^{-1}.
3 The energy of an X-ray photon with a frequency of 3×10^{17} Hz.

A 1 2 3

B 3 1 2

C 2 1 3

D 1 3 2

Your answer ☐ **[1]**

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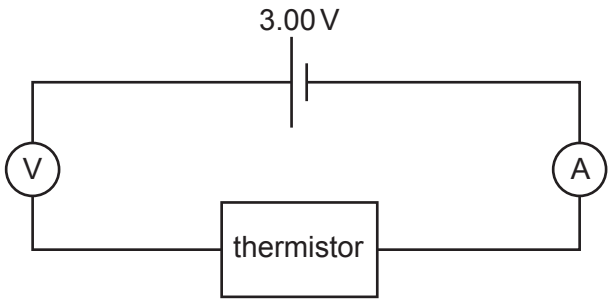
Section B

16 Thermistors are circuit components whose resistance varies with temperature.

There are two major types; negative temperature coefficient (NTC) thermistors, whose resistance decreases with increasing temperature and positive temperature coefficient (PTC) thermistors, whose resistance increases with increasing temperature.

A student is investigating how the resistance of a thermistor varies with temperature by measuring current and voltage. The thermistor is placed in a water bath and the temperature of the water measured using a thermometer.

The diagram below shows how the student set up the experiment (water bath not shown). The circuit has been set up **incorrectly**.



(a) Describe how the student should change the circuit.

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..... **[1]**

(b) The circuit was corrected and then used to collect data.

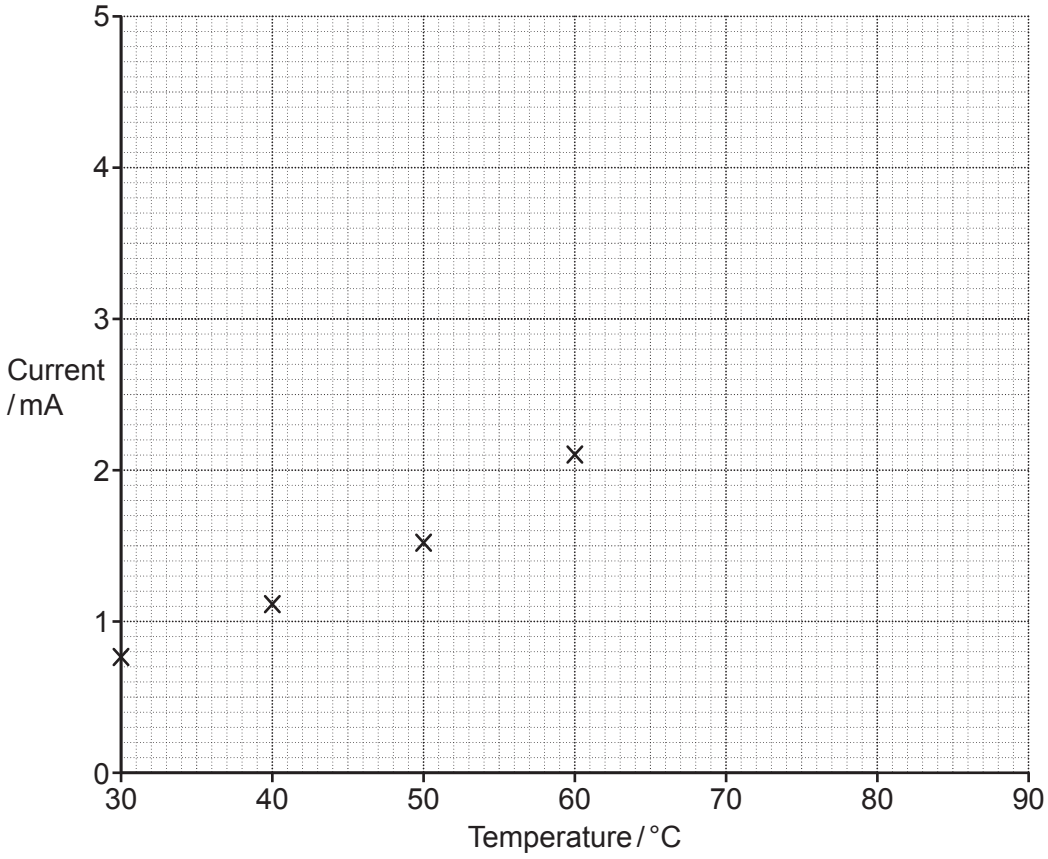
The table shows data collected from the investigation.

Temperature / °C	Current / mA	Voltage / V
30	0.75	3.00
40	1.10	3.00
50	1.51	3.00
60	2.10	3.00
70	2.80	3.00
80	3.66	3.00
90	4.76	3.00

(i) The axes below show a plot of current against temperature. The first four points from the table have been plotted. Plot the remaining points.

[1]

(ii) Draw a suitable line of best fit through the data points. **[1]**



(c) Describe, using the graph and calculations using data from the table, how the resistance of the thermistor varies for increasing temperature.
Hence determine whether the thermistor the student used was an NTC or a PTC thermistor.

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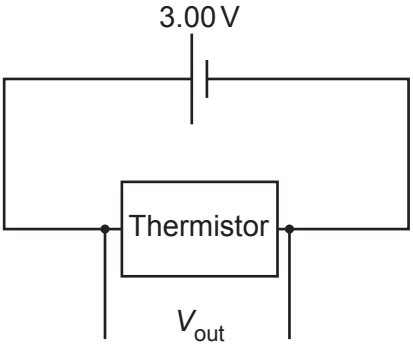
..... **[3]**

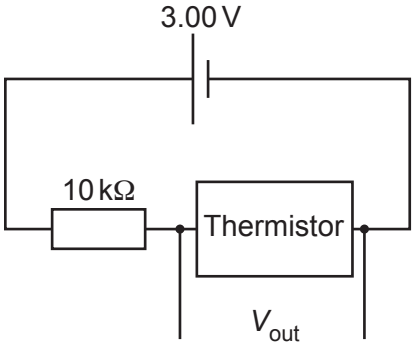
(d) The thermistor is used in a temperature-sensing circuit for a heating system to warm milk for a baby.

The student considers two possible designs for the circuit which are shown below.

Circuit 1



Circuit 2



In each circuit, the voltage V_{out} across the thermistor is connected to the heating system for warming the milk.

Discuss which circuit may be suitable for the heating system by considering the response of the circuit to changes in temperature.

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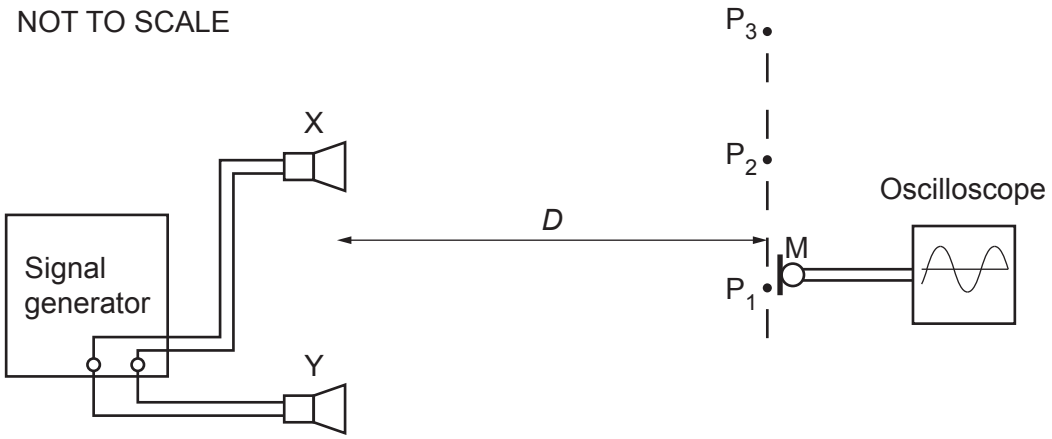
..... **[4]**

17 The diagram shows two identical loudspeakers X and Y connected to a signal generator. The loudspeakers emit sound waves of the same amplitude and frequency which are in phase.

A microphone M is moved along a line from P_1 to P_3 and the signal recorded on an oscilloscope.



As the microphone is moved along the line P_1 to P_3 the oscilloscope shows maximum signal at P_1, zero signal at P_2 and the next maximum signal at P_3.

(a) Explain these observations.

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..... **[2]**

(b) The distance between the centres of X and Y is 70.0 cm, the distance *D* (as shown in the diagram) is 4.00 m and the distance from P_1 to P_2 is 1.25 m.

Use the two source interference formula to calculate the frequency of the sound waves. (Speed of sound = 340 m s^{-1})

frequency = ... Hz **[3]**

(c) Loudspeaker Y is now replaced with a loudspeaker that produces sound waves of twice the original amplitude.

Describe how the signal observed on the oscilloscope varies as the microphone is moved along the line P_1 to P_3.

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..... **[2]**

(d)

(i) Explain what is meant by the term *intensity*.

.....

..... **[1]**

(ii) Calculate the factor by which the intensity of the sound waves at P_1 in **(c)** is larger than the intensity of the original sound waves at P_1.

factor = ... **[3]**

18*

(a) Describe how an experiment can be conducted to determine how the output current of a step-up transformer depends on the number of turns on the secondary coil.

Explain how the data collected can be analysed to establish the relationship between the output current and the number of turns on the secondary coil.

You are provided with wire and a suitable core on which to wind the wire, as well as any other normal laboratory equipment.

Use the space below to draw a labelled circuit diagram. **[6]**

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(b) A simple laminated iron-core transformer takes mains voltage 230 V, 50 Hz into the primary coil. The output voltage from the secondary coil is 5.0 V. The primary coil has 920 turns.

(i) State *Faraday's law*.

.....

..... **[1]**

(ii) Show that the number of turns on the secondary coil is 20.

[2]

(iii) At one particular instant, the output voltage from the transformer is 3.4 V.

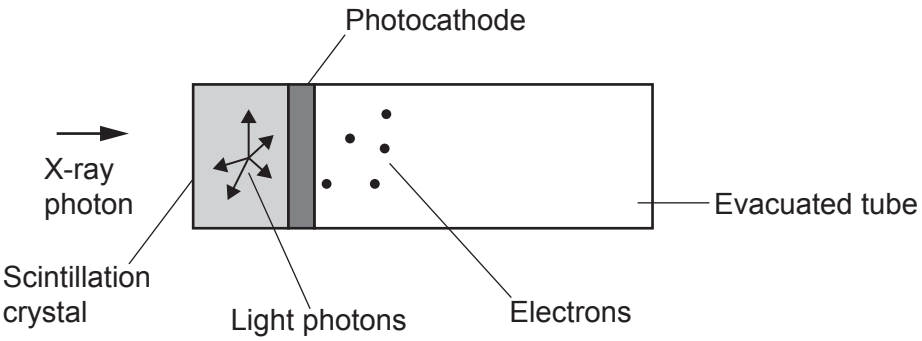
Calculate the change in magnetic flux experienced by the secondary coil in a short time interval of 1.2 ms and state its unit.

Assume that the output voltage from the transformer remains constant at 3.4 V over this time interval.

$\Delta\Phi$ = ... unit ..... **[4]**

19 The diagram shows part of an X-ray telescope which uses a crystal scintillation device to detect low energy X-rays from the stars.

X-rays hit the crystal and cause it to emit visible light photons. These travel to the photocathode in an evacuated tube. The photocathode uses the light photons to produce electrons.



Each X-ray photon detected by the telescope has an energy of 32 keV.

The light photons have a wavelength of 510 nm.

The efficiency of the crystal is 15%.

(a) Show that each X-ray photon produces about 2000 light photons.

[3]

(b) The photocathode has a work function of 2.3 eV.

(i) Explain what is meant by the *work function*.

.....

..... **[1]**

(ii) Calculate the maximum kinetic energy of the electrons leaving the photocathode.

maximum kinetic energy = ...J **[2]**

(iii) 12 X-ray photons are detected every minute.

Use your answer to **(a)** to calculate the current I leaving the photocathode. Assume that all the photons of light produce photoelectrons.

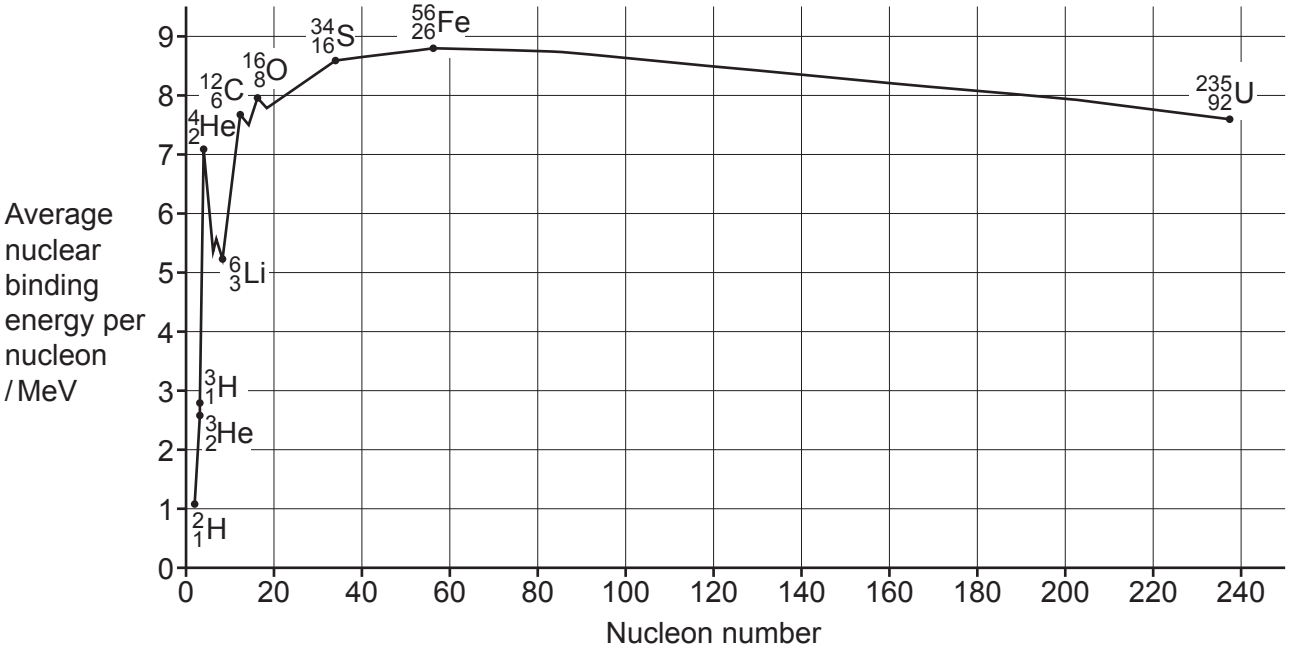
I = ... A **[2]**

(iv) State one other assumption you have made to enable you to calculate the current I in **(b)(iii)**.

.....

..... **[1]**

20 The diagram below shows the average nuclear binding energy per nucleon for a number of different isotopes.



(a) Explain what is meant by *nuclear binding energy* of a nucleus.

.....

..... **[1]**

(b) Suggest why the $^{1}_{1}$H isotope of hydrogen has **not** been included on the above diagram.

.....

..... **[1]**

(c) The main nuclear fusion reaction in the Sun is between nuclei of deuterium ($^{2}_{1}$H) and tritium ($^{3}_{1}$H). This reaction can be written as shown below.

$$^{2}_{1}\text{H} + {}^{3}_{1}\text{H} \rightarrow {}^{4}_{2}\text{He} + {}^{1}_{0}\text{n}$$

(i) Explain why isotopes with low mass numbers, such as hydrogen, are those which undergo nuclear fusion.

.....

.....

..... **[1]**

(ii) Use the diagram given at the start of this question to show that, for the reaction of deuterium and tritium, the energy released in each fusion event is approximately 3×10^{-12} J.

[3]

(iii) The Sun's mass deceases by 4.3×10^{9} kg every second. Assume that the mass loss is only due to this reaction.

Calculate the number of fusion events per second occurring in the Sun.

number of fusion events per second = ... s^{-1} **[2]**

(d) In the Sun, deuterium ($^{2}_{1}H$) is produced from fusion of two hydrogen ($^{1}_{1}H$) nuclei, as shown below. There is a particle missing.

$$^{1}_{1}H + {}^{1}_{1}H \rightarrow {}^{2}_{1}H + {}^{0}_{1}\beta^{+} + ...$$

(i) Determine the charge of the missing particle.

..... **[1]**

(ii) The missing particle is a lepton. Name this lepton.

..... **[1]**

(iii) In the fusion reaction above, determine the total number of up quarks at the **start** of the reaction.

..... **[1]**

(e) Tritium ($^{3}_{1}H$) is another isotope of hydrogen which is formed in stars. On the Earth, tritium is a radioactive element which decays by β^{-} emission.

Write down the equation for β^{-} decay in terms of quarks.

[2]

21 Technetium-99m ($^{99}_{43}Tc^{m}$) is a metastable radioisotope which can be used as a tracer in medical diagnosis. It is injected into the body and decays by gamma emission into technetium-99 according to the following chemical equation.

$$^{99}_{43}Tc^{m} \rightarrow {}^{99}_{43}Tc + {}^{0}_{0}\gamma$$

(a)

(i) Explain what is meant by a *tracer*.

.....

..... **[1]**

(ii) $^{99}_{43}Tc^{m}$ only emits gamma radiation.

Give **two** advantages of using a tracer which only emits gamma radiation.

1 .....

.....

2 .....

.....

[2]

(b)

(i) A technetium-99m tracer with an activity of 900 MBq is injected into a body. The half-life of technetium-99m is 6.01 hours.

Calculate the number of technetium-99m nuclei initially present in the tracer.

number = ... **[3]**

(ii) Calculate the time in hours taken for the activity of the tracer to have fallen to 3.0% of its initial activity.

time = ... hours **[3]**

(c) The daughter nucleus ($^{99}_{43}$Tc) decays by beta emission with a half-life of a little over 200 000 years. Approximately 50% of it is stored in the bones, and 50% is passed out of the body.

Suggest why the presence of this remaining $^{99}_{43}$Tc in the body causes little additional risk to the patient.

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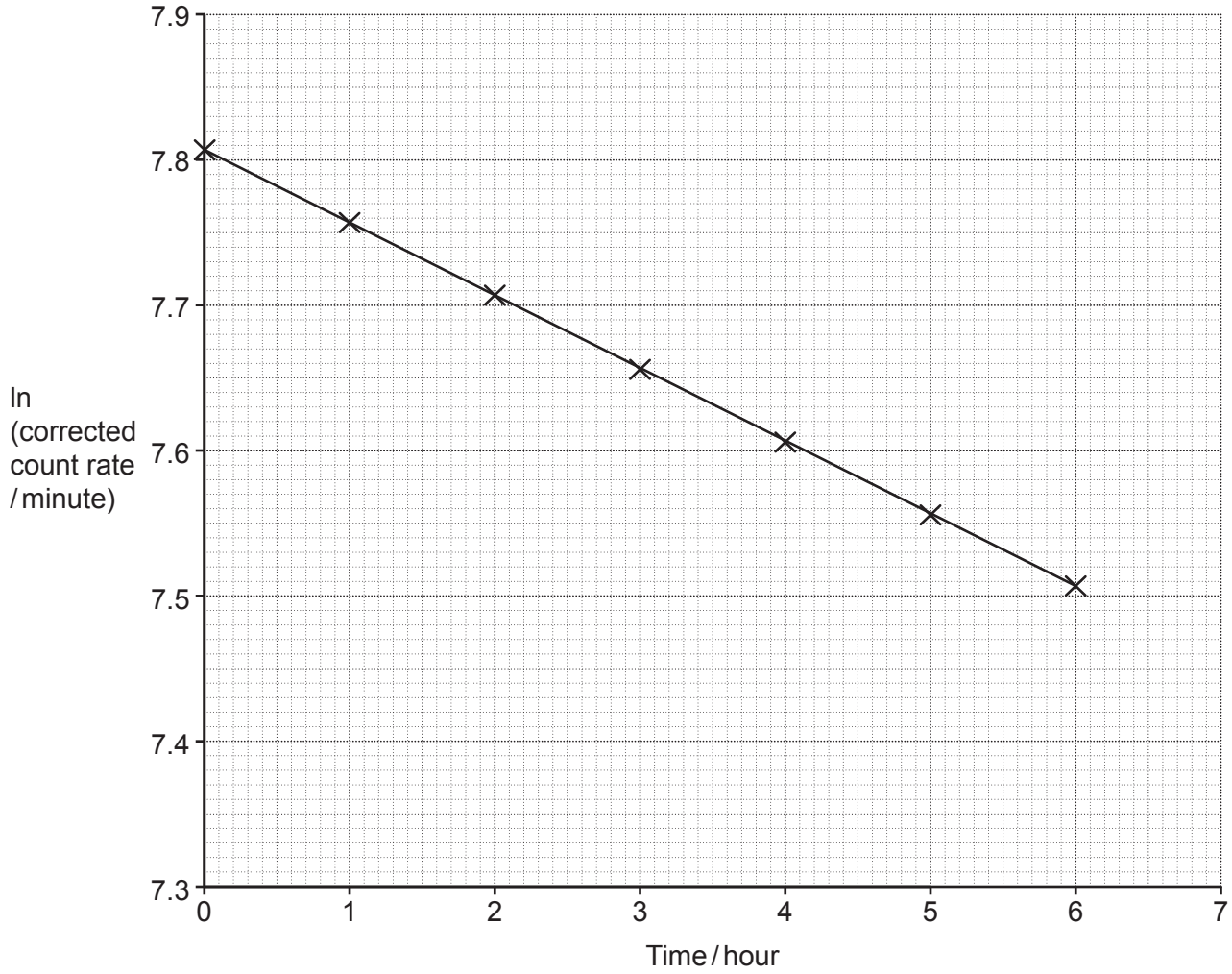
..... **[1]**

(d)* The half-life of a different radioisotope is to be determined using suitable apparatus. Each count represents one decay. The number of counts is measured for one minute every hour over a period of 6 hours. When the data has been collected, a graph of ln(corrected count rate / minute) against time is plotted and shown below.



- Describe an appropriate method that could be used to obtain this data, naming any apparatus and safety precautions taken.
- Use the graph given above to determine the half-life of this radioisotope showing clear working. **[6]**

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22 This question is about lightning.

(a) Sheet lightning occurs when there is an electrical discharge between the upper and lower regions of a thunder cloud.
The upper regions are positive and the lower regions are negative.

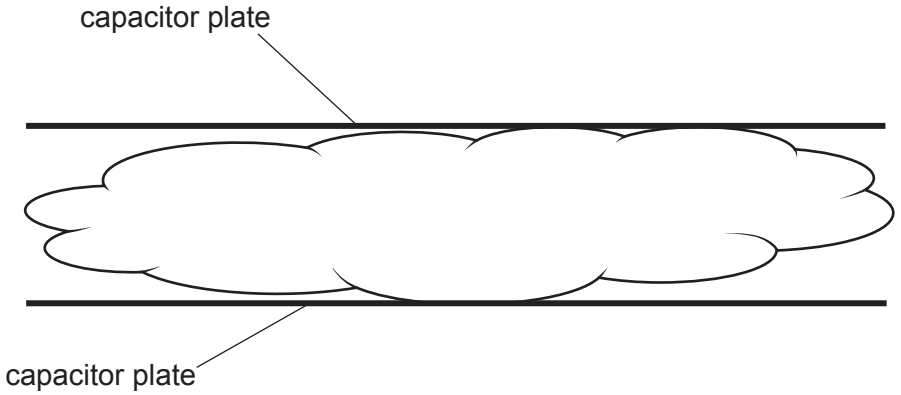
The thunder cloud can be modelled as an ideal parallel plate capacitor with circular horizontal plates.

The data for the capacitor comes from the cloud.

Diameter of cloud	24 km
Distance between upper and lower regions	3.2 km
Electric field strength between the regions	$4.0 \times 10^5\,\text{V m}^{-1}$

(i) The diagram shows the plates of the model capacitor superimposed on the cloud.

Draw on the diagram to show the electric field lines between capacitor plates. **[2]**



(ii) Suggest why the actual electric field lines of the cloud would differ from what you have drawn.

.....

..... **[1]**

(iii) Show that the potential difference (p.d.) V between the plates is about $1 \times 10^9\,\text{V}$.

[1]

(iv) Calculate the capacitance C of the model capacitor.

Assume the permittivity of the material of the cloud is the same as the permittivity of free space.

C = ... F **[2]**

(v) Calculate the magnitude of the charge Q on one of the plates of the model capacitor.

Q = ... C **[2]**

(b) Fork lightning is an electrical discharge that occurs between the bottom of the cloud and the surface of the Earth.

Another cloud has a charge of 155 C and is at a height of 2.0 km.

The surface of the Earth has an electrical potential V of 0 V.

(i) Assume the cloud acts as a **point** charge.

Calculate the magnitude of the electrical potential V between the cloud and the surface of the Earth.

V = ... V **[2]**

(ii) A fork lightning strike has a duration of 25 ms. The cloud discharges at a constant rate. The cloud is uncharged after the strike.

Calculate the number of electrons reaching the ground in 1.0 ms.

number of electrons in 1.0 ms = ... **[3]**

END OF QUESTION PAPER

EXTRA ANSWER SPACE

If you need extra space use these lined pages. You must write the question numbers clearly in the margin.