Oxford Cambridge and RSA

Friday 24 May 2019 – Morning

A Level Physics A

H556/02 Exploring physics

Time allowed: 2 hours 15 minutes

You must have:
- the Data, Formulae and Relationships Booklet (sent with general stationery)

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

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 may use an HB pencil for graphs and diagrams.
- Answer **all** the questions.
- Where appropriate, your answers should be supported with working. Marks may be given for a correct method even if the answer is incorrect.
- Write your answer to each question in the space provided. If additional space is required, use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.

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 consists of **32** pages.

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 Which law indicates that charge is conserved?

A Lenz's law

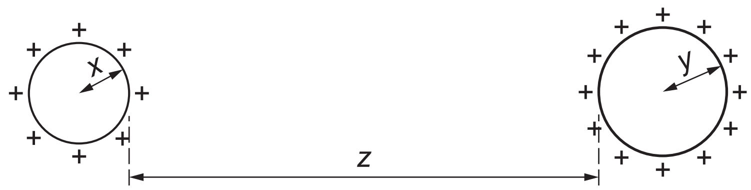
B Coulomb's law

C Kirchhoff's first law

D Faraday's law of electromagnetic induction

Your answer [1]

2 The diagram below shows two uniformly charged spheres separated by a large distance *z*.



The radius of the small sphere is *x* and the radius of the large sphere is *y*.

Which is the correct distance to use when determining the electric force between the charged spheres?

A z

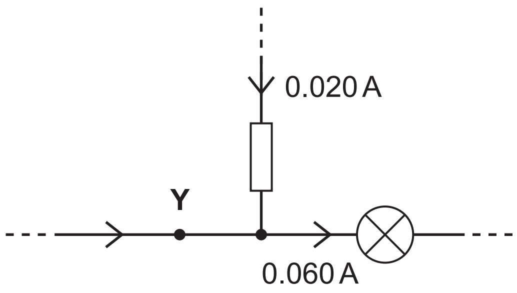
B $x + z$

C $y + z$

D $x + y + z$

Your answer [1]

3 Part of an electric circuit is shown below.



The direction of all the currents and the magnitude of two currents are shown.

How many electrons pass through the point **Y** in 10 s?

A 1.25×10^{18}

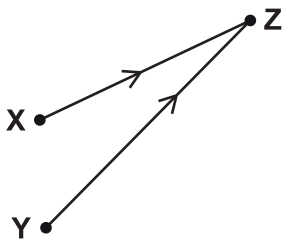
B 2.50×10^{18}

C 3.75×10^{18}

D 5.00×10^{18}

Your answer **[1]**

4 Coherent radio waves from transmitters **X** and **Y** are emitted in phase. The waves interfere **constructively** at point **Z**.



The distance **XZ** is 16.0 m and the distance **YZ** is 20.0 m.
The radio waves have wavelength λ.

Which value of λ is **not** possible?

A 1.0 m

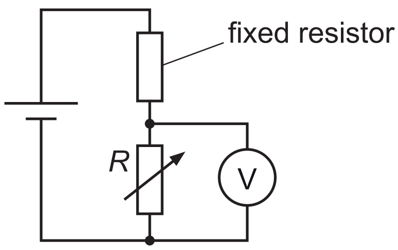
B 2.0 m

C 3.0 m

D 4.0 m

Your answer **[1]**

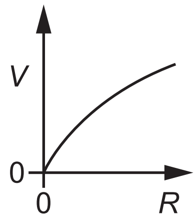
5 A potential divider circuit is shown below.



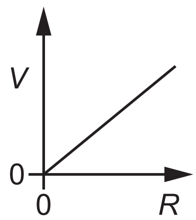
The resistance of the variable resistor is R. The potential difference across the variable resistor is V.

Which graph shows the correct variation with R of V?

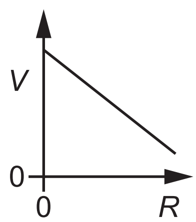
A



B



C



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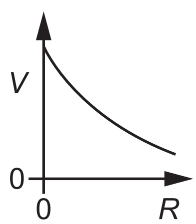


Your answer ☐ **[1]**

6 Wires **P** and **Q**, made from the same metal, are connected in **parallel** across a cell of negligible internal resistance.
The table shows some data.

Wire	Length of wire	Diameter of wire	Mean drift velocity of electrons in the wire / $mm s^{-1}$
P	*L*	*d*	0.60
Q	3*L*	2*d*	*v*

What is the mean drift velocity *v* of the electrons in wire **Q**?

A $0.15\,mm\,s^{-1}$

B $0.20\,mm\,s^{-1}$

C $0.30\,mm\,s^{-1}$

D $0.60\,mm\,s^{-1}$

Your answer [1]

7 Which of the following statements is/are correct about electromagnetic waves?

1 They can be plane polarised.
2 They can be refracted and diffracted.
3 They have the same speed in a vacuum and in glass.

A Only 1

B Only 3

C Only 1 and 2

D 1, 2 and 3

Your answer [1]

8 The electric field strength at a distance of 2.0×10^{-8} m from a nucleus is 3.3×10^{8} N C^{-1}.

What is the charge on the nucleus?

A 1.6×10^{-19} C

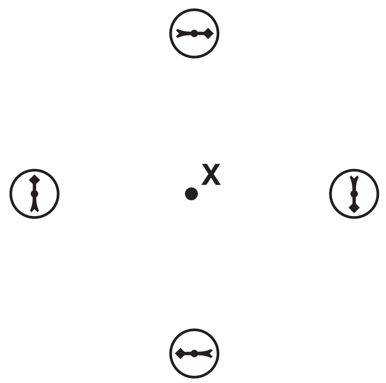
B 1.5×10^{-17} C

C 7.3×10^{-10} C

D 3.8×10^{-9} C

Your answer **[1]**

9 The diagram shows four magnetic compasses placed at the same distance from point **X**.



Which of the following is most likely to be at point **X**?

A permanent magnet

B current-carrying solenoid

C current-carrying flat coil

D straight current-carrying wire

Your answer **[1]**

10 A coil with 500 turns is placed in a uniform magnetic field.
The average cross-sectional area of the coil is $3.0 \times 10^{-4}\,m^2$.
The magnetic flux through the plane of the coil is reduced from 1.8×10^{-4} Wb to zero in a time *t*.
The average electromotive force (e.m.f.) induced across the ends of the coil is 0.75 V.

What is the value of *t*?

A 3.6×10^{-5} s

B 2.4×10^{-4} s

C 0.12 s

D 8.3 s

Your answer ☐ **[1]**

11 The radius of a gold nucleus with 197 nucleons is 7.3×10^{-15} m.

What is the best estimate for the volume of a uranium nucleus with 235 nucleons?

A $1.6 \times 10^{-42}\,m^3$

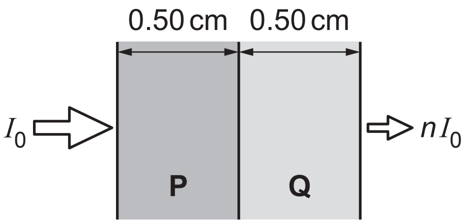
B $1.9 \times 10^{-42}\,m^3$

C $2.1 \times 10^{-42}\,m^3$

D $2.8 \times 10^{-42}\,m^3$

Your answer ☐ **[1]**

12 The intensity of a beam of X-rays incident on material **P** is I_0.
The beam passes through 0.50 cm of material **P** and 0.50 cm of material **Q**.



The absorption (attenuation) coefficients of **P** and **Q** are 0.60 cm^{-1} and 0.20 cm^{-1} respectively.
The intensity of the beam after passing through both **P** and **Q** is nI_0.

What is the value of n?

A 0.67

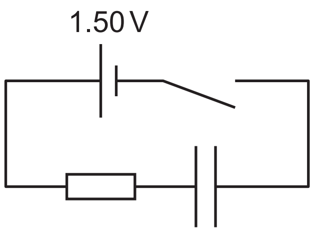
B 0.74

C 0.82

D 0.90

Your answer **[1]**

13 A capacitor is charged through a resistor.



The cell has electromotive force (e.m.f.) 1.50 V and negligible internal resistance.
The time constant of the circuit is 10 s. The switch is closed at time t = 0. At time t, the potential difference across the resistor is 0.60 V.

Which expression is correct?

A $0.60 = 1.50e^{-0.10t}$

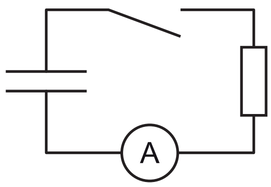
B $0.90 = 1.50e^{-0.10t}$

C $0.60 = 1.50e^{-10t}$

D $0.60 = 1.50(1-e^{-10t})$

Your answer **[1]**

14 A capacitor is discharged through a resistor.



The capacitor is fully charged at time $t = 0$. The time constant of the circuit is 10 s. The switch is closed at time $t = 0$. The current in the resistor is I.

Which row is correct?

	Current I at $t = 0$	**Current I at $t = 10$ s**
A	maximum	0
B	maximum	37% of the current at $t = 0$
C	0	63% of the current at $t = \infty$
D	0	37% of the current at $t = \infty$

Your answer ☐ **[1]**

15 The number of turns on the coils of four ideal iron-cored transformers **A**, **B**, **C** and **D** are shown in the table below.

Transformer	**Number of turns on the secondary coil**	**Number of turns on the primary coil**
A	100	100
B	50	200
C	200	50
D	500	100

Each transformer is connected in turn to an alternating 240 V supply.

Which transformer will give the largest output current?

Your answer ☐ **[1]**

SECTION B

Answer **all** the questions.

16 This question is about waves.

(a) The **period** of a progressive wave can be determined from Fig. 16.1. Add a correct label to the horizontal axis so that the period can be found. **[1]**

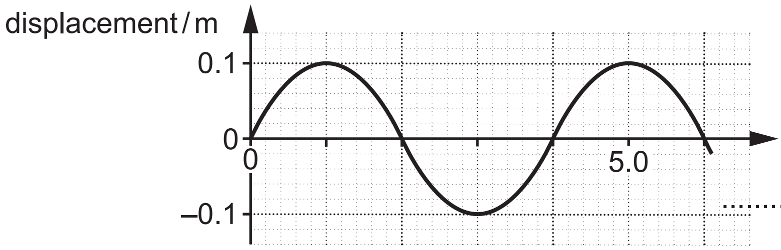


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Fig. 16.1

(b) A progressive wave has wavelength λ, frequency f and period T.

Show that the speed v of the wave is given by the equation $v = f\lambda$.

[2]

(c) A scientist is investigating the interference of light using very thin transparent material.
A sample of the transparent material is placed in a vacuum.
Fig. 16.2 shows the path of two identical rays of light **L** and **M** from a laser.

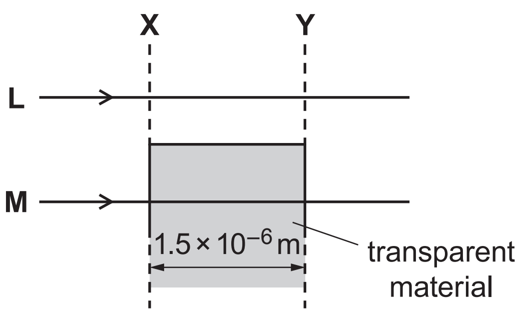

Fig. 16.2

The refractive index of the material is 1.20. The thickness of the material is 1.5×10^{-6} m. The wavelength of the light in vacuum is 6.0×10^{-7} m.

(i) Show that the difference in time t for the two rays to travel between the dashed lines **X** and **Y** is 1.0×10^{-15} s.

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

(ii) Calculate the period T of the light wave.

T = ... s **[2]**

(iii) The rays of light are in phase at the dashed line **X**.

Use your two answers above to state the phase difference ϕ in degrees between the light rays at **Y**.

ϕ = ... ° **[1]**

Question 16 continues on page 12

(d)* The speed v of surface water waves in shallow water of depth d is given by the equation $v = \sqrt{gd}$, where g is the acceleration of free fall.

The speed v is about $1\,\mathrm{m\,s^{-1}}$ for a depth of about 10 cm.

You are provided with a rectangular plastic tray, supply of water and other equipment available in the laboratory.

Describe how an experiment can be conducted in the laboratory to test the validity of the equation above and how the data can be analysed to determine a value for g. **[6]**

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Additional answer space if required.

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17 **(a)** Fig. 17.1 shows the variation with distance of the displacement of a **stationary** wave at time $t = 0$.

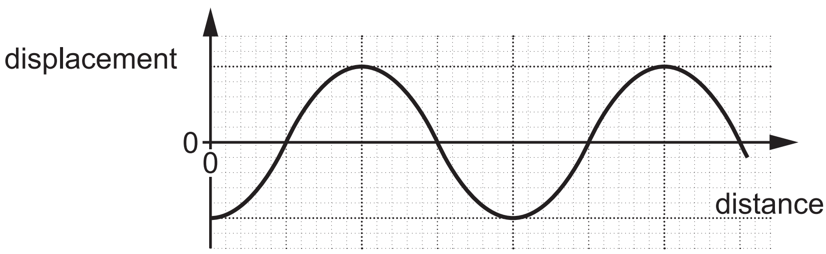

Fig. 17.1

The period of the wave is T.

(i) On Fig. 17.1, sketch a graph to show the variation of the displacement at time $t = \frac{T}{2}$. **[1]**

(ii) On Fig. 17.1, show the positions of **all** the nodes. Label each node **N**. **[1]**

(b) Stationary sound waves are formed in a tube closed at one end.
Fig. 17.2 shows three stationary wave patterns formed in the air column of the tube.

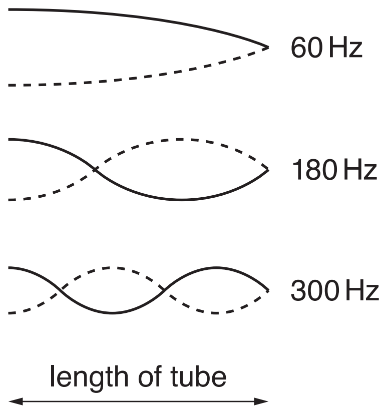

Fig. 17.2

The frequency f of the oscillations for each stationary wave is shown in Fig. 17.2.

Use Fig. 17.2 to explain how the frequency f of the sound wave depends on the wavelength λ.

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.... **[3]**

18 **(a)** State Kirchhoff's second law **and** the physical quantity that is conserved according to this law.

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.... **[2]**

(b) The S.I. base units for the ohm (Ω) are $\text{kg}\,\text{m}^2\,\text{s}^{-3}\,\text{A}^{-2}$.

Use the equation $R = \frac{\rho L}{A}$ to determine the S.I. base units for resistivity ρ.

base units for ρ .... **[2]**

Question 18 continues on page 16

Turn over

(c) Fig. 18.1 shows a circuit used by a student to determine the resistivity of the material of a wire.

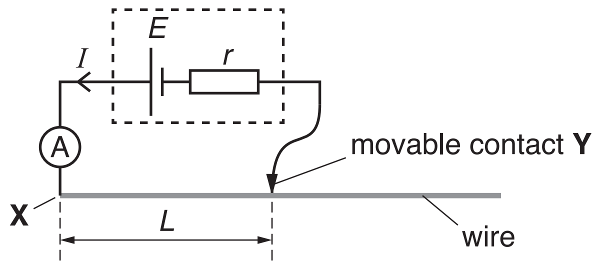

Fig. 18.1

The wire is uniform and has diameter 0.38 mm. The cell has electromotive force (e.m.f.) E and internal resistance r. The length of the wire between **X** and **Y** is L.

The student varies the length L and measures the current I in the circuit for each length.

Fig. 18.2 shows the data points plotted by the student.

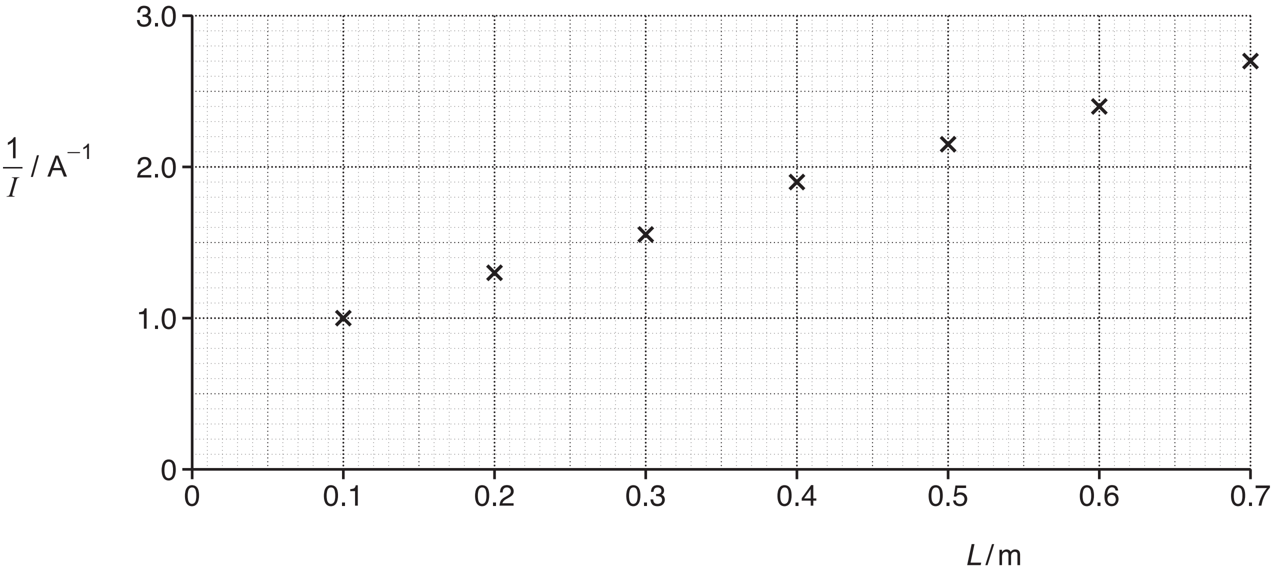

Fig. 18.2

(i) On Fig. 18.2 draw the straight line of best fit. Determine the gradient of this line.

gradient = ... $A^{-1}\,m^{-1}$ **[2]**

(ii) Show that the gradient of the line is $\frac{\rho}{AE}$, where ρ is the resistivity of the material of the wire, A is the area of cross-section of the wire and E is the e.m.f. of the cell.

[2]

(iii) The e.m.f. E of the cell is 1.5 V. The diameter of the wire is 0.38 mm.

Use your answer to **(i)** and the equation given in **(ii)** to determine ρ.

ρ = ... Ω m **[2]**

(iv) Fig. 18.3 illustrates how the student had incorrectly measured all the lengths L of the wire.

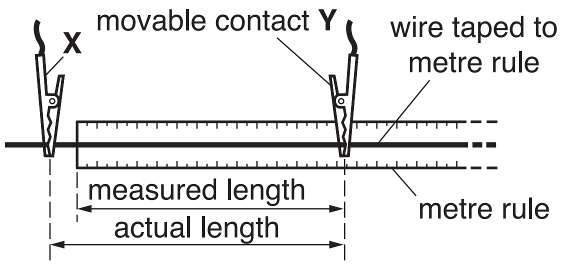

Fig. 18.3

According to the student, re-plotting the data points using the **actual** lengths of the wire will not affect the value of the resistivity obtained in **(iii)**.

Explain why the student is correct.

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.... **[2]**

19 Fig. 19.1 shows an electric circuit.

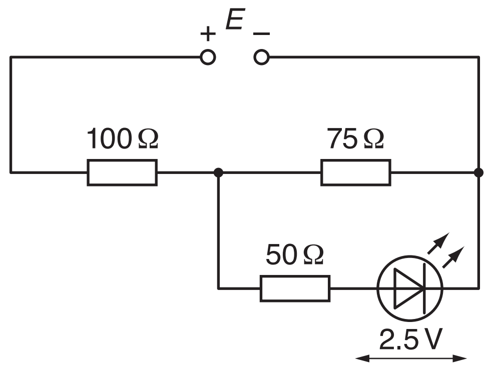

Fig. 19.1

The power supply has electromotive force (e.m.f.) *E* and negligible internal resistance.

The resistance values of the resistors are shown in Fig. 19.1. The *I*–*V* characteristic of the light-emitting diode (LED) is shown in Fig. 19.2.

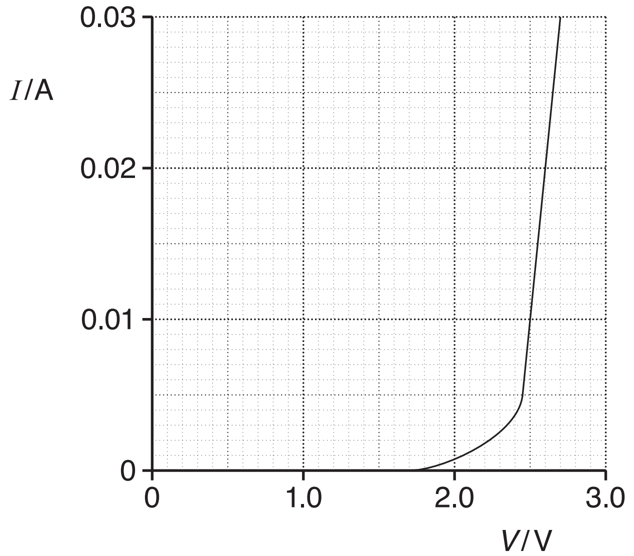

Fig. 19.2

The potential difference (p.d.) across the LED is 2.5 V.

(a) Use Fig. 19.2 to show that the p.d. across the 50 Ω resistor is 0.50 V.

[2]

(b) Calculate the e.m.f. E of the power supply.

E = ... V **[3]**

(c) The LED emits blue light of wavelength 4.7×10^{-7} m.

(i) Estimate the number of blue light photons emitted from the LED per second.

number of photons per second = ... s^{-1} **[3]**

(ii) The light from the LED is incident on a metal of work function 2.3 eV.

Explain, with the help of a calculation, whether or not photoelectrons will be emitted from the surface of the metal.

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.... **[2]**

20 Fig. 20 illustrates a device used to determine the relative abundance of charged rubidium ions.

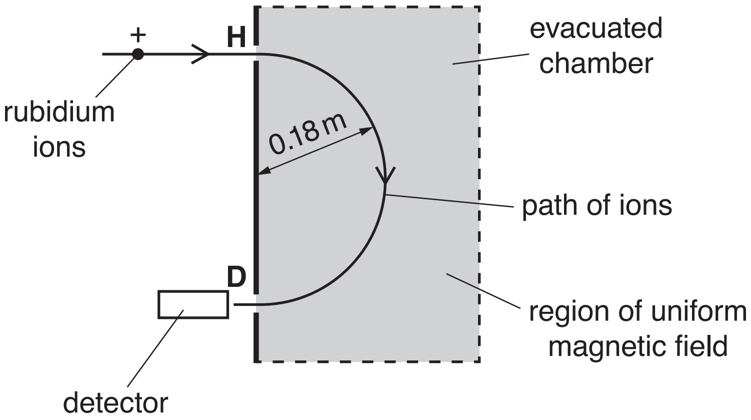

Fig. 20

A uniform magnetic field is applied to an evacuated chamber. The direction of the magnetic field is perpendicular to the plane of the paper.

A beam of positive rubidium ions enters the chamber through a hole at **H**. The ions travel in a semi-circular path in the magnetic field. The ions are detected at point **D**.

(a) Each rubidium ion has charge $+1.6 \times 10^{-19}$ C and speed 4.8×10^{4} m s^{-1}.
The radius of the semi-circular path of the ions is 0.18 m.
The mass of a rubidium ion is 1.4×10^{-25} kg.

Calculate the magnitude of the magnetic flux density B of the magnetic field.

B = ... T **[3]**

(b) The chemical composition of ancient rocks found on the Earth can be used to estimate the age of the Earth.
Nuclei of rubidium-87 ($^{87}_{37}Rb$) decay spontaneously into nuclei of strontium-87 ($^{87}_{38}Sr$).
The half-life of rubidium-87 is 49 billion years.

(i) Name the two leptons emitted in the decay of a rubidium-87 nucleus.

1. ....

2. ....
[1]

(ii) The percentage of rubidium **left** in a sample of an ancient rock is 95%.

Estimate the age of the Earth in billion years.

age = ... billion years **[3]**

21 **(a)** Fig. 21 shows stable and unstable nuclei of some light elements plotted on a grid. This grid has number of neutrons N on the vertical axis and number of protons Z on the horizontal axis.

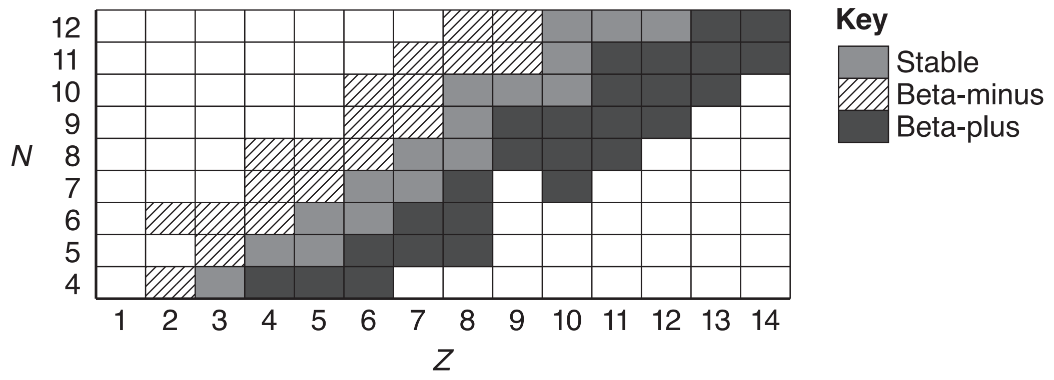

Fig. 21

The key on Fig. 21 shows whether a nucleus is stable, emits a beta-plus particle or emits a beta-minus particle to become stable.

For Z = 7, suggest in terms of N why an isotope may emit

(i) a beta-minus particle

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.... **[1]**

(ii) a beta-plus particle.

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.... **[1]**

(b) Inside a nuclear reactor, fission reactions are controlled and **chain reactions** are prevented. A typical fission reaction of the uranium-235 nucleus ($^{235}_{92}U$) is illustrated below.

$$^{1}_{0}n + ^{235}_{92}U \rightarrow ^{141}_{55}Cs + ^{93}_{37}Rb + 2^{1}_{0}n$$

The neutron triggering the fission reaction moves slowly. The neutrons produced in the fission reaction move fast.

(i) Describe what is meant by **chain reaction**.

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.... **[2]**

(ii) Explain how chain reactions are prevented inside a nuclear reactor.

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.... **[2]**

(iii) The energy released in each fission reaction is equivalent to a decrease in mass of 0.19 u.
A fuel rod in a nuclear reactor contains 3.0% of uranium-235 by mass.

Estimate the total energy produced from 1.0 kg of fuel rod.

molar mass of uranium-235 = 0.235 kg mol^{-1}
1 u = 1.66×10^{-27} kg

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

22 (a) Fig. 22.1 shows two horizontal metal plates in a vacuum.

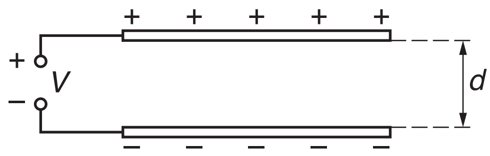

Fig. 22.1

The plates are connected to a power supply. The potential difference *V* between the plates is constant. The magnitude of the charge on each plate is *Q*. The separation between the plates is *d*.

Fig. 22.2 shows the variation with *d* of the charge *Q* on the positive plate.

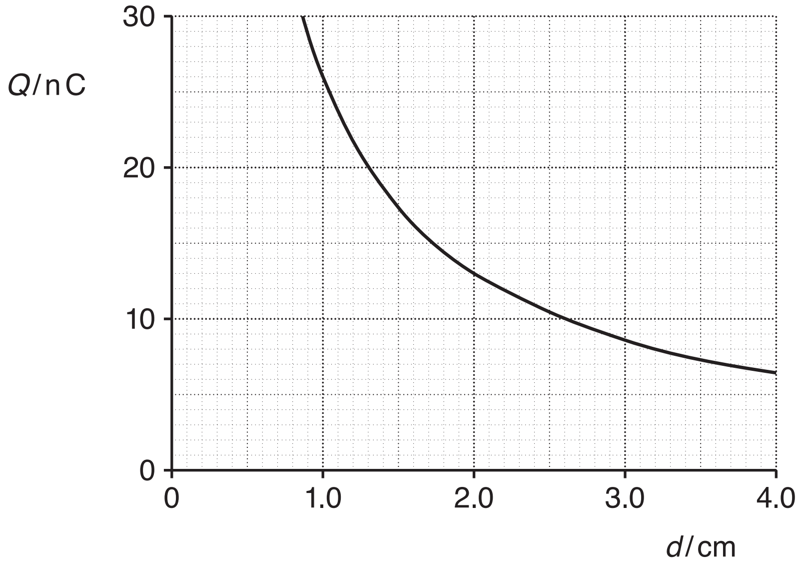

Fig. 22.2

(i) Use Fig. 22.2 to propose and carry out a test to show that *Q* is inversely proportional to *d*.

Test proposed:

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Working:

[2]

(ii) Use capacitor equations to show that Q is inversely proportional to d.

[2]

(b) Fig. 22.3 shows a negatively charged oil drop between two oppositely charged horizontal plates in a vacuum.

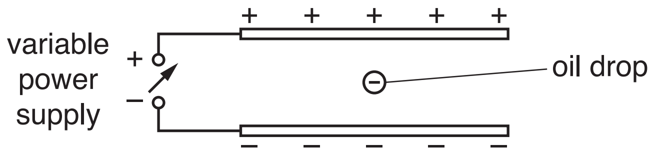

Fig. 22.3

The plates are fixed and connected to a variable power supply. The weight of the oil drop is 1.8×10^{-14} N.

(i) The power supply is adjusted so that the potential difference between the plates is 200 V when the oil drop becomes **stationary**.

State the magnitude of the vertical electric force F_E acting on the charged oil drop.

F_E = ... N **[1]**

(ii) The potential difference between the plates is now increased to 600 V.
The oil drop accelerates upwards.

Calculate the acceleration a of the oil drop.

a = ... m s^{-2} **[3]**

Question 22 continues on page 26

(c)* Fig. 22.4 shows an arrangement used by a student to investigate the forces experienced by a small length of charged gold foil placed in a uniform electric field.

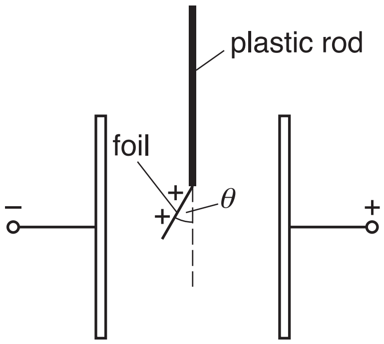

Fig. 22.4

The two vertical metal plates are connected to a high-voltage supply.

The foil is given a positive charge by briefly touching it to the positive plate.

The angle θ made with the vertical by the foil in the electric field is given by the expression

$$\tan\theta = \frac{qE}{W}$$

where q is the charge on the foil, E is the electric field strength between the plates and W is the weight of the foil.

The angle θ can be determined by taking photographs with the camera of a mobile phone.

Describe how the student can safely conduct an experiment to investigate the relationship between θ and E.
Identify any variables that must be controlled. **[6]**

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Additional answer space if required.

23 **(a)** Describe the basic structure of an X-ray tube and explain how X-ray photons are produced. You may draw a labelled diagram.

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.... **[3]**

(b) A beam of X-rays is directed at tissues in a patient.
The X-ray photons interact with the atoms of the tissues.

Simple scatter is one of the attenuation mechanisms.

Name and describe **two** other attenuation mechanisms.

1. ....

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2. ....

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[4]

24 **(a)** Explain how an ultrasound transducer can **emit** ultrasound.
You do **not** need to describe the design of the transducer.

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.... **[2]**

(b) Explain how the reflection of ultrasound at a boundary between two tissues depends on the physical properties of the tissues.

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.... **[3]**

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).

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