OCR
Oxford Cambridge and RSA

A Level Physics A

H556/02 Exploring physics

Wednesday 21 June 2017 – Morning

Time allowed: 2 hours 15 minutes

6829545160

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

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

First name										
Last name										
Centre number						Candidate number				

INSTRUCTIONS
- Use black ink. You may use an HB pencil for graphs and diagrams.
- Complete the boxes above with your name, centre number and candidate number.
- Answer **all** the questions.
- 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.
- Do **not** write in the barcodes.

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.

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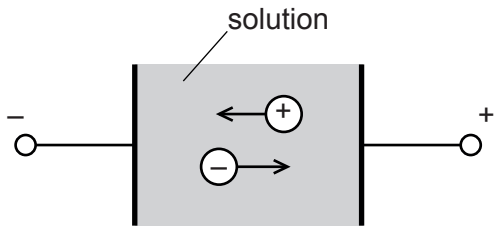
SECTION A

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 The diagram below shows the motion of positive and negative particles in a conducting solution.



Which statement is correct?

A The current in the solution is zero.

B The conventional current is to the left.

C The positive particles are always protons.

D The negative particles are always electrons.

Your answer ☐ **[1]**

2 One million electrons travel between two points in a circuit.
The **total** energy gained by the electrons is 1.6×10^{-10} J.

What is the potential difference between the two points?

A 1.6×10^{-16} V

B 1.6×10^{-4} V

C 1.0×10^{3} V

D 1.0×10^{9} V

Your answer ☐ **[1]**

3 Which is **not** a unit of energy?

A kW h

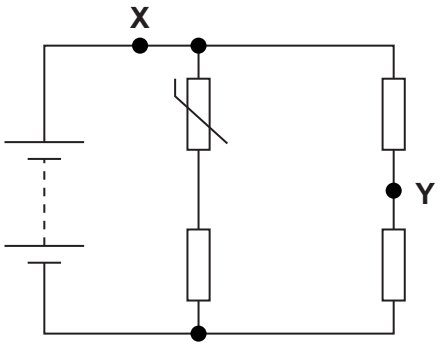
B eV

C J

D W

Your answer [ ] **[1]**

4 A circuit is shown below.



The battery has negligible internal resistance. The temperature of the NTC thermistor is **decreased**.

Which of the following statements is/are correct?

1 The current at **X** increases.
2 The current at **Y** remains the same.
3 The potential difference across the thermistor increases.

A 1, 2 and 3

B Only 2 and 3

C Only 3

D Only 2

Your answer [ ] **[1]**

5 A progressive wave of amplitude *a* has intensity I. This wave combines with another wave of amplitude 0.6*a* at a point in space. The phase difference between the waves is 180°.

What is the resultant intensity of the combined waves in terms of I?

A $0.16I$

B $0.4I$

C $1.6I$

D $2.6I$

Your answer ☐ **[1]**

6 Stationary waves are produced in a tube closed at one end and open at the other end. The fundamental frequency is 120 Hz.

What is a possible frequency of a harmonic for this tube?

A 60 Hz

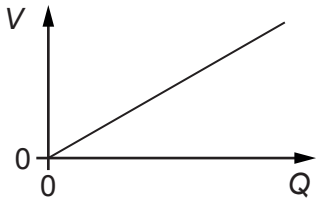
B 240 Hz

C 360 Hz

D 480 Hz

Your answer ☐ **[1]**

7 The graph below shows the variation of potential difference V with charge Q for a capacitor.



Which row is correct for the gradient of the graph and the area under the graph?

	Gradient of graph	Area under the graph
A	capacitance^{-1}	work done
B	capacitance^{-1}	permittivity
C	capacitance	power
D	capacitance	energy

Your answer ☐ **[1]**

8 A capacitor discharges through a resistor. At time $t = 0$, the charge stored by the capacitor is 600 μC. The capacitor loses 5.0 % of its charge every second.

What is the charge **left** on the capacitor at time $t = 4.0$ s?

A 111 μC

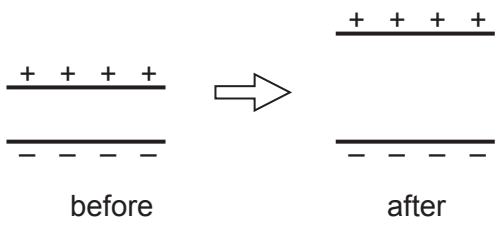
B 120 μC

C 480 μC

D 489 μC

Your answer ☐ **[1]**

9 Two isolated parallel capacitor plates have an equal and opposite charge.
The separation between the plates is doubled.
The charge on each plate remains the same but the potential difference between the plates doubles.



Which statement is correct?

A The capacitance of the capacitor doubles.

B The energy stored by the capacitor is halved.

C The permittivity of free space doubles.

D The electric field strength between the plates remains the same.

Your answer ☐ **[1]**

10 Which statement is correct?

A Hadrons are made up of protons and neutrons.

B A positron and a proton are examples of leptons.

C The positron and the electron have the same mass.

D The weak nuclear force is responsible for alpha-decay.

Your answer ☐ **[1]**

11 An electron moves in a circle of radius 2.0 cm in a uniform magnetic field of flux density 170 mT.

What is the momentum of this electron?

A $3.4 \times 10^{-3}\,\text{kg m s}^{-1}$

B $5.4 \times 10^{-17}\,\text{kg m s}^{-1}$

C $1.4 \times 10^{-18}\,\text{kg m s}^{-1}$

D $5.4 \times 10^{-22}\,\text{kg m s}^{-1}$

Your answer ☐ **[1]**

12 A proton collides with a stationary oxygen-18 nucleus. The collision produces a fluorine-18 nucleus and particle X.

$$^{1}_{1}\text{p} + {}^{18}_{8}\text{O} \rightarrow {}^{18}_{9}\text{F} + \text{X}$$

What is particle X?

A neutron

B proton

C electron

D positron

Your answer ☐ **[1]**

13 A beam of charged particles is not deflected when it passes through a region where both electric and magnetic fields are present.

Which statement is **not** correct?

A All the particles have the same speed.

B The resultant force on each particle is zero.

C The magnetic force is equal to the electric force on each particle.

D The magnetic field and the electric field are in the same direction.

Your answer ☐ **[1]**

14 There are four important attenuation mechanisms by which X-ray photons may interact when they pass through matter.

In which mechanism is the X-ray photon scattered with a longer wavelength?

A simple scattering

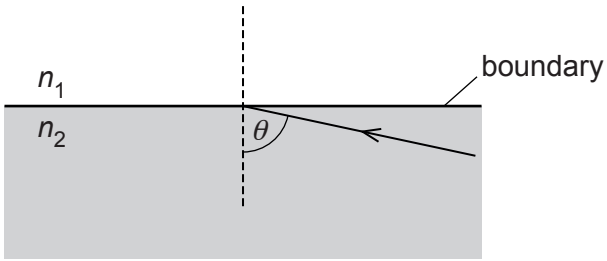
B Compton effect

C pair production

D photoelectric effect

Your answer ☐ **[1]**

15 A ray of monochromatic light is incident at the boundary between two transparent materials of refractive index n_1 and n_2. The critical angle θ is equal to 80°.



What is the ratio $\frac{n_1}{n_2}$?

A 0.17

B 0.98

C 1.02

D 5.76

Your answer ☐ **[1]**

SECTION B

Answer **all** the questions.

16 (a) State the *principle of superposition* of waves.

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

(b) Fig. 16.1 shows an arrangement to demonstrate the interference of monochromatic light.

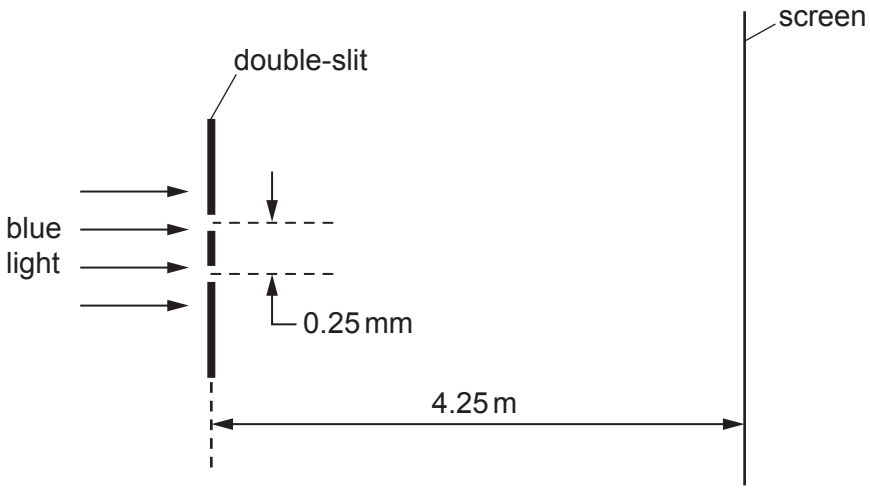

Fig. 16.1

Coherent blue light from a laser is incident at a double-slit. The separation between the slits is 0.25 mm. A series of dark and bright lines (fringes) appear on the screen. The screen is 4.25 m from the slits.
Fig. 16.2 shows the dark and bright fringes observed on the screen.

Fig. 16.2

The pattern shown in Fig. 16.2 is **drawn to scale**.

(i) Use Fig. 16.2 to determine accurately the wavelength of the blue light from the laser.

wavelength = ... m **[3]**

(ii) The blue light is now replaced by a similar beam of red light.
State and explain the effect, if any, on the fringes observed on the screen.

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

17 **(a)** State **one** S.I. base quantity other than length, mass and time.

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

(b) Fig. 17 shows two resistors **X** and **Y** connected in series.

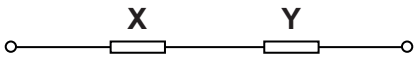

Fig. 17

The resistors are wires. Both wires have the same length L and diameter d. The material of **X** has resistivity ρ and the material of **Y** has resistivity 2ρ.

(i) Show that the total resistance R of the wires is given by the equation

$$R = \frac{12\rho L}{\pi d^2}.$$

[2]

(ii) A student uses the equation in **(i)** to determine R.
The table below shows the data recorded by the student in her lab book.

Quantity	Value
ρ	$4.7 \times 10^{-7}\,\Omega\,\text{m}$
L	$9.5 \pm 0.1\,\text{cm}$
d	$0.270 \pm 0.003\,\text{mm}$

1. Name the likely instruments used by the student to measure L and d.

L: .....

d: .....
[1]

2. Use the data in the table and the equation in **(i)** to determine R and the absolute uncertainty. Write your answer to the correct number of significant figures.

R = ... ± ..... Ω **[4]**

3. The instrument used to measure d has a zero-error. The measured d is much **larger** than the actual value.
Discuss how the actual value of R compares with the value calculated above.

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18 **(a)** Fig. 18.1 shows a circuit.

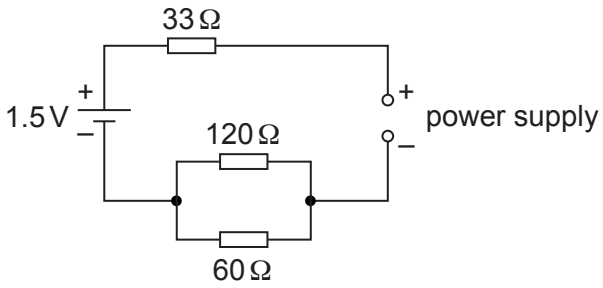

Fig. 18.1

The cell has e.m.f. 1.5 V. The cell and the variable power supply both have negligible internal resistance.

(i) The e.m.f. of the power supply is set at 4.2 V.
Calculate the current I in the 33 Ω resistor.

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

(ii) The e.m.f. of the variable supply is now slowly decreased from 4.2 V to 0 V.
Describe the effect on the current I in the 33 Ω resistor.

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

(b)* A group of students are investigating the power dissipated in a variable resistor connected across the terminals of a cell. The cell has e.m.f. 1.5 V.
The students determine the power P dissipated in the variable resistor of resistance R.

Fig. 18.2 shows the data points plotted by the students on a graph of P (y-axis) against R (x-axis).

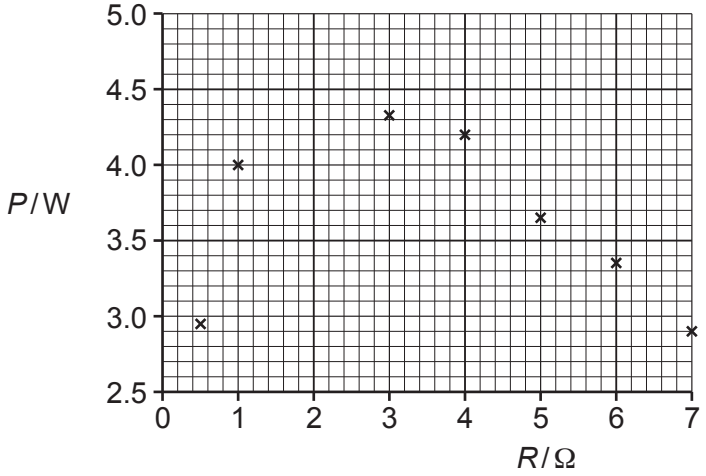

Fig. 18.2

The group of students know that **maximum power** is dissipated in the variable resistor when R is equal to the internal resistance r of the cell.

Describe, with the help of a suitable circuit diagram, how the students may have determined P and R. Use Fig. 18.2 to estimate the internal resistance r of the cell and discuss any limitations of the data plotted by the group.

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19 **(a)** Electromagnetic radiation is incident on a negatively charged zinc plate. Electrons are emitted from the surface of the plate when a weak intensity ultraviolet source is used. Electrons are not emitted at all when an intense visible light from a lamp is used.

Explain these observations.

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

(b) The **maximum** wavelength of the electromagnetic radiation incident on the surface of a metal which causes electrons to be emitted is 2.9×10^{-7} m.

Calculate the maximum kinetic energy of electrons emitted from the surface of the metal when each incident photon has energy of 5.1 eV.

maximum kinetic energy = ... J **[3]**

(c) Electromagnetic radiation of constant wavelength is incident on a metal plate. Photoelectrons are emitted from the metal plate. Fig. 19.1 shows an arrangement used to determine the maximum kinetic energy of electrons emitted from a metal plate.

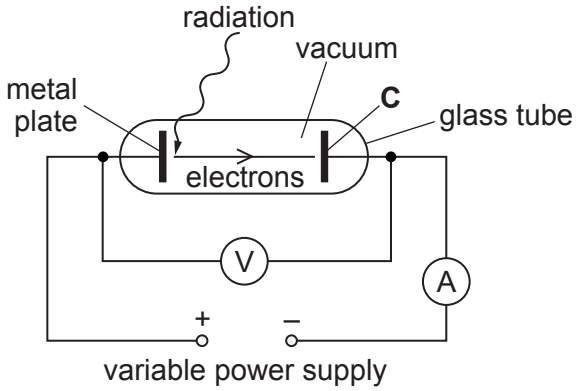

Fig. 19.1

The metal plate and the electrode **C** are both in a vacuum. The electrode **C** is connected to the negative terminal of the variable power supply.
Fig. 19.2 shows the variation of current I in the circuit as the potential difference V between the metal plate and **C** is increased from 0 V to 3.0 V.

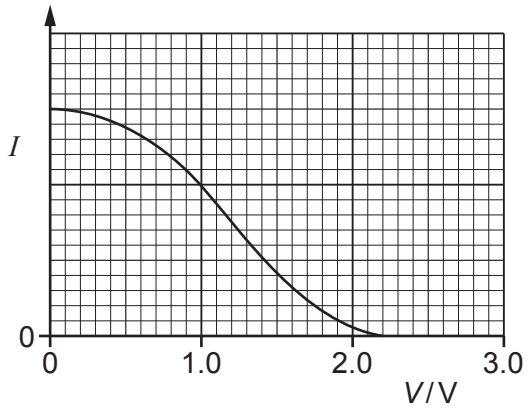

Fig. 19.2

Explain why the current decreases as V increases and describe how you can determine the maximum kinetic energy of the emitted electrons.

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20 **(a)** Fig. 20.1 shows a positively charged metal sphere and a negatively charged metal plate.

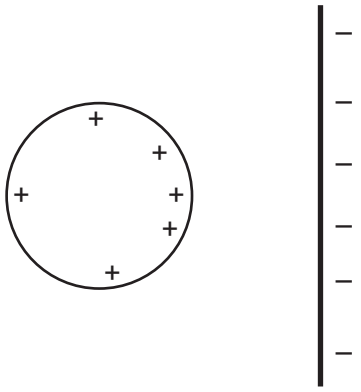

Fig. 20.1

On Fig. 20.1, draw a minimum of **five** electric field lines to show the field pattern between the sphere and the plate. **[2]**

(b) Define *electric potential* at a point in space.

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

(c) A metal sphere is given a positive charge by connecting its surface briefly to the positive terminal of a power supply. The electric potential at the surface of the sphere is + 5.0 kV. The sphere has radius 1.5 cm.

(i) Show that the charge Q on the surface of the sphere is 8.3×10^{-9} C.

[2]

(ii) Fig. 20.2 shows the charged sphere from **(i)** suspended from a nylon thread and placed between two oppositely charged vertical plates.

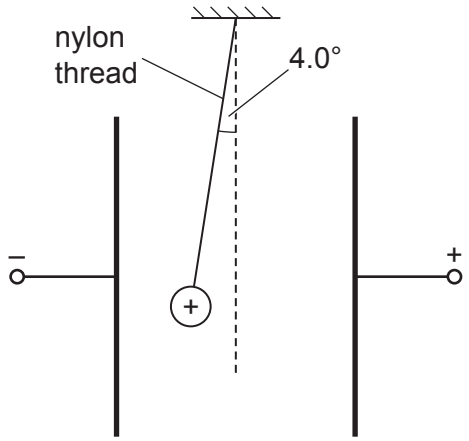

Fig. 20.2 (not to scale)

The weight of the sphere is 1.7×10^{-2} N. The string makes an angle of 4.0° with the vertical.

1. Show that the electric force on the charged sphere is 1.2×10^{-3} N.

[1]

2. Calculate the uniform electric field strength E between the parallel plates.

E = ... NC^{-1} **[2]**

21 **(a)** A capacitor of capacitance 7.2 pF consists of two parallel metal plates separated by an insulator of thickness 1.2 mm. The area of overlap between the plates is $4.0 \times 10^{-4}\,m^2$. Calculate the permittivity of the insulator between the capacitor plates.

permittivity = ... $F\,m^{-1}$ **[2]**

(b) Fig. 21 shows a circuit.

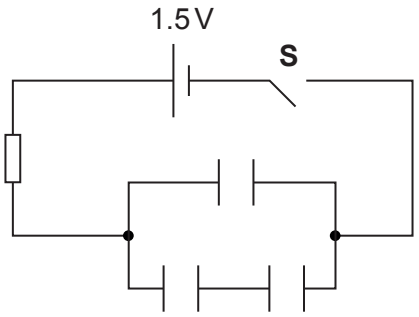

Fig. 21

The capacitance of each capacitor is 1000 μF. The resistance of the resistor is 10 kΩ. The cell has e.m.f. 1.5 V and negligible internal resistance.

(i) Calculate the total capacitance *C* in the circuit.

C = ... μF **[2]**

(ii) The switch **S** is closed at time $t = 0$. There is zero potential difference across the capacitors at $t = 0$.
Calculate the potential difference V across the resistor at time $t = 12\,\text{s}$.

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

22 (a)* A student conducts an experiment to confirm that the uniform magnetic flux density *B* between the poles of a magnet is 30 mT.

A current-carrying wire of length 5.0 cm is placed perpendicular to the magnetic field.

The current *I* in the wire is changed and the force *F* experienced by the wire is measured. Fig. 22.1 shows the graph plotted by the student.

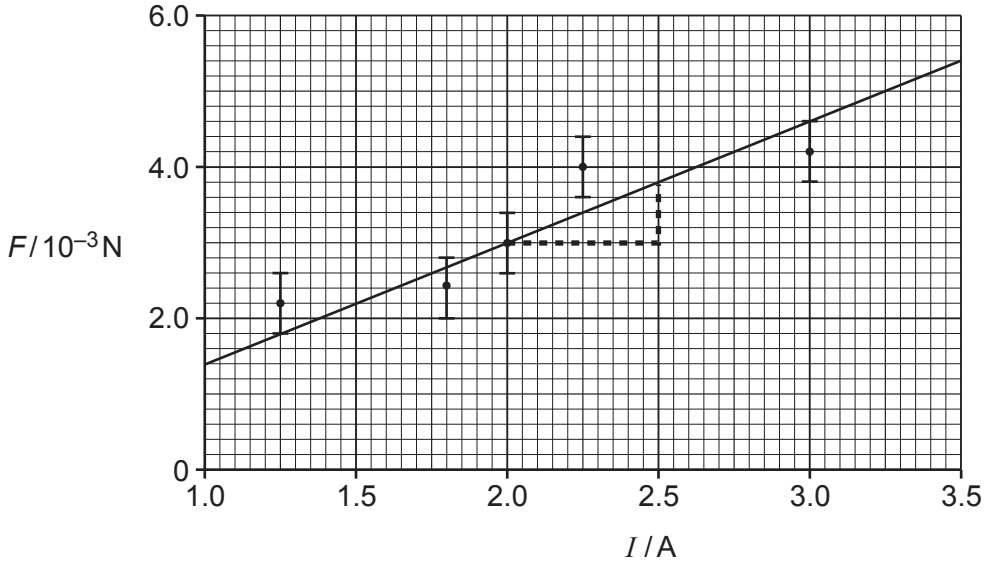

Fig. 22.1

The student's analysis is shown on the graph of Fig. 22.1 and in the space below.

$F = BIL$

$\text{gradient} = BL = \dfrac{(3.8 - 3.0) \times 10^{-3}}{2.5 - 2.0} = 0.0016$

$B = \dfrac{0.0016}{0.05} = 0.032\,\text{T} = 32\,\text{mT}$

This is just 2 mT out from the 30 mT value given by the manufacturer, so the experiment is very accurate.

Evaluate the information from Fig. 22.1 and the analysis of the data from the experiment. No further calculations are necessary.

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(b) Fig. 22.2 shows a transformer circuit.

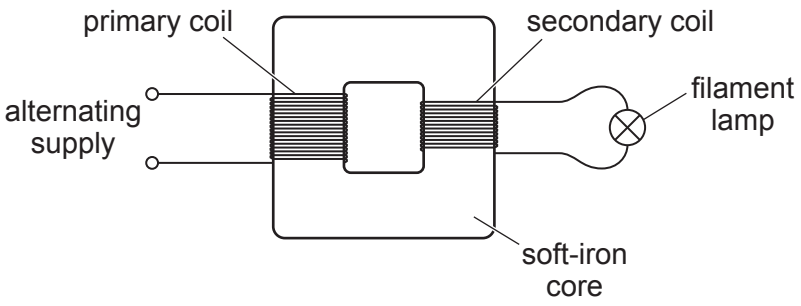

Fig. 22.2

The primary coil is connected to an alternating voltage supply. A filament lamp is connected to the output of the secondary coil.

(i) Use Faraday's law of electromagnetic induction to explain why the filament lamp is lit.

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

(ii) The primary coil has 400 turns and the secondary coil has 20 turns. The potential difference across the lamp is 12 V and it dissipates 24 W. The transformer is 100% efficient.

1. Calculate the current in the primary coil.

current = ... A **[2]**

2. The alternating voltage supply is replaced by a battery and an open switch in series. The switch is closed. The lamp is lit for a short period of time and then remains off. Explain this observation.

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23 **(a)** Describe the nature of the *strong nuclear force*.

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

(b) **(i)** Name a hadron found in the nucleus of an atom and state its quark combination.

name of hadron: ..... quark combination: ..... **[1]**

(ii) Write a decay equation in terms of a quark model for beta-minus decay.

[2]

(c) The radius of a nucleus is directly proportional to $A^{1/3}$, where A is the nucleon number.
The mass of a proton and a neutron are similar.
Explain why the mean density of all nuclei is about the same.

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

24 Stars produce energy by nuclear fusion.
One particular fusion reaction between two protons ($^{1}_{1}H$) is shown below.

$$^{1}_{1}H \quad + \quad ^{1}_{1}H \quad \rightarrow \quad ^{2}_{1}H \quad + \quad ^{0}_{+1}e \quad + \quad \nu$$

In this reaction 2.2 MeV of energy is released.

(a) Only one of the particles shown in the reaction has binding energy.
Determine the binding energy per nucleon of this particle. Explain your answer.

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(b) Explain why high temperatures are necessary for fusion reactions to occur in stars.

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

(c) A gamma photon in a star can spontaneously create an electron-positron pair.
Calculate the **maximum** wavelength of a gamma photon for this creation event.

maximum wavelength = ... m **[3]**

25 Fluorine-18 is a common radioactive isotope used in positron emission tomography (PET). Fluorine-18 emits positrons. A patient is injected with a radiopharmaceutical containing fluorine-18.

(a) Describe how a PET scanner is used to locate an area of increased activity within the patient.

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

(b) The half-life of fluorine-18 is 110 minutes.
Calculate the time *t* in minutes for the activity of the radiopharmaceutical to decrease to 30% of its initial activity.

t = ... minutes **[3]**

(c) PET scanners are not available in all hospitals. This is because fluorine-18 requires expensive on-site particle accelerators and fluorine-18 has a very small 'shelf-life'.
Suggest the impact this may have on the treatment and diagnosis of patients in the country.

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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

A Level Physics A

H556/02 Exploring physics

Friday 8 June 2018 – Morning

Time allowed: 2 hours 15 minutes

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

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

H 5 5 6 0 2

First name	
Last name	
Centre number	Candidate number

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INFORMATION
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- This document consists of **36** 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 electrical quantity has S.I. units ampere-second (As)?

A charge

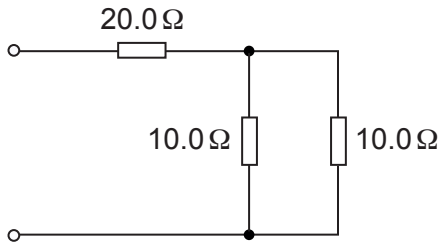
B current

C resistance

D potential difference

Your answer ☐ **[1]**

2 Three resistors are connected in a circuit.



The resistance of each resistor is shown in the circuit diagram.

What is the total resistance of this circuit?

A 10.0 Ω

B 20.2 Ω

C 25.0 Ω

D 40.0 Ω

Your answer ☐ **[1]**

3 An electron has a de Broglie wavelength equal to the wavelength of X-rays.

What is the **best** estimate of the momentum of this electron?

A $10^{-30}\,\text{kg m s}^{-1}$

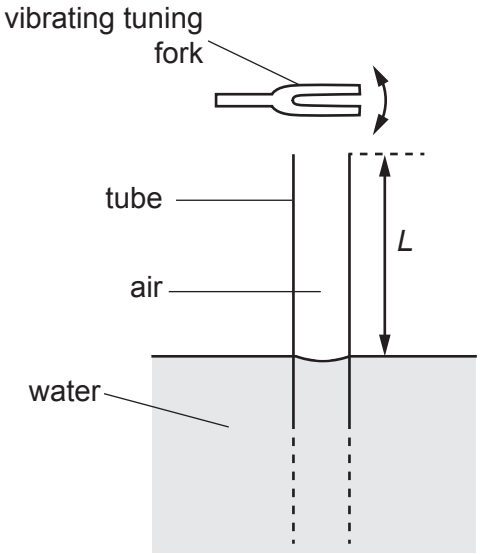
B $10^{-27}\,\text{kg m s}^{-1}$

C $10^{-23}\,\text{kg m s}^{-1}$

D $10^{-18}\,\text{kg m s}^{-1}$

Your answer ☐ **[1]**

4 A vibrating tuning fork is held above the open end of a long vertical tube. The other end of the tube, which is also open, is immersed in a tank of water. The length *L* of the air column within the tube is changed by raising or lowering the tube.



The wavelength of sound from the vibrating tuning fork is 150.0 cm.

What length *L* of air column will **not** produce a stationary wave within the tube?

A 37.5 cm

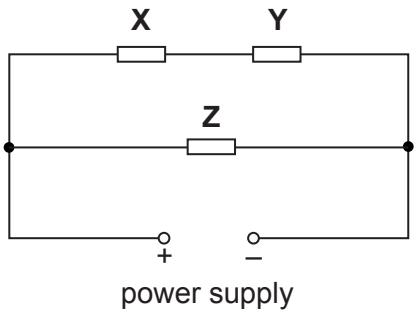
B 75.0 cm

C 112.5 cm

D 187.5 cm

Your answer ☐ **[1]**

5 Three identical resistors **X**, **Y** and **Z** are connected to a power supply.



The power dissipated in the resistor **Z** is 24 W.

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

A 6.0 W

B 12 W

C 24 W

D 48 W

Your answer ☐ **[1]**

6 Which is the **best** value for the elementary charge *e* in terms of both accuracy and precision?

A $(1.5 \pm 0.5) \times 10^{-19}$ C

B $(1.5 \pm 0.4) \times 10^{-19}$ C

C $(1.7 \pm 0.2) \times 10^{-19}$ C

D $(1.8 \pm 0.2) \times 10^{-19}$ C

Your answer ☐ **[1]**

7 A small loudspeaker emits sound uniformly in all directions.
The amplitude of the sound is 12 μm at a distance of 1.5 m from the loudspeaker.

What is the amplitude of the sound at a distance of 4.5 m from the loudspeaker?

A 1.3 μm

B 4.0 μm

C 6.9 μm

D 12 μm

Your answer ☐ **[1]**

8 An isolated metal sphere is charged using a power supply.

Which single quantity can be used to determine the capacitance of the sphere?

A The diameter of the sphere.

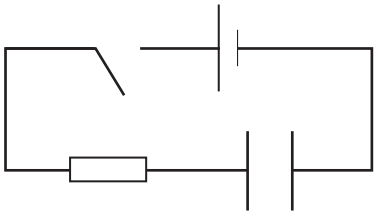
B The charge on the sphere.

C The resistance of the metal.

D The e.m.f. of the power supply.

Your answer ☐ **[1]**

9 A capacitor is charged through a resistor.



The cell has e.m.f. 1.50 V and negligible internal resistance.
The capacitor is initially uncharged. The time constant of the circuit is 100 s.
The switch is closed at time $t = 0$.

What is the potential difference across the capacitor at time $t = 200$ s?

A 0.20 V

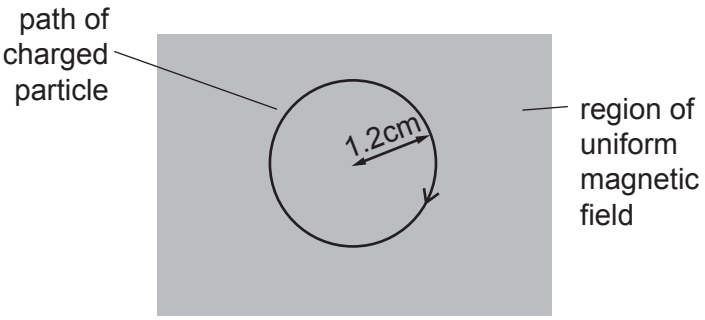
B 0.55 V

C 0.95 V

D 1.30 V

Your answer ☐ **[1]**

10 A charged particle moves in a circular path of radius 1.2 cm in a uniform magnetic field.



The direction of the magnetic field is perpendicular to the plane of the paper.

The particle has mass m, charge $+Q$ and speed v.

Another particle of mass $3m$, charge $+2Q$ and speed v moves in a circular path of radius R in the same magnetic field.

What is the value of R?

A 0.8 cm

B 1.2 cm

C 1.8 cm

D 7.2 cm

Your answer ☐ **[1]**

11 The acoustic impedance Z of a material in the shape of a cube can be determined using the equation

$$Z = \frac{Mc}{L^3}$$

where M is the mass of the material, L is the length of each side of the cube and c is the speed of ultrasound in the material.

The percentage uncertainty in L is 1.2% and the percentage uncertainty in c is 1.8%. The percentage uncertainty in M is negligible.

What is the percentage uncertainty in Z?

A 2.2%

B 3.0%

C 4.2%

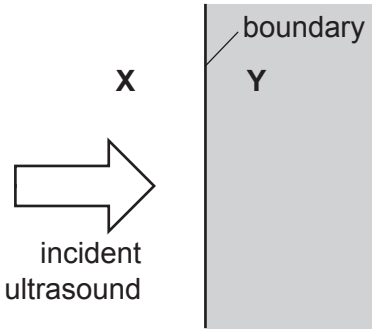
D 5.4%

Your answer ☐ **[1]**

12 The table shows some data on two tissues in a patient.

Tissue	Density	Acoustic impedance
X	ρ	$1.5Z$
Y	1.3ρ	Z

Ultrasound in tissue **X** is incident at the boundary between the tissues **X** and **Y**.



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

A 1.7 %

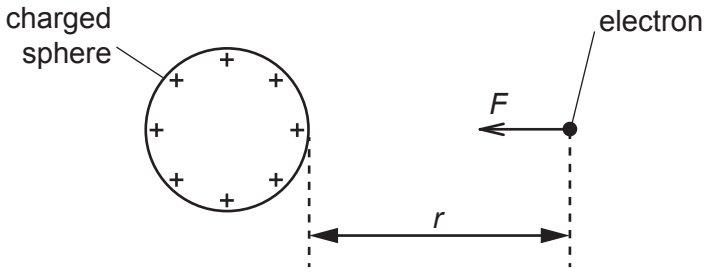
B 4.0 %

C 13 %

D 20 %

Your answer ☐ **[1]**

13 An electron is released at a distance r from the surface of a positively charged sphere. It is attracted towards the centre of the sphere and moves until it touches the surface.



Which of the following statements is/are correct?

1 The area under the F against r graph is equal to work done on the electron.

2 The electric field strength E at distance r is equal to $\frac{F}{1.6 \times 10^{-19}}$.

3 The work done on the electron is equal to $F \times r$.

A Only 1

B Only 1 and 2

C Only 1 and 3

D 1, 2 and 3

Your answer ☐ **[1]**

14 Which lepton is emitted in the decay of an up quark and is affected by a magnetic field?

A neutrino

B electron

C positron

D antineutrino

Your answer ☐ **[1]**

15 A contrast material is used while taking an X-ray image of a patient.

Which statement is correct?

A Iodine is a contrast material.

B Technetium is a contrast material.

C A contrast material must have a short half-life.

D A contrast material is used for acoustic matching.

Your answer ☐ **[1]**

SECTION B

Answer **all** the questions.

16 **(a)** Derive the S.I. base units for resistance.

base units: ..... **[2]**

(b) Fig. 16.1 shows the I-V characteristics of two electrical components **L** and **R**.

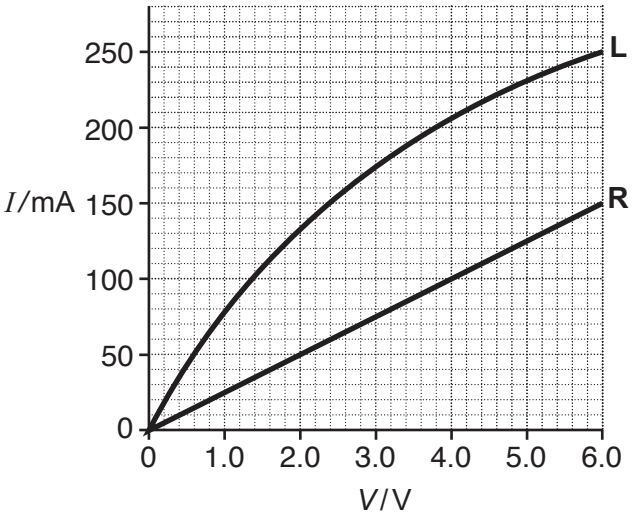


Fig. 16.1

The component **L** is a filament lamp and the component **R** is a resistor.

(i) Show that the resistance of **R** is 40 Ω.

[1]

(ii) Fig. 16.2 shows the components **L** and **R** connected in series to a battery of e.m.f. 6.0 V.

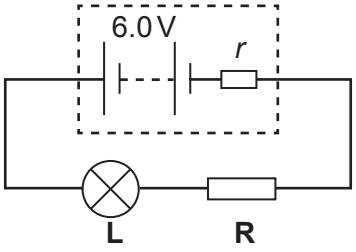


Fig. 16.2

The resistor **R** is a cylindrical rod of length 8.0 mm and cross-sectional area 2.4×10^{-6} m^2. The current in the circuit is 100 mA.

1 Use Fig. 16.1 to determine the internal resistance r of the battery.

r = ... Ω **[3]**

2 Calculate the resistivity ρ of the material of the resistor **R**.

ρ = ... Ω m **[2]**

3 There are 6.5×10^{17} charge carriers within the volume of **R**.

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

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

17* A metal circular plate is rotated at a constant frequency by an electric motor.
The plate has a small hole close to its rim.
Fig. 17.1 shows an arrangement used by a student to determine the frequency of the rotating plate.

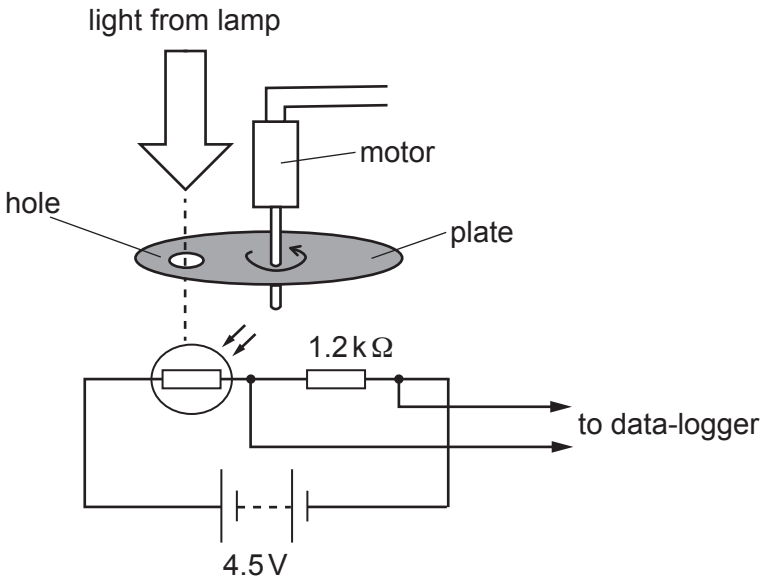


Fig. 17.1

A light-dependent resistor (LDR) and a fixed resistor of resistance 1.2 kΩ are connected in series to a battery. The battery has e.m.f. 4.5 V and has negligible internal resistance. The potential difference V across the resistor is monitored using a data-logger.

Fig. 17.2 shows the variation of V with time t.

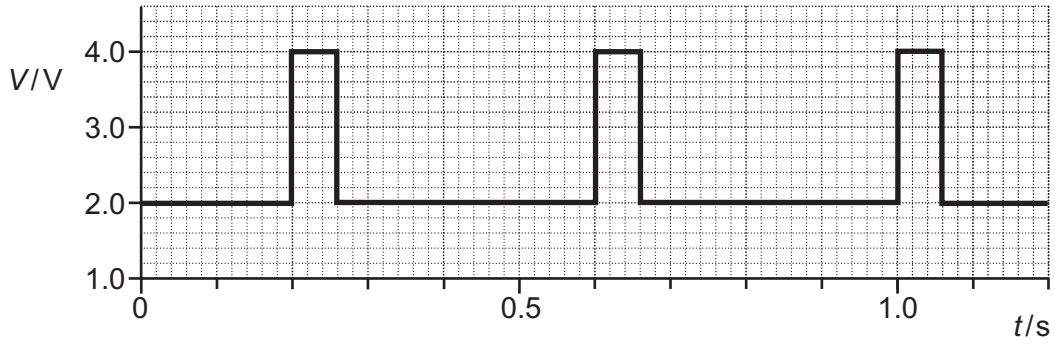


Fig. 17.2

Use your knowledge and understanding of potential divider circuits to explain the shape of the graph shown in Fig. 17.2. Include in your answer the maximum and minimum values of the resistance of the LDR.
Describe how the student can determine the frequency of the rotating plate.

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..... **[6]**

18 A narrow beam of unpolarised light is incident at the boundary between air and glass.

Fig. 18 shows the incident ray, the reflected ray and the refracted ray at the air-glass boundary.

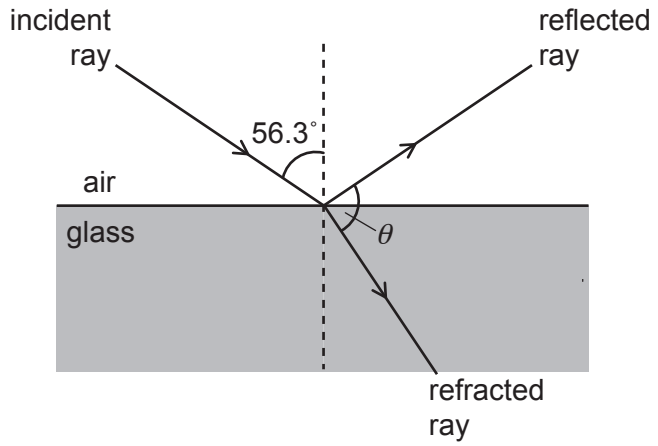

Fig. 18 (not to scale)

The refractive index of air is 1.00 and the refractive index of the glass is 1.50.
The angle of incidence of the light is 56.3°.

(a) Show that the angle θ between the refracted ray in the glass and the reflected ray in the air is 90.0°.

[3]

(b) Describe how you can demonstrate in the laboratory that the reflected light is plane polarised.

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

(c) Calculate the time *t* taken for the refracted light to travel a **depth** of 6.0 cm of glass.

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

19 (a) Fig. 19.1 shows the image from an experiment using a ripple tank.

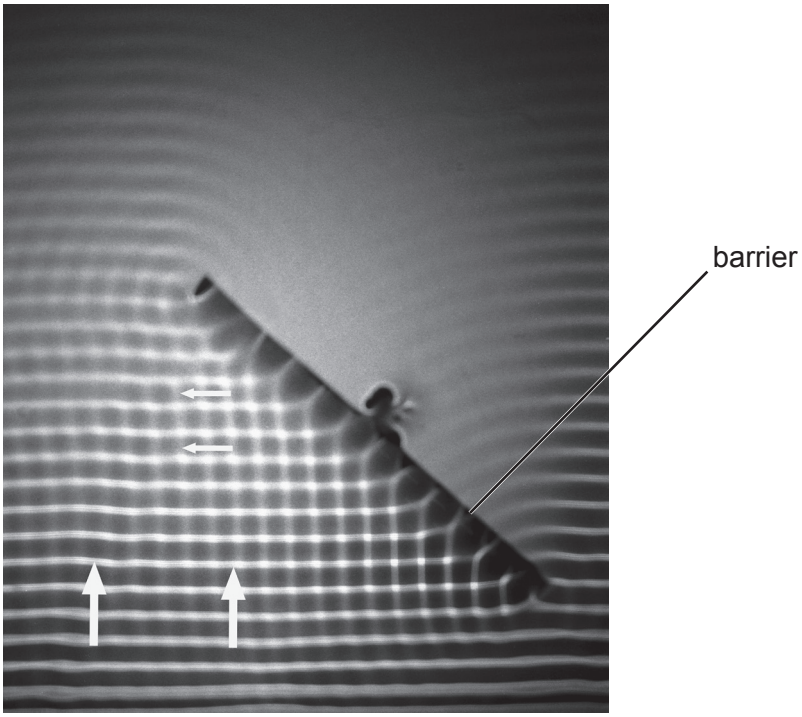

Fig. 19.1

A straight ruler repeatedly hits the surface of water. Waves on the surface of the water travel in the direction shown by the two large upward white arrows. The waves are incident at a solid barrier.

Closely examine the image shown in Fig. 19.1.

State **two** wave phenomena (properties) that can be observed in this image. You may annotate Fig. 19.1 to support your answer.

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

(b) Two transmitters, **A** and **B**, emit coherent microwaves in all directions. A receiver is moved at constant speed along the line from **P** to **Q** which is parallel to the line joining the two transmitters, as shown in Fig. 19.2.

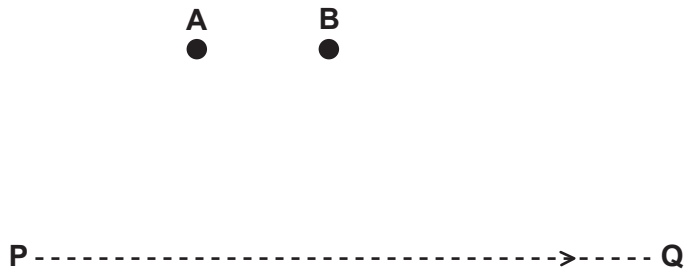

Fig. 19.2

Explain why the output signal from the receiver fluctuates between minimum and maximum values as the receiver moves from **P** to **Q**.

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20 **(a)** An approximate value of the Planck constant h can be determined in the laboratory using light-emitting diodes (LEDs). An LED suddenly starts to conduct and emit monochromatic light when the potential difference across an LED exceeds a minimum value V_0.
The potential difference V_0 and the wavelength λ of the emitted light are related by the equation

$$V_0 = \left(\frac{hc}{e}\right) \times \frac{1}{\lambda}$$

where e is the elementary charge and c is the speed of light in a vacuum.

Fig. 20.1 shows some data points plotted by a student on a V_0 against $\frac{1}{\lambda}$ graph for five different LEDs.

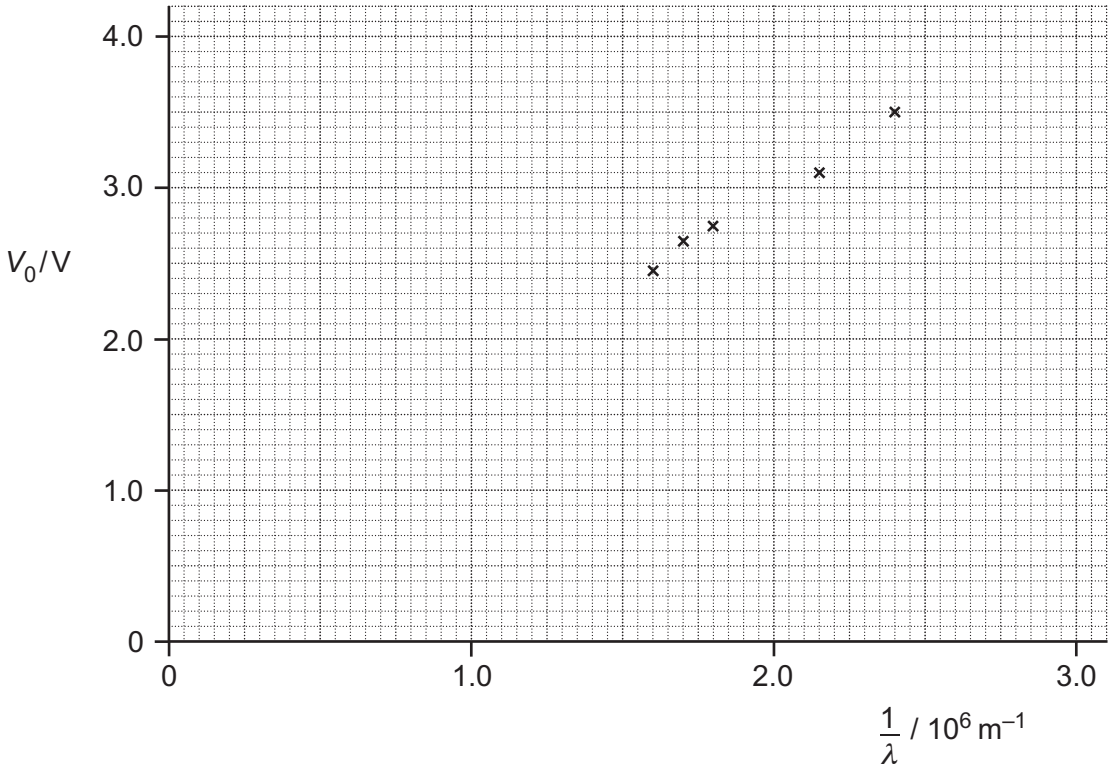

Fig. 20.1

The potential difference across each LED was measured using a digital voltmeter with divisions ±0.01 V. The values for the wavelengths are accurate and were provided by the manufacturer of the LEDs.

The value of V_0 was determined by directly observing the state of the LED in the **brightly** lit laboratory.

(i) Draw the straight line of best fit on Fig 20.1 and determine the gradient of the line.

gradient = ... V m **[2]**

(ii) Use your answer in **(i)** and the equation on page 20 to determine a value for h to 2 significant figures. Show your working.

h = ... J s **[3]**

(iii) Calculate the percentage difference between your value in **(ii)** and the accepted value of the Planck constant.

difference = ... % **[1]**

(iv) Identify the two types of errors shown by the data in Fig. 20.1 and suggest how you could have refined the experiment to reduce or eliminate these errors.

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(b) Fig. 20.2 shows a gold-leaf electroscope with a clean zinc plate.

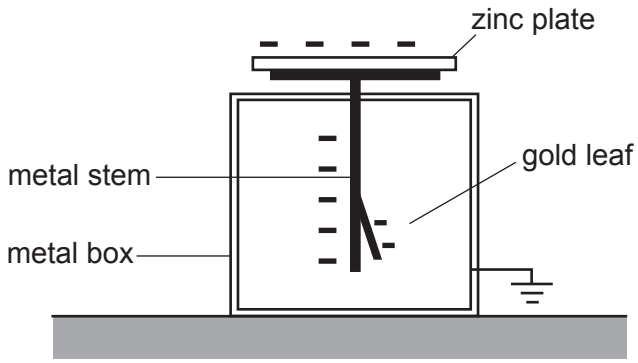

Fig. 20.2

The zinc plate, metal stem and the gold-leaf are given a negative charge by briefly connecting the zinc plate to the negative electrode of a high-voltage supply.

The gold leaf is fully diverged.

The position of the leaf is not affected by intense white light from a table lamp incident on the zinc plate. The gold leaf collapses very quickly when low-intensity ultraviolet radiation from a mercury lamp is incident on the zinc plate.

Explain these observations in terms of photons.

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Question 21 is on page 24

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21 Fig. 21.1 shows a coil of a simple generator rotating in a uniform magnetic field.

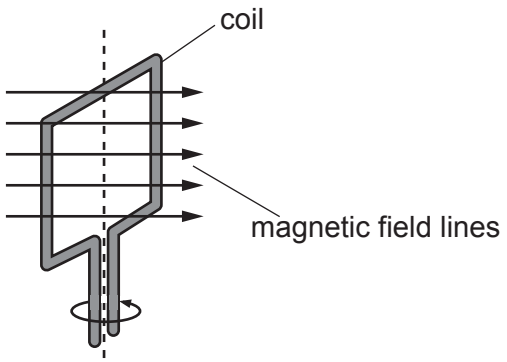

Fig. 21.1

The coil has 85 turns of insulated wire. The cross-sectional area of the coil is 14 cm^2.
Fig. 21.2 shows the variation of magnetic flux density *B* through the plane of the coil with time *t* as it rotates.

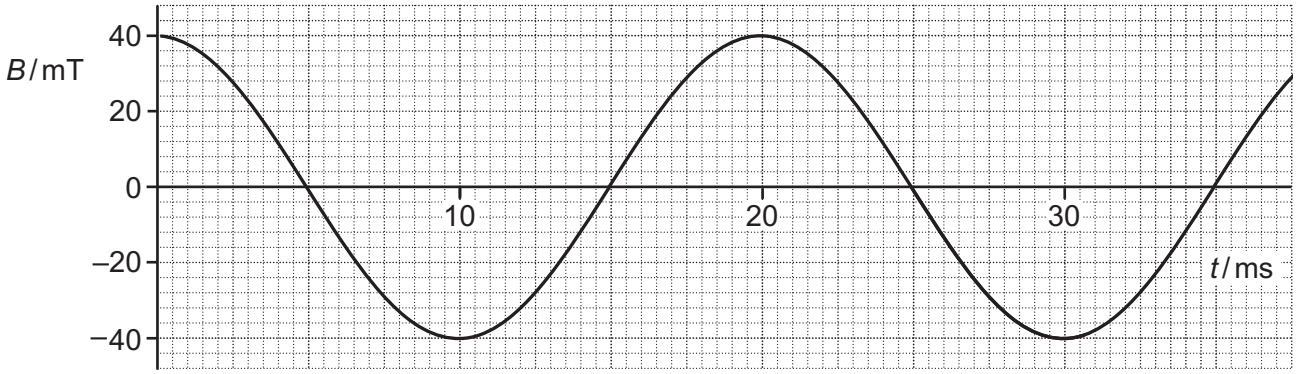

Fig. 21.2

(a) (i) Explain why the electromotive force (e.m.f.) induced across the ends of the coil is a **maximum** at the times when $B = 0$.

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

(ii) Draw a tangent to the curve in Fig. 21.2 when $B = 0$, and hence determine the **maximum** e.m.f. induced across the ends of the coil.

maximum e.m.f. = ... V **[3]**

(b) Fig. 21.3 shows the variation of the e.m.f. induced across the ends of the coil with time t.

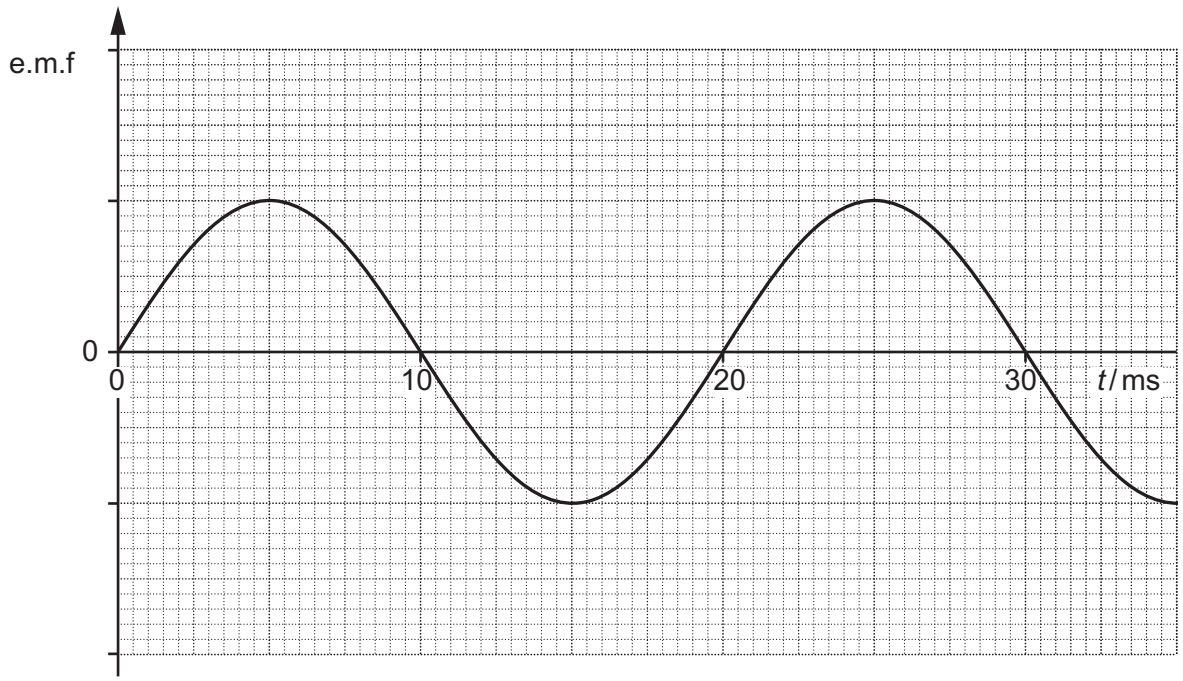

Fig. 21.3

The magnitude of the magnetic flux density of the uniform field is now halved and the coil is rotated at twice its previous frequency.

On Fig. 21.3 sketch the new variation of the e.m.f. induced with time t. **[2]**

22 A student wishes to determine the permittivity ε of paper using a capacitor made in the laboratory.

The capacitor consists of two large parallel aluminium plates separated by a very thin sheet of paper.

The capacitor is initially charged to a potential difference V_0 using a battery. The capacitor is then discharged through a fixed resistor of resistance 1.0 MΩ.

The potential difference V across the capacitor after a time t is recorded by a data-logger. The student uses the data to draw the ln$V$ against t graph shown in Fig. 22.

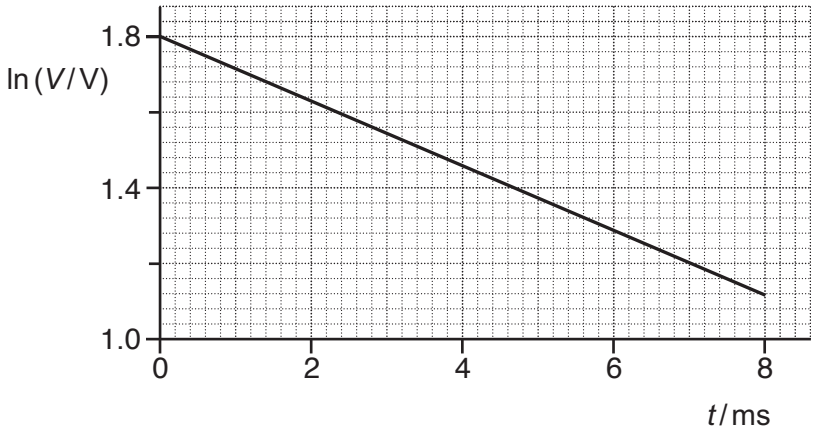

Fig. 22

(a) Show that the magnitude of the gradient of the line shown in Fig. 22 is equal to

$$\frac{1}{CR}$$

where C is the capacitance of the capacitor and R is the resistance of the resistor.

[2]

(b)* Use Fig. 22 to determine the capacitance C of the capacitor. Describe how the student can then use this value of C to determine a value for ε.
In your description, mention any additional measurements required on the capacitor.

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23 (a) The structure of atoms was deduced in the early 1900s by Rutherford and his co-workers from the scattering of alpha-particles by a very thin sheet of gold.

Rutherford assumed that the scattering of the alpha-particles was due to electrostatic forces. Fig. 23 shows a detector used to record the number N of alpha-particles scattered through an angle θ.

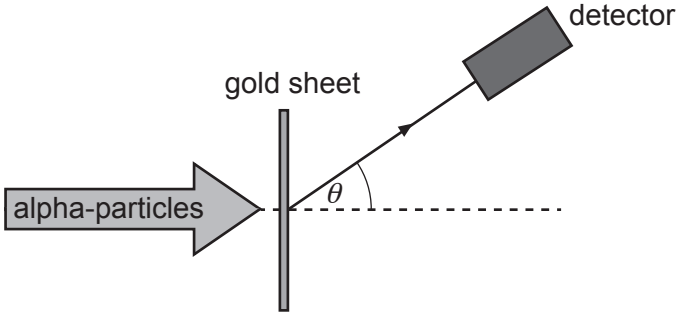

Fig. 23

At $\theta = 0°$, N was too large to be measured. The table below summarises some of the collected data.

θ / °	lg (N)
150	1.5
75	2.3
60	2.7
30	3.9
15	5.1
0	N too large

(i) Show that the number of alpha-particles scattered through 15° is about 4000 times more than those scattered through 150°.

[1]

(ii) Use the evidence from the table to explain the structure of the atom.

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

(b) A proton with kinetic energy 0.52 MeV is travelling directly towards a stationary nucleus of cobalt-59 ($^{59}_{27}$Co) in a head-on collision.

(i) Explain what happens to the electric potential energy of the proton-nucleus system.

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

(ii) Calculate the **minimum** distance *R* between the proton and cobalt nucleus.

R = ... m **[3]**

24 An isotope of polonium-213 ($^{213}_{84}$Po) first decays into an isotope of lead-209 ($^{209}_{82}$Pb) and this lead isotope then decays into the stable isotope of bismuth (Bi).

Fig. 24 shows two arrows on a neutron number *N* against proton number *Z* chart to illustrate these two decays.

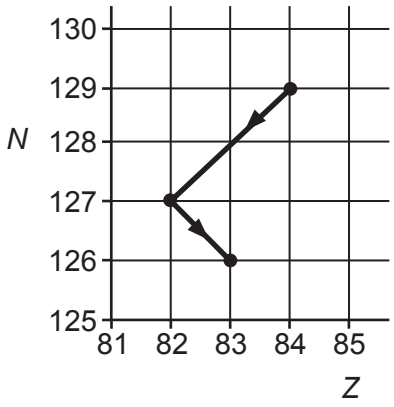

Fig. 24

(a) Complete the nuclear decay equations for

(i) the polonium isotope

$^{213}_{84}\text{Po} \longrightarrow {}^{209}_{82}\text{Pb} + \text{.....}$ **[1]**

(ii) the lead isotope.

$^{209}_{82}\text{Pb} \longrightarrow {}^{\text{.....}}_{83}\text{Bi} + {}^{0}_{-1}\text{e} + \text{.....}$ **[2]**

(b) A pure sample of polonium-213 is being produced in a research laboratory.

The half-life of $^{213}_{84}Po$ is very small compared with the half-life of $^{209}_{82}Pb$.

After a very short time, the ionising radiation detected from the sample is mainly from the beta-minus decay of the lead-209 nuclei.

(i) Briefly describe and explain an experiment that can be carried out to confirm the beta-minus radiation emitted from the lead nuclei.

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

(ii) The activity of the sample of $^{209}_{82}Pb$ after 7.0 hours is 12 kBq.

The half-life of $^{209}_{82}Pb$ is 3.3 hours.

Calculate the initial number of lead-209 nuclei in this sample.

number of nuclei = ... **[4]**

25 (a) The nuclear reaction below shows how the isotope of fluorine-18 ($^{18}_{9}F$) is made from the isotope of oxygen-18 ($^{18}_{8}O$).

$$^{18}_{8}O + {}^{1}_{1}p \rightarrow {}^{18}_{9}F + {}^{1}_{0}n + \gamma$$

The oxygen-18 nucleus is **stationary** and the proton has kinetic energy of 0.25×10^{-11} J.
The binding energy of the $^{18}_{8}O$ nucleus is 2.24×10^{-11} J and the binding energy of the $^{18}_{9}F$ nucleus is 2.20×10^{-11} J. The proton and the neutron have zero binding energy.

(i) Explain why a high-speed proton is necessary to trigger the nuclear reaction shown above.

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

(ii) Estimate the minimum wavelength λ of the gamma ray photon (γ).

λ = ... m **[3]**

(iii) Fluorine-18 is a positron emitter.
Name a medical imaging technique that uses fluorine-18 and state one benefit of the technique.

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

(b) Describe how the components of a computerised axial tomography (CAT) scanner can produce high-quality images of the internal structures of a patient.

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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 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

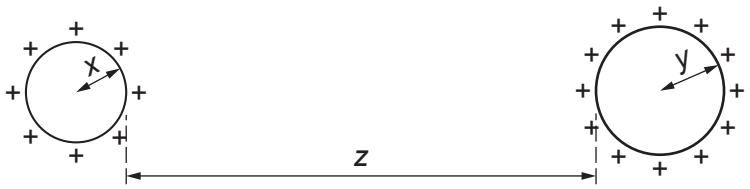
B Coulomb's law

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

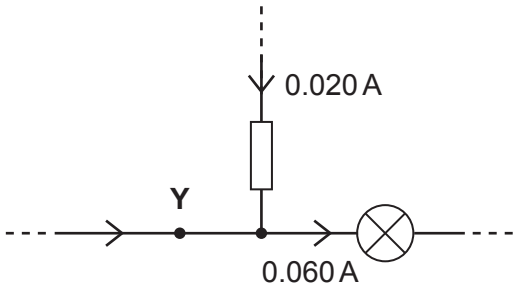
B $x + z$

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}

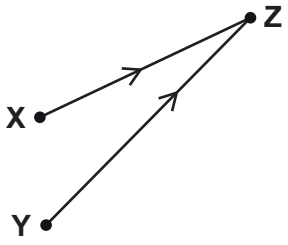
B 2.50×10^{18}

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

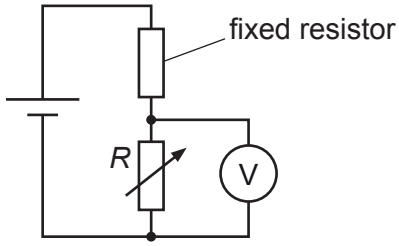
B 2.0 m

C 3.0 m

D 4.0 m

Your answer ☐ **[1]**

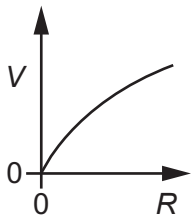
5 A potential divider circuit is shown below.



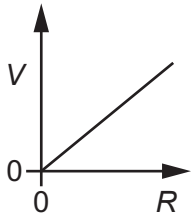
The resistance of the variable resistor is R. The potential difference across the variable resistor is V.

Which graph shows the correct variation with R of V?

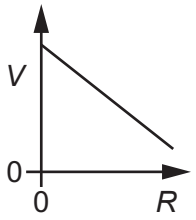
A



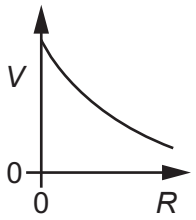
B



C



D



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	$3L$	$2d$	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

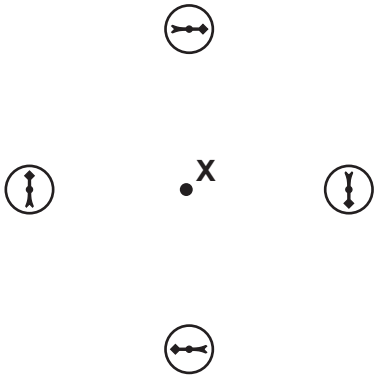
B 1.5×10^{-17} C

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 $1.8 \times 10^{-4}\,Wb$ 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 $3.6 \times 10^{-5}\,s$

B $2.4 \times 10^{-4}\,s$

C $0.12\,s$

D $8.3\,s$

Your answer ☐ **[1]**

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

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

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

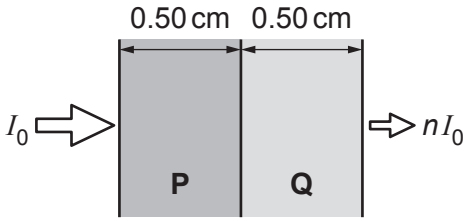
B $1.9 \times 10^{-42}\,m^3$

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

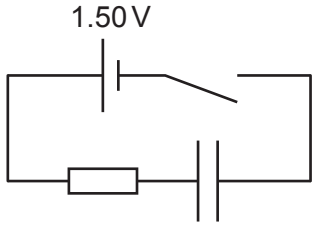
B 0.74

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

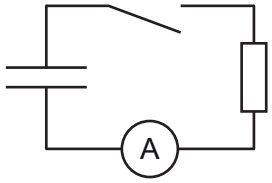
B $0.90 = 1.50e^{-0.10t}$

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]**

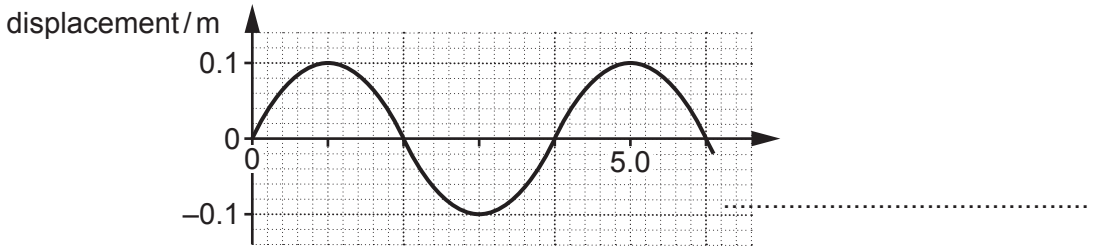


Fig. 16.1

(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.

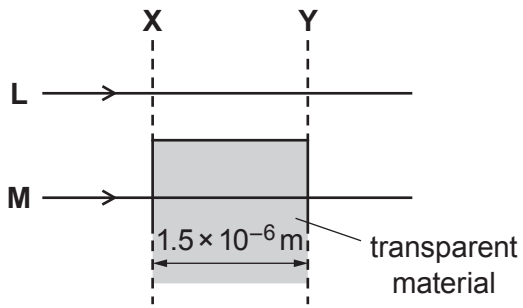


Fig. 16.2

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 $1\,m\,s^{-1}$ 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 $t = 0$.

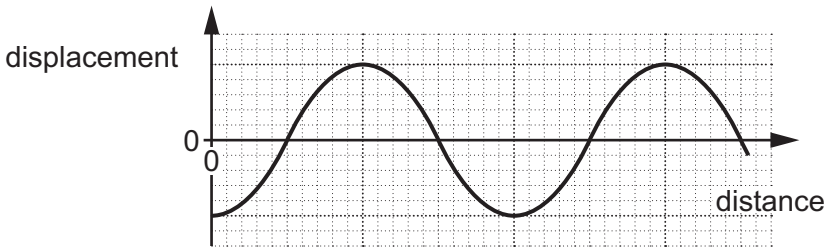

Fig. 17.1

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.

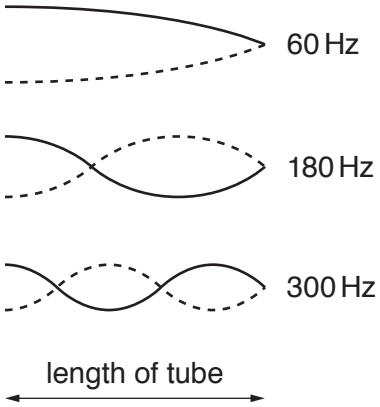

Fig. 17.2

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 $kg\,m^2\,s^{-3}A^{-2}$.

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

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

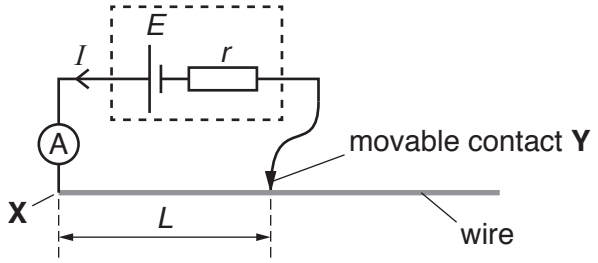

Fig. 18.1

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.

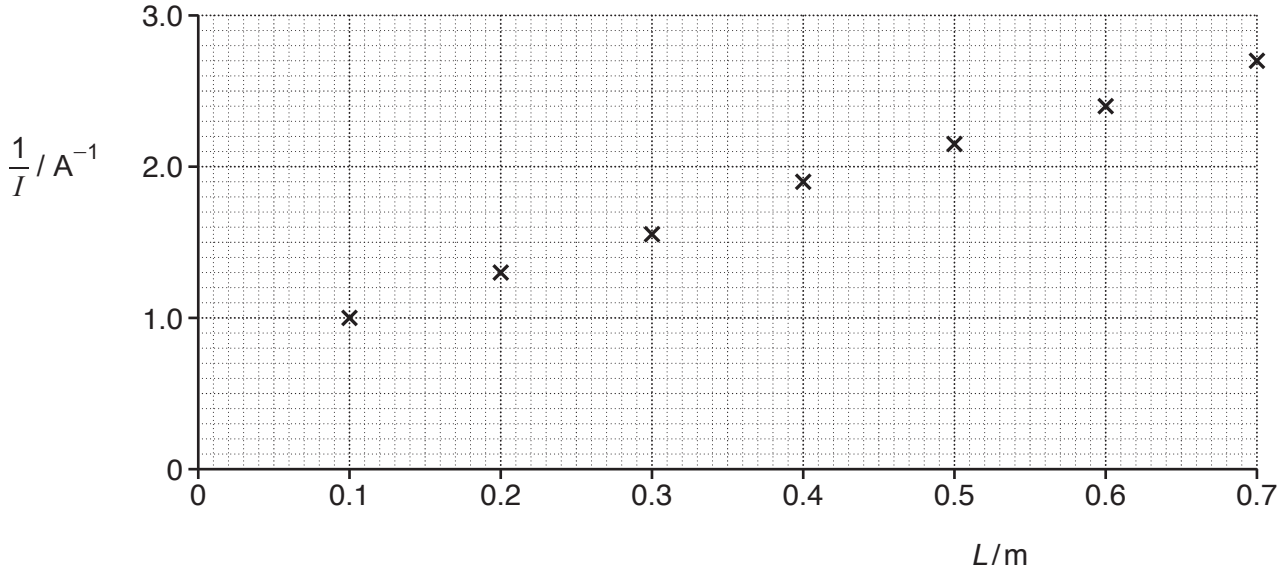

Fig. 18.2

(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.

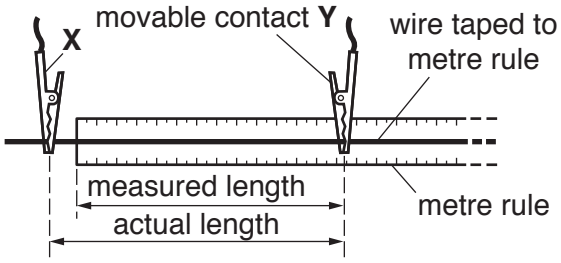

Fig. 18.3

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.

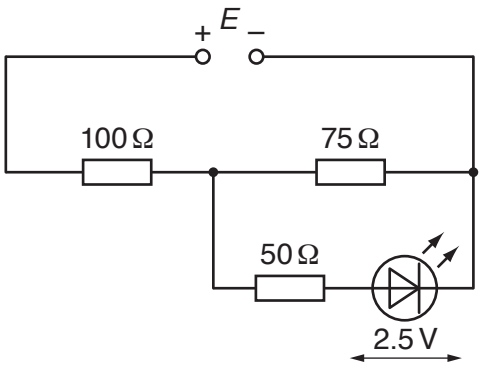

Fig. 19.1

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.

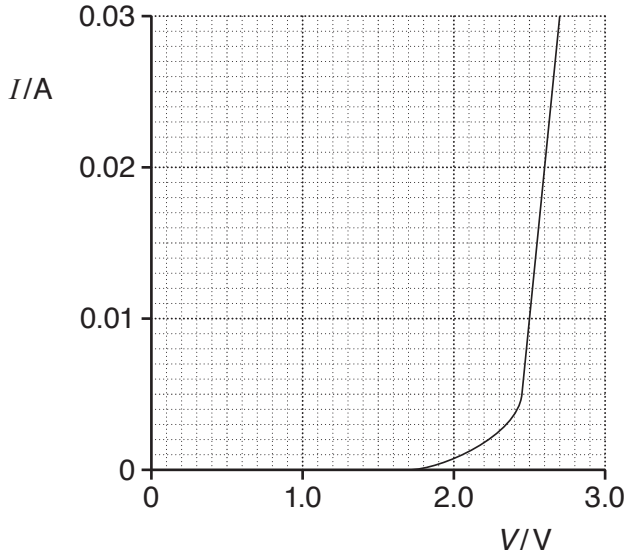

Fig. 19.2

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.

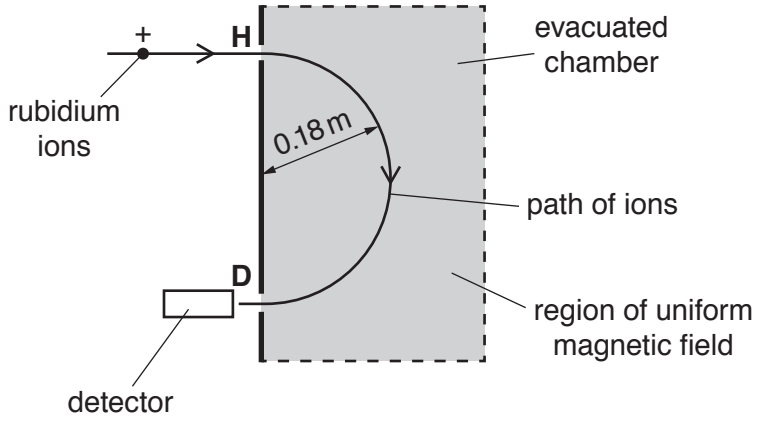

Fig. 20

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.

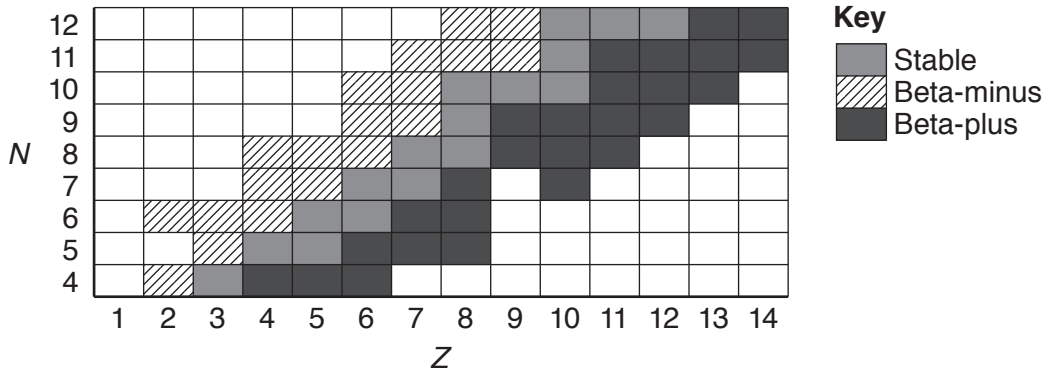

Fig. 21

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

.....

..... **[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.

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

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.

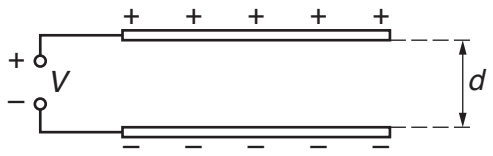

Fig. 22.1

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.

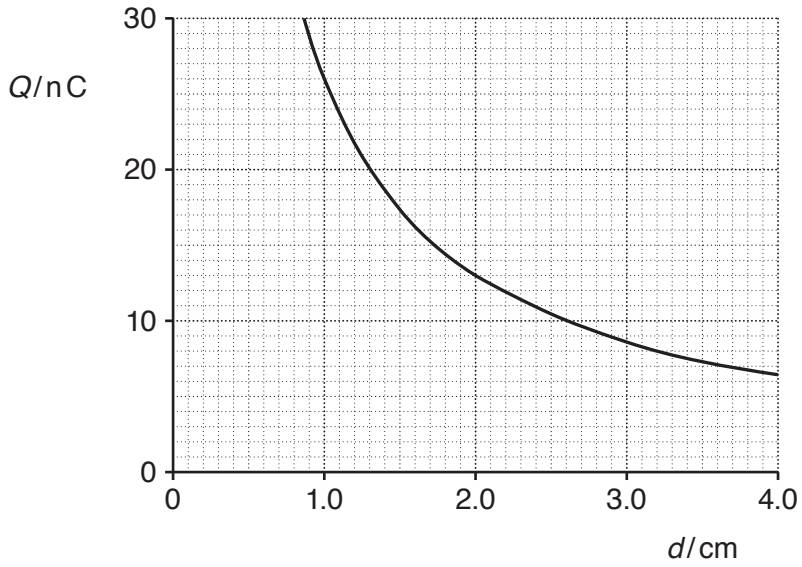

Fig. 22.2

(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.

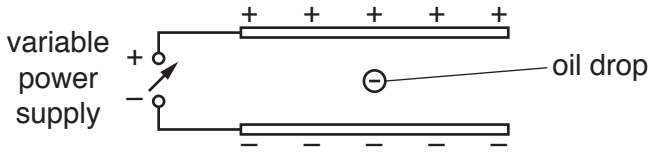

Fig. 22.3

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.

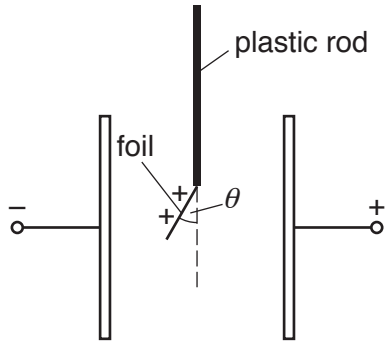

Fig. 22.4

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.

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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).

OCR
Oxford Cambridge and RSA

Thursday 15 October 2020 – 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)

8255066181

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 **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 The Doppler effect is used to measure the speed of blood flow in arteries.

Which medical diagnostic method uses this technique?

A barium scan

B CAT scan

C PET scan

D ultrasound scan

Your answer ☐ **[1]**

2 Which sequence shows the materials arranged in the order of increasing number density of charge carriers?

increasing number density ⟶

A conductor, insulator, semiconductor

B conductor, semiconductor, insulator

C insulator, semiconductor, conductor

D semiconductor, insulator, conductor

Your answer ☐ **[1]**

3 Electromagnetic radiation is incident on a metal of work function 2.3 eV.
The maximum kinetic energy (KE) of the photoelectrons is 1.7 eV.

The frequency of this incident electromagnetic radiation is kept the same but its intensity is doubled.

What is the maximum KE of the photoelectrons now?

A 1.7 eV

B 2.9 eV

C 3.4 eV

D 4.0 eV

Your answer ☐ **[1]**

4 A student is doing an experiment on the magnetic force experienced by a current-carrying wire in a uniform magnetic field. The magnetic flux density *B* can be varied.

For a particular flux density, the current in the wire is 2.0 A. The length of the wire in the field is 0.12 m. The angle between the current and the magnetic field is 30°. The force experienced by the wire is 7.7×10^{-2} N.

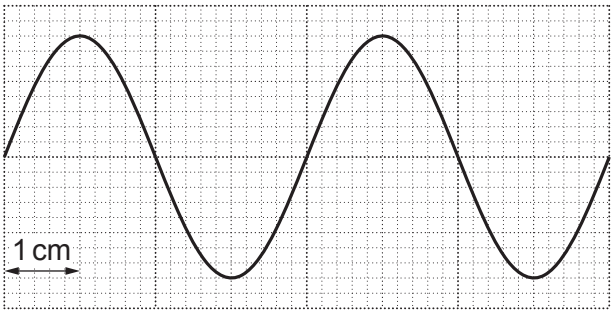
The student calculates *B* and records the results in a table.

Which row shows the correct table heading for *B* and the correct value for *B*?

	Table heading for *B*	**Value for *B***
A	*B*/T	0.37
B	*B*/T	0.64
C	*B*/Wb	0.37
D	*B*/Wb	0.64

Your answer ☐ **[1]**

5 The diagram below shows the oscilloscope trace for an electrical signal.



The time-base setting of the oscilloscope is $2\,\mu s\,cm^{-1}$.

What is the frequency of the signal?

A 125 Hz

B 250 Hz

C 125 kHz

D 250 kHz

Your answer ☐ **[1]**

6 This question is about a progressive wave and a stationary wave.

Which statement is correct?

A A progressive wave has at least one node.

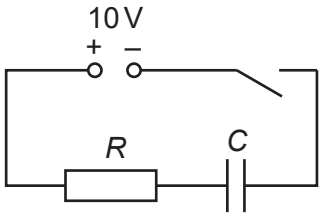
B All progressive waves are longitudinal.

C All particles oscillating between two adjacent nodes in a stationary wave are in phase.

D The superposition of two waves travelling in the same direction produces a stationary wave.

Your answer ☐ **[1]**

7 The diagram below shows a circuit used to charge a capacitor.



The power supply has electromotive force (e.m.f.) 10 V and negligible internal resistance.
The capacitor has capacitance C and the resistor has resistance R.
The switch is closed at time $t = 0$.
The table below shows potential difference V across the resistor at various values of time t.

V/V	10	6.3	5.0	3.7
t/s	0	2.8	4.2	6.0

What is the product $C \times R$ for this circuit?

A 0 s

B 2.8 s

C 4.2 s

D 6.0 s

Your answer ☐ **[1]**

8 A capacitor discharges through a resistor.
At time $t = 0$ the potential difference V across the capacitor is V_0.
At time $t = 2.0$ s, $V = 0.90\,V_0$.

Which statement is **not** correct?

A At $t = 4.0$ s, $V = 0.81\,V_0$.

B The capacitor is fully discharged after $t = 10$ s.

C The potential difference across the resistor is the same as that for the capacitor.

D The potential difference V decreases exponentially with time t.

Your answer ☐ **[1]**

9 A student is modelling the decay of a radioactive source using the equation $\Delta N / \Delta t = -0.5N$.
The student decides to use $\Delta t = 0.10\,\text{s}$.
The number N of radioactive nuclei is 2000 at $t = 0$.

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

t / s	Number N of radioactive nuclei remaining at time t	Number of nuclei decaying in the next 0.10 s
0	2000	100
0.10	1900	
0.20		
0.30		

What is the value of N at $t = 0.30\,\text{s}$?

A 1700

B 1710

C 1715

D 1805

Your answer ☐ **[1]**

10 The total energy released in a single fusion reaction is 4.0 MeV.

What is the change in mass in this fusion reaction?

A $7.1 \times 10^{-36}\,\text{kg}$

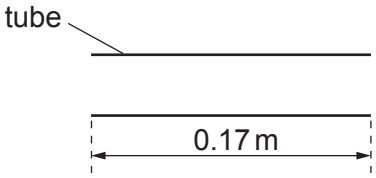
B $7.1 \times 10^{-30}\,\text{kg}$

C $2.1 \times 10^{-21}\,\text{kg}$

D $4.4 \times 10^{-17}\,\text{kg}$

Your answer ☐ **[1]**

11 A stationary sound wave, in its fundamental mode of vibration, is formed in a tube open at both ends.



The length of the tube is 0.17 m. The speed of sound in air is 340 m s^{-1}.

Which row for this stationary wave is correct?

	Number of nodes	Frequency of stationary wave / Hz
A	1	500
B	1	1000
C	2	1000
D	2	2000

Your answer ☐ **[1]**

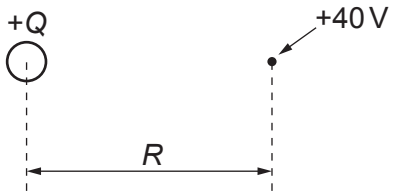
12 The table below shows the quark compositions of four particles **A**, **B**, **C** and **D**.

A	B	C	D
u u d	u d d	u d s	s s s

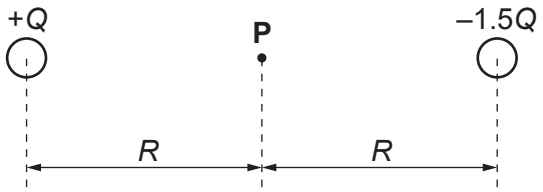
Which particle has a positive charge?

Your answer ☐ **[1]**

13 The electric potential at a distance R from the centre of a charge $+Q$ is + 40 V.



What is the potential at the point **P** for the arrangement of the charges $+Q$ and $-1.5Q$ as shown below?



A − 20 V

B − 60 V

C + 80 V

D + 100 V

Your answer ☐ **[1]**

14 The potential difference across a lamp is 2.5 V. The current in the lamp is 20 mA.

What is the energy dissipated in the lamp in 3.0 hours?

A 0.050 J

B 0.15 J

C 9.0 J

D 540 J

Your answer ☐ **[1]**

15 What can be deduced from the diffraction of electrons by a thin film of graphite?

A Electrons are leptons.

B Electrons are negatively charged.

C Electrons interact with atoms on a one-to-one basis.

D Electrons travel as waves.

Your answer [ ] **[1]**

SECTION B

Answer **all** the questions.

16 This question is about the medical use of ultrasound.

(a) In ultrasound scanning, explain what is meant by **impedance (acoustic) matching** and how it may be achieved.

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

(b) There are several different types of ultrasound scanning techniques.

Explain how an A-scan could be used to measure the thickness of a patient's eye lens. You may draw a diagram to help with your answer.

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

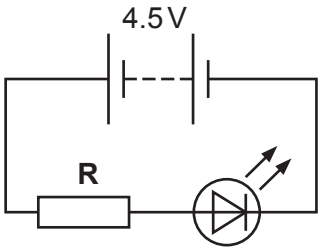
17 A light-emitting diode (LED) emits red light when it is positively biased and has a potential difference (p.d.) greater than about 1.8 V.

(a) The energy of a photon of red light is about 1.8 eV.

Calculate the wavelength λ of this red light.

λ = ... m **[3]**

(b) The LED is connected into a circuit, as shown below.

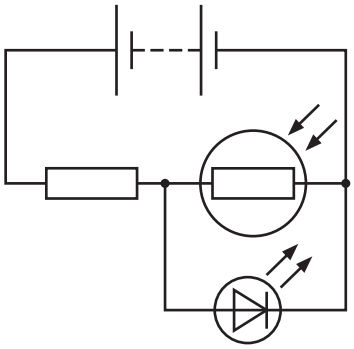


The battery has electromotive force (e.m.f.) 4.5 V and negligible internal resistance.
The resistor **R** has resistance 150 Ω.
Assume the p.d. across the LED is 1.8 V.

Calculate the ratio $\frac{\text{power dissipated by LED}}{\text{power dissipated by resistor}}$.

ratio = ... **[2]**

(c) The diagram below shows a circuit designed by a student.



The LED is very close to, and facing the light dependent resistor (LDR).
The circuit is taken into a dark room.

(i) The student thought that the LED would switch on.
Instead, the LED was found to repeatedly switch on and off.

Explain this behaviour of the LED in this potential divider circuit.

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(ii) Suggest a possible refinement so that the LED switches on permanently when taken into the dark room.

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18* A resistance wire is coiled around a thermistor. The coil of wire will warm the thermistor.

It is suggested that the relationship between the power P dissipated in the coiled wire and the stable resistance R of the thermistor is given by the expression $P = kR^n$, where k and n are constants.

Describe how an experiment can be conducted to assess the validity of this expression and how the data collected can be analysed to determine k and n.

Use the space below for a circuit diagram. **[6]**

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Additional answer space if required

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19 **(a)** The Planck constant h is an important fundamental constant in quantum physics.

Determine the S.I. base units for h.

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

(b) A researcher is investigating the de Broglie wavelength of charged particles.

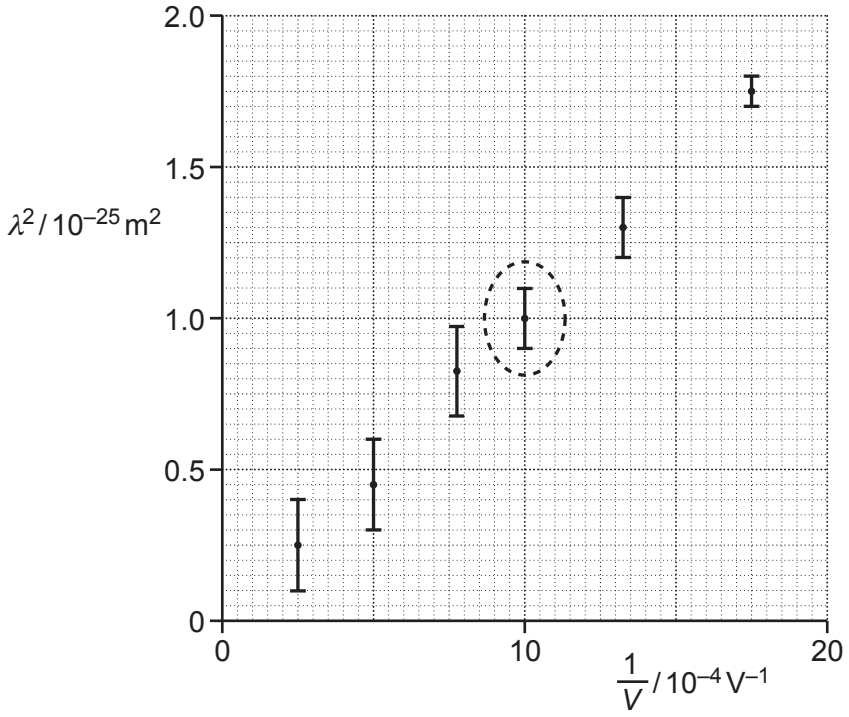
The charged particles are accelerated through a potential difference V. The de Broglie wavelength λ of these particles is then determined by the researcher.

Each particle has mass m and charge q.

(i) Show that the de Broglie wavelength λ is given by the expression $\lambda^2 = \frac{h^2}{2mq} \times \frac{1}{V}$.

[2]

(ii) The researcher plots data points on a λ^2 against $\frac{1}{V}$ grid, as shown below.



1 Calculate the percentage uncertainty in λ for the data point circled on the grid.

percentage uncertainty = ... % **[2]**

2 Draw a straight line of best fit through the data points. **[1]**

3 The charge q on the particle is $2e$, where e is the elementary charge.

Use your best fit straight line to show that the mass m of the particle is about 10^{-26} kg.

[4]

20 **(a)** A sound wave is incident at the ear.

The amplitude of the sound wave is 7.8 nm. The intensity of the sound at the earhole is $4.8 \times 10^{-7}\,W\,m^{-2}$.

(i) Determine the power of the sound incident at the earhole by estimating the diameter of the earhole in mm.

diameter of earhole ≈ ..... mm

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

(ii) A different sound wave is now incident at the ear.
The intensity of this wave is $9.6 \times 10^{-7}\,W\,m^{-2}$.

Calculate the amplitude A in nm of this sound wave.

A = ... nm **[2]**

(b) State the **principle of superposition**.

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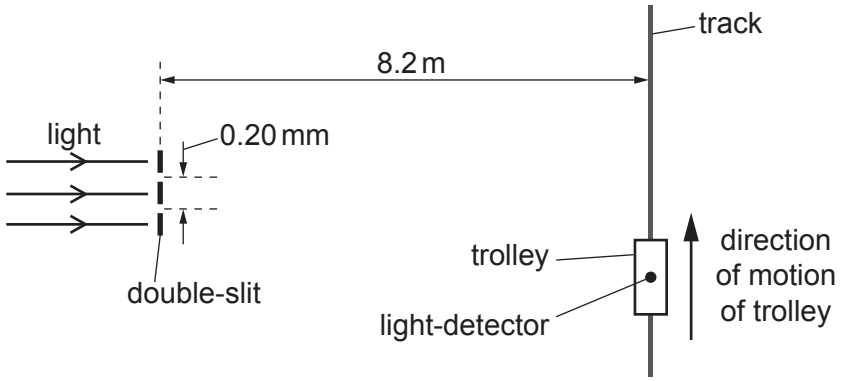
..... **[1]**

(c) The diagram below shows monochromatic light from a laser incident normally at a double-slit.



The diagram is **not** drawn to scale.

A small light-detector is mounted onto a trolley on a frictionless track. The trolley travels along the track at a constant speed.

The separation between the slits is 0.20 mm. The perpendicular distance between the slits and the track is 8.2 m.

A series of bright and dark fringes are detected at the moving light-detector.

(i) Explain, in terms of phase difference, the origin of the fringes.

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

(ii) The speed of the trolley is $0.18\,m\,s^{-1}$ and the frequency of the light is 4.75×10^{14} Hz.

Calculate the time interval t between successive bright fringes.
Write your answer to 2 significant figures.

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

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21 **(a)** In the 1800s, the atom was considered to be a fundamental particle. It was an indivisible particle of matter. Modern physics shows that this idea is not correct.

Describe the fundamental particles within an atom of carbon-14 ($^{14}_{6}C$).
In your answer state the composition of the hadrons.

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

(b) The half-life of the isotope carbon-14 is 5700 years (y).

(i) Show that the decay constant λ for this isotope is about $1.2 \times 10^{-4}\,y^{-1}$.

[1]

(ii) Carbon-dating is a technique used to date an ancient wooden axe.
The ratio of carbon-14 to carbon-12 in the axe material is 78% of the current ratio of carbon-14 to carbon-12 in a living tree.

Calculate the age in years of the wooden axe.

age = ... y **[3]**

(iii) State **one** assumption made in the calculation in **(ii)**.

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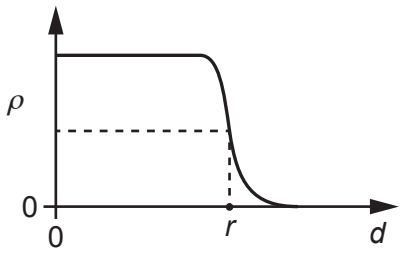
..... **[1]**

(c)* A graph of the density ρ of a nucleus against distance d from the centre of the nucleus is shown below.



The radius of the nucleus r is taken as the distance d where the density is half the maximum density.

Fig. 21.1 shows the density ρ variation for three different nuclei and **Table 21.1** shows the nucleon number A of each nucleus.

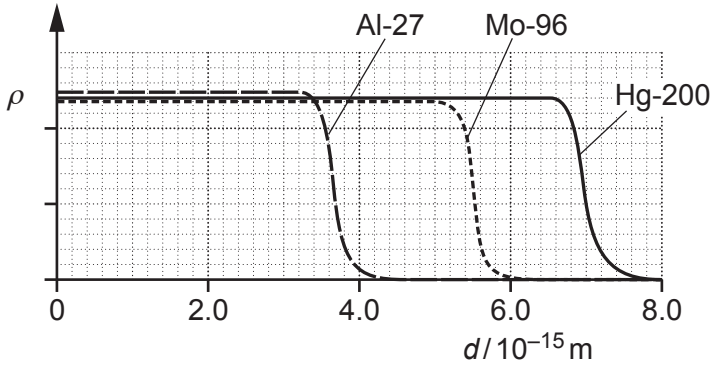


Fig. 21.1

Nucleus	**Nucleon number *A***
Al-27	27
Mo-96	96
Hg-200	200

Table 21.1

Use the information provided opposite to

- describe how the density of a nucleus depends on its nucleon number A
- show numerically that $r \propto A^{1/3}$
- estimate the mean density of the nuclei. **[6]**

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Additional answer space if required

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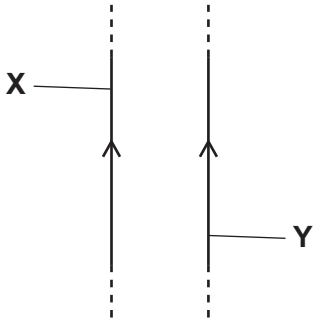
22 **(a)** The diagram below shows two long vertical current-carrying wires **X** and **Y**.



The direction of the current in each wire is the same.

Explain why wire **Y** experiences a force and deduce the direction of this force.

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

(b) (i) State **Faraday's law of electromagnetic induction**.

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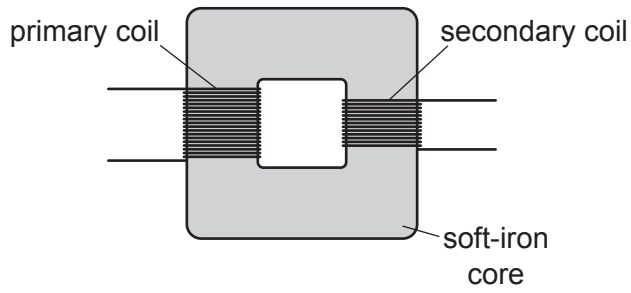
..... **[1]**

(ii) The diagram below shows a simple transformer constructed by a student.



Describe how the student can do an experiment in the laboratory to show that the maximum electromotive force (e.m.f.) E induced in the secondary coil is directly proportional to the number of turns N on the secondary coil.

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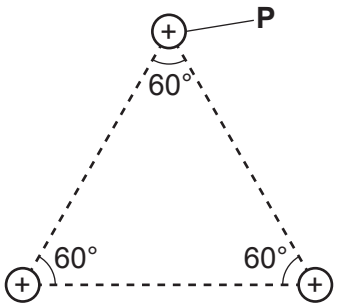
..... **[3]**

23 **(a)** The diagram below shows the arrangement of the 3 protons inside the nucleus of lithium-6 ($^{6}_{3}$Li).



The separation between each proton is about 1.0×10^{-15} m.

(i) Calculate the magnitude of the repulsive electric force F experienced by the proton **P**.

F = ... N **[4]**

(ii) On the diagram above, draw an arrow to show the direction of the electric force F experienced by **P**. **[1]**

(iii) Explain how protons stay within the nucleus of lithium-6.

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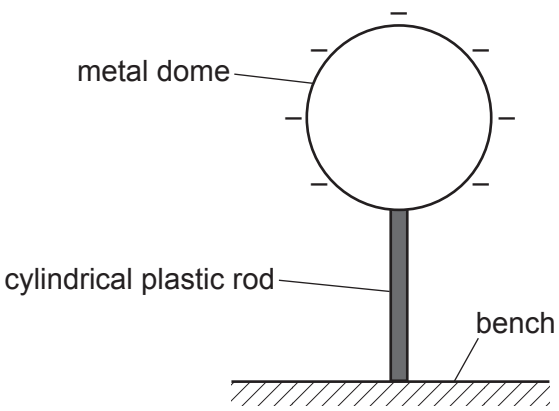
..... **[2]**

(b) A spherical metal dome shown below is charged to a potential of −12 kV.



The dome is supported by a cylindrical plastic rod. The radius of the dome is 0.19 m.

(i) Show that the magnitude of the total charge Q on the dome is 2.5×10^{-7} C.

[2]

(ii) The dome discharges slowly through the plastic rod.
It takes 78 hours for the dome to completely discharge.

1 Show that the mean current I in the plastic rod is about 9×10^{-13} A.

[2]

2 The average potential difference across the plastic rod during discharge is 6000 V.
The rod has cross-sectional area 1.1×10^{-4} m^2 and length 0.38 m.

Calculate the resistivity ρ of the plastic.

ρ = ... Ω m **[3]**

24 The medical tracer technetium-99m is used in imaging organs such as the brain.

(a) Explain the advantages of using technetium-99m for this purpose.

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(b) A gamma-camera uses powerful computers and sophisticated software to produce three-dimensional images of the patient's organ.

Name and describe the remaining three main components of the gamma camera.

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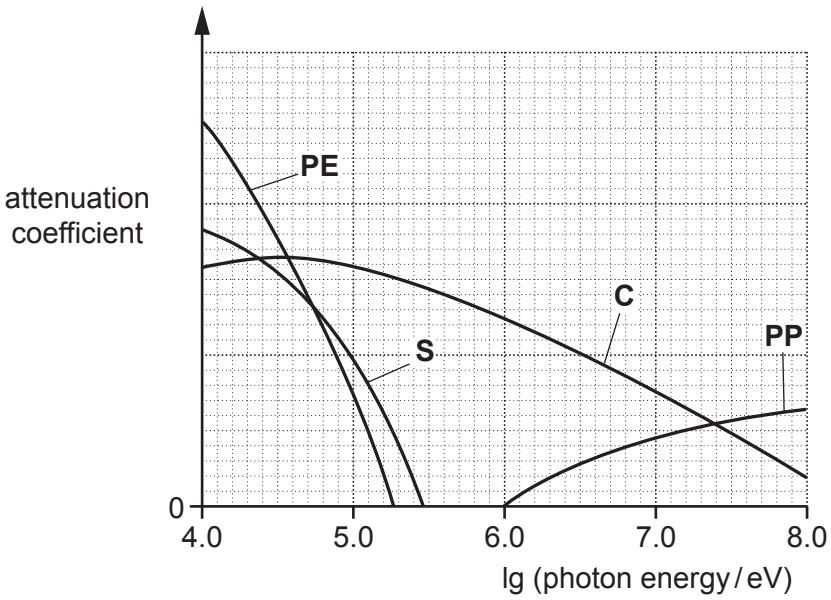
..... **[3]**

25 X-ray photons interact with atoms.

The attenuation coefficient against lg(photon energy) graphs for simple scattering (**S**), photoelectric effect (**PE**), Compton effect (**C**) and pair production (**PP**) are shown below.



(a) For the X-ray tubes used in hospital, the X-ray photons have energy of about 10^5 eV.

State the attenuation mechanisms for these photons.

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

(b) With the help of a calculation, explain the minimum photon energy shown on the graph for pair production.

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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).