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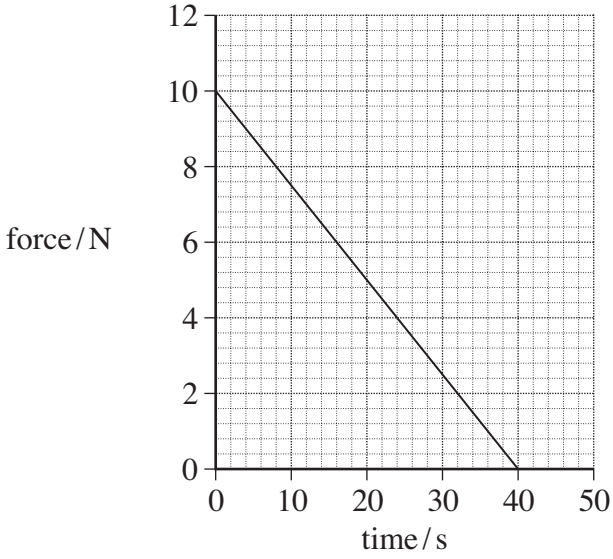
Multiple choice questions

Each of Questions **1** to **25** is followed by four responses, **A**, **B**, **C**, and **D**. For each question select the best response and mark its letter on the answer sheet.

You are advised to spend approximately **45 minutes** on this section.

1 The graph shows how the force acting on a body changes with time.



The body has a mass of 0.25 kg and is initially at rest. What is the speed of the body after 40 s assuming no other forces are acting?

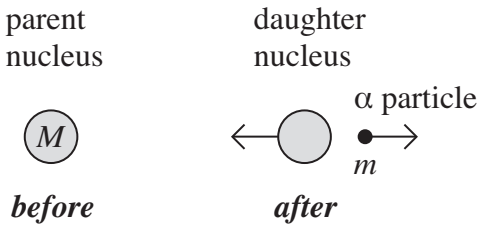
A $200\,\text{m s}^{-1}$

B $400\,\text{m s}^{-1}$

C $800\,\text{m s}^{-1}$

D $1600\,\text{m s}^{-1}$

2 A stationary unstable nucleus of mass M emits an α particle of mass m with kinetic energy E.



What is the speed of recoil of the daughter nucleus?

A $\dfrac{\sqrt{2mE}}{(M-m)}$

B $\dfrac{\sqrt{2mE}}{M}$

C $\dfrac{(M-m)}{\sqrt{2mE}}$

D $\dfrac{2mE}{(M-m)^2}$

3 Two ice skaters, initially at rest and in contact, push apart from each other.
Which line, **A** to **D**, in the table states correctly the change in the total momentum and the total kinetic energy of the two skaters?

	total momentum	**total kinetic energy**
A	unchanged	increases
B	unchanged	unchanged
C	increases	increases
D	increases	unchanged

4 The Earth moves around the Sun in a circular orbit with a radius of 1.5×10^8 km.
What is the Earth's approximate speed?

A $1.5 \times 10^3\,\text{m s}^{-1}$

B $5.0 \times 10^3\,\text{m s}^{-1}$

C $1.0 \times 10^4\,\text{m s}^{-1}$

D $3.0 \times 10^4\,\text{m s}^{-1}$

5 A particle moves in a circular path at constant speed. Which one of the following statements is correct?

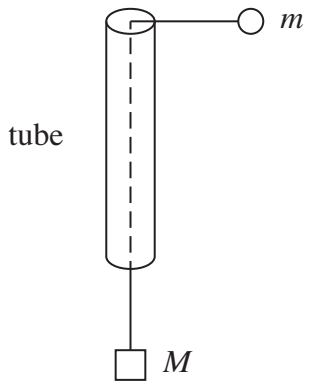
A The velocity of the particle is directed towards the centre of the circle.

B There is no force acting on the particle.

C There is no change in the kinetic energy of the particle.

D The particle has an acceleration directed along a tangent to the circle.

6 The diagram shows a smooth thin tube through which passes a string with masses m and M attached to its ends. The tube is moved so that the mass m travels in a horizontal circle of constant radius r at constant speed v.



Which one of the following expressions is equal to M?

A $\frac{mv^2}{2r}$

B mv^2rg

C $\frac{mv^2}{rg}$

D $\frac{mv^2g}{r}$

7 A mass on the end of a spring undergoes vertical simple harmonic motion. At which point(s) is the magnitude of the resultant force on the mass a minimum?

A at the centre of the oscillation
B only at the top of the oscillation
C only at the bottom of the oscillation
D at both the top and bottom of the oscillation

8 A baby bouncer consisting of a harness and elastic ropes is suspended from a doorway. When a baby of mass 10 kg is placed in the harness, the ropes stretch by 0.25 m. When the baby bounces, she starts to move with vertical simple harmonic motion. What is the time period of her motion?

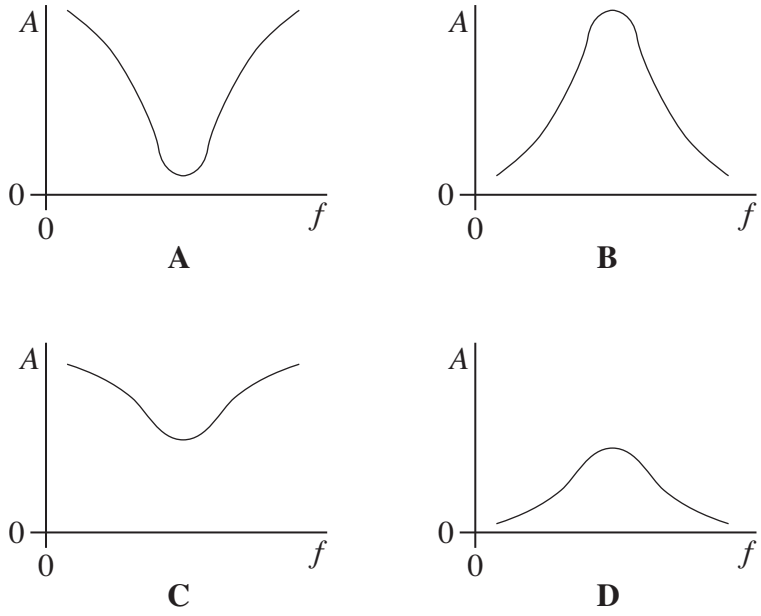
A 1.0 s
B 2.1 s
C 2.3 s
D 3.1 s

9 A simple pendulum and a mass-spring system both have the same time period T at the surface of the Earth. If taken to another planet where the acceleration due to gravity is twice that on Earth, which line, **A** to **D**, in the table gives the correct new time periods?

	simple pendulum	**mass-spring**
A	$T\sqrt{2}$	$\frac{T}{\sqrt{2}}$
B	$T\sqrt{2}$	T
C	$\frac{T}{\sqrt{2}}$	T
D	$\frac{T}{\sqrt{2}}$	$T\sqrt{2}$

10 An oscillatory system, subject to damping, is set into vibration by a periodic driving force of frequency f. The graphs, **A** to **D**, which are to the same scale, show how the amplitude of vibration A of the system might vary with f, for various degrees of damping.

Which graph best shows the lightest damping?



11 Which one of the following statements about gravitational fields is **incorrect**?

A Moving a mass in the direction of the field lines reduces its potential energy.

B A stronger field is represented by a greater density of field lines.

C Moving a mass perpendicularly across the field lines does not alter its potential energy.

D At a distance r from a mass the field strength is inversely proportional to r.

12 An object on the surface of a planet of radius R and mass M has weight W. What would be the weight of the same object when on the surface of a planet of radius $2R$ and mass $2M$?

A $\frac{W}{4}$

B $\frac{W}{2}$

C W

D $2W$

13 The gravitational field strength on the surface of a planet orbiting a star is $8.0\,\text{N kg}^{-1}$. If the planet and star have a similar density but the diameter of the star is 100 times greater than the planet, what would be the gravitational field strength at the surface of the star?

A $0.0008\,\text{N kg}^{-1}$

B $0.08\,\text{N kg}^{-1}$

C $800\,\text{N kg}^{-1}$

D $8000\,\text{N kg}^{-1}$

14 Two satellites, P and Q, of the same mass, are in circular orbits around the Earth. The radius of the orbit of Q is three times that of P. Which one of the following statements is correct?

A The kinetic energy of P is greater than that of Q.

B The weight of P is three times that of Q.

C The time period of P is greater than that of Q.

D The speed of P is three times that of Q.

15 The force between two point charges is F when they are separated by a distance r. If the separation is increased to $3r$, what is the force between the charges?

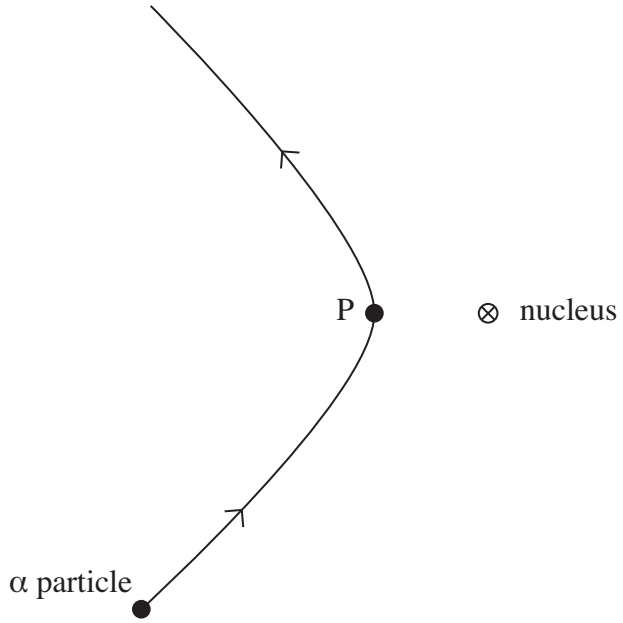
A $\frac{F}{3r}$

B $\frac{F}{9r}$

C $\frac{F}{3}$

D $\frac{F}{9}$

16 The diagram shows the path of an α particle deflected by the nucleus of an atom. Point P on the path is the point of closest approach of the α particle to the nucleus.



Which one of the following statements about the α particle on this path is correct?

A Its acceleration is zero at P.

B Its kinetic energy is greatest at P.

C Its speed is least at P.

D Its potential energy is least at P.

17 A 1000 μF capacitor and a 10 μF capacitor are charged so that they store the same energy. The pd across the 1000 μF capacitor is V_1 and the pd across the other capacitor is V_2.

What is the value of the ratio $\left(\frac{V_1}{V_2}\right)^2$?

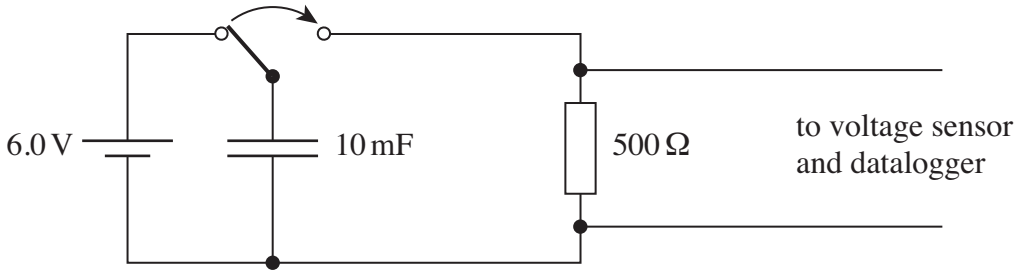
A $\frac{1}{1000}$

B $\frac{1}{100}$

C $\frac{1}{10}$

D 10

18 A voltage sensor and a datalogger are used to record the discharge of a 10 mF capacitor in series with a 500 Ω resistor from an initial pd of 6.0 V. The datalogger is capable of recording 1000 readings in 10 s. Which line, **A** to **D**, in the table gives the pd and the number of readings made after a time equal to the time constant of the discharge circuit?



	potential difference/V	number of readings
A	2.2	50
B	3.8	50
C	3.8	500
D	2.2	500

19 When a 220 μF capacitor is discharged through a resistor R, the capacitor pd decreases from 6.0 V to 1.5 V in 92 s.

What is the resistance of R?

A 210 kΩ

B 300 kΩ

C 420 kΩ

D 440 kΩ

20 A section of current-carrying wire is placed at right angles to a uniform magnetic field of flux density B. When the current in the wire is I, the magnetic force that acts on this section is F.

What force acts when the same section of wire is placed at right angles to a uniform magnetic field of flux density $2B$ when the current is $0.25I$?

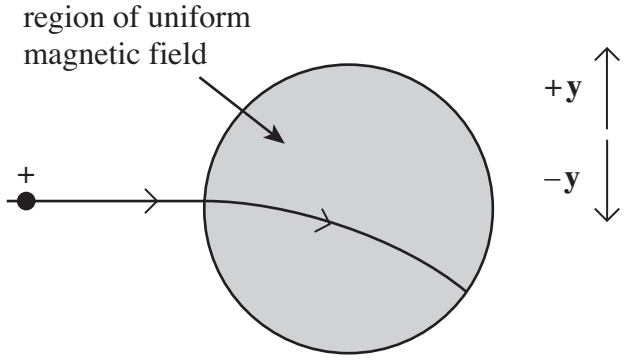
A $\frac{F}{4}$

B $\frac{F}{2}$

C F

D $2F$

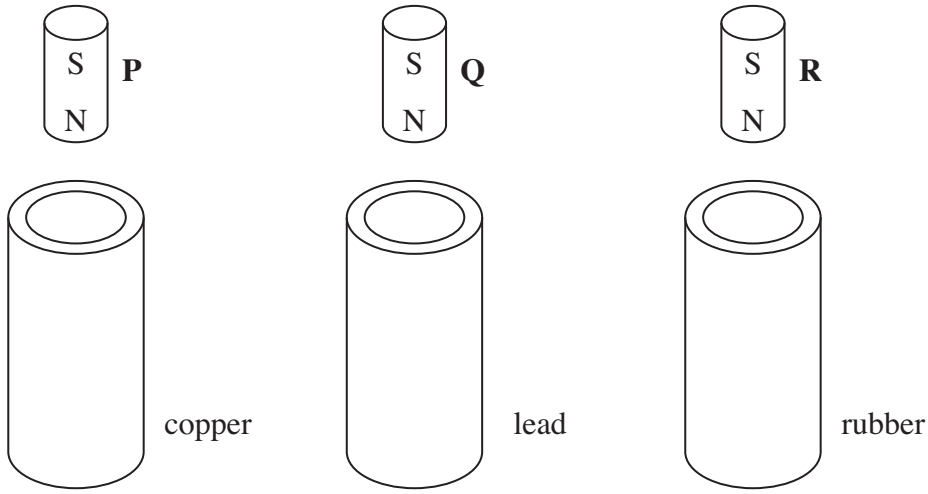
21 A beam of positive ions enters a region of uniform magnetic field, causing the beam to change direction as shown in the diagram.



What is the direction of the magnetic field?

A out of the page and perpendicular to it
B into the page and perpendicular to it
C in the direction indicated by **+y**
D in the direction indicated by **–y**

22 Three vertical tubes, made from copper, lead and rubber respectively, have identical dimensions. Identical, strong, cylindrical magnets **P**, **Q** and **R** are released simultaneously from the same distance above each tube. Because of electromagnetic effects, the magnets emerge from the bottom of the tubes at different times.

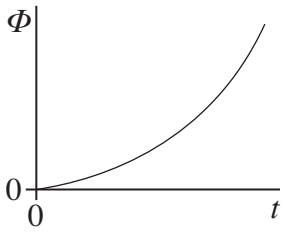


Which line, **A** to **D**, in the table shows the correct order in which they will emerge?

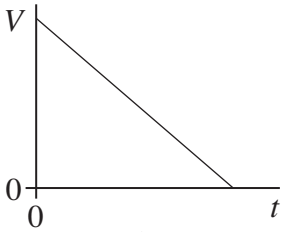
resistivity of copper = $1.7 \times 10^{-8} \Omega m$
resistivity of lead = $22 \times 10^{-8} \Omega m$
resistivity of rubber = $50 \times 10^{13} \Omega m$

	emerges first	**emerges second**	**emerges third**
A	**P**	**Q**	**R**
B	**R**	**P**	**Q**
C	**P**	**R**	**Q**
D	**R**	**Q**	**P**

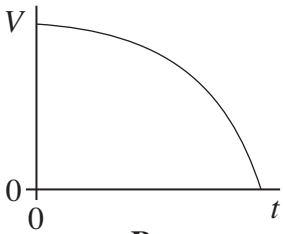
23 The graph shows how the magnetic flux, Φ, passing through a coil changes with time, t.



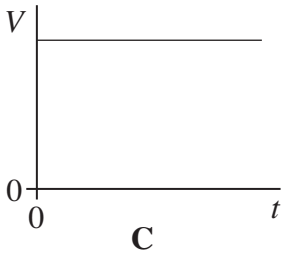
Which one of the following graphs could show how the magnitude of the emf, V, induced in the coil varies with t?



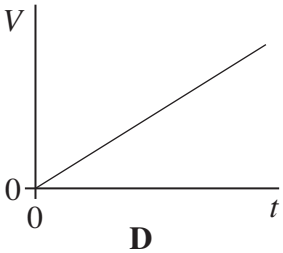
A



B

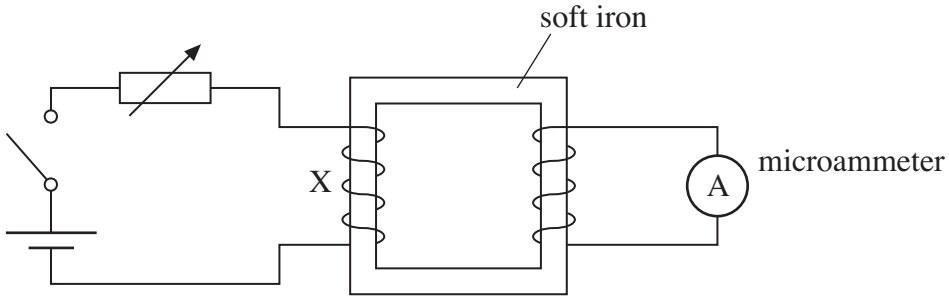


C



D

24 Using the circuit shown, and with the switch closed, a small current was passed through the coil X. The current was slowly increased using the variable resistor. The current reached a maximum value and was then switched off.



The maximum reading on the microammeter occurred when

A the small current flowed at the start.
B the current was being increased.
C the current was being switched off.
D the current in X was zero.

25 When a mobile phone is being recharged, the charger heats up. The efficiency of the transformer in the charger can be as low as 15% when drawing a current of 50 mA from a 230 V mains supply. If the charging current required is 350 mA, what is the approximate output voltage at this efficiency?

A 4.9 V
B 11 V
C 28 V
D 33 V

END OF QUESTIONS

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Answer **all** questions.
You are advised to spend approximately **one hour** on this section.

1 (a) State, in words, the relationship between the force acting on a body and the momentum of the body.

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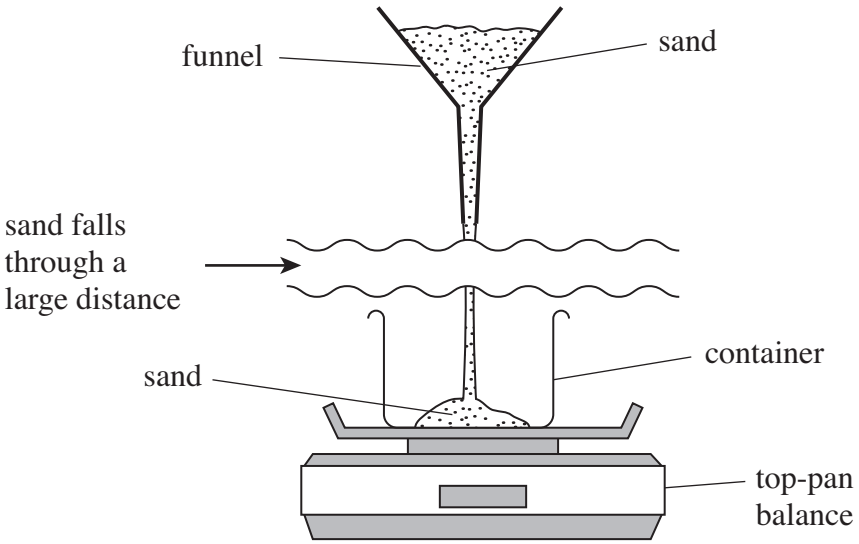
(1 mark)

1 (b) A container rests on a top-pan balance, which measures mass in kg. A funnel above the container holds some sand. The sand falls at a constant rate of $0.300\,\text{kg}\,\text{s}^{-1}$ into the container, having fallen through an average vertical height of 1.60 m.
This arrangement is shown in **Figure 1**.

Figure 1



1 (b) (i) Show that the velocity of the sand as it lands in the container is $5.6\,\text{m}\,\text{s}^{-1}$.

(1 mark)

1 (b) (ii) Calculate the magnitude of the momentum of the sand that lands in the container in each second.

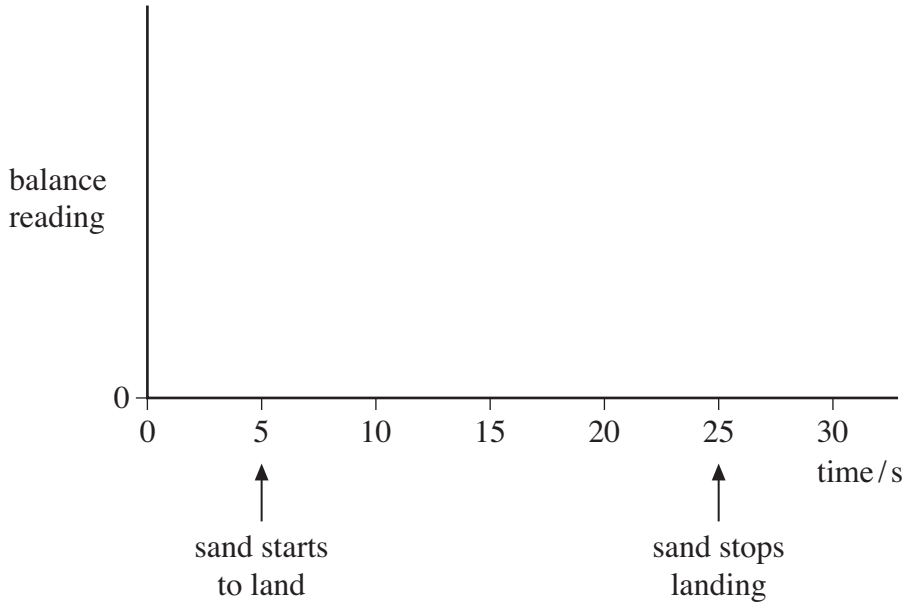
answer = ... N s
(1 mark)

Do not write outside the box

1 (b) (iii) The mass of the container is 0.650 kg. Show that the reading of the balance, 10.0 s after the sand starts landing continuously in the container, will be 3.82 kg. You may assume that the sand comes to rest without rebounding when it lands in the container.

(3 marks)

1 (c) It takes 20.0 s for all of the sand to fall into the container.
On the axes below, sketch a graph to show how the reading of the balance will change over a 30.0 s period, where t = 5.0 s is the time at which the sand starts to land in the container. No further calculations are required and values need not be shown on the vertical axis of the graph.

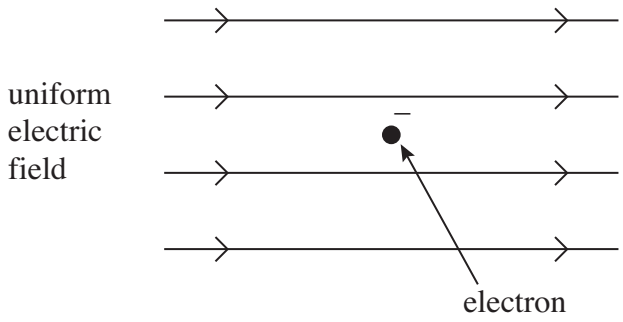


(3 marks)

9

2 (a) **Figure 2** shows an electron at a point in a uniform electric field at an instant when it is stationary.

Figure 2



2 (a) (i) Draw an arrow on **Figure 2** to show the direction of the electrostatic force that acts on the stationary electron.

(1 mark)

2 (a) (ii) State and explain what, if anything, will happen to the magnitude of the electrostatic force acting on the electron as it starts to move in this field.

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(2 marks)

2 (b) **Figure 3a** shows a stationary electron in a non-uniform electric field. **Figure 3b** shows a stationary proton, placed in exactly the same position in the same electric field as the electron in **Figure 3a**.

Figure 3a

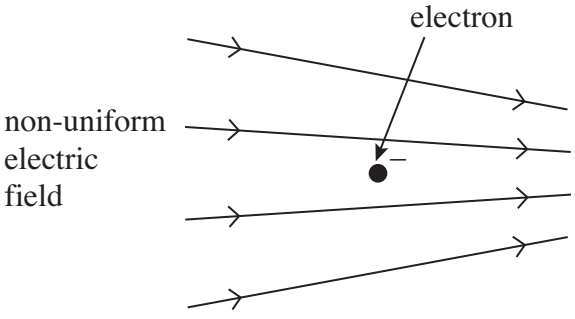
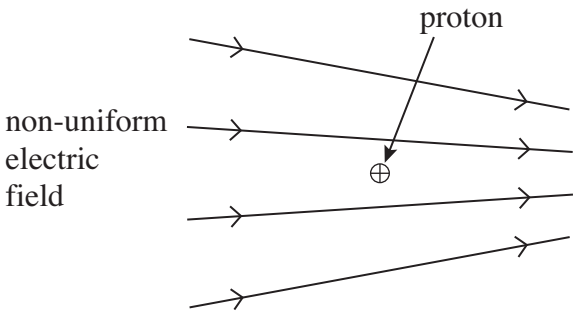


Figure 3b



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2 (b) (i) State and explain how the electrostatic force on the proton in **Figure 3b** compares with that on the electron in **Figure 3a**.

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(2 marks)

2 (b) (ii) Each of the particles starts to move from the positions shown in **Figure 3a** and **Figure 3b**. State and explain how the magnitude of the **initial** acceleration of the proton compares with that of the electron.

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(2 marks)

2 (b) (iii) Describe and explain what will happen to the acceleration of each of these particles as they continue to move in the electric field.

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(2 marks)

Do not write outside the box

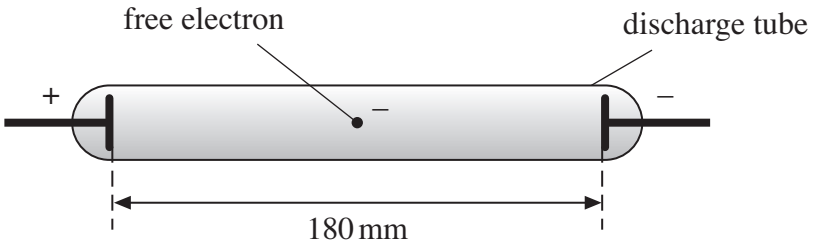
2 (c) The line spectrum of neon gas contains a prominent red line of wavelength 650 nm.

2 (c) (i) Show that the energy required to excite neon atoms so that they emit light of this wavelength is about 2 eV.

(3 marks)

2 (c) (ii) An illuminated shop sign includes a neon discharge tube, as shown in **Figure 4**.
A pd of 4500 V is applied across the electrodes, which are 180 mm apart.

Figure 4



Assuming that the electric field inside the tube is uniform, calculate the minimum distance that a free electron would have to move from rest in order to excite the red spectral line in part (c).

answer = ... m

(3 marks)

15

3 The Large Hadron Collider (LHC) uses magnetic fields to confine fast-moving charged particles travelling repeatedly around a circular path. The LHC is installed in an underground circular tunnel of circumference 27 km.

3 (a) In the presence of a suitably directed uniform magnetic field, charged particles move at constant speed in a circular path of constant radius. By reference to the force acting on the particles, explain how this is achieved and why it happens.

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(4 marks)

3 (b) (i) The charged particles travelling around the LHC may be protons. Calculate the centripetal force acting on a proton when travelling in a circular path of circumference 27 km at one-tenth of the speed of light. Ignore relativistic effects.

answer = ... N

(3 marks)

3 (b) (ii) Calculate the flux density of the uniform magnetic field that would be required to produce this force. State an appropriate unit.

answer = ... unit .....

(3 marks)

3 (c) The speed of the protons gradually increases as their energy is increased by the LHC. State and explain how the magnetic field in the LHC must change as the speed of the protons is increased.

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(2 marks)

12

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4 (a) Define the gravitational potential at a point in a gravitational field.

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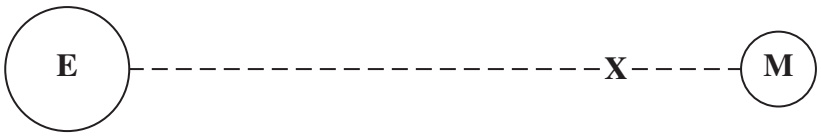
(2 marks)

4 (b) **Figure 5**, which is not drawn to scale, shows the region between the Earth (**E**) and the Moon (**M**).

Figure 5



4 (b) (i) The gravitational potential at the Earth's surface is $-62.6\,\text{MJ kg}^{-1}$. Point **X** shown in **Figure 5** is on the line of centres between the Earth and the Moon At **X** the resultant gravitational field is zero, and the gravitational potential is $-1.3\,\text{MJ kg}^{-1}$.

Calculate the minimum amount of energy that would be required to move a Moon probe of mass $1.2 \times 10^4\,\text{kg}$ from the surface of the Earth to point **X**. Express your answer to an appropriate number of significant figures.

answer = ... J

(3 marks)

4 (b) (ii) Explain why, once the probe is beyond **X**, no further energy would have to be supplied in order for it to reach the surface of the Moon.

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(1 mark)

Turn over ▶

4 (b) (iii) In the vicinity of the Earth's orbit the gravitational potential due to the Sun's mass is $-885\,\text{MJ}\,\text{kg}^{-1}$. With reference to the variation in gravitational potential with distance, explain why the gravitational potential due to the Sun's mass need not be considered when carrying out the calculation in part (b)(i).

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(2 marks)

4 (c) The amount of energy required to move a manned spacecraft from the Earth to the Moon is much greater than that required to return it to the Earth. By reference to the forces involved, to gravitational field strength and gravitational potential, and to the point **X**, explain why this is so.

The quality of your written communication will be assessed in your answer.

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(6 marks)

END OF QUESTIONS

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Answer **all** questions in the spaces provided.

1 (a) The K^- meson has strangeness –1.

1 (a) (i) State the quark composition of a meson.

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(1 mark)

1 (a) (ii) State the baryon number of the K^- meson.

.....

(1 mark)

1 (a) (iii) What is the quark composition of the K^- meson?

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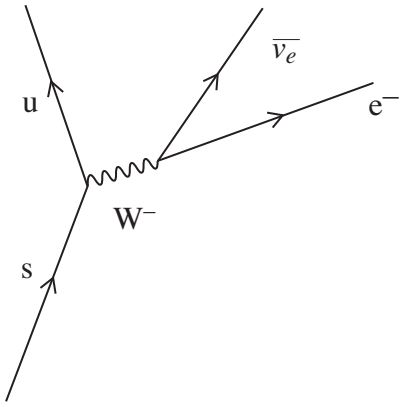
(1 mark)

1 (b) **Figure 1** shows a Feynman diagram for a possible decay of the strange quark.

Figure 1



1 (b) (i) Which interaction is responsible for this decay?

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(1 mark)

1 (b) (ii) Energy and momentum are conserved when the W^- particle is produced. State **two** other quantities that are also conserved and **one** that is not.

conserved .....

conserved .....

not conserved .....

(3 marks)

1 (b) (iii) Complete this equation for the decay of a K^- meson.

$K^- \rightarrow$ ..... + ... + ...

(2 marks)

9

2 (a) The nucleus of a particular atom has a *nucleon number* of 14 and a *proton number* of 6.

2 (a) (i) State what is meant by nucleon number and proton number.

nucleon number .....

.....

.....

proton number .....

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(1 mark)

2 (a) (ii) Calculate the number of neutrons in the nucleus of this atom.

answer = ...

(1 mark)

2 (a) (iii) Calculate the specific charge of the nucleus.

answer = ... $C\,kg^{-1}$

(3 marks)

Question 2 continues on the next page

Do not write outside the box

2 (b) The specific charge of the nucleus of another isotope of the element is 4.8×10^7 C kg^{-1}.

2 (b) (i) State what is meant by an isotope.

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(2 marks)

2 (b) (ii) Calculate the number of neutrons in this isotope.

answer = ...

(3 marks)

10

3 (a) Protons can interact with electrons by gravity and by two other fundamental interactions. In the following table identify these interactions and name the exchange particle involved.

interaction	exchange particle

(2 marks)

3 (b) State the quark composition of a proton.

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(1 mark)

3 (c) A change in quark identity is involved in *electron capture*.

3 (c) (i) Explain what is meant by electron capture.

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(3 marks)

3 (c) (ii) In the space below draw a Feynman diagram representing electron capture.

(3 marks)

9

Do not write outside the box

4 (a) When monochromatic light is shone on a clean cadmium surface, electrons with a range of kinetic energies up to a maximum of 3.51×10^{-20} J are released. The *work function* of cadmium is 4.07 e V.

4 (a) (i) State what is meant by work function.

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(2 marks)

4 (a) (ii) Explain why the emitted electrons have a range of kinetic energies up to a maximum value.

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(4 marks)

4 (a) (iii) Calculate the frequency of the light. Give your answer to an appropriate number of significant figures.

answer = ... Hz

(4 marks)

Do not write outside the box

4 (b) In order to explain the photoelectric effect the wave model of electromagnetic radiation was replaced by the photon model. Explain what must happen in order for an existing scientific theory to be modified or replaced with a new theory.

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(2 marks)

12

Turn over for the next question

Do not write outside the box

5 (a) An alternating current supply provides an output voltage of 12 V rms at a frequency of 50 Hz. Describe how you would use an oscilloscope to check the accuracy of the rms output voltage and the frequency of the supply.

The quality of your written communication will be assessed in your answer.

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(6 marks)

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5 (b) The power supply in part (a) is connected to a 12 V 24 W lamp.

5 (b) (i) Calculate the rms current in the lamp.

answer = ... A
(1 mark)

5 (b) (ii) Calculate the peak current in the lamp.

answer = ... A
(1 mark)

5 (b) (iii) Calculate the peak power of the lamp.

answer = ... W
(2 marks)

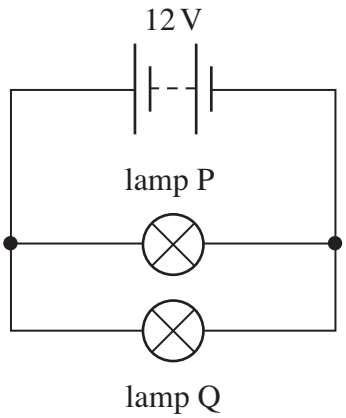
10

Turn over for the next question

Do not write outside the box

6 A battery of negligible internal resistance is connected to lamp P in parallel with lamp Q as shown in **Figure 2**. The emf of the battery is 12 V.

Figure 2



6 (a) Lamp P is rated at 12 V 36 W and lamp Q is rated at 12 V 6 W.

6 (a) (i) Calculate the current in the battery.

answer = ... A
(2 marks)

6 (a) (ii) Calculate the resistance of P.

answer = ... Ω
(1 mark)

Do not write outside the box

6 (a) (iii) Calculate the resistance of Q.

answer = ... Ω

(1 mark)

6 (b) State and explain the effect on the brightness of the lamps in the circuit shown in **Figure 2** if the battery has a significant internal resistance.

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(3 marks)

Question 6 continues on the next page

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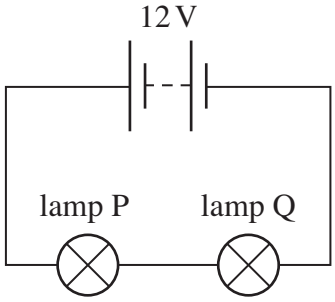
6 (c) The lamps are now reconnected to the 12 V battery in series as shown in **Figure 3**.

Figure 3



6 (c) (i) Explain why the lamps will not be at their normal brightness in this circuit.

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.....

(2 marks)

6 (c) (ii) State and explain which of the lamps will be brighter assuming that the resistance of the lamps does not change significantly with temperature.

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(3 marks)

12

Turn to page 14 for the next question

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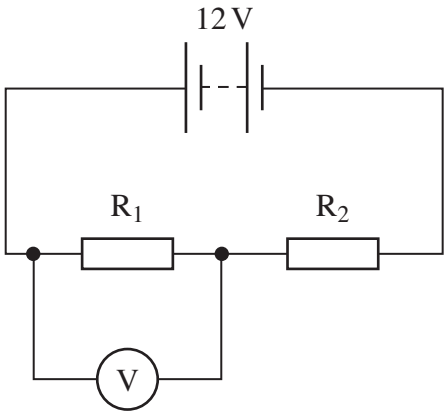
There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

Do not write outside the box

7 **Figure 4** shows two resistors, R_1 and R_2, connected in series with a battery of emf 12 V and negligible internal resistance.

Figure 4



7 (a) The reading on the voltmeter is 8.0 V and the resistance of R_2 is 60 Ω.

7 (a) (i) Calculate the current in the circuit.

answer = ... A
(2 marks)

7 (a) (ii) Calculate the resistance of R_1.

answer = ... Ω
(1 mark)

7 (a) (iii) Calculate the charge passing through the battery in 2.0 minutes. Give an appropriate unit for your answer.

answer = ... unit = ...
(2 marks)

7 (b) In the circuit shown in **Figure 4** R_2 is replaced with a thermistor. State and explain what will happen to the reading on the voltmeter as the temperature of the thermistor increases.

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(3 marks)

8

END OF QUESTIONS

SECTION A

Answer ALL questions.

For questions 1–10, in Section A, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 The nucleus of one of the isotopes of nickel is represented by $^{60}_{28}Ni$.

Which line correctly identifies a neutral atom of this isotope?

	Number of protons	Number of neutrons	Number of electrons
☒ **A**	28	32	28
☒ **B**	28	32	32
☒ **C**	28	60	28
☒ **D**	60	28	28

(Total for Question 1 = 1 mark)

2 A charged, non-magnetic particle is moving in a magnetic field.

Which of the following would **not** affect the magnetic force acting on the particle?

☒ **A** the magnitude of the charge on the particle

☒ **B** the strength of the magnetic field

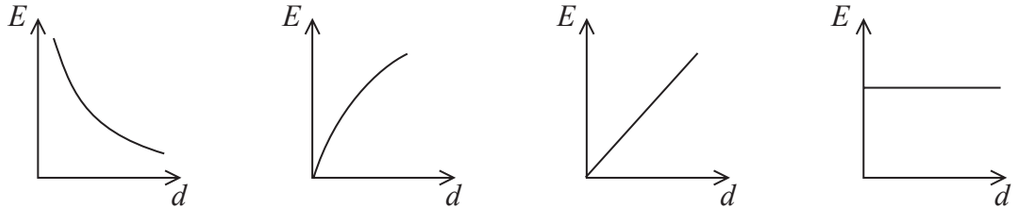
☒ **C** the velocity component parallel to the magnetic field direction

☒ **D** the velocity component perpendicular to the magnetic field direction

(Total for Question 2 = 1 mark)

3 Two parallel, conducting plates are connected to a battery. One plate is connected to the positive terminal and the other plate to the negative terminal. The plate separation d is gradually increased while the plates stay connected to the battery.

Select the graph that shows how the electric field strength E between the plates varies with separation d.



A **B** **C** **D**

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 3 = 1 mark)

4 A fairground roundabout makes 8 revolutions in 1 minute. The angular velocity of the roundabout is

☒ **A** 0.10 rad s^{-1}

☒ **B** 0.42 rad s^{-1}

☒ **C** 0.84 rad s^{-1}

☒ **D** 0.94 rad s^{-1}

(Total for Question 4 = 1 mark)

5 A correct re-statement of the equation $E_k = p^2/2m$ is

☒ **A** $\frac{1}{2}mv^2 = p^2$

☒ **B** $p^2 = m^2v^2$

☒ **C** $p^2/m = 2v^2$

☒ **D** $mv^2 = \frac{1}{2}p^2$

(Total for Question 5 = 1 mark)

Turn over ▶

6 A muon has a mass of 106 MeV/c^2.

The mass of a muon, to two significant figures, is

☒ **A** 1.7×10^{-11} kg

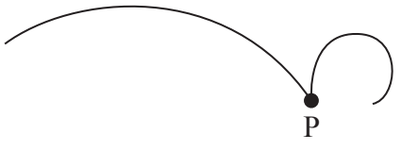
☒ **B** 5.7×10^{-20} kg

☒ **C** 1.9×10^{-28} kg

☒ **D** 1.9×10^{-34} kg

(Total for Question 6 = 1 mark)

7 The diagram shows the tracks from an event at a point P in a bubble chamber. A magnetic field is directed into the page.



The tracks cannot show the production of a proton-antiproton pair with equal kinetic energies because

☒ **A** the curvature is perpendicular to the magnetic field.

☒ **B** the tracks curve in different directions.

☒ **C** the tracks have different curvatures.

☒ **D** there is no track before point P.

(Total for Question 7 = 1 mark)

8 A racing car of mass 1200 kg travels at 0.63 rad s^{-1} around a bend of radius 50 m. The force on the car necessary for this motion is

☒ **A** 2.4×10^4 N away from the centre of the circle.

☒ **B** 2.4×10^4 N towards the centre of the circle.

☒ **C** 3.8×10^4 N away from the centre of the circle.

☒ **D** 3.8×10^4 N towards the centre of the circle.

(Total for Question 8 = 1 mark)

9 A cyclotron is a type of particle accelerator. It consists of two metal Dees which are connected to a high frequency voltage supply and are in a strong magnetic field.

The particles change their speed because

☒ **A** of the magnetic field they are in.

☒ **B** the voltage supply is alternating.

☒ **C** there is a potential difference between the two Dees.

☒ **D** the magnetic field is at right angles to the Dees.

(Total for Question 9 = 1 mark)

10 The de Broglie wavelength for neutrons used to study crystal structure is 1.2 nm.
mass of a neutron = 1.67×10^{-27} kg

The speed of these neutrons would be

☒ **A** 3.0×10^{6} m s^{-1}

☒ **B** 3.3×10^{2} m s^{-1}

☒ **C** 3.0×10^{-3} m s^{-1}

☒ **D** 3.3×10^{-7} m s^{-1}

(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

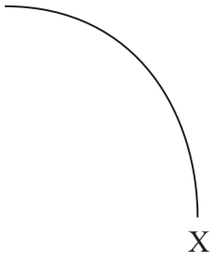
Turn over ▶

SECTION B

Answer ALL questions in the spaces provided.

11 Scientists studying anti-matter recently observed the creation of a nucleus of anti-helium 4, which consists of two anti-protons and two anti-neutrons.

The diagram represents the path of a proton through a magnetic field starting at point X.



Add to the diagram the path of an anti-helium 4 nucleus also starting at point X and initially travelling at the same velocity as the proton.

Explain any differences between the paths.

(5)

(Total for Question 11 = 5 marks)

12 The table gives some of the properties of the up, down and strange quarks.

Type of quark	Charge/*e*	Strangeness
u	+2/3	0
d	–1/3	0
s	–1/3	–1

There are nine possible ways of combining u, d and s quarks and their antiquarks to make nine different mesons. These are listed below

$u\bar{u}$ $u\bar{d}$ $u\bar{s}$ $d\bar{d}$ $d\bar{u}$ $d\bar{s}$ $s\bar{s}$ $s\bar{u}$ $s\bar{d}$

(a) From the list select the four strange mesons and state the charge and strangeness of each of them.

(4)

Meson	Charge/*e*	Strangeness

(b) Some of the mesons in the list have zero charge and zero strangeness.

Suggest what might distinguish these mesons from each other.

(1)

.....

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.....

(Total for Question 12 = 5 marks)

Turn over ▶

13 In an experiment to investigate the structure of the atom, α-particles are fired at a thin metal foil, which causes the α-particles to scatter.

(a) (i) State the direction in which the number of α-particles detected will be a maximum.

(1)

.....

(ii) State what this suggests about the structure of the atoms in the metal foil.

(1)

.....

(b) Some α-particles are scattered through 180°.

State what this suggests about the structure of the atoms in the metal foil.

(2)

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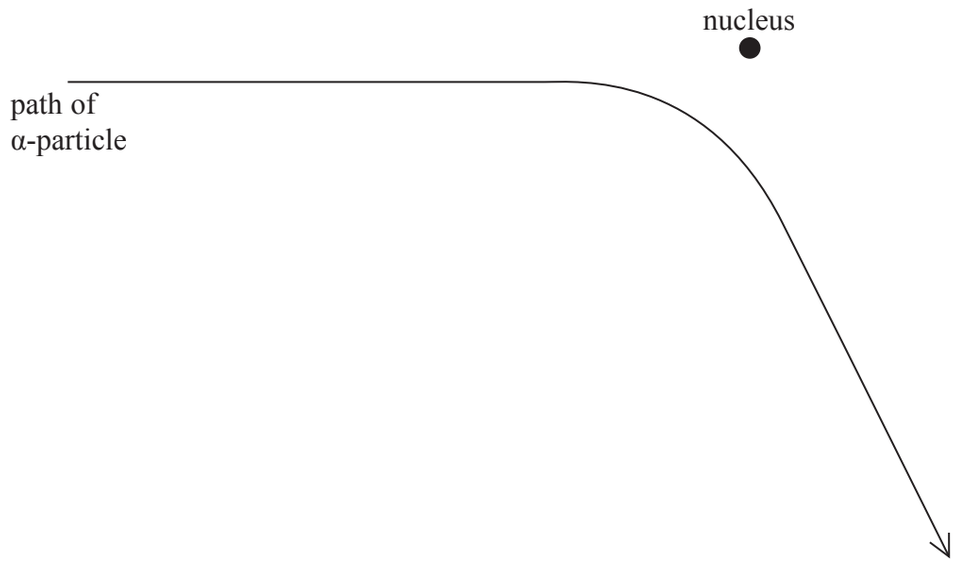
(c) The diagram shows the path of an α-particle passing near to a single nucleus in the metal foil.



(i) Name the force that causes the deflection of the α-particle.

(1)

(ii) On the diagram, draw an arrow to show the direction of the force acting on the α-particle at the point where the force is a maximum. Label the force F.

(2)

(iii) The foil is replaced by a metal of greater proton number.

Draw the path of an α-particle that has the same initial starting point and velocity as the one drawn in the diagram.

(2)

(Total for Question 13 = 9 marks)

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14 A student is investigating how the potential difference across a capacitor varies with time as the capacitor is charging.

He uses a 100 μF capacitor, a 5.0 V d.c. supply, a resistor, a voltmeter and a switch.

(a) (i) Draw a diagram of the circuit he should use.

(2)

(ii) Suggest why a voltage sensor connected to a data logger might be a suitable instrument for measuring the potential difference across the capacitor in this investigation.

(1)

.....

.....

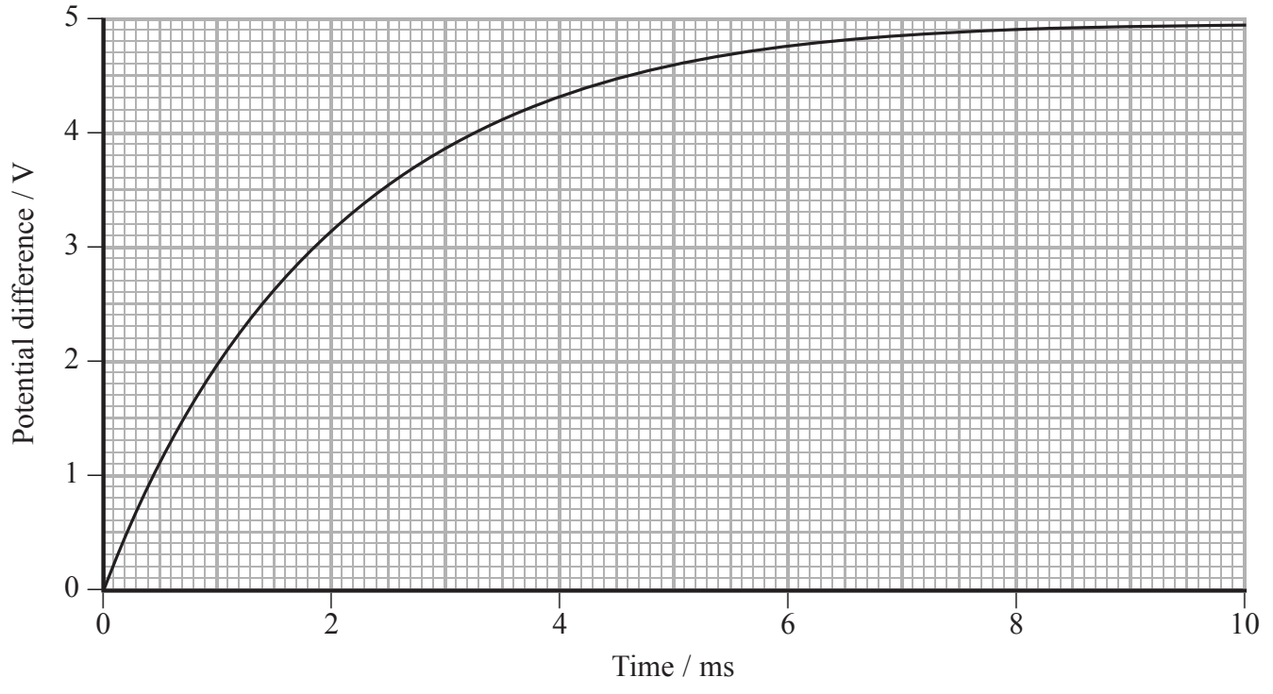
Turn over for Question 14(b)

(b) Calculate the maximum charge stored on the capacitor.

(2)

Charge = ...

(c) The graph shows how the potential difference across the capacitor varies with time as the capacitor is charging.



(i) Estimate the average charging current over the first 10 ms.

(2)

Average charging current = ...

(ii) Use the graph to estimate the initial rate of increase of potential difference across the capacitor and hence find the initial charging current.

(3)

Initial charging current = ...

(iii) Use the value of the initial charging current to find the resistance of the resistor.

(2)

Resistance = ...

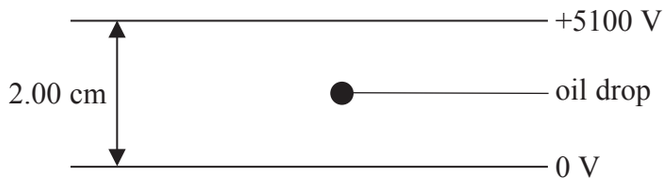
(Total for Question 14 = 12 marks)

Turn over ▶

15 The charge on an electron was originally measured in an experiment called the Millikan Oil Drop experiment.

In a simplified version of this experiment, an oil drop with a small electric charge is placed between two horizontal, parallel plates with a large potential difference (p.d.) across them. The p.d. is adjusted until the oil drop is stationary.

For a particular experiment, a p.d. of 5100 V was required to hold a drop of mass 1.20×10^{-14} kg stationary.



(a) Add to the diagram to show the electric field lines between the plates.

(3)

(b) State whether the charge on the oil drop is positive or negative.

(1)

(c) Complete the free-body force diagram to show the forces acting on the oil drop. You should ignore upthrust.

(2)

(d) (i) Calculate the magnitude of the charge on the oil drop.

(4)

Charge = ...

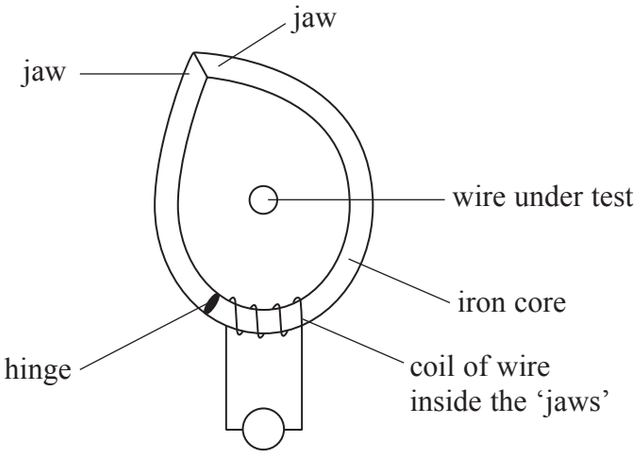
(ii) Calculate the number of electrons that would have to be removed or added to a neutral oil drop for it to acquire this charge.

(2)

Number of electrons = ...

(Total for Question 15 = 12 marks)

16 The photograph shows a digital clamp meter or 'amp-clamp'. This can be used to measure the current in the live wire coming from the mains supply without breaking the circuit.



The 'jaws' of the clamp are opened, placed around the wire carrying the current and then closed. Inside the 'jaws' is an iron core with a coil of wire wrapped around it.

*(a) Explain how an e.m.f. would be produced in the coil of wire inside the amp-clamp when the 'jaws' are placed around a wire carrying an alternating current.

(4)

(b) State why the amp-clamp cannot be used with a steady direct current.

(1)

(c) The amp-clamp cannot be used with a cable that is used to plug a domestic appliance like a lamp into the mains supply.

Explain why not.

(2)

(d) (i) Explain why the amp-clamp can be used to determine the magnitude of different alternating currents with the same frequency.

(2)

(ii) The amp-clamp may **not** be reliable when comparing alternating currents of different frequencies.

Suggest why not.

(2)

(Total for Question 16 = 11 marks)

Turn over ▶

17 (a) Explain what is meant by the principle of conservation of momentum.

(2)

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(b) The picture shows a toy car initially at rest with a piece of modelling clay attached to it.

A student carries out an experiment to find the speed of a pellet fired from an air rifle. The pellet is fired horizontally into the modelling clay. The pellet remains in the modelling clay as the car moves forward. The motion of the car is filmed for analysis.

The car travels a distance of 69 cm before coming to rest after a time of 1.3 s.

(i) Show that the speed of the car immediately after being struck by the pellet was about 1 m s^{-1}.

(2)

.....

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.....

(ii) State an assumption you made in order to apply the equation you used.

(1)

.....

.....

(iii) Show that the speed of the pellet just before it collides with the car is about 120 m s^{-1}

mass of car and modelling clay = 97.31g
mass of pellet = 0.84 g

(3)

(c) The modelling clay is removed and is replaced by a metal plate of the same mass. The metal plate is fixed to the back of the car. The experiment is repeated but this time the pellet bounces backwards.

*(i) Explain why the speed of the toy car will now be greater than in the original experiment.

(3)

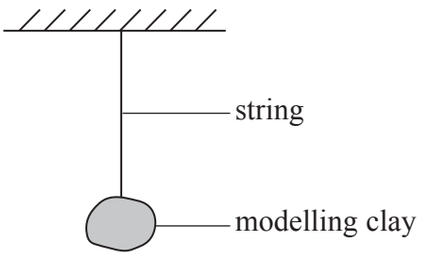
(ii) The film of this experiment shows that the pellet bounces back at an angle of 72° to the horizontal.

Explain why the car would move even faster if the pellet bounced directly backwards at the same speed.

(1)

Turn over ▶

(d) The student tests the result of the first experiment by firing a pellet into a pendulum with a bob made of modelling clay. She calculates the energy transferred.



The student's data and calculations are shown:

Data
mass of pellet = 0.84 g
mass of pendulum and pellet = 71.6 g
change in vertical height of pendulum = 22.6 cm

Calculations
change in gravitational potential energy of pendulum and pellet
$= 71.6 \times 10^{-3}$ kg $\times$ 9.81 N kg^{-1} $\times$ 0.226 m = 0.16 J
therefore kinetic energy of pendulum and pellet immediately after collision = 0.16 J
therefore kinetic energy of pellet immediately before collision = 0.16 J
therefore speed of pellet before collision = 19.5 m s^{-1}

There are no mathematical errors but her answer for the speed is too small.

State and explain which of the statements in the calculations are correct and which are not.

(4)

(Total for Question 17 = 16 marks)

TOTAL FOR SECTION B = 70 MARKS

TOTAL FOR PAPER = 80 MARKS

SECTION A

Answer ALL questions.

For questions 1–10, in Section A, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 A gymnast of mass 40 kg falls vertically onto a trampoline with a speed of 5 m s^{-1} and rebounds with the same speed.

She is in contact with the trampoline for 0.2 s. The average force exerted on the gymnast by the trampoline during this period is

☒ **A** 10 N

☒ **B** 20 N

☒ **C** 1000 N

☒ **D** 2000 N

(Total for Question 1 = 1 mark)

2 The drum of a washing machine rotates with an angular velocity of 8.5 rad s^{-1}.
The time to complete 10 revolutions is

☒ **A** 0.85 s

☒ **B** 1.3 s

☒ **C** 3.7 s

☒ **D** 7.4 s

(Total for Question 2 = 1 mark)

3 Select the row in the table that correctly identifies what happens in an inelastic collision.

		Momentum	Kinetic energy	Total energy
☒	**A**	conserved	conserved	conserved
☒	**B**	not conserved	conserved	conserved
☒	**C**	conserved	not conserved	conserved
☒	**D**	conserved	not conserved	not conserved

(Total for Question 3 = 1 mark)

4 Two protons, separated by a distance x, experience a repulsive force F.
If the separation is reduced to $x/3$ the force between the protons will be

☒ **A** $F/9$

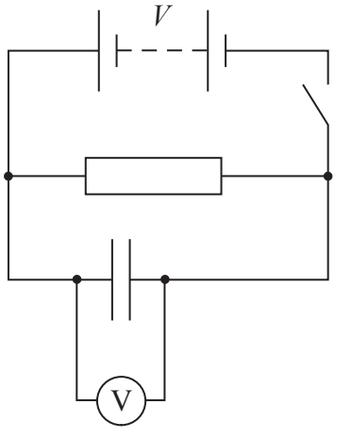
☒ **B** $F/3$

☒ **C** $3F$

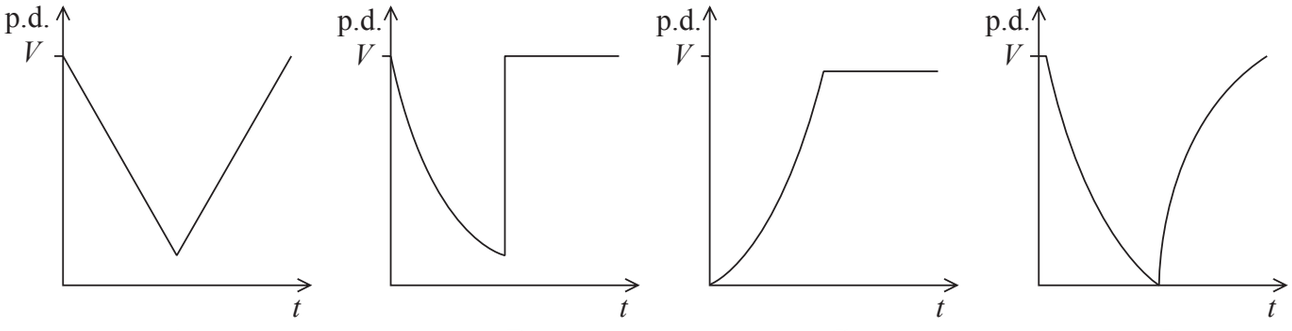
☒ **D** $9F$

(Total for Question 4 = 1 mark)

5 The capacitor shown in the circuit below is initially charged to a potential difference (p.d.) V by closing the switch.
The power supply has negligible internal resistance.



The switch is opened and the p.d. across the capacitor allowed to fall. A short time later the switch is closed again. Select the graph that shows how the p.d. across the capacitor varies with time, after the switch is opened.



☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 5 = 1 mark)

Turn over ▶

6 Charged particles are travelling at a speed v, at right angles to a magnetic field of flux density B. Each particle has a mass m and a charge Q.

Which of the following changes would cause a decrease in the radius of the circular path of the particles?

☒ **A** an increase in B

☒ **B** an increase in m

☒ **C** an increase in v

☒ **D** a decrease in Q

(Total for Question 6 = 1 mark)

7 The de Broglie wavelength associated with electrons moving at 2.5×10^6 m s^{-1} is

☒ **A** 2.9×10^{-4} m

☒ **B** 2.4×10^{-8} m

☒ **C** 2.9×10^{-10} m

☒ **D** 2.4×10^{-39} m

(Total for Question 7 = 1 mark)

8 Which of the following is **not** a valid conclusion from Rutherford's alpha particle scattering experiment?

☒ **A** The atom is mainly empty space.

☒ **B** The mass of the atom is mostly concentrated in the nucleus.

☒ **C** The nucleus must be positively charged.

☒ **D** The nucleus must be very small compared to the atom.

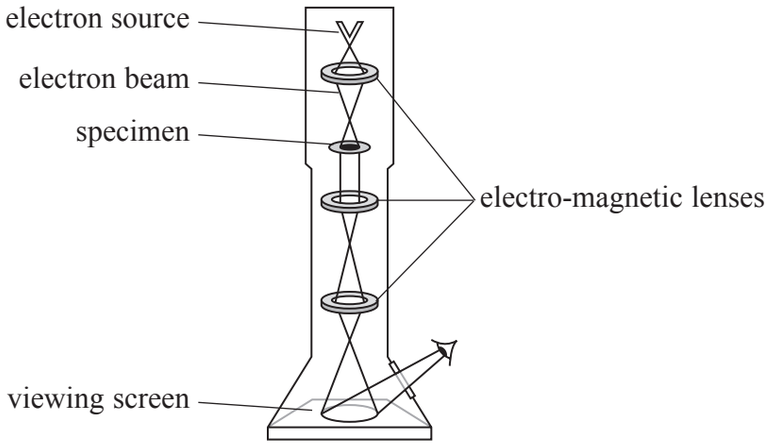
(Total for Question 8 = 1 mark)

9 Select the row in the table that correctly identifies the composition of a $^{235}_{92}U^{+}$ ion.

		Number of protons	Number of neutrons	Number of electrons
☒	**A**	92	143	91
☒	**B**	92	143	92
☒	**C**	92	235	91
☒	**D**	93	235	92

(Total for Question 9 = 1 mark)

10 A transmission electron microscope passes a beam of electrons through a tiny specimen to form an image on a viewing screen.



Due to the wave nature of electrons, diffraction occurs which can blur the image. To reduce this effect when viewing a smaller object the beam must contain

☒ **A** more electrons per second.

☒ **B** fewer electrons per second.

☒ **C** faster moving electrons.

☒ **D** slower moving electrons.

(Total for Question 10 = 1 mark)

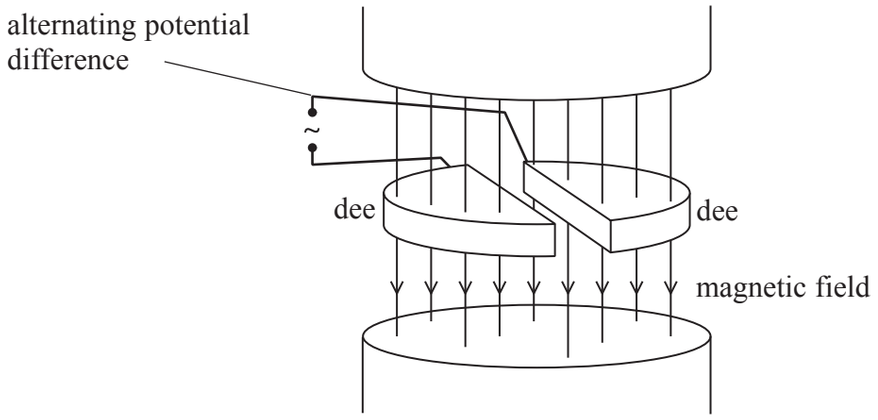
TOTAL FOR SECTION A = 10 MARKS

Turn over ▶

SECTION B

Answer ALL questions in the spaces provided.

***11** The diagram shows the basic structure of a cyclotron.



With reference to the magnetic field and the alternating potential difference explain how the cyclotron produces a beam of high speed particles.

(4)

(Total for Question 11 = 4 marks)

***12** In 2012 Neil Armstrong, the first man to step on the moon during the Apollo 11 lunar mission, died at the age of 82.

During this mission, a planned explosion caused the separation of the module in which Armstrong was travelling and the final-stage rocket. This explosion resulted in an increase in the speed of the module.

Discuss how the conservation of momentum and the conservation of energy apply to this situation.

(5)

(Total for Question 12 = 5 marks)

Turn over ▶

13 The magnetic force F that acts on a current-carrying conductor in a magnetic field is given by the equation

$$F = BIl.$$

(a) State the condition under which this equation applies.

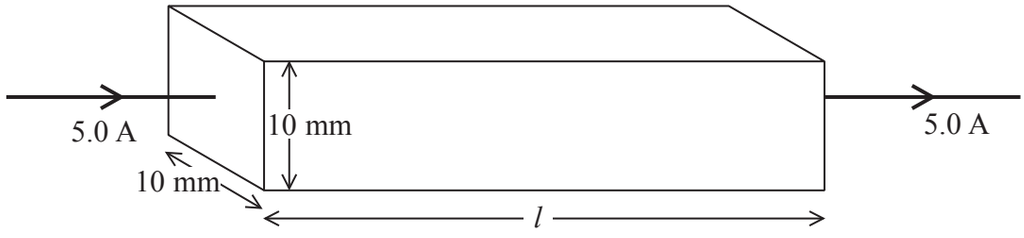
(1)

(b) The unit for magnetic flux density B is the tesla.

Express the tesla in base units.

(2)

(c) The diagram shows a rectangular bar of aluminium which has a current of 5.0 A through it.



The bar is placed in a magnetic field so that its weight is supported by the magnetic field.

Calculate the minimum value of the magnetic flux density B needed for this to occur.

density of aluminium = 2.7×10^3 kg m^{-3}

(3)

Minimum B = ...

(d) State the direction of the magnetic field.

(1)

.....

(Total for Question 13 = 7 marks)

Turn over ▶

14 Hadrons are a group of particles composed of quarks. Hadrons can be either baryons or mesons.

(a) (i) State the quark structure of a baryon.

(1)

(ii) State the quark structure of a meson.

(1)

(b) State **one** similarity and **one** difference between a particle and its antiparticle.

(2)

Similarity

Difference

(c) (i) The table gives some of the properties of up, down and strange quarks.

Type of quark	Charge/*e*	Strangeness
u	+2/3	0
d	–1/3	0
s	–1/3	–1

One or more of these quarks combine to form a K^+, a meson with a strangeness of +1.

Write down the quark combination of the K^+.

(1)

.....

(ii) The K^+ can decay in the following way

$$K^+ \rightarrow \mu^+ + \nu_\mu$$

K^- is the antiparticle of the K^+.

Complete the equation below by changing each particle to its corresponding antiparticle in order to show an allowed decay for the K^- meson.

(2)

$$K^- \rightarrow$$

(iii) The rest mass of the K^+ is 494 MeV/c^2.

Calculate, in joules, how much energy is released if a K^+ meets and annihilates a K^-.

(3)

.....

.....

.....

Energy = ... J

(Total for Question 14 = 10 marks)

Turn over ▶

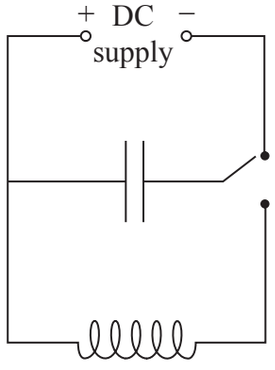
15 A particular experiment requires a very large current to be provided for a short time.

(a) An average current of 2.0×10^3 A is to be supplied to a coil of wire for a time of 1.4×10^{-3} s. The resistance of the coil is 0.50 Ω.

(i) Show that the charge that flows through the coil during this time is about 3 C.

(2)

(ii) The circuit shows how a capacitor could be charged and then discharged through the coil to provide the current.



The circuit contains a capacitor of capacitance 600 μF. This capacitor is suitable to provide the current for 1.4×10^{-3} s.

Explain why the capacitor is suitable.

(3)

(b) It can be assumed that the 600 μF capacitor completely discharges in 1.4×10^{-3} s.

(i) Calculate the potential difference of the power supply.

(2)

Potential difference = ...

(ii) Calculate the average power delivered to the coil in this time.

(3)

Average power = ...

(Total for Question 15 = 10 marks)

Turn over ▶

16 In order to make an object move around a circular path at a constant speed a resultant force must act on it.

(a) Explain why a resultant force is required and state the direction of this force.

(2)

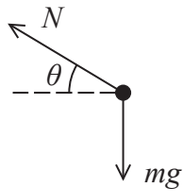
(b) When vehicles move around a bend on a level road, the resultant force is provided by friction between the tyres and the road. For a given vehicle and road surface there is a maximum value for this sideways frictional force.

Explain why roads designed for high-speed travel, such as motorways, do not have any sharp bends.

(2)

(c) Some cycling tracks are banked. When cornering, a cyclist moves up the track until the sideways frictional force is zero.

The free-body force diagram for a cyclist and bicycle is shown. The normal contact force exerted by the track is N and the weight of cyclist and bicycle is mg.



(i) By considering the vertical and horizontal motion, show that

$$\tan \theta = gr/v^2$$

where r is the radius of the cyclist's path and v is the cyclist's speed.

(3)

(ii) Calculate the value of θ for a cyclist travelling at 11.0 m s^{-1} around a bend of radius 18.7 m.

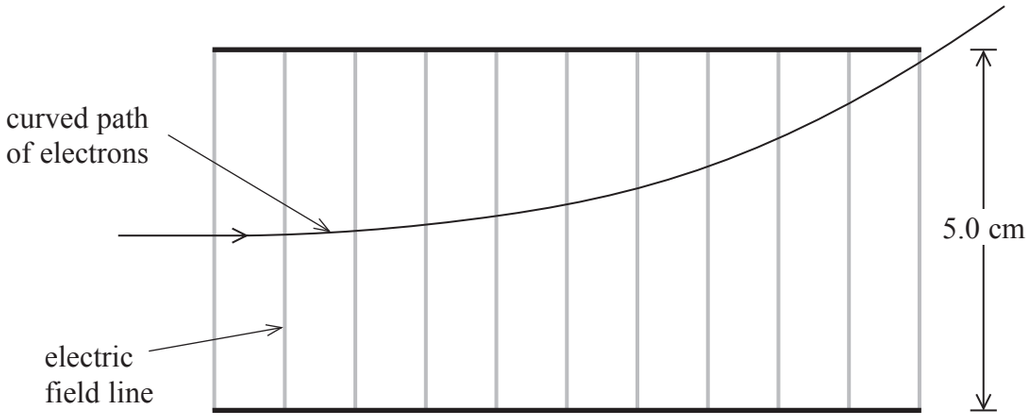
(2)

$\theta =$ .....

(Total for Question 16 = 9 marks)

Turn over ▶

17 A teacher uses an electron beam tube to demonstrate the behaviour of electrons in an electric field. The diagram shows the path of an electron in a uniform electric field between two parallel conducting plates.



(a) Mark on the diagram the direction of the electric field.

(1)

(b) The conducting plates are 5.0 cm apart and have a potential difference of 160 V across them.
Calculate the force on the electron due to the electric field.

(3)

Force = ...

(c) Explain why the path of the electron is curved between the plates and straight when it has left the plates.

(3)

(d) The electron was initially released from a metal by thermionic emission and then accelerated through a potential difference before entering the region of the electric field.

(i) State what is meant by thermionic emission.

(1)

.....

.....

(ii) In order to be able to just leave the plates as shown, the electron must enter the electric field between the plates with a speed of 1.2×10^7 m s^{-1}.

Calculate the potential difference required to accelerate an electron from rest to this speed.

(3)

.....

.....

.....

.....

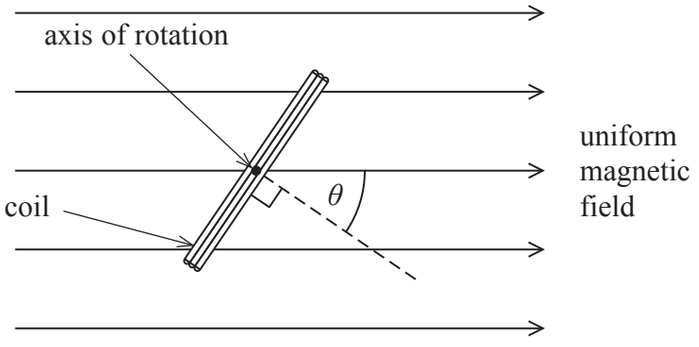
.....

Potential difference = ...

(Total for Question 17 = 11 marks)

Turn over ▶

18 The diagram shows an end view of a simple electrical generator. A rectangular coil of wire is rotated in a uniform magnetic field of magnetic flux density 3.0×10^{-2} T. The axis of rotation is at right angles to the field direction.



(a) The coil has 200 turns and an area of 2.0×10^{-4} m^2.

Calculate the magnetic flux linkage for the coil when $\theta = 0°$.

(2)

Flux linkage = ...

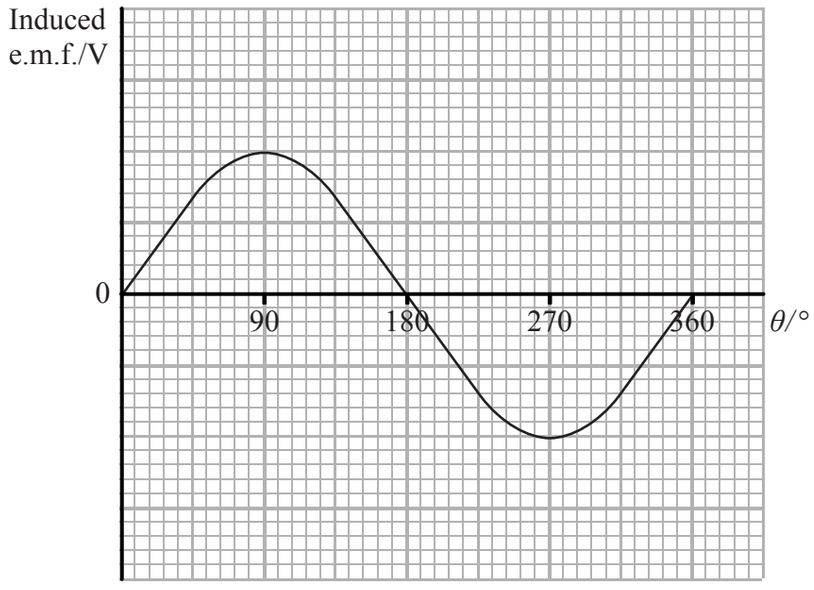
(b) The coil is rotated at a constant rate of 2 revolutions per second.

(i) Calculate the average e.m.f. induced in the time taken for the coil to rotate from $\theta = 0°$ to $\theta = 90°$.

(3)

Average e.m.f. = ...

(ii) The graph shows how the induced e.m.f. varies over one cycle of rotation of the coil.



Explain why the magnitude of the e.m.f. is smallest and greatest at the values of θ shown in the graph.

(3)

(iii) State and explain how the graph would differ if the coil rotated at a slower rate.

(2)

(c) Vehicles such as electric cars are driven by electric motors. These vehicles use regenerative braking to reduce the speed of the vehicle. The motor is operated as a generator during braking and the output from the generator is used to recharge the batteries of the car.

(i) Explain how using the motor as a generator slows the car down.

(2)

(ii) In practice, these vehicles also use friction braking as well as regenerative braking. This is because regenerative braking on its own will not fully stop a car. Suggest why.

(2)

(Total for Question 18 = 14 marks)

TOTAL FOR SECTION B = 70 MARKS

TOTAL FOR PAPER = 80 MARKS

SECTION A

Answer ALL questions.

For questions 1–10, in Section A, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 A mass is bouncing on the end of a vertical spring. Its motion will be simple harmonic if the spring

☒ **A** can store energy.

☒ **B** has elasticity.

☒ **C** is hung vertically.

☒ **D** obeys Hooke's law.

(Total for Question 1 = 1 mark)

2 When energy is supplied to a substance, changes in the average molecular kinetic energy (E_k) and the average molecular potential energy (E_p) can occur.

When energy is supplied to an ideal gas

☒ **A** both E_k and E_p increase.

☒ **B** E_k may increase.

☒ **C** E_p may increase.

☒ **D** E_k increases but E_p decreases.

(Total for Question 2 = 1 mark)

3 The force between two masses and the force between two charges can be modelled in a similar way, using gravitational and electric fields. A difference between these models is that

☒ **A** an electric field is always a radial field.

☒ **B** an electric field is always the stronger field.

☒ **C** a gravitational field cannot be shielded.

☒ **D** a gravitational field extends over an infinite range.

(Total for Question 3 = 1 mark)

4 α-Centauri is one of the nearest stars to our Sun. The surface temperatures of these two stars are about the same. α-Centauri has a 20% greater diameter than the Sun.

The ratio of the luminosity of α-Centauri to the luminosity of the Sun is about

☒ **A** 1.2

☒ **B** 1.4

☒ **C** 1.7

☒ **D** 2.1

(Total for Question 4 = 1 mark)

5 Scientists cannot be sure what their current models predict for the ultimate fate of the universe because

☒ **A** of the matter-antimatter asymmetry.

☒ **B** the average density of the universe is uncertain.

☒ **C** the Big Bang is just a theory.

☒ **D** the nature of dark matter is unknown.

(Total for Question 5 = 1 mark)

6 When measuring the count rate from a radioactive source it is usual to also measure the background count rate.

The background count rate must be

☒ **A** as large as possible for an accurate experiment.

☒ **B** measured when the source is in place.

☒ **C** recorded for the same time as the count rate.

☒ **D** subtracted from the count rate measured from the source.

(Total for Question 6 = 1 mark)

7 Air is a mixture of mostly nitrogen and oxygen molecules. The mass of an oxygen molecule is slightly greater than the mass of a nitrogen molecule.

On average, in a sample of air at a given temperature

☒ **A** the nitrogen and oxygen molecules have the same speed.

☒ **B** the nitrogen molecules are travelling more slowly than the oxygen molecules.

☒ **C** the oxygen molecules are travelling more slowly than the nitrogen molecules.

☒ **D** the molecules have relative speeds that depend upon the amount of each gas present.

(Total for Question 7 = 1 mark)

8 A lamp consists of a filament in a vacuum. Under normal working conditions the filament has a temperature of 1600 K. A similar filament lamp that is gas-filled has a filament temperature of 3200 K.

The ratio of the wavelength at which maximum intensity of radiation is emitted by the vacuum lamp to that for the gas-filled lamp is

☒ **A** 1:2

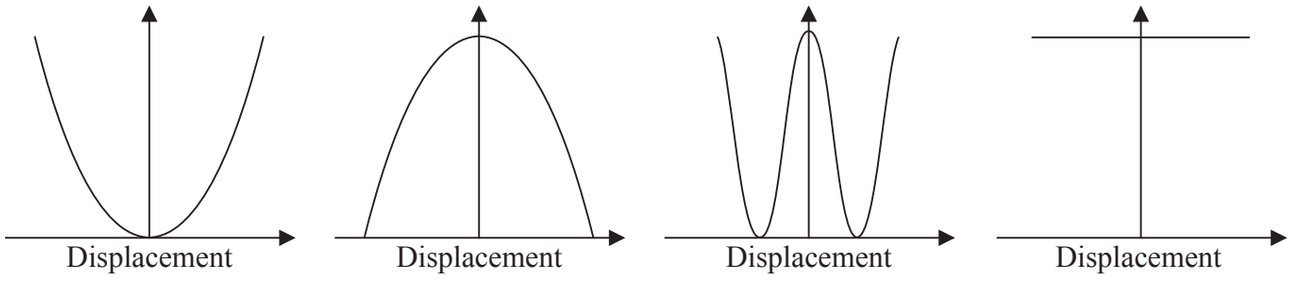
☒ **B** 1:1

☒ **C** 2:1

☒ **D** 16:1

(Total for Question 8 = 1 mark)

Questions 9 and 10 refer to the graphs below.



A **B** **C** **D**

9 For an object undergoing simple harmonic motion select the graph that represents the variation of kinetic energy with displacement.

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 9 = 1 mark)

10 For an object undergoing simple harmonic motion select the graph that represents the variation of the total energy with displacement.

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 10 = 1 mark)

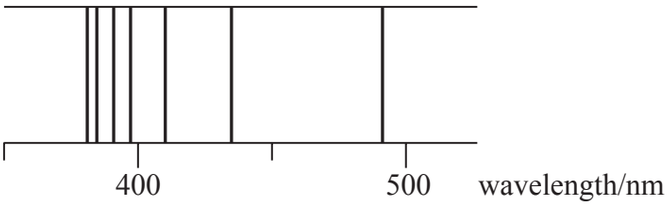
TOTAL FOR SECTION A = 10 MARKS

Turn over ▶

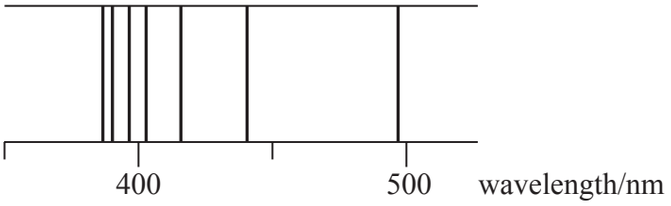
SECTION B

Answer ALL questions in the spaces provided.

11 The diagram shows part of the hydrogen line spectra obtained for radiation emitted from hydrogen in the laboratory and received from hydrogen in a distant galaxy.



Laboratory Spectrum



Distant Galaxy Spectrum

The lines in the distant galaxy spectrum are all shifted in wavelength compared to the lines in the laboratory spectrum.

State why the lines are shifted and what we can conclude about this distant galaxy.

(2)

.....

.....

.....

.....

(Total for Question 11 = 2 marks)

12 The heating element of an electric shower has a power of 6.0 kW.

(a) The shower is operated from a 230 V mains supply.

Calculate the resistance of the heating element.

(2)

Resistance = ...

(b) Water enters the shower at a temperature of 7.5 °C.

Calculate the water flow rate required to give an output temperature of 37.5 °C.

specific heat capacity of water = 4200 J kg^{-1} K^{-1}

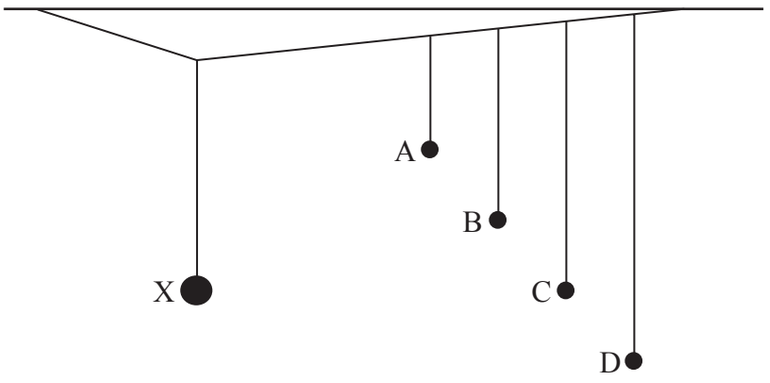
(3)

Flow rate = ...

(Total for Question 12 = 5 marks)

Turn over ▶

13 The diagram shows a number of pendulums hanging from a single thread. Pendulum X has a heavy lead sphere as the bob and the others have low mass bobs. When X is set into motion energy is transferred to the others which all begin to oscillate.

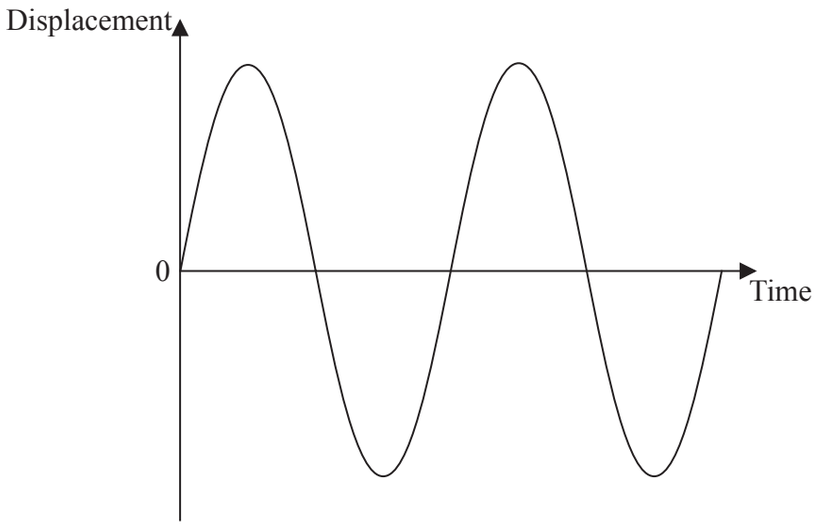


After a short time C is observed to have the largest amplitude of oscillation.

(a) Explain why pendulum C has the largest amplitude of oscillation.

(3)

(b) For an efficient energy transfer pendulum C must be at rest when pendulum X has its maximum kinetic energy. The graph below shows how the displacement of pendulum X varies with time.



Mark a point P on this graph showing an instant when pendulum X has a maximum kinetic energy, and add a curve to show how the displacement of pendulum C varies over the same time interval.

(2)

(Total for Question 13 = 5 marks)

Turn over ▶

***14** Parallax measurements are used to determine the distance to nearby stars, but this method is unsuitable for more distant objects.

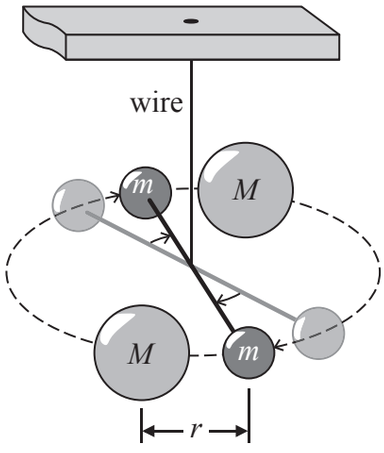
Outline how parallax measurements are used to determine the distance to nearby stars and explain how the use of a standard candle enables the distance to more distant objects to be determined.

(6)

(Total for Question 14 = 6 marks)

15 In the 18th century Henry Cavendish devised an experiment to determine the average density of the Earth. This involved the first laboratory determination of the universal gravitational constant G.

A light horizontal rod with a small metal sphere at each end was hung from a fixed point by a very thin wire. Two large lead spheres were then brought close to the small spheres causing the rod to oscillate and then settle into a new position of equilibrium.



(a) In a modern version of the experiment the following data was obtained:

mass of large lead sphere $M = 160$ kg

mass of small sphere $m = 0.75$ kg

distance $r = 0.23$ m

gravitational force between adjacent large and small spheres $F = 1.5 \times 10^{-7}$ N.

Use this data to calculate a value for G.

(2)

.....

.....

.....

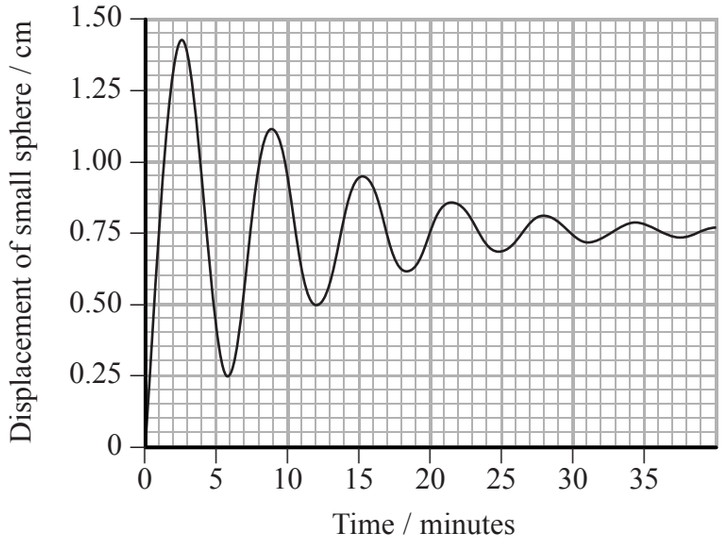
.....

.....

$G =$ ..... $Nm^2\ kg^{-2}$

Turn over ▶

(b) The graph shows how the displacement of one of the small spheres varies with time.



(i) Use the graph to determine the period of oscillation of the sphere.

(2)

.....

.....

.....

.....

.....

Period = ...

(ii) The amplitude of the oscillation decreases with each cycle.

Explain why this effect is observed.

(2)

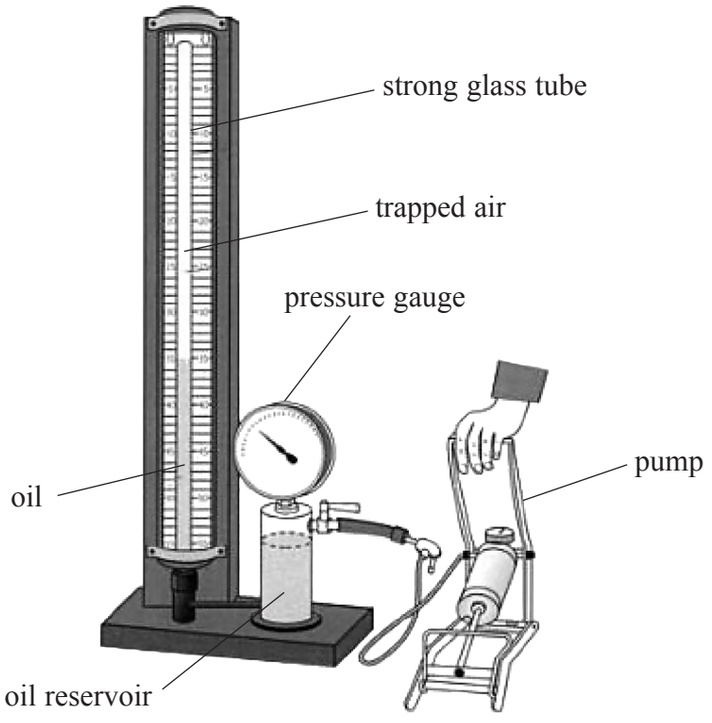
(iii) It is suggested that the decrease in amplitude is exponential. Use the graph to determine if this is approximately true.

(3)

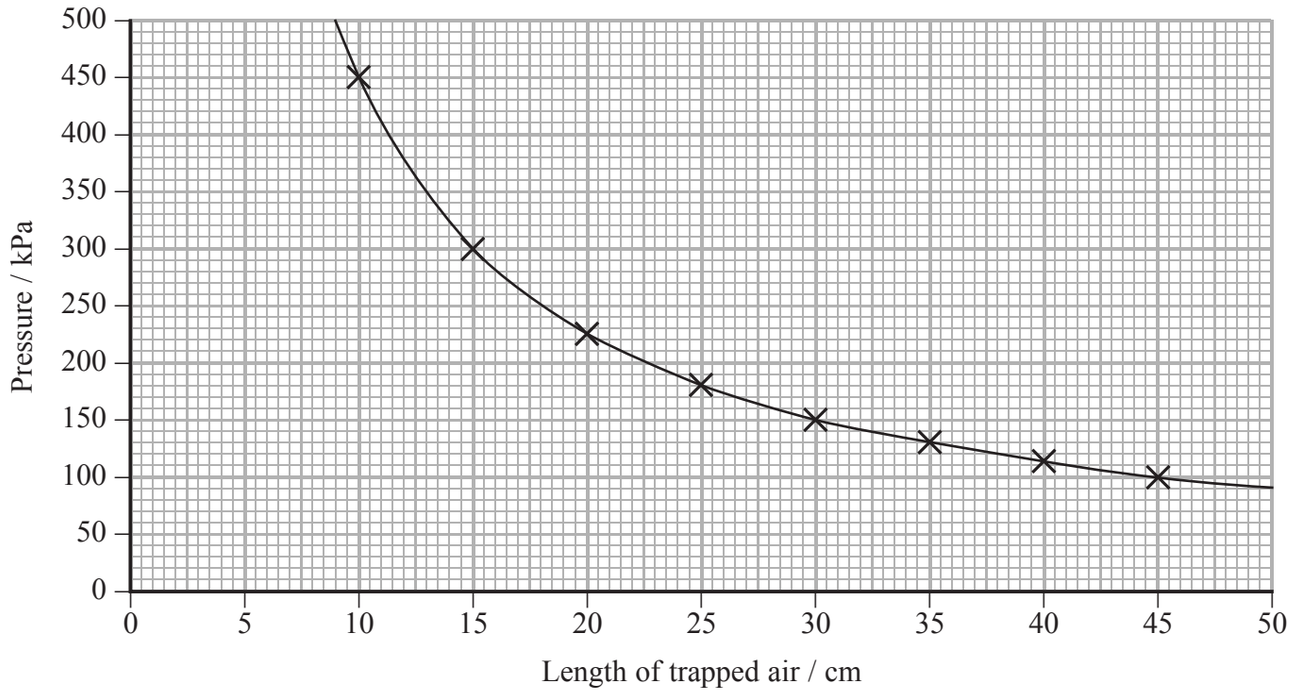
(Total for Question 15 = 9 marks)

Turn over ▶

16 A student uses the apparatus shown to investigate the relationship between pressure and volume of a gas.



Air is trapped in a glass tube of uniform cross-sectional area. As the pressure of the trapped air is increased, the length of trapped air decreases. The student collects data and plots the following graph.



(a) State the variables that should be controlled in this investigation.

(2)

(b) Theory suggests that, for the air trapped in the tube, the pressure p is inversely proportional to the volume V.

Use the graph to show that this relationship is correct. State an assumption that you are making.

(4)

Turn over ▶

(c) On the day that the investigation was carried out, the temperature in the laboratory was 20 °C.

Calculate the number of air molecules trapped in the tube.

cross-sectional area of tube = 7.5×10^{-5} m^2

(3)

Number of air molecules = ...

(d) State how the graph would change if

(i) the air molecules in the tube were replaced by the same number of molecules of hydrogen gas.

(1)

(ii) the temperature of the laboratory was substantially higher.

(2)

(Total for Question 16 = 12 marks)

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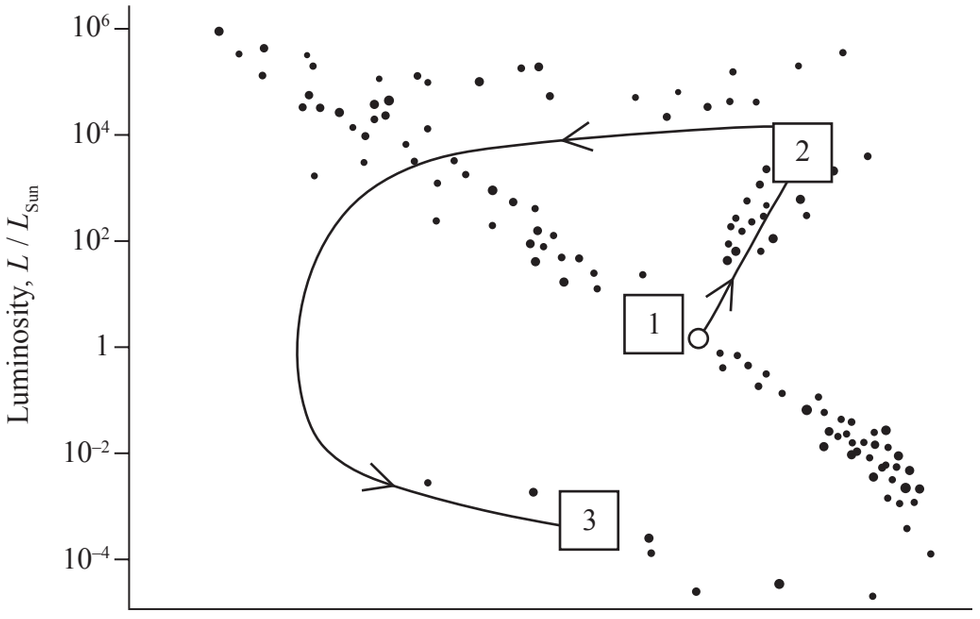
Turn over ▶

17 The Sun has a surface temperature of 5800 K and is approximately 4.5 billion years old.

The Hertzsprung-Russell diagram maps the future evolution of the Sun, from its current position in area 1 of the diagram, through to its final position in area 3 of the diagram.



(a) (i) Complete a suitable temperature scale on the x-axis.

(2)

*(ii) Use the diagram to describe the lifecycle of the Sun starting from its present position in area 1 and concluding in area 3.

(6)

(b) The energy source for the Sun is the fusion of light nuclei to heavy nuclei. In its present stage of evolution hydrogen is being converted into helium in the core of the Sun.

(i) State and explain the conditions necessary for fusion to occur in a star.

(3)

Turn over ▶

(ii) In a star the fusion of hydrogen into helium takes place in a number of stages. The final stage is:

$$^{3}_{2}\mathrm{He} + {}^{3}_{2}\mathrm{He} \rightarrow {}^{4}_{2}\mathrm{He} + 2 \times {}^{1}_{1}\mathrm{H}$$

Calculate the energy released in MeV when one nucleus of the normal isotope of helium is produced.

(4)

Isotope	**Mass / 10^{-27} kg**
^{3}He	5.008238
^{4}He	6.646483
^{1}H	1.673534

Energy released = ... MeV

(Total for Question 17 = 15 marks)

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Turn over ▶

18 On 1st November 2006, the former Russian spy Alexander Litvinenko fell ill. Twenty one days later he died from the radiation effects of polonium-210. Experts suggest that as little as 0.89 μg of polonium-210 would be enough to kill, although Mr Litvinenko's death was linked to a much larger dose of the radioactive isotope. Traces of the isotope were later found in washrooms at five locations around London visited by the Russian.

Polonium-210 has a half life of 138 days.

(a) (i) In a 0.89 μg sample of polonium-210 there are 2.54×10^{15} atoms of polonium. Show that the decay constant for polonium-210 is about 6×10^{-8} s^{-1}, and hence calculate the activity of a sample of this size.

(4)

Activity = ...

(ii) Calculate the fraction of polonium-210 nuclei that have decayed after a time of 21 days.

(3)

Fraction decayed = ...

(b) Polonium-210 emits alpha particles. Explain why polonium-210 is virtually harmless unless it is taken into the body.

(2)

(c) (i) Complete the equation below for the decay of polonium.

(2)

$$^{210}_{84}\text{Po} \rightarrow \text{\_\_\_\_}\text{Pb} + \text{\_\_\_\_}\alpha$$

(ii) State why the Pb nuclei would recoil from the alpha particles emitted during the decay.

(1)

(d) Radioactive decay is said to occur spontaneously and randomly. Explain what is meant by spontaneous and random in this context.

(2)

Spontaneous .....

Random .....

(e) Suggest why traces of the isotope were found in locations visited by the Russian.

(2)

(Total for Question 18 = 16 marks)

TOTAL FOR SECTION B = 70 MARKS

TOTAL FOR PAPER = 80 MARKS