Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

Time 1 hour 45 minutes

Paper reference **WPH14/01**

Physics

International Advanced Level
UNIT 4: Further Mechanics, Fields and Particles

You must have:
Scientific calculator, ruler, protractor

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B).
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need*.
- **Show all your working out** in calculations and **include units** where appropriate.

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question*.
- In the question marked with an **asterisk (*)**, marks will be awarded for your ability to structure your answer logically, showing how the points that you make are related or follow on from each other where appropriate.
- The list of data, formulae and relationships is printed at the end of this booklet.

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ▶

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 Which row of the table describes the mass and charge of an anti-proton?

	Mass / kg	Charge / C
☒ **A**	1.67×10^{-27}	1.6×10^{-19}
☒ **B**	1.67×10^{-27}	-1.6×10^{-19}
☒ **C**	-1.67×10^{-27}	1.6×10^{-19}
☒ **D**	-1.67×10^{-27}	-1.6×10^{-19}

(Total for Question 1 = 1 mark)

2 Which of the following is a valid conclusion from alpha particle scattering experiments?

☒ **A** Atoms contain positive and negative charge distributed evenly.

☒ **B** The nucleus of an atom contains protons and neutrons.

☒ **C** The nucleus of an atom is very small compared to the size of the atom.

☒ **D** Atoms contain very little empty space.

(Total for Question 2 = 1 mark)

3 Which of the following describes why electrons are released from the metal filament during thermionic emission?

☒ **A** The metal filament is heated by an electric current.

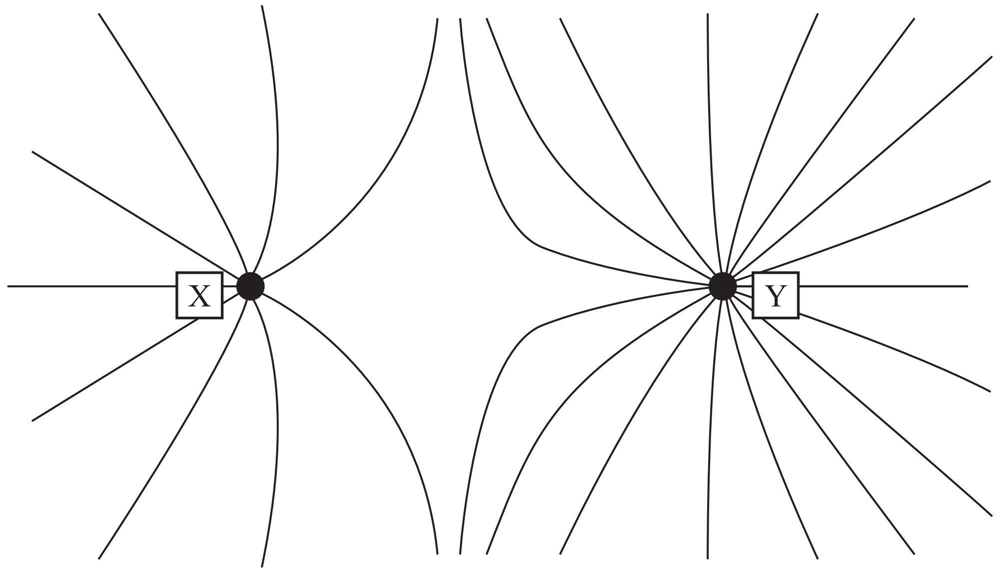
☒ **B** The metal filament is contained within a vacuum.

☒ **C** The metal filament is bombarded by high-energy electrons.

☒ **D** The metal filament is maintained at a high potential.

(Total for Question 3 = 1 mark)

4 The diagram shows the shape of the electric field pattern between two charged particles, X and Y.



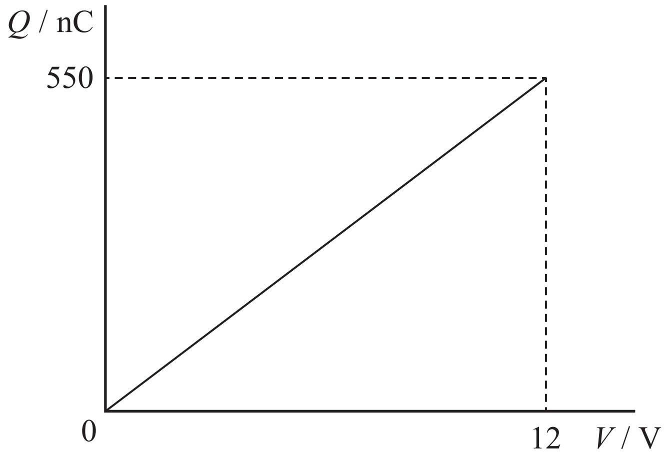
X has a charge of $-Q$.

Which of the following could be the charge of Y?

- ☒ **A** $-Q$
- ☒ **B** $-2Q$
- ☒ **C** $+Q$
- ☒ **D** $+2Q$

(Total for Question 4 = 1 mark)

5 The graph shows how the charge Q stored on the plates of a capacitor varies with the potential difference V across the plates.



Which of the following expressions gives the energy, in J, stored by the capacitor when V is 12 V?

☒ **A** $\dfrac{550}{12}$

☒ **B** $\dfrac{12}{550 \times 10^{-9}}$

☒ **C** $\dfrac{550 \times 12}{2}$

☒ **D** $\dfrac{550 \times 10^{-9} \times 12}{2}$

(Total for Question 5 = 1 mark)

6 The SI unit of magnetic flux density is the tesla.

Which of the following gives the base units of the tesla?

☒ **A** $\mathrm{N\,A^{-1}\,m^{-1}}$

☒ **B** $\mathrm{N\,C^{-1}\,m^{2}}$

☒ **C** $\mathrm{kg\,A^{-1}\,s^{-2}}$

☒ **D** $\mathrm{kg\,C^{-1}\,s^{-1}}$

(Total for Question 6 = 1 mark)

7 The table shows the relative charges on up and down quarks.

u	$\frac{2}{3}e$
d	$-\frac{1}{3}e$

Which of the following could be the quark composition for a baryon with a charge of $+2e$?

☒ **A** ddd

☒ **B** $\mathrm{u\bar{d}}$

☒ **C** $\mathrm{u\bar{u}}$

☒ **D** uuu

(Total for Question 7 = 1 mark)

8 A linac is a particle accelerator. It consists of drift tubes of increasing length with potential differences (p.d.) applied between them.

Which of the following is the reason the drift tubes are of increasing length?

☒ **A** So that the p.d. can have a constant frequency.

☒ **B** So that the particle gains the same amount of energy in each tube.

☒ **C** So that the p.d. between the tubes increases for each successive tube.

☒ **D** So that the time spent in each successive tube increases.

(Total for Question 8 = 1 mark)

9 An object of mass m has momentum p and kinetic energy E.

Which of the following is the mass of an object with momentum $2p$ and kinetic energy $4E$?

☒ **A** $\frac{1}{2}m$

☒ **B** m

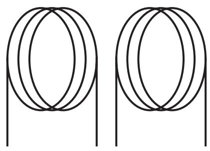
☒ **C** $2m$

☒ **D** $4m$

(Total for Question 9 = 1 mark)

---

10 Two coils, L and M, are placed next to each other as shown.



An alternating e.m.f. is induced across coil M.

Which of the following could produce this?

☒ **A** an alternating current in coil L

☒ **B** a constant current in coil L

☒ **C** a decreasing current in coil L

☒ **D** an increasing current in coil L

(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA

SECTION B

Answer ALL questions. Write your answers in the spaces provided.

11 (a) Pions belong to a group of particles known as mesons.

State the quark structure of mesons.

(1)

....

(b) Muons belong to a family of particles known as leptons.

State one property of leptons.

(1)

....

....

(c) Charged pions usually decay into a muon (μ) and another particle X, as shown by the decay equation:

$$\pi^- \rightarrow \mu^- + X$$

A student suggests that X is an anti-neutrino due to particle conservation laws.

Deduce whether the student is correct.

(4)

....

....

....

....

....

....

....

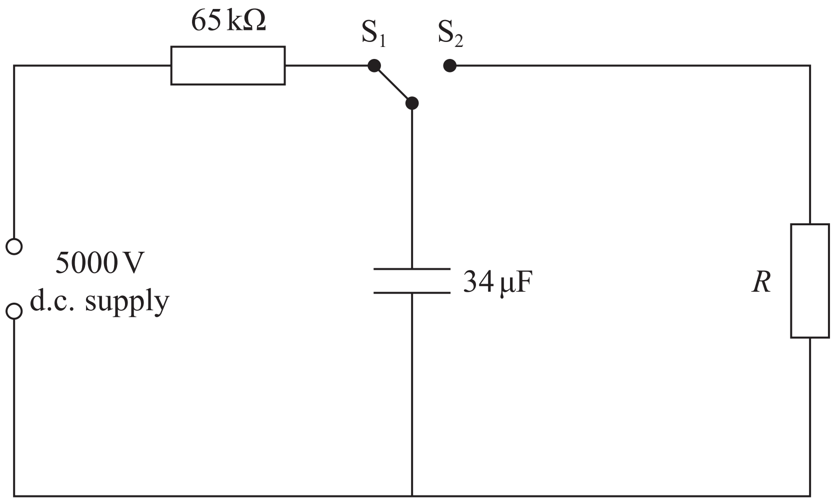
....

(Total for Question 11 = 6 marks)

12 A defibrillator is a device that can restart a person's heart. The defibrillator applies an electric current to a person's heart for a short time.

The defibrillator uses a capacitor circuit. A person's body has an electrical resistance R.

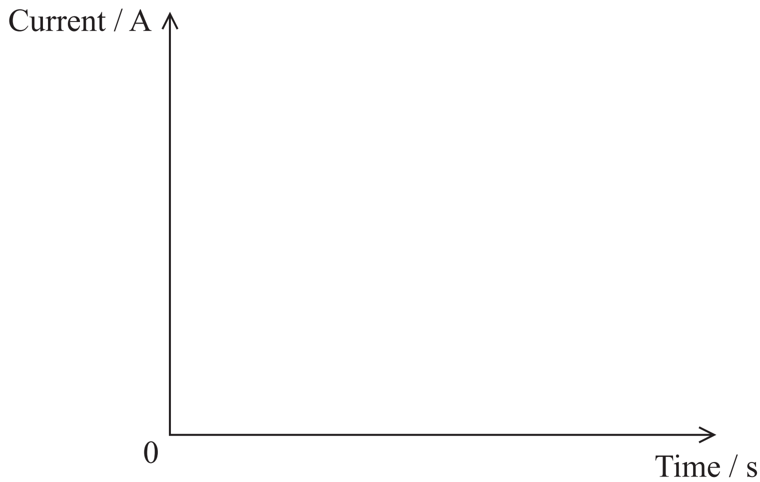
A simplified circuit diagram is shown.



(a) When the capacitor is completely discharged, the two-way switch is moved to position S_1 at time $t = 0$ s.

Complete the graph to show how the current varies with time until the capacitor is fully charged.

(4)



....

....

....

....

(b) The capacitor in the defibrillator discharges when the switch is moved to position S_2.

The defibrillator is required to deliver a discharge current of at least 30 A for a time of 2.0 ms.

A typical person's body has an electrical resistance of 150 Ω.

Deduce whether the design of the defibrillator meets this requirement.

(4)

(Total for Question 12 = 8 marks)

13 The Proton-Antiproton Collider (S$p\bar{p}$S) was a large particle accelerator. An experiment using the S$p\bar{p}$S proved the existence of a particle called a Z boson.

(a) The mass of the Z boson is 91 GeV/c^2.

Show that the mass of the Z boson is nearly 100 times greater than the mass of a proton.

(4)

....

....

....

....

....

....

....

(b) Protons and anti-protons were accelerated in the S$p\bar{p}$S to very high energies before they collided.

Explain why the protons and anti-protons needed high energies to produce the Z boson.

(3)

....

....

....

....

....

....

(c) Z bosons produced by high energy collisions can have a range of lifetimes. The Z bosons with the longest lifetimes are those that were moving very fast.

Explain this observation.

(2)

....

....

....

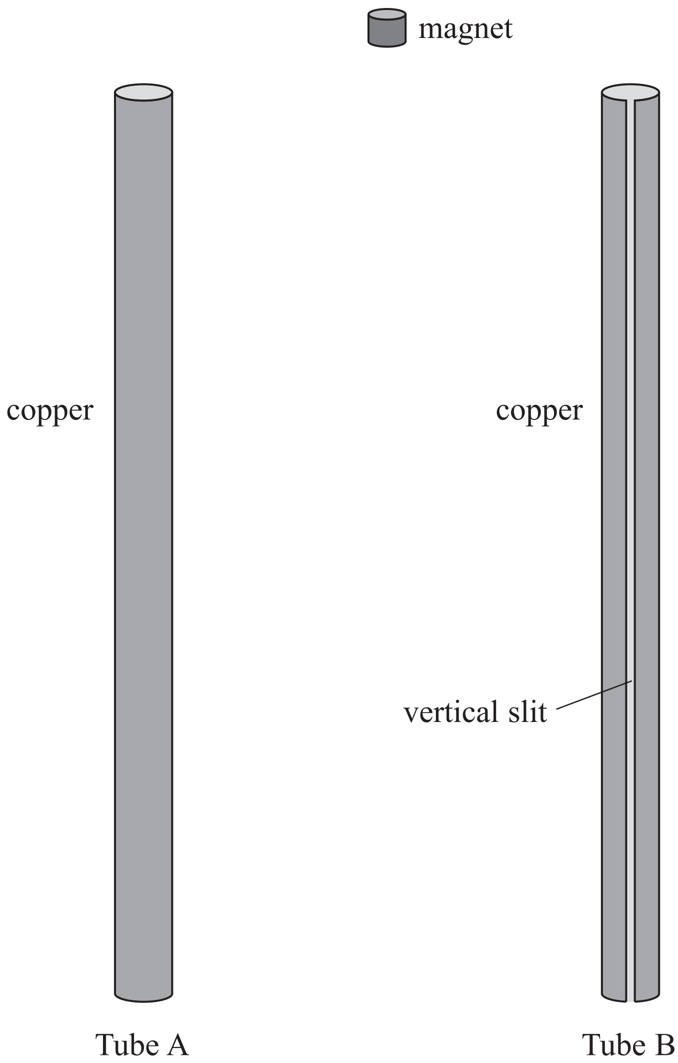
....

(Total for Question 13 = 9 marks)

***14** A student uses a strong, cylindrical magnet to investigate Lenz's law.

The student records the time taken for the magnet to fall through two hollow tubes of copper, tube A and tube B.

The two tubes have the same length and cross-sectional area. Tube B has a vertical slit cut into it, as shown.



Discuss the differences in the time taken for the magnet to fall through each tube.

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

(Total for Question 14 = 6 marks)

15 Alpha particles were chosen by Rutherford for large-angle scattering experiments.

(a) Explain why alpha particles are more suitable for these experiments compared to beta particles or gamma rays.

(3)

....

....

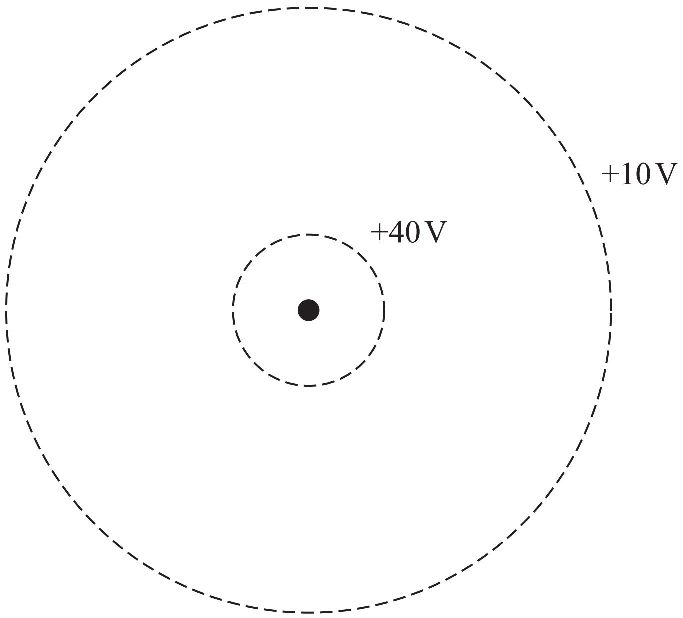
....

....

....

....

(b) The scaled diagram shows two equipotential lines in the electric field around a gold nucleus.



(i) Sketch lines to show the electric field between these two lines of equipotential.

(3)

(ii) The 40 V line is drawn to scale correctly.

Deduce whether the 10 V equipotential line is in the correct scaled position.

(3)

....

....

....

....

....

....

(iii) An alpha particle moves from the +10 V potential to the +40 V potential.

Calculate the increase in the potential energy of the alpha particle in eV.

(3)

....

....

....

....

....

....

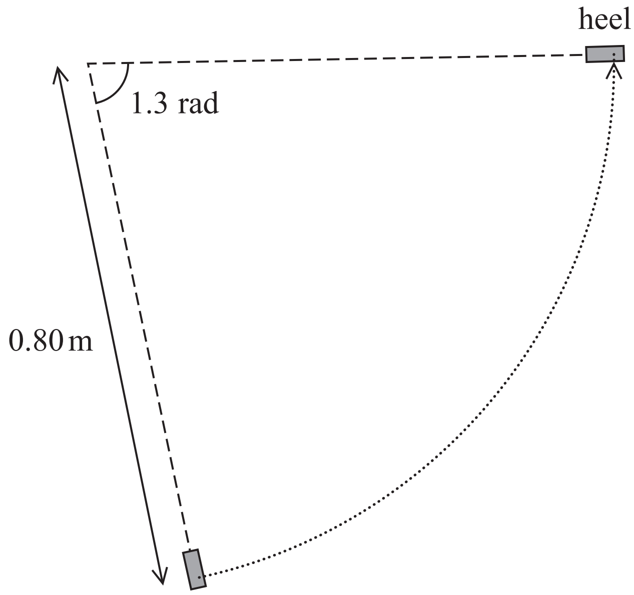
Increase in potential energy = ... eV

(Total for Question 15 = 12 marks)

16 Hockey is a sport played with a stick and a ball. The player tries to hit the ball with part of the stick called the 'heel', as shown.

(Source: © Studio77 FX vector/Shutterstock)

(a) The player swings her stick so that the heel moves horizontally in a circle of radius 0.80 m across the ground, as shown below.



Plan view

Not to scale

It takes a time of 0.22 s for the heel to move through an angle of 1.3 radians.

Calculate the speed of the heel.

(3)

....

....

....

....

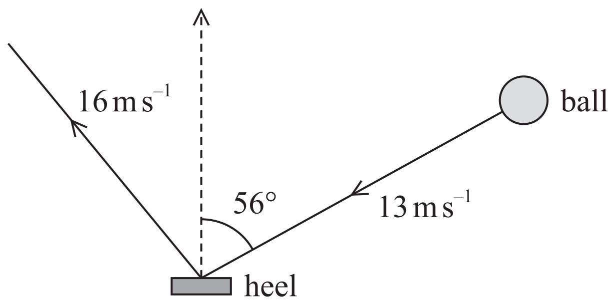
Speed of heel = ...

DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA

(b) A ball has a speed of $13\,m\,s^{-1}$. The heel has a momentum p_{heel} of $3.0\,N\,s$, in the direction of the dashed line, as shown.

The heel collides with the ball and stops.

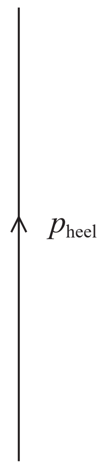
The speed of the ball after being hit by the heel is $16\,m\,s^{-1}$.



(i) Deduce whether momentum is conserved for this collision by completing the vector diagram below. A scaled line representing p_{heel} is shown.

mass of ball = 160 g

(5)



....

....

....

....

DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA

(ii) Deduce whether the collision is elastic.

speed of heel before collision = $5.0\,\mathrm{m\,s^{-1}}$

(4)

....

....

....

....

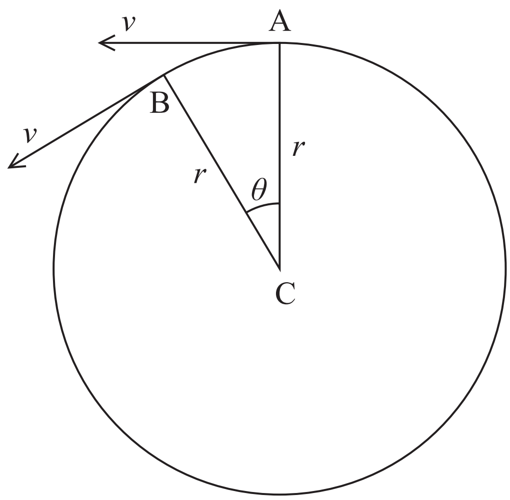
....

....

(Total for Question 16 = 12 marks)

17 An aeroplane flies in a horizontal circular path whilst waiting to land at an airport.

(a) The aeroplane flies at a constant speed v around a horizontal circular path of radius r. The diagram shows two positions A and B of the aeroplane, on its circular path.



The acceleration of the aeroplane is a.

Derive the expression $a = \dfrac{v^2}{r}$

You should include a vector diagram.

(5)

....

....

....

....

....

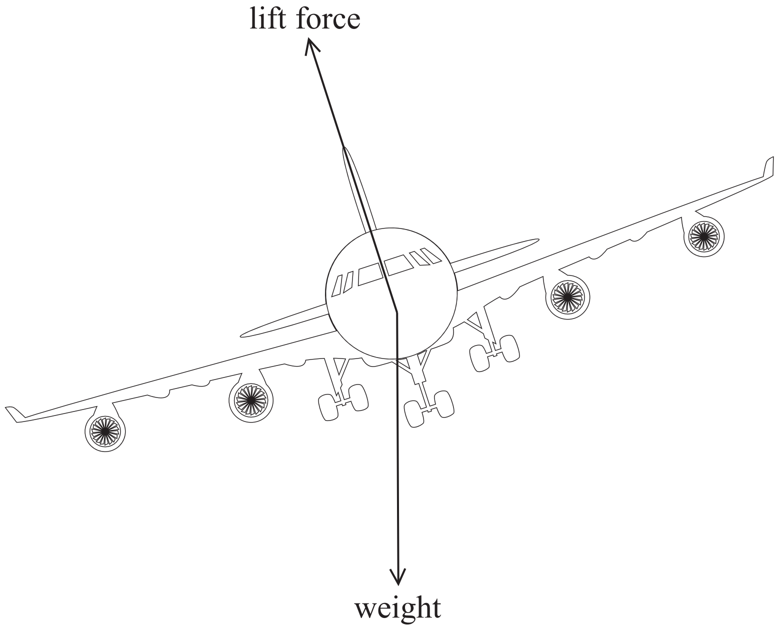
....

....

(b) The aeroplane flies in a horizontal circle by tilting to one side in a movement called 'banking'.

The aeroplane creates an upwards lift force, which acts in a direction perpendicular to its wings.

(i) The diagram shows this lift force when the aeroplane is banking.



(Source: © Nadezda0704/Shutterstock)

Explain how banking allows the aeroplane to fly in a horizontal circular path.

(4)

....

....

....

....

....

....

....

....

(ii) During banking, the angle between the wings and the horizontal is 5.2°.

Calculate the radius of the circular path when the aeroplane flies at a constant speed of $530\,m\,s^{-1}$.

mass of aeroplane = 4.1×10^5 kg

(4)

....

....

....

....

....

....

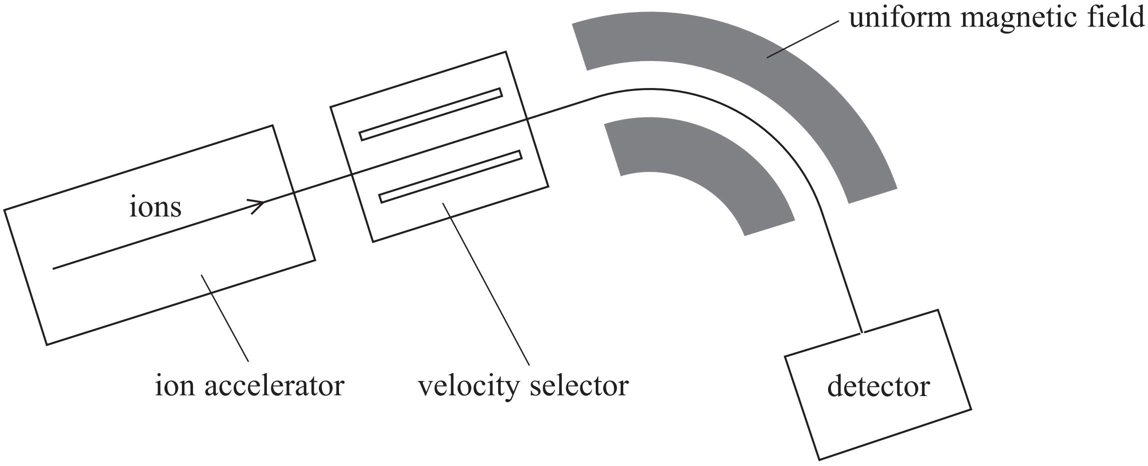
....

Radius = ...

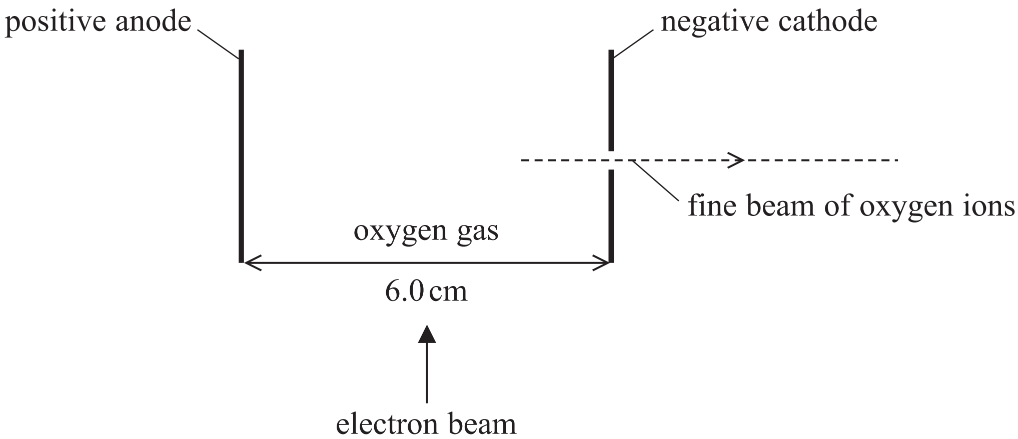
(Total for Question 17 = 13 marks)

18 Mass spectrometry is used to determine the masses of different isotopes of an element.

Atoms of the isotopes are ionised and accelerated. They pass through a velocity selector and into a region with a uniform magnetic field, as shown.



(a) An ion accelerator uses an electron beam to ionise atoms of oxygen gas. The positive ions are then accelerated across a high potential difference between an anode and a cathode, as shown in the diagram below. The cathode has a hole in it so that the accelerated ions may pass in a fine beam to the velocity selector.



(i) The electric field strength between the anode and cathode is $7.5 \times 10^5\,\mathrm{V\,m^{-1}}$.

Calculate the potential difference between the anode and cathode.

(2)

....

....

....

Potential difference = ...

(ii) A stationary oxygen ion is formed half-way between the anode and cathode with a charge of $+1.6 \times 10^{-19}$ C.

Show that the velocity of the ion as it passes through the hole in the cathode is about $5 \times 10^{5}\,\mathrm{m\,s^{-1}}$.

mass of oxygen ion = 2.7×10^{-26} kg

(4)

....

....

....

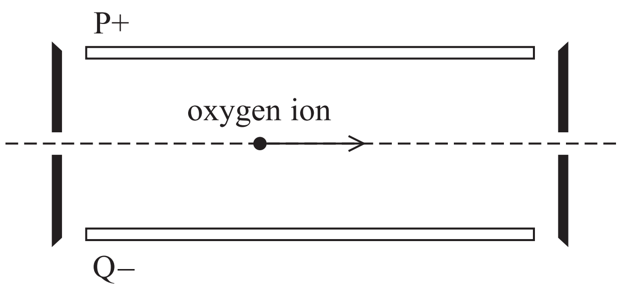
....

....

....

....

(b) Oxygen ions enter the velocity selector with a range of velocities. The velocity selector allows ions with a specific velocity to travel in a straight line, as shown. Plate P is positive and plate Q is negative.



(i) A uniform electric field between the plates acts on an oxygen ion. A uniform magnetic field acts so that the magnetic force on the oxygen ion is in the opposite direction to the electric force.

Explain the direction of the magnetic field.

(2)

....

....

....

....

(ii) The velocity selector is used to produce a beam of oxygen ions travelling in a straight line with a speed of $5.0 \times 10^5 \, m \, s^{-1}$.

Calculate the magnetic flux density of the magnetic field that is required.

electric field strength between plates = $10\,500 \, N \, C^{-1}$

(3)

....

....

....

....

....

....

Magnetic flux density = ...

(c) After passing through the velocity selector, a beam of oxygen ions with the same velocity enters a region of uniform magnetic flux density. Different isotopes of oxygen can be present in the beam.

Explain why the detector will only detect one particular isotope.

(3)

....

....

....

....

....

....

(Total for Question 18 = 14 marks)

TOTAL FOR SECTION B = 80 MARKS
TOTAL FOR PAPER = 90 MARKS

List of data, formulae and relationships

Acceleration of free fall	$g = 9.81 \text{ m s}^{-2}$	(close to Earth's surface)
Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$	
Coulomb's law constant	$k = 1/4\pi\varepsilon_0$	
	$= 8.99 \times 10^{9} \text{ N m}^2 \text{ C}^{-2}$	
Electron charge	$e = -1.60 \times 10^{-19} \text{ C}$	
Electron mass	$m_e = 9.11 \times 10^{-31} \text{ kg}$	
Electronvolt	$1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$	
Gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$	
Gravitational field strength	$g = 9.81 \text{ N kg}^{-1}$	(close to Earth's surface)
Permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$	
Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$	
Proton mass	$m_p = 1.67 \times 10^{-27} \text{ kg}$	
Speed of light in a vacuum	$c = 3.00 \times 10^{8} \text{ m s}^{-1}$	
Stefan-Boltzmann constant	$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$	
Unified atomic mass unit	$u = 1.66 \times 10^{-27} \text{ kg}$	

Unit 1

Mechanics

Kinematic equations of motion

$$s = \frac{(u + v)t}{2}$$

$$v = u + at$$

$$s = ut + \frac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

Forces

$$\Sigma F = ma$$

$$g = \frac{F}{m}$$

$$W = mg$$

Momentum

$$p = mv$$

Moment of force

$$\text{moment} = Fx$$

Work and energy

$$\Delta W = F\Delta s$$

$$E_k = \frac{1}{2}mv^2$$

$$\Delta E_{grav} = mg\Delta h$$

Power

$$P = \frac{E}{t}$$

$$P = \frac{W}{t}$$

Efficiency

$$\text{efficiency} = \frac{\text{useful energy output}}{\text{total energy input}}$$

$$\text{efficiency} = \frac{\text{useful power output}}{\text{total power input}}$$

Materials

Density $\rho = \dfrac{m}{V}$

Stokes' law $F = 6\pi\eta rv$

Hooke's law $\Delta F = k\Delta x$

Elastic strain energy $\Delta E_{el} = \dfrac{1}{2}F\Delta x$

Young modulus $E = \dfrac{\sigma}{\varepsilon}$ where

Stress $\sigma = \dfrac{F}{A}$

Strain $\varepsilon = \dfrac{\Delta x}{x}$

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

P 7 1 8 6 7 A 0 2 6 3 2

Unit 2

Waves

Wave speed $v = f\lambda$

Speed of a transverse wave on a string $v = \sqrt{\frac{T}{\mu}}$

Intensity of radiation $I = \frac{P}{A}$

Refractive index $n_1 \sin\theta_1 = n_2 \sin\theta_2$

$n = \frac{c}{v}$

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

Diffraction grating $n\lambda = d\sin\theta$

Electricity

Potential difference $V = \frac{W}{Q}$

Resistance $R = \frac{V}{I}$

Electrical power, energy $P = VI$

$P = I^2R$

$P = \frac{V^2}{R}$

$W = VIt$

Resistivity $R = \frac{\rho l}{A}$

Current $I = \frac{\Delta Q}{\Delta t}$

$I = nqvA$

Resistors in series $R = R_1 + R_2 + R_3$

Resistors in parallel $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

Particle nature of light

Photon model $E = hf$

Einstein's photoelectric equation $hf = \phi + \frac{1}{2}mv^2_{max}$

de Broglie wavelength $\lambda = \frac{h}{p}$

Unit 4

Further mechanics

Impulse	$F\Delta t = \Delta p$
Kinetic energy of a non-relativistic particle	$E_k = \dfrac{p^2}{2m}$
Motion in a circle	$v = \omega r$
	$T = \dfrac{2\pi}{\omega}$
	$a = \dfrac{v^2}{r}$
	$a = r\omega^2$
Centripetal force	$F = ma = \dfrac{mv^2}{r}$
	$F = mr\omega^2$

Electric and magnetic fields

Electric field	$E = \dfrac{F}{Q}$
Coulomb's law	$F = \dfrac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$
	$E = \dfrac{Q}{4\pi\varepsilon_0 r^2}$
	$E = \dfrac{V}{d}$
Electrical potential	$V = \dfrac{Q}{4\pi\varepsilon_0 r}$
Capacitance	$C = \dfrac{Q}{V}$
Energy stored in capacitor	$W = \dfrac{1}{2}QV$
	$W = \dfrac{1}{2}CV^2$
	$W = \dfrac{1}{2}\dfrac{Q^2}{C}$
Capacitor discharge	$Q = Q_0 e^{-t/RC}$

Resistor-capacitor discharge	$I = I_0 e^{-t/RC}$
	$V = V_0 e^{-t/RC}$
	$\ln Q = \ln Q_0 - \frac{t}{RC}$
	$\ln I = \ln I_0 - \frac{t}{RC}$
	$\ln V = \ln V_0 - \frac{t}{RC}$
In a magnetic field	$F = Bqv \sin \theta$
	$F = BIl \sin \theta$
Faraday's and Lenz's laws	$\mathscr{E} = \frac{-d(N\phi)}{dt}$

Nuclear and particle physics

In a magnetic field	$r = \frac{p}{BQ}$
Mass-energy	$\Delta E = c^2 \Delta m$

BLANK PAGE

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA

BLANK PAGE

P 7 1 8 6 7 A 0 3 1 3 2

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

BLANK PAGE

P 7 1 8 6 7 A 0 3 2 3 2