Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number

Candidate Number

Pearson Edexcel International Advanced Level

Wednesday 23 October 2024

Morning (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

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 An electron gun produces a beam of electrons in a vacuum tube. The electrons are released from a metal filament using a current.

Which of the following causes electrons to be released from the filament?

☒ **A** beta decay

☒ **B** excitation

☒ **C** photoelectric effect

☒ **D** thermionic emission

(Total for Question 1 = 1 mark)

---

2 Which of the following is **not** the unit of a vector quantity?

☒ **A** $\mathrm{kg\,m^{-3}}$

☒ **B** $\mathrm{m\,s^{-2}}$

☒ **C** $\mathrm{N\,C^{-1}}$

☒ **D** $\mathrm{N\,s}$

(Total for Question 2 = 1 mark)

---

3 Which row of the table shows a fundamental particle and a non-fundamental particle?

		Fundamental	Non-fundamental
☒	**A**	alpha	neutron
☒	**B**	lepton	meson
☒	**C**	proton	electron
☒	**D**	quark	muon

(Total for Question 3 = 1 mark)

---

4 The isotope $^{222}_{86}\text{Rn}$ decays by emitting an alpha particle.

Which of the following shows the nucleons in the isotope produced by this decay?

☒ **A** 134 neutrons, 84 protons

☒ **B** 136 neutrons, 82 protons

☒ **C** 218 neutrons, 84 protons

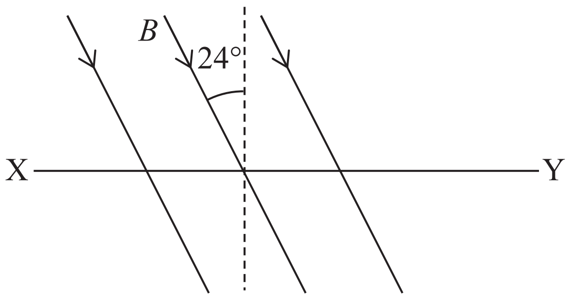
☒ **D** 220 neutrons, 82 protons

(Total for Question 4 = 1 mark)

5 An electron is travelling horizontally at velocity *v* through a uniform magnetic field of magnetic flux density *B*.

The magnetic field is at an angle of 24° to the vertical, as shown.

Not to scale



There is a force *F* acting on the electron due to the magnetic field. The force *F* is acting into the page.

Which row of the table gives the magnitude and direction of *v*?

		Magnitude of *v*	Direction of *v*
☒	**A**	$\frac{F}{B \times e \times \sin 24°}$	from X to Y
☒	**B**	$\frac{F}{B \times e \times \sin 24°}$	from Y to X
☒	**C**	$\frac{F}{B \times e \times \sin 66°}$	from X to Y
☒	**D**	$\frac{F}{B \times e \times \sin 66°}$	from Y to X

(Total for Question 5 = 1 mark)

6 An electron has a kinetic energy of 3.5×10^{-28} J.

Which of the following gives the momentum of the electron in kg m s^{-1}?

☒ **A** $\dfrac{(3.5 \times 10^{-28})^2}{2 \times 9.11 \times 10^{-31}}$

☒ **B** $\dfrac{(9.11 \times 10^{-31})^2}{2 \times 3.5 \times 10^{-28}}$

☒ **C** $\sqrt{2 \times 1.6 \times 10^{-19} \times 3.5 \times 10^{-28}}$

☒ **D** $\sqrt{2 \times 9.11 \times 10^{-31} \times 3.5 \times 10^{-28}}$

(Total for Question 6 = 1 mark)

7 A moving trolley collides with a stationary trolley and they move off together.

Frictional forces are negligible and the collision is inelastic.

Which row of the table shows what happens to the total momentum and to the total kinetic energy in the collision?

		Total momentum	Total kinetic energy
☒	**A**	conserved	conserved
☒	**B**	conserved	not conserved
☒	**C**	not conserved	conserved
☒	**D**	not conserved	not conserved

(Total for Question 7 = 1 mark)

8 Cyclotrons accelerate charged particles to high speeds. Cyclotrons use electric fields and magnetic fields.

Which of the following statements is **not** correct?

☒ **A** The magnetic field is at right angles to the velocity of the particles.

☒ **B** The magnetic fields in the dees keep the particles following circular paths.

☒ **C** The particles are accelerated by electric fields between the dees.

☒ **D** The particles are accelerated by electric fields inside the dees.

(Total for Question 8 = 1 mark)

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

9 Scientists in the early twentieth century directed beams of alpha particles at thin metal foils.

Which of the following conclusions were they able to make from their observations?

☒ **A** All of the charge of the atom is concentrated in a small volume in the atom.

☒ **B** Most of the mass of the atom is concentrated in a small volume in the atom.

☒ **C** The electrons orbit the centre of the atom in specific energy levels.

☒ **D** There is a nucleus made of protons and neutrons.

(Total for Question 9 = 1 mark)

10 A proton and an anti-proton travel in opposite directions towards each other.

Each particle has energy of 450 GeV.

When the particles collide, they annihilate and create a particle-antiparticle pair.

Which of the following expressions gives the maximum mass, in kg, of the antiparticle produced?

☒ **A** $\dfrac{450 \times 10^{6} \times 1.6 \times 10^{-19}}{2 \times (3.00 \times 10^{8})^{2}}$

☒ **B** $\dfrac{450 \times 10^{6} \times 1.6 \times 10^{-19}}{(3.00 \times 10^{8})^{2}}$

☒ **C** $\dfrac{450 \times 10^{9} \times 1.6 \times 10^{-19}}{(3.00 \times 10^{8})^{2}}$

☒ **D** $\dfrac{2 \times 450 \times 10^{9} \times 1.6 \times 10^{-19}}{(3.00 \times 10^{8})^{2}}$

(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

SECTION B

Answer ALL questions in the spaces provided.

11 In 2021 scientists identified Amaterasu, the second most energetic cosmic ray particle ever detected on Earth.

Amaterasu had an energy of 2.4×10^{20} eV. A newspaper article stated that this energy was equivalent to dropping a brick from waist height.

Deduce whether the newspaper article was correct.

mass of brick = 2.8 kg
waist height = 1.1 m

....

....

....

....

....

....

(Total for Question 11 = 3 marks)

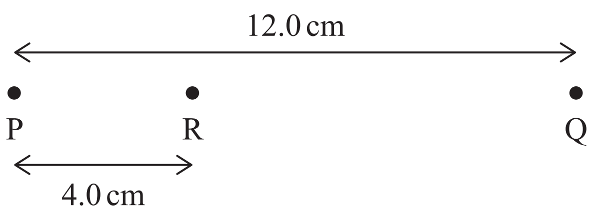
DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA

12 The diagram represents a positive point charge.

(a) Draw field lines to show the electric field around the charge.

(3)

(b) The positive point charge is placed at P. A negative point charge is placed at Q, as shown below.



R is 4.0 cm from P, as shown.

Calculate the magnitude of the electric field strength at R.

charge at P = +14 nC
charge at Q = –14 nC

(3)

....

....

....

....

....

Magnitude of electric field strength = ...

(Total for Question 12 = 6 marks)

13 In some particle interactions in the atmosphere, muons are produced with speeds near the speed of light.

Muons have a typical lifetime of 2.20 μs.

(a) A muon is travelling at 98.0% of the speed of light.

Show that the distance travelled by the muon in 2.20 μs is about 650 m.

(2)

....

....

....

....

(b) Some muons are produced 15 000 m above the ground and travel vertically downwards.

Explain why most of these muons reach the ground before decaying.

(3)

....

....

....

....

....

....

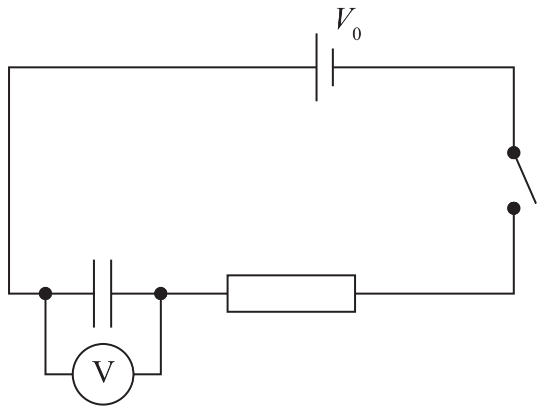
(Total for Question 13 = 5 marks)

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

BLANK PAGE

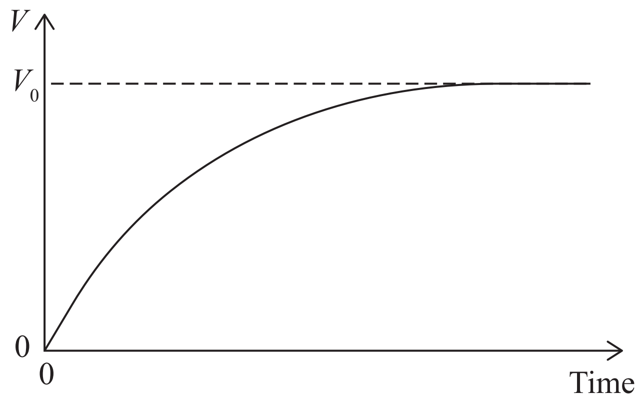
***14** The diagram shows a circuit with a cell of potential difference (p.d.) V_0 in series with a capacitor, a resistor and a switch.

A voltmeter measures the potential difference V across the capacitor.



The capacitor is initially uncharged.

The switch is then closed and the following graph is obtained.



Explain the variation of V with time as shown in the graph.

You should refer to the charge on the capacitor and the current in the circuit.

....

....

....

....

....

....

....

....

....

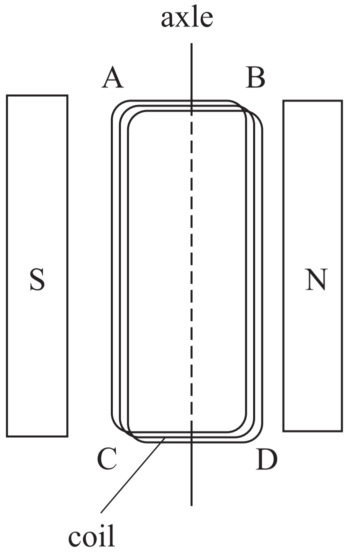
....

....

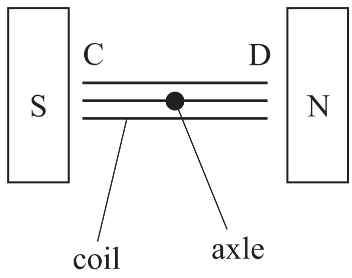
....

(Total for Question 14 = 6 marks)

15 A student mounts a coil of wire on an axle. She places the coil between the north and south poles of two magnets to make a simple electric motor, as shown.



View from above



View from end

(a) The student connects the ends of the coil to a power supply. There is a current in the coil in the direction ABDC and the coil rotates.

(i) Explain why the coil rotates in the clockwise direction when viewed from the end, as shown above.

(2)

....

....

....

....

....

....

(ii) Calculate the resultant moment, about the axle, of the magnetic forces acting on the coil.

length of coil, BD = 5.0 cm
width of coil, DC = 3.5 cm
magnetic flux density = 0.68 T
number of turns on coil = 32
current in coil = 0.24 A

(3)

....

....

....

....

....

....

Moment = ...

(b) The student disconnects the motor from the power supply. She connects a sensitive voltmeter across the coil.

(i) She pushes one side of the coil down quickly, so that the coil starts to rotate.

Explain why a reading may be shown on the sensitive voltmeter.

(2)

....

....

....

....

(ii) The student replaces the sensitive voltmeter with a different voltmeter, with a resolution of 0.1 V.

The coil makes one quarter of a turn, from a horizontal position to a vertical position.

Deduce whether this movement of the coil will produce a reading on the voltmeter.

time for one quarter of a turn = 0.080 s
length of coil, BD = 5.0 cm
width of coil, DC = 3.5 cm
magnetic flux density = 0.68 T
number of turns on coil = 32

(5)

....

....

....

....

....

....

....

....

....

....

(Total for Question 15 = 12 marks)

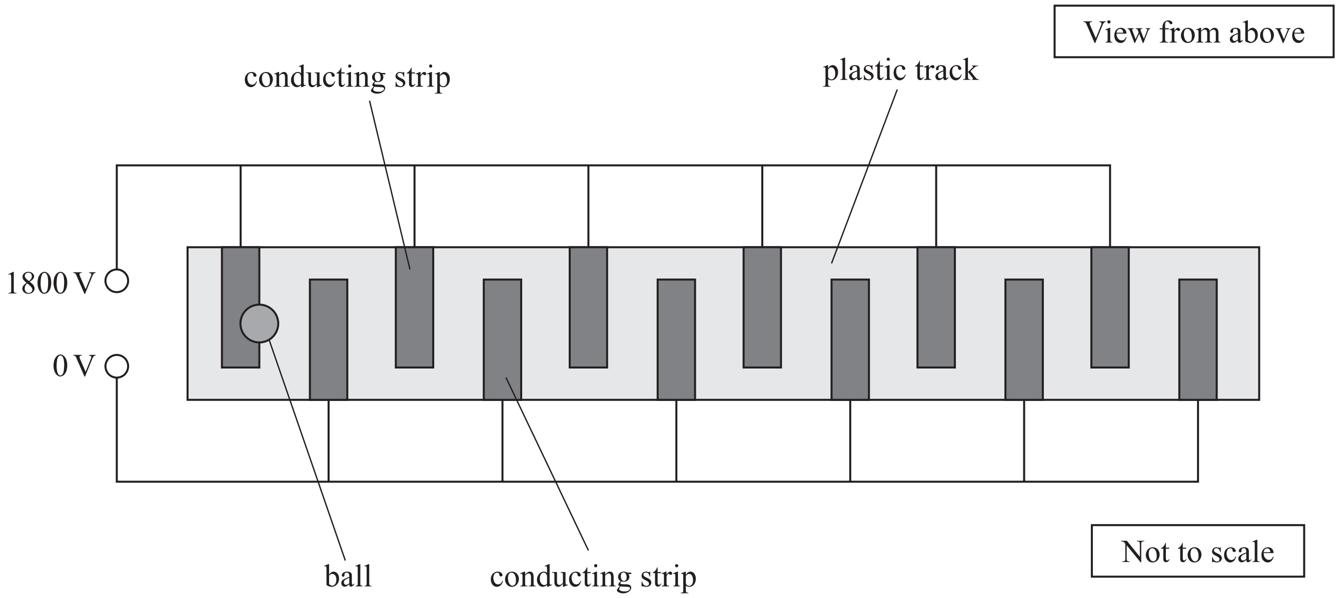
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

BLANK PAGE

16 The diagram shows some equipment used by a teacher to demonstrate the action of electric fields.

A long white plastic track has strips of conducting material attached to it. The strips on one side of the track are connected to a potential of 1800 V. The strips on the other side are connected to a potential of 0 V.

A ball with a conducting surface can be accelerated along the track.



(a) The teacher places the ball on the first strip. The teacher switches on the power supply and the ball accelerates.

The size of the gap between the strips is 2.0 cm.

(i) The ball accelerates uniformly across the gap between the first strip and the second strip in 0.22 s.

Show that the acceleration of the ball is about $0.8\,\mathrm{m\,s^{-2}}$.

(2)

....

....

....

....

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

P 7 8 3 9 9 A 0 1 6 3 2

(ii) When placed on the first strip, the ball is charged to a potential of 1800 V.

Show that the charge on the ball is about 2×10^{-9} C.

radius of ball = 0.95 cm

(2)

....

....

....

....

(iii) There is a force on the ball due to the uniform electric field between the strips.

Deduce whether this is the only force acting to accelerate the ball at about $0.8\,\text{m}\,\text{s}^{-2}$.

mass of ball = 0.18 g

(4)

....

....

....

....

....

....

....

....

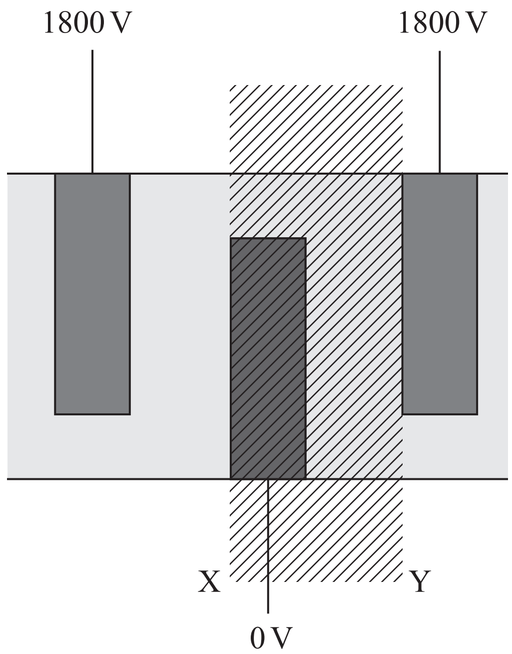
(b) The equipment can be used as a model to demonstrate the acceleration of charged particles in a linac.

When placed on the first strip, the ball is charged to a potential of 1800 V. The ball then accelerates towards the next strip at 0 V, where it discharges.

The ball then moves at constant speed to the next 1800 V strip. The ball is charged again and accelerates to the next 0 V strip.

This pattern of movement continues until the ball reaches the end of the track.

The diagram shows part of the model.



(i) The shaded section of the diagram between X and Y corresponds to the drift tube in a linac.

Give **one** similarity and **two** differences in the way this section of the model works and the way a drift tube in a linac works.

(3)

....

....

....

....

....

....

(ii) In the model, the lengths corresponding to drift tubes are constant.

Explain why the lengths of the drift tubes in a linac are not constant.

(3)

....

....

....

....

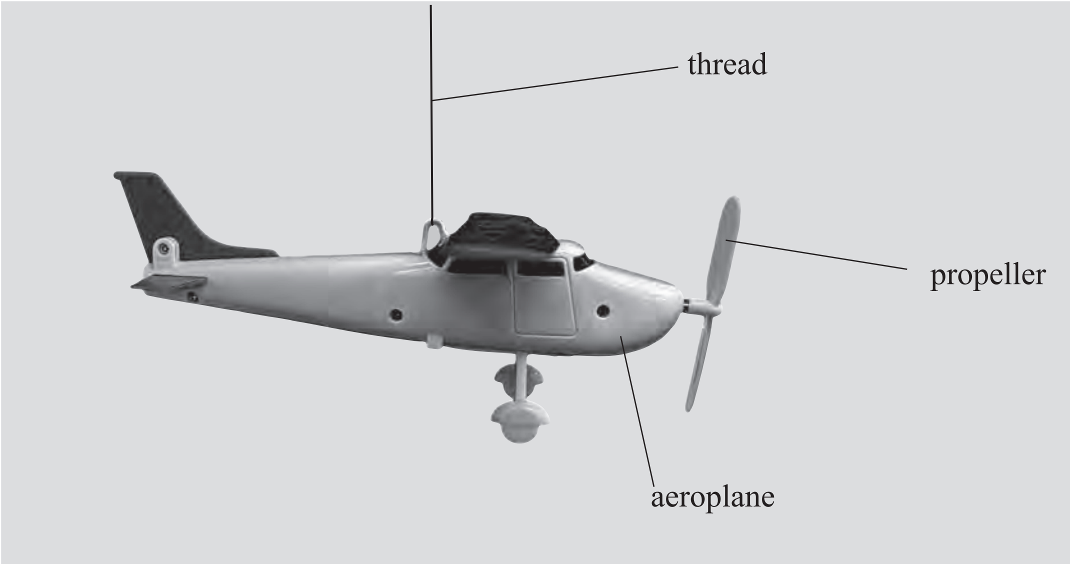
....

....

(Total for Question 16 = 14 marks)

BLANK PAGE

17 The photograph shows a toy aeroplane suspended from a fixed point by a thread.



(a) The toy aeroplane has a motor that turns a propeller.

As the propeller rotates, it sweeps out a circle of radius 4.1 cm. The propeller pushes air backwards at a speed of 2.4 m s^{-1}.

(i) Show that the propeller pushes a mass of air of about 3×10^{-3} kg backwards in a time of 0.20 s.

density of air = 1.3 kg m^{-3}

(5)

....

....

....

....

....

....

....

....

....

....

(ii) Determine the momentum of the air pushed backwards by the propeller in a time of 0.20 s.

(2)

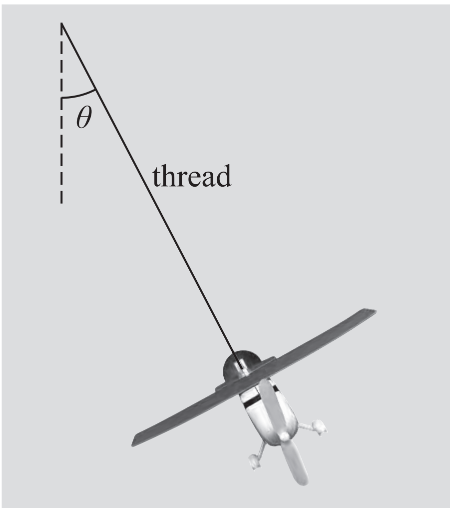
Momentum = ...

(iii) Determine the forwards force exerted on the aeroplane by the action of the propeller.

(2)

Force = ...

(b) The toy aeroplane moves in a horizontal circular path of radius r at constant speed v. The thread is at an angle θ to the vertical, as shown.



(i) The forwards and backwards forces on the toy aeroplane are equal in magnitude.

Add to the diagram to show the other forces acting on the toy aeroplane.

(2)

P 7 8 3 9 9 A 0 2 2 3 2

(ii) Show that the angle θ of the thread to the vertical is given by

$$\tan\theta = \frac{v^2}{rg}$$

(3)

....

....

....

....

....

....

....

....

(iii) Calculate the time taken for the toy aeroplane to complete one revolution.

$\theta = 22°$
$r = 21\,\text{cm}$

(3)

....

....

....

....

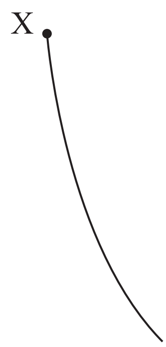
....

....

Time = ...

(Total for Question 17 = 17 marks)

18 The diagram shows the track of a Σ^+ particle in a bubble chamber. The particle decays at point X.



There is a magnetic field of magnetic flux density B perpendicular to the velocity of the particle.

(a) The Σ^+ particle is following a circular path of radius 1.99 m.

Calculate the value of B.

momentum of Σ^+ particle = 3.67×10^{-19} kg m s^{-1}

(2)

....

....

....

B = ...

(b) The equation shows the decay of the Σ^+ particle.

$$\Sigma^+ \rightarrow \pi^+ + n$$

(i) The Σ^+ particle is made of two up quarks and one strange quark.

State what type of particle Σ^+ is.

(1)

....

(ii) Deduce whether the conservation of charge and the conservation of lepton number apply to this decay.

(4)

....

....

....

....

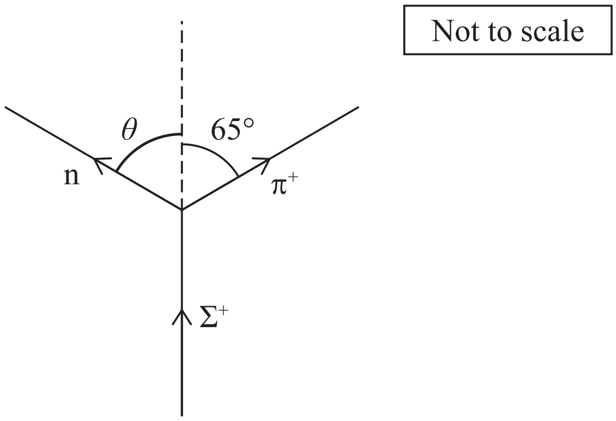
....

....

....

....

(iii) The diagram shows the directions of the three particles involved in the decay.



Determine the magnitude and direction of the momentum of the neutron.

momentum of Σ^+ particle = $3.67 \times 10^{-19}\,\text{kg m s}^{-1}$
magnitude of momentum of π^+ = $1.07 \times 10^{-19}\,\text{kg m s}^{-1}$

(6)

....

....

....

....

....

....

....

....

....

....

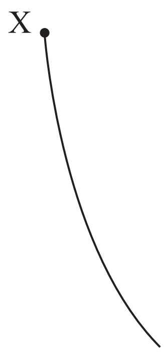
....

....

Magnitude of momentum = ...

Direction of momentum = ...

(iv) The diagram shows the track of the Σ^+ particle in the bubble chamber.



Add to the diagram to show all tracks visible in the bubble chamber after the decay at X.

You should label your diagram.

(4)

(Total for Question 18 = 17 marks)

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

P 7 8 3 9 9 A 0 2 7 3 2

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 $F = 6\pi\eta r v$

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

Unit 2

Waves

Wave speed	$v = f\lambda$
Speed of a transverse wave on a string	$v = \sqrt{\dfrac{T}{\mu}}$
Intensity of radiation	$I = \dfrac{P}{A}$
Refractive index	$n_1 \sin\theta_1 = n_2 \sin\theta_2$
	$n = \dfrac{c}{v}$
Critical angle	$\sin C = \dfrac{1}{n}$
Diffraction grating	$n\lambda = d\sin\theta$

Electricity

Potential difference	$V = \dfrac{W}{Q}$
Resistance	$R = \dfrac{V}{I}$
Electrical power, energy	$P = VI$
	$P = I^2R$
	$P = \dfrac{V^2}{R}$
	$W = VIt$
Resistivity	$R = \dfrac{\rho l}{A}$
Current	$I = \dfrac{\Delta Q}{\Delta t}$
	$I = nqvA$
Resistors in series	$R = R_1 + R_2 + R_3$
Resistors in parallel	$\dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3}$

Particle nature of light

Photon model	$E = hf$
Einstein's photoelectric equation	$hf = \phi + \frac{1}{2}mv^2_{\max}$
de Broglie wavelength	$\lambda = \dfrac{h}{p}$

Unit 4

Further mechanics

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

Electric and magnetic fields

Electric field	$E = \frac{F}{Q}$
Coulomb's law	$F = \frac{Q_1Q_2}{4\pi\varepsilon_0 r^2}$
	$E = \frac{Q}{4\pi\varepsilon_0 r^2}$
	$E = \frac{V}{d}$
Electrical potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
Capacitance	$C = \frac{Q}{V}$
Energy stored in capacitor	$W = \frac{1}{2}QV$
	$W = \frac{1}{2}CV^2$
	$W = \frac{1}{2}\frac{Q^2}{C}$
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 $\mathscr{E} = \frac{-\mathrm{d}(N\phi)}{\mathrm{d}t}$

Nuclear and particle physics

In a magnetic field $r = \frac{p}{BQ}$

Mass-energy $\Delta E = c^2 \Delta m$

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