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.
- **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 of the following is a fundamental particle?

☐ **A** pion

☐ **B** proton

☐ **C** neutrino

☐ **D** neutron

(Total for Question 1 = 1 mark)

---

2 A proton collides with an antiproton.

Which of the following could be produced by this collision?

☐ **A** $\pi^{+} + n$

☐ **B** $\pi^{-} + p^{+}$

☐ **C** $\pi^{+} + e^{-}$

☐ **D** $\pi^{+} + \pi^{-}$

(Total for Question 2 = 1 mark)

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3 When the potential difference across a capacitor is V, the energy stored by the capacitor is W.

Which of the following gives the energy stored by the capacitor when the potential difference across the capacitor is $2V$?

☐ **A** W

☐ **B** $2W$

☐ **C** $3W$

☐ **D** $4W$

(Total for Question 3 = 1 mark)

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4 Two equally-charged ions exert a force of 4.0×10^{-9} N on each other. The distance between the centres of the ions is 2.4×10^{-10} m.

Which of the following is equal to the charge on each ion?

☒ **A** $\sqrt{\dfrac{4.0 \times 10^{-9} \times (2.4 \times 10^{-10})^2}{8.99 \times 10^9}}$

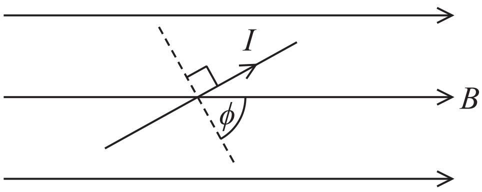
☒ **B** $\sqrt{\dfrac{4.0 \times 10^{-9} \times (2.4 \times 10^{-10})^2}{4 \times \pi \times 8.85 \times 10^{-12}}}$

☒ **C** $\dfrac{4.0 \times 10^{-9} \times (2.4 \times 10^{-10})^2}{8.99 \times 10^9}$

☒ **D** $\dfrac{4.0 \times 10^{-9} \times (2.4 \times 10^{-10})^2}{4 \times \pi \times 8.85 \times 10^{-12}}$

(Total for Question 4 = 1 mark)

5 A wire is in the same plane as a magnetic field of magnetic flux density B as shown. The wire is of length l and carries a current I.



Which row of the table gives the magnitude and direction of the force on the wire?

	Magnitude	Direction
☒ **A**	$BIl \cos \phi$	into page
☒ **B**	$BIl \cos \phi$	out of page
☒ **C**	$BIl \sin \phi$	into page
☒ **D**	$BIl \sin \phi$	out of page

(Total for Question 5 = 1 mark)

6 Electrons can be used to probe the nuclei of atoms.

Which of the following best explains this?

☒ **A** Electrons can be accelerated to very high energies.

☒ **B** Electrons can be deflected by a magnetic field.

☒ **C** Electrons can be part of an atom.

☒ **D** Electrons can be released by thermionic emission.

(Total for Question 6 = 1 mark)

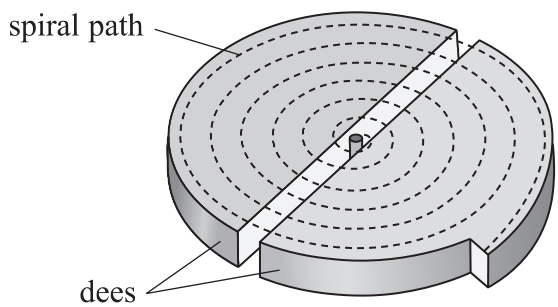
7 Muons can travel at speeds close to the speed of light. At these speeds the lifetime and mass of a muon are different from those of a stationary muon.

Which row of the table describes the lifetime and the mass of a high-speed muon compared to a stationary muon?

		Lifetime	Mass
☒	**A**	shorter	smaller
☒	**B**	shorter	larger
☒	**C**	longer	smaller
☒	**D**	longer	larger

(Total for Question 7 = 1 mark)

8 In a cyclotron, a charged particle is accelerated in a spiral path.



Which of the following increases as the radius of the spiral path increases?

☒ **A** The frequency of the alternating p.d. across the dees.

☒ **B** The magnetic flux density acting perpendicularly to the spiral path.

☒ **C** The potential difference between the dees.

☒ **D** The velocity of the charged particles.

(Total for Question 8 = 1 mark)

9 Which of the following units is equivalent to the farad?

☒ **A** $\mathrm{C\,V^{-1}}$

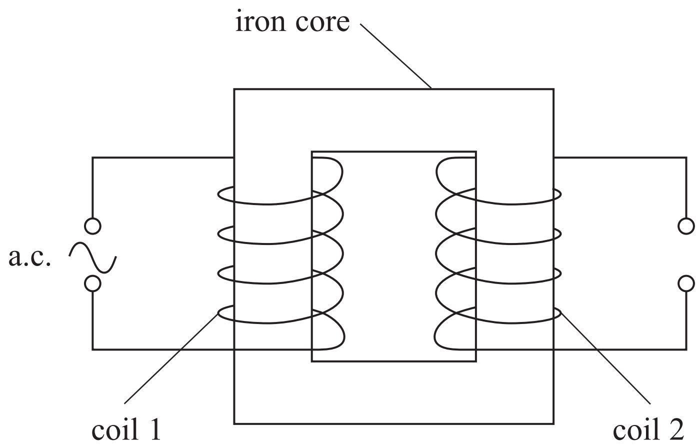
☒ **B** $\mathrm{J\,V^{-1}}$

☒ **C** $\Omega\,\mathrm{s^{-1}}$

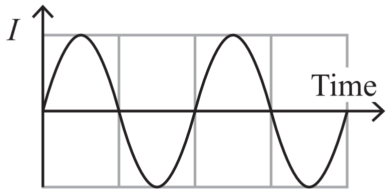
☒ **D** $\mathrm{s\,J^{-1}}$

(Total for Question 9 = 1 mark)

10 Two coils are linked by an iron core as shown. Coil 1 carries an alternating current *I*.

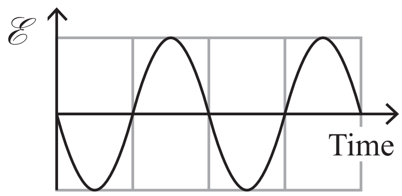


The graph shows the variation of *I* with time for two complete cycles.

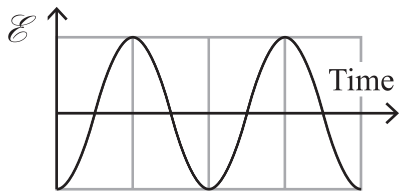


Which of the following graphs gives the corresponding induced e.m.f. $\mathscr{E}$ across coil 2?

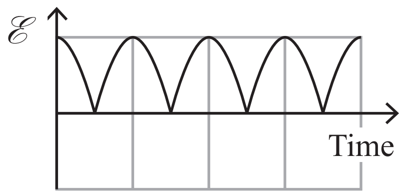
☒ **A**



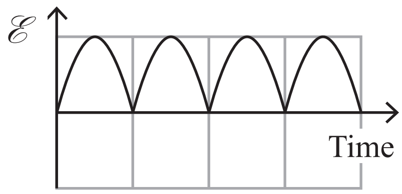
☒ **B**



☒ **C**



☒ **D**



(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

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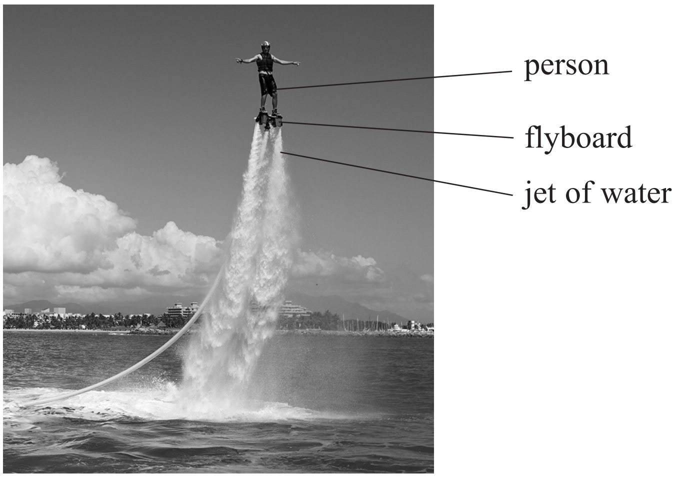
SECTION B

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

11 A flyboard enables a person to hover at a constant height above the sea as shown. Water is constantly pumped up to the flyboard in a thick pipe. A jet of water is then forced downwards, causing an upwards force on the flyboard.



(Source: © Justin Lewis/Getty Images)

Calculate the velocity of the jet of water as it leaves the flyboard. Assume the water has negligible velocity before it leaves the flyboard.

mass of person and flyboard equipment = 175 kg
mass flow rate of water = 114 kg s^{-1}

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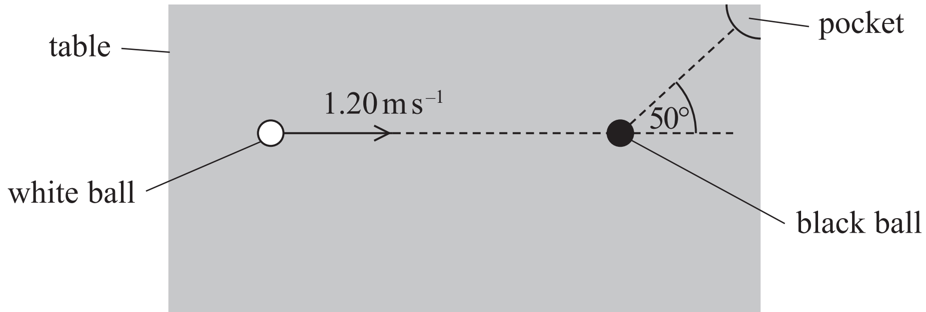
Velocity of water jet = ...

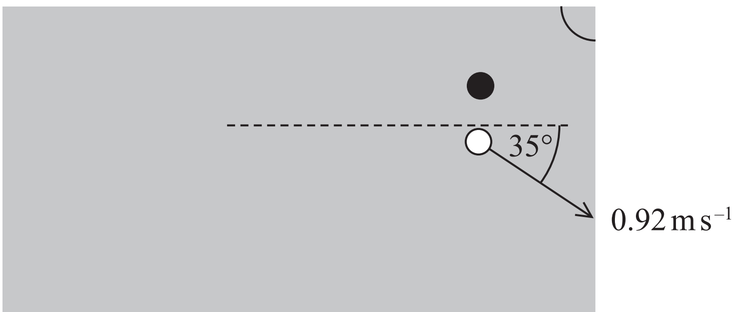
(Total for Question 11 = 3 marks)

12 In a game of snooker, a white ball and a black ball of equal mass are on a horizontal table. A player hits the white ball which then moves with a velocity of $1.20\,m\,s^{-1}$ before colliding with the black ball. The player hopes that the collision will knock the black ball towards the pocket at the corner of the table as shown.

Plan view



After the collision, the velocity of the white ball was at 35° to its original path, as shown below.



(a) This collision was inelastic.

State what is meant by inelastic.

(1)

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(b) For this situation, a scaled vector diagram showing the velocities of the balls can be used to demonstrate the law of conservation of momentum.

Explain why.

(2)

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(c) Deduce whether the black ball moves towards the pocket. You should use a scaled vector diagram.

(5)

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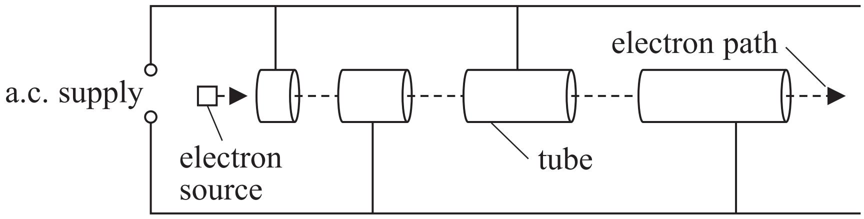
(Total for Question 12 = 8 marks)

13 Some particle physics experiments use electrons which are accelerated to very high energies by a linac. The diagram shows the first section of the linac.



*(a) Explain why the distances between consecutive tubes increase in the first section of the linac but are almost equally spaced in the last section of the linac.

(6)

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(b) In some experiments, a high-energy electron collides with a stationary atom. In other experiments beams of high-energy electrons, travelling in opposite directions, collide head-on. New particles can be created from collisions.

Deduce which type of collision is more likely to produce new particles with the largest mass.

(3)

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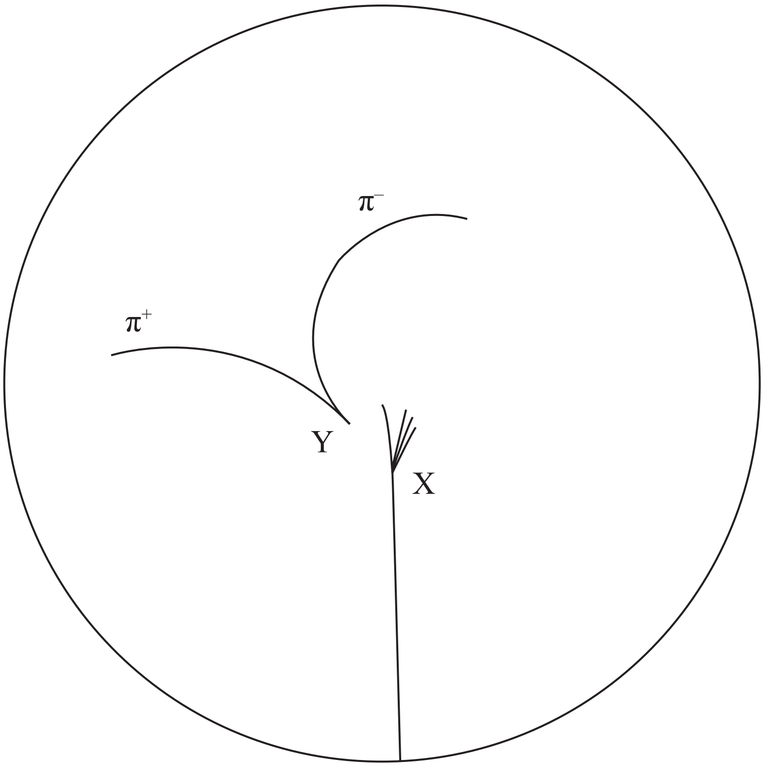
(Total for Question 13 = 9 marks)

14 The diagram shows the paths of particles in a circular particle detector. There is a magnetic field acting at right angles to the plane of the paper. The diagram is drawn to scale. 1 cm on the diagram represents 10 cm in the particle detector.

An antiproton enters the detector and collides with a stationary proton at X. Several particles are produced. One particle is a kaon (K^0). The kaon then decays into two pions (π^+ and π^-) at Y.



(a) Determine the momentum of the negative pion.

magnetic flux density of field in the detector = 7.0 T

(4)

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Momentum = ...

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(b) State two ways that the diagram shows the kaon is neutral.

(2)

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(c) The table shows the charge for the up quark and the down quark as a fraction of the charge on the proton.

Quark	**Charge**
u	+2/3
d	–1/3

Deduce the quark structure of the antiproton and the negative pion.

(2)

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Quark structure of the antiproton ....

Quark structure of the negative pion ....

(d) Calculate the mass of a proton in GeV/c^2.

(3)

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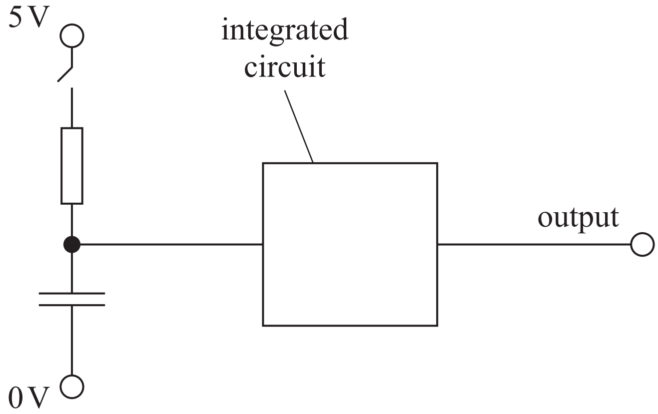
Mass = ... GeV/c^2

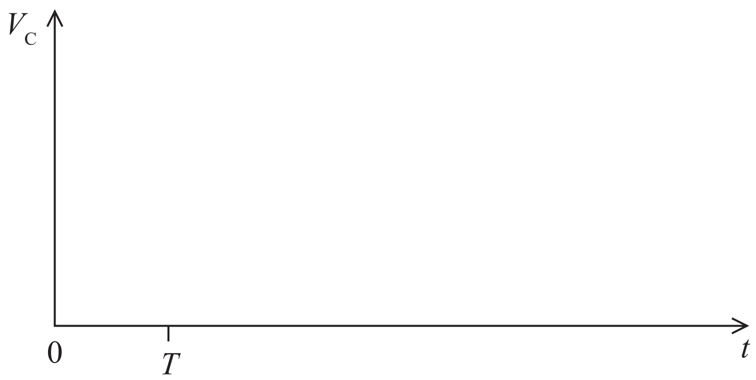
(Total for Question 14 = 11 marks)

15 A resistor-capacitor circuit provides an input for an integrated circuit as shown. The integrated circuit can be assumed to have infinite resistance.



(a) (i) Sketch a graph to show how the potential difference V_C across the capacitor varies with time t as the switch is closed. The time constant T for this circuit is marked on the time axis.

(2)



(ii) Explain how the potential difference V_R across the resistor varies with time after the switch is closed.

(2)

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P 7 0 9 7 1 A 0 1 4 2 8

(iii) Show that V_C is given by the equation

$$V_C = 5 - 5e^{-\frac{t}{RC}}$$

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

(2)

(b) The input to the integrated circuit should be 3.3 V at a time 3.5 seconds after the switch is closed.

The following capacitors are available:

4.7 μF   10 μF   15 μF   47 μF   150 μF

Deduce which capacitor should be used.

$R = 68\,\text{k}\Omega$

(3)

(Total for Question 15 = 9 marks)

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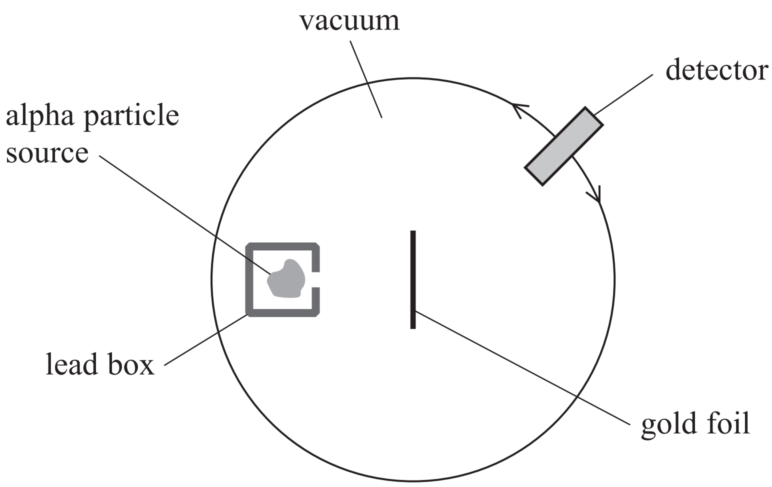
16 In the early 20th century, experiments were carried out in which alpha particles were directed towards thin gold foil.

A simplified diagram of the apparatus used is shown.



(a) State three observations and the corresponding conclusions made from the alpha particle scattering experiment.

(6)

(b) One experiment used gold foil made from the gold isotope ${}^{197}_{79}Au$. The alpha particles had an initial kinetic energy of 4.7 MeV.

(i) Show that the closest distance these alpha particles can get to a gold nucleus is about 5×10^{-14} m.

(4)

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(ii) Calculate the strength of the electric field due to the gold nucleus at this distance.

(3)

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Strength of electric field = ...

(Total for Question 16 = 13 marks)

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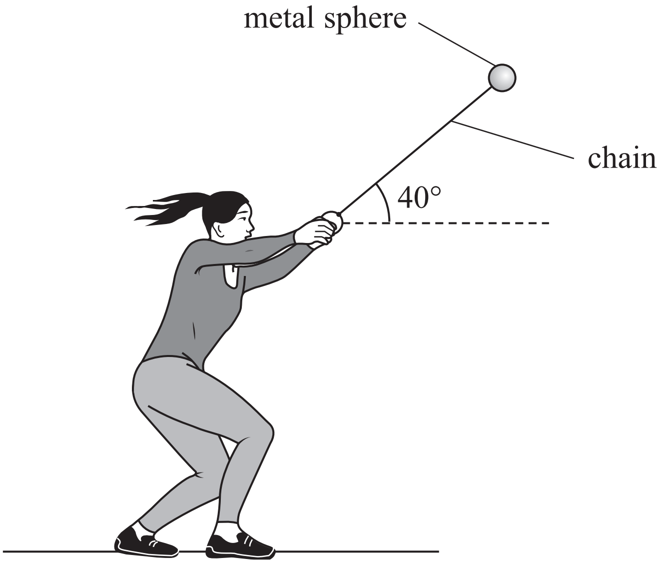
17 Hammer throwing is an Olympic sport. A hammer is a metal sphere attached to a chain. An athlete holds the chain and spins around so that the sphere moves in a circle. The chain is inclined at 40° to the horizontal, as shown.



(a) (i) The tension in the chain, acting on the sphere, is T.

Draw the free-body force diagram for the sphere at the position shown in the diagram.

(2)

(ii) Explain why the sphere moves with circular motion.

(2)

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(iii) The sphere completes 2.8 revolutions per second.

Calculate the acceleration of the sphere.

distance from sphere to centre of circle = 1.5 m

(3)

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Acceleration = ...

(b) The athlete finally releases the sphere with a velocity of $28\,\mathrm{m\,s^{-1}}$ at an angle of 40° to the horizontal. She releases the sphere at a height of 1.5 m above the ground.

The women's Olympic record distance for the hammer throw is 83 m.

Deduce whether this throw would break the record.

(5)

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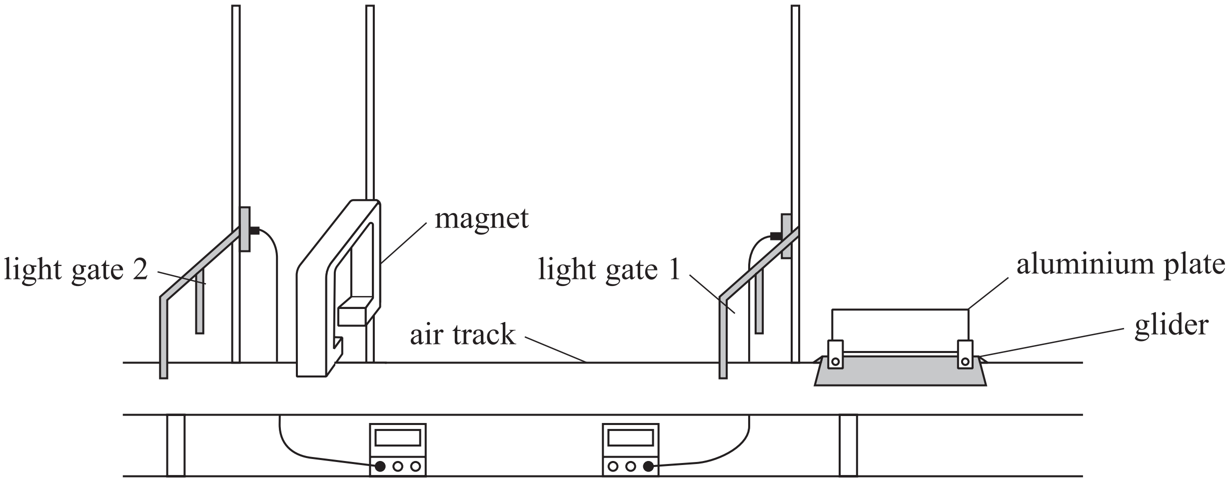
(Total for Question 17 = 12 marks)

18 A student investigated electromagnetic braking using the apparatus shown.

A vehicle consisting of a glider and aluminium plate was placed on an air track. A powerful magnet was positioned between the two light gates so that the aluminium plate could pass between the poles of the magnet. The air resistance on the vehicle was negligible.



(a) (i) The vehicle was given a push. The aluminium plate took 0.19 s to pass through light gate 1.

Show that the momentum of the vehicle was about 0.3 N s.

length of plate = 15.0 cm
mass of vehicle = 0.40 kg

(3)

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(ii) The vehicle then moved between the poles of the magnet before passing through light gate 2.

The magnet caused the kinetic energy of the vehicle to reduce by 10%.

Calculate the velocity of the vehicle at light gate 2.

(3)

Velocity = ...

(b) (i) Explain why a current was produced in the aluminium plate as it passed between the poles of the magnet.

(2)

(ii) The kinetic energy of the vehicle decreased as the aluminium plate moved between the poles of the magnet.

Explain why.

(2)

(c) The investigation was repeated using different aluminium plates with the same length but different thicknesses. The vehicle was given the same approximate initial velocity each time. The table shows the thickness of each aluminium plate and the corresponding percentage reduction in the kinetic energy of the vehicle.

	Thickness / mm	**Percentage reduction in kinetic energy**
Initial plate	0.50	10
Second plate	0.80	16
Third plate	1.1	22

(i) Show that the percentage reduction in kinetic energy is proportional to the thickness of the plate.

(2)

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(ii) Suggest why the percentage reduction in kinetic energy increases as the thickness of the plate increases.

(3)

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(Total for Question 18 = 15 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 $\rho = \frac{m}{V}$

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

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

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

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

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

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

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	$F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$
	$E = \frac{Q}{4\pi\varepsilon_0 r^2}$
	$E = \frac{V}{d}$
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 $\mathscr{E} = \frac{-d(N\phi)}{dt}$

Nuclear and particle physics

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

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

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