Write your name here

Surname	Other names

Pearson Edexcel GCE

Centre Number | Candidate Number

Physics

Advanced
Unit 4: Physics on the Move

Thursday 15 June 2017 – Morning
Time: 1 hour 35 minutes

Paper Reference
6PH04/01

You must have:
Ruler

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.*

Information

- The total mark for this paper is 80.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- Questions labelled with an **asterisk** (*) are ones where the quality of your written communication will be assessed – *you should take particular care with your spelling, punctuation and grammar, as well as the clarity of expression, on these questions.*
- The list of data, formulae and relationships is printed at the end of this booklet.
- Candidates may use a scientific calculator.

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 ▶

1/1/1/1/1/1/

Pearson

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 scalar quantity?

☒ **A** centripetal force

☒ **B** electric field strength

☒ **C** magnetic flux density

☒ **D** work done

(Total for Question 1 = 1 mark)

2 A demonstration uses a beam of electrons in an evacuated tube. The electrons for the beam are produced by heating a metal filament.

This process is called

☒ **A** excitation.

☒ **B** ionisation.

☒ **C** the photoelectric effect.

☒ **D** thermionic emission.

(Total for Question 2 = 1 mark)

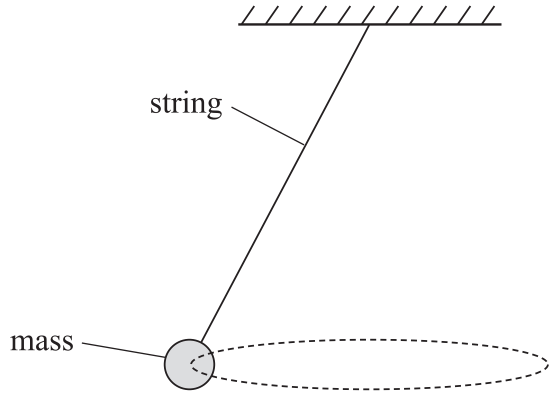
3 When particles approach the speed of light we observe effects on their mass and decay time due to relativity.

Which row of the table correctly describes these effects as seen by an observer?

		Mass of particle	Decay time of particle
☒	**A**	decreased	decreased
☒	**B**	decreased	increased
☒	**C**	increased	decreased
☒	**D**	increased	increased

(Total for Question 3 = 1 mark)

Questions 4 and 5 refer to a conical pendulum as shown in the diagram.



The mass rotates along a circular path, as indicated by the dotted line. The diameter of the circular path is 0.80 m and the period of rotation is 0.60 s.

4 Which of the following shows how the angular velocity can be determined?

☒ **A** 2π × 0.60

☒ **B** 2π ÷ 0.60

☒ **C** 2π × 0.40 ÷ 0.60

☒ **D** 2π × 0.40 × 0.60

(Total for Question 4 = 1 mark)

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5 The mass of the pendulum is 0.30 kg and its speed is 4.2 m s^{-1}.
What is the centripetal force acting on the mass?

☒ **A** 13 N

☒ **B** 6.6 N

☒ **C** 3.2 N

☒ **D** 2.1 N

(Total for Question 5 = 1 mark)

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6 The Large Hadron Collider at CERN can be used to collide lead ions at very high speeds.
This is because high energies are required to

☒ **A** allow lead ions to annihilate.

☒ **B** allow the creation of new particles.

☒ **C** avoid diffraction effects.

☒ **D** avoid relativistic effects.

(Total for Question 6 = 1 mark)

7 Two point objects each with charge Q are separated by a distance r and the force between them is F.
Both the distance of separation and the charge on each object are doubled.

The force between the objects will now be

☒ **A** $8F$

☒ **B** $4F$

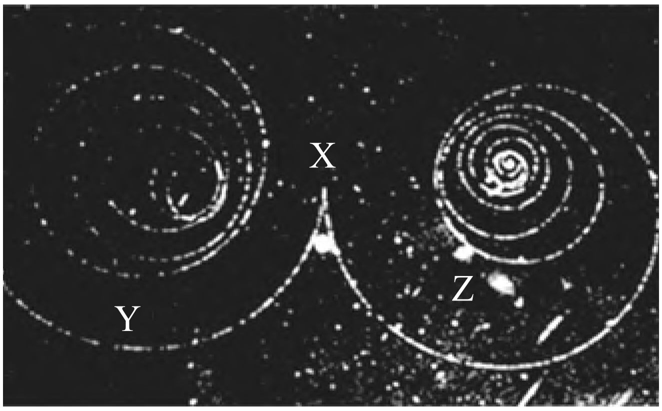
☒ **C** F

☒ **D** $\frac{F}{4}$

(Total for Question 7 = 1 mark)

Questions 8 and 9 refer to the photograph below.

The photograph shows particle tracks from a particle detector.



Two new particles are created at point X. The tracks of the new particles are labelled Y and Z.

8 Which of the following can be concluded from the tracks?

☒ **A** The magnetic field acts into the page.

☒ **B** The new particles are an electron and a positron.

☒ **C** The new particles have opposite charge.

☒ **D** The particle at Y is positively charged.

(Total for Question 8 = 1 mark)

9 Why are Track Y and Track Z both spirals?

☒ **A** The magnetic field is oscillating.

☒ **B** The particles are gaining mass.

☒ **C** The particles are losing energy.

☒ **D** The speed of the particles is increasing.

(Total for Question 9 = 1 mark)

10 The mass of an electron expressed in keV/c^2 is

☒ **A** 8.2×10^{-17}

☒ **B** 1.7×10^{-6}

☒ **C** 5.7×10^{-3}

☒ **D** 5.1×10^{2}

(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

SECTION B

Answer ALL questions in the spaces provided.

11 The table shows the charges of the six types of quark in the standard model.

quark			**charge / *e***
u	c	t	$\frac{2}{3}$
d	s	b	$-\frac{1}{3}$

(a) State the quark structure of baryons and mesons.

(2)

baryons ....

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mesons ....

....

(b) All baryons and mesons have a charge equal to an integer multiple of *e*.

Use an example for a baryon and for a meson to demonstrate how their structure accounts for this.

(2)

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(Total for Question 11 = 4 marks)

12 A proton in a particle detector is travelling in a direction perpendicular to the magnetic field. The proton moves in a curved path. At one point the radius of the path is 0.091 m.

(a) Show that the speed of the proton at this point is about 3×10^7 m s^{-1}.

magnetic flux density = 3.2 T

(3)

(b) Calculate the force acting on the proton at this point.

(2)

Force = ...

(Total for Question 12 = 5 marks)

13 The interior lights in a car are switched on when the car door is opened. When the door is closed the lights stay on for a short time. This time is controlled by a resistor-capacitor circuit. The capacitance of the capacitor is 22 μF.

When the door is closed, a switch opens and the capacitor discharges. The initial potential difference (p.d.) across the capacitor is 12.0 V and the lights switch off when the p.d. has decreased to 2.0 V.

(a) The lights remain on for 20 s.

Determine the resistance in this circuit.

(2)

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Resistance = ...

(b) Calculate the maximum energy stored in the capacitor.

(2)

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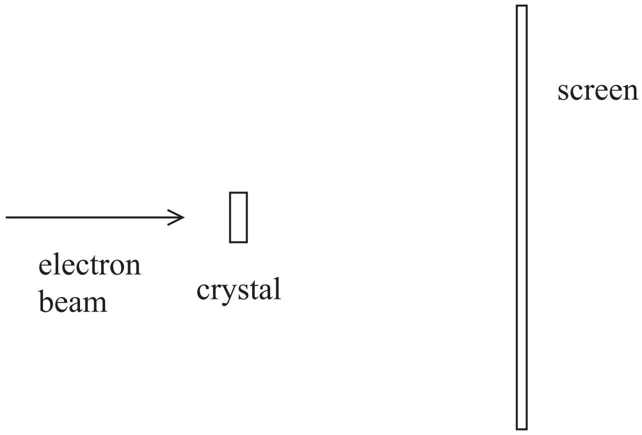
Maximum energy = ...

(Total for Question 13 = 4 marks)

14 An electron beam is directed at a small sample of crystal to investigate the wave properties of electrons.
The experiment was carried out using the following arrangement.



The screen recorded the positions where electrons were observed after passing through the crystal.

Use the de Broglie wavelength of the electrons to explain whether an electron energy of 7.3×10^{-18} J would be suitable for this experiment.
The spacing of the interatomic layers in the crystal is 1.8×10^{-10} m.

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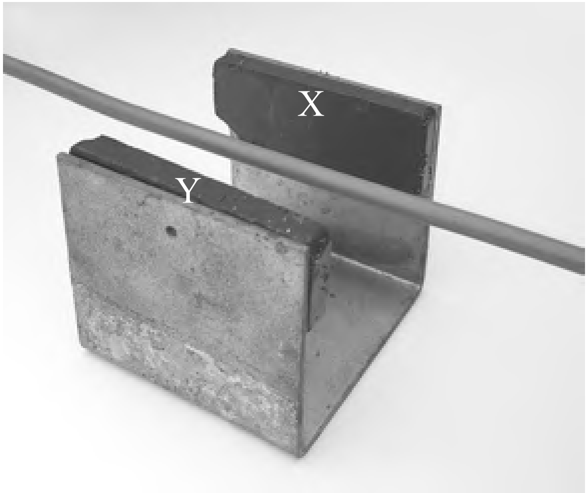
(Total for Question 14 = 5 marks)

15 A student investigating the motor effect places a wire between two magnets on a holder, as shown in the photograph.



The arrangement is placed on a digital balance calibrated to display force. The reading on the balance is 1.4776 N.

When there is a current of 0.82 A in the wire, the reading on the balance becomes 1.4772 N.

(a) Determine the magnetic flux density between the two magnets.

length of wire in the field = 5.0 cm

(2)

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Magnetic flux density = ...

(b) In the arrangement shown the direction of the current is from right to left. Explain why the direction of the magnetic field is from Y to X.

(2)

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(c) Explain one way in which the uncertainty in the value determined for the magnetic flux density could be reduced, using the same apparatus.

(2)

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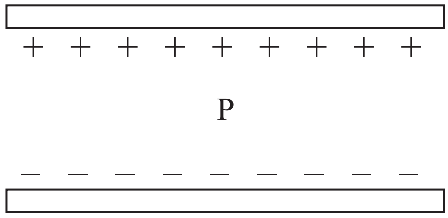
(Total for Question 15 = 6 marks)

16 The diagram shows two metal plates with uniformly distributed electric charge.



(a) Explain the direction of the electric field at point P due to all of the charges on the plates.

(4)

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(b) Calculate the resultant electric force on an electron at point P.

potential difference between plates = 0.40 V
separation of plates = 3.5 cm

(3)

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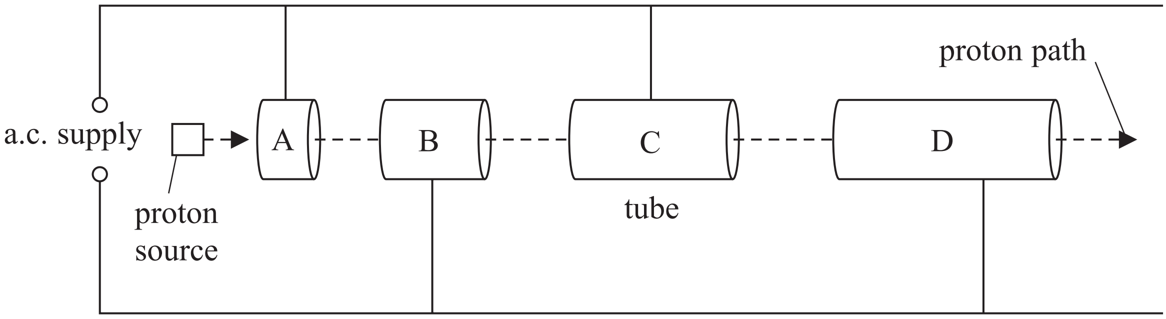
Resultant electric force = ...

(Total for Question 16 = 7 marks)

***17** At CERN a linear accelerator (linac) is used to accelerate protons before they are injected into the Large Hadron Collider.
The diagram represents a simplified linac.



A, B, C and D represent drift tubes to which a large alternating potential is applied.

Explain how a proton is accelerated by the linac.

(4)

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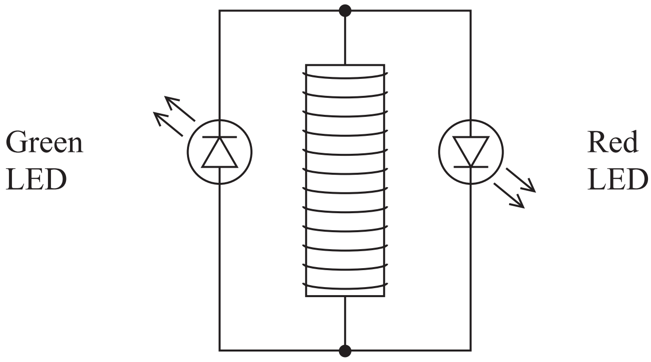
(Total for Question 17 = 4 marks)

18 Red and green light emitting diodes (LED) are connected in parallel across a coil of wire as shown.



A magnet is pushed into the coil and then withdrawn.

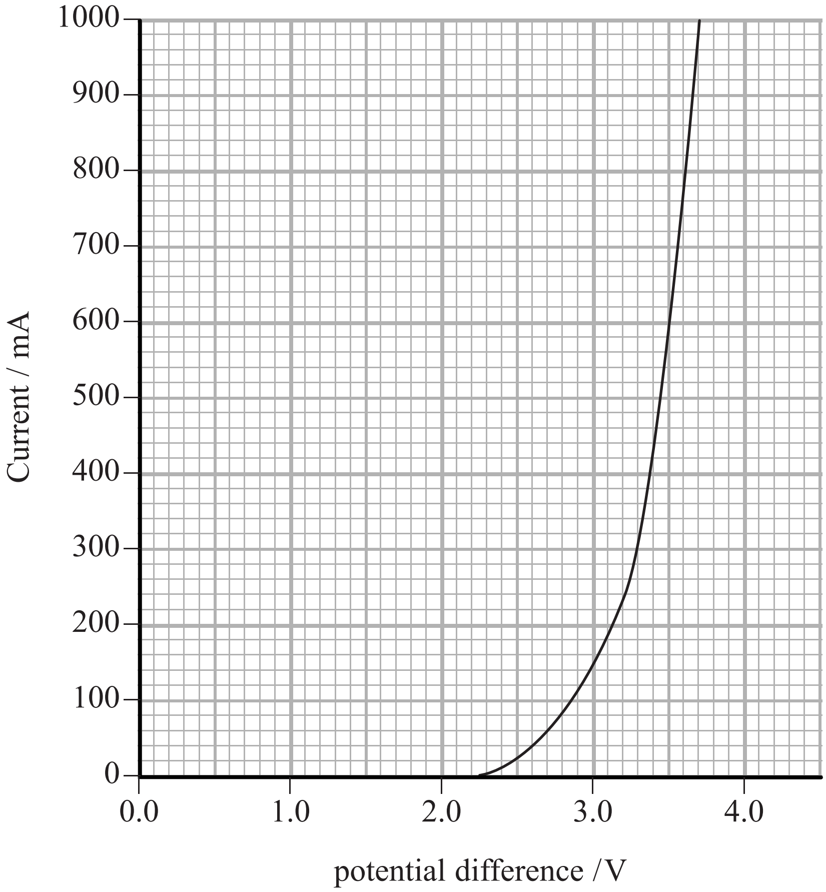
The following observations are made:

- as the north pole of a magnet is pushed into the coil the green LED lights briefly
- the red LED lights briefly as the north pole is withdrawn
- neither LED lights when the magnet is moving completely within the coil.

*(a) Explain these observations.

(5)

(b) The diodes do not light when the coil is wound with a single layer of wire but only if many layers are used. The graph shows how current varies with potential difference for the diodes.



Explain why the coil must be wound with many layers of wire to observe the LEDs lighting.

(2)

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(c) Explain, with reference to Lenz's law, how the magnet does work as it enters the coil.

(4)

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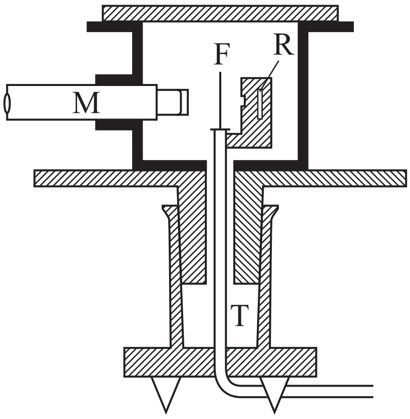
(Total for Question 18 = 11 marks)

19 In the early 1900s, Geiger and Marsden carried out experiments in which a beam of high speed alpha particles was directed at a thin piece of gold foil.
This diagram of the apparatus is taken from a 1913 paper.



M = microscope
F = gold foil
R = source of alpha particles
T = tube

(a) Tube T is used for pumping out air.

Explain why it is necessary to pump out the air.

(2)

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(b) The following observations were made during the experiments.

1. Most of the alpha particles were undeflected.
2. A few alpha particles were deflected by small angles.
3. A very small proportion of alpha particles were deflected through more than 90°.

Using our current understanding of atomic structure, explain these observations.

(6)

(c) The source of alpha particles in some of the experiments was radium.
Complete the nuclear equation to show the alpha decay of radium.

(2)

$$^{\cdots\cdots}_{\cdots\cdots}\mathrm{Ra} \rightarrow {}^{\cdots\cdots}_{\cdots\cdots}\alpha + {}^{222}_{86}\mathrm{Rn}$$

(d) An alpha particle has a speed of 1.50×10^7 m s^{-1}.

Determine the potential difference that would be required to accelerate an alpha particle to this speed from rest. You may ignore relativistic effects at this speed.

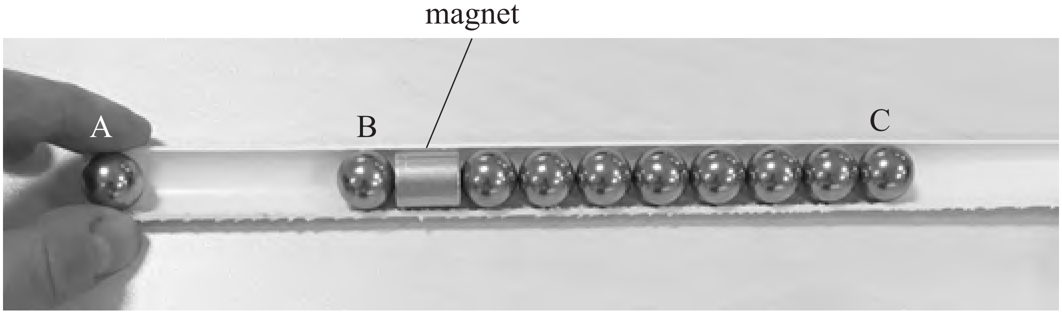
mass of alpha particle = 4.00 *u*

(3)

Potential difference = ...

(Total for Question 19 = 13 marks)

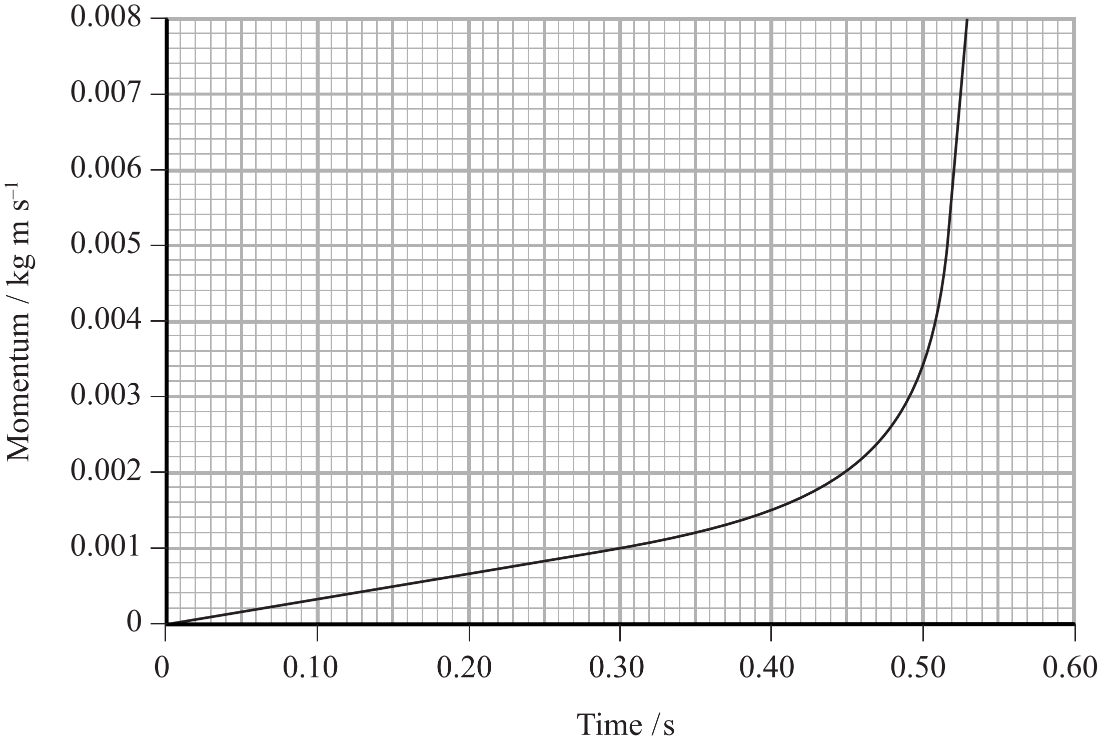
20 The photograph shows an arrangement of identical steel spheres and a strong magnet. The arrangement is in a track so that the spheres can only move in a straight line. Three of the spheres have been labelled A, B and C.



Apart from sphere A, all the spheres are initially in contact.

When sphere A is released, it is attracted by the magnet and accelerates towards B. When sphere A strikes sphere B, sphere A stops and sphere C moves away. The speed of sphere C as it moves away is equal to the speed of sphere A at the point of impact. All of the other spheres remain stationary.

The motion of sphere A is recorded and software is used to produce a graph of momentum against time.



(a) (i) State why the gradient of a graph of momentum against time is equal to force.
(1)

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(ii) Use the graph to determine the resultant force acting on sphere A at time $t = 0.5$ s.
(2)

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Resultant force = ...

(iii) The motion of the sphere was recorded at 30 frames per second.

Suggest why the maximum momentum of the sphere cannot be determined accurately.
(2)

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(b) The speed of sphere C after the collision was measured with a light gate to be 0.80 m s^{-1}.
Use this speed to determine the average force acting on sphere A as it accelerates along the track.
You may assume that sphere A accelerates for 0.53 s.

mass of sphere = 0.017 kg

(3)

Average force = ...

(c) The principle of conservation of momentum could be obeyed if two spheres moved off together at a speed of 0.40 m s^{-1} after the collision.
Determine whether this would be an elastic collision.

(3)

(Total for Question 20 = 11 marks)

TOTAL FOR SECTION B = 70 MARKS

TOTAL FOR PAPER = 80 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	$v = u + at$ $s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
Forces	$\Sigma F = ma$ $g = F/m$ $W = mg$
Work and energy	$\Delta W = F\Delta s$ $E_k = \frac{1}{2}mv^2$ $\Delta E_{grav} = mg\Delta h$

Materials

Stokes' law	$F = 6\pi\eta rv$
Hooke's law	$F = k\Delta x$
Density	$\rho = m/V$
Pressure	$p = F/A$
Young modulus	$E = \sigma/\varepsilon$ where Stress $\sigma = F/A$ Strain $\varepsilon = \Delta x/x$
Elastic strain energy	$E_{el} = \frac{1}{2}F\Delta x$

Unit 2

Waves

Wave speed $v = f\lambda$

Refractive index ${}_1\mu_2 = \sin i/\sin r = v_1/v_2$

Electricity

Potential difference $V = W/Q$

Resistance $R = V/I$

Electrical power, energy and efficiency

$P = VI$
$P = I^2R$
$P = V^2/R$
$W = VIt$

$$\% \text{ efficiency} = \frac{\text{useful energy output}}{\text{total energy input}} \times 100$$

$$\% \text{ efficiency} = \frac{\text{useful power output}}{\text{total power input}} \times 100$$

Resistivity $R = \rho l/A$

Current

$I = \Delta Q/\Delta t$
$I = nqvA$

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

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

Quantum physics

Photon model $E = hf$

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

Unit 4

Mechanics

Momentum	$p = mv$
Kinetic energy of a non-relativistic particle	$E_k = p^2/2m$
Motion in a circle	$v = \omega r$ $T = 2\pi/\omega$ $F = ma = mv^2/r$ $a = v^2/r$ $a = r\omega^2$

Fields

Coulomb's law	$F = kQ_1Q_2/r^2$ where $k = 1/4\pi\varepsilon_0$
Electric field	$E = F/Q$ $E = kQ/r^2$ $E = V/d$
Capacitance	$C = Q/V$
Energy stored in capacitor	$W = \frac{1}{2}QV$
Capacitor discharge	$Q = Q_0 e^{-t/RC}$
In a magnetic field	$F = BIl \sin\theta$ $F = Bqv \sin\theta$ $r = p/BQ$
Faraday's and Lenz's laws	$\varepsilon = -d(N\phi)/dt$

Particle physics

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

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