Write your name here

Surname	Other names

Edexcel GCE

Centre Number	Candidate Number

Physics

Advanced
Unit 4: Physics on the Move

Wednesday 16 January 2013 – Afternoon
Time: 1 hour 35 minutes

Paper Reference
6PH04/01

You must have:
Protractor
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

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Turn over ▶

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

P 4 1 6 2 9 A 0 1 2 4

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 A unit for magnetic flux is the

☐ **A** Wb

☐ **B** Wb m^2

☐ **C** T

☐ **D** T m^{-2}

(Total for Question 1 = 1 mark)

2 A body, initially at rest, explodes into two masses M_1 and M_2. These masses move apart with speeds v_1 and v_2 respectively.

The ratio v_1/v_2 is equal to

☐ **A** $\dfrac{M_1}{M_2}$

☐ **B** $\dfrac{M_2}{M_1}$

☐ **C** $\dfrac{\sqrt{M_1}}{\sqrt{M_2}}$

☐ **D** $\dfrac{\sqrt{M_2}}{\sqrt{M_1}}$

(Total for Question 2 = 1 mark)

3 Which of the following is a property of a uniform electric field?

☐ **A** A field that doesn't change over time.

☐ **B** A field that acts equally in all directions.

☐ **C** A field that only produces a force on moving charged particles.

☐ **D** A field that has the same strength at all points.

(Total for Question 3 = 1 mark)

4 A potential difference of 50 V is applied between two identical parallel aluminium plates. The plates are separated by a distance of 10 mm.

Which combination of potential difference and separation would double the electric field strength?

	Separation/mm	**Potential difference/ V**
☒ **A**	20	100
☒ **B**	20	25
☒ **C**	10	100
☒ **D**	10	25

(Total for Question 4 = 1 mark)

5 Which of the following is **not** a vector quantity?

☒ **A** electric field strength

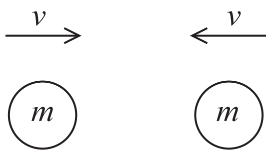
☒ **B** magnetic flux density

☒ **C** momentum

☒ **D** potential difference

(Total for Question 5 = 1 mark)

6 Two identical spheres of mass m are both travelling with a speed v towards each other.



The spheres collide head-on.

Which of the following statements **must** be true after the collision?

☒ **A** total momentum = $2mv$

☒ **B** total momentum = 0

☒ **C** total kinetic energy = mv^2

☒ **D** total kinetic energy = 0

(Total for Question 6 = 1 mark)

---

7 A cyclist travels along a straight horizontal road at a steady speed. A net force of 20 N is then applied for 6 s. The change in momentum of the cyclist is

☒ **A** 3.3 kg m s^{-1}

☒ **B** 26 kg m s^{-1}

☒ **C** 120 kg m s^{-1}

☒ **D** 720 kg m s^{-1}

(Total for Question 7 = 1 mark)

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8 A conductor of length 50 mm carries a current of 3.0 A at 30° to a magnetic field of magnetic flux density 0.40 T.

The magnitude of the magnetic force acting on the conductor is

☒ **A** 0.030 N

☒ **B** 0.050 N

☒ **C** 30 N

☒ **D** 52 N

(Total for Question 8 = 1 mark)

9 An alpha particle and a beta particle both move into the same uniform magnetic field which is perpendicular to their direction of motion. The beta particle travels at 15 times the speed of the alpha particle.

The ratio of the force on the beta particle to the force on the alpha particle is

☒ **A** 3.7

☒ **B** 7.5

☒ **C** 30

☒ **D** 60

(Total for Question 9 = 1 mark)

10 The tubes of a linear accelerator (linac) get progressively longer down its length because

☒ **A** the accelerating particles become relativistic.

☒ **B** the frequency of the applied potential difference changes.

☒ **C** the accelerating particles must spend the same time in each tube.

☒ **D** the accelerating particles gain mass.

(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

SECTION B

Answer ALL questions in the spaces provided.

11 Early in the twentieth century physicists observed the scattering of alpha particles after they had passed through a thin gold foil. This scattering experiment provided evidence for the structure of the atom.

(a) State why it is necessary to remove the air from the apparatus that is used for this experiment.

(1)

....

(b) From the results of such an experiment give **two** conclusions that can be deduced about the nucleus of an atom.

(2)

Conclusion 1 ....

....

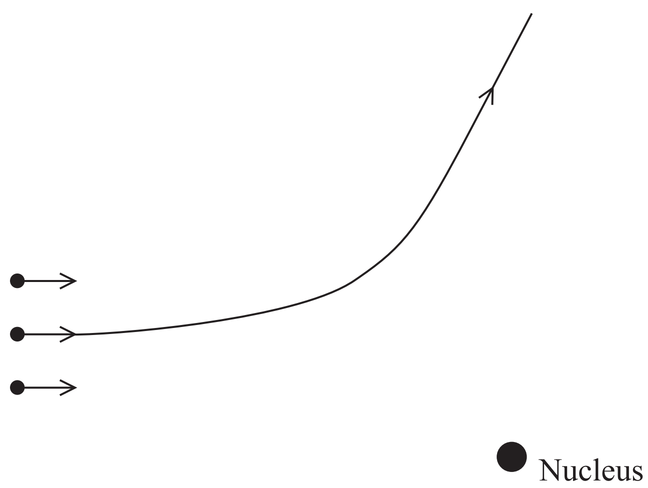
Conclusion 2 ....

....

(c) The diagram shows three α-particles, all with the same kinetic energy. The path followed by one of the particles is shown.

Add to the diagram to show the paths followed by the other two particles.

(3)



(Total for Question 11 = 6 marks)

12 The electron in a hydrogen atom can be described by a stationary wave which is confined within the atom. This means that the de Broglie wavelength associated with it must be similar to the size of the atom which is of the order of 10^{-10} m.

(a) (i) Calculate the speed of an electron whose de Broglie wavelength is 1.00×10^{-10} m.

(3)

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Speed = ...

(ii) Calculate the kinetic energy of this electron in electronvolts.

(3)

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Kinetic energy = ... eV

(b) When β radiation was first discovered, it was suggested that there were electrons in the atomic nucleus, but it was soon realised that this was impossible because the energy of such an electron would be too great.

Suggest why an electron confined within a nucleus would have a much greater energy than the energy calculated in (a)(ii).

(2)

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(Total for Question 12 = 8 marks)

13 The London Eye consists of a large vertical circle with 32 equally-spaced passenger cabins attached to it. The wheel rotates so that each cabin has a constant speed of 0.26 m s^{-1} and moves around a circle of radius 61 m.

(a) Calculate the time taken for each cabin to make one complete revolution.

(2)

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Time = ...

(b) Calculate the centripetal force acting on each cabin.

mass of cabin = 9.7×10^3 kg

(2)

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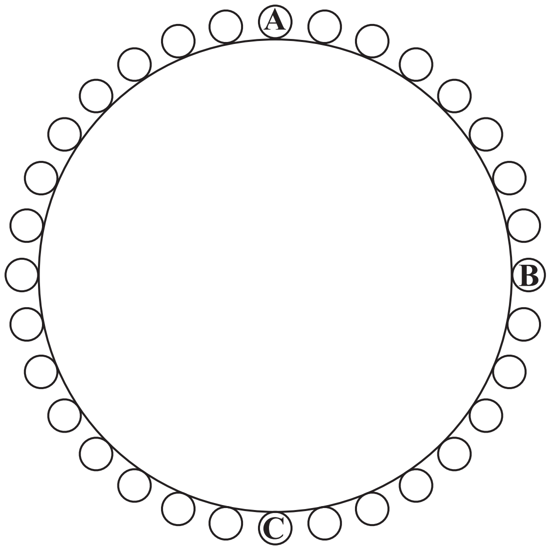
Centripetal force = ...

P 4 1 6 2 9 A 0 8 2 4

(c) (i) The diagram shows just the circle and the cabins.
Draw arrows to show the direction of the centripetal force acting on a person in a cabin when the person is at each of positions **A**, **B** and **C**.

(1)



*(ii) As the person in a cabin moves around the circle, the normal contact force between the person and the cabin varies.

State the position at which this force will be a maximum and the position at which it will be a minimum. Explain your answers.

(4)

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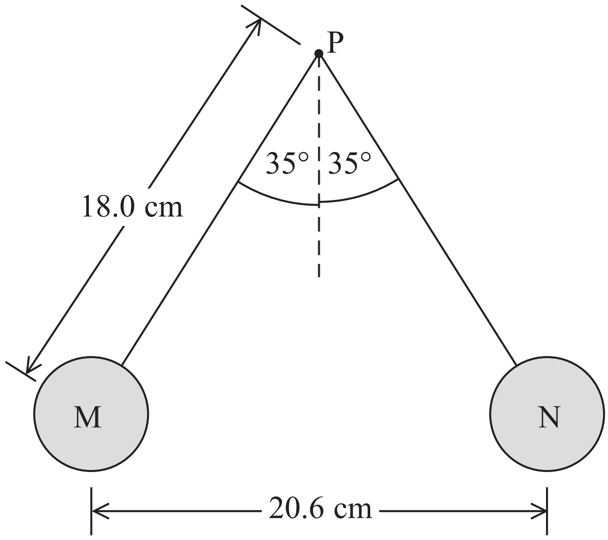
(Total for Question 13 = 9 marks)

14 Two identical table tennis balls, M and N, are attached to non-conducting threads and suspended from a point P. The balls are each given the same positive charge and they hang as shown in the diagram. The mass of each ball is 2.7 g.



(a) Draw a free-body force diagram for ball M, label your diagram with the names of the forces.

(2)

P 4 1 6 2 9 A 0 1 0 2 4

(b) (i) Show that the tension in one of the threads is about 3×10^{-2} N.
(3)

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(ii) Show that the electrostatic force between the balls is about 2×10^{-2} N.
(2)

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(iii) Calculate the charge on each ball.
(3)

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Charge = ...

(c) State and explain what would have happened if the charge given to ball M was greater than the charge given to ball N.
(2)

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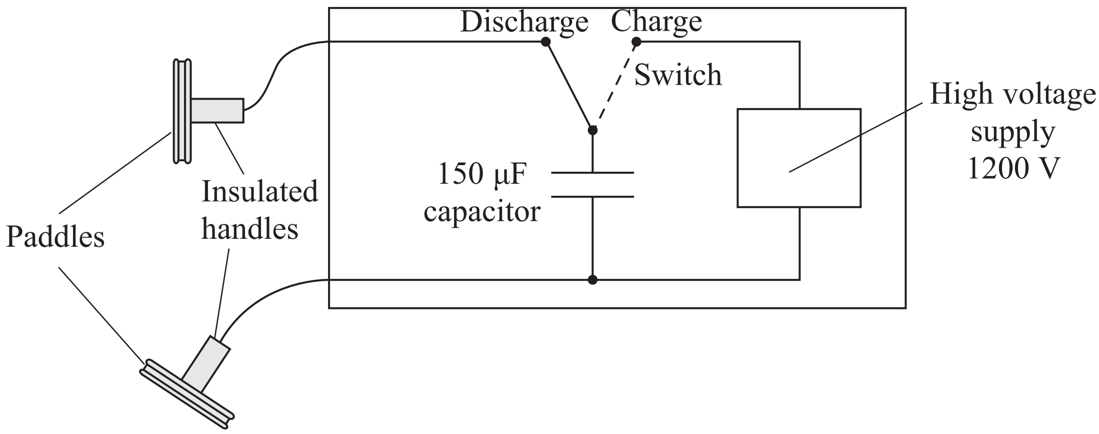
(Total for Question 14 = 12 marks)

15 A defibrillator is a machine that is used to correct an irregular heartbeat or to start the heart of someone who is in cardiac arrest.

The defibrillator passes a large current through the heart for a short time.

The machine includes a high voltage supply which is used to charge a capacitor. Two defibrillation ‘paddles’ are placed on the chest of the patient and the capacitor is discharged through the patient.



(a) The 150 μF capacitor is first connected across the 1200 V supply.

Calculate the charge on the capacitor.

(2)

....

....

Charge = ...

(b) Calculate the energy stored in the capacitor.

(2)

Energy stored = ...

(c) When the capacitor discharges there is an initial current of 14 A in the chest of the patient.

(i) Show that the electrical resistance of the body tissue between the paddles is about 90 Ω.

(1)

(ii) Calculate the time it will take for three quarters of the charge on the capacitor to discharge through the patient.

(3)

Time = ...

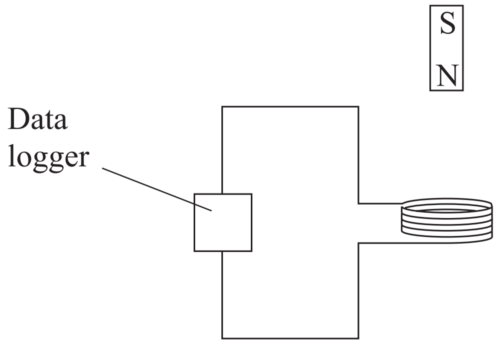
(iii) Body resistance varies from person to person. If the body resistance was lower, the initial current would be greater.

State how this lower body resistance affects the charge passed through the body from the defibrillator.

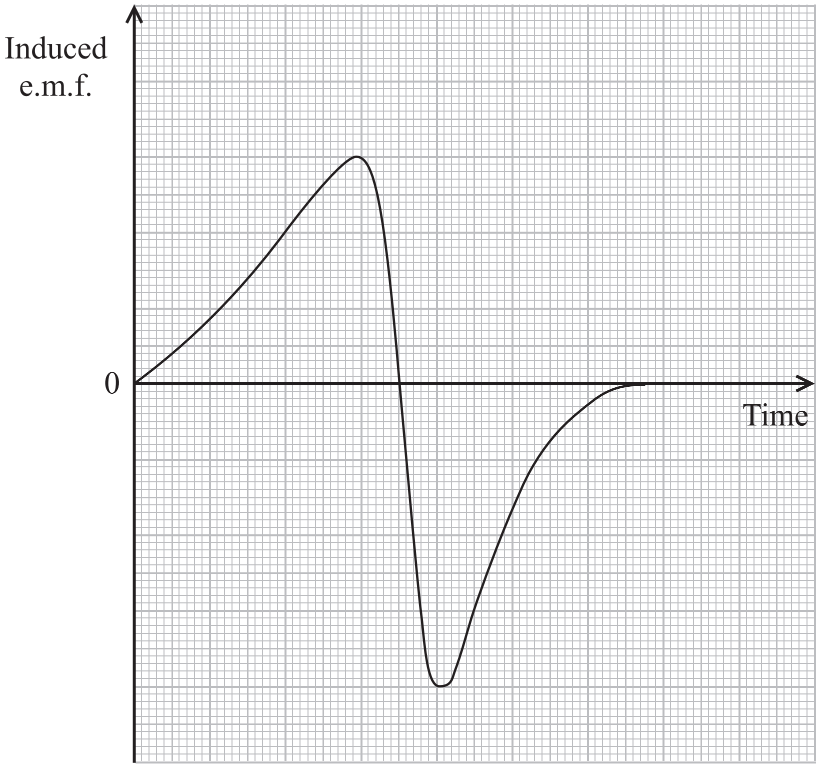
(1)

(Total for Question 15 = 9 marks)

16 A teacher demonstrates electromagnetic induction by dropping a bar magnet through a flat coil of wire connected to a data logger.



The data from the data logger is used to produce a graph of induced e.m.f. across the coil against time.



*(a) Explain the shape of the graph and the relative values on both axes.

(6)

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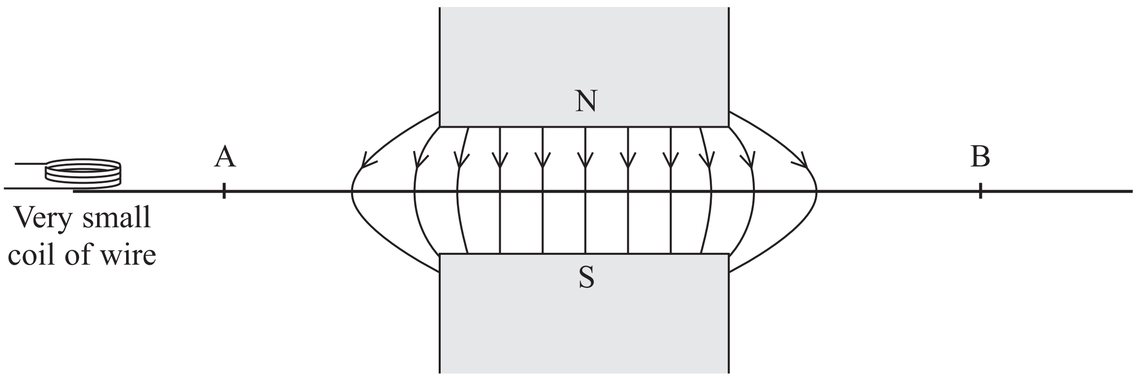
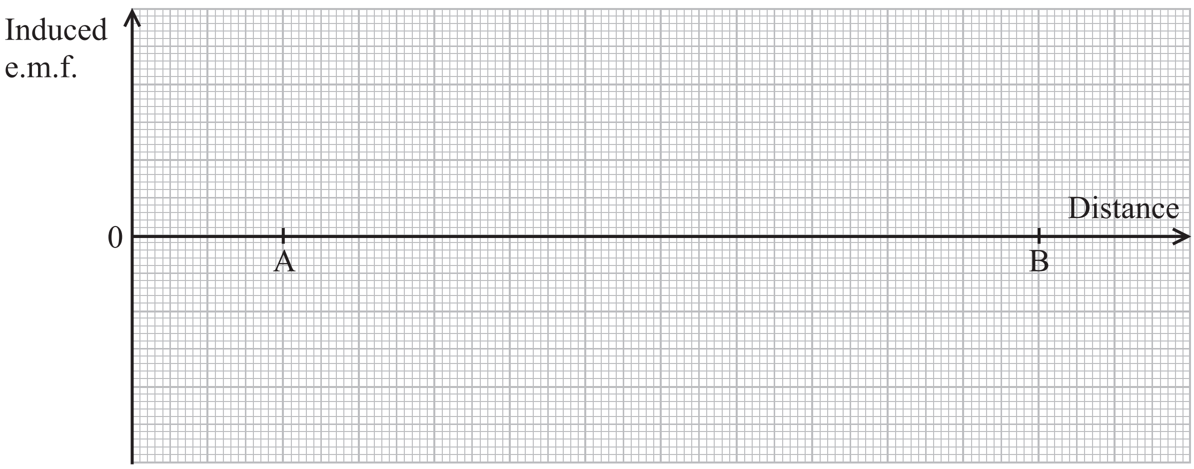
(b) The teacher then sets up another demonstration using a large U-shaped magnet and a very small coil of wire which is again connected to a data logger.

The north pole is vertically above the south pole and the coil is moved along the line AB which is midway between the poles. The magnetic field due to the U-shaped magnet has been drawn. The plane of the coil is horizontal.



Sketch a graph to show how the e.m.f. induced across the coil varies as the coil moves from A to B at a constant speed.

(4)



(Total for Question 16 = 10 marks)

17 In 2011 physicists at the Relativistic Heavy Ion Collider (RHIC) announced the creation of nuclei of anti-helium-4 which consists of anti-protons and anti-neutrons instead of protons and neutrons.

(a) 'Ordinary' helium-4 is written as ${}^{4}_{2}He$.

What do the numbers 4 and 2 represent?

(2)

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(b) In the RHIC experiment, nuclei of gold ${}^{197}_{79}Au$ travelling at speeds greater than 2.99×10^{8} m s^{-1}, in opposite directions, collided, releasing energies of up to 200 GeV. After billions of collisions, 18 anti-helium nuclei had been detected.

(i) What is meant by 'relativistic' in the collider's name?

(1)

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....

(ii) State why it is necessary to use very high energies in experiments such as these.

(1)

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(iii) Show that the mass of a stationary anti-helium nucleus is about 4 GeV/c^2.

(4)

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(iv) State why the small number of anti-helium nuclei produced only survive for a fraction of a second.

(1)

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(v) A slow moving anti-helium nucleus meets a slow moving helium nucleus. If they were to combine to produce 2 high energy gamma rays, calculate the frequency of each gamma ray.

(2)

....

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Frequency = ...

(c) There are two families of hadrons, called baryons and mesons. Baryons such as protons are made of three quarks.

(i) Describe the structure of a meson.

(1)

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(ii) Up quarks have a charge of +2/3e and down quarks a charge of –1/3e.
Describe the quark composition of anti-protons and anti-neutrons and use this to deduce the charge on each of these particles.

(4)

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(Total for Question 17 = 16 marks)

TOTAL FOR SECTION B = 70 MARKS

TOTAL FOR PAPER = 80 MARKS

List of data, formulae and relationships

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

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	$P = VI$ $P = I^2R$ $P = V^2/R$ $W = VIt$ $\% \text{ efficiency} = \dfrac{\text{useful energy output}}{\text{total energy input}} \times 100$ $\% \text{ efficiency} = \dfrac{\text{useful power output}}{\text{total power input}} \times 100$
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	$\dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3}$

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	$\Delta E = c^2 \Delta m$
de Broglie wavelength	$\lambda = h/p$

Write your name here

Surname	Other names

Edexcel GCE

Centre Number

Candidate Number

Physics

Advanced

Unit 4: Physics on the Move

Monday 11 June 2012 – Afternoon

Time: 1 hour 35 minutes

Paper Reference

6PH04/01

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Ruler

Total Marks

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1/1/1/1/1/1/C2

P 3 9 8 5 5 A 0 1 2 8

PEARSON

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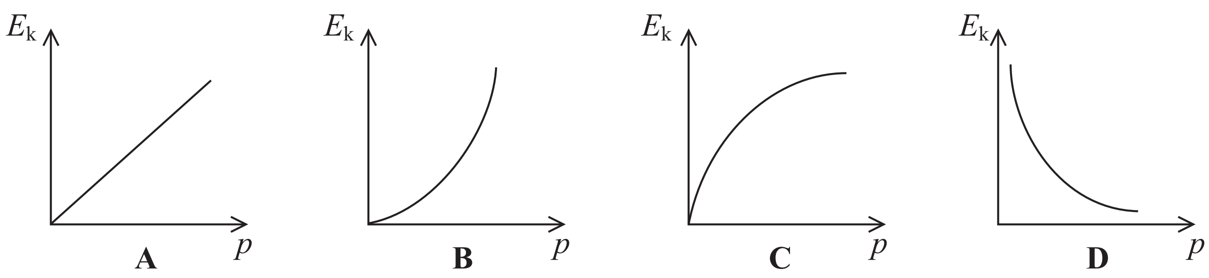
1 $^{208}_{82}Pb$ is the symbol for the heaviest, stable nucleus. The table shows possible numbers of neutrons and protons.

Which line of the table correctly shows the numbers of neutrons and protons for this nucleus?

	Number of neutrons	Number of protons
☒ **A**	82	208
☒ **B**	82	126
☒ **C**	126	82
☒ **D**	208	82

(Total for Question 1 = 1 mark)

2 A car is accelerated from rest. Which graph correctly shows how the kinetic energy E_k varies with momentum p?



☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 2 = 1 mark)

3 An inelastic collision is one in which

- ☒ **A** momentum is not conserved.
- ☒ **B** momentum and kinetic energy are not conserved.
- ☒ **C** momentum and kinetic energy are conserved.
- ☒ **D** kinetic energy is not conserved.

(Total for Question 3 = 1 mark)

4 A unit of electric field strength is

- ☒ **A** J C^{-2}
- ☒ **B** $\text{N m}^2\ \text{C}^{-2}$
- ☒ **C** N m C^{-1}
- ☒ **D** N C^{-1}

(Total for Question 4 = 1 mark)

5 A capacitor is discharging through a resistor and the time constant is 5.0 s. The time taken for the capacitor to lose half its charge is

- ☒ **A** 0.14 s
- ☒ **B** 0.81 s
- ☒ **C** 3.2 s
- ☒ **D** 3.5 s

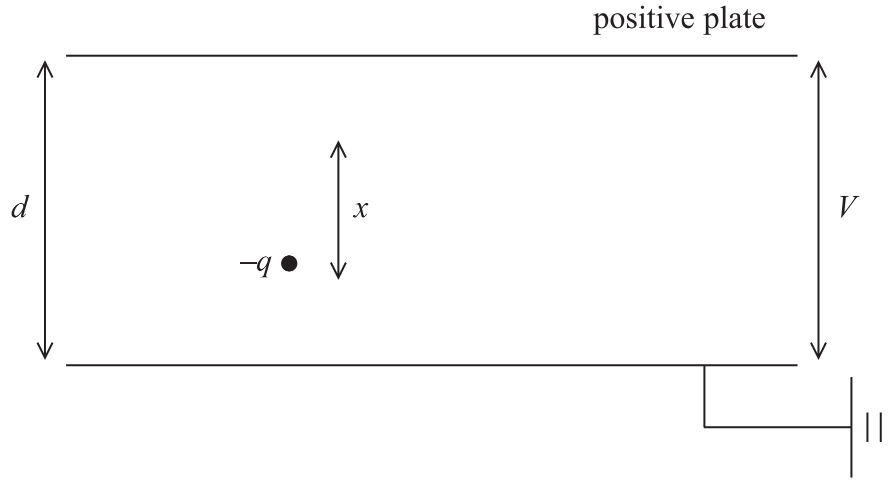
(Total for Question 5 = 1 mark)

6 Which one of the following statements does **not** help to explain why electrons can be used to probe the nuclei of atoms.

- ☒ **A** Electrons are negatively charged.
- ☒ **B** Electrons can have wavelengths similar in size to nuclear diameters.
- ☒ **C** Electrons can be accelerated to high energies.
- ☒ **D** Electrons can exhibit diffraction effects.

(Total for Question 6 = 1 mark)

7 The diagram shows two parallel plates a distance d apart. There is a potential difference V across the two plates. A particle, charge $-q$, is placed between the plates as shown. The particle is attracted to the positive plate and moves through a distance x.



Which of the following expressions gives the work done on the particle as it moves through the distance x?

☒ **A** $\dfrac{qV}{xd}$

☒ **B** $\dfrac{qVx}{d}$

☒ **C** $\dfrac{V}{xdq}$

☒ **D** $\dfrac{xV}{qd}$

(Total for Question 7 = 1 mark)

8 A coil of N turns and cross-sectional area A lies perpendicular to a magnetic field of flux density B. The magnetic flux linkage is X.

A second coil with twice the number of turns but half the cross-sectional area lies perpendicular to a magnetic field of flux density $2B$. The magnetic flux linkage with the second coil is

☒ **A** $\frac{X}{2}$

☒ **B** X

☒ **C** $2X$

☒ **D** $4X$

(Total for Question 8 = 1 mark)

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9 A pion can decay to produce two leptons. Which one of the following is possible?

☒ **A** $\pi^+ \rightarrow e^+ + \nu_e$

☒ **B** $\pi^0 \rightarrow e^- + \nu_e$

☒ **C** $\pi^+ \rightarrow e^+ + e^-$

☒ **D** $\pi^0 \rightarrow \pi^+ + e^-$

(Total for Question 9 = 1 mark)

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10 As a particle accelerates in a linac, it passes through drift tubes of increasing lengths. This is so that

☒ **A** the particle can be given more energy within each tube.

☒ **B** the frequency of the accelerating voltage can be constant.

☒ **C** the accelerating voltage can be as high as possible.

☒ **D** the time spent in the tube by the particle is longer.

(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

SECTION B

Answer ALL questions in the spaces provided.

11 The positively charged particles in the solar wind are accelerating away from the Sun. Some scientists have therefore concluded that the Sun is positively charged.

(a) Explain this conclusion.

(2)

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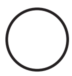
(b) The circle below represents the Sun.

Complete the diagram to show the electric field produced by a positively-charged Sun.

(2)



(Total for Question 11 = 4 marks)

12 A spacecraft called Deep Space 1, mass 486 kg, uses an "ion-drive" engine. This type of engine is designed to be used in deep space.

The following statement appeared in a web site.

> The ion propulsion system on Deep Space 1 expels 0.13 kg of xenon propellant each day. The xenon ions are expelled from the spacecraft at a speed of 30 km s^{-1}. The speed of the spacecraft is predicted to initially increase by about 8 m s^{-1} each day.

Use a calculation to comment on the prediction made in this statement.

(4)

(Total for Question 12 = 4 marks)

13 An electron and a positron annihilate with the emission of two photons of equal energy.

Calculate the wavelength of the photons.

(5)

Wavelength = ...

(Total for Question 13 = 5 marks)

*14 A bubble chamber is a particle detector which makes use of electric and magnetic fields.

Explain the role of electric and magnetic fields in a particle detector.

(5)

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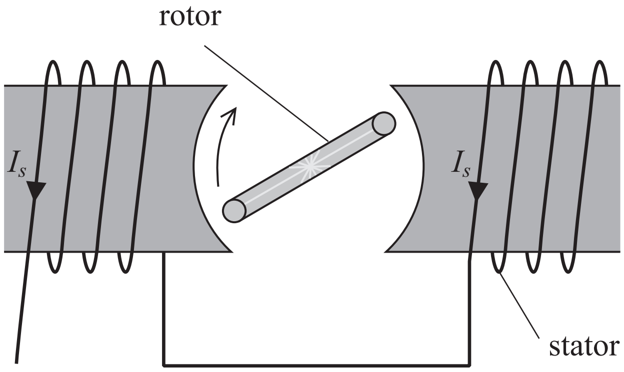
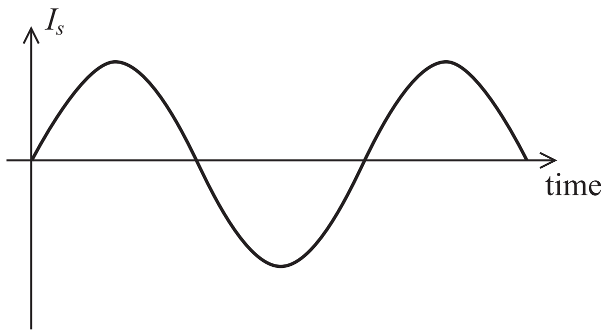
(Total for Question 14 = 5 marks)

15 The diagram represents a simple induction motor. An alternating current I_s is supplied to a stationary coil (stator). This coil is wrapped around an iron core.

A rotating coil (rotor) is shown end on in the diagram.



(a) The graph shows the variation of the alternating current I_s with time.



*(i) Explain how current is induced in the rotor coil.

(4)

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(ii) Explain why the rotor turns.

(2)

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(iii) State **two** ways of making the rotor turn faster.

(2)

1 ....

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2 ....

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(b) An induction motor is used to rotate the turntable in a record deck. Long-play records require the turntable to rotate at 33 revolutions per minute.

(i) Calculate the angular velocity of the turntable.

(3)

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Angular velocity = ...

(ii) Calculate the acceleration of a speck of dust at the outside edge of a rotating record.

radius of record = 12.5 cm

(2)

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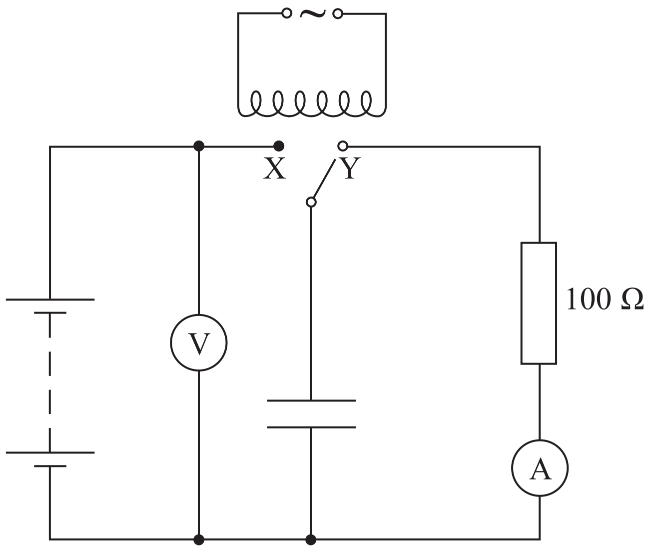
Acceleration = ...

(Total for Question 15 = 13 marks)

16 A student is investigating capacitors. She uses the circuit below to check the capacitance of a capacitor labelled 2.2 μF which has a tolerance of ±30%.



The switch flicks between contacts, X and Y, so that the capacitor charges and discharges *f* times per second.

(a) The capacitor must discharge fully through the 100 Ω resistor.

(i) Explain why 400 Hz is a suitable value for *f*.

(3)

(ii) Show that the capacitance C can be given by

$$C = \frac{I}{fV}$$

where I is the reading on the ammeter and V is the reading on the voltmeter.

(3)

....

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(iii) The student records I as 5.4 mA and V as 5.0 V.

Calculate the capacitance C.

(2)

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C = ...

(iv) Explain whether you think this value is consistent with the tolerance given for this capacitor.

(2)

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....

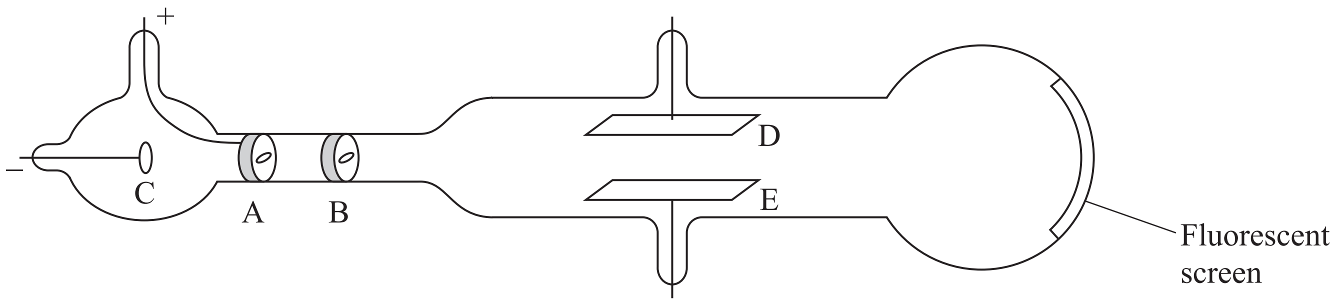
(b) Calculate the energy stored on the capacitor when it is charged to a potential difference of 5.0 V.

(2)

Energy = ...

(Total for Question 16 = 12 marks)

17 J J Thomson is credited with the discovery of the electron. He measured the 'charge to mass ratio' *e/m* for the electron, using the apparatus shown.



A metal disc at C emits electrons. A positively-charged disc at A accelerates the electrons along the tube. Slits in A and B produce a narrow horizontal beam of electrons. An electric field is produced between plates D and E, which can be used to deflect the beam vertically. The final position of the beam is shown on a fluorescent screen at the end of the tube.

(a) Describe how a metal disc can be made to emit electrons.

(2)

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(b) The length of plates D and E is l. Thomson deduced that the vertical component v_v of velocity gained by the electrons as they leave the plates is given by

$$v_V = \frac{Ee}{m} \times \frac{l}{v}$$

where E is the electric field strength between the plates and v is the velocity with which the electrons entered the field.

Show that this expression is correct.

(3)

(c) Thomson determined the angle θ at which the beam was deflected.

Suggest how this angle could be determined.

(3)

(d) The angle θ is also given by

$$\tan\theta = \frac{Ee}{m} \times \frac{l}{v^2}$$

Show that this equation is correct.

(2)

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(e) Thomson replaced the electric field with a uniform magnetic field which acted over the same length as the plates. He adjusted the flux density B to obtain the same deflection on the screen.

For this arrangement he assumed that the vertical component of velocity gained by the electrons as they leave the plates is given by

$$v_{\mathrm{v}} = \frac{Bev}{m} \times \frac{l}{v}$$

(i) Thomson just replaced the term eE in the equation in part (b) with Bev.

Suggest why he did this.

(1)

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....

....

....

....

(ii) Give **two** reasons why the equation $v_{\mathrm{v}} = \frac{Bev}{m} \times \frac{l}{v}$ is **not** correct.

(2)

1 ....

....

2 ....

....

(Total for Question 17 = 13 marks)

18 (a) Physicists were able to confidently predict the existence of a sixth quark. State why.

(1)

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....

(b) The mass of the top quark was determined by an experiment. Collisions between protons and anti-protons occasionally produce two top quarks.

(i) How do the properties of a proton and an anti-proton compare?

(2)

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(ii) After the collision the two top quarks move in opposite directions with the same speed.

Explain why.

(2)

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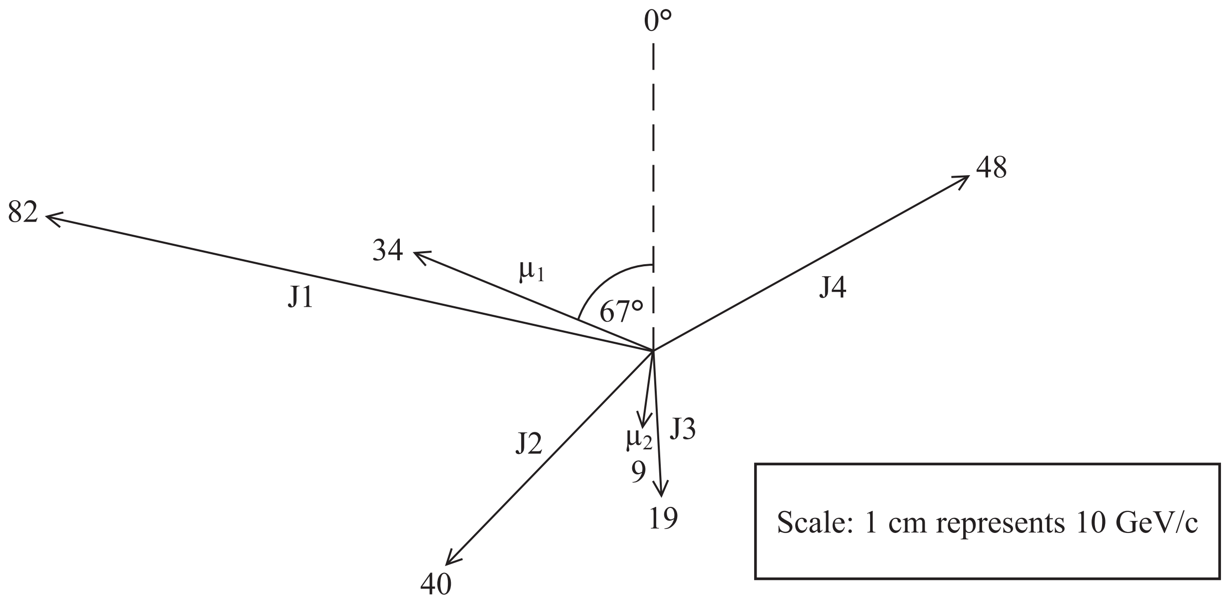
(c) The two top quarks decay rapidly into two muons and four jets of particles. These can be detected and their momenta measured.

The diagram shows an end-on view of the directions of the four jets (J1 to J4) of particles. The two muons are shown as μ_1 and μ_2. A muon neutrino is also produced but cannot be detected, so is **not** shown. Each momentum is measured in GeV/c.

The magnitude of the momentum for each particle or 'jet' is shown by the number printed at the end of each arrow.



(i) Explain why GeV/c is a valid unit for momentum.

(2)

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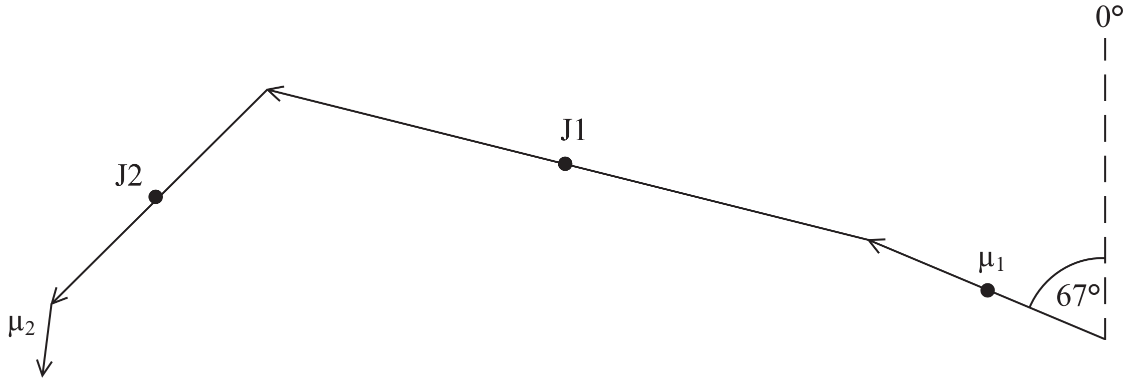
....

P 3 9 8 5 5 A 0 2 0 2 8

(ii) The vector diagram shown below is **not** complete. Add to the diagram arrows to represent the momenta of J3 and J4.

(2)



Scale: 1 cm represents 10 GeV/c

(iii) Complete the diagram to determine the magnitude of the momentum of the muon neutrino.

(1)

Momentum = ... GeV/c.

(iv) Show that the total energy of all the products of this event is about 300 GeV.

(1)

....

....

(v) Deduce the mass of a top quark in GeV/c^2.

(1)

....

....

(vi) Suggest why it took a long time to find experimental evidence for the top quark.

(2)

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(Total for Question 18 = 14 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	$P = VI$ $P = I^2R$ $P = V^2/R$ $W = VIt$
	$\% \text{ efficiency} = \dfrac{\text{useful energy output}}{\text{total energy input}} \times 100$
	$\% \text{ efficiency} = \dfrac{\text{useful power output}}{\text{total power input}} \times 100$
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	$\dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3}$

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	$\Delta E = c^2 \Delta m$
de Broglie wavelength	$\lambda = h/p$

Write your name here

Surname	Other names

Centre Number | Candidate Number

Edexcel GCE

Physics

Advanced
Unit 4: Physics on the Move

Thursday 13 June 2013 – Afternoon
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.
- Keep an eye on the time.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ▶

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1/1/1/1/

P 4 1 6 3 5 A 0 1 2 4

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

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

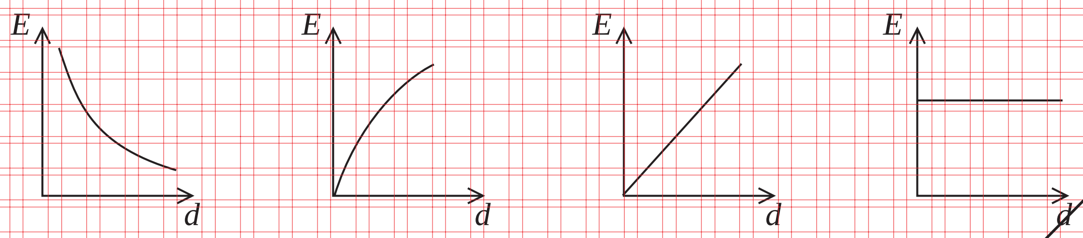
☒ **C** the velocity component parallel to the magnetic field direction

☒ **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 [illegible] revolutions in [illegible] 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.[illegible]4 ra[illegible]

(Total for Question 4 = 1 mark)

[illegible] A [illegible] 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)

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

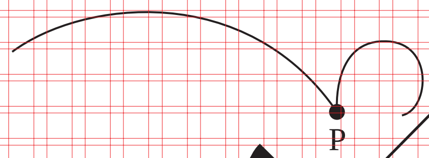
☒ **B** 5.7×10^{-20} kg

☒ **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)

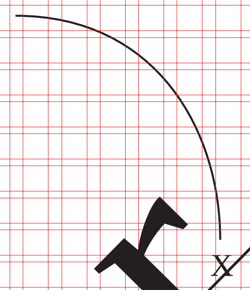
TOTAL FOR SECTION A = 10 MARKS

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)

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(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)

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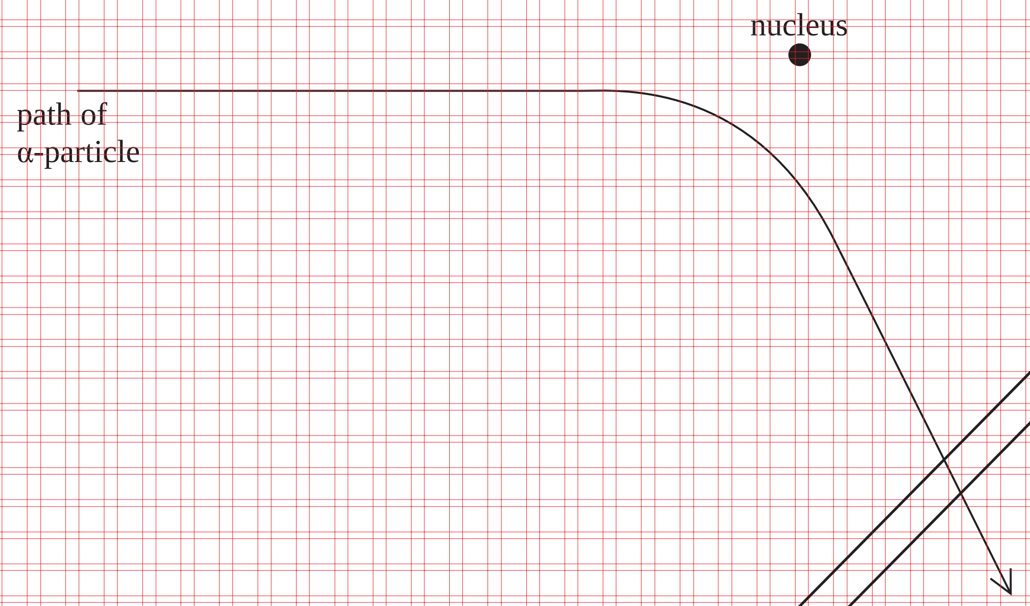
(c) The diagram shows the path of an α-particle passing near to a single nucleus in the metal foil.



(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 shown 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)

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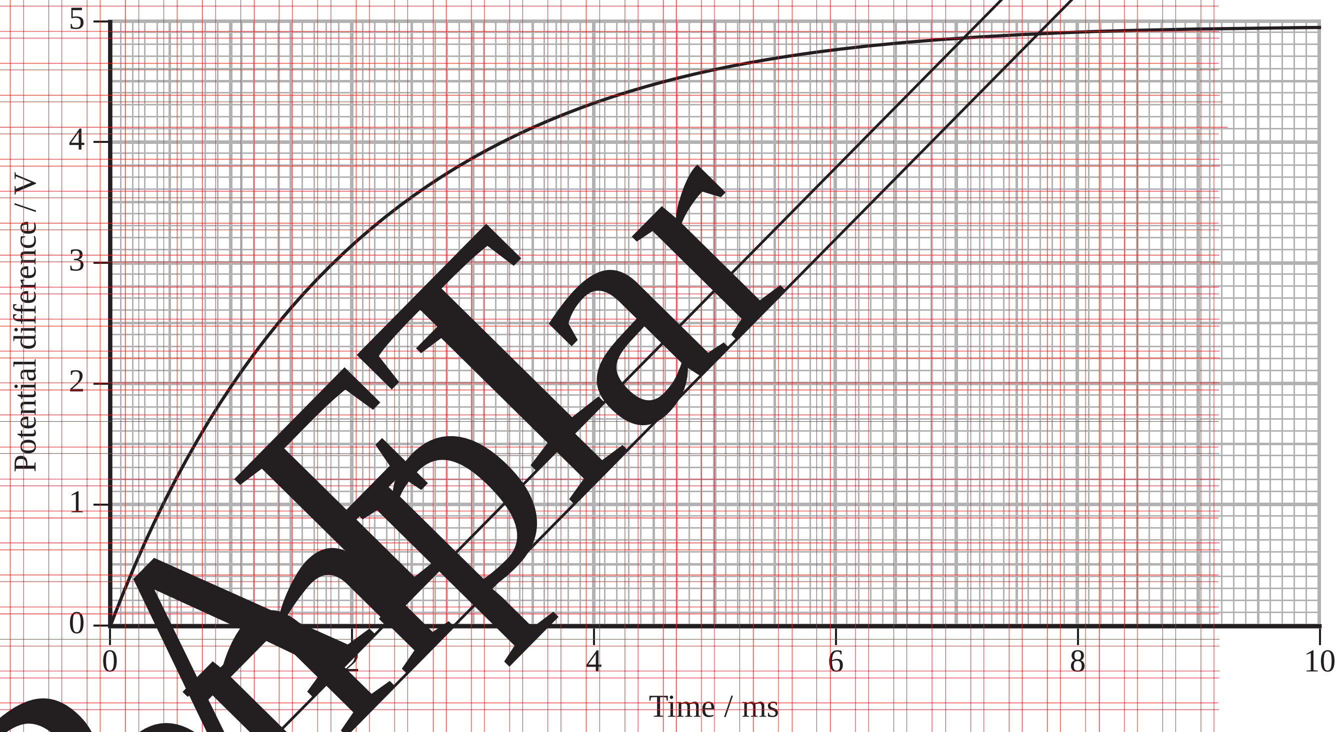
Charge = ...

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



Estimate the average charging current over the first 10 ms.

(2)

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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)

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Initial charging current = ...

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

(2)

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....

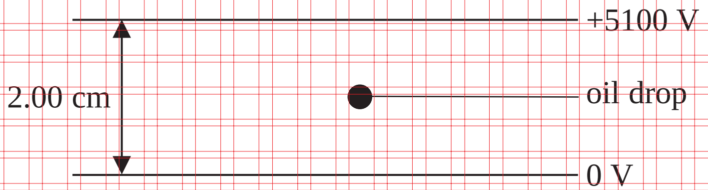
Resistance = ...

(Total for Question 14 = 12 marks)

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)

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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)

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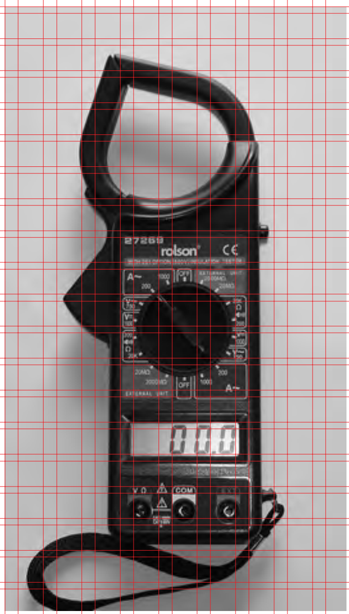
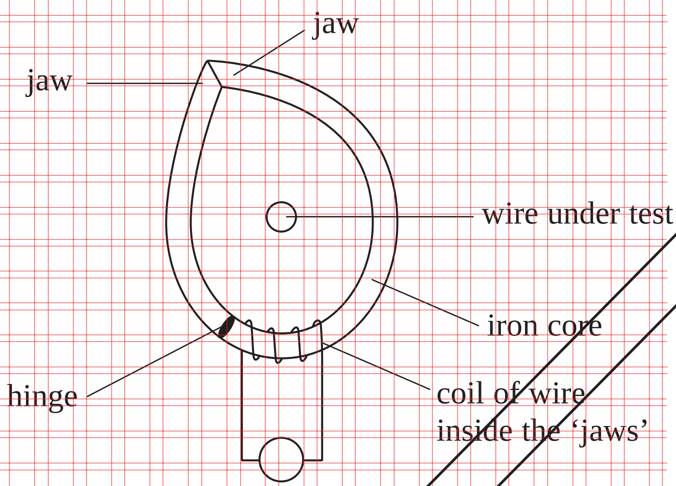
Number of electrons = ...

(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)

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

(1)

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(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)

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

(2)

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

Suggest why not.

(2)

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(Total for Question 16 = 11 marks)

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

(2)

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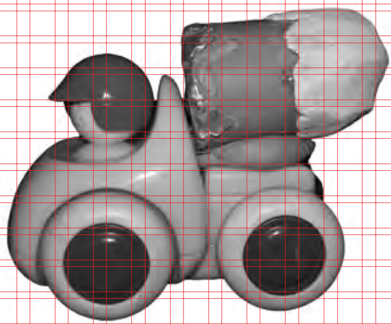
(b) The picture shows a toy car initially at rest with a piece of modelling clay attached to it.



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)

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(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)

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(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)

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(ii) The filming 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)

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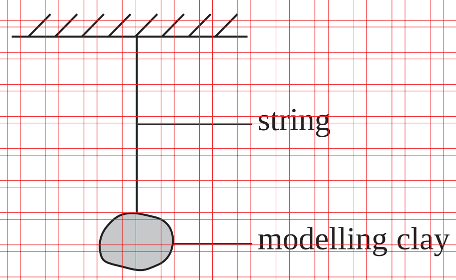
(d) The student tests the result of the first experiment by firing a pellet into a pendulum with a bob made of modelling clay. She calculates the energy transferred.



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
$= 71.6 \times 10^{-3}\ \text{kg} \times 9.81\ \text{N kg}^{-1} \times 0.226\ \text{m} = 0.16\ \text{J}$
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 = $19.5\ \text{m s}^{-1}$

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)

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(Total for Question 17 = 16 marks)

TOTAL FOR SECTION B = 70 MARKS

TOTAL FOR PAPER = 80 MARKS

List of data, formulae and relationships

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

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	$P = VI$ $P = I^2R$ $P = V^2/R$ $W = VIt$
	$\% \text{ efficiency} = \dfrac{\text{useful energy output}}{\text{total energy input}} \times 100$
	$\% \text{ efficiency} = \dfrac{\text{useful power output}}{\text{total power input}} \times 100$
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	$\dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3}$

Quantum physics

Photon model	$E = hf$
Einstein's photoelectric equation	$hf = \phi + \tfrac{1}{2}mv^2_{max}$

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	$\Delta E = c^2 \Delta m$
de Broglie wavelength	$\lambda = h/p$

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