Please check the examination details below before entering your candidate information

Candidate surname	Other names
StemUp Model Solution	

Centre Number | Candidate Number

Pearson Edexcel Level 3 GCE

Wednesday 24 May 2023

Afternoon (Time: 1 hour 45 minutes)

Paper reference **9PH0/01**

Physics

Advanced
PAPER 1: Advanced Physics I

You must have:
Scientific calculator, ruler, protractor

Total Marks

Instructions

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

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.
- You are advised to show your working in calculations including units where appropriate.

Turn over ▶

P71915A

©2023 Pearson Education Ltd.
N:1/1/1/

P 7 1 9 1 5 A 0 1 2 8

Pearson

Answer ALL questions.

All multiple choice questions must be answered with a cross in the box ☒ for the correct answer from A to D. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 One isotope of oxygen is $^{17}_{8}O$.

Which row of the table shows the number of neutrons and the number of protons in a nucleus of $^{17}_{8}O$?

		Number of neutrons	Number of protons
☐	**A**	8	9
☐	**B**	8	17
☒	**C**	9	8
☐	**D**	17	8

(Total for Question 1 = 1 mark)

2 A subatomic particle consists of the quark combination u $\bar{s}$.

Which of the following is the classification for this particle?

☐ **A** baryon

☐ **B** lepton

☒ **C** meson

☐ **D** nucleon

(Total for Question 2 = 1 mark)

3 A charged capacitor is discharged through a resistor. The potential difference across the capacitor halved in a time t. The time constant is T.

Which of the following is the equation for t?

☐ **A** $t = \dfrac{\ln 2}{T}$

☐ **B** $t = \ln \dfrac{1}{2T}$

☐ **C** $t = T \ln \dfrac{1}{2}$

☒ **D** $t = T \ln 2$

(Total for Question 3 = 1 mark)

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

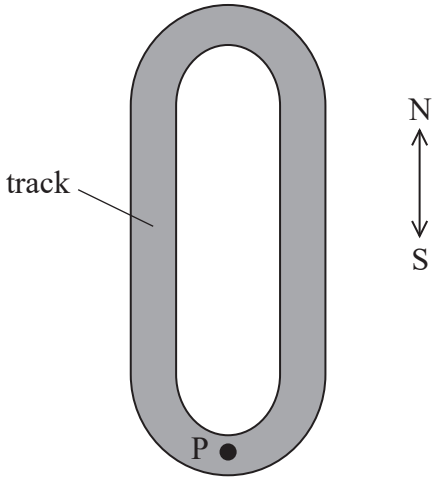
4 Muons created in the upper atmosphere can travel towards the Earth's surface at speeds close to the speed of light. Changes to the mass and average lifetime of the muons can then be observed.

Which row of the table describes these changes when muons travel at speeds close to the speed of light?

		Mass	Average lifetime
☒	**A**	increases	increases
☐	**B**	increases	decreases
☐	**C**	decreases	increases
☐	**D**	decreases	decreases

(Total for Question 4 = 1 mark)

5 The plan view of a model racing car track is shown. Friction acts between a model racing car and the track. A car is moving round the track with a constant speed and reaches point P. Arrows indicating directions North and South are also shown.



The car then slides off the track at P.

Which of the following is the reason why the car slides off the track?

☐ **A** The centripetal force is acting in the N direction.

☐ **B** The centripetal force is acting in the S direction.

☐ **C** The frictional force is equal to the centripetal force.

☒ **D** The frictional force is not large enough.

(Total for Question 5 = 1 mark)

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

6 In a boiler, energy is transferred to water at a rate of 40 kW. The corresponding power loss from the boiler to the surroundings is 4.0 kW.

Which of the following is the efficiency of this boiler?

- ☒ **A** 0.10
- ☒ **B** 0.11
- ☒ **C** 0.90
- ☒ **D** 0.91

(Total for Question 6 = 1 mark)

7 A car is fitted with an airbag which will inflate if the car stops very suddenly.



(Source: © KAIROS, LATIN STOCK/SCIENCE PHOTO LIBRARY)

Which of the following is increased if the airbag inflates because the car suddenly stops?

- ☒ **A** change in momentum of the driver
- ☒ **B** change in velocity of the driver
- ☒ **C** force on the driver
- ☒ **D** time that the driver takes to stop

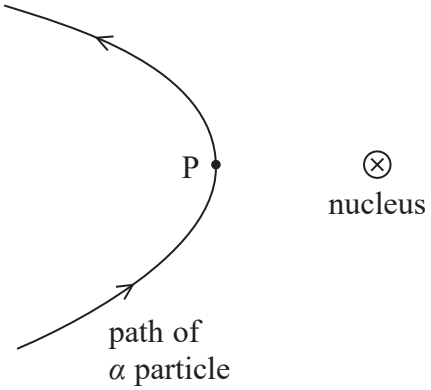
(Total for Question 7 = 1 mark)

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

Questions 8 and 9 refer to the information below.

Alpha particle scattering investigations were first carried out in the early part of the 20th century.

The diagram shows the path of an α particle that is being deflected by the nucleus of a gold atom. The closest distance of approach of the α particle to the nucleus is at point P.



8 Which row in the table describes the speed and potential energy of the α particle at point P on this path?

		Speed at P	Potential energy at P
☒	**A**	greatest	greatest
☒	**B**	greatest	least
☒	**C**	least	greatest
☒	**D**	least	least

(Total for Question 8 = 1 mark)

9 Which of the following can be concluded about a gold atom from the deflection of this α particle?

☒ **A** The atom contains electrons.

☒ **B** The atom has zero charge.

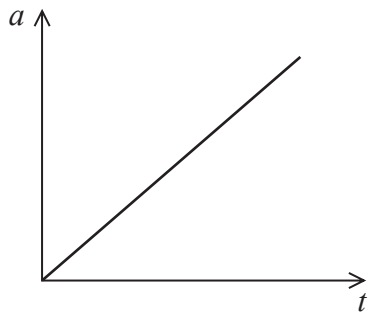
☒ **C** The nucleus is very small compared to the atom.

☒ **D** The nucleus of the atom is positively charged.

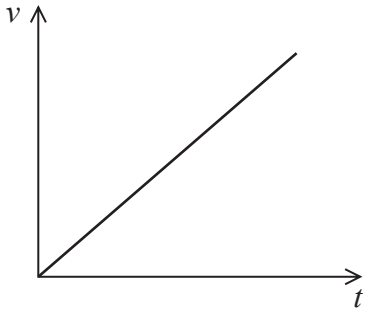
(Total for Question 9 = 1 mark)

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

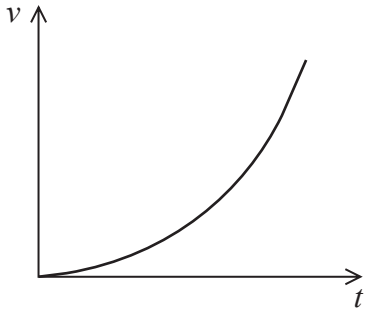
10 An object moves from rest. The graph shows how the acceleration a varies with time t.



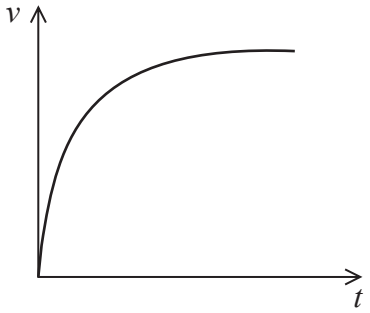
Which of the following graphs best shows how the velocity v of the object varies with t over the same time interval?



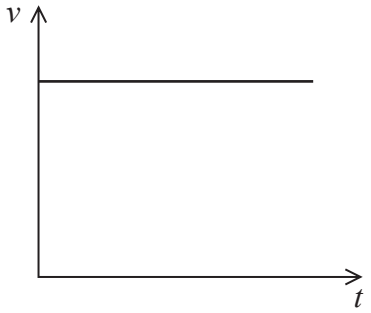
☒ **A**



☒ **B**



☒ **C**

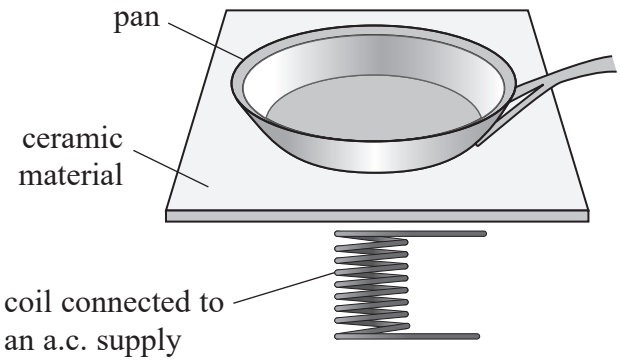


☒ **D**

(Total for Question 10 = 1 mark)

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

11 An induction hob consists of a coil beneath a sheet of ceramic material. The coil is connected to an alternating current (a.c.) supply as shown.



(a) A steel pan containing water is placed on the induction hob.

Explain why the pan becomes hot when the supply is switched on.

(4)

The alternating current in the coil produces a magnetic field (flux) which is continually changing in magnitude and direction.

So there is a changing magnetic flux (flux linkage) through the steel pan.

By Faraday's law, this changing flux induces an emf in the pan.

The steel pan is an electrical conductor, so the induced emf causes (eddy) currents in the pan, which heat the pan.

(b) The a.c. supply to the coil in an induction hob has a much higher frequency than normal mains frequency.

Explain why this is an advantage in this case.

(2)

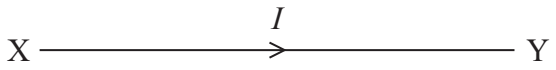
A higher frequency means the magnetic flux through the pan changes more quickly (a greater rate of change of flux).

So a larger emf is induced in the pan, giving a larger induced current and so a greater heating effect.

(Total for Question 11 = 6 marks)

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

12 An electrical conductor XY carries a current I as shown.



The current density j is defined as $j = \frac{I}{A}$ where A is the cross-sectional area of the conductor.

(a) Current density is a vector quantity.

State what is meant by a vector quantity.

(1)

A vector quantity has both magnitude and direction.

(b) I is constant but A decreases towards end Y.

Explain how this affects the drift velocity of the free electrons in the conductor.

(2)

$I = nqvA$, where n and q are constant, and I is constant, so $v \propto 1/A$.

As A decreases towards end Y, the drift velocity of the free electrons increases.

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

(c) The resistivity ρ of the conducting material is given by $\rho = \frac{E}{j}$

where E is the electric field strength.

Show that the units are the same on both sides of this equation.

(4)

Units of ρ: $R = \rho l/A$ so $\rho = RA/l$, units = $\Omega\ m^2 \div m = \Omega\ m$

Units of E: $N\ C^{-1} = V\ m^{-1}$ (from $E = V/d$)

Units of $j = I/A$: $A\ m^{-2}$

Units of $E/j = V\ m^{-1} \div A\ m^{-2} = (V\ A^{-1}) \times (m^2\ m^{-1}) = \Omega\ m$, since $R = V/I$ so $1\ V\ A^{-1} = 1\ \Omega$

So both sides of $\rho = E/j$ have units of Ω m: the units are the same.

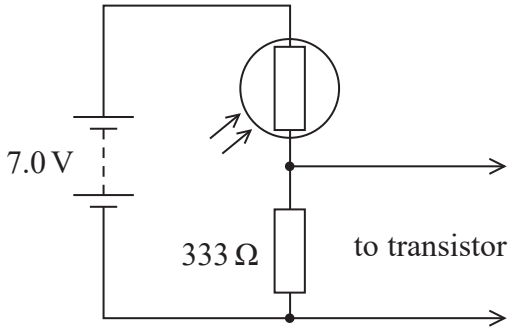
(Total for Question 12 = 7 marks)

DO NOT WRITE IN THIS AREA

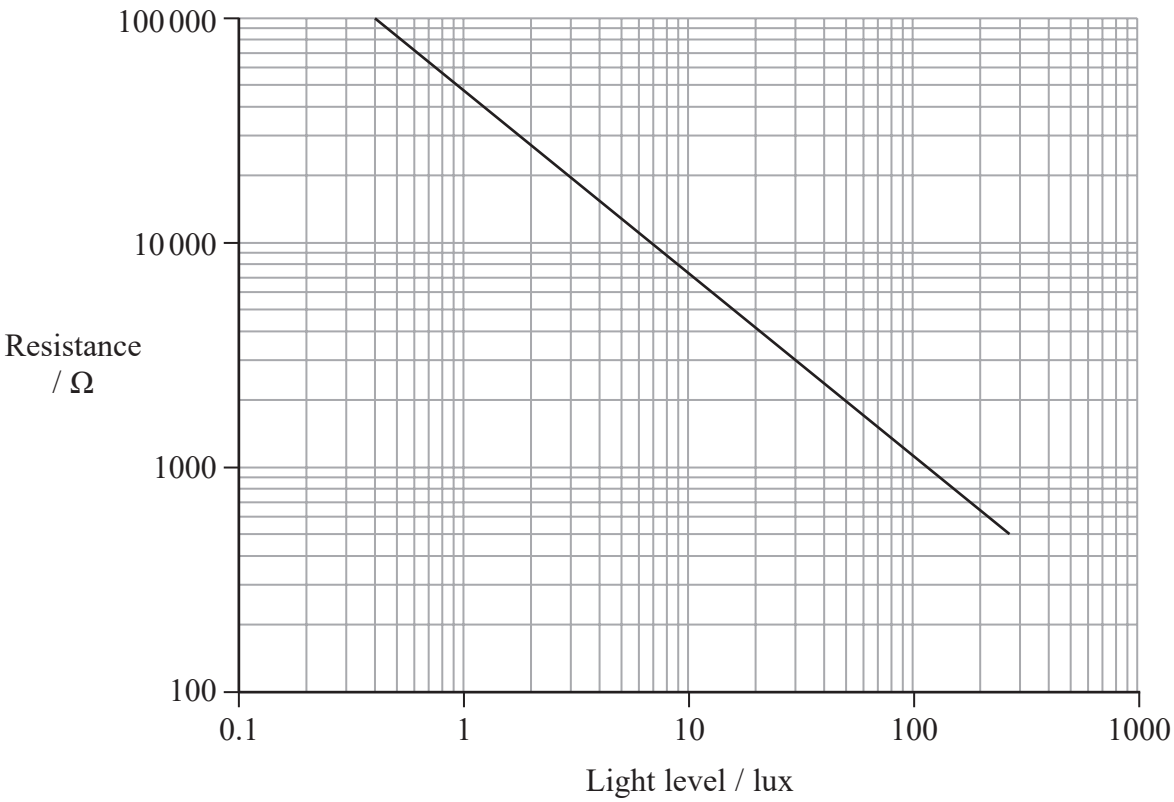
DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

13 The circuit shown provides an input to a transistor. A transistor is a type of electronic switch and in this circuit it can be assumed to have infinite resistance.



The resistance of the LDR varies with light level as shown below.



The transistor switches on when the potential difference across the input increases above 0.7 V. This should happen as the light level reaching the LDR increases above 30 lux.

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

(a) Deduce whether this circuit responds as required.

(6)

From the graph, at 30 lux the resistance of the LDR is 3000 Ω.

Potential divider: the p.d. across the 333 Ω resistor (the input to the transistor) is in the ratio of the resistances:

V/7.0 V = 333 Ω/(333 Ω + 3000 Ω), so V = 7.0 V × 333/3333 = 0.70 V

So at 30 lux the input p.d. is 0.7 V, the p.d. at which the transistor switches on.

If the light level increases above 30 lux, the resistance of the LDR decreases, so the 333 Ω resistor gets a greater share of the 7.0 V.

So the p.d. across the input increases above 0.7 V and the transistor switches on: the circuit does respond as required.

(b) Explain how the resistance of the LDR changes as the light level increases.

(2)

As the light level increases, more photons are absorbed, so more electrons are released into the conduction band (more electrons become free).

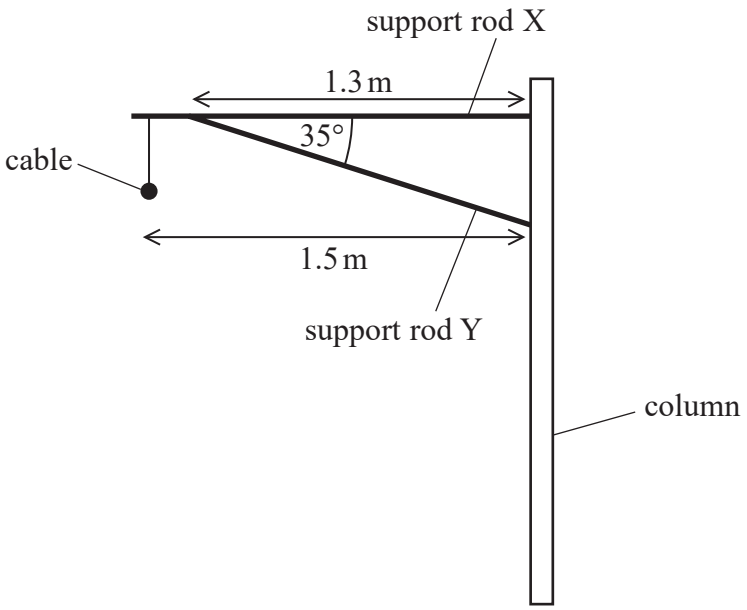
So there are more charge carriers, and the resistance of the LDR decreases.

(Total for Question 13 = 8 marks)

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

14 Overhead electricity cables for railway lines are supported by structures like the one shown.

An electric cable of mass 45 kg is suspended from a support rod X. A second support rod Y is attached to X. X and Y are attached at one end to a column.



Not to scale

The masses of support rods X and Y are negligible.

(a) (i) Determine, by taking moments, the force exerted on rod X by rod Y.

(4)

Take moments about the right-hand end of X, where X joins the column.

Weight of cable W = mg = 45 kg × 9.81 N kg^{-1} = 441 N

Component of the force T from Y perpendicular to X = T sin 35°, acting 1.3 m from the column.

Principle of moments: 441 N × 1.5 m = T sin 35° × 1.3 m

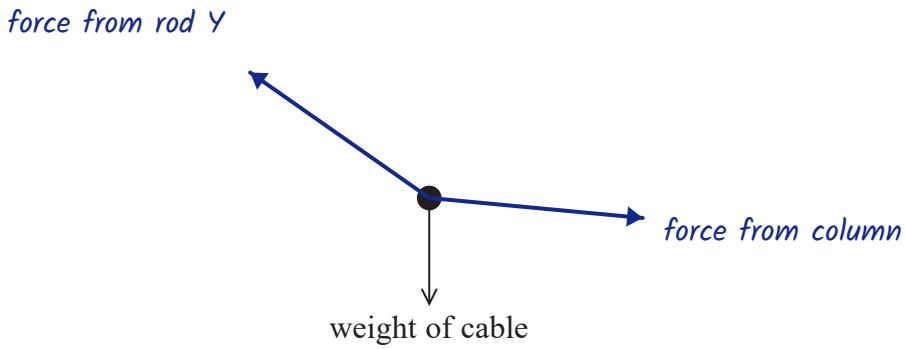
T = 662 N m ÷ (1.3 m × sin 35°) = 888 N

Force = 890 N

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

(ii) Complete the free-body force diagram for support rod X.

(2)



(b) A website gives a value of the electric field strength E, at two distances from the electric cable.

Distance / m	E / N C^{-1}
3	1200
25	100

Deduce whether these data are consistent with an inverse square law.

(3)

For an inverse square law, $E = k/r^2$, so Er^2 should be constant.

At 3 m: $Er^2 = 1200\ N\ C^{-1} \times (3\ m)^2 = 10\ 800\ N\ m^2\ C^{-1}$

At 25 m: $Er^2 = 100\ N\ C^{-1} \times (25\ m)^2 = 62\ 500\ N\ m^2\ C^{-1}$

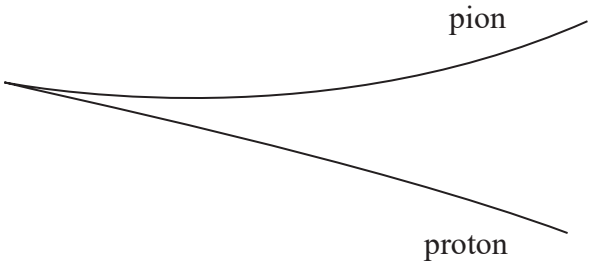
The two values of Er^2 are not equal, so the data are not consistent with an inverse square law.

(Total for Question 14 = 9 marks)

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

15 A delta particle decays into a proton and a pion.

(a) The diagram shows tracks in a particle detector formed when the delta particle decays.



(i) State why it can be concluded from the diagram that the delta particle is neutral.

(1)

The delta particle leaves no track before the point of decay (only charged particles leave tracks).

(ii) Deduce the charge on the pion.

(2)

The proton is positive (charge +1). The pion's track curves in the opposite direction to the proton's track, so the pion has the opposite charge.

Charge is conserved: 0 = (+1) + (−1), so the pion is negative, charge −1 (e).

(iii) Complete the particle equation for the decay of the delta (Δ^0) particle.

(1)

$\Delta^0 \rightarrow p^+ + \pi^-$

(iv) State why the delta particle must be classified as a baryon based on the evidence of its decay.

(1)

Baryon number is conserved: the proton is a baryon (B = +1) and the pion is not (B = 0), so the delta has B = +1.

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

(v) Explain how the momentum of the proton compares with the momentum of the pion.

(3)

The proton's track has a much larger radius of curvature (is less curved) than the pion's track.

For a charged particle in a magnetic field, $p = BQr$, and B and the magnitude of Q are the same for both, so $p \propto r$.

So the momentum of the proton is greater than the momentum of the pion.

(b) The mass of the delta particle is 1232 MeV/c^2.

(i) Calculate the mass of the delta particle in kg.

(3)

$E = 1232 \times 10^6$ eV $\times$ 1.60×10^{-19} J eV^{-1} $= 1.97 \times 10^{-10}$ J

$\Delta E = c^2 \Delta m$, so $m = E/c^2 = 1.97 \times 10^{-10}$ J $\div$ $(3.00 \times 10^8$ m $s^{-1})^2$

$m = 2.19 \times 10^{-27}$ kg

Mass = 2.19×10^{-27} kg

(ii) The mass of the proton is 939 MeV/c^2 and the mass of the pion is 139 MeV/c^2.

Explain why the sum of the masses of the two particles after the decay is not equal to the mass of the delta particle.

(3)

Total mass after = 939 + 139 = 1078 MeV/c^2, which is less than 1232 MeV/c^2: a difference of 154 MeV/c^2.

According to $\Delta E = c^2 \Delta m$, this mass difference is converted to energy (154 MeV).

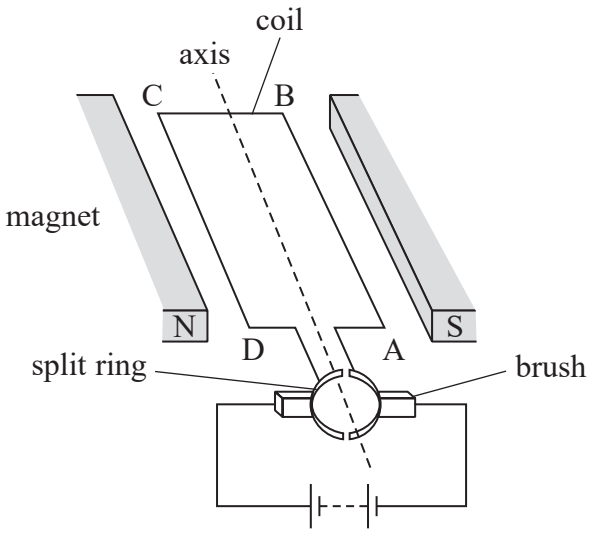
This energy becomes the (extra) kinetic energy of the proton and pion after the decay.

(Total for Question 15 = 14 marks)

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

16 Electric vehicles use a direct current (d.c.) electric motor powered by a battery for propulsion. A simplified diagram of a d.c. electric motor is shown.

A split ring consists of two semi-circular sections that are attached to a coil. The coil is labelled ABCD. Two brushes, made of carbon, rub against and make electrical contact with the split ring.



*(a) Describe how this arrangement can lead to the coil rotating.

(6)

The battery drives a current through the brushes and split ring into the coil, e.g. from D to C in side DC and from B to A in side BA.

Sides DC and BA are current-carrying conductors perpendicular to the magnetic field between N and S, so each experiences a force ($F = BIl$).

By Fleming's left-hand rule the force on side DC is vertically downwards and the force on side BA is vertically upwards.

These forces are in opposite directions on either side of the axis, so they produce a moment (couple) about the axis, so the coil rotates (anticlockwise).

As the coil moves through half a turn, the split ring swaps contact between the brushes, so the current in each side of the coil switches direction.

So the side on the left always has a downward force, the moment stays in the same direction and the coil continues to rotate in the same direction.

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

(b) An advert for an electric car has the following information:

- electric motor can develop up to 390 kW output power
- car achieves a velocity of 28 m s^{-1} from rest in 4.0 s at maximum power

Calculate the work done by resistive forces when the car accelerates to a velocity of 28 m s^{-1} from rest in 4.0 s.

mass of car = 1950 kg

(3)

Work done by the motor $W = Pt = 390 \times 10^3$ W $\times$ 4.0 s $= 1.56 \times 10^6$ J

Kinetic energy gained $E_k = \frac{1}{2}mv^2 = \frac{1}{2} \times 1950$ kg $\times$ (28 m s^{-1})$^2 = 7.64 \times 10^5$ J

Work done by resistive forces $= 1.56 \times 10^6$ J $- 7.64 \times 10^5$ J $= 7.96 \times 10^5$ J

Work done by resistive forces = 8.0×10^5 J

(c) A website suggests that 'fast-charging' the battery in an electric vehicle can increase the internal resistance of the battery.

Explain why an increase in internal resistance of a battery is a disadvantage.

(3)

With a greater internal resistance, more energy is transferred (as heat) in the battery itself, rather than to the motor.

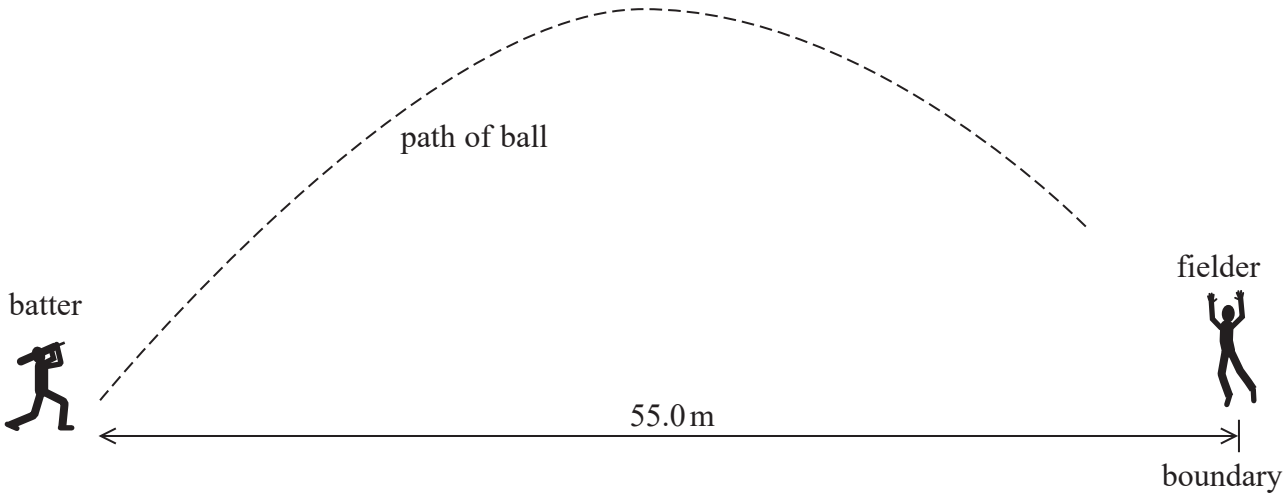
So the battery (and car) is less efficient, and the terminal p.d. and current are reduced, so less power reaches the motor.

So the battery will need charging more often, i.e. journeys will be shorter.

(Total for Question 16 = 12 marks)

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

17 In cricket a fielder is often placed at the boundary edge as shown. If the fielder catches the ball, the batter is out.



The fielder is 55.0 m away from the batter. The fielder can catch the ball providing the ball is less than three metres above the height at which it was hit.

The ball is hit with a velocity of 23.8 m s^{-1} and at an angle of 50.0° to the horizontal.

(a) Deduce whether the fielder can catch the ball in this case.

(5)

Vertical component: $u_v = 23.8 \sin 50.0° = 18.23 \text{ m s}^{-1}$. Horizontal component: $u_h = 23.8 \cos 50.0° = 15.30 \text{ m s}^{-1}$

Horizontally (constant velocity): $t = s/v = 55.0 \text{ m} \div 15.30 \text{ m s}^{-1} = 3.595 \text{ s}$

Vertically, taking upwards as positive, $a = -9.81 \text{ m s}^{-2}$: $s = ut + \frac{1}{2}at^2$

$s = 18.23 \text{ m s}^{-1} \times 3.595 \text{ s} - \frac{1}{2} \times 9.81 \text{ m s}^{-2} \times (3.595 \text{ s})^2$

$s = 65.5 \text{ m} - 63.4 \text{ m} = 2.1 \text{ m}$

When it reaches the fielder the ball is 2.1 m above the height at which it was hit, which is less than 3 m, so the fielder can catch the ball.

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

(b) The ball was bowled. Just after the bat hit the ball, the ball had a velocity of 23.8 m s^{-1} at an angle of 50° to the horizontal.

(i) Show that the magnitude of the momentum of the ball, after it was hit, was about 3.3 N s.

mass of cricket ball = 0.140 kg

(1)

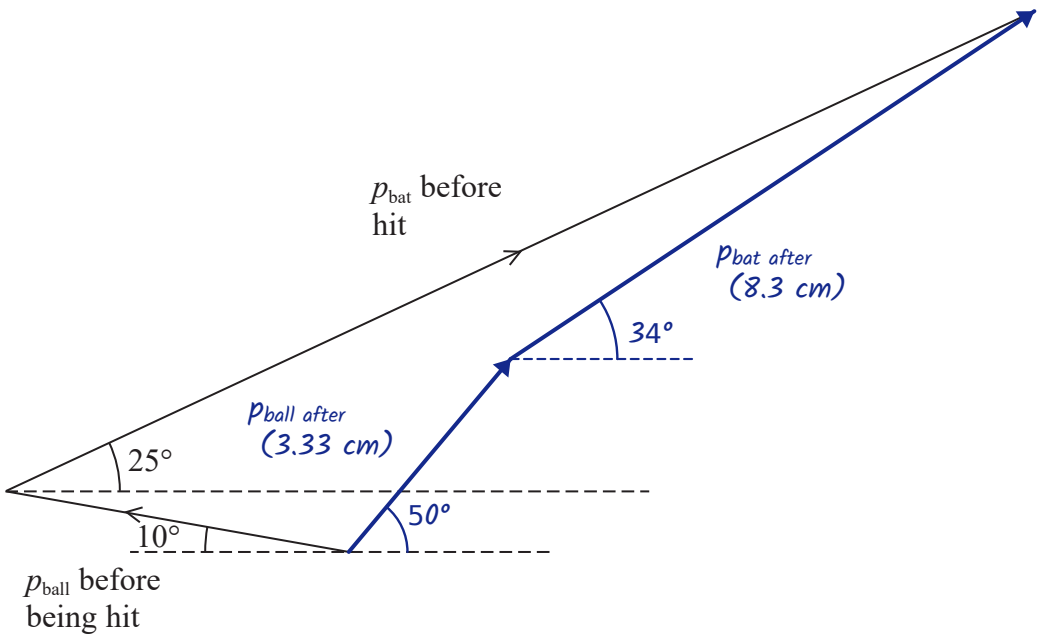
$p = mv = 0.140\ kg \times 23.8\ m\ s^{-1} = 3.33\ N\ s$ (about 3.3 N s)

(ii) The vector diagram below shows, accurately to scale, the momentum of the ball and the momentum of the bat before the hit.

Determine, by completing the vector diagram, the momentum of the bat after it hit the ball.

momentum of bat before hitting ball = 15.0 N s at 25° to the horizontal
momentum of ball before hitting bat = 4.6 N s at 10° to the horizontal

(5)



Scale: 1 cm = 1 N s

Total momentum before = total momentum after

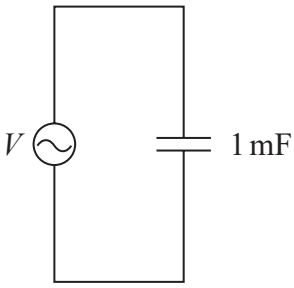
Momentum of bat after hitting ball = 8.3 N s

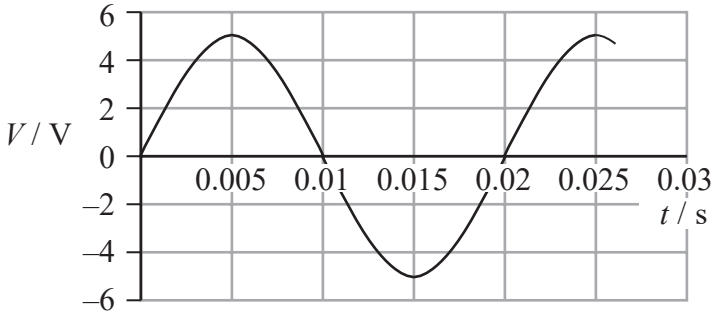
at an angle of 34° to the horizontal

(Total for Question 17 = 11 marks)

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

18 The circuit shows a 1 mF capacitor connected to an a.c. supply. The graph shows how the potential difference V varies with time t.





(a) (i) Calculate the root-mean-square potential difference.

(1)

$V_{rms} = V_0/\sqrt{2} = 5.0\ V \div \sqrt{2} = 3.54\ V$

Root-mean-square potential difference = 3.5 V

(ii) The formula used to generate this graph is $V = 5\sin(100\pi t)$

Explain why this formula leads to the graph above.

(3)

The 5 is the peak value (amplitude) of the p.d., 5 V, as shown on the graph.

The formula is $V = V_0 \sin(2\pi ft)$, so $\omega = 2\pi f = 100\pi$ rad s^{-1}, so $f = 50$ Hz.

So the time period $T = 1/f = 1/50$ Hz $= 0.02$ s, which is the period of one cycle on the graph (at $t = 0.02$ s, $100\pi t = 2\pi$).

At $t = 0$, $\sin 0 = 0$, so V starts at zero and increases, as shown.

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

(b) A spreadsheet is used to model how the current I in the 1 mF capacitor varies with t. Six rows of the spreadsheet are shown below.

	A	B	C	D	E	F	G
	t / s	Δt / s	V / V	$Q_{initial}$ / C	Q_{final} / C	ΔQ / C	I / A
7	0.0050	0.0010	5.00	0.00476	0.00500	0.00024	0.24
8	0.0060	0.0010	4.76	0.00500	0.00476	–0.00024	–0.24
9	0.0070	0.0010	4.05	0.00476	0.00405	–0.00071	–0.71
10	0.0080	0.0010	2.94	0.00405	0.00294	–0.00111	–1.11
11	0.0090	0.0010	1.55	0.00294	0.00155	–0.00139	–1.39
12	0.0100	0.0010	0	0.00155	0.00000	–0.00155	–1.55

(i) Explain how cell E10 has been calculated.

(2)

Using $Q = CV$: E10 = C10 × C, i.e. $Q_{final} = V \times C$,

where C = 1 mF = 0.001 F, so E10 = 2.94 V × 0.001 F = 0.00294 C

(ii) State the formula used to calculate cell G11.

(1)

$I = \Delta Q/\Delta t$, so G11 = F11/B11

(iii) Calculate the maximum energy stored on the capacitor.

(2)

Maximum energy when V is maximum, V_0 = 5.0 V

$W = \frac{1}{2}CV^2 = \frac{1}{2} \times 0.001\ F \times (5.0\ V)^2 = 0.0125\ J$

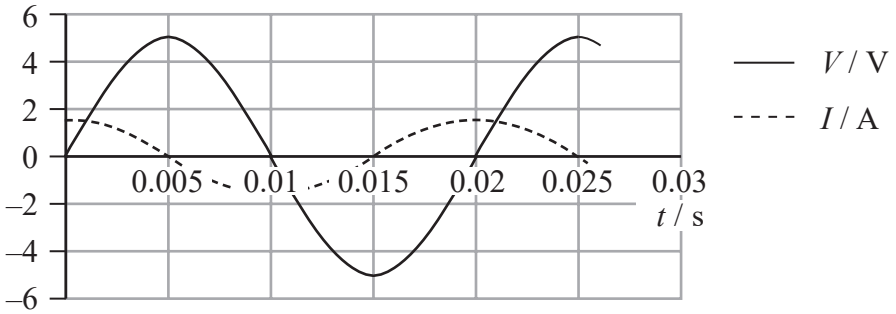
Maximum energy stored on the capacitor = 0.0125 J

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

(c) The spreadsheet data are used to plot a graph to show how I varies with t. This is shown as a dashed line below.



The corresponding graph of V against t is also shown as a continuous line.

Deduce whether the capacitor dissipates power over one cycle of the a.c. supply.

(4)

Power P = IV. From 0 to 0.005 s, V and I are both positive, so P is positive, e.g. at 0.0025 s, P = 3.5 V × 1.1 A = +3.9 W.

From 0.005 s to 0.01 s, V is positive but I is negative, so P is negative, e.g. at 0.0070 s, P = 4.05 V × (−0.71 A) = −2.9 W.

The quarter cycles are symmetrical, so the energy stored is returned to the supply; overall power over one cycle is zero, so no power is dissipated.

(Total for Question 18 = 13 marks)

TOTAL FOR PAPER = 90 MARKS

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

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 law constant	$k = \frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9} \text{ N m}^2 \text{ C}^{-2}$	
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	$u = 1.66 \times 10^{-27} \text{ kg}$	

Mechanics

Kinematic equations of motion

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

$$v = u + at$$

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

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

Forces

$$\Sigma F = ma$$

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

$$W = mg$$

moment of force $= Fx$

Momentum

$$p = mv$$

Work, energy and power

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

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

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

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

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

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

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

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

Electric circuits

Potential difference

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

Resistance

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

Electrical power and energy

$$P = VI$$

$$P = I^2R$$

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

$$W = VIt$$

Resistivity

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

Current

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

$$I = nqvA$$

Materials

Density

$$\rho = \frac{m}{V}$$

Stokes' law

$$F = 6\pi\eta rv$$

Hooke's law

$$\Delta F = k\Delta x$$

Young modulus

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

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

$$E = \frac{\sigma}{\varepsilon}$$

Elastic strain energy

$$\Delta E_{\text{el}} = \tfrac{1}{2}F\Delta x$$

Waves and particle nature of light

Wave speed

$$v = f\lambda$$

Speed of a transverse wave on a string

$$v = \sqrt{\frac{T}{\mu}}$$

Intensity of radiation

$$I = \frac{P}{A}$$

Power of a lens

$$P = \frac{1}{f}$$

$$P = P_1 + P_2 + P_3 + \ldots$$

Thin lens equation

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

Magnification for a lens

$$m = \frac{\text{image height}}{\text{object height}} = \frac{v}{u}$$

Diffraction grating

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

Refractive index

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

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

Critical angle

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

Photon model

$$E = hf$$

Einstein's photoelectric equation

$$hf = \phi + \tfrac{1}{2}mv^2_{\text{max}}$$

de Broglie wavelength

$$\lambda = \frac{h}{p}$$

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

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

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

$$v = \omega r$$

$$T = \frac{2\pi}{\omega}$$

$$F = ma = \frac{mv^2}{r}$$

$$a = \frac{v^2}{r}$$

$$a = r\omega^2$$

$$F = mr\omega^2$$

Fields

Coulomb's law

$$F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$$

Electric field strength

$$E = \frac{F}{Q}$$

$$E = \frac{Q}{4\pi\varepsilon_0 r^2}$$

$$E = \frac{V}{d}$$

Electric potential

$$V = \frac{Q}{4\pi\varepsilon_0 r}$$

Capacitance

$$C = \frac{Q}{V}$$

Energy stored in a capacitor

$$W = \tfrac{1}{2}QV$$

$$W = \tfrac{1}{2}CV^2$$

$$W = \tfrac{1}{2}\frac{Q^2}{C}$$

Capacitor discharge

$$Q = Q_0 e^{-t/RC}$$

$$I = I_0 e^{-t/RC}$$

$$V = V_0 e^{-t/RC}$$

$$\ln Q = \ln Q_0 - \frac{t}{RC}$$

$$\ln I = \ln I_0 - \frac{t}{RC}$$

$$\ln V = \ln V_0 - \frac{t}{RC}$$

In a magnetic field

$$F = BIl \sin\theta$$

$$F = Bqv \sin\theta$$

Faraday's and Lenz's laws

$$\mathscr{E} = \frac{-\mathrm{d}(N\phi)}{\mathrm{d}t}$$

Root-mean-square values

$$V_{rms} = \frac{V_0}{\sqrt{2}}$$

$$I_{rms} = \frac{I_0}{\sqrt{2}}$$

Nuclear and particle physics

In a magnetic field

$$r = \frac{p}{BQ}$$

Thermodynamics

Heating

$$\Delta E = mc\Delta\theta$$

$$\Delta E = L\Delta m$$

Molecular kinetic theory

$$\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$$

$$pV = \frac{1}{3}Nm\langle c^2\rangle$$

Ideal gas equation

$$pV = NkT$$

Stefan-Boltzmann law

$$L = \sigma AT^4$$

$$L = 4\pi r^2\sigma T^4$$

Wien's law

$$\lambda_{max}T = 2.898 \times 10^{-3}\ \text{m K}$$

Space

Intensity

$$I = \frac{L}{4\pi d^2}$$

Redshift of electromagnetic radiation

$$z = \frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}$$

Cosmological expansion

$$v = H_0 d$$

Nuclear radiation

Mass-energy

$$\Delta E = c^2\Delta m$$

Radioactive decay

$$A = \lambda N$$

$$\frac{dN}{dt} = -\lambda N$$

$$\lambda = \frac{\ln 2}{t_{½}}$$

$$N = N_0\, e^{-\lambda t}$$

$$A = A_0\, e^{-\lambda t}$$

Gravitational fields

Gravitational force

$$F = \frac{Gm_1m_2}{r^2}$$

Gravitational field strength

$$g = \frac{Gm}{r^2}$$

Gravitational potential

$$V_{grav} = \frac{-Gm}{r}$$

Oscillations

Simple harmonic motion

$$F = -kx$$

$$a = -\omega^2 x$$

$$x = A\cos\omega t$$

$$v = -A\omega\sin\omega t$$

$$a = -A\omega^2\cos\omega t$$

$$T = \frac{1}{f} = \frac{2\pi}{\omega}$$

$$\omega = 2\pi f$$

Simple harmonic oscillator

$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$T = 2\pi\sqrt{\frac{l}{g}}$$

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

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

BLANK PAGE

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

BLANK PAGE