AQA A-LEVEL PHYSICS

PHYSICS



EXAM QUESTION PACK

UNIT 4 OLD SPECIFICATION PAPERS

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A-level PHYSICS A

Unit 4 Fields and Further Mechanics Section A

Monday 20 June 2016 Morning

Time allowed: The total time for both sections of this paper is 1 hour 45 minutes. You are advised to spend approximately 45 minutes on this section.

Materials

In addition to this paper you will require:
- an objective test answer sheet
- a black ball-point pen
- a calculator
- a question paper/answer book for Section B (enclosed)
- a Data and Formulae booklet.

Instructions
- Use a black ball-point pen.
- Answer **all** questions in this section.
- For each question there are four responses. When you have selected the response which you think is the most appropriate answer to a question, mark this response on your answer sheet.
- Mark all responses as instructed on your answer sheet. If you wish to change your answer to a question, follow the instructions on your answer sheet.
- Do all rough work in this book **not** on the answer sheet.

Information
- The maximum mark for this section is 25.
- All questions in Section A carry equal marks. No deductions will be made for incorrect answers.
- A *Data and Formulae Booklet* is provided as a loose insert.
- The question paper/answer book for Section B is enclosed within this question paper.

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Multiple choice questions

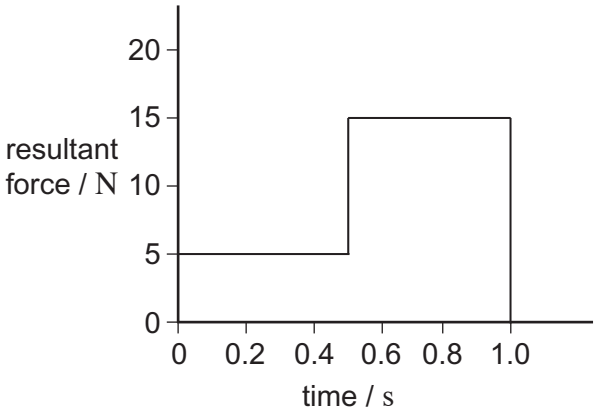
Each of Questions **1** to **25** is followed by four responses, **A**, **B**, **C**, and **D**. For each question select the best response and mark its letter on the answer sheet.

You are advised to spend about **45 minutes** on this section.

1 Which line, **A** to **D**, in the table correctly shows what is conserved in an elastic collision?

	Mass	Momentum	Kinetic energy	Total energy
A	conserved	not conserved	conserved	conserved
B	not conserved	conserved	conserved	not conserved
C	conserved	conserved	not conserved	conserved
D	conserved	conserved	conserved	conserved

2 The graph shows how the resultant force applied to an object of mass $2.0\ \text{kg}$, initially at rest, varies with time.



What is the speed of the object after $1.0\ \text{s}$?

A $2.5\ \text{m s}^{-1}$

B $5.0\ \text{m s}^{-1}$

C $7.5\ \text{m s}^{-1}$

D $10\ \text{m s}^{-1}$

3 What is the angular speed of a car wheel of diameter $0.400\ \text{m}$ when the speed of the car is $108\ \text{km h}^{-1}$?

A $75\ \text{rad s}^{-1}$

B $150\ \text{rad s}^{-1}$

C $270\ \text{rad s}^{-1}$

D $540\ \text{rad s}^{-1}$

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4 A ball of mass $0.30\ \text{kg}$ is attached to a string and moves in a **vertical** circle of radius $0.60\ \text{m}$ at a constant speed of $5.0\ \text{m s}^{-1}$.

Which line, **A** to **D**, in the table gives the correct values of the minimum and maximum tension in the string?

	Minimum tension / N	Maximum tension / N
A	2.5	5.4
B	6.7	9.6
C	13	13
D	9.6	15

5 Which one of the following statements is true when an object performs simple harmonic motion about a central point?

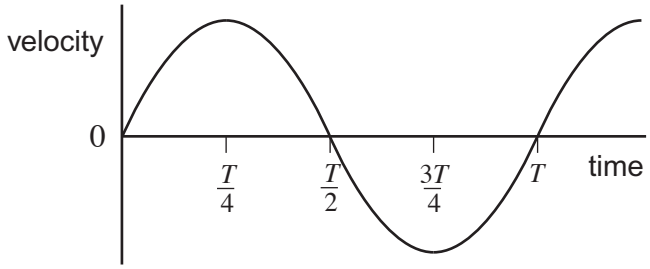
A The acceleration is always directed away from the central point.

B The acceleration and velocity are always 180° out of phase.

C The velocity and displacement are always in the same direction.

D Acceleration and displacement are always 180° out of phase.

6 The graph shows how velocity changes with time for a simple pendulum moving with simple harmonic motion.



Which one of the following statements related to the motion of the pendulum is **incorrect**?

A The acceleration is a minimum at $\frac{T}{4}$.

B The acceleration is a maximum at $\frac{T}{2}$.

C The kinetic energy is a maximum at $\frac{T}{2}$.

D The restoring force is a minimum at $\frac{3T}{4}$.

7 A mass hanging on the end of a spring undergoes vertical simple harmonic motion. At which point(s) is the magnitude of the resultant force on the mass a minimum?

A at both the top and bottom of the oscillation

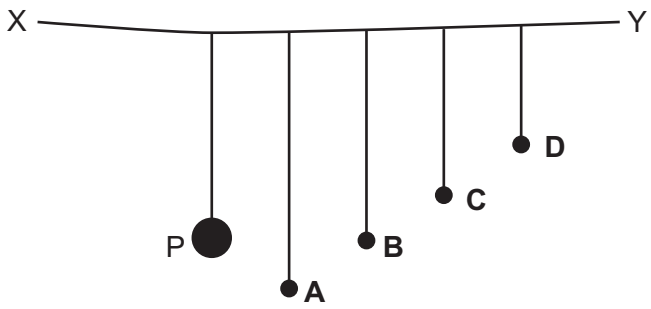
B only at the top of the oscillation

C only at the bottom of the oscillation

D at the centre of the oscillation

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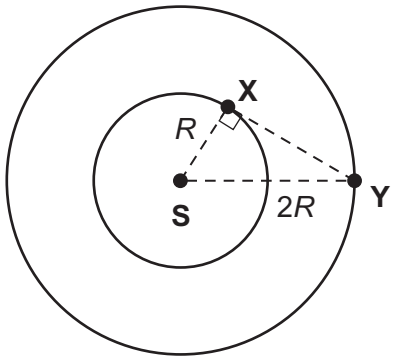
8 The diagram shows a string XY supporting a heavy pendulum P and four pendulums **A**, **B**, **C** and **D** of smaller mass.



Pendulum P is set in oscillation perpendicular to the plane of the diagram.

Which one of the pendulums, **A** to **D**, then oscillates with the largest amplitude?

9 Two planets **X** and **Y** are in concentric circular orbits about a star **S**. The radius of the orbit of **X** is R and the radius of orbit of **Y** is $2R$.



The gravitational force between **X** and **Y** is F when angle **SXY** is 90°, as shown in the diagram.
What is the gravitational force between **X** and **Y** when they are nearest to each other?

A $2F$

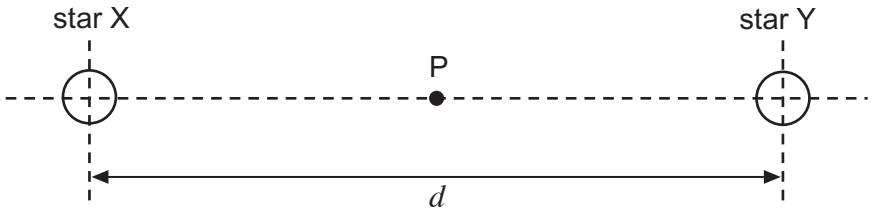
B $3F$

C $4F$

D $5F$

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10 X and Y are two stars of equal mass M. The distance between their centres is d.



What is the gravitational potential at the mid-point P between them?

A $\frac{GM}{2d}$

B $-\frac{GM}{d}$

C $-\frac{4GM}{d}$

D $-\frac{8GM}{d}$

11 A geosynchronous satellite is in a constant radius orbit around the Earth. The Earth has a mass of 6.0×10^{24} kg and a radius of 6.4×10^{6} m.

What is the height of the satellite above the Earth's surface?

A 1.3×10^{7} m

B 3.6×10^{7} m

C 4.2×10^{7} m

D 4.8×10^{7} m

12 A +2.0 nC point charge X is at a fixed distance from a −1.0 nC point charge Y. The force between the two charges is F.



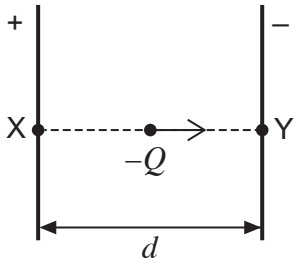
If an **additional** charge of +2.0 nC is supplied to both X and Y, which line, **A** to **D**, in the table gives the magnitude and direction of the force on X?

	Magnitude	Direction
A	$2F$	from X to Y
B	$4F$	from X to Y
C	$2F$	from Y to X
D	$4F$	from Y to X

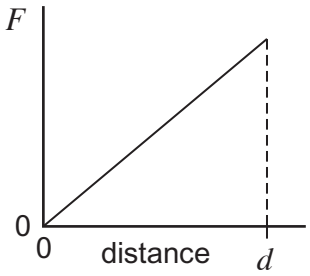
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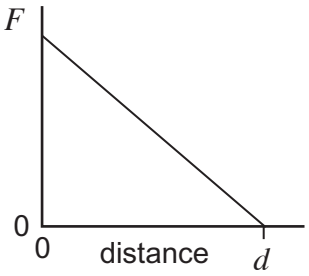
13 The diagram shows a charge $-Q$ being moved from point X to point Y between two charged parallel plates separated by a distance d.



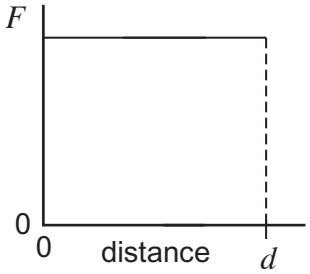
Which one of the following graphs best illustrates how the magnitude of force F on the charge varies with distance as it moves towards Y?



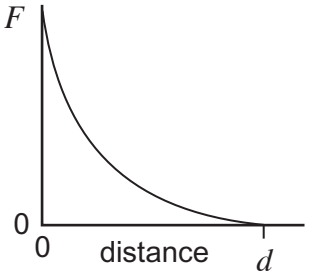
A



B



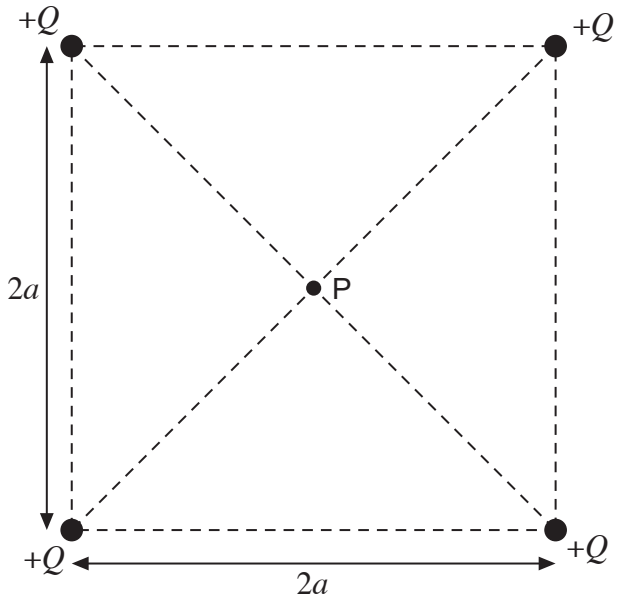
C



D

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14 The diagram shows four point charges, each $+Q$, at the corners of a square of side $2a$.



What is the electric field strength at P, the centre of the square?

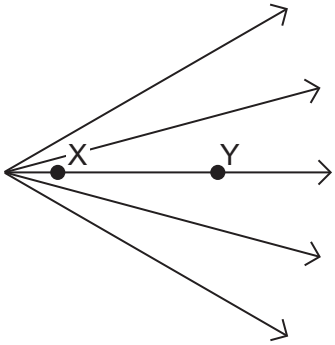
A zero

B $\dfrac{Q}{4\pi\varepsilon_0 a^2}$

C $\dfrac{Q}{2\pi\varepsilon_0 a^2}$

D $\dfrac{Q}{\pi\varepsilon_0 a^2}$

15 The diagram shows the field lines in a region of an electric field created by a positive charge.



Which one of the following statements is correct?
When moving from X to Y

A the electric potential is constant.

B the electric potential increases.

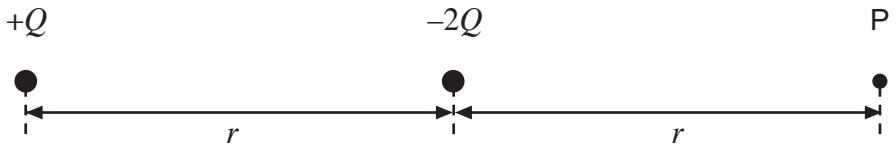
C the electric potential decreases.

D the electric potential changes from positive to negative.

Turn over ▶

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16 The diagram shows two point charges of magnitude $+Q$ and $-2Q$ placed a distance r apart.



What is the electric potential at point P, a distance r to the right of the $-2Q$ charge?

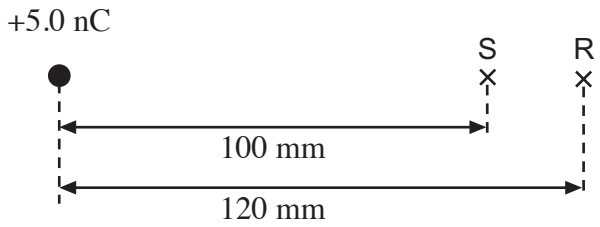
A $-\dfrac{3Q}{8\pi\varepsilon_0 r}$

B $-\dfrac{Q}{2\pi\varepsilon_0 r}$

C $+\dfrac{Q}{8\pi\varepsilon_0 r}$

D $+\dfrac{5Q}{8\pi\varepsilon_0 r}$

17



The potentials at points R and S due to the +5.0 nC charge are 375 V and 450 V respectively.

How much work is done when a +2.0 nC charge is moved from R to S?

A 0.12 μJ

B 0.15 μJ

C 0.19 μJ

D 0.38 μJ

18 The gravitational constant, G, is a constant of proportionality in Newton's law of gravitation. The permittivity of free space, ε_0, is a constant of proportionality in Coulomb's law.

When comparing the electrostatic force acting on a pair of charged particles to the gravitational force between them, the product $\varepsilon_0 G$ can appear in the calculation.

Which is a unit for $\varepsilon_0 G$?

A $C^2\ kg^{-2}$

B $C^2\ m^{-2}$

C $F\ kg^2\ N^{-1}\ m^{-2}$

D it has no unit

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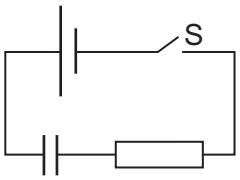
19 A variable capacitor has a capacitance which can be varied from 6.0×10^{-12} F to 3.0×10^{-12} F. The capacitor is set to its maximum capacitance and fully charged using a 48 V supply. The capacitor is then disconnected from the supply and isolated. Finally the capacitance is reduced to its minimum value without any charge being lost by the capacitor.

Which line, **A** to **D**, in the table correctly shows the potential difference (pd) across the capacitor and the charge it stores after the capacitance has been reduced?

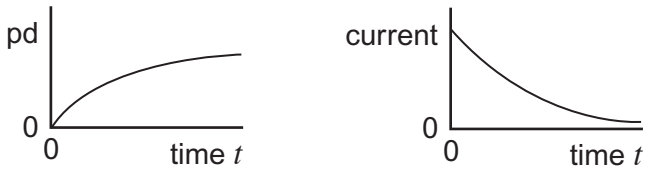
	pd / V	Charge / C
A	48	2.9×10^{-10}
B	24	2.9×10^{-10}
C	96	2.9×10^{-10}
D	96	1.4×10^{-10}

20 The capacitor in the circuit is initially uncharged. The switch S is closed at time $t = 0$.

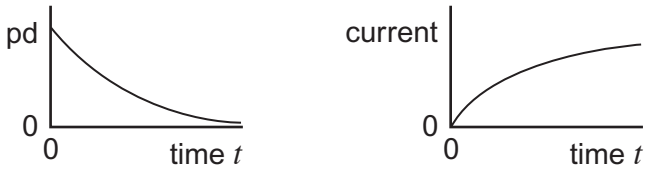
Which pair of graphs, **A** to **D**, correctly shows how the pd across the capacitor and the current in the circuit change with time?



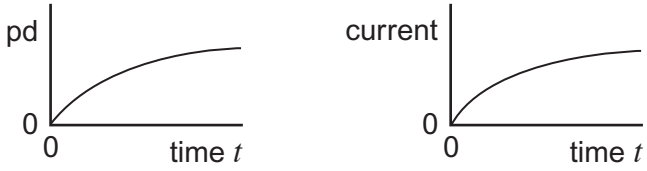
A



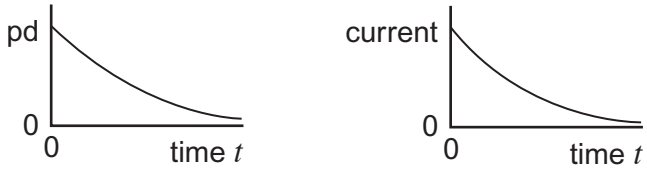
B



C



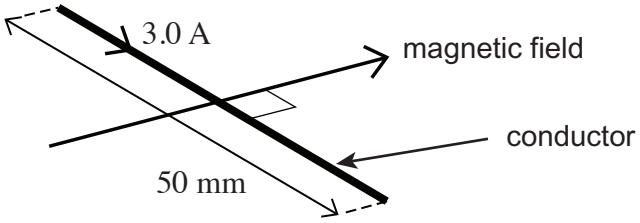
D



Turn over ▶

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21 The diagram shows a horizontal conductor of length $50\ \text{mm}$ carrying a current of $3.0\ \text{A}$ at right angles to a uniform horizontal magnetic field of flux density $0.50\ \text{T}$.



What is the magnitude and direction of the magnetic force on the conductor ?

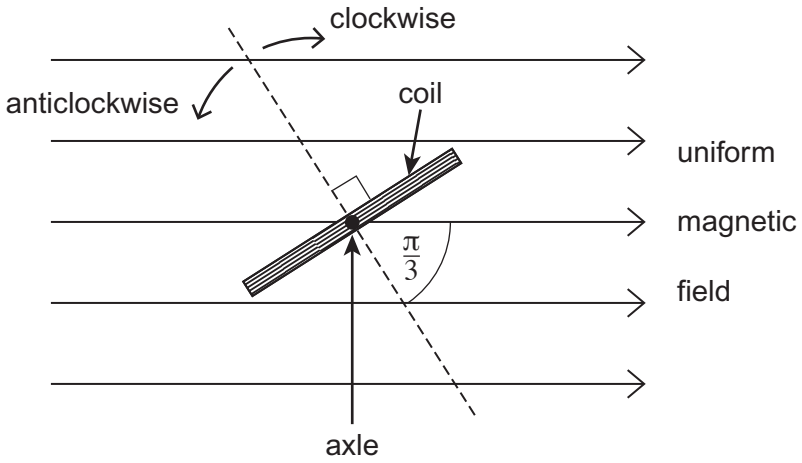
A $0.075\ \text{N}$ vertically upwards

B $0.075\ \text{N}$ vertically downwards

C $75\ \text{N}$ vertically upwards

D $75\ \text{N}$ vertically downwards

22 The diagram shows a coil placed in a uniform magnetic field. In the position shown, the angle between the normal to the plane of the coil and the magnetic field is $\frac{\pi}{3}$ rad.



Which line, **A** to **D**, in the table shows the angles through which the coil should be rotated, and the direction of rotation, so that the flux linkage becomes (i) a maximum, and (ii) a minimum?

	Angle of rotation / rad	
	(i) for maximum flux linkage	**(ii) for minimum flux linkage**
A	$\frac{\pi}{6}$ clockwise	$\frac{\pi}{3}$ anticlockwise
B	$\frac{\pi}{6}$ anticlockwise	$\frac{\pi}{3}$ clockwise
C	$\frac{\pi}{3}$ clockwise	$\frac{\pi}{6}$ anticlockwise
D	$\frac{\pi}{3}$ anticlockwise	$\frac{\pi}{6}$ clockwise

Do not write outside the box

23 A train is travelling at $20\ \text{m s}^{-1}$ along a horizontal track through a uniform magnetic field of flux density $4.0 \times 10^{-5}\ \text{T}$ acting vertically downwards.

What is the emf induced between the ends of an axle $1.5\ \text{m}$ long?

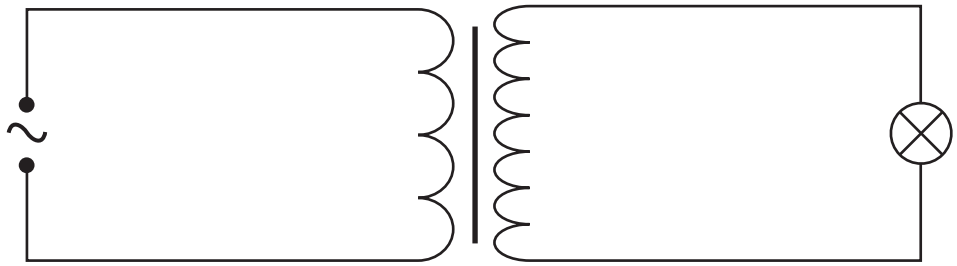
A $3.0 \times 10^{-6}\ \text{V}$

B $5.3 \times 10^{-4}\ \text{V}$

C $1.2 \times 10^{-3}\ \text{V}$

D $7.5 \times 10^{5}\ \text{V}$

24 The primary coil of a step-up transformer is connected to a source of alternating pd. The secondary coil is connected to a lamp.



Which line, **A** to **D**, in the table correctly describes the ratios of flux linkages and currents through the secondary coil in relation to the primary coil?

	$\frac{\text{Secondary magnetic flux linkage}}{\text{Primary magnetic flux linkage}}$	$\frac{\text{Secondary current}}{\text{Primary current}}$
A	< 1	< 1
B	> 1	< 1
C	> 1	> 1
D	< 1	> 1

25 Which one of the following statements is the main reason for operating power lines at high voltage?

A Transformers are never perfectly efficient.

B High voltages are required by many industrial users of electricity.

C Electrical generators produce alternating current.

D For a given amount of transmitted power, increasing the voltage decreases the current.

END OF QUESTIONS

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A-level PHYSICS A

Unit 4 Fields and Further Mechanics Section B

Monday 20 June 2016 Morning

Time allowed: The total time for both sections of this paper is 1 hour 45 minutes. You are advised to spend approximately one hour on this section.

Materials

For this paper you must have:
- a calculator
- a ruler
- a Data and Formulae Booklet (enclosed).

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the space provided. Answers written in margins or on blank pages will not be marked.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 50.
- You are expected to use a calculator where appropriate.
- A *Data and Formulae Booklet* is provided as a loose insert.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use specialist vocabulary where appropriate.

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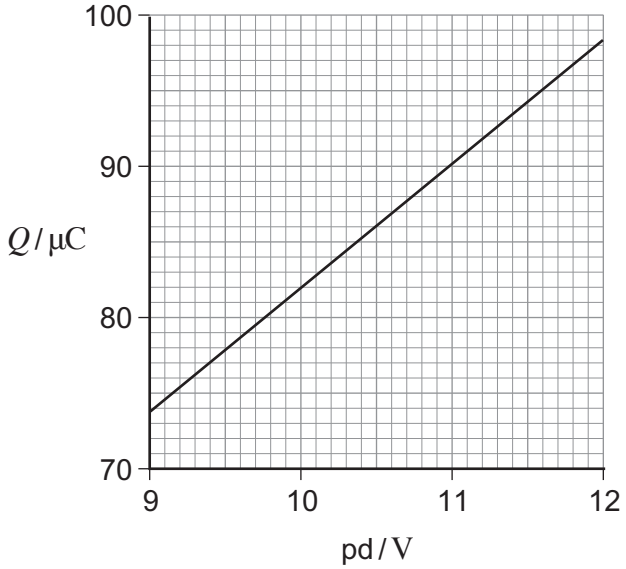
Section B

Answer **all** questions.

You are advised to spend approximately **one hour** on this section.

1 (a) **Figure 1** shows how the charge Q stored by a capacitor varies with the potential difference (pd) V across it as V is increased from 9.0 V to 12.0 V.

Figure 1



1 (a) (i) Use **Figure 1** to determine an accurate value for the capacitance of the capacitor.

[2 marks]

capacitance = _____ μF

1 (a) (ii) Calculate the additional energy stored by the capacitor when V is increased from 9.0 V to 12.0 V.

[3 marks]

additional energy = _____ J

Do not write outside the box

1 (b) When a 470 μF capacitor is discharged through a fixed resistor R, the pd across it decreases by 80% in 45 s.

1 (b) (i) Calculate the time constant of the capacitor–resistor circuit.

[3 marks]

time constant = _____ s

1 (b) (ii) Determine the resistance of R.

[2 marks]

resistance = _____ Ω

1 (b) (iii) At which point during the discharging process is the capacitor losing charge at the smallest rate? Tick (✓) the correct answer.

[1 mark]

	✓ if correct
when the charge on the capacitor is greatest	
when energy is dissipated at the greatest rate	
when the current in the resistor is greatest	
when the pd across R is least	

11

Turn over ▶

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2 The planet Venus may be considered to be a sphere of uniform density 5.24×10^3 kg m^{-3}.
The gravitational field strength at the surface of Venus is 8.87 N kg^{-1}.

2 (a) (i) Show that the gravitational field strength g_s at the surface of a planet is related to the the density ρ and the radius R of the planet by the expression

$$g_s = \frac{4}{3}\pi GR\rho$$

where G is the gravitational constant.

[2 marks]

2 (a) (ii) Calculate the radius of Venus.
Give your answer to an appropriate number of significant figures.

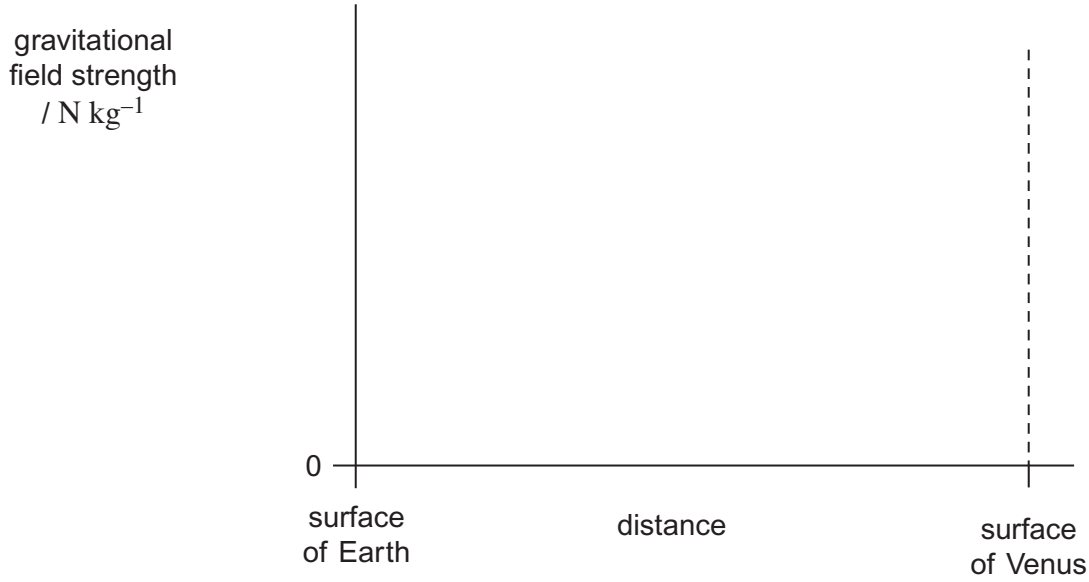
[3 marks]

radius = _____ m

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2 (b) At a certain time, the positions of Earth and Venus are aligned so that the distance between them is a minimum.
Sketch a graph on the axes below to show how the magnitude of the gravitational field strength g varies with distance along the shortest straight line between their surfaces.
Consider only the contributions to the field produced by Earth and Venus.
Mark values on the vertical axis of your graph.

[3 marks]



8

Turn over for the next question

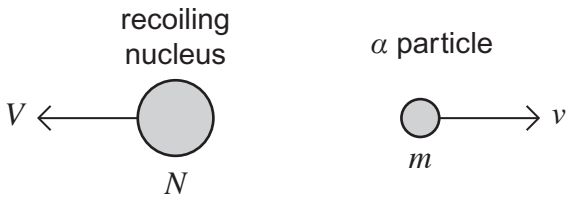
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3 (a) State the condition for momentum to be conserved in a system.

[1 mark]

3 (b) When a stationary unstable nucleus emits an α particle with velocity v the resulting nucleus recoils with velocity V, as shown in **Figure 2**.

Figure 2



The mass of the α particle is m and the mass of the recoiling nucleus is N.

3 (b) (i) Show how the principle of conservation of momentum may be used to derive an expression for V in terms of N, m and v.

[2 marks]

Do not write outside the box

3 (b) (ii) Assume that all of the energy released in the emission process is transferred as kinetic energy to the α particle and the recoiling nucleus. The total energy released is E. Use your result from part **(b)(i)** to show that the kinetic energy of the α particle is given by

$$E_\alpha = \left(\frac{N}{N+m}\right)E$$

[4 marks]

3 (c) (i) The isotope of radon $^{220}_{86}\mathrm{Rn}$ decays by emitting an α particle.

State the nucleon number of the recoiling nucleus.

[1 mark]

nucleon number = _____

Question 3 continues on the next page

Do not write outside the box

3 (c) (ii) The total energy released when a nucleus of $^{220}_{86}\mathrm{Rn}$ decays is 1.02×10^{-12} J.

Calculate the magnitude of the momentum of the α particle.
State an appropriate unit for your answer.

Mass of a nucleon = 1.66×10^{-27} kg

[4 marks]

momentum = _____ unit _____

3 (d) Explain why the expressions in parts **(b)(i)** and **(b)(ii)** could **not** be applied when an unstable nucleus decays by emitting a β^- particle.

[1 mark]

_____

_____

_____

_____

13

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Turn over for the next question

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

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4 Within certain limits, the bob of a simple pendulum of length l may be considered to move with simple harmonic motion of period T, where

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

4 (a) State **one** limitation that applies to the pendulum when this equation is used.

[1 mark]

4 (b) Describe an experiment to determine the value of the Earth's gravitational field strength g using a simple pendulum and any other appropriate apparatus.

In your answer you should:

- describe how you would arrange the apparatus
- indicate how you would make the measurements
- explain how you would calculate the value of g by a graphical method
- state the experimental procedures you would use to ensure that your result was accurate.

You may draw a diagram to help you with your answer.

The quality of your written communication will be assessed in your answer.

[6 marks]

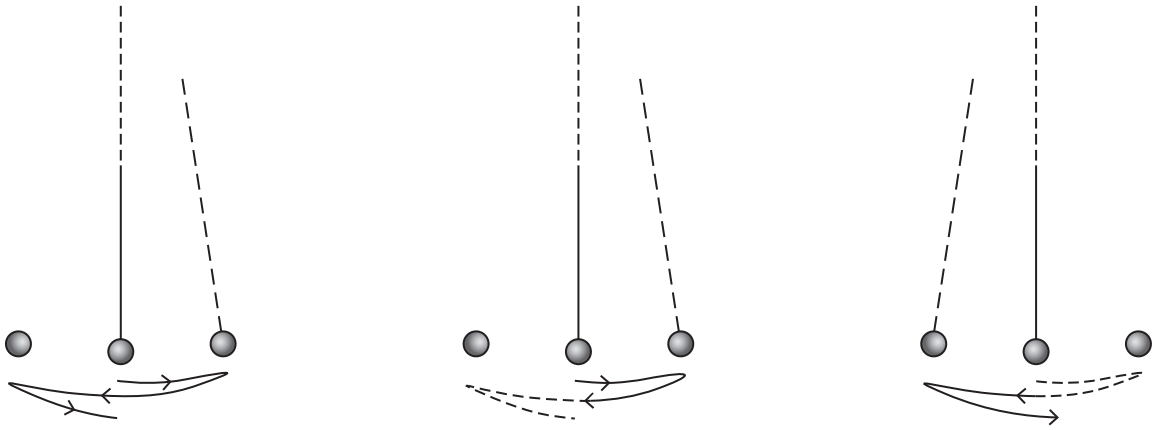
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Question 4 continues on the next page

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4 (c) When carrying out the experiment in part **(b)**, a student measures the time period incorrectly. Mistakenly, the student thinks that the time period is the time taken for half of an oscillation instead of a full oscillation, as illustrated in **Figure 3**.

Figure 3



full oscillation half oscillation

Deduce the effect this will have on the value of g obtained from the experiment, explaining how you arrive at your answer.

[3 marks]

10

Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

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5 (a) State, in words, the two laws of electromagnetic induction.

[3 marks]

Law 1 _____

_____

_____

_____

Law 2 _____

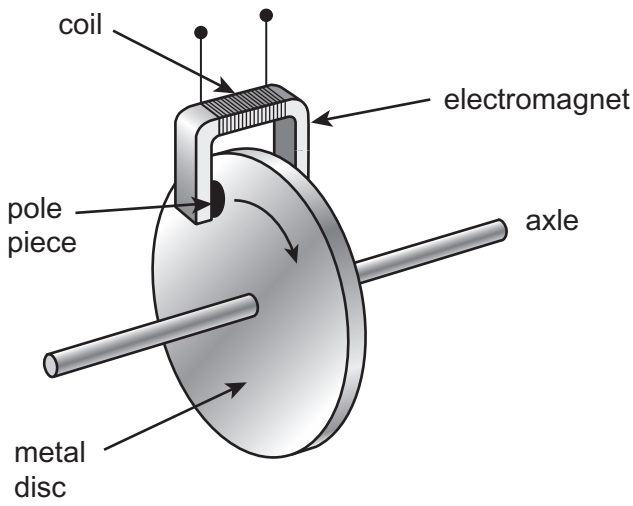
_____

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_____

5 (b) **Figure 4** illustrates the main components of one type of electromagnetic braking system. A metal disc is attached to the rotating axle of a vehicle. An electromagnet is mounted with its pole pieces placed either side of the rotating disc, but not touching it. When the brakes are applied, a direct current is passed through the coil of the electromagnet and the disc slows down.

Figure 4



Do not write outside the box

5 (b) (i) Explain, using the laws of electromagnetic induction, how the device in **Figure 4** acts as an electromagnetic brake.

[3 marks]

5 (b) (ii) A conventional braking system has friction pads that are brought into contact with a moving metal surface when the vehicle is to be slowed down.
State **one** advantage and **one** disadvantage of an electromagnetic brake compared to a conventional brake.

[2 marks]

Advantage _____

Disadvantage _____

8

END OF QUESTIONS

There are no questions printed on this page

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AQA

A-Level
Physics

PHYA4 – Fields and Further Mechanics
Mark scheme

2450
June 2016

Version: 1.0 Final

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It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of students' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

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Section A

1	**D**	14	**A**
2	**B**	15	**C**
3	**B**	16	**A**
4	**D**	17	**B**
5	**D**	18	**A**
6	**C**	19	**C**
7	**D**	20	**A**
8	**B**	21	**A**
9	**B**	22	**D**
10	**C**	23	**C**
11	**B**	24	**B**
12	**C**	25	**D**
13	**C**		

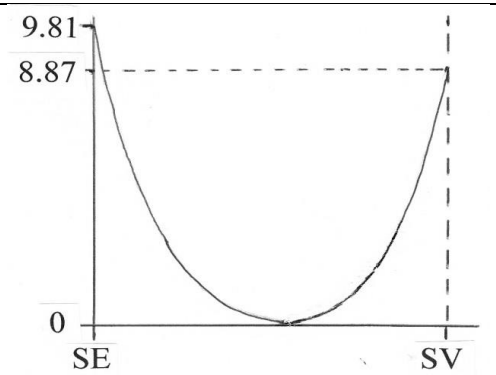
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Question	Answers	Additional Comments/Guidance	Mark	ID details
1(a)(i)	capacitance $\left(=\frac{Q}{V}\right) = \frac{98.2-73.9}{12.0-9.0}$ ✓ = 8.1 (μF) ✓ (± 0.2 μF)	1 mark only if correct value of C is found from a single point. 2 marks if correct value of C is found from at least 2 points and a mean value, or from gradient. (Check graph.) Accept 8 (μF) if from correct working.	2	
1(a)(ii)	additional energy = area between line and Q or V axis ✓ = {½ × (98.2 – 73.9) × 3.0} + {(98.2 – 73.9) × 9.0} ✓ = (36.5 + 218.7) = 255 μJ or 2.6×10^{-4} (J) ✓ [**or**, using ½ QV: additional energy = ½ Q_2V_2 – ½ Q_1V_1 ✓ = ½ {(98.2 × 12) – (73.9 × 9)} ✓ = 257 μJ or 2.6×10^{-4} (J) ✓] [**or**, using ½ CV^2: additional energy = ½ CV_2^2 – ½ CV_1^2 ✓ = ½ × 8.1 × ($12^2 – 9^2$) ✓ = 255 μJ or 2.6×10^{-4} (J) ✓] [**or**, using ½ Q^2/C: additional energy = ½ Q_2^2/C – ½ Q_1^2/C ✓ = ($98.2^2 – 73.9^2$) ÷ (2 × 8.1) ✓ = 258 μJ or 2.6×10^{-4} (J) ✓]	*First scheme*: alternative for 2nd mark = {½ × (98.2 – 73.9) × 3.0} + {73.9 × 3.0} ✓ *All schemes*: second mark subsumes the first mark. In all methods, allow tolerance of ± 10 μJ in final answer to allow for variation in graph measurements. Allow ECF for incorrect C value from (a)(i).	3	
1(b)(i)	($V = V_0e^{-t/RC}$ gives) $0.2V_0 = V_0e^{-t/RC}$ and $0.2 = e^{-45/RC}$ ✓	Condone use of 0.8 for 0.2 in first mark only.	3	

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	$\ln 0.2 = -\frac{45}{RC}$ **or** $\ln 5 = \frac{45}{RC}$ ✓ time constant $RC = -\frac{45}{\ln 0.2}$ **or** $\frac{45}{\ln 5}$ = 28(.0) (s) ✓			
1(b)(ii)	resistance of R = $\left(= \frac{\text{time constant}}{C}\right) = \frac{28.0}{470 \times 10^{-6}}$ ✓ $= 5.96 \times 10^4$ (Ω) or 60 kΩ ✓	Allow ECF for incorrect RC value from (b)(i).	2	
1(b)(iii)	tick in 4th box **only**		1	
Total			11	

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Question	Answers	Additional Comments/Guidance	Mark	ID details
2(a)(i)	$M = \frac{4}{3}\pi R^3 \rho$ ✓ combined with $g_S = \frac{GM}{R^2}$ (gives $g_S = \frac{4}{3}\pi GR\rho$) ✓	Do not allow *r* instead of *R* in final answer but condone in early stages of working. Evidence of combination, eg cancelling R^2 required for second mark.	2	
2(a)(ii)	$R = \left(\frac{3g_S}{4\pi G\rho}\right) = \frac{3\times 8.87}{4\pi \times 6.67\times 10^{-11}\times 5.24\times 10^3}$ ✓ gives R = 6.06 × 10^6 (m) ✓ answer to **3SF** ✓	SF mark is independent but may only be awarded after some working is presented.	3	
2(b)	line starts at 9.81 and ends at 8.87 ✓ correct shape curve which falls and rises ✓ falls to zero value near centre of and to right of centre of distance scale ✓ [*Minimum of graph in 3rd point to be >0.5 and <0.75 of SE-SV distance*]	 For 3rd mark accept flatter curve than the above in central region.	3	
Total			8	

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Question	Answers	Additional Comments/Guidance	Mark	ID details
3(a)	no external forces (act on the system of particles) [**or** forces between particles are internal forces] ✓	Allow "in a closed system".	1	
3(b)(i)	$NV = (-)\,mv$ [**or** $NV + mv = 0$] ✓ (gives) $V = (-)\frac{mv}{N}$ ✓	For 2nd mark, V must be the subject of the eqn.	2	
3(b)(ii)	½ NV^2 + ½ mv^2 = E ✓ substitution for V gives $\frac{1}{2}N\left(\frac{mv}{N}\right)^2 + E_\alpha = E$ ✓ from which $\frac{1}{2}\left(\frac{m}{N}\right)mv^2 + E_\alpha = E$ and $\left(\frac{m}{N}+1\right)E_\alpha = E$ ✓ rearrangement gives $E_\alpha = \frac{E}{\left(\frac{m+N}{N}\right)} = \left(\frac{N}{N+m}\right)E$ ✓	The 4 marks are for • conservation of energy • substitution for V • separation of E and E_α, with v eliminated • rearrangement to give final result Allow ECF for incorrect V expression from (b)(i): for 1st and 2nd marks only (ie max 2).	4	
3(c)(i)	nucleon number = 216		1	
3(c)(ii)	$E_\alpha = \left(\frac{216}{220}\right)\times 1.02\times 10^{-12}$ **or** = 1.00×10^{-12} (J) ✓ momentum of α = $m\sqrt{\frac{2E_\alpha}{m}}$ or = $\sqrt{2mE_\alpha}$ [**or** ½ × 4 × $1.66 \times 10^{-27} \times v^2 = 1.00 \times 10^{-12}$ gives momentum of α = $4\times 1.66\times 10^{-27}\times\sqrt{\frac{2\times 1.00\times 10^{-12}}{4\times 1.66\times 10^{-27}}}$] ✓ $\therefore$momentum of α = $\sqrt{\left(2\times 4\times 1.66\times 10^{-27}\times 1.00\times 10^{-12}\right)}$	Allow ECF for wrong value of A from (c)(i). **Alternative solution** for first three marks: energy of nucleus = 0.0185×10^{-12} (J) ✓ momentum of nucleus = $\sqrt{2NE_N}$ ✓ $\sqrt{\left(2\times 216\times 1.66\times 10^{-27}\times 0.0185\times 10^{-12}\right)}$ = 1.2 (1.15) × 10^{-19} ✓	4	

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	= 1.2 (1.15) × 10^{-19} ✓ N s **or** kg m s^{-1} ✓	Unit mark is independent.		
3(d)	an (anti)neutrino is emitted OR two particles are emitted by unstable nucleus in β^- decay [**or** calculation must account for momentum of (anti)neutrino] **[or** momentum is shared between three particles] ✓		1	
Total			13	

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Question	Answers	Additional Comments/Guidance	Mark	ID details
4(a)	amplitude (of bob) is small [**or** (angular) amplitude is less than or = 10°] [**or** sin $\theta \approx \theta$ with θ explained] ✓	**or** string is inextensible (or of negligible mass) **or** bob is a point mass Ignore references to "air resistance".	1	
4(b)	**The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.** The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. **High Level (Good to excellent): 5 or 6 marks** The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. *The candidate describes the arrangement of the apparatus clearly. They identify correctly the measurements to be made, and indicate how these measurements would be made. They describe a valid method by which a straight line graph may be obtained and show how g would be calculated from their graph. They are also aware of precautions that should be taken during the experiment to ensure that the result is accurate.* **Intermediate Level (Modest to adequate): 3 or 4 marks** The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used	A **high level** answer must include 1. a description of the apparatus, 2. a correct statement of the measurements to be made, 3. a correct graph plot, 4. a correct indication of how *g* would be found from the graph, 5. at least two precautions. An **intermediate level** answer must include (at least) 1 and 2, **or** 1 and 3, **or** 2 and 3, above and at least one precaution. A **low level** answer must include (at least) any one of 1,2,3,4 above. An inappropriate, irrelevant or physically incorrect answer should be awarded **a mark of zero.** If the experiment described relates to a	max 6	

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	incorrectly. The form and style of writing is less appropriate. *The candidate is less clear about the experimental arrangement, gives a reasonable account of the measurements to be made and indicates a valid method by which a straight line graph may be obtained. They are less clear about how the result would be calculated from the graph, and they know the precautions less well.* **Low Level (Poor to limited): 1 or 2 marks** The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. *The candidate gives a superficial account of the experimental arrangement, has some knowledge of the measurements to be made, but has only limited ability to show how a graphical method could be used to calculate the result. Some precautions may be known.* **The description expected in a competent answer should include a coherent selection of the following points.** • Diagram or description showing a bob suspended from a fixed point, on which the length l may be labelled correctly. • Length l of pendulum measured by ruler from fixed point of support to centre of mass of bob. • Period T measured by stopwatch, by timing a number of oscillations. • Measurement of T repeated for the same l and a mean value of T calculated. • Measurements repeated for at least five different values of l.	**compound pendulum**, mark to max 2. If a log graph is plotted and explained, it may gain credit. If a correct graph is **not** used, then maximum mark awarded is 3.		

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	• Graph of T^2 against l (or any other suitable linear graph) would be plotted. • Graph is a straight line through origin, gradient is $4\pi^2/g$ (or correct expression for g from their graph). **Experimental measures such as the following are likely to be given:** • Small amplitude oscillations. • Measure l to centre of mass of bob. • Measure T from a large number of oscillations. • Repeat timing for each length. • Begin counting oscillations at nought when t = 0. • Measure complete oscillations. • Use of fiducial mark at centre of oscillations. • Pendulum should swing in a vertical plane. • Avoid very small values of l when repeating the experiment. **Credit may be given for any of these points which are described by reference to an appropriate labelled diagram.**			
4(c)	measured value of g will be 4× true value of g ✓ gradient of T^2 against l graph will be ¼ of expected value [**or** reference to $g \propto 1/T^2$ or equivalent] ✓ (T is halved so) T^2 is ¼ of true value ✓	2nd and 3rd marks may be covered by an analysis of the period equation.	3	
Total			10	

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Question	Answers	Additional Comments/Guidance	Mark	ID details
5(a)	*(Faraday's law)* (induced) emf ∝ rate of change of flux (linkage) ✓ *(Lenz's law)* direction of induced emf (or current) ✓ is such as to oppose the change (in flux) producing it ✓	In either order. Allow "(induced) emf = rate of change of *flux linkage*". Ignore incorrect reference to names of laws.	3	
5(b)(i)	current in coil produces magnetic field or flux (that passes through disc) ✓ rotating disc cuts flux inducing/producing emf **or** current (in disc) ✓ induced (eddy) currents (in disc) interact with magnetic field ✓ force on (eddy) currents slows (or opposes) rotation (of disc) ✓	**Alternative** for last two points: (eddy) currents in disc cause heating of disc ✓ energy for heating comes from ke of disc or vehicle (which is slowed) ✓	max 3	
5(b)(ii)	*Advantage:* any one ✓ • no material (eg pads or discs or drums) to wear out • no pads needing replacement • no additional (or fewer) moving parts *Disadvantage:* any one ✓ • ineffective at low speed **or** when stationary • dependent on vehicle's electrical system remaining in working order • requires an electrical circuit (or source of electrical energy) to operate whereas pads do not	Answers must refer to advantages and disadvantages of the *electromagnetic* brake. Only accept points from these lists.	2	
Total			8	

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Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

General Certificate of Education
Advanced Level Examination
June 2015

Physics A PHYA4/1

Unit 4 Fields and Further Mechanics
Section A

Thursday 11 June 2015 9.00 am to 10.45 am

In addition to this paper you will require:
- an objective test answer sheet
- a black ball-point pen
- a calculator
- a question paper/answer book for Section B (enclosed)
- a Data and Formulae booklet.

Time allowed
- The total time for both sections of this paper is 1 hour 45 minutes. You are advised to spend approximately 45 minutes on this section.

Instructions
- Use a black ball-point pen.
- Answer **all** questions in this section.
- For each question there are four responses. When you have selected the response which you think is the most appropriate answer to a question, mark this response on your answer sheet.
- Mark all responses as instructed on your answer sheet. If you wish to change your answer to a question, follow the instructions on your answer sheet.
- Do all rough work in this book **not** on the answer sheet.

Information
- The maximum mark for this section is 25.
- All questions in Section A carry equal marks. No deductions will be made for incorrect answers.
- A *Data and Formulae Booklet* is provided as a loose insert.
- The question paper/answer book for Section B is enclosed within this question paper.

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Multiple choice questions

Each of Questions **1** to **25** is followed by four responses, **A**, **B**, **C**, and **D**. For each question select the best response and mark its letter on the answer sheet.

You are advised to spend about **45 minutes** on this section.

1 Which one of the following has the same unit as the rate of change of momentum?

A work

B energy

C acceleration

D weight

2 The nucleus of a radioactive isotope X is at rest and decays by emitting an α particle so that a new nuclide Y is formed.
Which one of the following statements about the decay is correct?

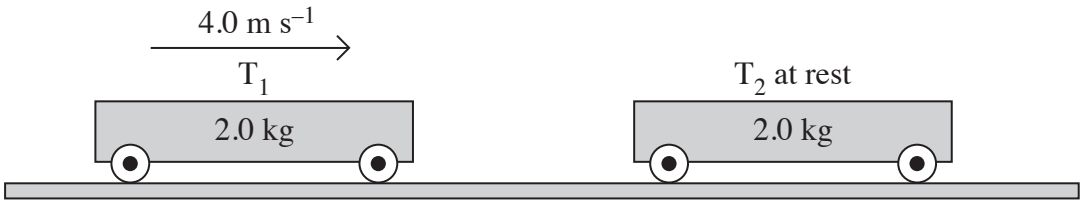
A The momentum of Y is equal and opposite to the momentum of the α particle.

B The momentum of Y is equal to the momentum of X.

C The kinetic energy of Y is equal to the kinetic energy of the α particle.

D The total kinetic energy is the same before and after the decay.

3 Trolley T_1, of mass $2.0\ kg$, collides on a horizontal surface with trolley T_2, which is also of mass $2.0\ kg$. The collision is elastic. Before the collision T_1 was moving at $4.0\ m\ s^{-1}$ and T_2 was at rest.



Which one of the following statements is correct?

Immediately after the collision

A T_1 is at rest and T_2 moves at $4.0\ m\ s^{-1}$.

B T_1 will rebound from T_2 at $4.0\ m\ s^{-1}$.

C T_1 and T_2 will both move at $2.8\ m\ s^{-1}$.

D T_1 and T_2 will both move at $1.4\ m\ s^{-1}$.

Do not write outside the box

4 For a body performing simple harmonic motion, which one of the following statements is correct?

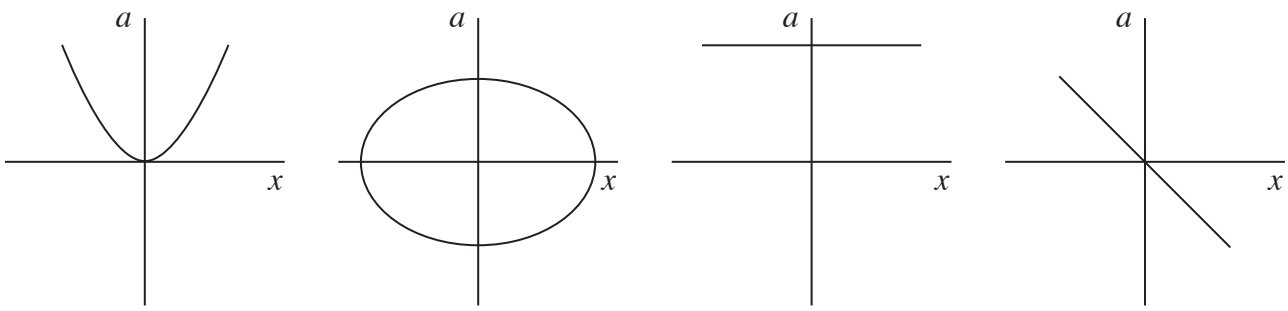
A The maximum kinetic energy is directly proportional to the frequency.

B The time for one oscillation is directly proportional to the frequency.

C The speed at any instant is directly proportional to the displacement.

D The maximum acceleration is directly proportional to the amplitude.

5 Which one of the following graphs shows how the acceleration, a, of a body moving with simple harmonic motion varies with its displacement, x?



A **B** **C** **D**

6 A particle of mass 5.0×10^{-3} kg, moving with simple harmonic motion of amplitude 0.15 m, takes 47 s to make 50 oscillations.
What is the maximum kinetic energy of the particle?

A 2.0×10^{-3} J

B 2.5×10^{-3} J

C 3.9×10^{-3} J

D 5.0×10^{-3} J

7 A simple pendulum has a time period of 1.42 s on Earth. The gravitational field strength at the surface of Mars is 0.37 times that at the surface of the Earth.
What is the time period of the pendulum on Mars?

A 0.53 s

B 0.86 s

C 2.33 s

D 3.84 s

Turn over ▶

Do not write outside the box

8 Two identical uniform spheres each of radius R are placed in contact. The gravitational force between them is F.

The spheres are now separated until the force of attraction is $\frac{F}{9}$.

What is the distance between the **surfaces** of the spheres after they have been separated?

A $2R$

B $4R$

C $8R$

D $12R$

9 A satellite of mass m is in a circular orbit at height R above the surface of a uniform spherical planet of radius R and density ρ.

What is the force of gravitational attraction between the satellite and the planet?

A $\frac{\pi\rho GmR}{3}$

B $\frac{2\pi\rho GmR}{3}$

C $\frac{\pi\rho GmR^2}{3}$

D $\frac{2\pi\rho GmR^2}{3}$

10 The following data refer to two planets, P and Q.

	Radius / km	**Density / kg m^{-3}**
planet P	8000	6000
planet Q	16 000	3000

The gravitational field strength at the surface of P is $13.4\ \text{N kg}^{-1}$.
What is the gravitational field strength at the surface of Q?

A $3.4\ \text{N kg}^{-1}$

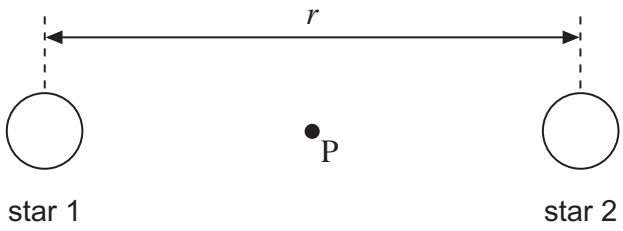
B $13.4\ \text{N kg}^{-1}$

C $53.6\ \text{N kg}^{-1}$

D $80.4\ \text{N kg}^{-1}$

Do not write outside the box

11 The diagram shows an isolated binary star system. The two stars have equal masses, M, and the distance between their centres is r.



The point P is half-way between the two stars.
What is the gravitational field strength at P?

A zero

B $-\frac{GM}{r^2}$

C $-\frac{2GM}{r^2}$

D $-\frac{4GM}{r^2}$

12 Which one of the following statements about gravitational potential is **incorrect**?

A It is analogous to the electric potential at a point in an electric field.

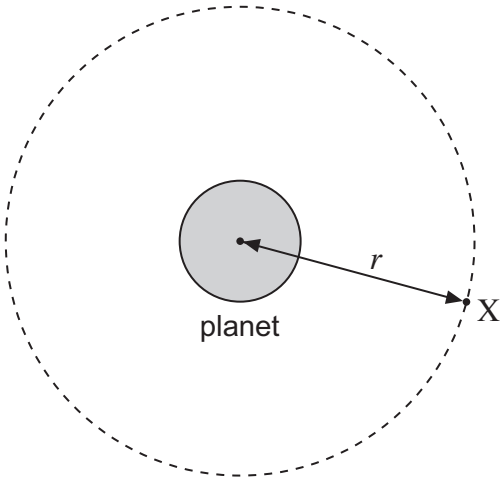
B It is equal to the gravitational potential energy of a mass of $1\ \text{kg}$.

C It is a vector quantity.

D The difference in gravitational potential between two points at different heights above the Earth depends on the position of the points.

Do not write outside the box

13 A satellite X is in a circular orbit of radius r about the centre of a spherical planet of mass M.



Which line, **A** to **D**, in the table gives correct expressions for the centripetal acceleration a and the speed v of the satellite?

	Centripetal acceleration a	**Speed v**
A	$\frac{GM}{2r}$	$\sqrt{\frac{GM}{2r}}$
B	$\frac{GM}{2r}$	$\sqrt{\frac{GM}{r}}$
C	$\frac{GM}{r^2}$	$\sqrt{\frac{GM}{2r}}$
D	$\frac{GM}{r^2}$	$\sqrt{\frac{GM}{r}}$

14 A satellite orbiting the Earth moves to an orbit which is closer to the Earth.

Which line, **A** to **D**, in the table shows correctly what happens to the speed of the satellite and to the time it takes for one orbit of the Earth?

	Speed of satellite	**Time for one orbit of Earth**
A	decreases	decreases
B	decreases	increases
C	increases	decreases
D	increases	increases

Do not write outside the box

15 A positive ion has a charge-to-mass ratio of 2.40×10^7 C kg^{-1}. It is held stationary in a vertical electric field.
Which line, **A** to **D**, in the table shows correctly both the strength and the direction of the electric field?

	Electric field strength / V m^{-1}	Direction
A	4.09×10^{-7}	upwards
B	4.09×10^{-7}	downwards
C	2.45×10^{6}	upwards
D	2.45×10^{6}	downwards

16 In the equation $X = \frac{ab}{r^n}$, X represents a physical variable in an electric or a gravitational field, a is a constant, b is either mass or charge and n is a number.

Which line, **A** to **D**, in the table provides a consistent representation of X, a and b according to the value of n?

The symbols E, g, V and r have their usual meanings.

	n	X	a	b
A	1	E	$\frac{1}{4\pi\varepsilon_0}$	charge
B	1	V	$\frac{1}{4\pi\varepsilon_0}$	mass
C	2	g	G	mass
D	2	V	G	charge

17 An uncharged 4.7 nF capacitor is connected to a 1.5 V supply and becomes fully charged.

How many electrons are transfered to the negative plate of the capacitor during this charging process?

A 2.2×10^{10}

B 3.3×10^{10}

C 4.4×10^{10}

D 8.8×10^{10}

Do not write outside the box

18 When fully charged the $2.0\ \text{mF}$ capacitor used as a backup for a memory unit has a potential difference of $5.0\ \text{V}$ across it. The capacitor is required to supply a constant current of $1.0\ \mu\text{A}$ and can be used until the potential difference across it falls by 10%. For how long can the capacitor be used before it must be recharged?

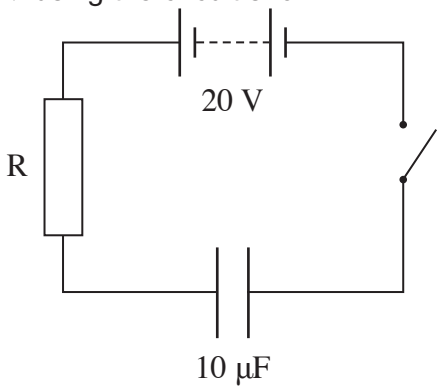
A $10\ \text{s}$

B $100\ \text{s}$

C $200\ \text{s}$

D $1000\ \text{s}$

19 A capacitor of capacitance $10\ \mu\text{F}$ is charged through a resistor R to a potential difference (pd) of $20\ \text{V}$ using the circuit shown.



When the capacitor is fully charged which one of the following statements is **incorrect**?

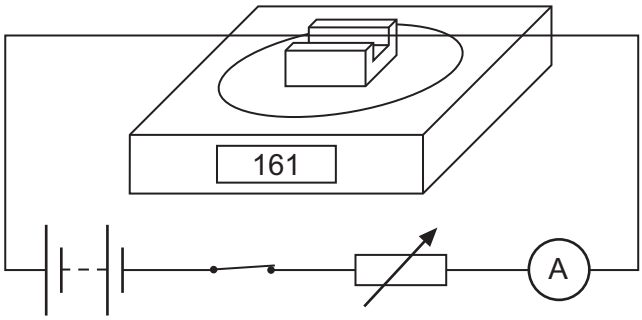
A The energy stored by the capacitor is $2\ \text{mJ}$.

B The total energy taken from the battery during the charging process is $2\ \text{mJ}$.

C The pd across the capacitor is $20\ \text{V}$.

D The pd across the resistor is $0\ \text{V}$.

20 The diagram shows a rigidly-clamped straight horizontal current-carrying wire held mid-way between the poles of a magnet on a top-pan balance. The wire is perpendicular to the magnetic field direction.



The balance, which was zeroed before the switch was closed, read $161\ \text{g}$ after the switch was closed. When the current is reversed and doubled, what would be the new reading on the balance?

A $-322\ \text{g}$

B $-161\ \text{g}$

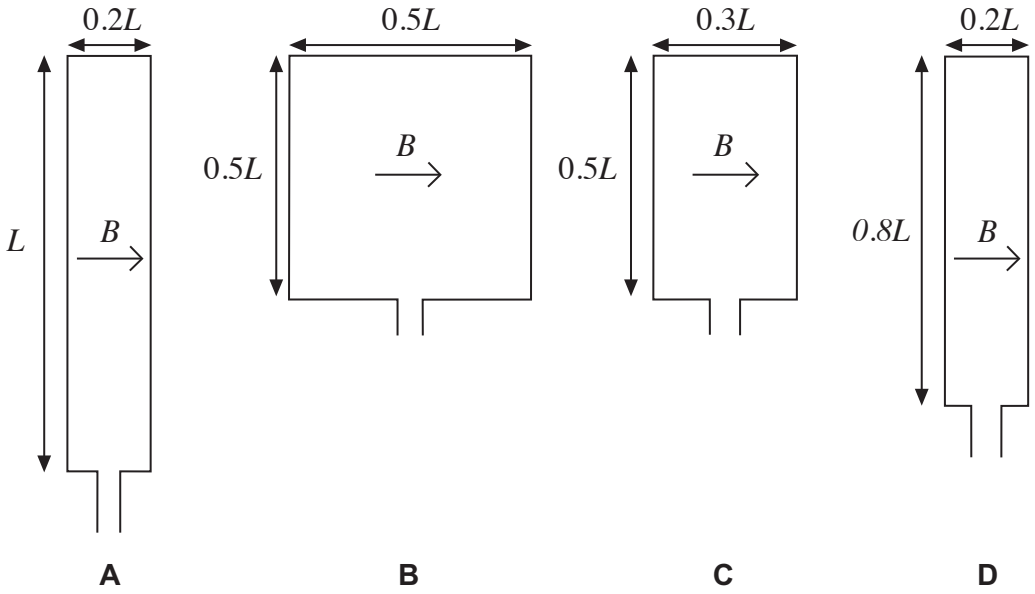
C zero

D $322\ \text{g}$

Do not write outside the box

21 Four rectangular loops of wire **A**, **B**, **C** and **D** are each placed in a uniform magnetic field of the same flux density B. The direction of the magnetic field is parallel to the plane of the loops as shown.

When a current of $1\ \text{A}$ is passed through each of the loops, magnetic forces act on them. The lengths of the sides of the loops are as shown.
Which loop experiences the largest couple?



22 Which one of the following statements is correct?

An electron follows a circular path when it is moving at right angles to

A a uniform magnetic field.

B a uniform electric field.

C uniform electric and magnetic fields which are perpendicular.

D uniform electric and magnetic fields which are in opposite directions.

Do not write outside the box

23 Two electrons, X and Y, travel at right angles to a uniform magnetic field. X experiences a magnetic force, F_X, and Y experiences a magnetic force, F_Y.

What is the ratio $\frac{F_X}{F_Y}$ if the kinetic energy of X is half that of Y?

A $\frac{1}{4}$

B $\frac{1}{2}$

C $\frac{1}{\sqrt{2}}$

D 1

24 A lamp rated at $12\ \text{V}\ 60\ \text{W}$ is connected to the secondary coil of a step-down transformer and is at full brightness. The primary coil is connected to a supply of $230\ \text{V}$. The transformer is 75% efficient.
What is the current in the primary coil?

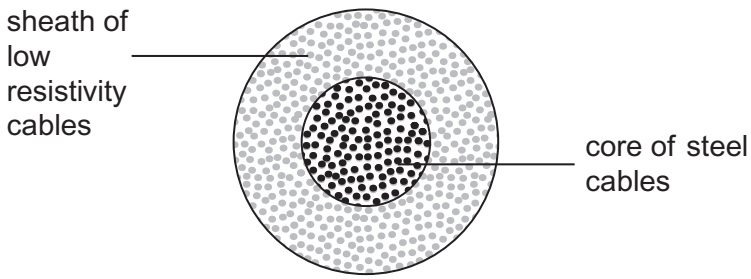
A $0.25\ \text{A}$

B $0.35\ \text{A}$

C $3.75\ \text{A}$

D $5.0\ \text{A}$

25 The overhead cables used to transmit electrical power by the National Grid usually consist of a central core of steel cables surrounded by a sheath of cables of low resistivity material, such as aluminium.



What is the main purpose of the steel core?

A to force more current into the outer sheath

B to provide additional current paths through the cables

C to reduce the power lost from the cables

D to increase the mechanical strength of the cables

END OF SECTION A

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

There are no questions printed on this page

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Centre Number						Candidate Number				
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Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
5	
TOTAL	

General Certificate of Education
Advanced Level Examination
June 2015

Physics A PHYA4/2

Unit 4 Fields and Further Mechanics
Section B

Thursday 11 June 2015 9.00 am to 10.45 am

For this paper you must have:
- a calculator
- a pencil and a ruler
- a Data and Formulae Booklet (enclosed).

Time allowed
- The total time for both sections of this paper is 1 hour 45 minutes. You are advised to spend approximately one hour on this section.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the space provided. Answers written in margins or on blank pages will not be marked.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 50.
- You are expected to use a calculator where appropriate.
- A *Data and Formulae Booklet* is provided as a loose insert.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use specialist vocabulary where appropriate.

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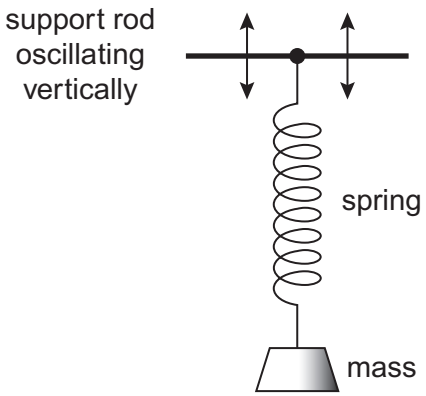
Section B

Answer **all** questions.

You are advised to spend approximately **one hour** on this section.

1 (a) A mass is attached to one end of a spring and the other end of the spring is suspended from a support rod, as shown in **Figure 1**.

Figure 1



The support rod oscillates vertically, causing the mass to perform forced vibrations. Under certain conditions, the system may demonstrate resonance.

Explain in your answer what is meant by forced vibrations and resonance. You should refer to the frequency, amplitude and phase of the vibrations.

[4 marks]

forced vibrations .....

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resonance .....

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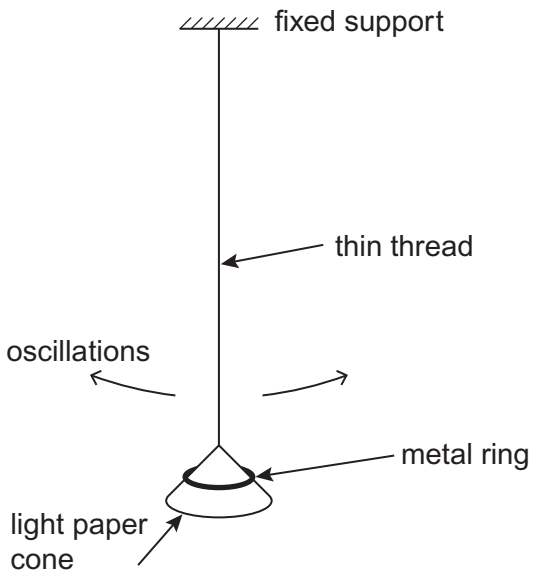
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1 (b) A simple pendulum is set up by suspending a light paper cone (acting as the pendulum bob) on the end of a length of thin thread. A metal ring may be placed over the cone to increase the mass of the bob, as shown in **Figure 2**.

Figure 2



The bob is displaced and released so that it oscillates in a vertical plane. The oscillations are subject to damping.

1 (b) (i) Are the oscillations of the pendulum more heavily damped when the cone oscillates with the metal ring on it, when it oscillates without the ring, or does the presence of the ring have no effect on the damping of the oscillations? Tick (✓) the correct answer.

[1 mark]

cone oscillates with ring	
cone oscillates without ring	
ring has no effect	

1 (b) (ii) Explain your answer to part (b)(i).

[3 marks]

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Turn over ▶

Do not write outside the box

2 (a) State, in words, Coulomb's law.

[2 marks]

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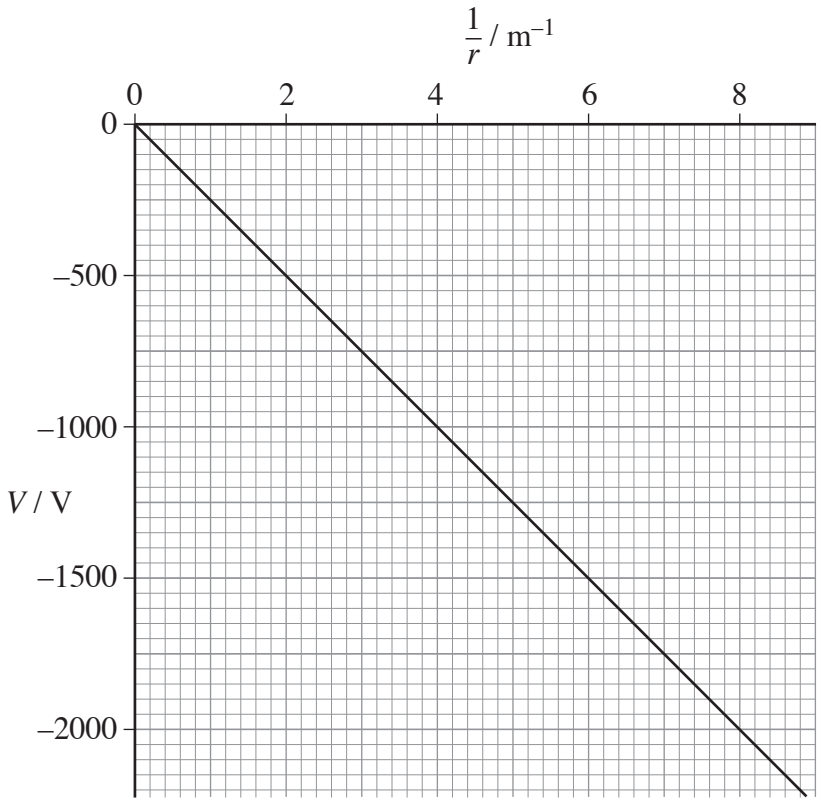
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2 (b) **Figure 3** shows how the electric potential, V, varies with $\frac{1}{r}$, where r is the distance from a point charge Q.

Figure 3



State what can be deduced from the graph about how V depends on r and explain why all the values of V on the graph are negative.

[2 marks]

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Do not write outside the box

2 (c) (i) Use data from the graph (**Figure 3**) to show that the magnitude of Q is about 30 nC.

[2 marks]

2 (c) (ii) A $+60$ nC charge is moved from a point where $r = 0.20$ m to a point where $r = 0.50$ m. Calculate the work done.

[2 marks]

work done ..... J

2 (c) (iii) Calculate the electric field strength at the point where $r = 0.40$ m.

[2 marks]

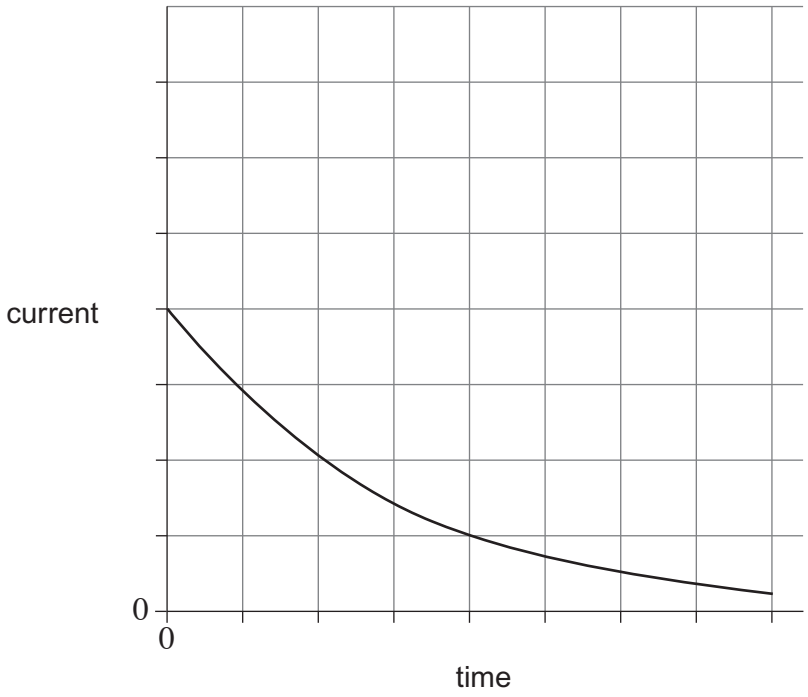
electric field strength ..... V m^{-1}

10

Do not write outside the box

3 (a) **Figure 4** shows how the current varies with time as a capacitor is discharged through a 150 Ω resistor.

Figure 4



3 (a) (i) Explain how the initial charge on the capacitor could be determined from a graph of current against time.

[1 mark]

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3 (a) (ii) The same capacitor is charged to the same initial potential difference (pd) and then discharged through a 300 kΩ resistor. Sketch a second graph on the same axes above to show how the current varies with time in this case.

[3 marks]

Do not write outside the box

3 (b) In an experiment to show that a capacitor stores energy, a student charges a capacitor from a battery and then discharges it through a small electric motor. The motor is used to lift a mass vertically.

3 (b) (i) The capacitance of the capacitor is $0.12\ \text{F}$ and it is charged to a pd of $9.0\ \text{V}$.
The weight of the mass raised is $3.5\ \text{N}$.
Calculate the maximum height to which the mass could be raised.
Give your answer to an appropriate number of significant figures.

[4 marks]

maximum height ..... m

3 (b) (ii) Give **two** reasons why the value you have calculated in part (b)(i) would not be achieved in practice.

[2 marks]

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2 .....

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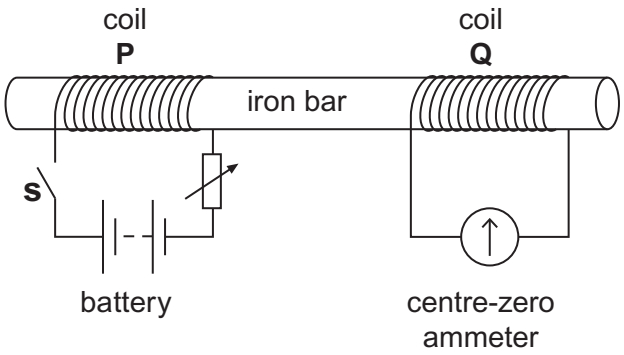
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4 (a) **Figure 5** shows two coils, **P** and **Q**, linked by an iron bar. Coil **P** is connected to a battery through a variable resistor and a switch **S**. Coil **Q** is connected to a centre-zero ammeter.

Figure 5



4 (a) (i) Initially the variable resistor is set to its minimum resistance and **S** is open. Describe and explain what is observed on the ammeter when **S** is closed.

[3 marks]

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4 (a) (ii) With **S** still closed, the resistance of the variable resistor is suddenly increased. Compare what is now observed on the ammeter with what was observed in part (a)(i). Explain why this differs from what was observed in part (a)(i).

[2 marks]

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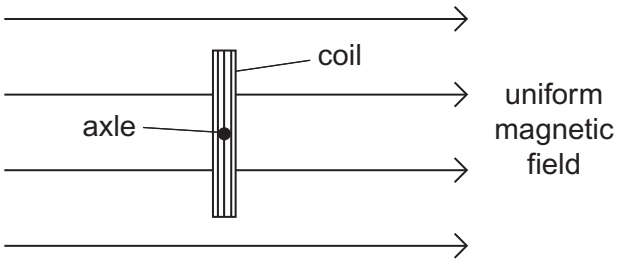
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4 (b) **Figure 6** shows a 40-turn coil of cross-sectional area 3.6×10^{-3} m^2 with its plane set at right angles to a uniform magnetic field of flux density 0.42 T.

Figure 6



4 (b) (i) Calculate the magnitude of the magnetic flux linkage for the coil.
State an appropriate unit for your answer.

[2 marks]

flux linkage ..... unit .....

4 (b) (ii) The coil is rotated through 90° in a time of 0.50 s.
Determine the mean emf in the coil.

[2 marks]

mean emf V

9

Turn over ▶

Do not write outside the box

5 A lead ball of mass 0.25 kg is swung round on the end of a string so that the ball moves in a horizontal circle of radius 1.5 m. The ball travels at a constant speed of 8.6 m s^{-1}.

5 (a) (i) Calculate the angle, in degrees, through which the string turns in 0.40 s.

[3 marks]

angle ..... degree

5 (a) (ii) Calculate the tension in the string.
You may assume that the string is horizontal.

[2 marks]

tension ..... N

5 (b) The string will break when the tension exceeds 60 N.
Calculate the number of revolutions that the ball makes in one second when the tension is 60 N.

[2 marks]

number of revolutions .....

Do not write outside the box

5 (c) Discuss the motion of the ball in terms of the forces that act on it. In your answer you should:

- explain how Newton's three laws of motion apply to its motion in a circle
- explain why, in practice, the string will not be horizontal.

You may wish to draw a diagram to clarify your answer.

The quality of your written communication will be assessed in your answer.

[6 marks]

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END OF QUESTIONS

13

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AQA

A-LEVEL
Physics

PHYA4 – Fields and Further Mechanics
Mark scheme

2450
June 2015

Version/Stage: 1.1 Final

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It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of students' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

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Section A

1	**D**	14	**C**
2	**A**	15	**A**
3	**A**	16	**C**
4	**D**	17	**C**
5	**D**	18	**D**
6	**B**	19	**B**
7	**C**	20	**A**
8	**B**	21	**B**
9	**A**	22	**A**
10	**B**	23	**C**
11	**A**	24	**B**
12	**C**	25	**D**
13	**D**		

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Question	Answers	Additional Comments/Guidance	Mark	ID details
1(a)	*Forced vibrations*: repeated upwards and downwards movement ✓ vibrations at frequency of support rod ✓ amplitude is small at high frequency **or** large at low frequency ✓ correct reference to phase difference between displacements of driving and forced vibrations ✓ *Resonance*: frequency of support rod **or** driver is equal to natural frequency of (mass-spring) system ✓ large (or maximum) amplitude vibrations of mass ✓ maximum energy transfer (rate) (from support rod to mass-spring system) ✓ correct reference to phase difference between displacements of driving and driven vibrations at resonance ✓	Acceptable references to phase differences: *Forced vibrations* – when frequency of driver » frequency of driven, displacements are out of phase by (almost) π radians or 180° (**or** ½ a period) **or** when frequency of driver « frequency of driven, displacements are (almost) in phase. [Accept either] [Condone >, < for », «] *Resonance* – displacement of driver leads on displacement of driven by π/2 radians or 90° **or** ¼ of a period (or driven lags on driver by π/2 radians or 90° **or** ¼ of a period) [Condone phase difference is π/2 radians or 90°]	max 4	
1(b)(i)	cone oscillates without ring *(ticked)*	Only one box to be ticked.	1	
1(b)(ii)	damping is caused by air resistance ✓ area is the same whether loaded or not loaded ✓ loaded cone has more kinetic energy **or** potential energy **or** momentum (at same amplitude) ✓ smaller <u>proportion</u> (or <u>fraction</u>) of (condone less) energy removed per oscillation from loaded cone (or vice versa) ✓ inertia of loaded cone is greater ✓	Award marks for correct physics even when answer to 1(b)(i) is incorrect.	max 3	
Total			8	

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Question	Answers	Additional Comments/Guidance	Mark	ID details
2(a)	force between two (point) charges is proportional to product of charges ✓ inversely proportional to square of distance between the charges ✓	Mention of force is essential, otherwise no marks. Condone "proportional to charges". Do not allow "square of radius" when radius is undefined. Award full credit for equation with all terms defined.	2	
2(b)	V is inversely proportional to r [**or** $V \propto (-)1/r$] ✓ (V has negative values) because charge is negative [**or** because force is attractive on + charge placed near it **or** because electric potential is + for + charge and – for – charge] ✓ potential is defined to be zero at infinity ✓	Allow $V \times r$ = constant for 1st mark	max 2	
2(c)(i)	$Q\left(= 4\pi\varepsilon_0 rV\right) = 4\pi\varepsilon_0 \times 0.125 \times 2000$ (for example, using any pair of values from graph) ✓ = 28 (27.8) (± 1) (nC) ✓	**or** gradient = $Q/4\pi\varepsilon_0$ = 2000/8 ✓ (gives Q = 28 (27.8) ±1 (nC) ✓	2	
2(c)(ii)	at r = 0.20m V = –1250V and at r = 0.50m V = –500V so pd ΔV = –500 – (–1250) = 750 (V) ✓ work done ΔW (= $Q\Delta V$) = $60 \times 10^{-9} \times 750$ = $4.5(0) \times 10^{-5}$ (J) (45 μJ) ✓ (final answer could be between 3.9 and 5.1×10^{-5})	Allow tolerance of ± 50V on graph readings. [Alternative for 1st mark: $\Delta V = \frac{27.8\times10^{-9}}{4\pi\varepsilon_0} \times \left(\frac{1}{0.2} - \frac{1}{0.5}\right)$ (**or** similar substitution using 60 nC instead of 27.8 nC: use of 60 nC gives ΔV = 1620V)]	2	
2(c)(iii)	$E\left(= \frac{Q}{4\pi\varepsilon_0 r^2}\right) = \frac{27.8\times10^{-9}}{4\pi\varepsilon_0 \times 0.40^2}$ ✓ = 1600 (1560) (V m^{-1}) ✓ [or deduce $E = \frac{V}{r}$ by combining $E = \frac{Q}{4\pi\varepsilon_0 r^2}$ with $V = \frac{Q}{4\pi\varepsilon_0 r}$ ✓ from graph $E = \frac{625 \pm 50}{0.40}$ = 1600 (1560 ± 130) (V m^{-1}) ✓]	Use of Q = 30 nC gives 1690 (V m^{-1}). Allow ecf from Q value in (c)(i). If Q = 60 nC is used here, no marks to be awarded.	2	
Total			10	

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Question	Answers	Additional Comments/Guidance	Mark	ID details
3(a)(i)	determine area under the graph [**or** determine area between line and time axis] ✓		1	
3(a)(ii) *as seen*	line starts at very low current (within bottom half of first square) ✓ **either** line continuing as (almost) horizontal straight line to end ✓✓ **or** very slight exponential decay curve ✓ which does not meet time axis ✓ **OR** suitable verbal comment that shows appreciation of difficulty of representing this line on the scales involved ✓✓✓	*Use this scheme for answers which treat the information in the question literally.*	3	
3(a)(ii) *as intended*	line starts at half of original initial current ✓ slower discharging exponential (ie. smaller initial gradient) than the original curve ✓ correct line that intersects the original curve (**or** meets it at the end) ✓	*Use this scheme for answers which assume that both resistance values should be in Ω or kΩ.* ½ initial current to be marked within ±2mm of expected value.	3	
3(b)(i)	energy stored (= ½ CV^2) = ½ × 0.12 × 9.0^2 ✓ (= 4.86 (J)) 4.86 = 3.5 Δh ✓ gives Δh = (1.39) = 1.4 (m) ✓ to 2SF only ✓	SF mark is independent. Students who make a PE in the 1st mark may still be awarded the remaining marks: treat as ECF.	4	
3(b)(ii)	energy is lost through heating of wires **or** heating the motor (as capacitor discharges) ✓ energy is lost in overcoming frictional forces in the motor (or in other rotating parts) ✓ [**or** any other well-expressed sensible reason that is valid eg. capacitor will not drive motor when voltage becomes low ✓]	Allow heating of circuit **or** $I^2 R$ heating. Location of energy loss (wires, or motor, etc) should be indicated in each correct answer. Don't allow losses due to sound, air resistance or resistance (rather than heating of) wires.	max 2	
Total			10	

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Question	Answers	Additional Comments/Guidance	Mark	ID details
4(a)(i)	meter deflects then returns to zero ✓ current produces (magnetic) field/flux ✓ change in field/flux through Q induces emf ✓ induced emf causes current in Q (and meter) ✓	Deflection to right (condone left) then zero is equivalent to 1st mark. Accept momentary deflection for 1st point. "change in field/flux induces current in Q" is just ✓ from the last two marking points.	max 3	
4(a)(ii)	meter deflects in opposite direction (or to left, or ecf) ✓ field/flux through P is reduced ✓ induces emf/current in opposite direction ✓	Ignore references to magnitude of deflection.	max 2	
4(b)(i)	flux linkage $\left(= n\Phi = nBA\right) = 40 \times 0.42 \times 3.6 \times 10^{-3}$ $= 6.0(5) \times 10^{-2}$ ✓ Wb turns ✓	Unit mark is independent. Allow 6×10^{-2} Accept 60 mWb turns if this unit is made clear. Unit: allow Wb	2	
4(b)(ii)	change in flux linkage = $\Delta(n\Phi) = 6.05 \times 10^{-2}$ (Wb turns) ✓ induced emf $\left(= \frac{\Delta(n\Phi)}{\Delta t}\right) = \frac{6.05 \times 10^{-2}}{0.50}$ = 0.12(1) (V) ✓	Essential to appreciate that 6.05×10^{-2} is *change in* flux linkage for 1st mark. Otherwise mark to max 1.	2	
Total			9	

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Question	Answers	Additional Comments/Guidance	Mark	ID details
5(a)(i)	$\omega\left(=\frac{v}{r}\right)=\frac{8.6}{1.5}$ (= 5.73 rad s^{-1}) ✓ $\theta(=\omega t)$ = 5.73 × 0.40 = 2.3 (2.29) (rad) ✓ = $\frac{2.29}{2\pi}\times 360$ = 130 (131) (degrees) ✓ [**or** $s((=vt)$ = 8.6 × 0.40 (= 3.44 m) ✓ $\theta=\frac{3.44}{2\pi\times 1.5}\times 360$ ✓ = 130 (131) (degrees) ✓]	Award full marks for any solution which arrives at the correct answer by valid physics.	3	
5(a)(ii)	tension $F\left(=m\omega^2 r\right)$ = 0.25 × 5.73^2 × 1.5 ✓ = 12(.3) (N) ✓ [**or** $F\left(=\frac{mv^2}{r}\right)=\frac{0.25\times 8.6^2}{1.5}$ ✓ = 12(.3) (N) ✓]	Estimate because rope is not horizontal.	2	
5(b)	maximum $\omega\left(=\sqrt{\frac{F}{mr}}\right)=\sqrt{\frac{60}{0.25\times 1.5}}$ (= 12.6) (rad s^{-1}) ✓ maximum $f\left(=\frac{\omega}{2\pi}\right)=\frac{12.6}{2\pi}$ = 2.01 (rev s^{-1}) ✓ [**or** maximum $v=\sqrt{\frac{Fr}{m}}=\sqrt{\frac{60\times 1.5}{0.25}}$ (= 19.0) (m s^{-1}) ✓ maximum $f\left(=\frac{v}{2\pi r}\right)=\frac{19.0}{2\pi\times 1.5}$ = 2.01 (rev s^{-1}) ✓]	Allow 2 (rev s^{-1}) for 2nd mark. Ignore any units given in final answer.	2	

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5(c)	**The student's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.** The student's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. **High Level (Good to excellent): 5 or 6 marks** The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. *The student appreciates that the velocity of the ball is not constant and that this implies that it is accelerating. There is a comprehensive and logical account of how Newton's laws apply to the ball's circular motion: how the first law indicates that an inward force must be acting, the second law shows that this force must cause an acceleration towards the centre and (if referred to) the third law shows that an equal outward force must act on the point of support at the centre. The student also understands that the rope is not horizontal and states that the weight of the ball is supported by the vertical component of the tension.* **Intermediate Level (Modest to adequate): 3 or 4 marks** The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. *The student appreciates that the velocity of the ball is not constant. The answer indicates how at least one of Newton's laws applies to the circular motion. The student's understanding of how the weight of the ball is supported is more superficial, the student possibly failing to appreciate that the rope would not be horizontal and omitting any reference to components of the tension*.	A **high level** answer must give a reasonable explanation of the application of at least two of Newton's laws, and an appreciation of why the rope will not be horizontal. An **intermediate level** answer must show a reasonable understanding of how at least one of Newton's laws applies to the swinging ball. A **low level** answer must show familiarity with at least one of Newton's laws, but may not show good understanding of how it applies to this situation. References to the effects of air resistance, and/or the need to keep supplying energy to the system would increase the value of an answer.	max 6	

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5(c)	**Low Level (Poor to limited): 1 or 2 marks** The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. *The student has a much weaker knowledge of how Newton's laws apply, but shows some understanding of at least one of them in this situation. The answer coveys little understanding of how the ball is supported vertically.* **The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences in this case.** • *First law*: ball does not travel in a straight line, so a force must be acting on it • although ball has constant speed its velocity is not constant because its direction changes constantly • because its velocity is changing it is accelerating • *Second law*: the force on the ball causes the ball to accelerate (or changes the momentum of it) in the direction of the force • the acceleration (or change in momentum) is in the same direction as the force • the force is centripetal: it acts towards the centre of the circle • *Third law*: the ball must pull on the central point of support with a force that is equal and opposite to the force pulling on the ball from the centre • the force acting on the point of support acts outwards • *Support of ball*: the ball is supported because the rope is not horizontal • there is equilibrium (or no resultant force) in the vertical direction • the weight of the ball, *mg*, is supported by the vertical component of the tension, $F \cos \theta$, where θ is the angle between the rope and the vertical and *F* is the tension • the horizontal component of the tension, $F \sin \theta$, provides the centripetal force $m \omega^2 r$ **Credit may be given for any of these points which are described by reference to an appropriate labelled diagram.**	A reference to Newton's 3rd law is not essential in an answer considered to be a high level response. 6 marks may be awarded when there is no reference to the 3rd law.	max 6	

Total			13	

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Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

General Certificate of Education
Advanced Level Examination
June 2014

Physics A PHYA4/1

Unit 4 Fields and Further Mechanics
Section A

Wednesday 11 June 2014 1.30 pm to 3.15 pm

In addition to this paper you will require:
- an objective test answer sheet
- a black ball-point pen
- a calculator
- a question paper/answer book for Section B (enclosed)
- a Data and Formulae booklet.

Time allowed
- The total time for both sections of this paper is 1 hour 45 minutes. You are advised to spend approximately 45 minutes on this section.

Instructions
- Use a black ball-point pen.
- Answer **all** questions in this section.
- For each question there are four responses. When you have selected the response which you think is the most appropriate answer to a question, mark this response on your answer sheet.
- Mark all responses as instructed on your answer sheet. If you wish to change your answer to a question, follow the instructions on your answer sheet.
- Do all rough work in this book **not** on the answer sheet.

Information
- The maximum mark for this section is 25.
- All questions in Section A carry equal marks. No deductions will be made for incorrect answers.
- A *Data and Formulae Booklet* is provided as a loose insert.
- The question paper/answer book for Section B is enclosed within this question paper.

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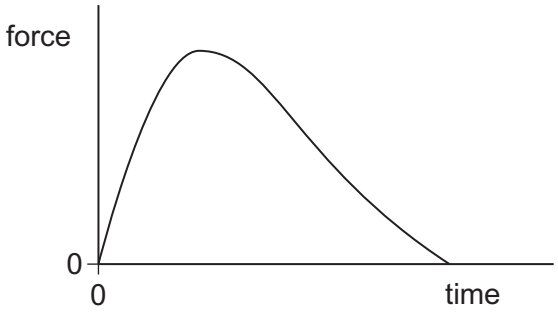
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Multiple choice questions

Each of Questions **1** to **25** is followed by four responses, **A**, **B**, **C**, and **D**. For each question select the best response and mark its letter on the answer sheet.

You are advised to spend about **45 minutes** on this section.

1 The graph shows how the force acting on a rocket varies with time.



Which one of the following is represented by the area under the graph?

A distance travelled

B gain in kinetic energy

C change in velocity

D change in momentum

2 A golf club strikes a stationary golf ball of mass $4.8 \times 10^{-2}\,\text{kg}$ and the ball leaves the club with a speed of $95\,\text{m s}^{-1}$. If the average force exerted on the ball is $7800\,\text{N}$, how long are the ball and club in contact?

A $5.8 \times 10^{-4}\,\text{s}$

B $1.2 \times 10^{-2}\,\text{s}$

C $0.51\,\text{s}$

D $0.58\,\text{s}$

3 Water of density $1000\,\text{kg m}^{-3}$ flows out of a garden hose of cross-sectional area $7.2 \times 10^{-4}\,\text{m}^2$ at a rate of $2.0 \times 10^{-4}\,\text{m}^3$ per second. How much momentum is carried by the water leaving the hose per second?

A $5.6 \times 10^{-5}\,\text{N s}$

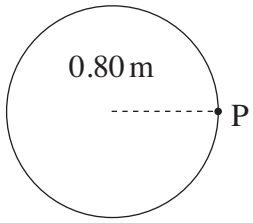
B $5.6 \times 10^{-2}\,\text{N s}$

C $0.20\,\text{N s}$

D $0.72\,\text{N s}$

Do not write outside the box

4 A model car moves in a circular path of radius $0.80\,\text{m}$ at an angular speed of $\frac{\pi}{2}\,\text{rad}\,\text{s}^{-1}$.



What is its displacement from point P $6.0\,\text{s}$ after passing P?

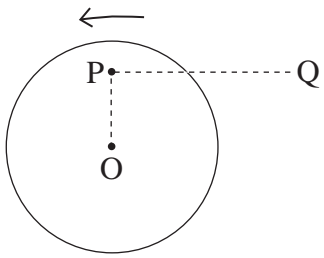
A zero

B $0.4\pi\,\text{m}$

C $1.6\,\text{m}$

D $1.6\pi\,\text{m}$

5 A small mass is placed at P on a horizontal disc which has its centre at O. The disc rotates anti-clockwise about a vertical axis through O with constant angular speed.



Which one of the following describes the force which keeps the mass at rest relative to the disc when in the position shown?

A the weight of the mass

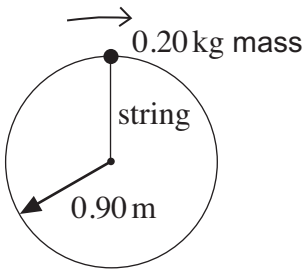
B a frictional force from P to Q

C a frictional force directed away from O

D a frictional force directed towards O

Do not write outside the box

6 A $0.20\,\text{kg}$ mass is whirled round in a vertical circle on the end of a light string of length $0.90\,\text{m}$.



At the top point of the circle the speed of the mass is $8.2\,\text{m s}^{-1}$. What is the tension in the string at this point?

A $10\,\text{N}$

B $13\,\text{N}$

C $17\,\text{N}$

D $20\,\text{N}$

7 Which line, **A** to **D**, in the table gives the amplitude and frequency of a body performing simple harmonic motion whose displacement x at time t is given by the equation $x = P\cos Qt$?

	Amplitude	Frequency
A	$\frac{P}{2}$	$\frac{Q}{2\pi}$
B	P	$2\pi Q$
C	P	$\frac{Q}{2\pi}$
D	$2P$	$\frac{Q}{2\pi}$

8 The tip of each prong of a tuning fork emitting a note of $320\,\text{Hz}$ vibrates in simple harmonic motion with an amplitude of $0.50\,\text{mm}$.
What is the speed of each tip when its displacement is zero?

A zero

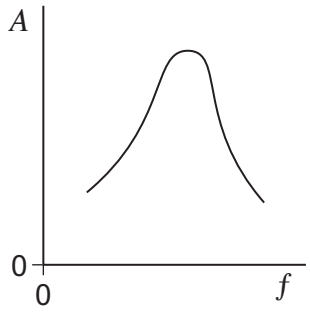
B $0.32\pi\ \text{mm s}^{-1}$

C $160\pi\ \text{mm s}^{-1}$

D $320\pi\ \text{mm s}^{-1}$

Do not write outside the box

9 A periodic force is applied to a lightly-damped object causing the object to oscillate. The graph shows how the amplitude A of the oscillations varies with the frequency f of the periodic force.



Which one of the following statements best describes how the shape of the curve would differ if the damping had been greater?

A The curve would be lower at all frequencies.

B The curve would be higher at all frequencies.

C The curve would be unchanged except at frequencies above the resonant frequency where it would be lower.

D The curve would be unchanged except at frequencies above the resonant frequency where it would be higher.

10 A spacecraft of mass m is at the mid-point between the centres of a planet of mass M_1 and its moon of mass M_2. If the distance between the spacecraft and the centre of the planet is d, what is the magnitude of the resultant gravitational force on the spacecraft?

A $\dfrac{Gm(M_1 - M_2)}{d}$

B $\dfrac{Gm(M_1 + M_2)}{d^2}$

C $\dfrac{Gm(M_1 - M_2)}{d^2}$

D $\dfrac{Gm(M_1 + M_2)}{d}$

Do not write outside the box

11 Which one of the following statements about gravitational potential is correct?

A Gravitational potential can have a positive value.

B The gravitational potential at the surface of the Earth is zero.

C The gravitational potential gradient at a point has the same numerical value as the gravitational field strength at that point.

D The unit of gravitational potential is $\mathrm{N\,kg^{-1}}$.

12 Which one of the following statements is correct?

The force between two charged particles

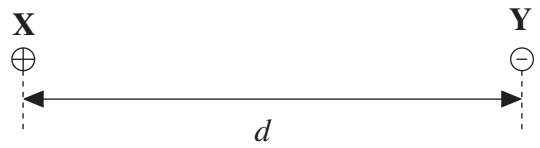
A is always attractive.

B can be measured in $\mathrm{C^2\,F^{-1}\,m^{-1}}$.

C is directly proportional to the distance between them.

D is independent of the magnitude of the charges.

13 Two point charges, **X** and **Y**, exert a force F on each other when they are at a distance d apart.



When the distance between them is $20\,\mathrm{mm}$, the force they exert on each other is $0.5\,F$.

What is the distance d?

A $7\,\mathrm{mm}$

B $14\,\mathrm{mm}$

C $15\,\mathrm{mm}$

D $28\,\mathrm{mm}$

14 Which one of the following statements is correct?

When a negative ion is projected into an electric field

A the field can change the magnitude of the velocity but not its direction.

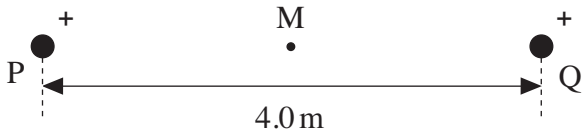
B the field can change the direction of the velocity but not its magnitude.

C the field can change both the magnitude and the direction of the velocity.

D the ion will accelerate in the direction of the field.

Do not write outside the box

15 Two identical positive point charges, P and Q, are separated by a distance of 4.0 m. The resultant electric potential at point M, which is mid-way between the charges, is 25.0 V.



What would be the resultant electrical potential at a point 1.0 m closer to P?

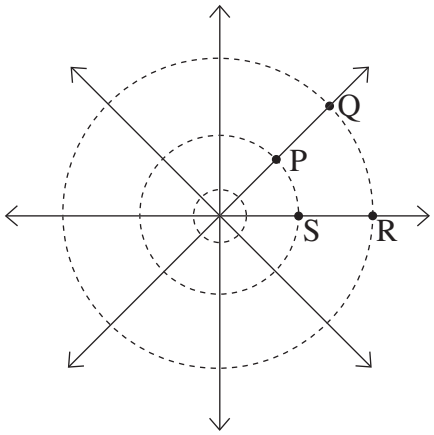
A 8.3 V

B 12.5 V

C 33.3 V

D 37.5 V

16 The diagram below shows the field lines and equipotential lines around an isolated positive point charge.



Which one of the following statements concerning the work done when a small charge is moved in the field is **incorrect**?

A When it is moved from either P to Q or S to R, the work done is the same in each case.

B When it is moved from Q to R no work is done.

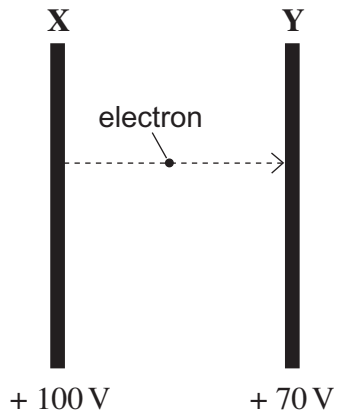
C When it is moved around the path PQRS, the overall work done is zero.

D When it is moved around the path PQRS, the overall work done is equal to twice the work done in moving from P to Q.

Turn over ▶

Do not write outside the box

17 Two fixed parallel metal plates **X** and **Y** are at constant potentials of $+ 100\,\text{V}$ and $+ 70\,\text{V}$ respectively. An electron travelling from **X** to **Y** experiences a change of potential energy ΔE_p

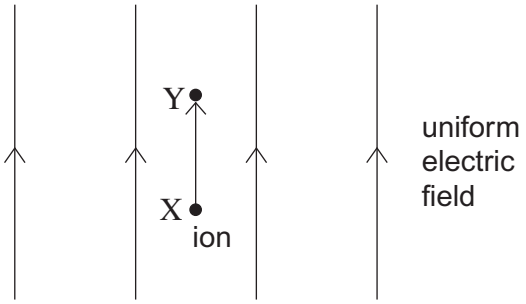


Which line, **A** to **D**, in the table shows correctly the direction of the electrostatic force F on the electron and the value of ΔE_p?

	Direction of F	**ΔE_p**
A	towards **X**	$+ 30\,\text{eV}$
B	towards **Y**	$- 30\,\text{eV}$
C	away from **X**	$+ 30\,\text{eV}$
D	away from **Y**	$- 30\,\text{eV}$

Do not write outside the box

18 A uniform electric field of electric field strength E is aligned so it is vertical. An ion moves vertically through a small distance Δd from point X to point Y in the field. There is a uniform gravitational field of field strength g throughout the region.



Which line, **A** to **D**, in the table correctly gives the gravitational potential difference, and the electric potential difference, between X and Y?

	Gravitational potential difference	Electric potential difference
A	$g\Delta d$	$E\Delta d$
B	$g\Delta d$	$\frac{E}{\Delta d}$
C	$\frac{g}{\Delta d}$	$E\Delta d$
D	$\frac{g}{\Delta d}$	$\frac{E}{\Delta d}$

19 Initially a charged capacitor stores $1600\,\mu J$ of energy. When the pd across it decreases by $2.0\,V$, the energy stored by it becomes $400\,\mu J$.

What is the capacitance of this capacitor?

A $100\,\mu F$

B $200\,\mu F$

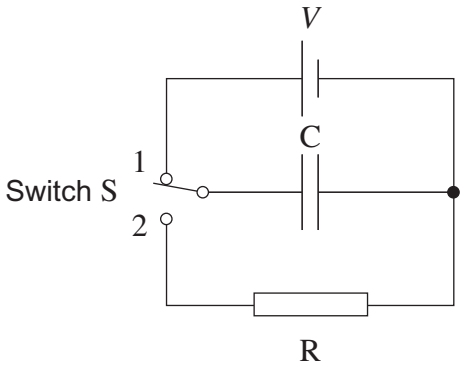
C $400\,\mu F$

D $600\,\mu F$

Turn over ▶

Do not write outside the box

20 Switch S in the circuit is held in position 1, so that the capacitor C becomes fully charged to a pd V and stores energy E.



The switch is then moved quickly to position 2, allowing C to discharge through the fixed resistor R. It takes 36 ms for the pd across C to fall to $\frac{V}{2}$. What period of time must elapse, after the switch has moved to position 2, before the energy stored by C has fallen to $\frac{E}{16}$?

A 51 ms

B 72 ms

C 432 ms

D 576 ms

21 The path followed by an electron of momentum p, carrying charge $-e$, which enters a magnetic field at right angles, is a circular arc of radius r.

What would be the radius of the circular arc followed by an α particle of momentum $2p$, carrying charge $+2e$, which entered the same field at right angles?

A $\frac{r}{2}$

B r

C $2r$

D $4r$

22 In which one of the following applications does electromagnetic induction **not** take place?

A the generators at a nuclear power station

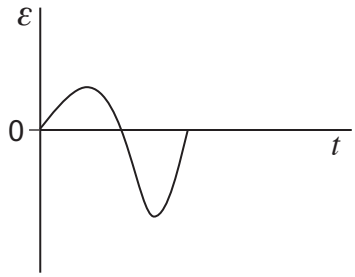
B the ac power adapter for a laptop computer

C the wings of an aircraft cutting through the Earth's magnetic field

D the back up capacitor of an electric timer

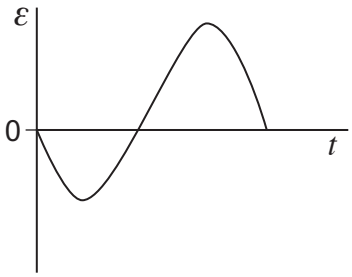
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23 When a magnet is dropped through an aluminium ring an emf is induced. A data logger connected to the ring records the variation of the induced emf ε with time t as shown below.

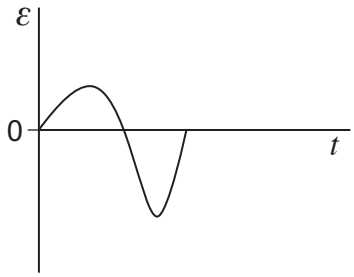


In a second experiment, the magnet is dropped from a greater height.

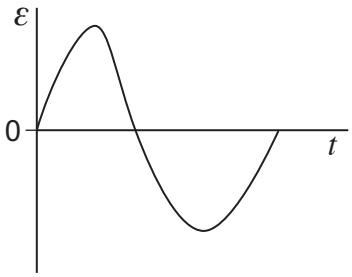
Which one of the following graphs best represents the induced emf in the second experiment?



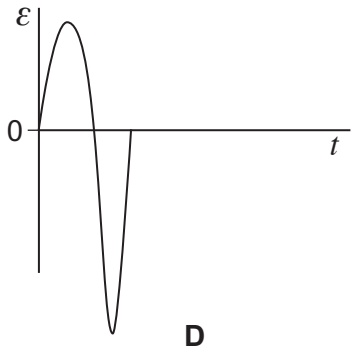
A



B



C



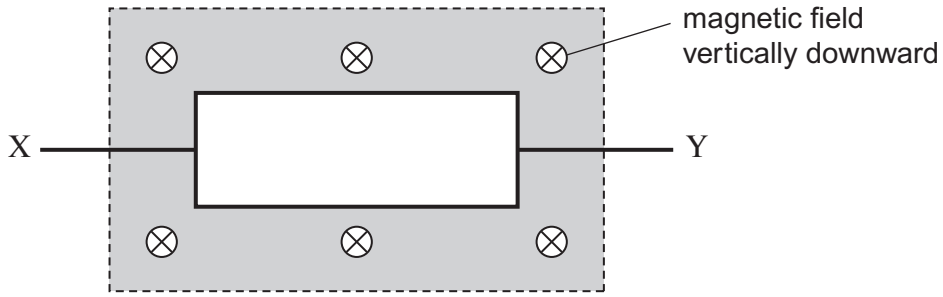
D

Turn over ▶

Do not write outside the box

24 A rectangular coil of area A has N turns of wire. The coil is in a uniform magnetic field, as shown in the diagram.

When the coil is rotated at a constant frequency f about its axis XY, an alternating emf of peak value ε_0 is induced in it.



What is the maximum value of the magnetic flux linkage through the coil?

A $\dfrac{\varepsilon_0}{2\pi f}$

B $\dfrac{\varepsilon_0}{\pi f}$

C $\pi f \varepsilon_0$

D $2\pi f \varepsilon_0$

25 A transformer has 1150 turns on the primary coil and 500 turns on the secondary coil. The primary coil draws a current of $0.26\,\text{A}$ from a $230\,\text{V}$ ac supply. The current in the secondary coil is $0.50\,\text{A}$. What is the efficiency of the transformer?

A 42%

B 50%

C 84%

D 100%

END OF QUESTIONS

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Centre Number						Candidate Number				
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Other Names										
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Examiner's Initials	
Question	Mark
1	
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TOTAL	

General Certificate of Education
Advanced Level Examination
June 2014

Physics A PHYA4/2

Unit 4 Fields and Further Mechanics
Section B

Wednesday 11 June 2014 1.30 pm to 3.15 pm

For this paper you must have:
- a calculator
- a ruler
- a Data and Formulae Booklet (enclosed).

Time allowed
- The total time for both sections of this paper is 1 hour 45 minutes. You are advised to spend approximately one hour on this section.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the space provided. Answers written in margins or on blank pages will not be marked.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 50.
- You are expected to use a calculator where appropriate.
- A *Data and Formulae Booklet* is provided as a loose insert.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use specialist vocabulary where appropriate.

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Section B

Answer **all** questions in the spaces provided.

1 (a) (i) Define gravitational field strength and state whether it is a scalar or vector quantity.

[2 marks]

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.....

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1 (a) (ii) A mass m is at a height h above the surface of a planet of mass M and radius R. The gravitational field strength at height h is g. By considering the gravitational force acting on mass m, derive an equation from Newton's law of gravitation to express g in terms of M, R, h and the gravitational constant G.

[2 marks]

1 (b) (i) A satellite of mass $2520\,\text{kg}$ is at a height of $1.39 \times 10^7\,\text{m}$ above the surface of the Earth. Calculate the gravitational force of the Earth attracting the satellite. Give your answer to an appropriate number of significant figures.

[3 marks]

force attracting satellite ..... N

Do not write outside the box

1 (b) (ii) The satellite in part (b)(i) is in a circular polar orbit. Show that the satellite would travel around the Earth three times every 24 hours.

[5 marks]

1 (c) State and explain **one** possible use for the satellite travelling in the orbit in part (b)(ii).

[2 marks]

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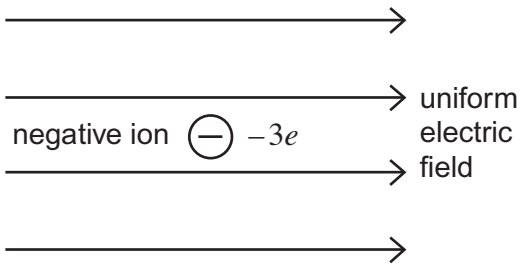
14

Turn over ▶

Do not write outside the box

2 (a) **Figure 1** shows a negative ion which has a charge of $-3e$ and is free to move in a uniform electric field. When the ion is accelerated by the field through a distance of $63\,\text{mm}$ parallel to the field lines its kinetic energy increases by $4.0 \times 10^{-16}\,\text{J}$.

Figure 1



2 (a) (i) State and explain the direction of the electrostatic force on the ion.

[2 marks]

.....

.....

.....

.....

2 (a) (ii) Calculate the magnitude of the electrostatic force acting on the ion.

[2 marks]

magnitude of electrostatic force ..... N

2 (a) (iii) Calculate the electric field strength.

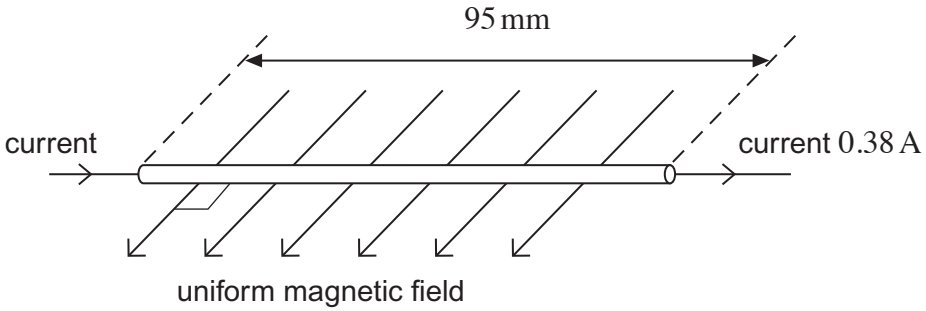
[1 mark]

electric field strength ..... N C^{-1}

Do not write outside the box

2 (b) **Figure 2** shows a section of a horizontal copper wire carrying a current of $0.38\,\text{A}$. A horizontal uniform magnetic field of flux density B is applied at right angles to the wire in the direction shown in the figure.

Figure 2



2 (b) (i) State the direction of the magnetic force that acts on the moving electrons in the wire as a consequence of the current and explain how you arrive at your answer.

[2 marks]

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.....

2 (b) (ii) Copper contains 8.4×10^{28} free electrons per cubic metre. The section of wire in **Figure 2** is $95\,\text{mm}$ long and its cross-sectional area is $5.1 \times 10^{-6}\,\text{m}^2$. Show that there are about 4×10^{22} free electrons in this section of wire.

[1 mark]

2 (b) (iii) With a current of $0.38\,\text{A}$, the average velocity of an electron in the wire is $5.5 \times 10^{-6}\,\text{m s}^{-1}$ and the average magnetic force on one electron is $1.4 \times 10^{-25}\,\text{N}$. Calculate the flux density B of the magnetic field.

[2 marks]

flux density ..... T

10

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3 (a) (i) Name the **two** types of potential energy involved when a mass–spring system performs vertical simple harmonic oscillations.

[1 mark]

.....

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3 (a) (ii) Describe the energy changes which take place during one complete oscillation of a vertical mass-spring system, starting when the mass is at its lowest point.

[2 marks]

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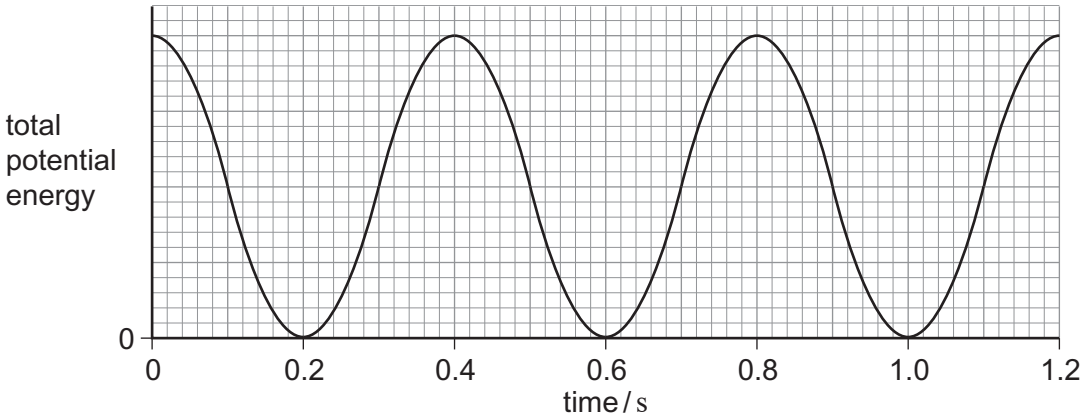
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3 (b) **Figure 3** shows how the **total** potential energy due to the simple harmonic motion varies with time when a mass-spring system oscillates vertically.

Figure 3



3 (b) (i) State the time period of the simple harmonic oscillations that produces the energy–time graph shown in **Figure 3**, explaining how you arrive at your answer.

[2 marks]

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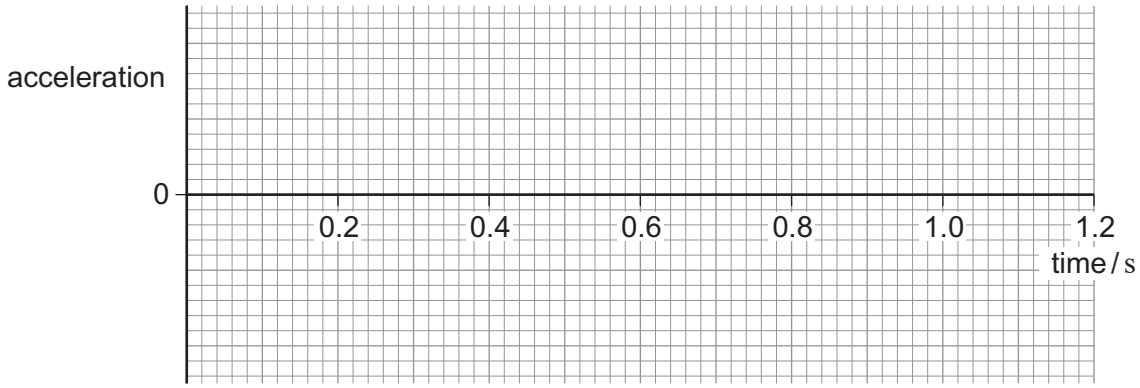
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3 (b) (ii) Sketch a graph on **Figure 4** to show how the acceleration of the mass varies with time over a period of 1.2 s, starting with the mass at the highest point of its oscillations. On your graph, upwards acceleration should be shown as positive and downwards acceleration as negative. Values are not required on the acceleration axis.

[2 marks]

Figure 4



3 (c) (i) The mass of the object suspended from the spring in part (b) is 0.35 kg. Calculate the spring constant of the spring used to obtain **Figure 3**. State an appropriate unit for your answer.

[3 marks]

spring constant ..... unit .....

3 (c) (ii) The maximum kinetic energy of the oscillating object is 2.0×10^{-2} J. Show that the amplitude of the oscillations of the object is about 40 mm.

[4 marks]

14

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4 (a) When an uncharged capacitor is charged by a **constant** current of $4.5\,\mu A$ for $60\,s$ the pd across it becomes $4.4\,V$.

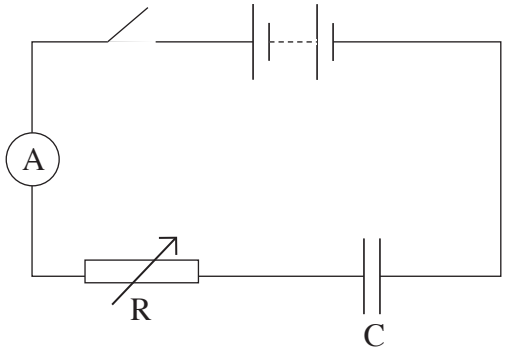
4 (a) (i) Calculate the capacitance of the capacitor.

[3 marks]

capacitance ..... F

4 (a) (ii) The capacitor is charged using the circuit shown in **Figure 5**. The battery emf is $6.0\,V$ and its internal resistance is negligible. In order to keep the current constant at $4.5\,\mu A$, the resistance of the variable resistor R is decreased steadily as the charge on the capacitor increases.

Figure 5



Calculate the resistance of R when the uncharged capacitor has been charging for $30\,s$.

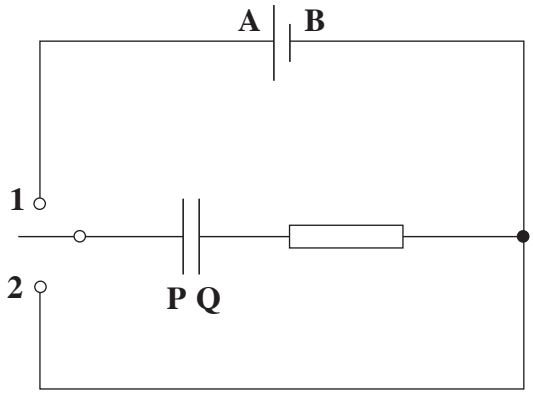
[3 marks]

resistance ..... Ω

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4 (b) The circuit in **Figure 6** contains a cell, an uncharged capacitor, a fixed resistor and a two-way switch.

Figure 6



The switch is moved to position **1** until the capacitor is fully charged. The switch is then moved to position **2**.

Describe what happens in this circuit after the switch is moved to position **1**, and after it has been moved to position **2**. In your answer you should refer to:

- the direction in which electrons flow in the circuit, and how the flow of electrons changes with time,
- how the potential differences across the resistor and the capacitor change with time,
- the energy changes which take place in the circuit.

The terminals of the cell are labelled **A** and **B** and the capacitor plates are labelled **P** and **Q** so that you can refer to them in your answer.

The quality of your written communication will be assessed in your answer.

[6 marks]

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END OF QUESTIONS

12

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A-LEVEL
PHYSICS A

PHYA4 – Fields and Further Mechanics
Mark scheme

2450
June 2014

Version: 1.1 Final

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Mark schemes are prepared by the Lead Assessment Writer and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all associates participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every associate understands and applies it in the same correct way. As preparation for standardisation each associate analyses a number of students' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Assessment Writer.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of students' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

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Section A:

1	**D**	14	**C**
2	**A**	15	**C**
3	**B**	16	**D**
4	**C**	17	**A**
5	**D**	18	**A**
6	**B**	19	**B**
7	**C**	20	**B**
8	**D**	21	**B**
9	**A**	22	**D**
10	**C**	23	**D**
11	**C**	24	**A**
12	**B**	25	**C**
13	**B**		

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Section B:

Question	Part	Sub-part	Marking guidance	Mark	Comment
1	a	i	force per unit mass ✓ a vector quantity ✓	2	Accept force on 1 kg (or a unit mass).
1	a	ii	force on body of mass *m* is given by $F = \frac{GMm}{(R+h)^2}$ ✓ gravitational field strength $g\left(=\frac{F}{m}\right) = \frac{GM}{(R+h)^2}$ ✓	2	For both marks to be awarded, correct symbols must be used for *M* and *m*.
1	b	i	$F\left(=\frac{GMm}{(R+h)^2}\right) = \frac{6.67\times10^{-11}\times5.98\times10^{24}\times2520}{\left((6.37\times10^{6})+(1.39\times10^{7})\right)^2}$ ✓ $= 2.45 \times 10^3$ (N) ✓ to **3SF** ✓	3	1st mark: all substituted numbers must be to at least 3SF. If 1.39×10^7 is used as the complete denominator, treat as AE with ECF available. 3rd mark: **SF mark is independent**.

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1	b	ii	$F = m\omega^2(R+h)$ gives $\omega^2 = \dfrac{2450}{2520\times 2.03\times 10^7}$ ✓ from which $\omega = 2.19\times 10^{-4}$ (rad s^{-1}) ✓ time period $T\left(=\dfrac{2\pi}{\omega}\right)=\dfrac{2\pi}{2.19\times 10^{-4}}$ **or** = 2.87×10^4 s ✓ [**or** $F=\dfrac{mv^2}{R+h}$ gives $v^2=\dfrac{2.45\times 10^3\times\left(\left(6.37\times 10^6\right)+\left(13.9\times 10^6\right)\right)}{2520}$ ✓ from which $v = 4.40\times 10^3$ (m s^{-1}) ✓ time period $T\left(=\dfrac{2\pi(R+h))}{v}\right)=\dfrac{2\pi\times 2.03\times 10^7}{4.40\times 10^3}$ **or** = 2.87×10^4 s ✓] [**or** $T^2=\dfrac{4\pi^2(R+h)^3}{GM}$ ✓ $=\dfrac{4\pi^2((6.37\times 10^6)+(13.9\times 10^6))^3}{6.67\times 10^{-11}\times 5.98\times 10^{24}}$ ✓ gives time period $T = 2.87\times 10^4$s ✓] $=\dfrac{2.87\times 10^4}{3600}$ = 7.97 (hours) ✓ number of transits in 1 day = $\dfrac{24}{7.97}$ = 3.01 (≈ 3) ✓	5	Allow ECF from wrong *F* value in (b)(i) but mark to max 4 (because final answer won't agree with value to be *shown*). First 3 marks are for determining time period (or frequency). Last 2 marks are for relating this to the number of transits. Determination of $f = 3.46\times 10^{-5}$ (s^{-1}) is equivalent to finding *T* by any of the methods.

1	c		acceptable use ✓ satisfactory explanation ✓ e.g. monitoring weather **or** surveillance: whole Earth may be scanned **or** Earth rotates under orbit **or** information can be updated regularly **or** communications: limited by intermittent contact **or** gps: several satellites needed to fix position on Earth	2	Any reference to equatorial satellite should be awarded 0 marks.

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2	a	i	force acts towards left **or** in opposite direction to field lines ✓ because ion (or electron) has negative charge (∴ experiences force in opposite direction to field) ✓	2	Mark sequentially. Essential to refer to negative charge (or force on + charge is to right) for 2nd mark.
2	a	ii	(use of $W = F\,s$ gives) force $F = \frac{4.0\times10^{-16}}{63\times10^{-3}}$ ✓ $= 6.3(5) \times 10^{-15}$ (N) ✓	2	If mass of ion m is used correctly **using algebra** with $F = ma$, allow both marks (since m will cancel). If numerical value for m is used, max 1.
2	a	iii	electric field strength $E\left(=\frac{F}{Q}\right)=\frac{6.35\times10^{-15}}{3\times1.6\times10^{-19}}$ = 1.3(2) × 10^4 (N C^{-1}) ✓ [**or** $\Delta V\left(=\frac{\Delta W}{Q}\right)=\frac{4.0\times10^{-16}}{3\times1.60\times10^{-19}}$ (833 V) $E\left(=\frac{\Delta V}{d}\right)=\frac{833}{63\times10^{-3}}$ = 1.3(2) × 10^4 (V m^{-1}) ✓]	1	Allow ECF from wrong F value in (a)(ii).
2	b	i	(vertically) downwards on diagram ✓ reference to Fleming's LH rule **or** equivalent statement ✓	2	Mark sequentially. 1st point: allow "into the page".
2	b	ii	number of free electrons in wire = $A \times l \times$ number density = 5.1 × 10^{-6} × 95 × 10^{-3} × 8.4 × 10^{28} = 4.1 (4.07) × 10^{22} ✓	1	Provided it is shown correctly to at least 2SF, final answer alone is sufficient for the mark. (Otherwise working is mandatory).
2	b	iii	$B\left(=\frac{F}{Qv}\right)=\frac{1.4\times10^{-25}}{1.60\times10^{-19}\times5.5\times10^{-6}}$ ✓ = 0.16 (0.159) (T) ✓ [**or** $B\left(=\frac{F}{I\,l}\right)=\frac{1.4\times10^{-25}\times4.07\times10^{22}}{0.38\times95\times10^{-3}}$ ✓ = 0.16 (0.158) (T) ✓]	2	In 2nd method allow ECF from wrong number value in (b)(ii).

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3	a	i	elastic potential energy **and** gravitational potential energy ✓	1	For elastic pe allow "pe due to tension", or "strain energy" etc

3	a	ii	elastic pe → kinetic energy → gravitational pe → kinetic energy → elastic pe ✓✓ [**or** pe→ke→pe→ke→pe is ✓ only] [**or** elastic pe → kinetic energy → gravitational pe is ✓ only]	2	If kinetic energy is not mentioned, no marks. Types of potential energy must be identified for full credit.

3	b	i	period = 0.80 s ✓ during one oscillation there are two energy transfer cycles (or elastic pe→ke→gravitational pe→ke→elastic pe in 1 cycle) **or** there are two potential energy maxima per complete oscillation ✓	2	Mark sequentially.

3	b	ii	sinusoidal curve of period 0.80 s ✓ – cosine curve starting at t = 0 continuing to t = 1.2s ✓	2	For 1st mark allow ECF from T value given in 3(b)(i).

3	c	i	use of $T = 2\pi\sqrt{\frac{m}{k}}$ gives $0.80 = 2\pi\sqrt{\frac{0.35}{k}}$ ✓ $\therefore\ k\left(=\frac{4\pi^2 \times 0.35}{0.80^2}\right)$ = 22 (21.6) ✓ N m^{-1} ✓	3	Unit mark is independent: insist on N m^{-1}. Allow ECF from wrong T value from (b)(i): use of 0.40s gives 86.4 (N m^{-1}).

3	c	ii	maximum ke = (½ mv_{max}^2) = 2.0 × 10^{-2} gives $v_{max}^2 = \frac{2.0 \times 10^{-2}}{0.5 \times 0.35}$ ✓ (= 0.114 m^{2}s^{-2}) and v_{max} = 0.338 (m s^{-1}) ✓ $v_{max} = 2\pi fA$ gives $A = \frac{0.338}{2\pi \times 1.25}$ ✓ and A = 4.3(0) × 10^{-2} m ✓ i.e. about 40 mm [**or** maximum ke = (½ mv_{max}^2) = ½ m $(2\pi fA)^2$ ✓ ½ × 0.35 × 4π^2 × 1.25^2 × A^2 = 2.0 × 10^{-2} ✓	4	First two schemes include recognition that $f = 1/T$ i.e. f = 1/0.80 = 1.25 (Hz). Allow ECF from wrong T value from (b)(i) – 0.40s gives A = 2.15 × 10^{-2}m but mark to max 3. Allow ECF from wrong k value from (c)(i) –

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			$\therefore\ A^2 = \frac{2\times 2.0\times 10^{-2}}{4\pi^2\times 0.35\times 1.25^2}$ ✓ (= 1.85×10^{-3}) and A = 4.3(0) × 10^{-2} m ✓ i.e. about 40 mm] [**or** maximum ke = maximum pe = 2.0 × 10^{-2} (J) maximum pe = ½ $k A^2$ ✓ $\therefore$ 2.0 × 10^{-2} = ½ × 21.6 × A^2 ✓ from which $A^2 = \frac{2\times 2.0\times 10^{-2}}{21.6}$ ✓ (= 1.85×10^{-3}) and A = 4.3(0) × 10^{-2} m ✓ i.e. about 40 mm]		86.4Nm^{-1} gives A = 2.15 × 10^{-2}m but mark to max 3.

4	a	i	$Q(=It) = 4.5\times 10^{-6}\times 60$ **or** = 2.70 × 10^{-4} (C) ✓ $C\left(=\frac{Q}{V}\right) = \frac{2.70\times 10^{-4}}{4.4}$ ✓ = 6.1(4) × 10^{-5} = 61 (μF) ✓	3	

4	a	ii	since V_C was 4.4V after 60s, when t = 30s V_C = 2.2 (V) ✓ [**or** by use of $Q = It$ and $V_C = Q/C$] $\therefore$ pd across R is (6.0 – 2.2) = 3.8 (V) ✓ $R\left(=\frac{V}{I}\right) = \frac{3.8}{4.5\times 10^{-6}}$ = 8.4(4) × 10^5 (Ω) ✓ (=844 kΩ)	3	In alternative method, Q = 4.5 × 10^{-6} × 30 = 1.35 × 10^{-4} (C) V_C = 1.35 × 10^{-4} / 6.14 × 10^{-5} = 2.2 (V) (allow ECF from wrong values in (a)(i))

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4	b		**The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.** The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. **High Level (Good to excellent): 5 or 6 marks** The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. *The candidate gives a coherent and logical description of the flow of electrons taking place during the charging and discharging processes, indicating the correct directions of flow and the correct time variations. There is clear understanding of how the pds change with time during charging and during discharging. The candidate also gives a coherent account of energy transfers that take place during charging and during discharging, naming the types of energy involved. They recognise that the time constant is the same for both charging and discharging.* **Intermediate Level (Modest to adequate): 3 or 4 marks** The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. *The candidate has a fair understanding of how the flow of electrons varies with time, but may not be entirely clear about the directions of flow. Description of the variation of pds with time is likely to be only partially correct and may not be complete. The candidate may show reasonable understanding of the energy transfers.*	max 6	A **High Level** answer must contain correct physical statements about at least **two** of the following for **both** the charging and the discharging positions of the switch:- • the direction of electron flow in the circuit • how the flow of electrons (or current) changes with time • how V_R and/or V_C change with time • energy changes in the circuit An **Intermediate Level** answer must contain correct physical statements about at least **two** of the above for **either** the charging or the discharging positions of the switch. A **Low Level** answer must contain a correct physical statement about at least **one** of the above for **either** the charging or the discharging positions of the switch. Any answer which does not satisfy the requirement for a Low Level answer should be awarded 0 marks.

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			Low Level (Poor to limited): 1 or 2 marks The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. *The candidate is likely to confuse electron flow with current and is therefore unlikely to make effective progress in describing electron flow. Understanding of the variation of pds with time is likely to be quite poor. The candidate may show some understanding of the energy transfers that take place.* **Incorrect, inappropriate or no response: 0 marks** No answer, or answer refers to unrelated, incorrect or inappropriate physics. **The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences in this case.** ***Charging*** • electrons flow from plate **P** to terminal **A** and from terminal **B** to plate **Q** (ie. from plate **P** to plate **Q** via **A** and **B**) • electrons flow in the opposite direction to current • plate **P** becomes + and plate **Q** becomes – • the rate of flow of electrons is greatest at the start, and decreases to zero when the capacitor is fully charged • V_R decreases from E to zero whilst V_C increases from zero to E. • at any time $V_R + V_C = E$ • time variations are exponential decrease for V_R and exponential increase for V_C • chemical energy of the battery is changed into electric potential energy stored in the capacitor, and into thermal energy by the resistor (which passes to the surroundings) • half of the energy supplied by the battery is converted into thermal energy and half is stored in the capacitor		

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			Discharging • electrons flow back from plate **Q** via the shorting wire to plate **P** • at the end of the process the plates are uncharged • the rate of flow of electrons is greatest at the start, and decreases to zero when the capacitor is fully discharged • V_C decreases from $-E$ to zero and V_R decreases from E to zero • at any time $V_C = -V_R$ • both V_C and V_R decrease exponentially with time • electrical energy stored by the capacitor is all converted to thermal energy by the resistor as the electrons flow through it and this energy passes to the surroundings • time constant of the circuit is the same for discharging as for charging		

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Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

General Certificate of Education
Advanced Level Examination
June 2013

Physics A PHYA4/1

Unit 4 Fields and Further Mechanics
Section A

Thursday 13 June 2013 1.30 pm to 3.15 pm

In addition to this paper you will require:
- an objective test answer sheet
- a black ball-point pen
- a calculator
- a question paper/answer book for Section B (enclosed)
- a Data and Formulae booklet.

Time allowed
- The total time for both sections of this paper is 1 hour 45 minutes. You are advised to spend approximately 45 minutes on this section.

Instructions
- Use a black ball-point pen.
- Answer **all** questions in this section.
- For each question there are four responses. When you have selected the response which you think is the most appropriate answer to a question, mark this response on your answer sheet.
- Mark all responses as instructed on your answer sheet. If you wish to change your answer to a question, follow the instructions on your answer sheet.
- Do all rough work in this book **not** on the answer sheet.

Information
- The maximum mark for this section is 25.
- All questions in Section A carry equal marks. No deductions will be made for incorrect answers.
- A *Data and Formulae Booklet* is provided as a loose insert.
- The question paper/answer book for Section B is enclosed within this question paper.

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Multiple choice questions

Each of Questions **1** to **25** is followed by four responses, **A**, **B**, **C**, and **D**. For each question select the best response and mark its letter on the answer sheet.

You are advised to spend approximately **45 minutes** on this section.

1 Which one of the following is a possible unit of impulse?

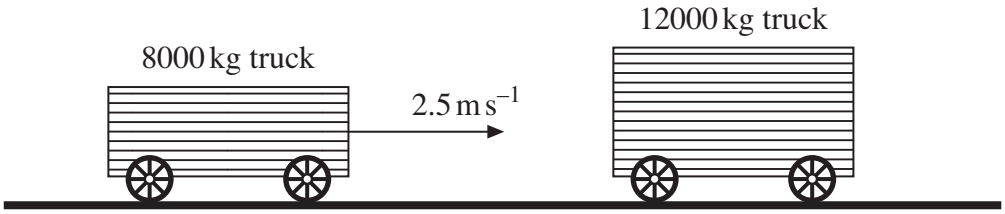
A $\mathrm{N\,s^{-1}}$

B $\mathrm{kg\,m\,s^{-1}}$

C $\mathrm{kg\,m\,s^{-2}}$

D $\mathrm{s\,N^{-1}}$

2 A railway truck of mass 8000 kg travels along a level track at a velocity of $2.5\,\mathrm{m\,s^{-1}}$ and collides with a stationary truck of mass 12000 kg. The two trucks move together at the same velocity after the collision.



What is the change in momentum of the 8000 kg truck due to the impact?

A 8000 N s

B 12000 N s

C 20000 N s

D 25000 N s

3 A gas molecule of mass m moving at velocity u collides at right angles with the side of a container and rebounds elastically. Which one of the following statements concerning the motion of the molecule is **incorrect**?

A The magnitude of the change in momentum of the molecule is zero.

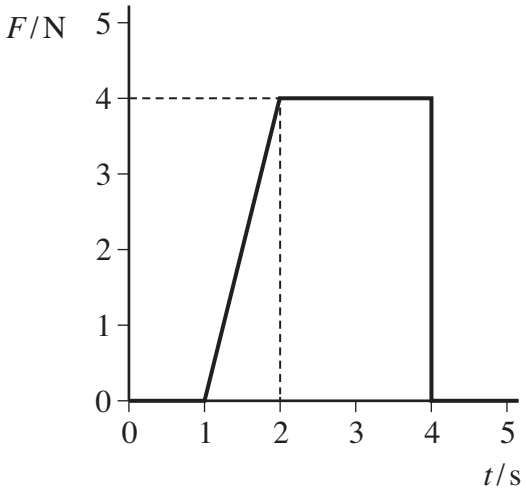
B The magnitude of the change in momentum of the molecule is $2mu$.

C The force exerted by the molecule on the side of the container is equal to the force exerted by the container on the molecule.

D The change in kinetic energy of the molecule is zero.

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4 The graph shows how the resultant force, F, acting on a body varies with time, t.



What is the change in momentum of the body over the 5 s period?

A 2 N s

B 8 N s

C 10 N s

D 12 N s

5 The wheel of the London Eye has a diameter of 130 m and rotates at a steady speed, completing one rotation every 30 minutes. What is the centripetal acceleration of a person in a capsule at the rim of the wheel?

A $1.2 \times 10^{-4}\,\text{m s}^{-2}$

B $2.5 \times 10^{-4}\,\text{m s}^{-2}$

C $3.9 \times 10^{-4}\,\text{m s}^{-2}$

D $7.9 \times 10^{-4}\,\text{m s}^{-2}$

6 A small body of mass m rests on a horizontal turntable at a distance r from the centre. If the maximum frictional force between the body and the turntable is $\frac{mg}{2}$, what is the angular speed at which the body starts to slip?

A $\sqrt{\frac{gr}{2}}$

B $\frac{g}{r}$

C $\sqrt{\frac{g}{2r}}$

D $\frac{1}{2}\sqrt{\frac{g}{r}}$

Turn over ▶

Do not write outside the box

7 A body of mass 0.50 kg, fixed to one end of a string, is rotated in a vertical circle of radius 1.5 m at an angular speed of 5.0 rad s^{-1}. What is the maximum tension in the string?

A 5.0 N

B 9.0 N

C 14 N

D 24 N

8 A particle of mass m oscillates in a straight line with simple harmonic motion of constant amplitude. The total energy of the particle is E. What is the total energy of another particle of mass $2m$, oscillating with simple harmonic motion of the same amplitude but double the frequency?

A E

B $2E$

C $4E$

D $8E$

9 When a mass suspended on a spring is displaced, the system oscillates with simple harmonic motion. Which one of the following statements regarding the energy of the system is **incorrect**?

A The potential energy has a minimum value when the spring is fully compressed or fully extended.

B The kinetic energy has a maximum value at the equilibrium position.

C The sum of the kinetic and potential energies at any time is constant.

D The potential energy has a maximum value when the mass is at rest.

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10 When a mass M attached to a spring X, as shown in **Figure 1**, is displaced downwards and released it oscillates with time period T. An identical spring is connected in series and the same mass M is attached, as shown in **Figure 2**.

What is the new time period?

Figure 1

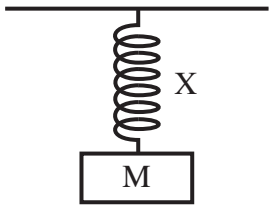
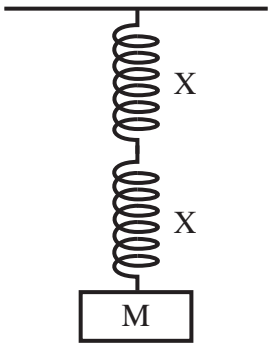


Figure 2



A $\frac{T}{2}$

B $\frac{T}{\sqrt{2}}$

C $\sqrt{2}T$

D $2T$

11 When a space shuttle is in a low orbit around the Earth it experiences gravitational forces F_E due to the Earth, F_M due to the Moon and F_S due to the Sun. Which one of the following correctly shows how the magnitudes of these forces are related to each other?

mass of Sun = 1.99×10^{30} kg
mass of Moon = 7.35×10^{22} kg
mean distance from Earth to Sun = 1.50×10^{11} m
mean distance from Earth to Moon = 3.84×10^{8} m

A $F_E > F_S > F_M$

B $F_S > F_E > F_M$

C $F_E > F_M > F_S$

D $F_M > F_E > F_S$

12 The gravitational field strengths at the surfaces of the Earth and the Moon are $9.8\,N\,kg^{-1}$ and $1.7\,N\,kg^{-1}$ respectively. If the mass of the Earth is 81 × the mass of the Moon, what is the ratio of the radius of the Earth to the radius of the Moon?

A 3.7

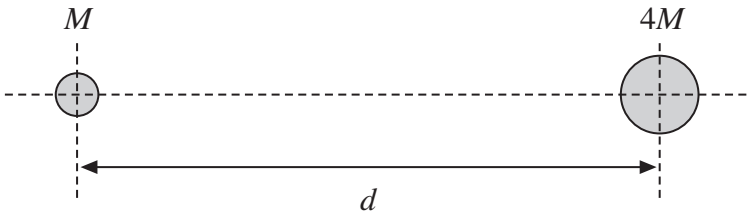
B 5.8

C 14

D 22

Do not write outside the box

13 Two stars of mass M and $4M$ are at a distance d between their centres.



The resultant gravitational field strength is zero along the line between their centres at a distance y from the centre of the star of mass M.

What is the value of the ratio $\frac{y}{d}$?

A $\frac{1}{2}$

B $\frac{1}{3}$

C $\frac{2}{3}$

D $\frac{3}{4}$

14 Mars has a diameter approximately 0.5 that of the Earth, and a mass of 0.1 that of the Earth.
The gravitational potential at the Earth's surface is $-63\,\text{MJ kg}^{-1}$.
What is the approximate value of the gravitational potential at the surface of Mars?

A $-13\,\text{MJ kg}^{-1}$

B $-25\,\text{MJ kg}^{-1}$

C $-95\,\text{MJ kg}^{-1}$

D $-320\,\text{MJ kg}^{-1}$

15 Two satellites P and Q, of equal mass, orbit the Earth at radii R and $2R$ respectively.
Which one of the following statements is correct?

A P has less kinetic energy and more potential energy than Q.

B P has less kinetic energy and less potential energy than Q.

C P has more kinetic energy and less potential energy than Q.

D P has more kinetic energy and more potential energy than Q.

Do not write outside the box

16 Two horizontal parallel plate conductors are separated by a distance of 5.0 mm in air. The lower plate is earthed and the potential of the upper plate is +50 V.

Which line, **A** to **D**, in the table gives correctly the electric field strength, E, and the potential, V, at a point midway between the plates?

	electric field strength E / V m^{-1}	**potential V / V**
A	1.0×10^4 upwards	25
B	1.0×10^4 downwards	25
C	1.0×10^4 upwards	50
D	1.0×10^4 downwards	50

17 Two identical positive point charges, P and Q, separated by a distance r, repel each other with a force F. If r is decreased so that the electrical potential energy of Q is doubled, what is the force of repulsion?

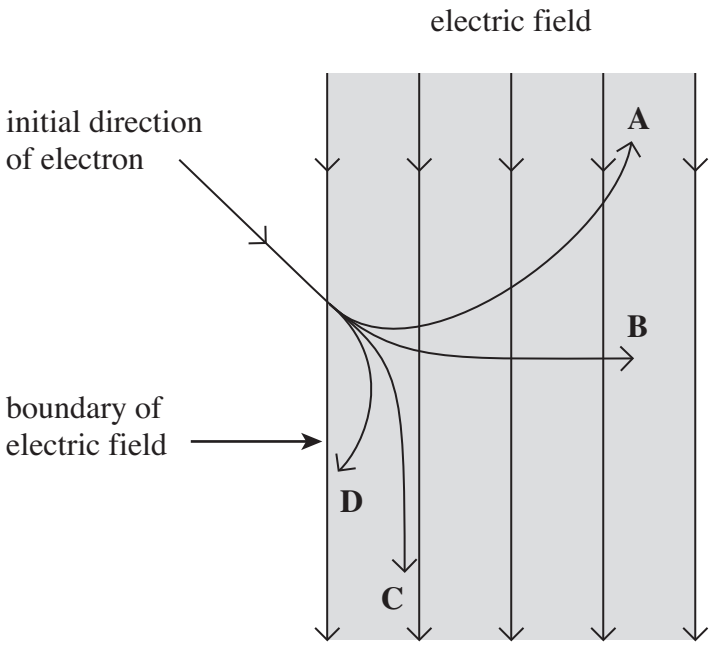
A $0.5F$

B F

C $2F$

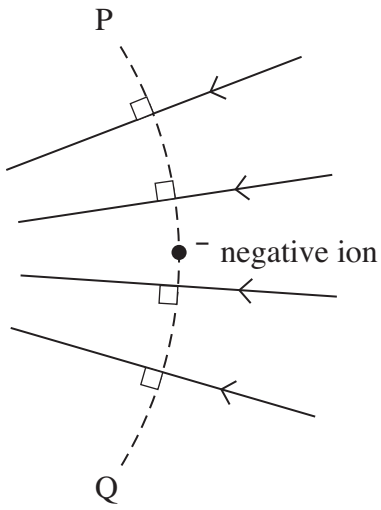
D $4F$

18 Which path, **A** to **D**, shows how an electron moves in the uniform electric field represented in the diagram?



Do not write outside the box

19 The diagram shows a negative ion at a point in an electric field, which is represented by the arrowed field lines.



Which one of the following statements correctly describes what happens when the ion is displaced?

When the negative ion is displaced

A to the left the magnitude of the electric force on it decreases.

B to the right its potential energy increases.

C along the line PQ towards Q its potential energy decreases.

D along the line PQ towards P the magnitude of the electric force on it is unchanged.

20 A nuclear fusion device is required to deliver at least 1 MJ of energy using capacitors. If the largest workable potential difference is 10 kV, what is the minimum capacitance of the capacitors that should be used?

A 0.01 F

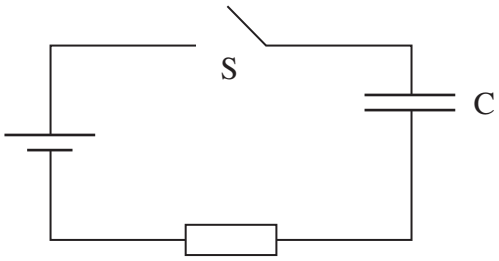
B 0.02 F

C 2 F

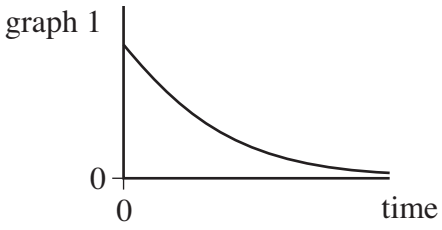
D 100 F

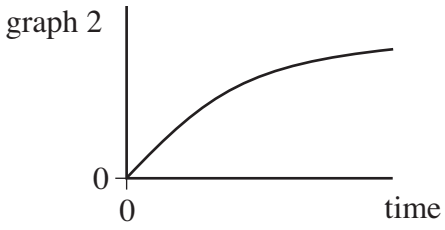
Do not write outside the box

21 In the circuit shown the capacitor C charges when switch S is closed.



Which line, **A** to **D**, in the table gives a correct pair of graphs showing how the charge on the capacitor and the current in the circuit change with time after S is closed?





	charge	**current**
A	graph 1	graph 1
B	graph 1	graph 2
C	graph 2	graph 2
D	graph 2	graph 1

Turn over for the next question

Do not write outside the box

22 The voltage across a capacitor falls from 10 V to 5 V in 48 ms as it discharges through a resistor.
What is the time constant of the circuit?

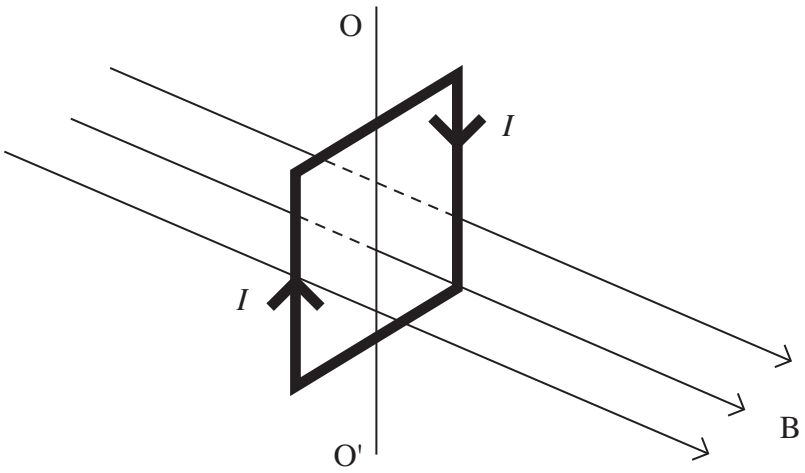
A 24 ms

B 33 ms

C 69 ms

D 96 ms

23 The diagram shows a vertical square coil whose plane is at right angles to a horizontal uniform magnetic field B. A current, *I*, is passed through the coil, which is free to rotate about a vertical axis OO'.



Which one of the following statements is correct?

A The forces on the two vertical sides of the coil are equal and opposite.

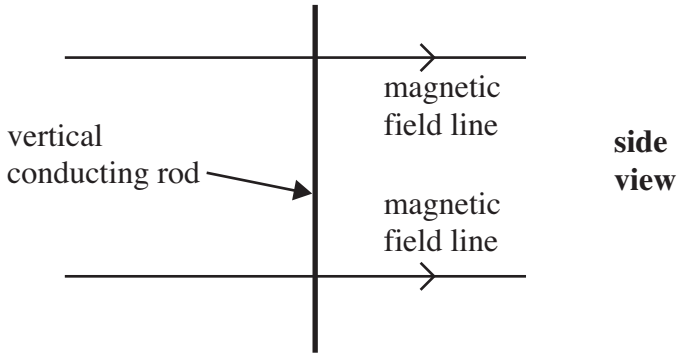
B A couple acts on the coil.

C No forces act on the horizontal sides of the coil.

D If the coil is turned through a small angle about OO' and released, it will remain in position.

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24 A vertical conducting rod of length l is moved at a constant velocity v through a uniform horizontal magnetic field of flux density B.



Which line, **A** to **D**, in the table gives a correct expression for the induced emf for the stated direction of the motion of the rod?

	direction of motion	**induced emf**
A	vertical	$\frac{B}{lv}$
B	horizontal at right angles to the field	Blv
C	vertical	Blv
D	horizontal at right angles to the field	$\frac{B}{lv}$

25 A transformer, which is not perfectly efficient, is connected to a 230 V rms mains supply and is used to operate a 12 V rms, 60 W lamp at normal brightness. The secondary coil of the transformer has 24 turns.

Which line, **A** to **D**, in the table is correct?

	number of turns on primary coil	**rms current in primary coil**
A	92	less than 0.26 A
B	92	more than 0.26 A
C	460	less than 0.26 A
D	460	more than 0.26 A

END OF QUESTIONS

There are no questions printed on this page

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Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
5	
TOTAL	

General Certificate of Education
Advanced Level Examination
June 2013

Physics A PHYA4/2

Unit 4 Fields and Further Mechanics
Section B

Thursday 13 June 2013 1.30 pm to 3.15 pm

For this paper you must have:
- a calculator
- a ruler
- a Data and Formulae Booklet (enclosed).

Time allowed
- The total time for both sections of this paper is 1 hour 45 minutes. You are advised to spend approximately one hour on this section.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the space provided. Answers written in margins or on blank pages will not be marked.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 50.
- You are expected to use a calculator where appropriate.
- A *Data and Formulae Booklet* is provided as a loose insert.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use specialist vocabulary where appropriate.

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Answer **all** questions in the spaces provided.
You are advised to spend approximately **one hour** on this section.

1 (a) A simple pendulum is given a small displacement from its equilibrium position and performs *simple harmonic motion*.

State what is meant by simple harmonic motion.

.....

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.....

.....

(2 marks)

1 (b) (i) Calculate the frequency of the oscillations of a simple pendulum of length 984 mm. Give your answer to an appropriate number of significant figures.

frequency ..... Hz

(3 marks)

1 (b) (ii) Calculate the acceleration of the bob of the simple pendulum when the displacement from the equilibrium position is 42 mm.

acceleration ..... $m\,s^{-2}$

(2 marks)

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1 (c) A simple pendulum of time period 1.90 s is set up alongside another pendulum of time period 2.00 s. The pendulums are displaced in the same direction and released at the same time.

Calculate the time interval until they next move in phase. Explain how you arrive at your answer.

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time interval ..... s

(3 marks)

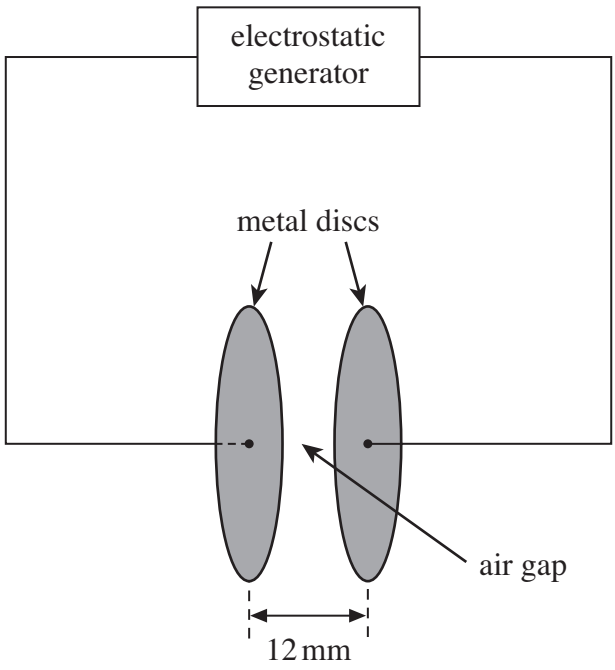
10

Turn over for the next question

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2 **Figure 1** shows an arrangement to demonstrate sparks passing across an air gap between two parallel metal discs. Sparks occur when the electric field in the gap becomes large enough to equal the breakdown field strength of the air. The discs form a capacitor, which is charged at a constant rate by an electrostatic generator until the potential difference (pd) across the discs is large enough for a spark to pass. Sparks are then produced at regular time intervals whilst the generator is switched on.

Figure 1



2 (a) The electrostatic generator charges the discs at a constant rate of 3.2×10^{-8} A on a day when the minimum breakdown field strength of the air is 2.5×10^{6} V m^{-1}. The discs have a capacitance of 3.7×10^{-12} F.

2 (a) (i) The air gap is 12 mm wide. Calculate the minimum pd required across the discs for a spark to occur. Assume that the electric field in the air gap is uniform.

pd V

(1 mark)

Do not write outside the box

2 (a) (ii) Calculate the time taken, from when the electrostatic generator is first switched on, for the pd across the discs to reach the value calculated in part (a)(i).

time ..... s

(2 marks)

2 (b) The discs are replaced by ones of larger area placed at the same separation, to give a larger capacitance.

State and explain what effect this increased capacitance will have on:

2 (b) (i) the time between consecutive discharges,

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(2 marks)

2 (b) (ii) the brightness of each spark.

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(2 marks)

7

Turn over ▶

Do not write outside the box

3 (a) (i) State **two** situations in which a charged particle will experience no magnetic force when placed in a magnetic field.

first situation .....

.....

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second situation .....

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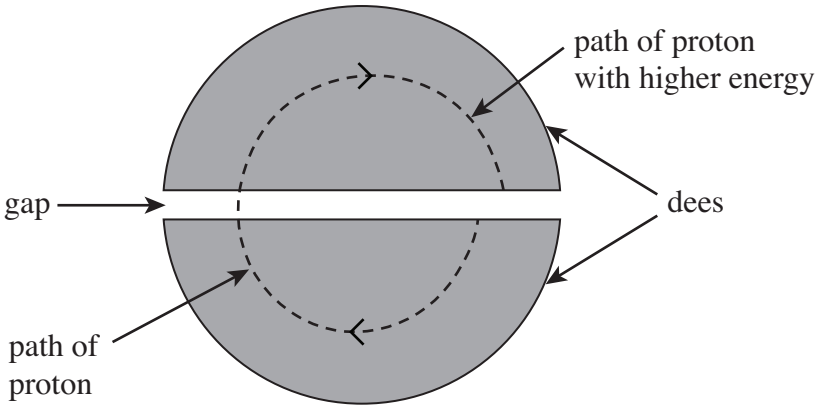
(2 marks)

3 (a) (ii) A charged particle moves in a circular path when travelling perpendicular to a uniform magnetic field. By considering the force acting on the charged particle, show that the radius of the path is proportional to the momentum of the particle.

(2 marks)

3 (b) In a cyclotron designed to produce high energy protons, the protons pass repeatedly between two hollow D-shaped containers called 'dees'. The protons are acted on by a uniform magnetic field over the whole area of the dees. Each proton therefore moves in a semi-circular path at constant speed when inside a dee. Every time a proton crosses the gap between the dees it is accelerated by an alternating electric field applied between the dees. **Figure 2** shows a plan view of this arrangement.

Figure 2



Do not write outside the box

3 (b) (i) State the direction in which the magnetic field should be applied in order for the protons to travel along the semicircular paths inside each of the dees as shown in **Figure 2**.

.....

(1 mark)

3 (b) (ii) In a particular cyclotron the flux density of the uniform magnetic field is 0.48 T. Calculate the speed of a proton when the radius of its path inside the dee is 190 mm.

speed ..... $m\,s^{-1}$

(2 marks)

3 (b) (iii) Calculate the time taken for this proton to travel at constant speed in a semicircular path of radius 190 mm inside the dee.

time ..... s

(2 marks)

3 (b) (iv) As the protons gain energy, the radius of the path they follow increases steadily, as shown in **Figure 2**. Show that your answer to part (b)(iii) does not depend on the radius of the proton's path.

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(2 marks)

Turn over ▶

Do not write outside the box

3 (c) The protons leave the cyclotron when the radius of their path is equal to the outer radius of the dees. Calculate the maximum kinetic energy, in MeV, of the protons accelerated by the cyclotron if the outer radius of the dees is 470 mm.

maximum kinetic energy ..... MeV
(3 marks)

14

4 Gravitational fields and electric fields have many features in common but also have several differences. For both radial and uniform gravitational and electric fields, compare and contrast their common features and their differences.

In your answer you should consider:

- the force acting between particles or charges
- gravitational field strength and electric field strength
- gravitational potential and electric potential.

The quality of your written communication will be assessed in your answer.

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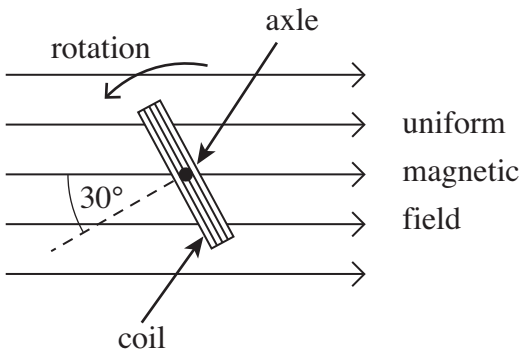
(6 marks)

6

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5 A rectangular coil is rotating anticlockwise at constant angular speed with its axle at right angles to a uniform magnetic field. **Figure 3** shows an end-on view of the coil at a particular instant.

Figure 3



5 (a) At the instant shown in **Figure 3**, the angle between the normal to the plane of the coil and the direction of the magnetic field is 30°.

5 (a) (i) State the minimum angle, in degrees, through which the coil must rotate from its position in **Figure 3** for the emf to reach its maximum value.

angle ..... degrees
(1 mark)

5 (a) (ii) Calculate the minimum angle, in radians, through which the coil must rotate from its position in **Figure 3** for the flux linkage to reach its maximum value.

angle ..... radians
(2 marks)

5 (b) **Figure 4** shows how, starting in a different position, the flux linkage through the coil varies with time.

5 (b) (i) What physical quantity is represented by the gradient of the graph shown in **Figure 4**?

.....
(1 mark)

5 (b) (ii) Calculate the number of revolutions per minute made by the coil.

revolutions per minute .....
(2 marks)

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Figure 4

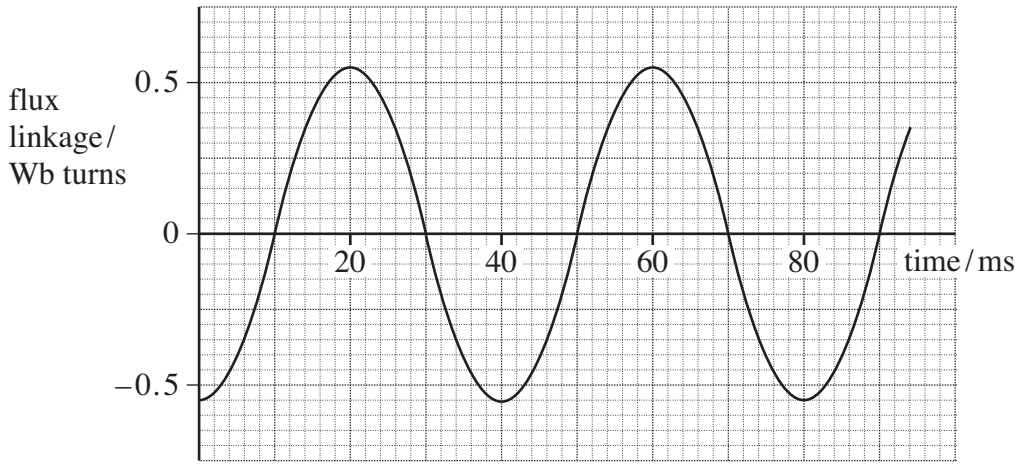
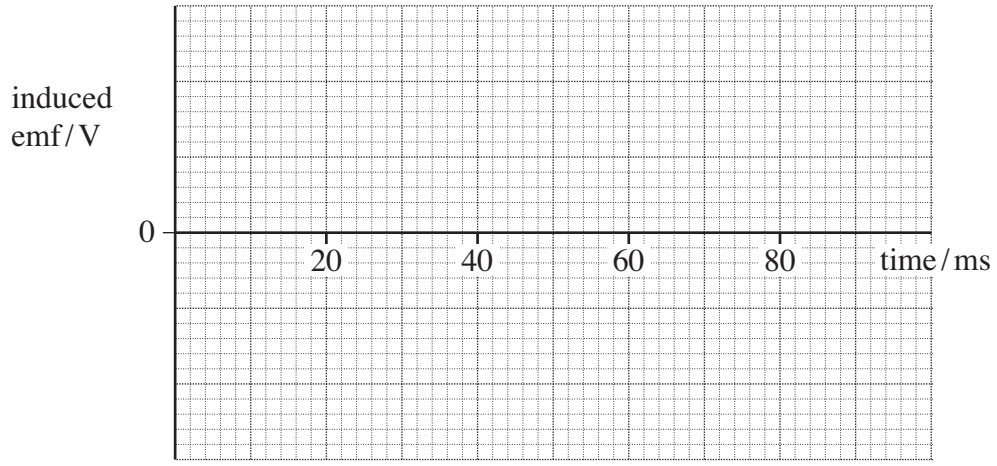


Figure 5



5 (b) (iii) Calculate the peak value of the emf generated.

peak emf V

(3 marks)

5 (c) Sketch a graph on the axes shown in **Figure 5** above to show how the induced emf varies with time over the time interval shown in **Figure 4**.

(2 marks)

Turn over ▶

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5 (d) The coil has 550 turns and a cross-sectional area of $4.0 \times 10^{-3}\,m^2$.

Calculate the flux density of the uniform magnetic field.

flux density ..... T

(2 marks)

13

END OF QUESTIONS

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Version 1.0



General Certificate of Education (A-level)
June 2013

Physics A PHYA4

(Specification 2450)

Unit 4: Fields and further mechanics

Final

Mark Scheme

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all examiners participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for standardisation each examiner analyses a number of students' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, examiners encounter unusual answers which have not been raised they are required to refer these to the Principal Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of students' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

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Section A:

1	**B**	14	**A**
2	**B**	15	**C**
3	**A**	16	**B**
4	**C**	17	**D**
5	**D**	18	**A**
6	**C**	19	**D**
7	**D**	20	**B**
8	**D**	21	**D**
9	**A**	22	**C**
10	**C**	23	**A**
11	**A**	24	**B**
12	**A**	25	**D**
13	**B**		

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Section B:

Question	Part	Subpart	Marking guidance	Mark	Comment
1	a		acceleration is proportional to displacement (from equilibrium) ✓ acceleration is in opposite direction to displacement **or** towards a fixed point/equilibrium position✓	2	Acceleration proportional to negative displacement is 1st mark only. Don't accept "restoring force" for accln.
1	b	i	$f\left(=\frac{1}{2\pi}\sqrt{\frac{g}{l}}\right)=\frac{1}{2\pi}\sqrt{\frac{9.81}{0.984}}$ ✓ = 0.503 (0.5025) (Hz) ✓ [**or** $T\left(=2\pi\sqrt{\frac{l}{g}}\right)=2\pi\sqrt{\frac{0.984}{9.81}}$ ✓ (= 1.9(90) (s)) $f\left(=\frac{1}{T}\right)=\frac{1}{1.990}$ = 0.503 (0.5025) (Hz) ✓] answer to **3SF** ✓	3	3SF is an independent mark. When g = 9.81 is used, allow either 0.502 or 0.503 for 2nd and 3rd marks. **Use of g = 9.8** gives 0.502 Hz: award only 1 of first 2 marks if quoted as 0.502, 0.503 0.50 or 0.5 Hz.
1	b	ii	$a\left(=-(2\pi f)^2 x\right)=(-)(2\pi\times 0.5025)^2\times 42\times 10^{-3}$ ✓ = 0.42 (0.419) (m s^{-2}) ✓	2	Allow ECF from **any** incorrect f from (b)(i).

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1	c		recognition of 20 oscillations of (shorter) pendulum **and/or** 19 oscillations of (longer) pendulum ✓ *Explanation:* difference of 1 oscillation **or** phase change of 2π **or** Δt = 0.1 so n = 2/0.1 =20, **or** other acceptable point ✓ time to next in phase condition = 38 (s) ✓ [**or** (T = 1.90 s so) $(n + 1) \times 1.90 = n \times 2.00$ ✓ gives n = 19 (oscillations of longer pendulum) ✓ minimum time between in phase condition = 19×2.00 = 38 (s) ✓]	3	Allow "back in phase (for the first time)" as a valid explanation.

2	a	i	required pd (= $2.5 \times 10^6 \times 12 \times 10^{-3}$) = $3.0(0) \times 10^4$ (V) ✓	1	

2	a	ii	charge required Q (= CV) = $3.7 \times 10^{-12} \times 3.00 \times 10^4$ ✓ (= 1.11×10^{-7} C) time taken $t\left(=\frac{Q}{I}\right)=\frac{1.11\times10^{-7}}{3.2\times10^{-8}}$ = 3.5 (3.47) (s) ✓	2	Allow ECF from incorrect V from (a)(i).

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2	b	i	time increases ✓ (larger C means) more charge required (to reach breakdown pd) **or** $t = \frac{CV}{I}$ **or** time ∝ capacitance ✓	2	**Mark sequentially** i.e. no explanation mark if effect is wrong.
2	b	ii	spark is brighter (**or** lasts for a longer time) ✓ more energy (**or** charge) is stored **or** current is larger **or** spark has more energy ✓	2	**Mark sequentially.**
3	a	i	*Two examples (any order):* • when charged particle is at rest **or** not moving relative to field ✓ • when charged particle moves parallel to magnetic field ✓	2	
3	a	ii	$BQv = \frac{mv^2}{r}$ ✓ (gives $BQr = mv$) B and Q are constant so $r \propto$ momentum (mv) ✓	2	Acceptable answers must include correct force equation (1st point). Insist on a reference to B and Q constant for 2nd mark.

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3	b	i	upwards (perpendicular to plane of diagram) ✓	1	Accept “out of the page” etc.

3	b	ii	$v\left(=\frac{BQr}{m}\right)=\frac{0.48\times1.60\times10^{-19}\times0.19}{1.67\times10^{-27}}$ ✓ = 8.7(4) × 10^{6} (m s^{-1}) ✓	2	

3	b	iii	length of path followed (= length of semi-circle) = πr ✓ time taken $t\left(=\frac{\pi r}{v}\right)=\frac{\pi\times0.19}{8.74\times10^{6}}$ = 6.8(3) × 10^{-8} (s) ✓ [**or** $\frac{v}{r}=\frac{BQ}{m}$ gives $t=\frac{\pi r}{v}=\frac{\pi m}{BQ}$ ✓ $=\frac{\pi\times1.67\times10^{-27}}{0.48\times1.60\times10^{19}}$ = 6.8(3) × 10^{-8} (s) ✓]	2	Allow ECF from incorrect v from (b)(ii). Max 1 if path length is taken to be $2\pi r$ (gives 1.37 × 10^{-7}s).

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3	b	iv	$v \propto r$ (and path length $\propto r$) ✓ t = (path length/ v) **or** (πr / v) so r cancels ($\therefore$ time doesn't depend on r) ✓ [**or** $t\left(=\frac{\pi r}{v}\right)=\frac{\pi rm}{BQr}$ ✓ $=\frac{\pi m}{BQ}$ (because r cancels) ✓] [**or** $BQv = m\omega^2 r$ gives $BQ\omega r = m\omega^2 r$ and $BQ = m\omega = 2\pi fm$ ✓ $\therefore$ frequency is independent of r ✓]	2	

3	c		$v_{max} = 8.74\times10^6 \times\left(\frac{0.47}{0.19}\right)$ = 2.16 × 10^7 (m s^{-1}) ✓ E_k (= ½ mv_{max}^2) = ½ × 1.67 × 10^{-27} × (2.16 × 10^7)^2 ✓ (= 3.90 × 10^{-13} J) = $\frac{3.90\times10^{-13}}{1.60\times10^{-13}}$ = 2.4(4) (MeV) ✓	3	1st mark can be achieved by full substitution, as in (b)(ii), or by use of data from (b)(i) and/or (b)(ii). Allow ECF from incorrect v from (b)(ii), or from incorrect t from (b)(iii).

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4			**The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.** The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. **High Level (Good to excellent): 5 or 6 marks** The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. *The candidate gives a comprehensive account of the similarities and differences between gravitational and electric fields, referring to both radial and uniform fields. There are clear statements showing good to excellent understanding of the forces between masses/charges, gravitational and electric field strengths, and gravitational and electric potentials and of how aspects of them differ for gravitational and electric effects.* **Intermediate Level (Modest to adequate): 3 or 4 marks** The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.	max 6	A **High Level** answer must refer to at least **two valid** similarities and at least **two valid** differences, and must also contain information about **both** radial and uniform fields. An **Intermediate Level** answer must refer to at least **two valid** similarities and at least **one valid** difference, and must also consider **either** radial or uniform fields, or both.

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			The candidate's comparisons are less complete but good understanding is shown of the factors affecting the respective forces and of the definitions of field strength and potential. There may be limited reference to radial and uniform fields. Similarities between gravitational and electric effects are better known than differences. **Low Level (Poor to limited): 1 or 2 marks** The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. *The candidate has a much weaker ability to convey the similarities and differences between gravitational and electric fields. There is likely to be little or no reference to radial and uniform fields. Factors affecting the respective forces are known, but understanding of field strength is likely to be weaker and understanding of potential may be poor or absent..* **The explanation expected in a competent answer should include a coherent selection of the following points.** ***Forces*** • In a radial field, both gravitational and electric involve an inverse square relationship. • In both cases the force is proportional to a product (masses/charges).		A **Low Level** answer must refer to at least **one valid** similarity but may not identify any **valid** differences. **(D)** = valid difference. Good candidates are likely to mention other valid differences e.g. electrostatic forces depend on the medium whereas gravitational forces don't, possibility of shielding an electric field but impossibility of shielding a gravitational field.

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			• In both cases a spherical body may be considered to act as a point mass or charge placed at the centre of the sphere. • In a uniform field the force is constant at all points. • Gravitational forces are always an attraction whilst electric forces may be attraction or repulsion. **(D)** • Gravitational forces are usually much smaller than electric forces (unless very large masses are involved). **(D)** ***Field Strengths*** • Both are defined as a *force per unit* mass or charge. • In both cases the field strength in a radial field is proportional to $1/r^2$. • In both cases the field strength in a radial field is proportional to the magnitude of the mass or charge that produces it. • In a uniform field the field has the same magnitude and same direction at all points. • A gravitational field is always directed towards the mass producing it whereas an electric field is directed towards a negative charge but away from a positive charge. **(D)** • A mass of 1 kg is small in terms of the gravitational field it produces but a charge of 1 C would produce a very strong electric field. **(D)** ***Potentials*** • Definitions of both involve work done in moving a mass or charge from infinity to a point.		

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			• Both definitions involve the work done *per unit* mass or charge. • Both types of potential are proportional to 1/*r* in a radial field. • Both types of potential are proportional to the mass or charge producing them. • In a uniform field the potential varies linearly with distance. • The work done in moving a mass or charge across a potential difference is calculated by multiplying the mass or charge by the potential difference. • Gravitational potential is always a negative quantity but electric potential is negative for negative charges and positive for positive charges. **(D)**		

5	a	i	60 (degrees) ✓	1	

5	a	ii	angle required is 150° ✓ which is 5π/6 [**or** 2.6(2)] (radians) ✓	2	Correct answer in radians scores both marks.

5	b	i	(magnitude of the induced) emf ✓	1	Accept “induced voltage” or “rate of change of flux linkage”, but not “voltage” alone.

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5	b	ii	frequency $\left(=\frac{1}{T}\right)=\frac{1}{40\times10^{-3}}$ ✓ (= 25 Hz) no of revolutions per minute = 25 × 60 = 1500 ✓	2	1500 scores both marks. Award 1 mark for 40s → 1.5 rev min^{-1}.

5	b	iii	maximum flux linkage (=BAN) = 0.55 (Wb turns) ✓ angular speed $\omega\left(=\frac{2\pi}{T}\right)=\frac{2\pi}{40\times10^{-3}}$ ✓ (= 157 rad s^{-1}) peak emf (= $BAN\omega$) = 0.55 × 157 = 86(.4) (V) ✓ [**or**, less accurately, use of gradient method ✓ {e.g. $\varepsilon\left(=\frac{\Delta(N\Phi)}{\Delta t}\right)=\frac{0.5-(-0.5)}{(16-4)\times10^{-3}}=\frac{1.0}{12\times10^{-3}}$ } = 83 (± 10) (V) ✓ ✓ (max 2 for (iii) for values between 63 and 72 V or 94 and 103V)]	3	

5	c		sinusoidal shape of constant period 40 ms ✓ correct phase (i.e. starts as a minus sin curve) ✓	2	**Mark sequentially.** Graph must cover at least 80ms. For 2nd mark, accept + sin curve. Perfect sin curves are not expected.

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5	d		BAN = 0.55 ∴ flux density $B = \frac{0.55}{4.0 \times 10^{-3} \times 550}$ ✓ = 0.25(0) (T) ✓	2	**OR** by use of ε from (b)(iii) and f from (b)(ii) substituted in $\varepsilon = BAN(2\pi f)$.

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Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

General Certificate of Education
Advanced Level Examination
January 2013

Physics A PHYA4/1

Unit 4 Fields and Further Mechanics
Section A

Wednesday 16 January 2013 1.30 pm to 3.15 pm

In addition to this paper you will require:
- an objective test answer sheet
- a black ink or black ball-point pen
- a calculator
- a question paper/answer book for Section B (enclosed)
- a Data and Formulae booklet.

Time allowed
- The total time for both sections of this paper is 1 hour 45 minutes. You are advised to spend approximately 45 minutes on this section.

Instructions
- Use black ink or black ball-point pen. Do **not** use pencil.
- Answer **all** questions in this section.
- For each question there are four responses. When you have selected the response which you think is the most appropriate answer to a question, mark this response on your answer sheet.
- Mark all responses as instructed on your answer sheet. If you wish to change your answer to a question, follow the instructions on your answer sheet.
- Do all rough work in this book **not** on the answer sheet.

Information
- The maximum mark for this section is 25.
- All questions in Section A carry equal marks. No deductions will be made for incorrect answers.
- A *Data and Formulae Booklet* is provided as a loose insert.
- The question paper/answer book for Section B is enclosed within this question paper.

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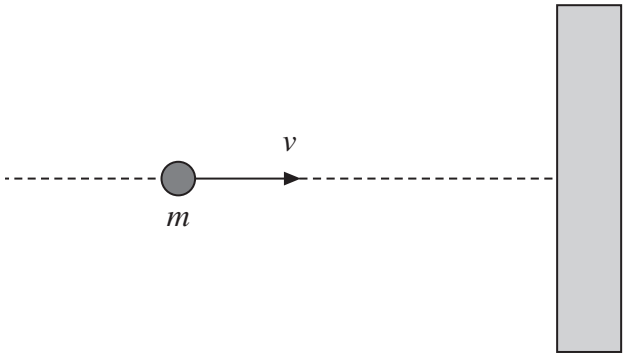
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Multiple choice questions

Each of Questions **1** to **25** is followed by four responses, **A**, **B**, **C**, and **D**. For each question select the best response and mark its letter on the answer sheet.

You are advised to spend approximately **45 minutes** on this section.

1 A ball of mass m travelling at velocity v collides normally with a smooth wall, as shown in the diagram, and rebounds elastically.



Which line, **A** to **D**, in the table, gives the correct expressions for the magnitude of the change of momentum, and the change of kinetic energy, of the ball?

	magnitude of change of momentum	**change of kinetic energy**
A	$2mv$	0
B	$2mv$	mv^2
C	0	0
D	0	mv^2

2 A cricket ball of mass 0.16 kg travelling at a speed of 35 m s^{-1} is hit by a bat and, as a result of the impact, leaves the bat in the opposite direction at 30 m s^{-1}. If the duration of the impact is 52 ms, what is the magnitude of the average force on the ball?

A 0.015 N

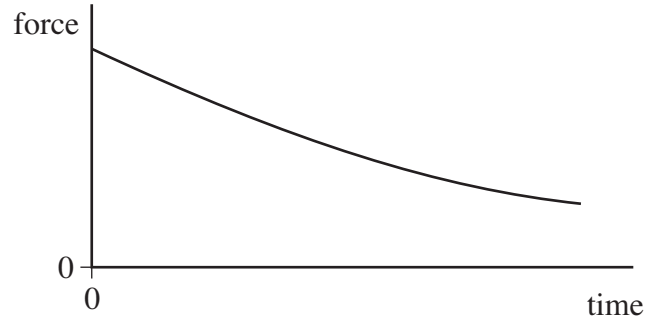
B 0.20 N

C 15 N

D 200 N

Do not write outside the box

3 A ball is released so that it falls vertically. The graph shows how the resultant force acting on the ball changes with time.



Which one of the following is represented by the area under the graph?

A distance travelled

B gain in kinetic energy

C acceleration

D impulse

4 For a particle moving in a circle with uniform speed, which one of the following statements is **incorrect**?

A There is no displacement of the particle in the direction of the force.

B The force on the particle is always perpendicular to the velocity of the particle.

C The velocity of the particle is constant.

D The kinetic energy of the particle is constant.

5 A revolving mountain top restaurant turns slowly, completing a full rotation in 50 minutes. A man is sitting in the restaurant 15 m from the axis of rotation. What is the speed of the man relative to a stationary point outside the restaurant?

A $\frac{\pi}{100}\ \text{m s}^{-1}$

B $\frac{3\pi}{5}\ \text{m s}^{-1}$

C $\frac{\pi}{200}\ \text{m s}^{-1}$

D $\frac{\pi}{1500}\ \text{m s}^{-1}$

Do not write outside the box

6 A particle of mass 0.20 kg moves with simple harmonic motion of amplitude 2.0×10^{-2} m. If the total energy of the particle is 4.0×10^{-5} J, what is the time period of the motion?

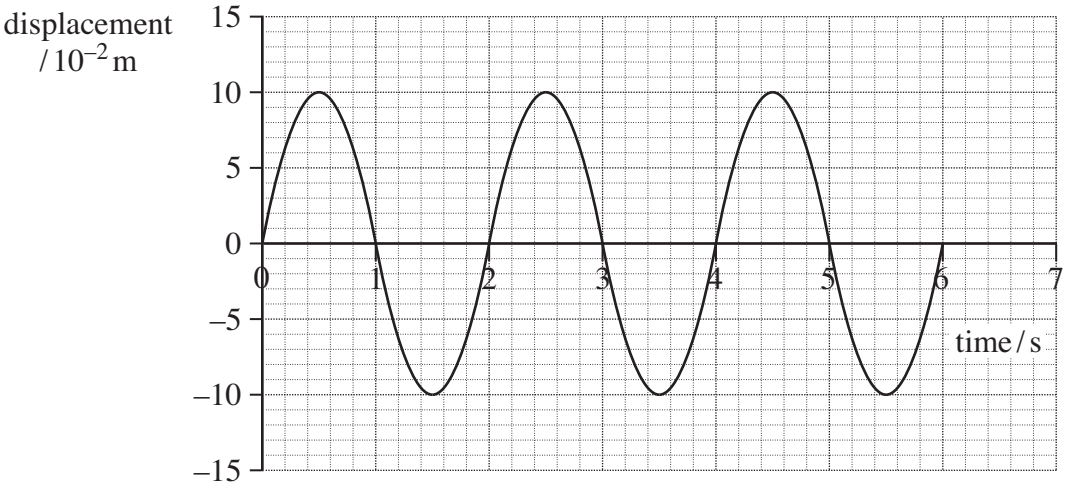
A $\frac{\pi}{4}$ seconds

B $\frac{\pi}{2}$ seconds

C π seconds

D 2π seconds

7 The graph shows the variation in displacement with time for an object moving with simple harmonic motion.



What is the maximum acceleration of the object?

A 0.025 m s^{-2}

B 0.99 m s^{-2}

C 2.5 m s^{-2}

D 9.8 m s^{-2}

8 A simple pendulum and a mass-spring system are taken to the Moon, where the gravitational field strength is less than on Earth. Which line, **A** to **D**, in the table correctly describes the change, if any, in the period when compared with its value on Earth?

	period of pendulum	**period of mass-spring system**
A	increase	no change
B	increase	increase
C	no change	decrease
D	decrease	decrease

Do not write outside the box

9 Two pendulums, P and Q, are set up alongside each other. The period of P is 1.90 s and the period of Q is 1.95 s.

How many oscillations are made by pendulum Q between two consecutive instants when P and Q move in phase with each other?

A 19
B 38
C 39
D 78

10 A small mass is situated at a point on a line joining two large masses m_1 and m_2 such that it experiences no resultant gravitational force. Its distance from the centre of mass of m_1 is r_1 and its distance from the centre of mass of m_2 is r_2.

What is the value of the ratio $\frac{r_1}{r_2}$?

A $\frac{{m_1}^2}{{m_2}^2}$

B $\frac{{m_2}^2}{{m_1}^2}$

C $\sqrt{\frac{m_1}{m_2}}$

D $\sqrt{\frac{m_2}{m_1}}$

11 Which one of the following gives a correct unit for $\left(\frac{g^2}{G}\right)$?

A $\mathrm{N\,m^{-2}}$
B $\mathrm{N\,kg^{-1}}$
C $\mathrm{N\,m}$
D N

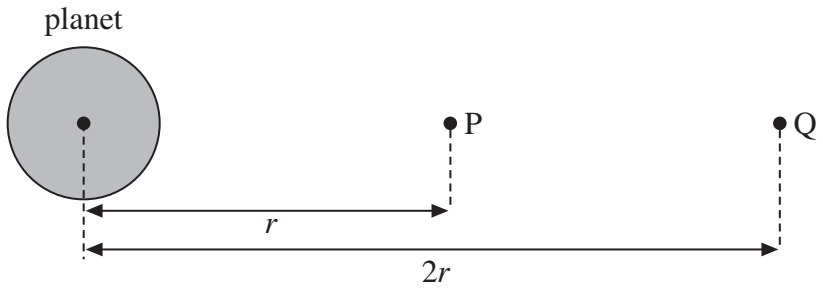
Do not write outside the box

12 The gravitational field strength at the surface of the Earth is 6 times its value at the surface of the Moon. The mean density of the Moon is 0.6 times the mean density of the Earth.

What is the value of the ratio $\left(\frac{\text{radius of Earth}}{\text{radius of Moon}}\right)$?

A 1.8
B 3.6
C 6.0
D 10

13 The diagram shows two points, P and Q, at distances r and $2r$ from the centre of a planet.

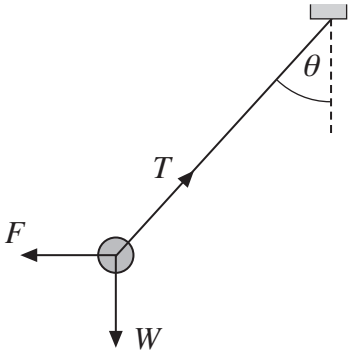


The gravitational potential at P is $-16\,\text{kJ}\,\text{kg}^{-1}$. What is the work done on a 10 kg mass when it is taken from P to Q?

A $-120\,\text{kJ}$
B $-80\,\text{kJ}$
C $+80\,\text{kJ}$
D $+120\,\text{kJ}$

Do not write outside the box

14 A small sphere, of mass m and carrying a charge Q, is suspended from a thread and placed in a uniform horizontal electric field of strength E. When the sphere comes to rest the thread makes an angle θ with the vertical and the tension in it is T, as shown in the diagram. W is the weight of the sphere and F is the electric force acting on it.



Under these conditions, which one of the following equations is **incorrect**?

A $T \sin \theta = EQ$

B $T = mg\cos\theta + EQ\sin\theta$

C $T^2 = (EQ)^2 + (mg)^2$

D $mg = EQ\tan\theta$

15 When a charge moves between two points in an electric field, or a mass moves between two points in a gravitational field, energy may be transferred.
Which one of the following statements is correct?

A No energy is transferred when the movement is parallel to the direction of the field.

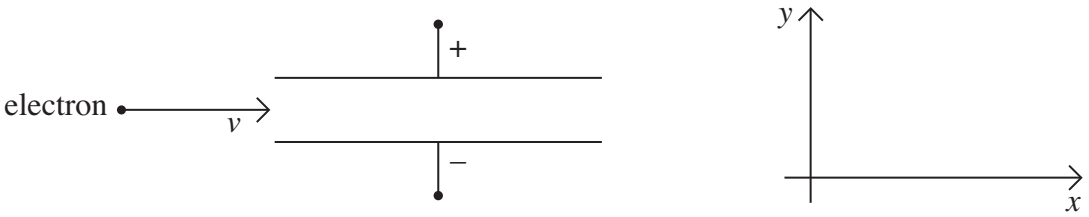
B The energy transferred is independent of the path followed.

C The energy transferred is independent of the start and finish points.

D Energy is transferred when the movement is perpendicular to the field lines.

Do not write outside the box

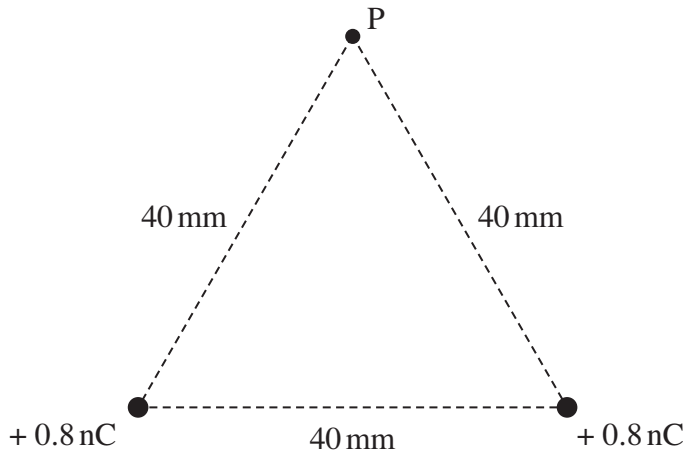
16 A beam of electrons, moving with a constant velocity v in a vacuum, enters a uniform electric field between two metal plates.



Which line, **A** to **D**, in the table describes the components of the acceleration of the electrons in the x and y directions as they move through the field?

	acceleration in *x* direction	**acceleration in *y* direction**
A	zero	zero
B	zero	constant
C	constant	zero
D	constant	constant

17 Two charges, each of +0.8 nC, are 40 mm apart.
Point P is 40 mm from each of the charges.



What is the electric potential at P?

A zero

B 180 V

C 360 V

D 4500 V

Do not write outside the box

18 An initially uncharged capacitor of capacitance 20 μF is charged by a constant current of 80 μA. Which line, **A** to **D**, in the table gives the potential difference across, and the energy stored in, the capacitor after 50 s?

	potential difference / V	**energy stored / J**
A	4.0×10^{-3}	2.0×10^{-3}
B	4.0×10^{-3}	4.0×10^{-1}
C	2.0×10^{2}	2.0×10^{-3}
D	2.0×10^{2}	4.0×10^{-1}

19 Which one of the following statements about a parallel plate capacitor is **incorrect**?

A The capacitance of the capacitor is the amount of charge stored by the capacitor when the pd across the plates is 1 V.

B A uniform electric field exists between the plates of the capacitor.

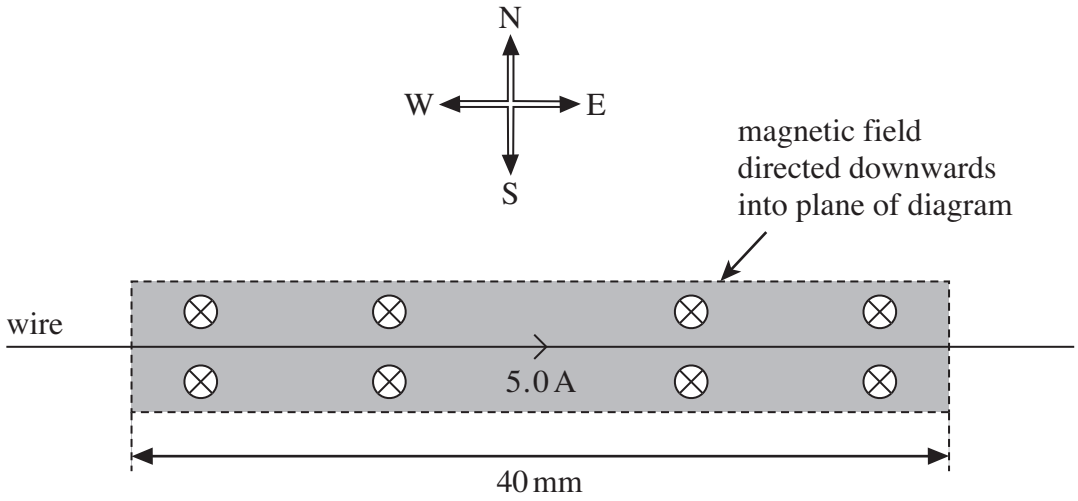
C The charge stored on the capacitor is inversely proportional to the pd across the plates.

D The energy stored when the capacitor is fully charged is proportional to the square of the pd across the plates.

Turn over for the next question

Do not write outside the box

20 A horizontal straight wire of length 40 mm is in an east-west direction as shown in the diagram. A uniform magnetic field of flux density 50 mT is directed downwards into the plane of the diagram.



When a current of 5.0 A passes through the wire from west to east, a horizontal force acts on the wire. Which line, **A** to **D**, in the table gives the magnitude and direction of this force?

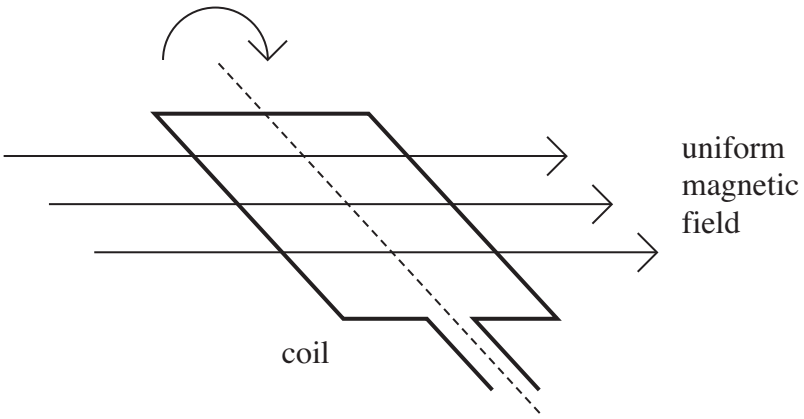
	magnitude / mN	**direction**
A	2.0	north
B	10.0	north
C	2.0	south
D	10.0	south

21 Which line, **A** to **D**, in the table correctly describes the trajectory of charged particles which enter separately, at right angles, a uniform electric field, and a uniform magnetic field?

	uniform electric field	**uniform magnetic field**
A	parabolic	circular
B	circular	parabolic
C	circular	circular
D	parabolic	parabolic

Do not write outside the box

22 A rectangular coil is rotated in a uniform magnetic field.



When the coil is rotated at a constant rate, an alternating emf ε is induced in it. The variation of emf ε, in volts, with time t, in seconds, is given by

$$\varepsilon = 20 \sin (100\ \pi t)$$

Which line, **A** to **D**, in the table gives the peak value ε_0 and the frequency f of the induced emf?

	ε_0 / V	f / Hz
A	10	50
B	10	100
C	20	50
D	20	100

23 The magnetic flux through a coil of 5 turns changes uniformly from 15×10^{-3} Wb to 7.0×10^{-3} Wb in 0.50 s. What is the magnitude of the emf induced in the coil due to this change in flux?

A 14 mV

B 16 mV

C 30 mV

D 80 mV

Do not write outside the box

24 Which one of the following statements concerning power losses in a transformer is **incorrect**?

Power losses can be reduced by

A laminating the core.

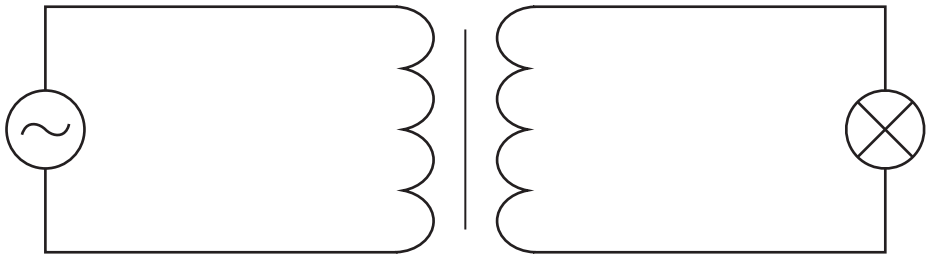
B using high resistance windings.

C using thick wire.

D using a core made of special iron alloys which are easily magnetised.

25 A transformer with 3000 turns in its primary coil is used to change an alternating pd from an rms value of 240 V to an rms value of 12 V.

When a 60 W, 12 V lamp is connected to the secondary coil, the lamp lights at normal brightness and a rms current of 0.26 A passes through the primary coil.



Which line, **A** to **D**, in the table gives correct values for the number of turns on the secondary coil and for the transformer efficiency?

	number of turns on the secondary coil	**efficiency**
A	150	96%
B	60 000	96%
C	150	90%
D	60 000	90%

END OF QUESTIONS

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Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

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Examiner's Initials	
Question	Mark
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General Certificate of Education
Advanced Level Examination
January 2013

Physics A PHYA4/2

Unit 4 Fields and Further Mechanics
Section B

Wednesday 16 January 2013 1.30 pm to 3.15 pm

For this paper you must have:
- a calculator
- a ruler
- a Data and Formulae Booklet (enclosed).

Time allowed
- The total time for both sections of this paper is 1 hour 45 minutes. You are advised to spend approximately one hour on this section.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Answers written in margins or on blank pages will not be marked.
- Do all rough work in this book. Cross through any work you do not want to be marked
- Show all your working.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this section is 50.
- You are expected to use a calculator where appropriate.
- A *Data and Formulae Booklet* is provided as a loose insert.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use specialist vocabulary where appropriate.

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Answer **all** questions in the spaces provided.
You are advised to spend approximately **one hour** on this section.

1 (a) State **one** similarity and **one** difference between an elastic collision and an inelastic collision.

similarity .....

.....

difference .....

.....

(2 marks)

1 (b) An unstable isotope of neodymium, $^{144}_{60}$Nd, decays into an isotope of cerium, Ce, by emitting an α particle.

1 (b) (i) Complete the following decay equation.

$$^{144}_{60}\text{Nd} \rightarrow {}^{\cdots\cdots}_{\cdots\cdots}\text{Ce} + {}^{\cdots\cdots}_{\cdots\cdots}\alpha$$

(1 mark)

1 (b) (ii) The α particle is emitted from a stationary $^{144}_{60}$Nd nucleus at a speed of $9.3 \times 10^6\,\text{m s}^{-1}$. Calculate the recoil speed of the daughter nucleus.

recoil speed ..... m s^{-1}

(2 marks)

Do not write outside the box

1 (b) (iii) Show that, when a stationary $^{144}_{60}$Nd nucleus decays, the kinetic energy of the recoiling cerium nucleus is only about 3% of the kinetic energy of the emitted α particle.

(3 marks)

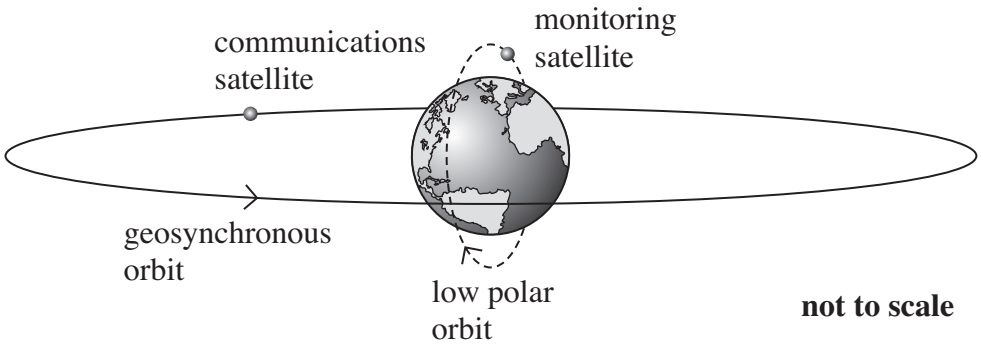
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Turn over for the next question

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2 **Figure 1** shows the orbits of two Earth satellites, a communications satellite in a geosynchronous orbit and a monitoring satellite in a low orbit that passes over the poles.

Figure 1



2 (a) The time period, T, of any satellite in a circular orbit around a planet is proportional to $r^{3/2}$, where r is the radius of its orbit measured from the centre of the planet.
For a satellite in a low orbit that passes over the poles of the Earth, T is 105 minutes when r is 7370 km.

2 (a) (i) Calculate the height above the surface of the Earth, in km, of a satellite in a geosynchronous circular orbit.
Give your answer to an appropriate number of significant figures.

height above surface ..... km
(4 marks)

Do not write outside the box

2 (a) (ii) Calculate the centripetal force acting on the polar orbiting satellite if its mass is 650 kg.

centripetal force ..... N
(2 marks)

2 (b) These geosynchronous and polar satellites have different applications because of their different orbits in relation to the rotation of the Earth.

Compare the principal features of the geosynchronous and polar orbits and explain the consequences for possible uses of satellites in these orbits.

In your answer you should explain why:

- a low polar orbit is suitable for a satellite used to monitor conditions on the Earth.
- a geosynchronous circular orbit above the Equator is especially suitable for a satellite used in communications.

The quality of your written communication will be assessed in your answer.

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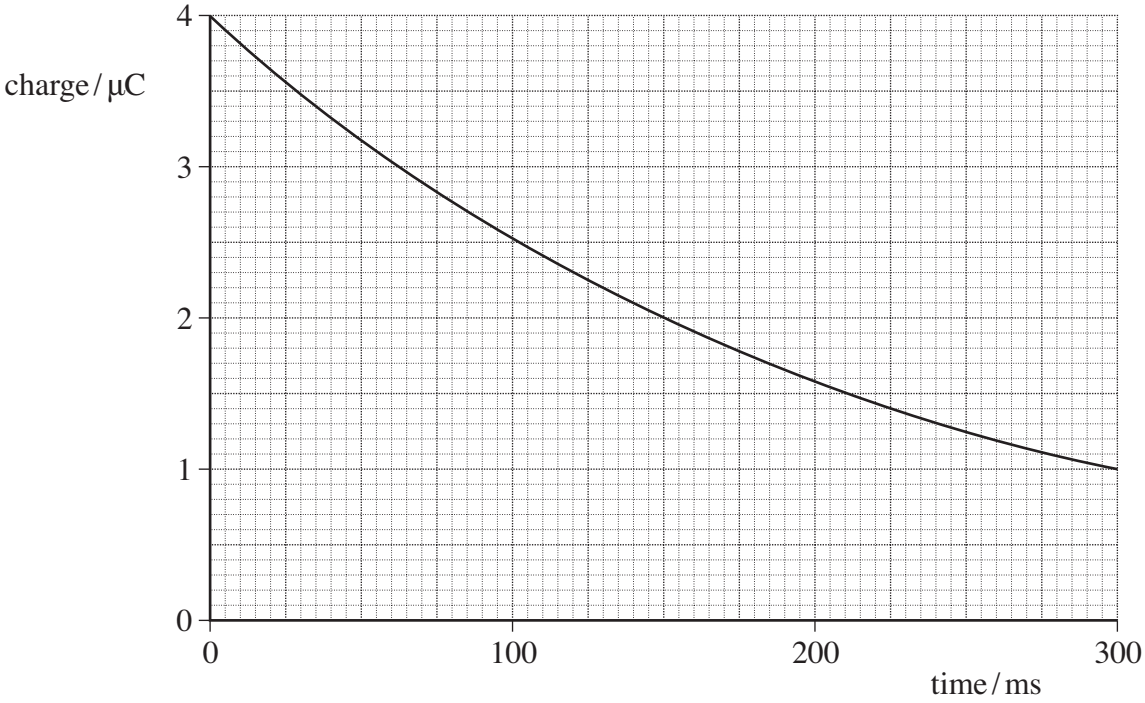
(6 marks)

12

Do not write outside the box

3 **Figure 2** shows how the charge stored by a capacitor varies with time when it is discharged through a fixed resistor.

Figure 2



3 (a) Determine the time constant, in ms, of the discharge circuit.

time constant ..... ms

(3 marks)

3 (b) Explain why the rate of discharge will be greater if the fixed resistor has a smaller resistance.

.....

.....

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(2 marks)

5

Turn over ▶

Do not write outside the box

4 (a) State, in words, Coulomb's law.

.....

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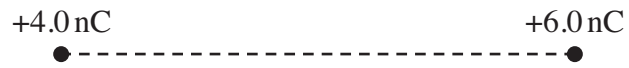
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(2 marks)

4 (b) **Figure 3** shows two point charges of +4.0 nC and +6.0 nC which are 68 mm apart.

Figure 3



4 (b) (i) Sketch on **Figure 3** the pattern of the electric field surrounding the charges.

(3 marks)

4 (b) (ii) Calculate the magnitude of the electrostatic force acting on the +4.0 nC charge.

magnitude of force ..... N

(2 marks)

Do not write outside the box

4 (c) (i) Calculate the magnitude of the resultant electric field strength at the mid-point of the line joining the two charges in **Figure 3**.
State an appropriate unit for your answer.

electric field strength ..... unit .....
(4 marks)

4 (c) (ii) State the direction of the resultant electric field at the mid-point of the line joining the charges.

.....
(1 mark)

12

Turn over for the next question

Do not write outside the box

5 (a) State Lenz's law.

.....

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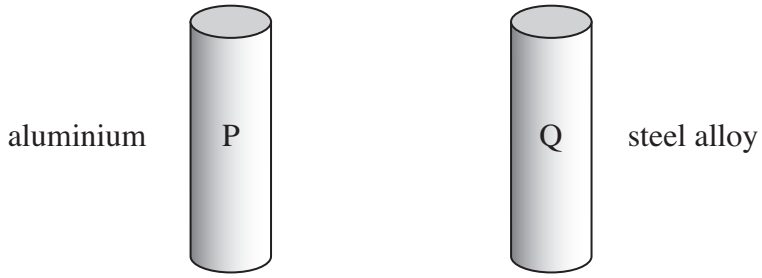
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(2 marks)

5 (b) **Figure 4** shows two small, solid metal cylinders, **P** and **Q**.
P is made from aluminium. **Q** is made from a steel alloy.

Figure 4



5 (b) (i) The dimensions of **P** and **Q** are identical but **Q** has a greater mass than **P**. Explain what material property is responsible for this difference.

.....

.....

.....

(1 mark)

Do not write outside the box

5 (b) (ii) When **P** and **Q** are released from rest and allowed to fall freely through a vertical distance of 1.0 m, they each take 0.45 s to do so. Justify this time value and explain why the times are the same.

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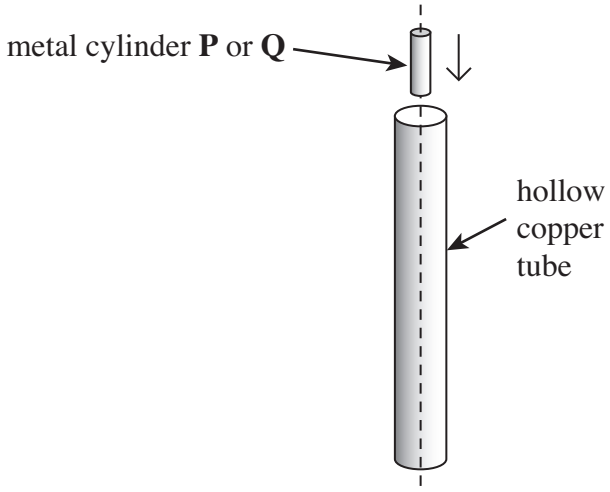
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(2 marks)

5 (c) The steel cylinder **Q** is a strong permanent magnet. **P** and **Q** are released separately from the top of a long, vertical copper tube so that they pass down the centre of the tube, as shown in **Figure 5**.

Figure 5



The time taken for **Q** to pass through the tube is much longer than that taken by **P**.

5 (c) (i) Explain why you would expect an emf to be induced in the tube as **Q** passes through it.

.....

.....

.....

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(2 marks)

Turn over ▶

Do not write outside the box

5 (c) (ii) State the consequences of this induced emf, and hence explain why **Q** takes longer than **P** to pass through the tube.

.....

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.....

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(3 marks)

5 (d) The copper tube is replaced by a tube of the same dimensions made from brass. The resistivity of brass is much greater than that of copper. Describe and explain how, if at all, the times taken by **P** and **Q** to pass through the tube would be affected.

P: .....

.....

.....

.....

Q: .....

.....

.....

.....

(3 marks)

13

END OF QUESTIONS

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Version 1.1



General Certificate of Education (A-level)
January 2013

Physics A PHYA4

(Specification 2450)

Unit 4: Fields and further mechanics

Final

Mark Scheme

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all examiners participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for standardisation each examiner analyses a number of students' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, examiners encounter unusual answers which have not been raised they are required to refer these to the Principal Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of students' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

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GCE Physics, Specification A, PHYA4, Fields and Further Mechanics

Section A

This component is an objective test for which the following list indicates the correct answers used in marking the candidates' responses.

Keys to Objective Test Questions												
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
A	D	D	C	A	D	B	A	B	C	A	B	C
14	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	
D	B	B	C	D	C	B	A	C	D	B	A	

Section B

Question	Part	Sub-part	Marking guidance	Mark	Comment
1	a		*Similarity*: momentum is conserved (in both cases) ✓ *Difference*: **kinetic** energy is conserved in an elastic collision but not in an inelastic collision ✓	2	For 2nd mark allow ke is **only** conserved in elastic collision, **or** ke is not conserved in an inelastic collision.
1	b	i	in the Ce nucleus $A = 140$ $Z = 58$ and for α $A = 4$ and $Z = 2$ ✓	1	All four correct values required
1	b	ii	$0 = 140v - 4 \times 9.3 \times 10^6$ ✓ gives $v = 2.6(6) \times 10^5$ (m s^{-1}) ✓	2	Allow $140v = 4 \times 9.3 \times 10^6$ for 1st mark. Allow ecf from values in (b)(i). Allow inclusion of mass of 58 electrons in recoil atom when shown.

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1	b	iii	E_k of α = ½ × 4 × 1.66 × 10^{-27} × (9.3 × 10^6)^2 ✓ (= 2.87 × 10^{-13} J) E_k of Ce = ½ × 140 × 1.66 × 10^{-27} × (2.66 × 10^5)^2 ✓ (= 8.22 × 10^{-15} J) $\frac{E_k \text{ of Ce}}{E_k \text{ of } \alpha} = \frac{8.22\times10^{-15}}{2.87\times10^{-13}}$ = 0.0286 or 2.86% ✓ [**or** $\frac{E_k \text{ of Ce}}{E_k \text{ of } \alpha} = \frac{35v_d^{\,2}}{v_\alpha^{\,2}}$ ✓ gives $\frac{35\times\left(2.66\times10^5\right)^2}{\left(9.3\times10^6\right)^2}$ ✓ = 0.0286 or 2.86% ✓] [**or** $\frac{E_k \text{ of Ce}}{E_k \text{ of } \alpha} = \frac{m_d v_d^{\,2}}{m_\alpha v_\alpha^{\,2}} = \frac{m_d}{m_\alpha}\times\left(\frac{m_\alpha}{m_d}\right)^2$ ✓ = $\frac{m_\alpha}{m_d} = \frac{1}{35}$ ✓ = 0.0286 or 2.86% ✓]	3	For 3rd mark, answer must be evaluated to at least 2SF (3% alone is insufficient); note that use of v_d = 2.7 × 10^5 m s^{-1} gives 0.0295 or 2.95%. Allow ecf from values in (b)(ii). When ecf is applied, 3rd mark is only available for answers between 2.5% and 3.5%.
2	a	i	$\left(T \propto r^{3/2} \text{ or } \frac{T_E}{T_P} = \left(\frac{r_E}{r_P}\right)^{3/2} \text{ gives}\right)$ $\frac{60\times24}{105} = \left(\frac{r_E}{7370}\right)^{3/2}$ ✓ from which $\frac{r_E}{7370} = \left(\frac{60\times24}{105}\right)^{2/3} = 5.73$ and r_E (= 5.73 × 7370) = 42 200 (km) ✓ height above surface = 42 200 – 6370 = 35 800 or 35 900 (km) ✓ answer to **3SF** only ✓ [**or** Newton's law approach for 1st two marks: $\left(\frac{GMm}{r^2} = m\omega^2 r \text{ and } \omega = \frac{2\pi}{T}\right)$ give $r^3\left(= \frac{GMT^2}{4\pi^2}\right)$ $\therefore r_E^{\,3} = \frac{6.67\times10^{-11}\times5.98\times10^{24}\times(24\times60\times60)^2}{4\pi^2}$ ✓ (=7.54 × 10^{22}) from which r_E = 42 200 (km) ✓]	4	Full solution derived from Newton's law of gravitation is acceptable for all 4 marks. For 3rd mark, final answer **must** be expressed in km. **3SF** mark is independent.

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2	a	ii	centripetal force (=$m\omega^2 r$) = $\frac{650\times 4\pi^2\times 7.37\times 10^6}{(105\times 60)^2}$ ✓ = 4800 (4760) (N) ✓ [**or** centripetal force $\left(=\frac{mv^2}{r}\right)$ and $v=\frac{2\pi r}{T}=\frac{2\pi\times 7.37\times 10^6}{105\times 60}$ gives v = 7350 (m s^{-1}) and centripetal force = $\frac{650\times 7350^2}{7.37\times 10^6}$ ✓ = 4800 (4760) (N) ✓] [**or** centripetal force $\left(=\frac{GMm}{r^2}\right)=\frac{6.67\times 10^{-11}\times 5.98\times 10^{24}\times 650}{(7.37\times 10^6)^2}$ ✓ = 4800 (4770) (N) ✓]	2	If **both** T and r values for the **geosynchronous** satellite are substituted, award 0 marks for (ii). If only **one** correct T or r value for the **polar** satellite is substituted, mark (ii) to max 1.

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2	b		**The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.** The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. **High Level (Good to excellent): 5 or 6 marks** The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. *The candidate gives a comprehensive comparison of the principal features of the satellite orbits and explains the consequences for the uses of the two types of satellites. There are clear statements showing good understanding of why the polar satellite is suitable for monitoring, and of why the geosynchronous satellite is useful for communications.* **Intermediate Level (Modest to adequate): 3 or 4 marks** The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. *The candidate's comparison of the principal features of the orbits is less complete and the consequences for the uses of satellites in them are less well understood. The candidate has an acceptable appreciation of why the polar satellite is suitable for monitoring, and of why the geosynchronous satellite is useful for communications.* **Low Level (Poor to limited): 1 or 2 marks** The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate.	max 6	**Four** aspects must be considered in a high level answer:- Features of polar orbit. Features of geosynchronous orbit. Why polar orbit is suitable for monitoring. Why geosynchronous orbit is suitable for communication.

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			The candidate has a much weaker knowledge of the principal features of the orbits and very limited knowledge of consequences for the uses of satellites in them. Understanding of why the polar satellite is suitable for monitoring, and why the geosynchronous satellite is suitable for communications, is limited or absent. **The explanation expected in a competent answer should include a coherent selection of the following points.** ***Low polar orbit*** • Orbital period is a few hours • Earth rotates relative to the orbit • Many orbits with different radii and periods are possible • Orbit height is less than geosynchronous satellite • Speed is greater than that of geosynchronous satellite • Satellite scans the whole surface of the Earth • Applications: surveillance of conditions/installations on Earth, mapping, weather observations, environmental monitoring • Gives access to every point on Earth's surface every day • Can collect data from regions inaccessible to man • Contact with transmitting/receiving aerial is intermittent • Aerial is likely to need a tracking facility • Lower signal strength required than that for geosynchronous satellite ***Geosynchronous orbit above Equator*** • Orbital period matches Earth's rotational period exactly • Satellite maintains same position relative to Earth • Only one particular orbit radius is possible • Travels west to east above Equator (in same direction as Earth's rotation) • Orbit height is greater than polar orbit satellite • Speed is less than that of polar orbiting satellite • Scans a restricted (and fixed) area of the Earth's surface only • Applications: telecommunications generally, cable and satellite TV, radio, digital information, etc. • Satellite is in continuous contact with transmitting/receiving aerial • Aerial can be in a fixed position		

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			• Higher signal strength required than that for polar satellite		
3	a		$\left(Q = Q_0 e^{-t/RC} \text{ gives}\right)$ $1.0 = 4.0e^{-300/RC}$ ✓ from which $\frac{300}{RC} = \ln 4$ ✓ and time constant RC = 220 (216) (ms) ✓ [***Alternative answer:*** time constant is time for charge to decrease to Q_0/e [**or** 0.37 Q_0] ✓ 4.0/e = 1.47 ✓ reading from graph gives time constant = 216 ± 10 (ms) ✓]	3	In alternative scheme, 4.0/e = 1.47 subsumes 1st mark. Also, accept $T_{½}$ = 0.693 RC (or = ln 2 RC) for 1st mark.
3	b		current is larger (for given V)(because resistance is lower) [**or** correct application of $I = V/R$] ✓ current is rate of flow of charge [**or** correct application of $I = \Delta Q/\Delta t$] ✓ larger rate of flow of charge (implies greater rate of discharge) [**or** causes larger rate of transfer of electrons from one plate back to the other] ✓ [***Alternative answer:*** time constant (or RC) is decreased (when R is decreased) ✓ explanation using $Q = Q_0e^{-t/RC}$ **or** time constant explained ✓]	max 2	Use either first or alternative scheme; do not mix and match. Time constant = RC is insufficient for time constant explained.
4	a		force between two (point) charges is proportional to (product of) charge**s** ✓ and inversely proportional to the square of their distance apart ✓	2	Formula not acceptable. Accept "charged particles" for charges. Accept separation for distance apart.
4	b	i	lines with arrows radiating outwards from each charge ✓ more lines associated with 6nC charge than with 4nC ✓ lines start radially and become non-radial with correct curvature further away from each charge ✓ correct asymmetric pattern (with neutral pt closer to 4nC charge) ✓	max 3	

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4	b	ii	force $\left(=\frac{Q_1Q_2}{4\pi\varepsilon_0 r^2}\right)=\frac{4.0\times10^{-9}\times6.0\times10^{-9}}{4\pi\times8.85\times10^{-12}\times(68\times10^{-3})^2}$ ✓ = 4.6(7) × 10^{-5} (N) ✓	2	Treat substitution errors such as 10^{-6} (instead of 10^{-9}) as AE with ECF available.
4	c	i	$E_4=\frac{4.0\times10^{-9}}{4\pi\varepsilon_0\times(34\times10^{-3})^2}$ (= 3.11 × 10^4 V m^{-1}) (to the right)✓ $E_6\left(=\frac{6.0\times10^{-9}}{4\pi\varepsilon_0\times(34\times10^{-3})^2}\right)$ = (4.67 × 10^4 V m^{-1}) (to the left) ✓ $E_{resultant}$ = (4.67 – 3.11) × 10^4 = 1.5(6) × 10^4 ✓ Unit: V m^{-1} (or N C^{-1}) ✓	4	For both of 1st two marks to be awarded, substitution for **either** or both of E_4 **or** E_6 (or a substitution in an expression for $E_6 - E_4$) must be shown. If no substitution is shown, but evaluation is correct for E_4 and E_6, award one of 1st two marks. Use of r = 68 × 10^{-3} is a physics error with no ECF. Unit mark is independent.
4	c	ii	*direction*: towards 4 nC charge **or** to the left ✓	1	
5	a		direction of induced emf (or current) ✓ opposes change (of magnetic flux) that produces it ✓	2	
5	b	i	(volumes are equal and mass of Q is greater than that of P) density of steel > density of aluminium ✓	1	Allow density of Q greater (than density of P).
5	b	ii	use of s = ½ g t^2 gives $t^2=\frac{2\times1.0}{9.81}$ (from which t = 0.45 s) ✓ (vertical) acceleration [**or** acceleration due to gravity] is independent of mass of falling object [**or** correct reference to $F = mg = ma$ with m cancelling] ✓	2	Backwards working is acceptable for 1st mark. 2nd mark must refer to mass. Do not allow “both in free fall” for 2nd mark.

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5	c	i	moving magnet [**or** magnetic field] passes through tube ✓ there is a change of flux (linkage)(in the tube) [**or** flux lines are cut **or** appropriate reference to $\varepsilon = N(\Delta\Phi/\Delta t)$]✓ [**Alternative:** (conduction) electrons in copper (or tube) acted on by (moving) magnetic field of Q ✓ induced emf (or current) is produced by redistributed electrons ✓]	2	In this part marks can be awarded for answers which mix and match these schemes.

5	c	ii	emf produces current (in copper) ✓ this current [*allow* emf] produces a magnetic field ✓ this field opposes magnetic field (or motion) of Q [**or** acts to reduce relative motion **or** produces upward force] ✓ no emf is induced by P because it is not magnetised (or not magnet) [**or** movement of P is not opposed by an induced emf or current] ✓	max 3	**Alternative** to 3rd mark: current gives heating effect in copper and energy for this comes from ke of Q ✓

5	d		time for P is unaffected because there is still no (induced) emf [**or** because P is not magnetised **or** because there is no repulsive force on P] ✓ time for Q is shorter (than in (c)) ✓ current induced by Q would be smaller ✓ because resistance of brass ∝ resistivity and is therefore higher [**or** resistance of brass is higher because resistivity is greater] ✓ giving weaker (opposing) magnetic field [**or** less opposition to Q's movement] ✓	max 3	Condone "will pass through faster" for 2nd mark. If emf is stated to be smaller for Q, mark (d) to max 2.

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Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

General Certificate of Education
Advanced Level Examination
June 2012

Physics A PHYA4/1

Unit 4 Fields and Further Mechanics
Section A

Monday 11 June 2012 1.30 pm to 3.15 pm

In addition to this paper you will require:
- an objective test answer sheet
- a black ball-point pen
- a calculator
- a question paper/answer book for Section B (enclosed)
- a Data and Formulae booklet.

Time allowed
- The total time for both sections of this paper is 1 hour 45 minutes. You are advised to spend approximately 45 minutes on this section.

Instructions
- Use a black ball-point pen.
- Answer **all** questions in this section.
- For each question there are four responses. When you have selected the response which you think is the most appropriate answer to a question, mark this response on your answer sheet.
- Mark all responses as instructed on your answer sheet. If you wish to change your answer to a question, follow the instructions on your answer sheet.
- Do all rough work in this book **not** on the answer sheet.

Information
- The maximum mark for this section is 25.
- All questions in Section A carry equal marks. No deductions will be made for incorrect answers.
- A *Data and Formulae Booklet* is provided as a loose insert.
- The question paper/answer book for Section B is enclosed within this question paper.

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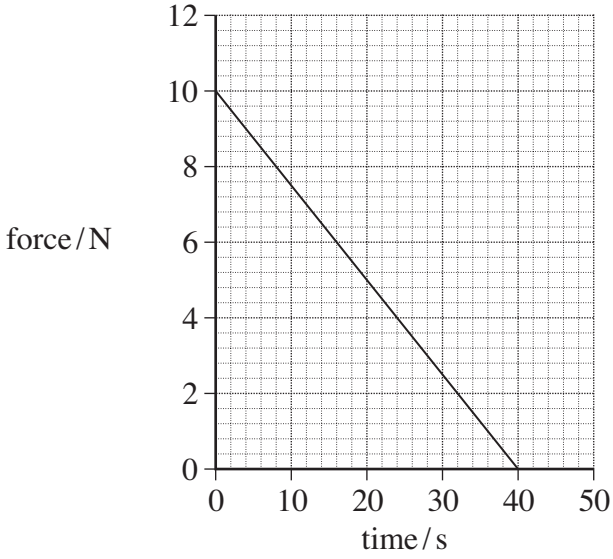
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Multiple choice questions

Each of Questions **1** to **25** is followed by four responses, **A**, **B**, **C**, and **D**. For each question select the best response and mark its letter on the answer sheet.

You are advised to spend approximately **45 minutes** on this section.

1 The graph shows how the force acting on a body changes with time.



The body has a mass of 0.25 kg and is initially at rest. What is the speed of the body after 40 s assuming no other forces are acting?

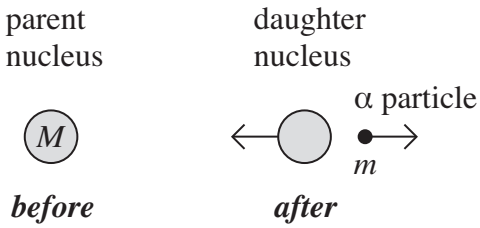
A $200\,\text{m s}^{-1}$

B $400\,\text{m s}^{-1}$

C $800\,\text{m s}^{-1}$

D $1600\,\text{m s}^{-1}$

2 A stationary unstable nucleus of mass M emits an α particle of mass m with kinetic energy E.



What is the speed of recoil of the daughter nucleus?

A $\dfrac{\sqrt{2mE}}{(M-m)}$

B $\dfrac{\sqrt{2mE}}{M}$

C $\dfrac{(M-m)}{\sqrt{2mE}}$

D $\dfrac{2mE}{(M-m)^2}$

Do not write outside the box

3 Two ice skaters, initially at rest and in contact, push apart from each other. Which line, **A** to **D**, in the table states correctly the change in the total momentum and the total kinetic energy of the two skaters?

	total momentum	**total kinetic energy**
A	unchanged	increases
B	unchanged	unchanged
C	increases	increases
D	increases	unchanged

4 The Earth moves around the Sun in a circular orbit with a radius of 1.5×10^8 km. What is the Earth's approximate speed?

A $1.5 \times 10^3\,m\,s^{-1}$

B $5.0 \times 10^3\,m\,s^{-1}$

C $1.0 \times 10^4\,m\,s^{-1}$

D $3.0 \times 10^4\,m\,s^{-1}$

5 A particle moves in a circular path at constant speed. Which one of the following statements is correct?

A The velocity of the particle is directed towards the centre of the circle.

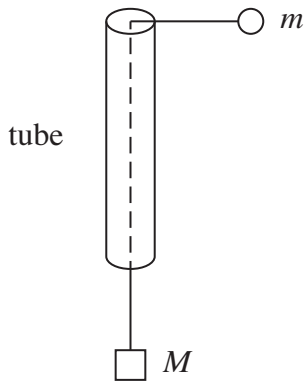
B There is no force acting on the particle.

C There is no change in the kinetic energy of the particle.

D The particle has an acceleration directed along a tangent to the circle.

Do not write outside the box

6 The diagram shows a smooth thin tube through which passes a string with masses m and M attached to its ends. The tube is moved so that the mass m travels in a horizontal circle of constant radius r at constant speed v.



Which one of the following expressions is equal to M?

A $\frac{mv^2}{2r}$

B mv^2rg

C $\frac{mv^2}{rg}$

D $\frac{mv^2g}{r}$

7 A mass on the end of a spring undergoes vertical simple harmonic motion. At which point(s) is the magnitude of the resultant force on the mass a minimum?

A at the centre of the oscillation
B only at the top of the oscillation
C only at the bottom of the oscillation
D at both the top and bottom of the oscillation

8 A baby bouncer consisting of a harness and elastic ropes is suspended from a doorway. When a baby of mass 10 kg is placed in the harness, the ropes stretch by 0.25 m. When the baby bounces, she starts to move with vertical simple harmonic motion. What is the time period of her motion?

A 1.0 s
B 2.1 s
C 2.3 s
D 3.1 s

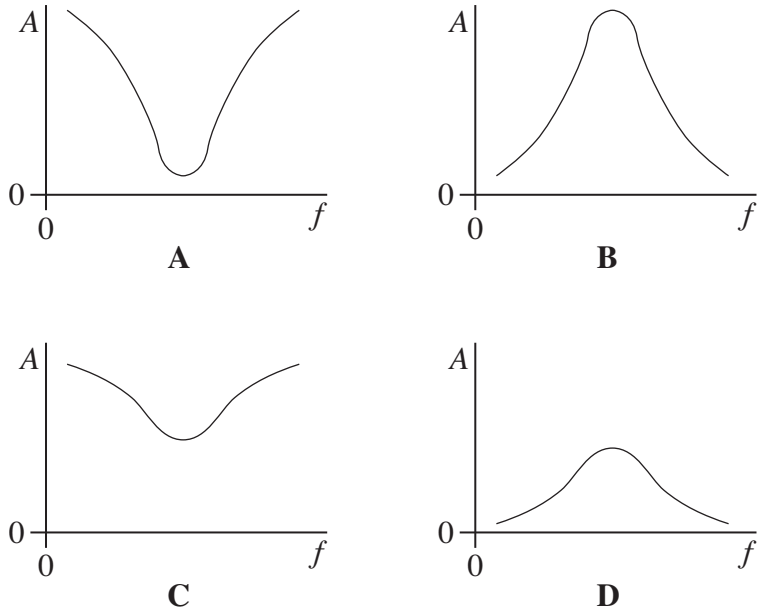
Do not write outside the box

9 A simple pendulum and a mass-spring system both have the same time period T at the surface of the Earth. If taken to another planet where the acceleration due to gravity is twice that on Earth, which line, **A** to **D**, in the table gives the correct new time periods?

	simple pendulum	**mass-spring**
A	$T\sqrt{2}$	$\frac{T}{\sqrt{2}}$
B	$T\sqrt{2}$	T
C	$\frac{T}{\sqrt{2}}$	T
D	$\frac{T}{\sqrt{2}}$	$T\sqrt{2}$

10 An oscillatory system, subject to damping, is set into vibration by a periodic driving force of frequency f. The graphs, **A** to **D**, which are to the same scale, show how the amplitude of vibration A of the system might vary with f, for various degrees of damping.

Which graph best shows the lightest damping?



11 Which one of the following statements about gravitational fields is **incorrect**?

A Moving a mass in the direction of the field lines reduces its potential energy.

B A stronger field is represented by a greater density of field lines.

C Moving a mass perpendicularly across the field lines does not alter its potential energy.

D At a distance r from a mass the field strength is inversely proportional to r.

Turn over ▶

Do not write outside the box

12 An object on the surface of a planet of radius R and mass M has weight W. What would be the weight of the same object when on the surface of a planet of radius $2R$ and mass $2M$?

A $\frac{W}{4}$

B $\frac{W}{2}$

C W

D $2W$

13 The gravitational field strength on the surface of a planet orbiting a star is $8.0\,\text{N kg}^{-1}$. If the planet and star have a similar density but the diameter of the star is 100 times greater than the planet, what would be the gravitational field strength at the surface of the star?

A $0.0008\,\text{N kg}^{-1}$

B $0.08\,\text{N kg}^{-1}$

C $800\,\text{N kg}^{-1}$

D $8000\,\text{N kg}^{-1}$

14 Two satellites, P and Q, of the same mass, are in circular orbits around the Earth. The radius of the orbit of Q is three times that of P. Which one of the following statements is correct?

A The kinetic energy of P is greater than that of Q.

B The weight of P is three times that of Q.

C The time period of P is greater than that of Q.

D The speed of P is three times that of Q.

15 The force between two point charges is F when they are separated by a distance r. If the separation is increased to $3r$, what is the force between the charges?

A $\frac{F}{3r}$

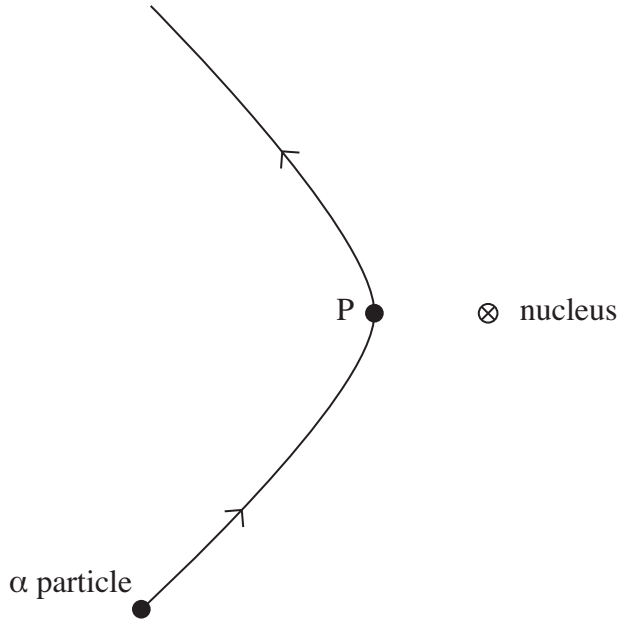
B $\frac{F}{9r}$

C $\frac{F}{3}$

D $\frac{F}{9}$

Do not write outside the box

16 The diagram shows the path of an α particle deflected by the nucleus of an atom. Point P on the path is the point of closest approach of the α particle to the nucleus.



Which one of the following statements about the α particle on this path is correct?

A Its acceleration is zero at P.

B Its kinetic energy is greatest at P.

C Its speed is least at P.

D Its potential energy is least at P.

17 A 1000 μF capacitor and a 10 μF capacitor are charged so that they store the same energy. The pd across the 1000 μF capacitor is V_1 and the pd across the other capacitor is V_2.

What is the value of the ratio $\left(\frac{V_1}{V_2}\right)^2$?

A $\frac{1}{1000}$

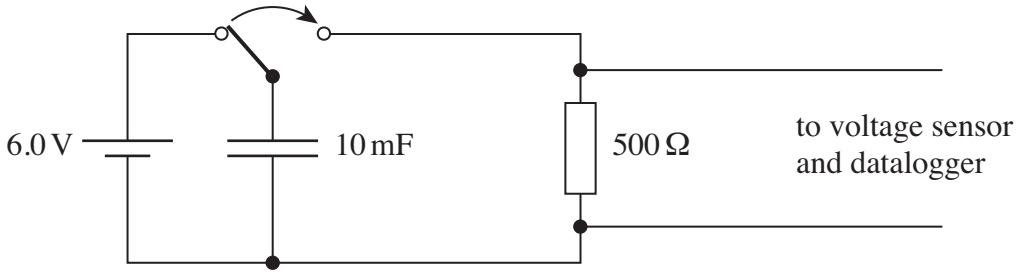
B $\frac{1}{100}$

C $\frac{1}{10}$

D 10

Do not write outside the box

18 A voltage sensor and a datalogger are used to record the discharge of a 10 mF capacitor in series with a 500 Ω resistor from an initial pd of 6.0 V. The datalogger is capable of recording 1000 readings in 10 s. Which line, **A** to **D**, in the table gives the pd and the number of readings made after a time equal to the time constant of the discharge circuit?



	potential difference/V	number of readings
A	2.2	50
B	3.8	50
C	3.8	500
D	2.2	500

19 When a 220 μF capacitor is discharged through a resistor R, the capacitor pd decreases from 6.0 V to 1.5 V in 92 s.

What is the resistance of R?

A 210 kΩ

B 300 kΩ

C 420 kΩ

D 440 kΩ

20 A section of current-carrying wire is placed at right angles to a uniform magnetic field of flux density B. When the current in the wire is I, the magnetic force that acts on this section is F.

What force acts when the same section of wire is placed at right angles to a uniform magnetic field of flux density $2B$ when the current is $0.25I$?

A $\frac{F}{4}$

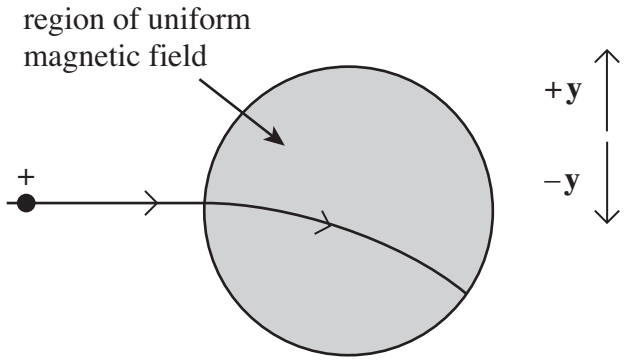
B $\frac{F}{2}$

C F

D $2F$

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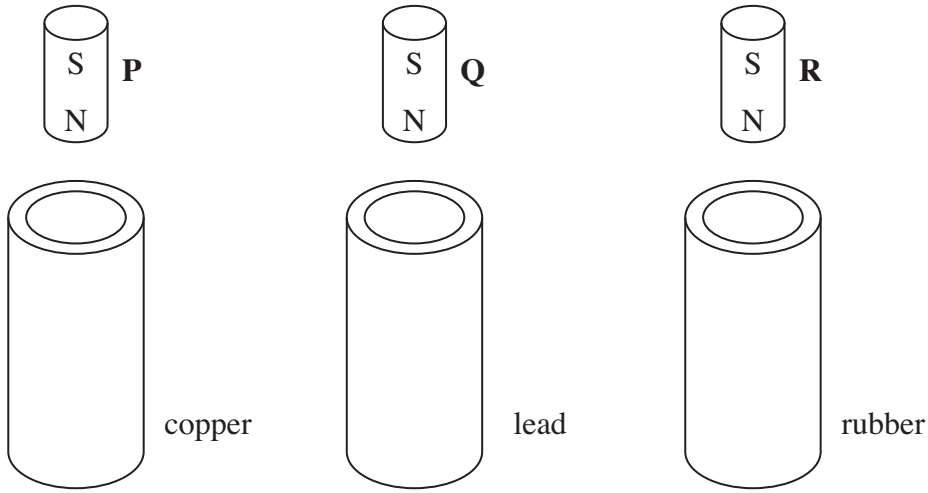
21 A beam of positive ions enters a region of uniform magnetic field, causing the beam to change direction as shown in the diagram.



What is the direction of the magnetic field?

A out of the page and perpendicular to it
B into the page and perpendicular to it
C in the direction indicated by **+y**
D in the direction indicated by **–y**

22 Three vertical tubes, made from copper, lead and rubber respectively, have identical dimensions. Identical, strong, cylindrical magnets **P**, **Q** and **R** are released simultaneously from the same distance above each tube. Because of electromagnetic effects, the magnets emerge from the bottom of the tubes at different times.



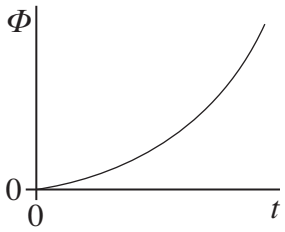
Which line, **A** to **D**, in the table shows the correct order in which they will emerge?

resistivity of copper = $1.7 \times 10^{-8} \Omega m$
resistivity of lead = $22 \times 10^{-8} \Omega m$
resistivity of rubber = $50 \times 10^{13} \Omega m$

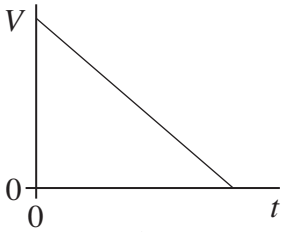
	emerges first	emerges second	emerges third
A	**P**	**Q**	**R**
B	**R**	**P**	**Q**
C	**P**	**R**	**Q**
D	**R**	**Q**	**P**

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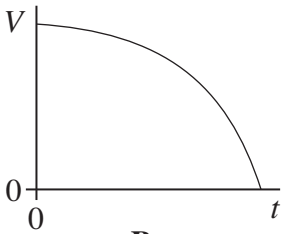
23 The graph shows how the magnetic flux, Φ, passing through a coil changes with time, t.



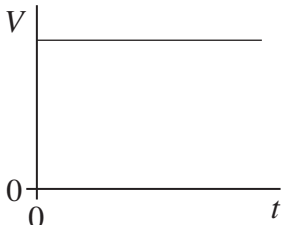
Which one of the following graphs could show how the magnitude of the emf, V, induced in the coil varies with t?



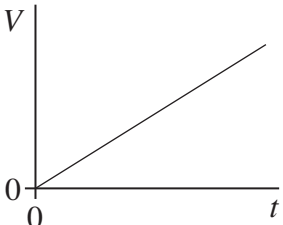
A



B

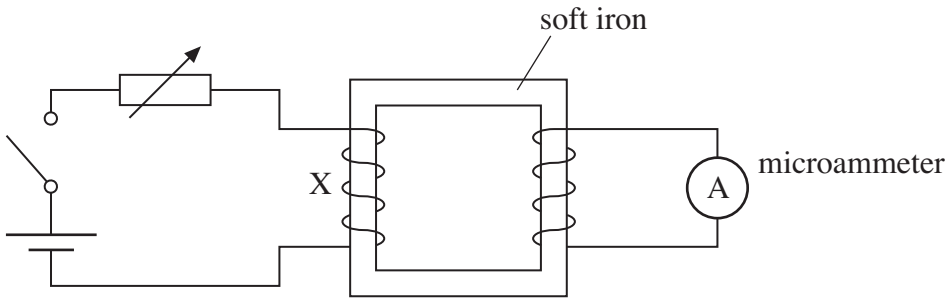


C



D

24 Using the circuit shown, and with the switch closed, a small current was passed through the coil X. The current was slowly increased using the variable resistor. The current reached a maximum value and was then switched off.



The maximum reading on the microammeter occurred when

A the small current flowed at the start.
B the current was being increased.
C the current was being switched off.
D the current in X was zero.

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25 When a mobile phone is being recharged, the charger heats up. The efficiency of the transformer in the charger can be as low as 15% when drawing a current of 50 mA from a 230 V mains supply. If the charging current required is 350 mA, what is the approximate output voltage at this efficiency?

A 4.9 V
B 11 V
C 28 V
D 33 V

END OF QUESTIONS

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Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
TOTAL	

General Certificate of Education
Advanced Level Examination
June 2012

Physics A PHYA4/2

Unit 4 Fields and Further Mechanics
Section B

Monday 11 June 2012 1.30 pm to 3.15 pm

For this paper you must have:
- a calculator
- a ruler
- a Data and Formulae Booklet.

Time allowed
- The total time for both sections of this paper is 1 hour 45 minutes. You are advised to spend approximately one hour on this section.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the space provided. Answers written in margins or on blank pages will not be marked.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 50.
- You are expected to use a calculator where appropriate.
- A *Data and Formulae Booklet* is provided as a loose insert.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use specialist vocabulary where appropriate.

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Answer **all** questions.
You are advised to spend approximately **one hour** on this section.

1 (a) State, in words, the relationship between the force acting on a body and the momentum of the body.

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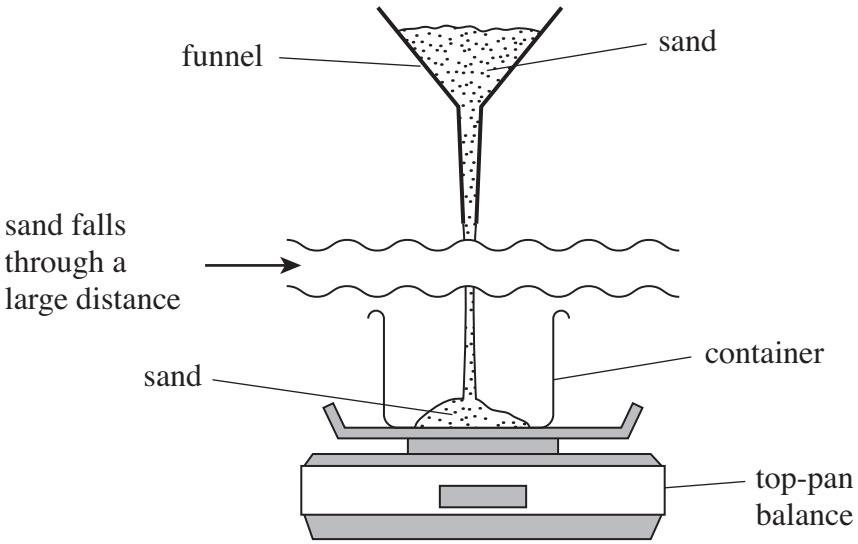
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(1 mark)

1 (b) A container rests on a top-pan balance, which measures mass in kg. A funnel above the container holds some sand. The sand falls at a constant rate of $0.300\,\text{kg}\,\text{s}^{-1}$ into the container, having fallen through an average vertical height of 1.60 m.
This arrangement is shown in **Figure 1**.

Figure 1



1 (b) (i) Show that the velocity of the sand as it lands in the container is $5.6\,\text{m}\,\text{s}^{-1}$.

(1 mark)

1 (b) (ii) Calculate the magnitude of the momentum of the sand that lands in the container in each second.

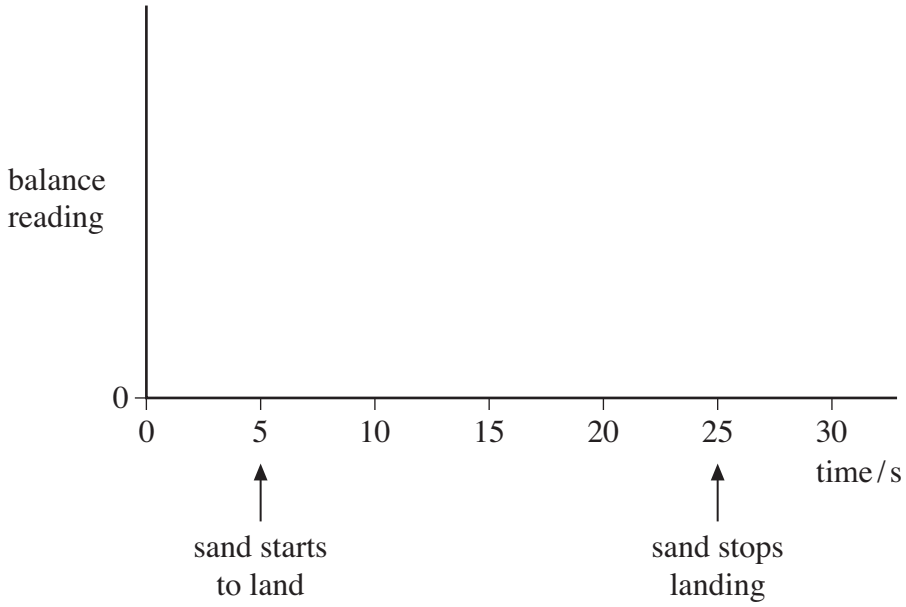
answer = ... N s
(1 mark)

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1 (b) (iii) The mass of the container is 0.650 kg. Show that the reading of the balance, 10.0 s after the sand starts landing continuously in the container, will be 3.82 kg. You may assume that the sand comes to rest without rebounding when it lands in the container.

(3 marks)

1 (c) It takes 20.0 s for all of the sand to fall into the container.
On the axes below, sketch a graph to show how the reading of the balance will change over a 30.0 s period, where t = 5.0 s is the time at which the sand starts to land in the container. No further calculations are required and values need not be shown on the vertical axis of the graph.



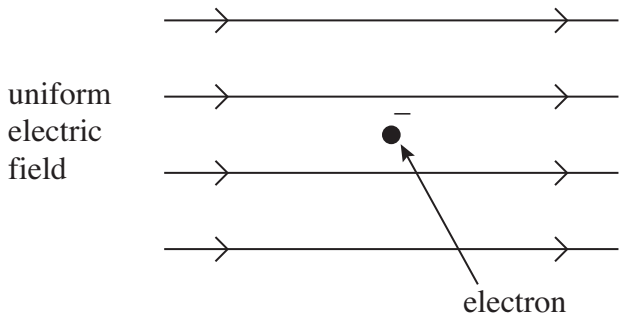
(3 marks)

9

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2 (a) **Figure 2** shows an electron at a point in a uniform electric field at an instant when it is stationary.

Figure 2



2 (a) (i) Draw an arrow on **Figure 2** to show the direction of the electrostatic force that acts on the stationary electron.

(1 mark)

2 (a) (ii) State and explain what, if anything, will happen to the magnitude of the electrostatic force acting on the electron as it starts to move in this field.

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(2 marks)

2 (b) **Figure 3a** shows a stationary electron in a non-uniform electric field. **Figure 3b** shows a stationary proton, placed in exactly the same position in the same electric field as the electron in **Figure 3a**.

Figure 3a

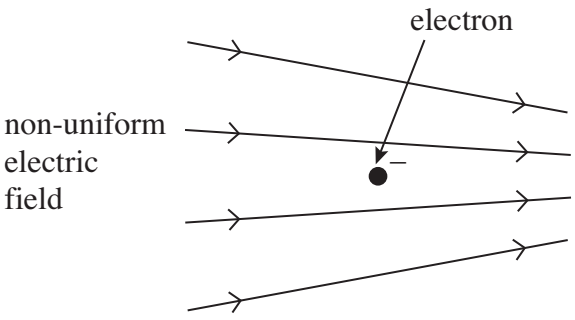
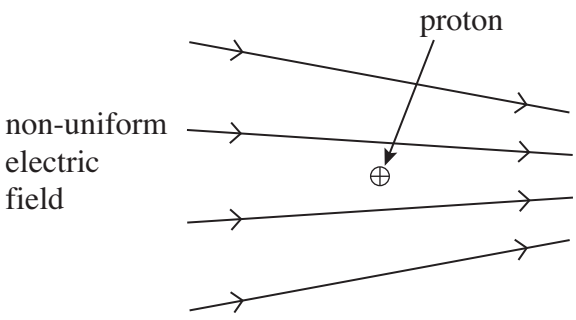


Figure 3b



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2 (b) (i) State and explain how the electrostatic force on the proton in **Figure 3b** compares with that on the electron in **Figure 3a**.

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(2 marks)

2 (b) (ii) Each of the particles starts to move from the positions shown in **Figure 3a** and **Figure 3b**. State and explain how the magnitude of the **initial** acceleration of the proton compares with that of the electron.

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(2 marks)

2 (b) (iii) Describe and explain what will happen to the acceleration of each of these particles as they continue to move in the electric field.

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(2 marks)

Turn over ▶

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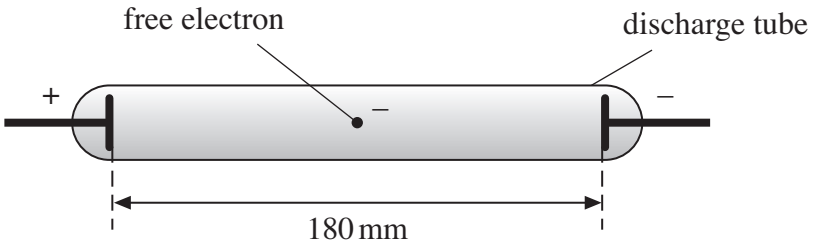
2 (c) The line spectrum of neon gas contains a prominent red line of wavelength 650 nm.

2 (c) (i) Show that the energy required to excite neon atoms so that they emit light of this wavelength is about 2 eV.

(3 marks)

2 (c) (ii) An illuminated shop sign includes a neon discharge tube, as shown in **Figure 4**.
A pd of 4500 V is applied across the electrodes, which are 180 mm apart.

Figure 4



Assuming that the electric field inside the tube is uniform, calculate the minimum distance that a free electron would have to move from rest in order to excite the red spectral line in part (c).

answer = ... m

(3 marks)

15

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3 The Large Hadron Collider (LHC) uses magnetic fields to confine fast-moving charged particles travelling repeatedly around a circular path. The LHC is installed in an underground circular tunnel of circumference 27 km.

3 (a) In the presence of a suitably directed uniform magnetic field, charged particles move at constant speed in a circular path of constant radius. By reference to the force acting on the particles, explain how this is achieved and why it happens.

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(4 marks)

3 (b) (i) The charged particles travelling around the LHC may be protons. Calculate the centripetal force acting on a proton when travelling in a circular path of circumference 27 km at one-tenth of the speed of light. Ignore relativistic effects.

answer = ... N

(3 marks)

Turn over ▶

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3 (b) (ii) Calculate the flux density of the uniform magnetic field that would be required to produce this force. State an appropriate unit.

answer = ... unit .....

(3 marks)

3 (c) The speed of the protons gradually increases as their energy is increased by the LHC. State and explain how the magnetic field in the LHC must change as the speed of the protons is increased.

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(2 marks)

12

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4 (a) Define the gravitational potential at a point in a gravitational field.

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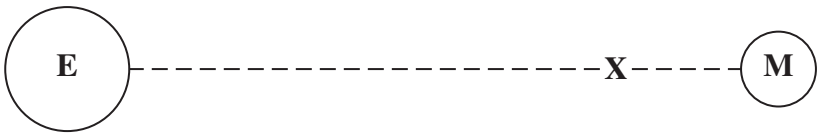
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(2 marks)

4 (b) **Figure 5**, which is not drawn to scale, shows the region between the Earth (**E**) and the Moon (**M**).

Figure 5



4 (b) (i) The gravitational potential at the Earth's surface is $-62.6\,\text{MJ kg}^{-1}$. Point **X** shown in **Figure 5** is on the line of centres between the Earth and the Moon At **X** the resultant gravitational field is zero, and the gravitational potential is $-1.3\,\text{MJ kg}^{-1}$.

Calculate the minimum amount of energy that would be required to move a Moon probe of mass $1.2 \times 10^4\,\text{kg}$ from the surface of the Earth to point **X**. Express your answer to an appropriate number of significant figures.

answer = ... J

(3 marks)

4 (b) (ii) Explain why, once the probe is beyond **X**, no further energy would have to be supplied in order for it to reach the surface of the Moon.

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(1 mark)

Turn over ▶

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4 (b) (iii) In the vicinity of the Earth's orbit the gravitational potential due to the Sun's mass is $-885\,\text{MJ kg}^{-1}$. With reference to the variation in gravitational potential with distance, explain why the gravitational potential due to the Sun's mass need not be considered when carrying out the calculation in part (b)(i).

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(2 marks)

4 (c) The amount of energy required to move a manned spacecraft from the Earth to the Moon is much greater than that required to return it to the Earth. By reference to the forces involved, to gravitational field strength and gravitational potential, and to the point **X**, explain why this is so.

The quality of your written communication will be assessed in your answer.

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(6 marks)

END OF QUESTIONS

14

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Version 1.0



General Certificate of Education (A-level)
June 2012

Physics A PHYA4

(Specification 2450)

Unit 4: Fields and further mechanics

Final

Mark Scheme

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all examiners participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the candidates' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for standardisation each examiner analyses a number of candidates' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, examiners encounter unusual answers which have not been raised they are required to refer these to the Principal Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of candidates' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

Further copies of this Mark Scheme are available from: aqa.org.uk

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Instructions to Examiners

1 Give due credit for alternative treatments which are correct. Give marks for what is correct in accordance with the mark scheme; do not deduct marks because the attempt falls short of some ideal answer. Where marks are to be deducted for particular errors, specific instructions are given in the marking scheme.

2 Do not deduct marks for poor written communication. Refer the scripts to the Awards meeting if poor presentation forbids a proper assessment. In each paper, candidates are assessed on their quality of written communication (QWC) in designated questions (or part-questions) that require explanations or descriptions. The criteria for the award of marks on each such question are set out in the mark scheme in three bands in the following format. The descriptor for each band sets out the expected level of the quality of written communication of physics for each band. Such quality covers the scope (eg relevance, correctness), sequence and presentation of the answer. Amplification of the level of physics expected in a good answer is set out in the last row of the table. To arrive at the mark for a candidate, their work should first be assessed holistically (ie in terms of scope, sequence and presentation) to determine which band is appropriate then in terms of the degree to which the candidate's work meets the expected level for the band.

QWC	descriptor	mark range
Good - Excellent	*see specific mark scheme*	**5-6**
Modest - Adequate	*see specific mark scheme*	**3-4**
Poor - Limited	*see specific mark scheme*	**1-2**
The description and/or explanation expected in a good answer should include a coherent account of the following points: *see specific mark scheme*		

Answers given as bullet points should be considered in the above terms. Such answers without an 'overview' paragraph in the answer would be unlikely to score in the top band.

3 An arithmetical error in an answer will cause the candidate to lose one mark and should be annotated AE if possible. The candidate's incorrect value should be carried through all subsequent calculations for the question and, if there are no subsequent errors, the candidate can score all remaining marks.

4 The use of significant figures is tested **once** on each paper in a designated question or part-question. The numerical answer on the designated question should be given to the same number of significant figures as there are in the data given in the question or to one more than this number. All other numerical answers should not be considered in terms of significant figures.

5 Numerical answers **presented** in non-standard form are undesirable but should not be penalised. Arithmetical errors by candidates resulting from use of non-standard form in a candidate's working should be penalised as in point 3 above. Incorrect numerical prefixes and the use of a given diameter in a geometrical formula as the radius should be treated as arithmetical errors.

6 Knowledge of units is tested on designated questions or parts of questions in each a paper. On each such question or part-question, unless otherwise stated in the mark scheme, the mark scheme will show a mark to be awarded for the numerical value of the answer and a further mark for the correct unit. No penalties are imposed for incorrect or omitted units at intermediate stages in a calculation or at the final stage of a non-designated 'unit' question.

7 All other procedures including recording of marks and dealing with missing parts of answers will be clarified in the standardising procedures.

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GCE Physics, Specification A, PHYA4, Fields and Further Mechanics

Section A

This component is an objective test for which the following list indicates the correct answers used in marking the candidates' responses.

Keys to Objective Test Questions												
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
C	A	A	D	C	C	A	A	C	B	D	B	C
14	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	
A	D	C	B	D	B	B	A	D	D	C	A	

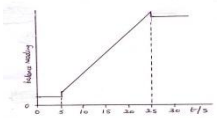
Section B

1	a		force is equal to (**or** proportional to) rate of <u>change of</u> momentum ✓ [**or** impulse = force × time = <u>change of</u> momentum] [Answer should **not** be in symbols unless all the symbols are explained]	1

1	b	i	use of $mg\Delta h = \frac{1}{2} mv^2$ gives v = $\sqrt{2gh} = \sqrt{2 \times 9.81 \times 1.6}$ ✓ (= 5.60 m s^{-1})	1

1	b	ii	momentum per second (= 0.30 × 5.60) = 1.68 (Ns) ✓	1

1	b	iii	mass of sand falling in 10s = (0.30 × 10) (= 3.00 kg) ✓ force due to arriving sand = momentum arriving per second = 1.68 (N) equivalent mass reading = $\frac{1.68}{9.81}$ ✓ (= 0.17 kg) so balance reading is 3.00 + 0.65 + 0.17 ✓ (= 3.82 kg)	3

1	c		horizontal lines up to 5 s and beyond 25 s ✓ line of constant positive gradient between 5 s and 25 s ✓  (near) vertical steps up at 5 s and down at 25 s ✓	3

2	a	i	horizontal arrow to the left ✓	1

2	a	ii	the electrostatic force is unchanged ✓	2

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			because electric field strength is constant ✓	
2	b	i	forces are equal in magnitude but opposite in direction ✓ (*E* is the same for both and) *Q* has same magnitude but opposite sign ✓	2
2	b	ii	acceleration of proton is (much) smaller (than acceleration of electron) ✓ because mass of proton is (much) greater (than mass of electron) ✓	2
2	b	iii	acceleration of proton increases and acceleration of electron decreases ✓ correct reference to changing strength of electric field (for either or both) ✓	2
2	c	i	energy of photon $E\left(=\frac{hc}{\lambda}\right)=\frac{6.63\times10^{-34}\times3.00\times10^{8}}{650\times10^{-9}}$ ✓ = 3.06 × 10^{-19} (J) ✓ energy required = $=\frac{3.06\times10^{-19}}{1.60\times10^{-19}}$ = 1.91 (eV) ✓	3
2	c	ii	electric field strength $\left(=\frac{V}{d}\right)=\frac{4500}{180\times10^{-3}}$ = 2.50 × 10^{4} (V m^{-1}) ✓ distance = $\left(\frac{V}{E}\right)=\frac{1.91}{2.50\times10^{4}}$ $\left[\text{or}=\left(\frac{W}{F}\right)=\frac{3.06\times10^{-19}}{4.0\times10^{-15}}\right]$ ✓ = 7.64 × 10^{-5} (m) ✓	3
3	a		(magnetic) <u>field</u> is applied perpendicular to path **or** direction **or** velocity of charged particles ✓ (magnetic) <u>force</u> acts perpendicular to path **or** direction **or** velocity of charged particles ✓ force depends on speed of particle **or** on *B* [or $F \propto v$ or $F = BQv$ explained] ✓ force provides (centripetal) acceleration towards centre of circle [**or** (magnetic) force is a centripetal force] ✓ $BQv=\frac{mv^2}{r}$ **or** $r=\frac{mv}{BQ}$ shows that *r* is constant when *B* and *v* are constant ✓	max 4
3	b	i	radius *r* of path = $\frac{\text{circumference}}{2\pi}=\frac{27\times10^{3}}{2\pi}$ = 4.30 × 10^{3} (m) (allow 4.3 km) ✓	3

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			centripetal force $\left(=\frac{mv^2}{r}\right)=\frac{1.67\times10^{-27}\times\left(3.00\times10^{7}\right)^2}{4.30\times10^{3}}$ ✓ = 3.50 × 10^{-16} (N) ✓	
3	b	ii	magnetic flux density $B\left(=\frac{F}{Qv}\right)=\frac{3.50\times10^{-16}}{1.60\times10^{-19}\times3.00\times10^{7}}$ ✓ = 7.29 × 10^{-5} ✓ T ✓	3
3	c		magnetic field must be increased ✓ to increase (centripetal) force **or** in order to keep *r* constant ✓ [**or** otherwise protons would attempt to travel in a path of larger radius] [**or**, referring to $r=\frac{mv}{BQ}$, *B* must increase when *v* increases to keep r constant]	2
4	a		work done (**or** energy required) per unit mass ✓ in moving a mass from infinity to the point ✓	2
4	b	i	ΔV (= –1.3 – (–62.6)) = 61.3 (MJ kg^{-1}) ✓ energy required (= $m\Delta V$) = 1.2 × 10^4 × 61.3 × 10^6 = 7.4 × 10^{11} (J) ✓ to **2SF** only ✓	3
4	b	ii	beyond **X**, gravitational potential decreases as Moon is approached [**or** gravitational field (or force) of Moon will now attract the probe] ✓	1
4	b	iii	distance from Earth to Sun » distance from Earth to Moon ✓ change in V_{sun} (**or** in g_{sun}) over Earth to Moon distance is negligible ✓ value of V_{sun} (**or** g_{sun}) is not (significantly) changed by relative positions of E+M ✓	max 2
4	c		**The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.** The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. **High Level (Good to excellent): 5 or 6 marks** The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.	Max 6

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			The candidate discusses the forces of attraction due to the Earth and due to the Moon, appreciates that they act in opposite directions, and that the former is generally much greater than the latter. *The candidate discusses the resultant gravitational field between E and M, understands that there is a 'neutral' point at which the resultant field strength is zero and that this point is much closer to M than E. It is recognised that this point has to be passed for the journey to be completed in either direction.* *There is a discussion of gravitational potential, in which it is pointed out that the resultant potential rises to a maximum at the neutral point. There is a reference to the much greater amount of work that has to be done on the spacecraft to reach this point from E than from M.* **Intermediate Level (Modest to adequate): 3 or 4 marks** The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. *The candidate discusses the forces of attraction due to the Earth and the Moon, and appreciates either that they act in opposite directions, or that the former is much greater than the latter. There is a relevant discussion of field strength or potential. The significance of the neutral point may not be appreciated. The candidate is likely to make some reference to the work that has to be done on the spacecraft.* **Low Level (Poor to limited): 1 or 2 marks** The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. *The candidate has some understanding of the forces that act during the journey but makes very limited references to the significance of the variation of the gravitational field. Discussions of gravitational potential and/or work done are likely to be superficial and may be absent.* **The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences in this case.** **Gravitational forces** • The spacecraft experiences gravitational attractions to both the Earth and the Moon during its journey. • These forces pull in opposite directions on the spacecraft. • Because E is much more massive than M, for most of the outward journey the force towards E is greater than that towards M. • Only in the later stages of the outward journey is the	

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			resultant force directed towards M. • On the return journey the resultant force is predominantly towards E. **Gravitational field strength** • During the outward journey E's gravitational field becomes weaker and M's becomes stronger. • The resultant field is the vector sum of those due to E and M separately. • A point (X) is reached at which these two component fields are equal and opposite, giving zero resultant. • X is much closer to M than to E. • Once X has been passed, the spacecraft will be attracted to M by M's gravitational field. • On the return journey the spacecraft will 'fall' to E once it is beyond X. **Gravitational potential** • The gravitational potential due E increases (i.e. becomes less negative) as the spacecraft moves away from E. • The resultant gravitational potential is the (scalar) sum of those due to E and M separately. • At X the gravitational potential reaches a maximum value before decreasing as M is approached. • In order to reach M on the outward journey, the spacecraft has to be given at least enough energy to reach X, and vice-versa for the return. • Much more work is needed to move the spacecraft from E to X than from M to X, since a larger force has to be overcome over a larger distance.	

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General Certificate of Education
Advanced Level Examination
January 2012

Physics A PHYA4/1

Unit 4 Fields and Further Mechanics
Section A

Tuesday 24 January 2012 1.30 pm to 3.15 pm

In addition to this paper you will require:
- an objective test answer sheet
- a black ink or black ball-point pen
- a calculator
- a question paper/answer book for Section B (enclosed)
- a Data and Formulae booklet.

Time allowed
- The total time for both sections of this paper is 1 hour 45 minutes. You are advised to spend approximately 45 minutes on this section.

Instructions
- Use black ink or black ball-point pen. Do **not** use pencil.
- Answer **all** questions in this section.
- For each question there are four responses. When you have selected the response which you think is the most appropriate answer to a question, mark this response on your answer sheet.
- Mark all responses as instructed on your answer sheet. If you wish to change your answer to a question, follow the instructions on your answer sheet.
- Do all rough work in this book **not** on the answer sheet.

Information
- The maximum mark for this section is 25.
- All questions in Section A carry equal marks. No deductions will be made for incorrect answers.
- A *Data and Formulae Booklet* is provided as a loose insert.
- The question paper/answer book for Section B is enclosed within this question paper.

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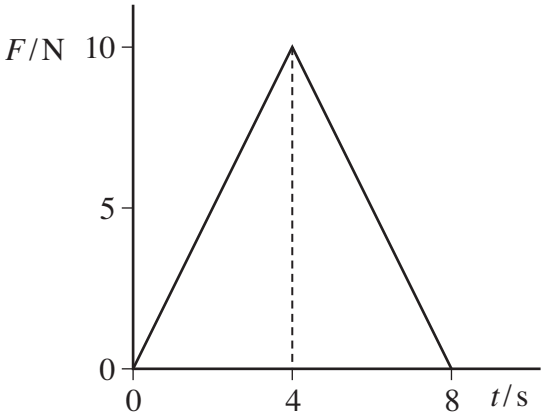
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Multiple choice questions

Each of Questions **1** to **25** is followed by four responses, **A**, **B**, **C**, and **D**. For each question select the best response and mark its letter on the answer sheet.

You are advised to spend approximately **45 minutes** on this section.

1 A ball of mass 2.0 kg, initially at rest, is acted on by a force F which varies with time t as shown by the graph.



What is the velocity of the ball after 8.0 s?

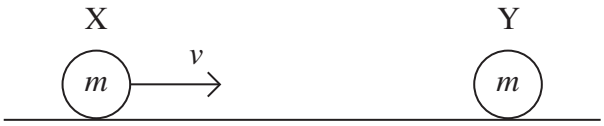
A $20\,\text{m s}^{-1}$

B $40\,\text{m s}^{-1}$

C $80\,\text{m s}^{-1}$

D $160\,\text{m s}^{-1}$

2 A body X moving with a velocity v makes an elastic collision with a stationary body Y of equal mass on a smooth horizontal surface.

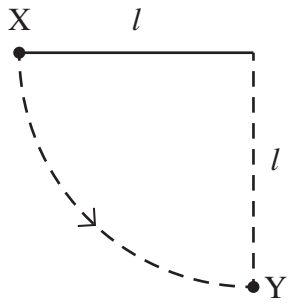


Which line, **A** to **D**, in the table gives the velocities of the two bodies after the collision?

	velocity of X	**velocity of Y**
A	$\frac{v}{2}$	$-\frac{v}{2}$
B	$-\frac{v}{2}$	$\frac{v}{2}$
C	v	0
D	0	v

Do not write outside the box

3 A ball of mass m, which is fixed to the end of a light string of length l, is released from rest at X.
It swings in a circular path, passing through the lowest point Y at speed v.



If the tension in the string at Y is T, which one of the following equations represents a correct application of Newton's laws of motion to the ball at Y?

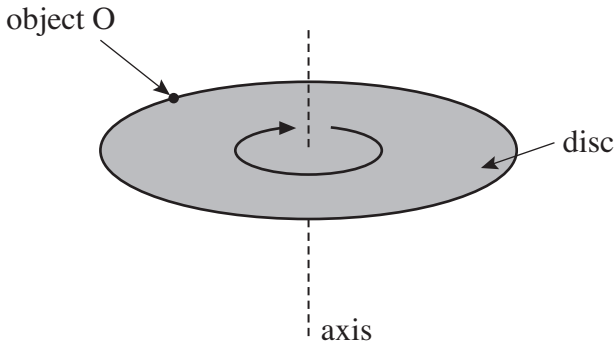
A $T = \frac{mv^2}{l} - mg$

B $mg - T = \frac{mv^2}{l}$

C $T - mg = \frac{mv^2}{l}$

D $T + \frac{mv^2}{l} = mg$

4 A disc of diameter D is turning at a steady angular speed at frequency f about an axis through its centre.



What is the centripetal force on a small object O of mass m on the perimeter of the disc?

A $2\pi mfD$

B $2\pi mf^2D$

C $2\pi^2mf^2D$

D $2\pi mf^2D^2$

Do not write outside the box

5 What is the angular speed of a car wheel of diameter 0.400 m when the speed of the car is 108 km h^{-1}?

A 75 rad s^{-1}

B 150 rad s^{-1}

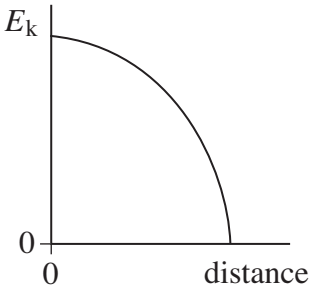
C 270 rad s^{-1}

D 540 rad s^{-1}

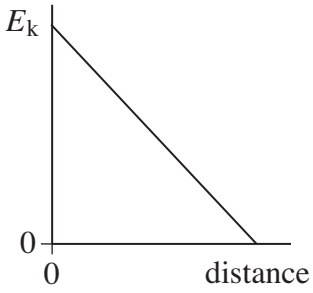
6 Which one of the following statements is true when an object performs simple harmonic motion about a central point O?

A The acceleration is always directed away from O.
B The acceleration and velocity are always in opposite directions.
C The acceleration and the displacement from O are always in the same direction.
D The graph of acceleration against displacement is a straight line.

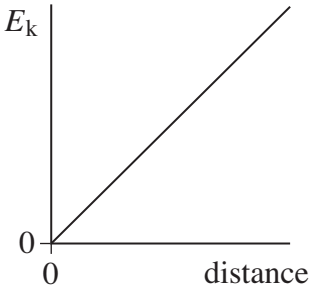
7 A body executes simple harmonic motion. Which one of the graphs, **A** to **D**, best shows the relationship between the kinetic energy, E_k, of the body and its distance from the centre of oscillation?



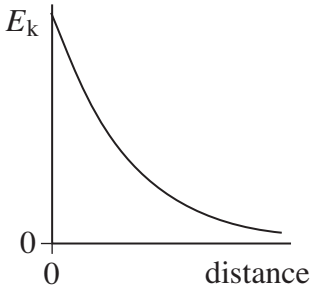
A



B



C



D

8 A mechanical system is oscillating at resonance with a constant amplitude. Which one of the following statements is **not** correct?

A The applied force prevents the amplitude from becoming too large.
B The frequency of the applied force is the same as the natural frequency of oscillation of the system.
C The total energy of the system is constant.
D The amplitude of oscillations depends on the amount of damping.

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9 Which one of the following statements about Newton's law of gravitation is correct?

Newton's law of gravitation explains

A the origin of gravitational forces.
B why a falling satellite burns up when it enters the Earth's atmosphere.
C why projectiles maintain a uniform horizontal speed.
D how various factors affect the gravitational force between two particles.

10 If an electron and proton are separated by a distance of 5×10^{-11}m, what is the approximate gravitational force of attraction between them?

A 2×10^{-57}N

B 3×10^{-47}N

C 4×10^{-47}N

D 5×10^{-37}N

11 A spherical planet of uniform density ρ has radius R.

Which line, **A** to **D**, in the table gives correct expressions for the mass of the planet and the gravitational field strength at its surface?

	mass of planet	**gravitational field strength at surface**
A	$\frac{4\pi R^2\rho}{3}$	$\frac{4\pi GR\rho}{3}$
B	$\frac{4\pi R^3\rho}{3}$	$\frac{4\pi GR\rho}{3}$
C	$\frac{4\pi R^2\rho}{3}$	$\frac{4\pi G\rho}{3}$
D	$\frac{4\pi R^3\rho}{3}$	$\frac{4\pi G\rho}{3}$

Do not write outside the box

12 The gravitational potential at the surface of the Earth, of radius R, is V. What is the gravitational potential at a point at a height R above the Earth's surface?

A $\frac{V}{4}$

B $\frac{V}{2}$

C V

D $2V$

13 A satellite is in orbit at a height h above the surface of a planet of mass M and radius R. What is the velocity of the satellite?

A $\sqrt{\frac{GM}{(R+h)}}$

B $\frac{\sqrt{GM(R+h)}}{R}$

C $\sqrt{\frac{GM(R+h)}{R}}$

D $\frac{\sqrt{GM}}{(R+h)}$

14 A repulsive force F acts between two positive point charges separated by a distance r. What will be the force between them if each charge is doubled and the distance between them is halved?

A F

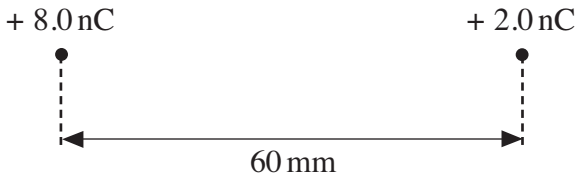
B $2F$

C $4F$

D $16F$

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15 The distance between two point charges of + 8.0 nC and + 2.0 nC is 60 mm.



At a point between the charges, on the line joining them, the resultant electric field strength is zero. How far is this point from the + 8.0 nC charge?

A 20 mm

B 25 mm

C 40 mm

D 45 mm

16 Which one of the following **cannot** be used as a unit for electric field strength?

A $J\,m^{-1}\,C^{-1}$

B $J\,A^{-1}\,s^{-1}\,m^{-1}$

C $N\,A^{-1}\,s^{-1}$

D $J\,C\,m^{-1}$

17 A capacitor stores a charge of 600 μC when charged to a potential difference (pd) of 6.0 V. What will be the pd across the plates if the charge stored increases by 50%?

A 3.0 V

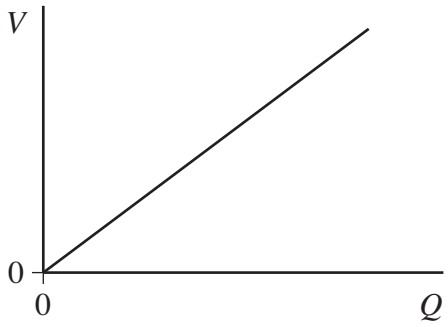
B 4.5 V

C 9.0 V

D 12.0 V

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18 The graph shows the results of an experiment which was carried out to investigate the relationship between the charge Q stored by a capacitor and the pd V across it.



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

A The energy stored can be calculated by finding the area under the line.

B If a capacitor of smaller capacitance had been used the gradient of the graph would be steeper.

C If Q were doubled, the energy stored would be quadrupled.

D The gradient of the graph is equal to the capacitance of the capacitor.

19 A 10 μF capacitor is fully charged to a pd of 3.0 kV. The energy stored in the capacitor can be used to lift a load of 5.0 kg through a vertical height h. What is the approximate value of h?

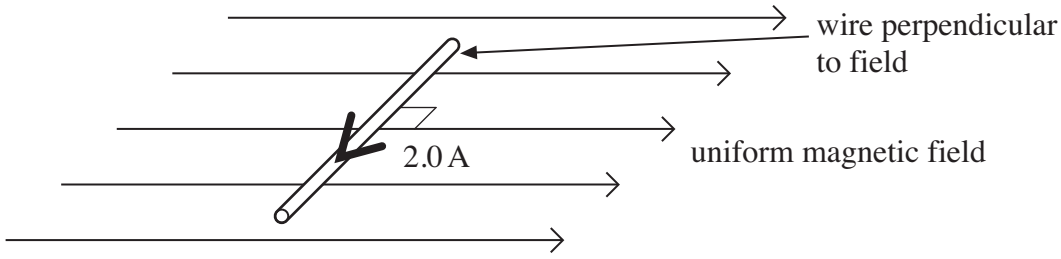
A 0.03 mm

B 0.9 mm

C 0.3 m

D 0.9 m

20 A horizontal straight wire of length 0.30 m carries a current of 2.0 A perpendicular to a horizontal uniform magnetic field of flux density 5.0×10^{-2} T. The wire 'floats' in equilibrium in the field.



What is the mass of the wire?

A 8.0×10^{-4} kg

B 3.1×10^{-3} kg

C 3.0×10^{-2} kg

D 8.2×10^{-1} kg

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21 When a β particle moves at right angles through a uniform magnetic field it experiences a force F. An α particle moves at right angles through a magnetic field of twice the magnetic flux density with velocity one tenth the velocity of the β particle. What is the magnitude of the force on the α particle?

A $0.2F$
B $0.4F$
C $0.8F$
D $4.0F$

22 Charged particles, each of mass m and charge Q, travel at a constant speed in a circle of radius r in a uniform magnetic field of flux density B. Which expression gives the frequency of rotation of a particle in the beam?

A $\dfrac{BQ}{2\pi m}$

B $\dfrac{BQ}{m}$

C $\dfrac{BQ}{\pi m}$

D $\dfrac{2\pi BQ}{m}$

23 A 500 turn coil of cross-sectional area $4.0 \times 10^{-3}\,\text{m}^2$ is placed with its plane perpendicular to a magnetic field of flux density $7.5 \times 10^{-4}\,\text{T}$. What is the value of the flux linkage for this coil?

A $3.0 \times 10^{-6}\,\text{Wb turns}$
B $1.5 \times 10^{-3}\,\text{Wb turns}$
C $0.19\,\text{Wb turns}$
D $94\,\text{Wb turns}$

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24 The output electromotive force (emf) of a simple ac generator can be increased by any of the four factors listed.

Which one of these factors should **not** be changed if the frequency of the output is to remain unaffected when the emf is increased?

A the area of the coil
B the number of turns on the coil
C the speed of rotation
D the strength of the magnetic field

25 Which one of the following would **not** reduce the energy losses in a transformer?

A using thinner wire for the windings
B using a laminated core instead of a solid core
C using a core made from iron instead of steel
D using a core that allows all the flux due to the primary coil to be linked to the secondary coil

END OF QUESTIONS

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General Certificate of Education
Advanced Level Examination
January 2012

Physics A PHYA4/2

Unit 4 Fields and Further Mechanics
Section B

Tuesday 24 January 2012 1.30 pm to 3.15 pm

For this paper you must have:
- a calculator
- a ruler
- a Data and Formulae Booklet (enclosed).

Time allowed
- The total time for both sections of this paper is 1 hour 45 minutes. You are advised to spend approximately one hour on this section.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the space provided. Answers written in margins or on blank pages will not be marked.
- Do all rough work in this book. Cross through any work you do not want to be marked
- Show all your working.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this section is 50.
- You are expected to use a calculator where appropriate.
- A *Data and Formulae Booklet* is provided as a loose insert.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use specialist vocabulary where appropriate.

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Answer **all** questions.
You are advised to spend approximately **one hour** on this section.

1 (a) Define the electric potential at a point in an electric field.

.....

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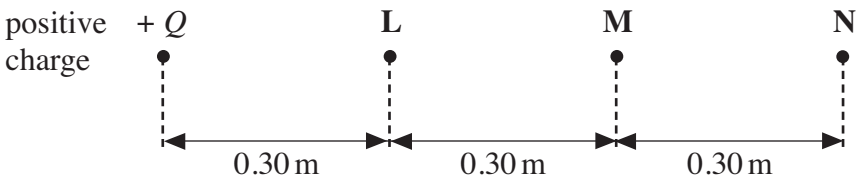
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(3 marks)

1 (b) **Figure 1** shows part of the region around a small positive charge.

Figure 1



1 (b) (i) The electric potential at point **L** due to this charge is + 3.0 V. Calculate the magnitude Q of the charge. Express your answer to an appropriate number of significant figures.

answer = ... C

(3 marks)

1 (b) (ii) Show that the electric potential at point **N**, due to the charge, is +1.0 V.

(1 mark)

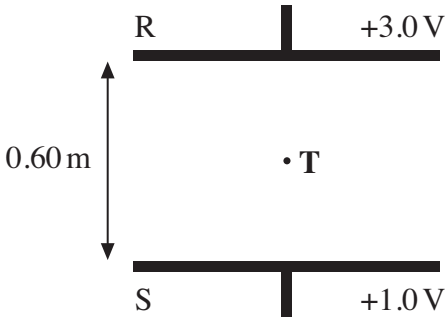
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1 (b) (iii) Show that the electric field strength at point **M**, which is mid-way between **L** and **N**, is 2.5 V m^{-1}.

(1 mark)

1 (c) R and S are two charged parallel plates, 0.60 m apart, as shown in **Figure 2**. They are at potentials of + 3.0 V and + 1.0 V respectively.

Figure 2



1 (c) (i) On **Figure 2**, sketch the electric field between R and S, showing its direction.

(2 marks)

1 (c) (ii) Point **T** is mid-way between R and S.
Calculate the electric field strength at **T**.

answer = ... V m^{-1}

(1 mark)

1 (c) (iii) Parts (b)(iii) and (c)(ii) both involve the electric field strength at a point mid-way between potentials of + 1.0 V and + 3.0 V. Explain why the magnitudes of these electric field strengths are different.

.....

.....

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(1 mark)

12

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2 (a) Define the capacitance of a capacitor.

.....

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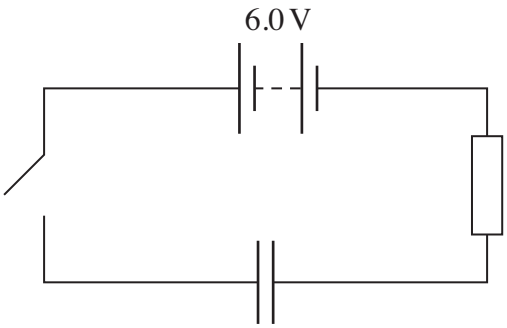
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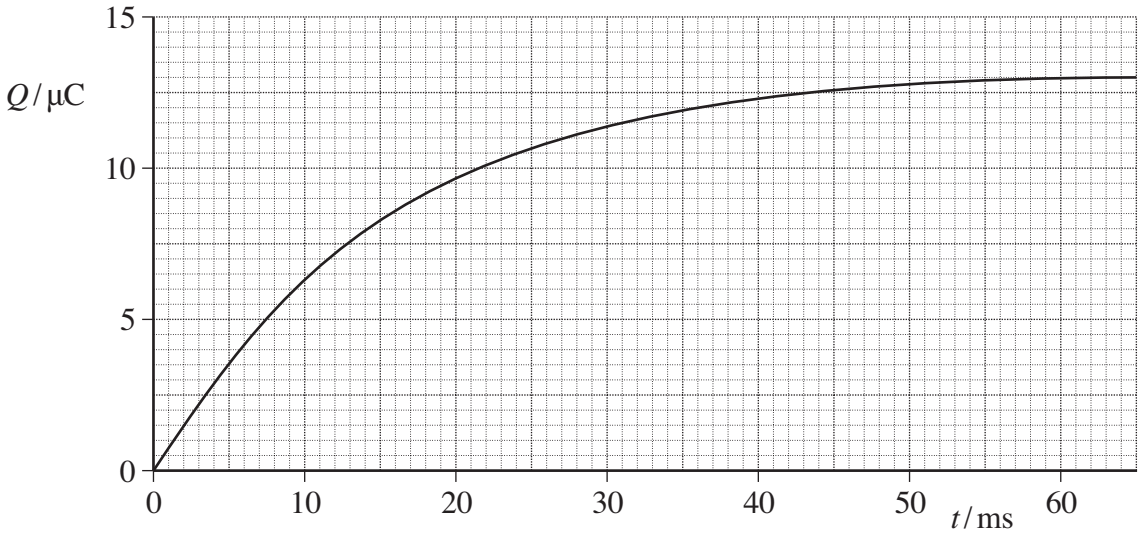
(2 marks)

2 (b) The circuit shown in **Figure 3** contains a battery, a resistor, a capacitor and a switch.

Figure 3



The switch in the circuit is closed at time $t = 0$. The graph shows how the charge Q stored by the capacitor varies with t.



2 (b) (i) When the capacitor is fully charged, the charge stored is 13.2 μC. The electromotive force (emf) of the battery is 6.0 V. Determine the capacitance of the capacitor.

answer = ... F

(2 marks)

Do not write outside the box

2 (b) (ii) The time constant for this circuit is the time taken for the charge stored to increase from 0 to 63% of its final value. Use the graph to find the time constant in milliseconds.

answer = ... ms

(2 marks)

2 (b) (iii) Hence calculate the resistance of the resistor.

answer = ... Ω

(1 mark)

2 (b) (iv) What physical quantity is represented by the gradient of the graph?

.....

.....

(1 mark)

2 (c) (i) Calculate the maximum value of the current, in mA, in this circuit during the charging process.

answer = ... mA

(1 mark)

2 (c) (ii) Sketch a graph on the outline axes to show how the current varies with time as the capacitor is charged. Mark the maximum value of the current on your graph.



(2 marks)

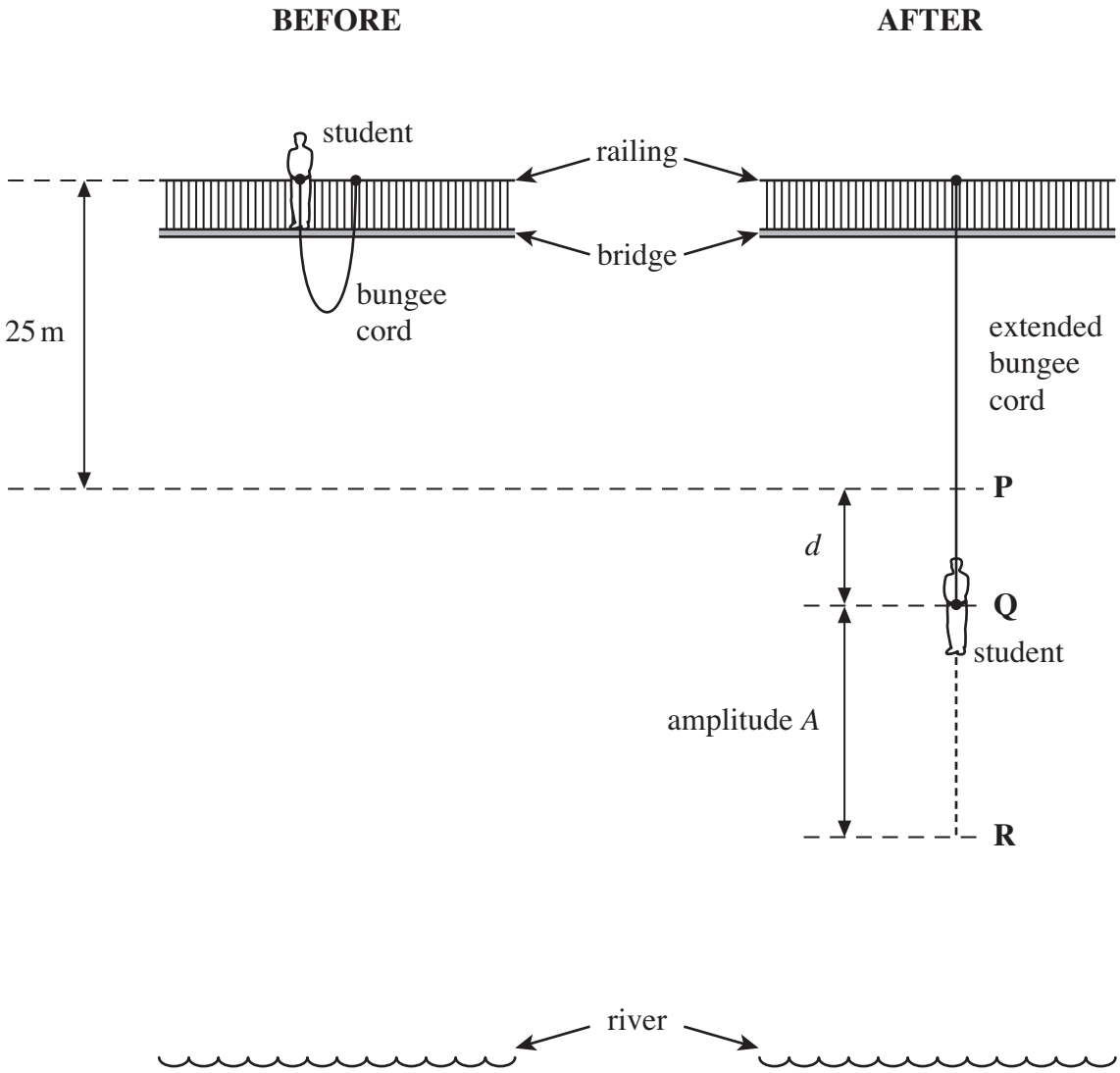
11

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3 The two diagrams in **Figure 4** show a student before and after she makes a bungee jump from a high bridge above a river. One end of the bungee cord, which is of unstretched length 25 m, is fixed to the top of a railing on the bridge. The other end of the cord is attached to the waist of the student, whose mass is 58 kg. After she jumps, the bungee cord goes into tension at point **P**. She comes to rest momentarily at point **R** and then oscillates about point **Q**, which is a distance *d* below **P**.

Figure 4



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3 (a) (i) Assuming that the centre of mass of the student has fallen through a vertical distance of 25 m when she reaches point **P**, calculate her speed at **P**.
You may assume that air resistance is negligible.

answer = ... $m\,s^{-1}$

(2 marks)

3 (a) (ii) The bungee cord behaves like a spring of spring constant 54 $N\,m^{-1}$.
Calculate the distance d, from **P** to **Q**, assuming the cord obeys Hooke's law.

answer = ... m

(2 marks)

3 (b) As the student moves below **P**, she begins to move with simple harmonic motion for part of an oscillation.

3 (b) (i) If the arrangement can be assumed to act as a mass-spring system, calculate the time taken for one half of an oscillation.

answer = ... s

(2 marks)

3 (b) (ii) Use your answers from parts (a) and (b)(i) to show that the amplitude A, which is the distance from **Q** to **R**, is about 25 m.

(3 marks)

Turn over ▶

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3 (c) Explain why, when the student rises above point **P**, her motion is no longer simple harmonic.

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(2 marks)

3 (d) (i) Where is the student when the stress in the bungee cord is a maximum?

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(1 mark)

3 (d) (ii) The bungee cord has a significant mass. Whereabouts along the bungee cord is the stress a maximum? Explain your answer.

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(2 marks)

14

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4 (a) A transformer operating on a 230 V mains supply provides a 12 V output. There are 1150 turns on the primary coil.

4 (a) (i) Calculate the number of turns on the secondary coil.

answer = ... turns
(1 mark)

4 (a) (ii) A number of identical lamps rated at 12 V, 24 W are connected in parallel across the secondary coil. The primary circuit of the transformer includes a 630 mA fuse. Calculate the maximum number of lamps that can be supplied by the transformer if its efficiency is 85%.

answer = ... lamps
(2 marks)

4 (a) (iii) The transformer circuit includes a fuse. Explain why this is necessary.

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(1 mark)

4 (a) (iv) Why is the fuse placed in the primary circuit rather than in the secondary circuit?

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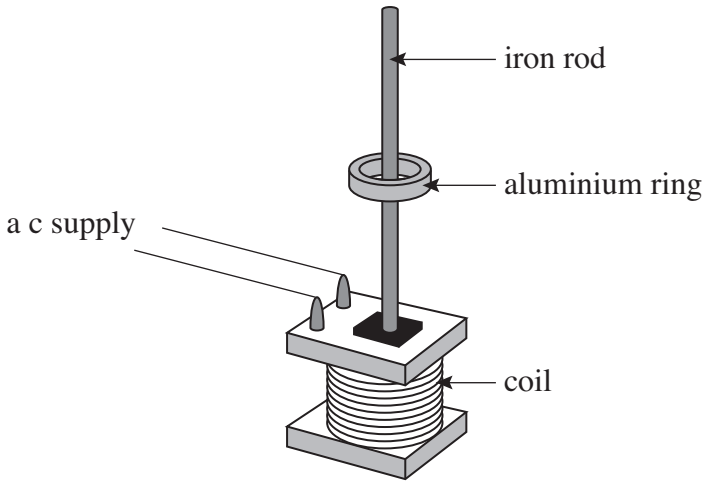
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(1 mark)

Question 4 continues on the next page

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4 (b) **Figure 5** shows an experimental arrangement that can be used to demonstrate magnetic levitation. The iron rod is fixed vertically inside a large coil of wire. When the alternating current supply to the coil is switched on, the aluminium ring moves up the rod until it reaches a stable position 'floating' above the coil.

Figure 5



4 (b) (i) By reference to the laws of electromagnetic induction explain

- why a current will be induced in the ring,
- why the ring experiences a force that moves it upwards,
- why the ring reaches a stable position.

The quality of your written communication will be assessed in your answer.

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(6 marks)

4 (b) (ii) What would happen to the ring if the alternating current in the coil was increased without changing the frequency? Explain your answer.

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(2 marks)

13

END OF QUESTIONS

There are no questions printed on this page

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Version 1.0



General Certificate of Education (A-level)
January 2012

Physics A PHYA4

(Specification 2450)

Unit 4: Fields and further mechanics

Final

Mark Scheme

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all examiners participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for standardisation each examiner analyses a number of students' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, examiners encounter unusual answers which have not been raised they are required to refer these to the Principal Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of students' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

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Instructions to Examiners

1 Give due credit for alternative treatments which are correct. Give marks for what is correct in accordance with the mark scheme; do not deduct marks because the attempt falls short of some ideal answer. Where marks are to be deducted for particular errors, specific instructions are given in the marking scheme.

2 Do not deduct marks for poor written communication. Refer the scripts to the Awards meeting if poor presentation forbids a proper assessment. In each paper, candidates are assessed on their quality of written communication (QWC) in designated questions (or part-questions) that require explanations or descriptions. The criteria for the award of marks on each such question are set out in the mark scheme in three bands in the following format. The descriptor for each band sets out the expected level of the quality of written communication of physics for each band. Such quality covers the scope (eg relevance, correctness), sequence and presentation of the answer. Amplification of the level of physics expected in a good answer is set out in the last row of the table. To arrive at the mark for a candidate, their work should first be assessed holistically (ie in terms of scope, sequence and presentation) to determine which band is appropriate then in terms of the degree to which the candidate's work meets the expected level for the band.

QWC	descriptor	mark range
Good - Excellent	*see specific mark scheme*	**5-6**
Modest - Adequate	*see specific mark scheme*	**3-4**
Poor - Limited	*see specific mark scheme*	**1-2**
The description and/or explanation expected in a good answer should include a coherent account of the following points: *see specific mark scheme*		

Answers given as bullet points should be considered in the above terms. Such answers without an 'overview' paragraph in the answer would be unlikely to score in the top band.

3 An arithmetical error in an answer will cause the candidate to lose one mark and should be annotated AE if possible. The candidate's incorrect value should be carried through all subsequent calculations for the question and, if there are no subsequent errors, the candidate can score all remaining marks.

4 The use of significant figures is tested **once** on each paper in a designated question or part-question. The numerical answer on the designated question should be given to the same number of significant figures as there are in the data given in the question or to one more than this number. All other numerical answers should not be considered in terms of significant figures.

5 Numerical answers **presented** in non-standard form are undesirable but should not be penalised. Arithmetical errors by candidates resulting from use of non-standard form in a candidate's working should be penalised as in point 3 above. Incorrect numerical prefixes and the use of a given diameter in a geometrical formula as the radius should be treated as arithmetical errors.

6 Knowledge of units is tested on designated questions or parts of questions in each a paper. On each such question or part-question, unless otherwise stated in the mark scheme, the mark scheme will show a mark to be awarded for the numerical value of the answer and a further mark for the correct unit. No penalties are imposed for incorrect or omitted units at intermediate stages in a calculation or at the final stage of a non-designated 'unit' question.

7 All other procedures including recording of marks and dealing with missing parts of answers will be clarified in the standardising procedures.

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GCE Physics, Specification A, PHYA4, Fields and Further Mechanics

Section A

This component is an objective test for which the following list indicates the correct answers used in marking the students' responses.

	Keys to Objective Test Questions													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	
	A	D	C	C	B	D	A	A	D	C	B	B	A	
	14	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**		
	D	C	D	C	D	D	B	B	A	B	C	A		

Section B

Question 1			
a		work done [or energy needed] per unit charge [**or** (change in) electric pe per unit charge] ✓ on [or of] a (small) positive (test) charge ✓ in moving the charge from infinity (to the point) ✓ [**not** from the point to infinity] ✓	**3**
b	i	$V = \frac{Q}{4\pi\varepsilon_0 r}$ gives Q ($=4\pi\varepsilon_0 rV$) $= 4\pi \times 8.85 \times 10^{-12} \times 0.30 \times 3.0$ ✓ $= 1.0 \times 10^{-10}$ (C) ✓ to **2 sf** only ✓	**3**
b	ii	use of $V \propto \frac{1}{r}$ gives $V_M = \frac{V_L}{3}$ ✓ (= (+) 1.0 V)	**1**
b	iii	$E\left(= \frac{Q}{4\pi\varepsilon_0 r^2}\right) = \frac{1.0 \times 10^{-10}}{4\pi \times 8.85 \times 10^{-12} \times 0.60^2}$ ✓ (= 2.50 V m^{-1})	**1**
c	i	uniformly spaced vertical parallel lines which start and end on plates ✓ relevant lines with arrow(s) pointing only downwards ✓	**2**
c	ii	= 3.3(3) (V m^{-1}) ✓	**1**
c	iii	part (b) is a radial field whilst part (c) is a uniform field ✓ [**or** field lines become further apart between **L** and **M** but are equally spaced between **R** and **S**]	**1**
		Total	**12**

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Question 2		
a	charge (stored) ✓ per unit potential difference ✓ [**or** $C = Q/V$ where Q = charge (stored by one plate) ✓ V = pd (across plates) ✓]	**2**
b i	$C\left(=\frac{Q}{V}\right)=\frac{13.2\times10^{-6}}{6.0}$ ✓ = 2.2×10^{-6} (F) ✓ (or 2.2 μF)	**2**
b ii	when t = time constant Q = 0.63 × 13.2 = 8.3 (μC) ✓ [**or** = 0.63 × 13(.0) (from graph) = 8.2 (μC)] reading from graph gives time constant = 15 (± 1) (ms) ✓	**2**
b iii	resistance of resistor = $\left(=\frac{\text{time constant}}{C}\right)=\frac{15\times10^{-3}}{2.2\times10^{-6}}$ = 6820 (Ω) ✓	**1**
b iv	gradient = current ✓	**1**
c i	maximum current = $\left(=\frac{V}{R}\right)=\frac{6.0}{6820}$ = 0.88 (mA) ✓ [**or** value from initial gradient of graph: allow 0.70 – 1.00 mA for this approach]	**1**
c ii	curve starts at marked I_{max} on I axis and has decreasing negative gradient ✓ line is asymptotic to t axis and approaches ≈ 0 by t = 60 ms ✓	**2**
	Total	**11**

Question 3		
a i	speed at P, v (= $\sqrt{2gh}$) = $\sqrt{2\times9.81\times25}$ ✓ = 22(.1) (m s^{-1}) ✓	**2**
a ii	use of $F = k\Delta L$ gives $d\left(=\frac{F}{k}\right)=\frac{58\times9.81}{54}$ ✓ = 11 (10.5) (m) ✓	**2**
b i	period $T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{58}{54}}$ ✓ (= 6.51 s) time for one half oscillation = 3.3 (3.26) (s) ✓	**2**
b ii	frequency $f\left(=\frac{1}{T}\right)=\frac{1}{6.51}$ ✓ (= 0.154 (Hz)) use of $v = \pm 2\pi f\sqrt{A^2-x^2}$ when x = 10.5 m and v = 22.1 m s^{-1} gives $22.1^2 = 4\pi^2\times0.154^2\,(A^2-10.5^2)$ ✓ from which A = 25.1 (m) ✓ [**alternatively**, using energy approach gives ½ mv_P^2 + $mg\Delta L$ = ½ $k(\Delta L)^2$ ✓ $\therefore$ $(29\times22.1^2)+(58\times9.81\times\Delta L)=27\,(\Delta L)^2$ solution of this quadratic equation gives ΔL = 35.7 (m) ✓ from which A = 25.2 (m) ✓]	**3**

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c		bungee cord becomes slack ✓ student's motion is under gravity (until she returns to **P**) ✓ has constant downwards acceleration **or** acceleration is not ∝ displacement ✓	**max 2**
d	i	when student is at **R** or at bottom of oscillation ✓	**1**
d	ii	at uppermost point **or** where it is attached to the railing ✓ because stress = *F*/*A* and force at this point includes weight of whole cord ✓ [accept alternative answers referring to mid-point of cord because cord will show thinning there as it stretches **or** near knots at top or bottom of cord where *A* will smaller with a reference to stress = *F*/*A*]	**2**
		Total	**14**

Question 4			
a	i	use of $\frac{N_S}{N_P} = \frac{V_S}{V_P}$ gives $N_S = \frac{12 \times 1150}{230}$ = 60 (turns) ✓	**1**
a	ii	max output power = 0.85 × 0.630 × 230 ✓ (= 123 W) max number of lamps $\left(= \frac{123}{24}\right)$ = 5 ✓ (no mark for non-integer answer) [**or** efficiency = $\frac{I_S V_S}{I_P V_P}$ gives 0.85 = $\frac{I_S \times 12}{0.630 \times 230}$ ✓ (and max I_S = 10.3 (A)) max number of lamps $\left(= \frac{10.3}{2.0}\right)$ = 5 ✓]	**2**
a	iii	fuse prevents transformer from overheating [**or** prevents transformer from supplying excessive currents] ✓	**1**
a	iv	(all of) transformer is disconnected from supply when fuse fails [**or** fuse in secondary circuit would leave primary circuit live] ✓	**1**

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b	i	**The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.** The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. **High level (good to excellent) 5 or 6 marks** The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. *The candidate states that the ac in the coil produces a constantly changing magnetic field that passes through the ring, causing an emf to be induced according to Faraday's law.* *The candidate recognises that the induced emf will cause a current to flow in the ring, that the current is likely be large because the coil acts as a single conductor with low resistance, and that this current also produces a magnetic field.* *The candidate appreciates that Lenz's law indicates that the direction of the induced current is such as to produce a magnetic field that will oppose the existing field, and that the two fields will interact.* *The candidate refers to the force that acts on a current-carrying conductor when it is in a magnetic field and that this force lifts the ring upwards (into an area where the magnetic field is weaker) until the upwards magnetic force is equal to the downwards weight of the ring.* **Intermediate level (modest to adequate) 3 or 4 marks** The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. *The candidate is familiar with either or both Faraday's and Lenz's laws but only applies one of them to explain what happens in this demonstration. There are correct references to the two forces that act on the ring, and a reasonable explanation of why the ring reaches a stable position.* **Low level (poor to limited) 1 or 2 marks** The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. *The candidate refers much more superficially to either Faraday's or Lenz's law (or to both of them) but shows some understanding of why the forces acting on the ring cause it to reach equilibrium.*	**max 6**

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	The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences in this case. **Faraday's law** • An emf is induced whenever there is a change in the magnetic flux passing through a conductor. • The magnitude of the emf is proportional to the rate of change of magnetic flux linkage. • The induced emf will cause a current to flow in any complete circuit, such as a single conducting ring. • Because the ring is made from aluminium, which is a good conductor, a large initial current will be induced in it. **Lenz's law** • The induced current flows in such a direction as to oppose the increase in magnetic flux when the current is switched on in the coil. • The current produces a magnetic field in the opposite direction to that produced by the coil. • These two (alternating) fields interact like the fields between two facing like magnetic poles, giving repulsion. **Forces** • The ring is a current-carrying conductor in a magnetic field, and consequently it experiences a force. • This magnetic force acts upwards, in the opposite direction to the weight of the ring. • As the ring rises, the magnetic field to which it is exposed becomes weaker as it moves away from the coil. • This reduces the induced current, reducing also the magnetic force on the ring. • The ring reaches a stable height when the magnetic force has decreased to the point where it is equal to the weight of the ring.	
b ii	ring would 'float' higher [**or** be expelled upwards] ✓ because (initial) current or emf (induced) *in ring* is greater ✓ **or** ring moves into weaker field until magnetic force balances weight [**or** (initially) magnetic force exceeds weight] ✓	**max 2**
	Total	**13**

	UMS conversion calculator www.aqa.org.uk/umsconversion	

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Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

General Certificate of Education
Advanced Level Examination
June 2011

Physics A PHYA4/1

Unit 4 Fields and Further Mechanics
Section A

Tuesday 21 June 2011 9.00 am to 10.45 am

In addition to this paper you will require:
- an objective test answer sheet
- a black ball-point pen
- a calculator
- a question paper/answer book for Section B (enclosed)
- a Data and Formulae booklet.

Time allowed
- The total time for both sections of this paper is 1 hour 45 minutes. You are advised to spend approximately 45 minutes on this section.

Instructions
- Use a black ball-point pen.
- Answer **all** questions in this section.
- For each question there are four responses. When you have selected the response which you think is the most appropriate answer to a question, mark this response on your answer sheet.
- Mark all responses as instructed on your answer sheet. If you wish to change your answer to a question, follow the instructions on your answer sheet.
- Do all rough work in this book **not** on the answer sheet.

Information
- The maximum mark for this section is 25.
- All questions in Section A carry equal marks. No deductions will be made for incorrect answers.
- A *Data and Formulae Booklet* is provided as a loose insert.
- The question paper/answer book for Section B is enclosed within this question paper.

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Multiple-choice questions

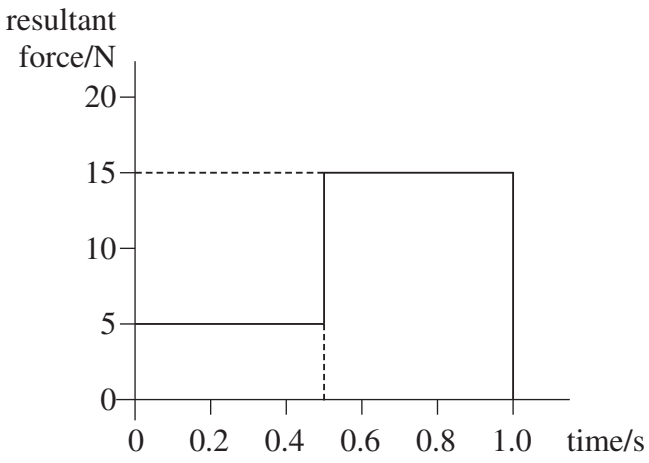
Each of Questions **1** to **25** is followed by four responses, **A**, **B**, **C**, and **D**. For each question select the best response and mark its letter on the answer sheet.

You are advised to spend about **45 minutes** on this section.

1 Which line, **A** to **D**, in the table shows correctly whether the moment of a force, and momentum, are scalar or vector quantities?

	moment of force	**momentum**
A	scalar	scalar
B	scalar	vector
C	vector	scalar
D	vector	vector

2 The graph shows how the resultant force applied to an object of mass 2.0 kg, initially at rest, varies with time.



What is the speed of the object after 1.0 s?

A $2.5\,m\,s^{-1}$
B $5.0\,m\,s^{-1}$
C $7.5\,m\,s^{-1}$
D $10\,m\,s^{-1}$

3 Which of the following is a possible unit for rate of change of momentum?

A $N\,s$
B $N\,s^{-1}$
C $kg\,m\,s^{-1}$
D $kg\,m\,s^{-2}$

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4 For a particle moving in a circle with uniform speed, which one of the following statements is correct?

A The kinetic energy of the particle is constant.
B The force on the particle is in the same direction as the direction of motion of the particle.
C The momentum of the particle is constant.
D The displacement of the particle is in the direction of the force.

5 A young child of mass 20 kg stands at the centre of a uniform horizontal platform which rotates at a constant angular speed of $3.0\,\text{rad}\,\text{s}^{-1}$. The child begins to walk radially outwards towards the edge of the platform. The maximum frictional force between the child and the platform is 200 N. What is the maximum distance from the centre of the platform to which the child could walk without the risk of slipping?

A 1.1 m
B 1.3 m
C 1.5 m
D 1.7 m

6 A particle travels at a constant speed around a circle of radius r with centripetal acceleration a. What is the time taken for ten complete rotations?

A $\frac{\pi}{5}\sqrt{\frac{a}{r}}$

B $\frac{\pi}{5}\sqrt{\frac{r}{a}}$

C $20\pi\sqrt{\frac{a}{r}}$

D $20\pi\sqrt{\frac{r}{a}}$

7 The frequency of a body moving with simple harmonic motion is doubled. If the amplitude remains the same, which one of the following is also doubled?

A the time period
B the total energy
C the maximum velocity
D the maximum acceleration

Do not write outside the box

8 The time period of a pendulum on Earth is 1.0 s. What would be the period of a pendulum of the same length on a planet with half the density but twice the radius of Earth?

A 0.5 s
B 1.0 s
C 1.4 s
D 2.0 s

9 Which one of the following statements always applies to a damping force acting on a vibrating system?

A It is in the same direction as the acceleration.
B It is in the same direction as the displacement.
C It is in the opposite direction to the velocity.
D It is proportional to the displacement.

10 Masses of M and $2M$ exert a gravitational force F on each other when the distance between their centres is r. What is the gravitational force between masses of $2M$ and $4M$ when the distance between their centres is $4r$?

A 0.25 F
B 0.50 F
C 0.75 F
D 1.00 F

11 A planet has a radius half the Earth's radius and a mass a quarter of the Earth's mass. What is the approximate gravitational field strength on the surface of the planet?

A 1.6 N kg^{-1}
B 5.0 N kg^{-1}
C 10 N kg^{-1}
D 20 N kg^{-1}

12 At the surface of the Earth the gravitational field strength is g, and the gravitational potential is V. The radius of the Earth is R. An object, whose weight on the surface of the Earth is W, is moved to a height $3R$ above the surface. Which line, **A** to **D**, in the table gives the weight of the object and the gravitational potential at this height?

	weight	**gravitational potential**
A	$\frac{W}{16}$	$\frac{V}{4}$
B	$\frac{W}{4}$	$\frac{V}{3}$
C	$\frac{W}{4}$	$\frac{V}{4}$
D	$\frac{W}{16}$	$\frac{V}{3}$

Do not write outside the box

13 A satellite of mass m travels in a circular orbit of radius r around a planet of mass M. Which one of the following expressions gives the angular speed of the satellite?

A $\sqrt{GMr}$

B $\sqrt{Gmr}$

C $\sqrt{\frac{Gm}{r^3}}$

D $\sqrt{\frac{GM}{r^3}}$

14 An electron and a proton are 1.0×10^{-10} m apart. In the absence of any other charges, what is the electric potential energy of the electron?

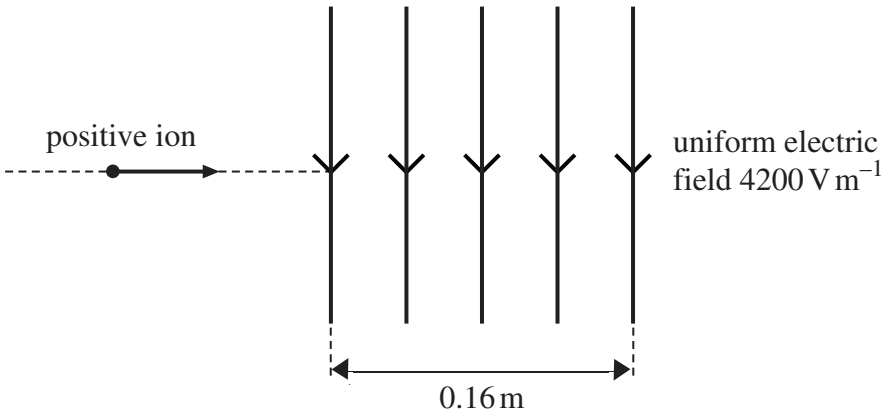
A $+2.3 \times 10^{-18}$ J

B -2.3×10^{-18} J

C $+2.3 \times 10^{-8}$ J

D -2.3×10^{-8} J

15



An ion carrying a charge of $+4.8 \times 10^{-19}$C travels horizontally at a speed of 8.0×10^{5} m s^{-1}. It enters a uniform vertical electric field of strength 4200 V m^{-1}, which is directed downwards and acts over a horizontal distance of 0.16m.
Which one of the following statements is **not** correct?

A The ion passes through the field in 2.0×10^{-7}s.
B The force on the ion acts vertically downwards at all points in the field.
C The magnitude of the force exerted on the ion by the field is 1.6×10^{-9} N.
D The horizontal component of the velocity of the ion is unaffected by the electric field.

Do not write outside the box

16 The electric potential at a distance r from a positive point charge is 45 V. The potential increases to 50 V when the distance from the charge decreases by 1.5 m. What is the value of r?

A 1.3 m
B 1.5 m
C 7.9 m
D 15 m

17 A 400 μF capacitor is charged so that the voltage across its plates rises at a constant rate from 0 V to 4.0 V in 20 s. What current is being used to charge the capacitor?

A 5 μA
B 20 μA
C 40 μA
D 80 μA

18 A capacitor of capacitance C stores an amount of energy E when the pd across it is V. Which line, **A** to **D**, in the table gives the correct stored energy and pd when the charge is increased by 50%?

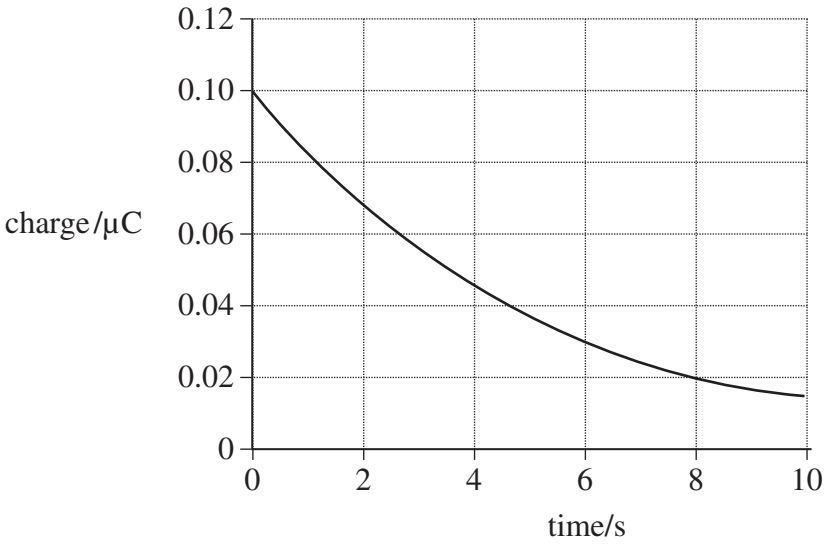
	energy	**pd**
A	1.5 E	1.5 V
B	1.5 E	2.25 V
C	2.25 E	1.5 V
D	2.25 E	2.25 V

19 A capacitor of capacitance C discharges through a resistor of resistance R. Which one of the following statements is **not** true?

A The time constant will decrease if C is increased.
B The time constant will increase if R is increased.
C After charging to the same voltage, the initial discharge current will increase if R is decreased.
D After charging to the same voltage, the initial discharge current will be unaffected if C is increased.

Do not write outside the box

20 The graph shows how the charge on a capacitor varies with time as it is discharged through a resistor.



What is the time constant for the circuit?

A 3.0 s
B 4.0 s
C 5.0 s
D 8.0 s

21 Two charged particles, P and Q, move in circular orbits in a magnetic field of uniform flux density. The particles have the same charge but the mass of P is less than the mass of Q. T_P is the time taken for particle P to complete one orbit and T_Q the time for particle Q to complete one orbit. Which one of the following is correct?

A $T_P = T_Q$

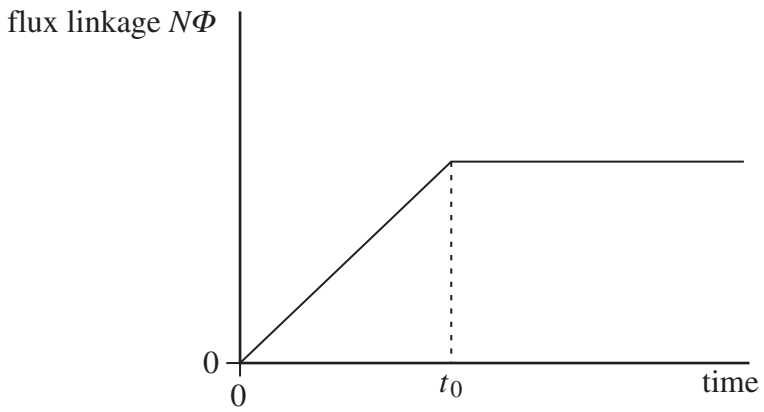
B $T_P > T_Q$

C $T_P < T_Q$

D $T_P - T_Q = 1$

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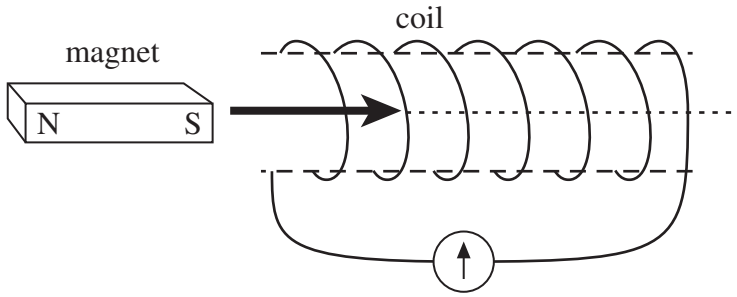
22 The graph shows how the flux linkage, $N\Phi$, through a coil changes when the coil is moved into a magnetic field.



The emf induced in the coil

A increases then becomes constant after time t_0.
B is constant then becomes zero after time t_0.
C is zero then increases after time t_0.
D decreases then becomes zero after time t_0.

23 A bar magnet is pushed into a coil connected to a sensitive ammeter, as shown in the diagram, until it comes to rest inside the coil.

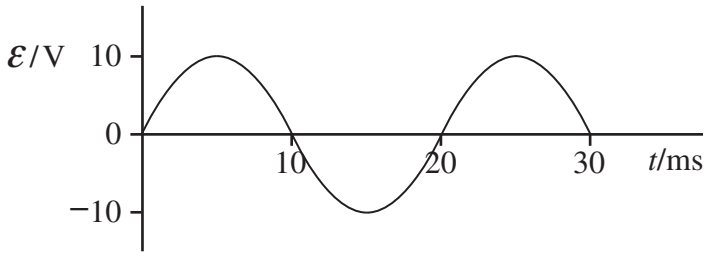


Why does the ammeter briefly show a non-zero reading?

A The magnetic flux linkage in the coil increases then decreases.
B The magnetic flux linkage in the coil increases then becomes constant.
C The magnetic flux linkage in the coil decreases then increases.
D The magnetic flux linkage in the coil decreases then becomes constant.

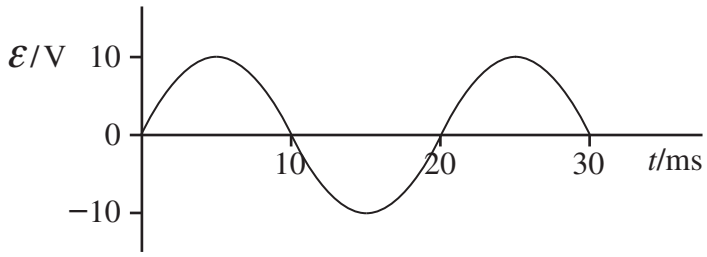
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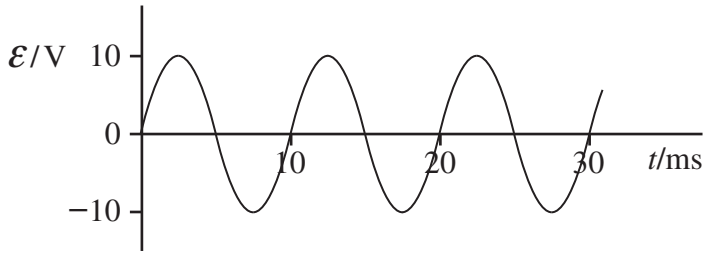


The above graph shows how the output emf, $\mathcal{E}$, varies with time, t, for a coil rotating at angular speed ω in a uniform magnetic field of flux density B. Which one of the following graphs shows how $\mathcal{E}$ varies with t when the same coil is rotated at angular speed 2ω in a uniform magnetic field of flux density $0.5\,B$?

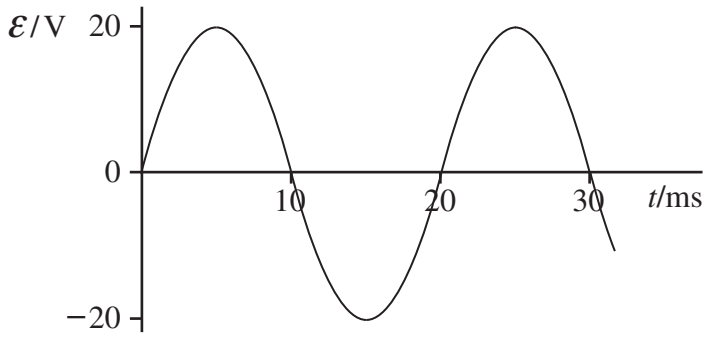
A



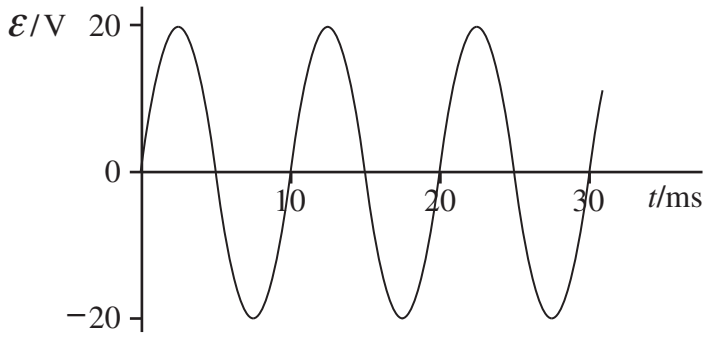
B



C



D



Do not write outside the box

25 Which one of the following is **not** a cause of energy loss in a transformer?

A good insulation between the primary and secondary coil
B induced currents in the soft iron core
C reversal of magnetism in the soft iron core
D resistances in the primary and secondary coil

END OF QUESTIONS

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

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Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
5	
TOTAL	

General Certificate of Education
Advanced Level Examination
June 2011

Physics A PHYA4/2

Unit 4 Fields and Further Mechanics
Section B

Tuesday 21 June 2011 9.00 am to 10.45 am

For this paper you must have:
- a calculator
- a ruler
- a Data and Formulae Booklet.

Time allowed
- The total time for both sections of this paper is 1 hour 45 minutes. You are advised to spend approximately one hour on this section

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the space provided. Answers written in margins or on blank pages will not be marked.
- Do all rough work in this book. Cross through any work you do not want to be marked

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 50.
- You are expected to use a calculator where appropriate.
- A *Data and Formulae Booklet* is provided as a loose insert.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use specialist vocabulary where appropriate.

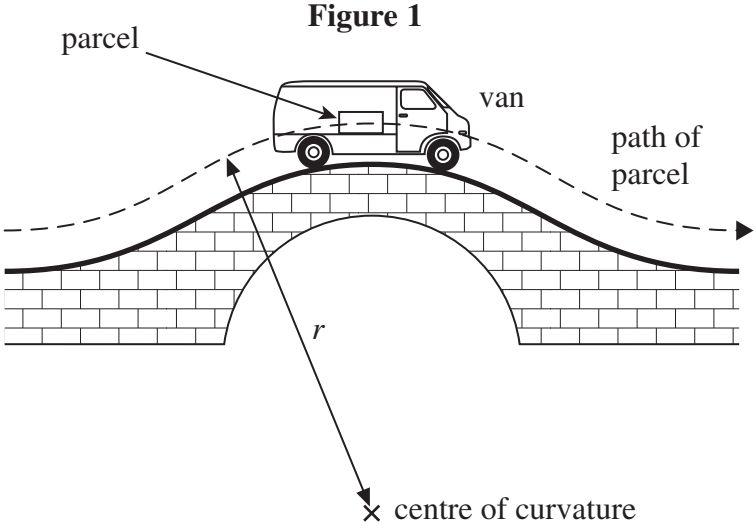
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Answer **all** questions
You are advised to spend approximately **one hour** on this section

1 **Figure 1** shows a parcel on the floor of a delivery van that is passing over a hump-backed bridge on a straight section of road. The radius of curvature of the path of the parcel is r and the van is travelling at a constant speed v. The mass of the parcel is m.

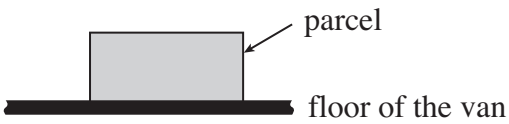
Figure 1



1 (a) (i) Draw arrows on **Figure 2** below to show the forces that act on the parcel as it passes over the highest point of the bridge. Label these forces.

(1 mark)

Figure 2



1 (a) (ii) Write down an equation that relates the contact force, R, between the parcel and the floor of the van to m, v, r and the gravitational field strength, g.

.....

.....

(1 mark)

Do not write outside the box

1 (a) (iii) Calculate R if $m = 12\,\text{kg}$, $r = 23\,\text{m}$, and $v = 11\,\text{m s}^{-1}$.

answer = ...N

(2 marks)

1 (b) Explain what would happen to the magnitude of R if the van passed over the bridge at a higher speed. What would be the significance of any van speed greater than $15\,\text{m s}^{-1}$? Support your answer with a calculation.

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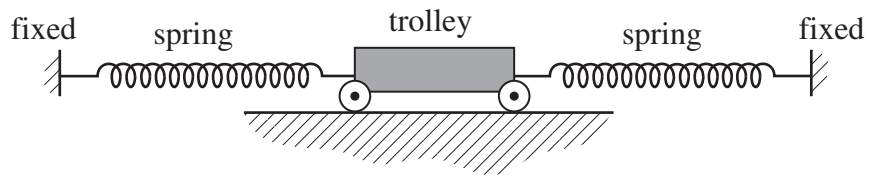
(3 marks)

7

Do not write outside the box

2 A trolley of mass 0.80 kg rests on a horizontal surface attached to two identical stretched springs, as shown in **Figure 3**. Each spring has a spring constant of 30 N m^{-1}, can be assumed to obey Hooke's law, and to remain in tension as the trolley moves.

Figure 3



2 (a) (i) The trolley is displaced to the left by 60 mm and then released. Show that the magnitude of the resultant force on it at the moment of release is 3.6 N.

(2 marks)

2 (a) (ii) Calculate the acceleration of the trolley at the moment of release and state its direction.

answer = ...m s^{-2}

direction .....

(2 marks)

Do not write outside the box

2 (b) (i) The oscillating trolley performs simple harmonic motion. State the **two** conditions which have to be satisfied to show that a body performs simple harmonic motion.

.....

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(2 marks)

2 (b) (ii) The frequency f of oscillation of the trolley is given by

$$f = \frac{1}{2\pi}\sqrt{\frac{2k}{m}}$$

where m = mass of the trolley
k = spring constant of one spring.

Calculate the period of oscillation of the trolley, stating an appropriate unit.

answer = ...

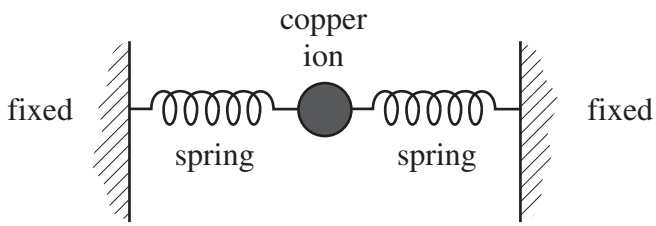
(3 marks)

Turn over ▶

Do not write outside the box

2 (c) Copper ions in a crystal lattice vibrate in a similar way to the trolley, because the inter-atomic forces act in a similar way to the forces exerted by the springs. **Figure 4** shows how this model of a vibrating ion can be represented.

Figure 4



2 (c) (i) The spring constant of each inter-atomic 'spring' is about 200 N m^{-1}. The mass of the copper ion is 1.0×10^{-25} kg. Show that the frequency of vibration of the copper ion is about 10^{13} Hz.

(1 mark)

2 (c) (ii) If the amplitude of vibration of the copper ion is 10^{-11}m, estimate its maximum speed.

answer = ...m s^{-1}

(1 mark)

2 (c) (iii) Estimate the maximum kinetic energy of the copper ion.

answer = ...J

(1 mark)

12

Do not write outside the box

3 Capacitors and rechargeable batteries are examples of electrical devices that can be used repeatedly to store energy.

3 (a) (i) A capacitor of capacitance 70 F is used to provide the emergency back-up in a low voltage power supply.
Calculate the energy stored by this capacitor when fully charged to its maximum operating voltage of 1.2 V. Express your answer to an appropriate number of significant figures.

answer = ...J
(3 marks)

3 (a) (ii) A rechargeable 1.2 V cell used in a cordless telephone can supply a steady current of 55 mA for 10 hours. Show that this cell, when fully charged, stores almost 50 times more energy than the capacitor in part (a)(i).

(2 marks)

3 (b) Give **two** reasons why a capacitor is **not** a suitable source for powering a cordless telephone.

Reason 1.....

.....

Reason 2.....

.....
(2 marks)

7

Do not write outside the box

4 (a) The equation $F = BQv$ may be used to calculate magnetic forces.

4 (a) (i) State the condition under which this equation applies.

.....

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(1 mark)

4 (a) (ii) Identify the physical quantities that are represented by the four symbols in the equation.

F .....

B .....

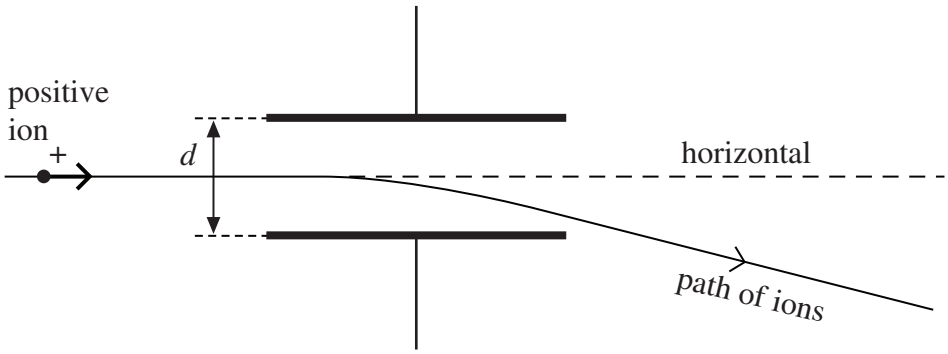
Q.....

v.....

(1 mark)

4 (b) **Figure 5** shows the path followed by a stream of identical positively-charged ions, of the same kinetic energy, as they pass through the region between two charged plates. Initially the ions are travelling horizontally and they are then deflected downwards by the electric field between the plates.

Figure 5



Whilst the electric field is still applied, the path of the ions may be restored to the horizontal, so that they have no overall deflection, by applying a magnetic field over the same region as the electric field. The magnetic field must be of suitable strength and has to be applied in a particular direction.

4 (b) (i) State the direction in which the magnetic field should be applied.

.....

(1 mark)

Do not write outside the box

4 (b) (ii) Explain why the ions have no overall deflection when a magnetic field of the required strength has been applied.

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(2 marks)

4 (b) (iii) A stream of ions passes between the plates at a velocity of $1.7 \times 10^5\ m\,s^{-1}$. The separation d of the plates is 65 mm and the pd across them is 48 V. Calculate the value of B required so that there is no overall deflection of the ions, stating an appropriate unit.

answer = ...

(4 marks)

4 (c) Explain what would happen to ions with a velocity higher than $1.7 \times 10^5\ m\,s^{-1}$ when they pass between the plates at a time when the conditions in part (b)(iii) have been established.

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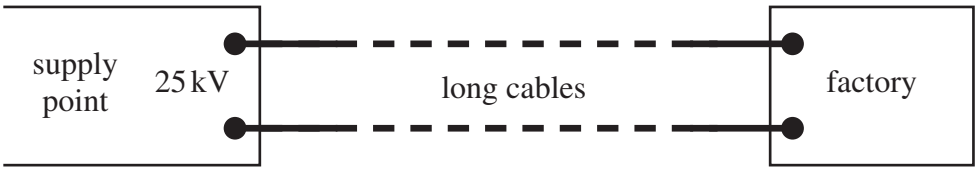
(2 marks)

11

Do not write outside the box

5 (a) Long cables are used to send electrical power from a supply point to a factory some distance away, as shown in **Figure 6**. An input power of 500 kW at 25 kV is supplied to the cables.

Figure 6



5 (a) (i) Calculate the current in the cables.

answer = ...A
(1 mark)

5 (a) (ii) The total resistance of the cables is 30 Ω. Calculate the power supplied to the factory by the cables.

answer = ...kW
(2 marks)

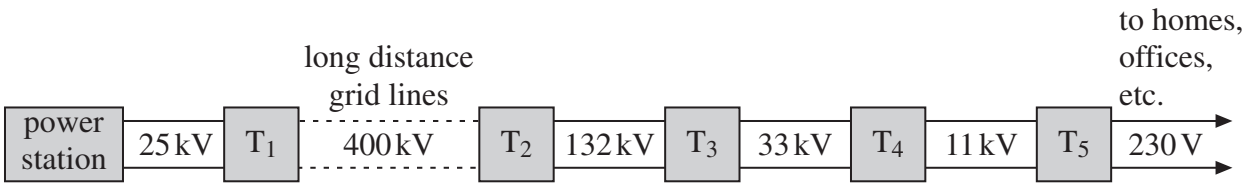
5 (a) (iii) Calculate the efficiency with which power is transmitted by the cables from the input at the supply point to the factory.

answer = ...%
(1 mark)

Do not write outside the box

5 (b) In Great Britain, the electrical generators at power stations provide an output at 25 kV. Most homes, offices and shops are supplied with electricity at 230 V. Power is transmitted from the power stations to the consumers by the grid system, the main principles of which are shown in **Figure 7**. In this network, T_1, T_2, T_3, etc, are transformers.

Figure 7



5 (b) (i) Explain how a step-down transformer differs in construction from a step-up transformer.

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(1 mark)

5 (b) (ii) Explain why the secondary windings of a step-down transformer should be made from thicker copper wire than the primary windings.

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(2 marks)

Question 5 continues on the next page

Do not write outside the box

5 (c) Discuss the principles involved in high voltage transmission systems, explaining why a.c. is used in preference to d.c. and how the energy losses are minimised.

The quality of your written communication will be assessed in this question.

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(6 marks)

13

END OF QUESTIONS

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Version 1.0



General Certificate of Education (A-level)
June 2011

Physics A PHYA4

(Specification 2450)

Unit 4: Fields and further mechanics

Final

Mark Scheme

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all examiners participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the candidates' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for standardisation each examiner analyses a number of candidates' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, examiners encounter unusual answers which have not been raised they are required to refer these to the Principal Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of candidates' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

Further copies of this Mark Scheme are available from: aqa.org.uk

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Instructions to Examiners

1 Give due credit for alternative treatments which are correct. Give marks for what is correct in accordance with the mark scheme; do not deduct marks because the attempt falls short of some ideal answer. Where marks are to be deducted for particular errors, specific instructions are given in the marking scheme.

2 Do not deduct marks for poor written communication. Refer the scripts to the Awards meeting if poor presentation forbids a proper assessment. In each paper, candidates are assessed on their quality of written communication (QWC) in designated questions (or part-questions) that require explanations or descriptions. The criteria for the award of marks on each such question are set out in the mark scheme in three bands in the following format. The descriptor for each band sets out the expected level of the quality of written communication of physics for each band. Such quality covers the scope (eg relevance, correctness), sequence and presentation of the answer. Amplification of the level of physics expected in a good answer is set out in the last row of the table. To arrive at the mark for a candidate, their work should first be assessed holistically (ie in terms of scope, sequence and presentation) to determine which band is appropriate then in terms of the degree to which the candidate's work meets the expected level for the band.

QWC	descriptor	mark range
Good - Excellent	*see specific mark scheme*	**5-6**
Modest - Adequate	*see specific mark scheme*	**3-4**
Poor - Limited	*see specific mark scheme*	**1-2**
The description and/or explanation expected in a good answer should include a coherent account of the following points: *see specific mark scheme*		

Answers given as bullet points should be considered in the above terms. Such answers without an 'overview' paragraph in the answer would be unlikely to score in the top band.

3 An arithmetical error in an answer will cause the candidate to lose one mark and should be annotated AE if possible. The candidate's incorrect value should be carried through all subsequent calculations for the question and, if there are no subsequent errors, the candidate can score all remaining marks.

4 The use of significant figures is tested **once** on each paper in a designated question or part-question. The numerical answer on the designated question should be given to the same number of significant figures as there are in the data given in the question or to one more than this number. All other numerical answers should not be considered in terms of significant figures.

5 Numerical answers **presented** in non-standard form are undesirable but should not be penalised. Arithmetical errors by candidates resulting from use of non-standard form in a candidate's working should be penalised as in point 3 above. Incorrect numerical prefixes and the use of a given diameter in a geometrical formula as the radius should be treated as arithmetical errors.

6 Knowledge of units is tested on designated questions or parts of questions in each a paper. On each such question or part-question, unless otherwise stated in the mark scheme, the mark scheme will show a mark to be awarded for the numerical value of the answer and a further mark for the correct unit. No penalties are imposed for incorrect or omitted units at intermediate stages in a calculation or at the final stage of a non-designated 'unit' question.

7 All other procedures including recording of marks and dealing with missing parts of answers will be clarified in the standardising procedures.

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GCE Physics, Specification A, PHYA4, Fields and Further Mechanics

Section A

This component is an objective test for which the following list indicates the correct answers used in marking the candidates' responses.

	Keys to Objective Test Questions													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	
	D	B	D	A	A	D	C	B	C	A	C	A	D	
	14	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**		
	B	C	D	D	C	A	C	C	B	B	B	A		

Section B

Question 1			
a	i	arrows to show *R* (or *N*) vertically up and *mg* (or *W*) vertically down and along the same line (within ± 2 mm) ✓	**1**
a	ii	$mg - R = \frac{mv^2}{r}$ ∴ $R = mg - \frac{mv^2}{r}$ ✓ $\left[= m\left(g - \frac{v^2}{r}\right)\right]$	**1**
a	iii	**use of** $R = m\left(g - \frac{v^2}{r}\right)$ gives $R = 12\left(9.81 - \frac{11^2}{23}\right)$ ✓ = 55 (54.6) (N) ✓	**2**
b		*R* decreases (as *v* increases) ✓ because *mg* is unchanged but $\frac{mv^2}{r}$ is larger ✓ at higher speeds *R* becomes = 0 [**or** package is not in contact with the floor] ✓ supported by calculation eg when $v = 15\,\text{m s}^{-1}$, $R = 0.33\,\text{N}$ (or ≈ 0) ✓	**max 3**
		Total	**7**

Question 2			
a	i	for one spring, change in force $\Delta F = k\Delta L = 30 \times 60 \times 10^{-3} = 1.8\,(\text{N})$ ✓ resultant force (= [*F* + Δ*F*] – [*F* – Δ*F*]) = 2Δ*F* ✓ (= 3.6 N) **alternative** using answer from (b) (ii) $a = (2\pi f)^2 x = (2\pi \times 1.38)^2 \times 60 \times 10^{-3} = 4.51\,(\text{m s}^{-2})$ ✓ resultant force = *ma* = 0.80 × 4.51 ✓ (= 3.6 N)	**2**
a	ii	acceleration $a\left(= \frac{F}{M}\right) = \frac{3.6}{0.8} = 4.5\,(\text{m s}^{-2})$ ✓ to the right ✓ **alternative** for first mark using answer from (b) (ii) $a = (2\pi f)^2 x = (2\pi \times 1.38)^2 \times 60 \times 10^{-3} = 4.5\,(\text{m s}^{-2})$ ✓	**2**

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b	i	acceleration is proportional to displacement (from equilibrium position) ✓ acceleration is in opposite direction to displacement [**or** acceleration is towards a fixed point/equilibrium position] ✓	**2**
b	ii	$f = \frac{1}{2\pi}\sqrt{\frac{2 \times 30}{0.80}}$ ✓ (= 1.38 Hz) period $T\left(=\frac{1}{f}\right) = \frac{1}{1.38}$ = 0.73 (0.726) ✓ [or 730] s ✓ [ms]	**3**
c	i	$f = \left(= \frac{1}{2\pi}\sqrt{\frac{2k}{m}}\right) = \frac{1}{2\pi}\sqrt{\frac{2 \times 200}{1.0 \times 10^{-25}}}$ = 1.0(1) × 10^{13} (Hz) ✓	**1**
c	ii	v_{max} (= 2π fA) = 2π × 10^{13} × 10^{-11} = 630 (628) (m s^{-1}) ✓	**1**
c	iii	max E_K (= ½ mv_{max}^2) = ½ × 1.0 × 10^{-25} × 628^2 = 2.0 × 10^{-20} (J) ✓ [or using ½ kA^2 approach]	**1**
		Total	**12**

Question 3			
a	i	energy stored by capacitor (= ½ CV^2) = ½ × 70 × 1.2^2 ✓ (= 50.4) = 50 (J) ✓ to **2 sf** only ✓	**3**
a	ii	energy stored by cell (= IVt) = 55 × 10^{-3} × 1.2 × 10 × 3600 ✓ (= 2380 J) $\frac{\text{energy stored by cell}}{\text{energy stored by capacitor}} = \frac{2380}{50}$ = 48 (ie about 50) ✓	**2**
b		capacitor would be impossibly large (to fit in phone) ✓ capacitor would need recharging very frequently [**or** capacitor could only power the phone for a short time] ✓ capacitor voltage [**or** current supplied or charge] would fall continuously whilst in use ✓	**max 2**
		Total	**7**

Question 4			
a	i	magnetic field (or B) must be at right angles to velocity (or v) ✓	**1**
a	ii	F = (magnetic) force (on a charged particle or ion) B = **flux density** (of a magnetic field) Q = charge (of particle or ion) v = velocity [**or** speed] (of particle or ion) all four correct ✓	**1**
b	i	into plane of diagram ✓	**1**
b	ii	magnetic **force** = electric **force** [or $BQv = EQ$] ✓ these forces act in opposite directions [**or** are balanced **or resultant** vertical force is zero] ✓	**2**

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b	iii	$BQv = EQ$ gives flux density $B = \frac{E}{v}$ ✓ $E \left(= \frac{V}{d}\right) = \frac{45}{65 \times 10^{-3}}$ ✓ (= 738 V m^{-1}) $B \left(= \frac{738}{1.7 \times 10^{5}}\right)$ = 4.3 × 10^{-3} ✓ T ✓	**4**
c		ions would be deflected upwards ✓ magnetic force increases but electrostatic force is unchanged [**or** magnetic force now exceeds electrostatic force] ✓	**2**
		Total	**11**

Question 5			
a	i	current $I \left(= \frac{P}{V}\right) = \frac{500 \times 10^{3}}{25 \times 10^{3}}$ = 20 (A) ✓	**1**
a	ii	wasted power ($I^2 R$) = 20^2 × 30 = 1.20 × 10^4 (W) (12.0 kW) ✓ power output from cables = 500 – 12 = 488 (kW) ✓ **or** voltage drop along cables = IR = 20 × 30 = 600 (V) ∴ output voltage = 25000 – 600 = 24400 (V) ✓ power output = IV = 20 × 24400 = 4.88 × 10^5 (W) ✓	**2**
a	iii	efficiency $\left(= \frac{P_{\text{out}}}{P_{\text{in}}}\right) = \frac{488}{500}$ × 100 = 98 (97.6) (%) ✓	**1**
b	i	primary coil must have more turns than secondary ✓	**1**
b	ii	to reduce heating (I^2R) loss [**or** energy/power/copper loss] ✓ (because) $I_S > I_P$ ✓ and R is reduced (by use of thicker wire) ✓	**max 2**
c		**The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.** The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. **High Level (Good to excellent): 5 or 6 marks** The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. The candidate provides a comprehensive and logical description of the main principles of the grid system. They should identify I^2R heating as the main cause of energy loss, and know that this can be reduced by using transformers to raise voltage and therefore decrease current (for the same power), and that transformers require ac. They may not have referred to safety and insulation issues that ultimately require the voltage to be reduced again or to energy losses from transformers.	**max 6**

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	Intermediate Level (Modest to adequate): 3 or 4 marks The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. The candidate provides a description of the main features of the grid system which recognises that heating losses can be reduced by use of transformers to decrease the current. They should know that transformers require ac. They may not fully explain the reasoning for the use of a higher voltage and they are unlikely to refer to safety and insulation issues that require the voltage to be reduced again. **Low Level (Poor to limited): 1 or 2 marks** The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. The candidate recognises that the use of higher voltage will reduce transmission losses and that transformers need ac. They give a much weaker account (if any) of the underlying principles. **Incorrect, inappropriate of no response: 0 marks** No answer or answer refers to unrelated, incorrect or inappropriate physics. **The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences in this case.** voltages are changed using transformers, which work with ac but not with dc ac generation and transmission is therefore essential current in cables causes joule heating (or I^2R loss) resistance of cables should be as low as possible losses are reduced if current in cables can be reduced current can be reduced (for same power I V) if voltage is increased the higher the voltage, the smaller the proportion of the input power that is wasted high voltage introduces insulation problems and raises safety issues voltage must be reduced as the supply reaches its consumers this is done in stages as the supply is moved from overhead cables to underground wires transformers cause energy losses because they are not perfectly efficient features are incorporated in the design of transformers to reduce losses from them	
	Total	**13**

	UMS conversion calculator www.aqa.org.uk/umsconversion	

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ERRATUM NOTICE

General Certificate of Education
January 2011

PHYSICS A PHYA4/1

Unit 4 Fields and Further Mechanics
Section A

Thursday 27 January 2011 1.30 pm to 3.15 pm

Instructions to Invigilators

Before the start of the examination please ask candidates to amend their question papers as follows. (Please read out this message twice to ensure understanding.)

In PHYA4/1 (Section A), Turn to page 7, Question 15

Cross through the question and do not attempt to complete it.

On the OTQ answer sheet

Please make sure you leave the answer space for question 15 blank.

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Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

General Certificate of Education
Advanced Level Examination
January 2011

Physics A PHYA4/1

Unit 4 Fields and Further Mechanics
Section A

Thursday 27 January 2011 1.30pm to 3.15 pm

In addition to this paper you will require:
- an objective test answer sheet
- a black ink or black ball-point pen
- a calculator
- a question paper/answer book for Section B (enclosed).
- a Data and Formulae booklet

Time allowed
- The total time for both sections of this paper is 1 hour 45 minutes. You are advised to spend approximately 45 minutes on this section.

Instructions
- Use black ink or black ball-point pen. Do **not** use pencil.
- Answer **all** questions in this section.
- For each question there are four responses. When you have selected the response which you think is the most appropriate answer to a question, mark this response on your answer sheet.
- Mark all responses as instructed on your answer sheet. If you wish to change your answer to a question, follow the instructions on your answer sheet.
- Do all rough work in this book **not** on the answer sheet.

Information
- The maximum mark for this section is 25.
- All questions in Section A carry equal marks. No deductions will be made for incorrect answers.
- A *Data and Formulae Booklet* is provided as a loose insert.
- The question paper/answer book for Section B is enclosed within this question paper.

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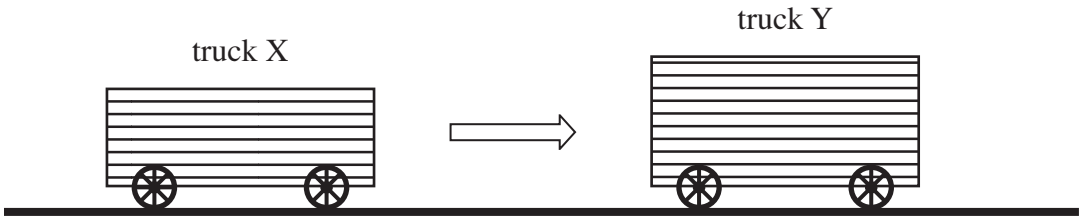
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Multiple choice questions

Each of Questions **1** to **25** is followed by four responses, **A**, **B**, **C**, and **D**. For each question select the best response and mark its letter on the answer sheet.

You are advised to spend approximately **45 minutes** on this section.

1 A rail truck X travels along a level track and collides with a stationary truck Y. The two trucks move together at the same velocity after the collision.

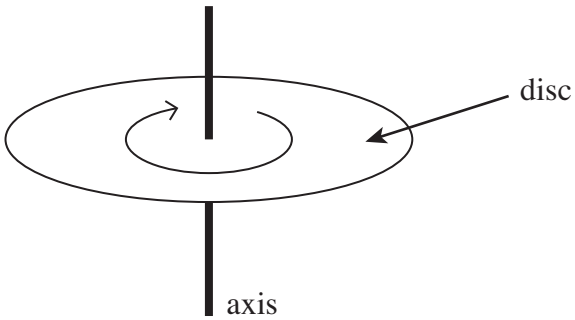


Which line, **A** to **D**, in the table states how the total momentum and the total kinetic energy of the trucks change as a result of the impact.

	total momentum	**total kinetic energy**
A	unchanged	unchanged
B	unchanged	decreases
C	decreases	decreases
D	decreases	unchanged

Do not write outside the box

2 The diagram shows a disc of diameter 120mm that can turn about an axis through its centre.



The disc is turned through an angle of 30° in 20 ms. What is the average speed of a point on the edge of the disc during this time?

A $0.5\pi\,\text{m s}^{-1}$

B $\pi\,\text{m s}^{-1}$

C $1.5\pi\,\text{m s}^{-1}$

D $2\pi\,\text{m s}^{-1}$

3 A particle of mass m moves in a circle of radius r at a uniform speed with frequency f. What is the kinetic energy of the particle?

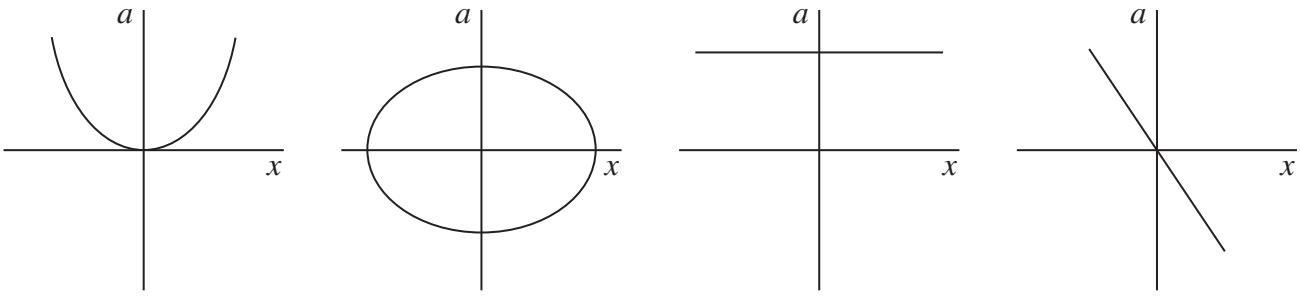
A $\dfrac{mf^2r^2}{4\pi^2}$

B $\dfrac{mf^2r}{2}$

C $2\pi^2 mf^2r^2$

D $4\pi^2 mf^2r^2$

4 Which one of the following graphs shows how the acceleration, a, of a body moving with simple harmonic motion varies with its displacement, x?



Turn over ▶

Do not write outside the box

5 A body moves with simple harmonic motion of amplitude A and frequency $\frac{b}{2\pi}$.

What is the magnitude of the acceleration when the body is at maximum displacement?

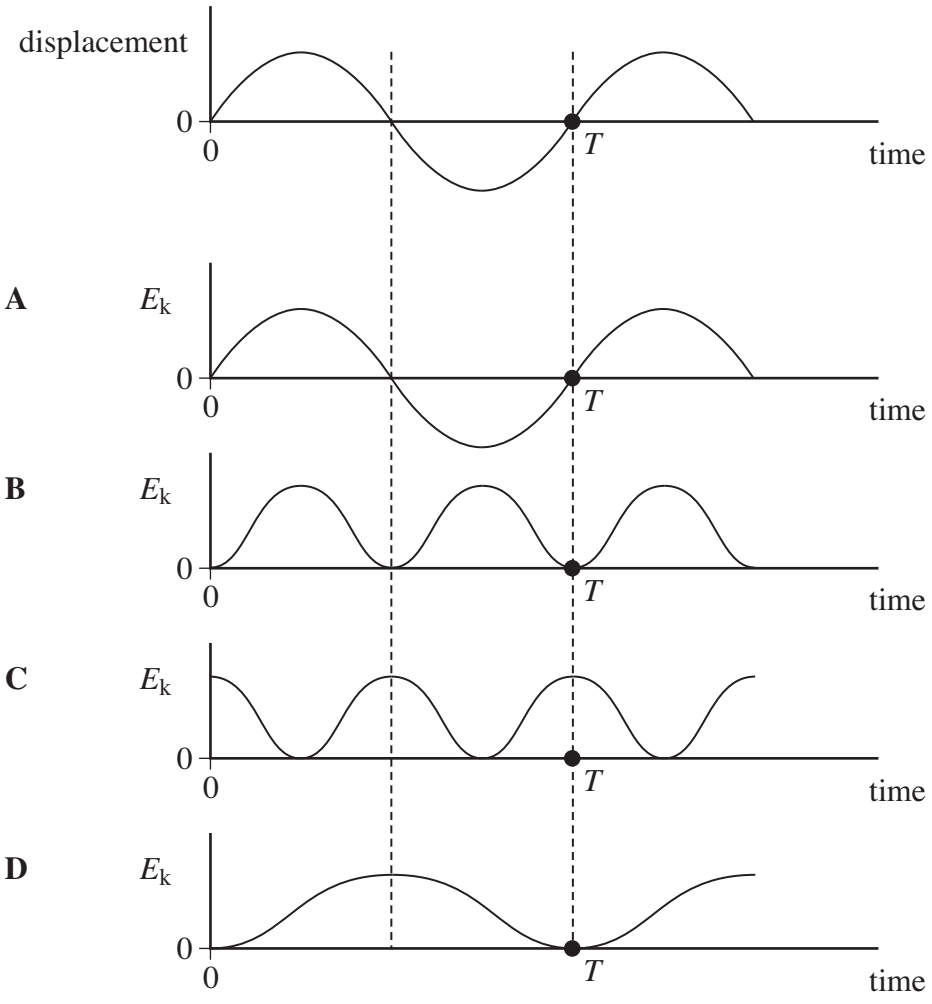
A zero

B $4\pi^2 Ab^2$

C Ab^2

D $\frac{4\pi^2 A}{b^2}$

6 An object oscillating in simple harmonic motion has a time period T. The first graph shows how its displacement varies with time. Which of the subsequent graphs, **A** to **D**, show how the kinetic energy, E_k, of the object varies with time?



Do not write outside the box

7 The period of vertical oscillation of a mass-spring system is T when the spring carries a mass of 1.00 kg. What mass should be added to the 1.00 kg if the period is to be increased to 1.50 T?

A 0.25 kg

B 1.00 kg

C 1.25 kg

D 2.00 kg

8 The gravitational force between two uniform spheres is 3.1×10^{-9} N when the distance between their centres is 150 mm. If the mass of one sphere is 2.5 kg, what is the mass of the other?

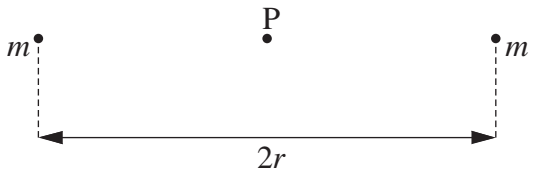
A 0.043 kg

B 0.42 kg

C 2.8 kg

D 4.1 kg

9 The diagram shows two point masses each of mass m separated by a distance $2r$.



What is the value of the gravitational field strength at the mid-point, P, between the two masses?

A $\frac{4Gm}{r^2}$

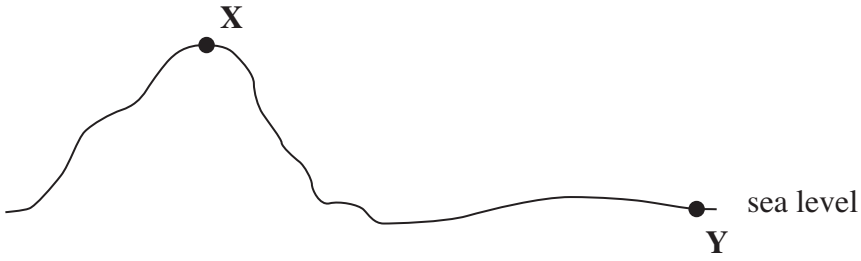
B $\frac{2Gm}{r^2}$

C $\frac{Gm}{2r^2}$

D zero

Do not write outside the box

10 The diagram shows two positions, **X** and **Y**, on the Earth's surface.



Which line, **A** to **D**, in the table gives correct comparisons at **X** and **Y** for gravitational potential and angular velocity?

	gravitational potential at X compared with Y	**angular velocity at X compared with Y**
A	greater	greater
B	greater	same
C	greater	smaller
D	same	same

11 What would the period of rotation of the Earth need to be if objects at the equator were to appear weightless?

radius of Earth = 6.4×10^6 m

A 4.5×10^{-2} hours

B 1.4 hours

C 24 hours

D 160 hours

12 As a comet orbits the Sun the distance between the comet and the Sun continually changes. As the comet moves towards the Sun this distance reaches a minimum value. Which one of the following statements is **incorrect** as the comet approaches this minimum distance?

A The potential energy of the comet increases.

B The gravitational force acting on the comet increases.

C The direction of the gravitational force acting on the comet changes.

D The kinetic energy of the comet increases.

Do not write outside the box

13 The repulsive force between two small negative charges separated by a distance r is F.

What is the force between the charges when the separation is reduced to $\frac{r}{3}$?

A $\frac{F}{9}$

B $\frac{F}{3}$

C $3F$

D $9F$

14 What is the acceleration of an electron at a point in an electric field where the field strength is 1.5×10^5 Vm^{-1}?

A 1.2×10^6 m s^{-2}

B 1.4×10^{13} m s^{-2}

C 2.7×10^{15} m s^{-2}

D 2.6×10^{16} m s^{-2}

15 At a distance R from a fixed charge, the electric field strength is E and the electric potential is V. Which line, **A** to **D**, in the table gives the electric field strength and electric potential at a distance $2R$ from the charge?

	electric field strength	**electric potential**
A	$\frac{E}{2}$	$\frac{V}{4}$
B	$\frac{E}{2}$	$\frac{V}{2}$
C	$\frac{E}{4}$	$\frac{V}{2}$
D	$\frac{E}{4}$	$\frac{V}{4}$

16 Two protons are 1.0×10^{-14}m apart. Approximately how many times is the electrostatic force between them greater than the gravitational force between them?
(Use the Data and Formulae booklet)

A 10^{23}

B 10^{30}

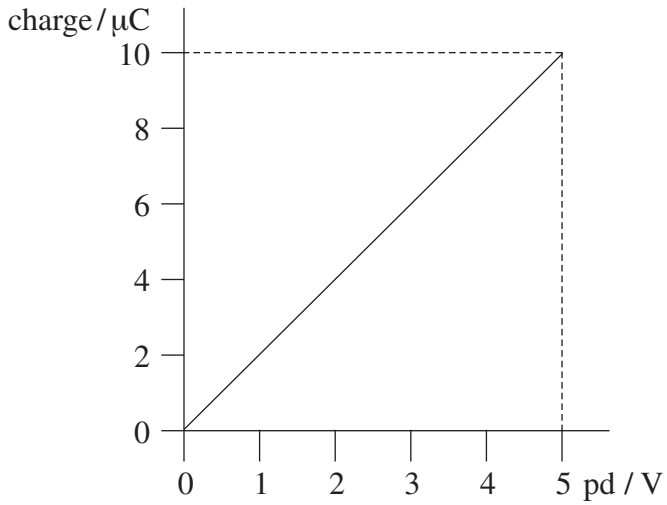
C 10^{36}

D 10^{42}

Turn over ▶

Do not write outside the box

17 The graph shows how the charge stored by a capacitor varies with the pd applied across it.



Which line, **A** to **D**, in the table gives the capacitance and the energy stored when the potential difference is 5.0 V?

	capacitance/μF	**energy stored/μJ**
A	2.0	25
B	2.0	50
C	10.0	25
D	10.0	50

18 A 10 mF capacitor is charged to 10 V and then discharged completely through a small motor. During the process, the motor lifts a weight of mass 0.10 kg. If 10% of the energy stored in the capacitor is used to lift the weight, through what approximate height will the weight be lifted?

A 0.05 m

B 0.10 m

C 0.50 m

D 1.00 m

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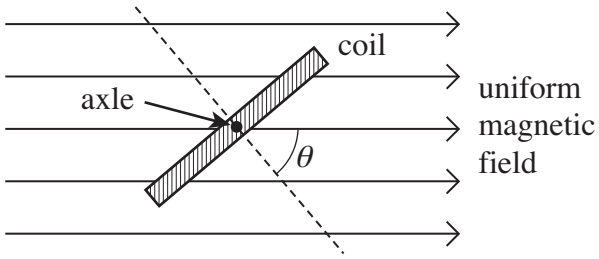
19 A negatively charged particle moves at right angles to a uniform magnetic field. The magnetic force on the particle acts

A in the direction of the field.
B in the opposite direction to that of the field.
C at an angle between 0° and 90° to the field.
D at right angles to the field.

20 An electron moving with a constant speed enters a uniform magnetic field in a direction perpendicular to the magnetic field. What is the shape of the path that the electron would follow?

A parabolic
B circular
C elliptical
D a line parallel to the magnetic field

21



A coil of 50 turns has a cross-sectional area of $4.2 \times 10^{-3}\,m^2$. It is placed at an angle to a uniform magnetic field of flux density $2.8 \times 10^{-2}\,T$, as shown in the diagram, so that angle $\theta = 50^o$.

What is the change in flux linkage when the coil is rotated anticlockwise until $\theta = 0^o$?

A The flux linkage decreases by 2.1×10^{-3} Wb turns.
B The flux linkage increases by 2.1×10^{-3} Wb turns.
C The flux linkage decreases by 3.8×10^{-3} Wb turns.
D The flux linkage increases by 3.8×10^{-3} Wb turns.

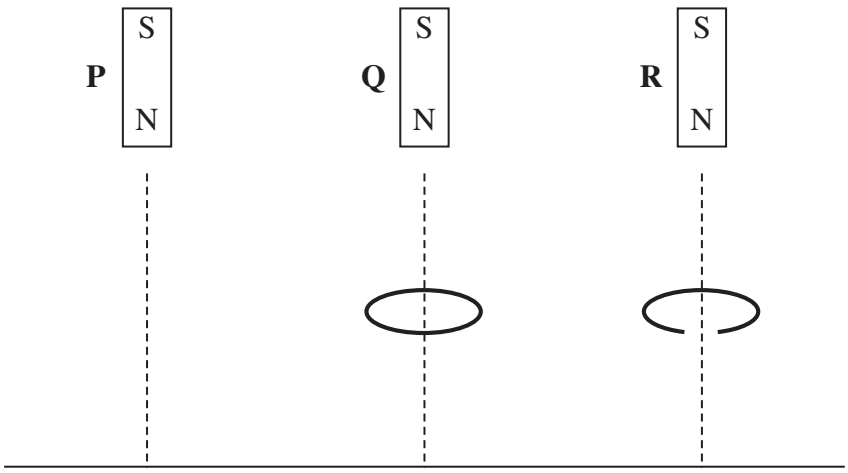
22 An aircraft, of wing span 60 m, flies horizontally at a speed of $150\,m\,s^{-1}$. If the vertical component of the Earth's magnetic field in the region of the plane is 1.0×10^{-5}T, what is the magnitude of the magnetic flux cut by the wings in 10 s?

A 1.0×10^{-5} Wb
B 1.0×10^{-4} Wb
C 9.0×10^{-2} Wb
D 9.0×10^{-1} Wb

Turn over ▶

Do not write outside the box

23



Three identical magnets **P**, **Q** and **R** are released simultaneously from rest and fall to the ground from the same height. **P** falls directly to the ground, **Q** falls through the centre of a thick conducting ring and **R** falls through a ring which is identical except for a gap cut into it. Which one of the statements below correctly describe the sequence in which the magnets reach the ground?

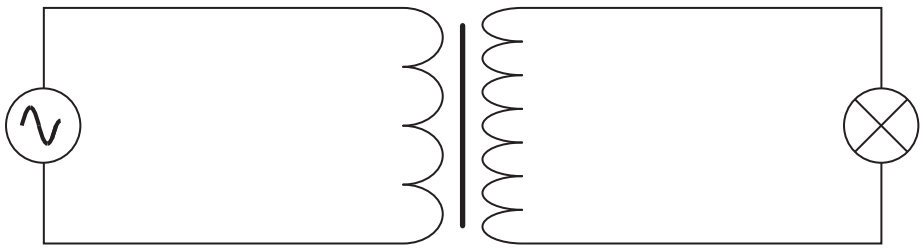
A **P** and **R** arrive together followed by **Q**.

B **P** and **Q** arrive together followed by **R**.

C **P** arrives first, follow by **Q** which is followed by **R**.

D All three magnets arrive simultaneously.

24 The primary coil of a step-up transformer is connected to a source of alternating pd. The secondary coil is connected to a lamp.



Which line, **A** to **D**, in the table correctly describes the flux linkage and current through the secondary coil in relation to the primary coil?

	$\frac{\text{secondary magnetic flux linkage}}{\text{primary magnetic flux linkage}}$	$\frac{\text{secondary current}}{\text{primary current}}$
A	>1	<1
B	<1	<1
C	>1	>1
D	<1	>1

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25 A transformer has 1200 turns on the primary coil and 500 turns on the secondary coil. The primary coil draws a current of 0.25 A from a 240 V ac supply. If the efficiency of the transformer is 83%, what is the current in the secondary coil?

A 0.10 A

B 0.21 A

C 0.50 A

D 0.60 A

END OF QUESTIONS

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Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
5	
TOTAL	

General Certificate of Education
Advanced Level Examination
January 2011

Physics A PHYA4/2

Unit 4 Fields and Further Mechanics
Section B

Thursday 27 January 2011 1.30 pm to 3.15 pm

For this paper you must have:
- a calculator
- a ruler
- a Data and Formulae Booklet.

Time allowed
- The total time for both sections of this paper is 1 hour 45 minutes. You are advised to spend approximately one hour on this section

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the space provided. Answers written in margins or on blank pages will not be marked.
- Do all rough work in this book. Cross through any work you do not want to be marked

Information
- The marks for questions are shown in brackets.
- The maximum mark for this section is 50.
- You are expected to use a calculator where appropriate.
- A *Data and Formulae Booklet* is provided as a loose insert.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use specialist vocabulary where appropriate.

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Answer **all** questions
You are advised to spend approximately **one hour** on this section

1 The Hubble space telescope was launched in 1990 into a circular orbit near to the Earth. It travels around the Earth once every 97 minutes.

1 (a) Calculate the angular speed of the Hubble telescope, stating an appropriate unit.

answer = ...
(3 marks)

1 (b) (i) Calculate the radius of the orbit of the Hubble telescope.

answer = ... m
(3 marks)

1 (b) (ii) The mass of the Hubble telescope is 1.1×10^4 kg. Calculate the magnitude of the centripetal force that acts on it.

answer = ... N
(2 marks)

8

Turn over ▶

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2 (a) State, in words, how the force acting on a body is related to the change in momentum of the body.

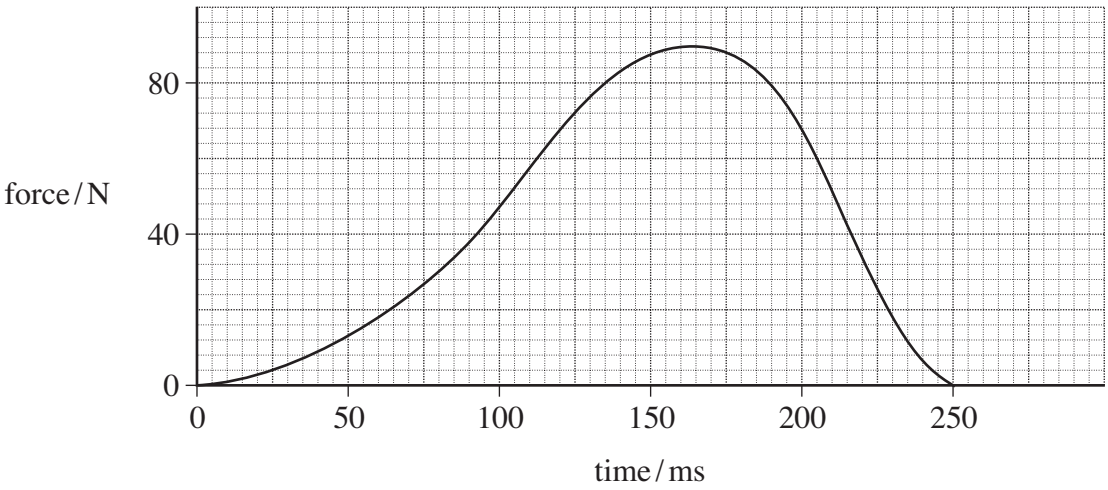
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(1 mark)

2 (b) A football of mass 0.42 kg is moving horizontally at 10 m s^{-1} towards a footballer's boot, which then kicks it. **Figure 1** shows how the force between the boot and the ball varies with time while they are in contact.

Figure 1



2 (b) (i) What is the significance of the area enclosed by the line on a force–time graph and the time axis when a force acts on a body for a short time?

.....

(1 mark)

2 (b) (ii) Estimate the impulse that acts on the ball, stating an appropriate unit.

answer = ...

(4 marks)

Do not write outside the box

2 (b) (iii) Calculate the speed of the ball after it has been kicked, assuming that it returns along the same horizontal line it followed when approaching the boot. Express your answer to an appropriate number of significant figures.

answer = ...m s^{-1}

(4 marks)

2 (c) Discuss the consequences if the ball had approached the boot at a higher speed but still received the same impulse.

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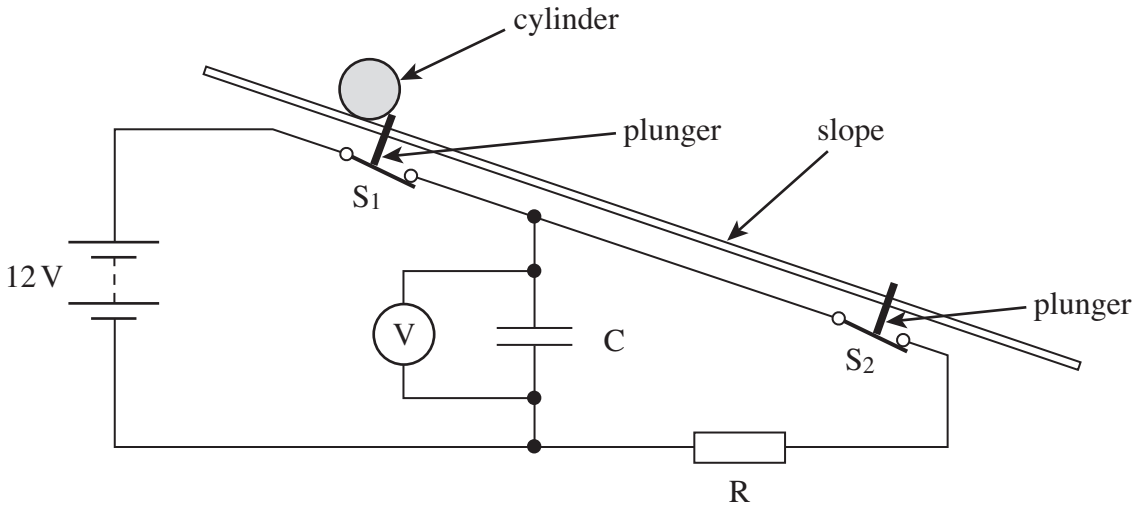
(3 marks)

13

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3 A student was required to design an experiment to measure the acceleration of a heavy cylinder as it rolled down an inclined slope of constant gradient. He suggested an arrangement that would make use of a capacitor-resistor discharge circuit to measure the time taken for the cylinder to travel between two points on the slope. The principle of this arrangement is shown in **Figure 2**.

Figure 2



S_1 and S_2 are two switches that would be opened in turn by plungers as the cylinder passed over them. Once opened, the switches would remain open. The cylinder would be released from rest as it opened S_1. The pd across the capacitator would be measured by the voltmeter.

3 (a) Describe the procedure the student should follow, including the measurements he should make, when using this arrangement. Explain how he should use the measurements taken to calculate the acceleration of the cylinder down the slope.

The quality of your written communication will be assessed in this question.

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(6 marks)

3 (b) When the student set up his experiment using the arrangement shown in **Figure 2**, he used a 22 μF capacitor, C, and a 200 kΩ resistor, R. In one of his results, the initial pd was 12.0 V and the final pd was 5.8 V. The distance between the plungers was 2.5 m.

3 (b) (i) From the student's result, calculate the time taken for the cylinder to reach the second plunger.

answer = ...s

(3 marks)

3 (b) (ii) What value does this result give for the acceleration of the cylinder down the slope, assuming the acceleration is constant?

answer = ...m s^{-2}

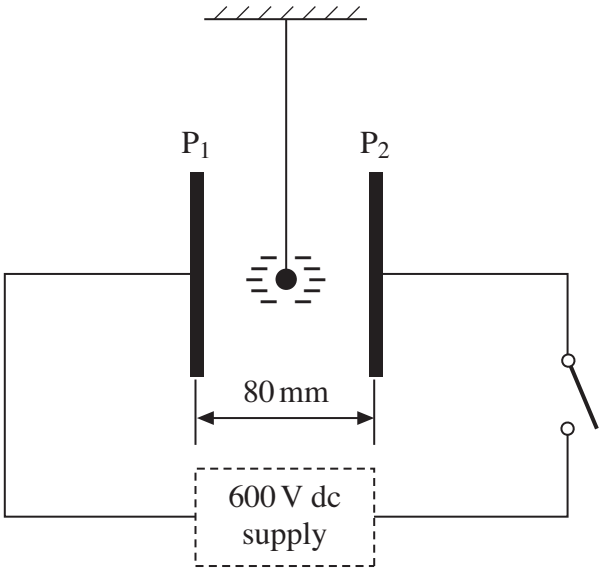
(2 marks)

11

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4 **Figure 3** shows a small polystyrene ball which is suspended between two vertical metal plates, $\mathbf{P_1}$ and $\mathbf{P_2}$, 80 mm apart, that are initially uncharged. The ball carries a charge of –0.17 μC.

Figure 3



4 (a) (i) A pd of 600 V is applied between $\mathbf{P_1}$ and $\mathbf{P_2}$ when the switch is closed. Calculate the magnitude of the electric field strength between the plates, assuming it is uniform.

answer = ...V m^{-1}

(2 marks)

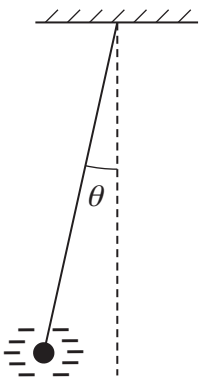
4 (a) (ii) Show that the magnitude of the electrostatic force that acts on the ball under these conditions is 1.3 mN.

(1 mark)

Do not write outside the box

4 (b) Because of the electrostatic force acting on it, the ball is displaced from its original position. It comes to rest when the suspended thread makes an angle θ with the vertical, as shown in **Figure 4**.

Figure 4



4 (b) (i) On **Figure 4**, mark and label the forces that act on the ball when in this position.

(2 marks)

4 (b) (ii) The mass of the ball is 4.8×10^{-4} kg. By considering the equilibrium of the ball, determine the value of θ.

answer = ...degrees

(3 marks)

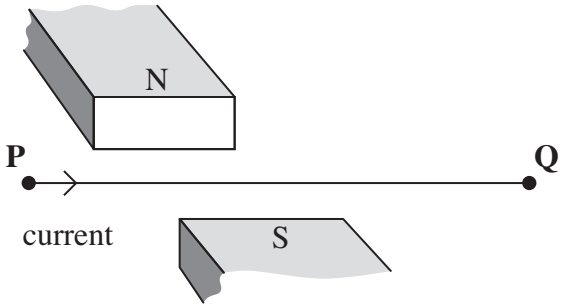
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5 **Figure 5** shows a horizontal wire, held in tension between fixed points at **P** and **Q**. A short section of the wire is positioned between the pole pieces of a permanent magnet, which applies a uniform horizontal magnetic field at right angles to the wire. Wires connected to a circuit at **P** and **Q** allow an electric current to be passed through the wire.

Figure 5



5 (a) (i) State the direction of the force on the wire when there is a direct current from **P** to **Q**, as shown in **Figure 5**.

.....

(1 mark)

5 (a) (ii) In a second experiment, an alternating current is passed through the wire. Explain why the wire will vibrate vertically.

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(3 marks)

5 (b) The permanent magnet produces a uniform magnetic field of flux density 220 mT over a 55 mm length of the wire. Show that the maximum force on the wire is about 40 mN when there is an alternating current of rms value 2.4 A in it.

(3 marks)

Do not write outside the box

5 (c) The length of **PQ** is 0.40 m. When the wire is vibrating, transverse waves are propagated along the wire at a speed of 64 m s^{-1}. Explain why the wire is set into large amplitude vibration when the frequency of the a.c. supply is 80 Hz.

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(3 marks)

10

END OF QUESTIONS

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Version 1.0



General Certificate of Education (A-level)
January 2011

Physics A PHYA4

(Specification 2450)

Unit 4: Fields and further mechanics

Final

Mark Scheme

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all examiners participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the candidates' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for standardisation each examiner analyses a number of candidates' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, examiners encounter unusual answers which have not been raised they are required to refer these to the Principal Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of candidates' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

Further copies of this Mark Scheme are available from: aqa.org.uk

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Instructions to Examiners

1 Give due credit for alternative treatments which are correct. Give marks for what is correct in accordance with the mark scheme; do not deduct marks because the attempt falls short of some ideal answer. Where marks are to be deducted for particular errors, specific instructions are given in the marking scheme.

2 Do not deduct marks for poor written communication. Refer the scripts to the Awards meeting if poor presentation forbids a proper assessment. In each paper, candidates are assessed on their quality of written communication (QWC) in designated questions (or part-questions) that require explanations or descriptions. The criteria for the award of marks on each such question are set out in the mark scheme in three bands in the following format. The descriptor for each band sets out the expected level of the quality of written communication of physics for each band. Such quality covers the scope (eg relevance, correctness), sequence and presentation of the answer. Amplification of the level of physics expected in a good answer is set out in the last row of the table. To arrive at the mark for a candidate, their work should first be assessed holistically (ie in terms of scope, sequence and presentation) to determine which band is appropriate then in terms of the degree to which the candidate's work meets the expected level for the band.

QWC	descriptor	mark range
Good - Excellent	*see specific mark scheme*	**5 – 6**
Modest - Adequate	*see specific mark scheme*	**3 – 4**
Poor - Limited	*see specific mark scheme*	**1 – 2**
The description and/or explanation expected in a good answer should include a coherent account of the following points: *see specific mark scheme*		

Answers given as bullet points should be considered in the above terms. Such answers without an 'overview' paragraph in the answer would be unlikely to score in the top band.

3 An arithmetical error in an answer will cause the candidate to lose one mark and should be annotated AE if possible. The candidate's incorrect value should be carried through all subsequent calculations for the question and, if there are no subsequent errors, the candidate can score all remaining marks.

4 The use of significant figures is tested **once** on each paper in a designated question or part-question. The numerical answer on the designated question should be given to the same number of significant figures as there are in the data given in the question or to one more than this number. All other numerical answers should not be considered in terms of significant figures.

5 Numerical answers **presented** in non-standard form are undesirable but should not be penalised. Arithmetical errors by candidates resulting from use of non-standard form in a candidate's working should be penalised as in point 3 above. Incorrect numerical prefixes and the use of a given diameter in a geometrical formula as the radius should be treated as arithmetical errors.

6 Knowledge of units is tested on designated questions or parts of questions in each a paper. On each such question or part-question, unless otherwise stated in the mark scheme, the mark scheme will show a mark to be awarded for the numerical value of the answer and a further mark for the correct unit. No penalties are imposed for incorrect or omitted units at intermediate stages in a calculation or at the final stage of a non-designated 'unit' question.

7 All other procedures including recording of marks and dealing with missing parts of answers will be clarified in the standardising procedures.

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GCE Physics, Specification A, PHYA4, Fields and Further Mechanics

Section A

This component is an objective test for which the following list indicates the correct answers used in marking the candidates' responses.

	Keys to Objective Test Questions													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	
	B	A	C	D	C	C	C	B	D	B	B	A	D	
	14	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**		
	D	C	C	A	A	D	B	B	D	A	A	C		

Section B

Question 1			
(a)	$\omega \left(= \frac{2\pi}{T}\right) = \frac{2\pi}{97 \times 60}$ ✓ [or $\omega \left(= \frac{360}{T}\right) = \frac{360}{97 \times 60}$] $= 1.1 \times 10^{-3}$ (1.08×10^{-3}) ✓ [$= 6.2\ (6.19) \times 10^{-2}$] rad s^{-1} [accept s^{-1}] ✓ [degree s^{-1}]		**3**
(b) (i)	$\frac{GMm}{r^2} = m\omega^2 r$ **or** $r^3 = \frac{GM}{\omega^2}$ ✓ gives $r^3 = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{(1.08 \times 10^{-3})^2}$ ✓ $\therefore r = 6.99 \times 10^6$ (m) ✓		**3**
(b) (ii)	$F\ (= m\omega^2 r) = 1.1 \times 10^4 \times (1.08 \times 10^{-3})^2 \times 6.99 \times 10^6$ ✓ $= 9.0 \times 10^4$ (8.97×10^4) (N) ✓ [**or** $F\left(= \frac{GMm}{r^2}\right) = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24} \times 1.1 \times 10^4}{(6.99 \times 10^6)^2}$ ✓ $= 9.0 \times 10^4$ (8.98×10^4) (N) ✓]		**2**
		Total	**8**

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Question 2		
(a)	force = rate of change of momentum ✓	**1**
(b) (i)	area under graph represents impulse **or change in** momentum ✓	**1**
(b) (ii)	suitable method to estimate area under graph ✓✓ [eg counting squares: 20 to 23 squares ✓ each of area $25 \times 10^{-3} \times 20 = 0.5\,(\text{N s})$ ✓ **or** approximate triangle etc ✓ $½ \times 250 \times 10^{-3} \times 90$ ✓] gives impulse = 11 ± 1 ✓ N s (or kg m s^{-1}) ✓	**4**
(b) (iii)	use of impulse = $\Delta(mv)$ ✓ $\Delta p = mv - (-mu) = m(v + u)$ **or** $11 = 0.42(v + 10)$ ✓ giving $0.42v = 6.8$ and $v = 16\,(\text{m s}^{-1})$ (impulse = 12 gives 19 m s^{-1}) ✓ answer to **2 sf** only ✓	**4**
(c)	final speed would be lower ✓ any **two** of the following points ✓✓ ● initial momentum would be greater [**or** greater u must be reversed] ● change in momentum [or velocity] is the same [**or** larger F acts for shorter t] ● initial and final momenta are (usually) in opposite directions ● initial and final momenta may be in same direction if initial speed is sufficiently high [**alternatively** final speed = $\frac{\text{impulse (from graph)}}{\text{mass of ball}}$ – initial speed ✓ gives final speed $v = (26 \pm 3)$ – initial speed u ✓ consequence is ● v is in opposite direction to u when $u < 26$ ● v is in same direction as u when $u > 26$ ● v is zero (ball stationary) when $u = 26$ any one of these bullet points ✓]	**3**
	Total	**13**

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Question 3		
(a)	**The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.** The candidate's answer will be assessed holistically. The answer will be assigned to one of the three levels according to the following criteria. **High Level (good to excellent) 5 or 6 marks** The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. The candidate provides a comprehensive and logical description of the sequence of releasing the ball and taking measurements of initial and final voltages. They should identify the correct distance measurement and show a good appreciation of how to use these measurements to calculate the time and acceleration from them. Time should be found from capacitor discharge, using known C and R values. Repeated readings would be expected in any answer worthy of full marks, but five marks may be awarded where repetition is omitted. **Intermediate Level (modest to adequate) 3 or 4 marks** The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. The candidate provides a comprehensive and logical description of the sequence of releasing the ball and taking measurements of the initial and final voltages. They are likely to show some appreciation of the use of suvat equations to calculate the acceleration, although they may not recognise the need to measure a distance. **Low Level (poor to limited) 1 or 2 marks** The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may only be partly appropriate. The candidate is likely to have recognised that initial and final voltages should be measured, but may not appreciate the need for any other measurement. They may present few details of how to calculate the acceleration from the voltage measurements. **The explanation expected in a competent answer should include a coherent selection of the following points.** **Measurements** ● initial pd across C (V_0) from voltmeter (before releasing roller) ● distance s along slope between plungers ● final pd across C (V_1) from voltmeter ● measurements repeated to provide a more reliable result **Analysis** ● time t is found from $V_1 = V_0e^{-t/RC}$, giving $t = RC \ln (V_0/V_1)$ ● from $s = ut + ½ at^2$ with $u = 0$, acceleration $a = 2s/t^2$ ● repeat and find average a from several results	**max 6**

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(b)	(i)	$RC = 22 \times 10^{-6} \times 200 \times 10^{3}$ [or = 4.4 (s)] ✓ (4.40) $5.8 = 12.0\ e^{-t/4.40}$ ✓ gives $t = 4.40 \ln (12.0/5.8) = 3.2$ (3.20) (s) ✓	**3**
(b)	(ii)	$a\left(= \frac{2s}{t^2}\right) = \frac{2 \times 2.5}{3.20^2}$ ✓ = 0.49 (0.488) ($m\,s^{-2}$) ✓	**2**
		Total	**11**

Question 4			
(a)	(i)	$E\left(= \frac{V}{d}\right) = \frac{600}{80 \times 10^{-3}}$ ✓ = 7.5×10^{3} ($V\,m^{-1}$) ✓	**2**
(a)	(ii)	force F ($= EQ$) = $7500 \times 0.17 \times 10^{-6}$ ✓ (= 1.28×10^{-3} N)	**1**
(b)	(i)	correct labelled arrows placed on diagram to show the three forces acting; ● electric force F (or 1.3 mN) horizontally to left ✓ ● W (or mg) vertically down **and** ● tension T upwards along the thread ✓	**2**
(b)	(ii)	$F = T \sin\theta$ and $mg = T \cos\theta$ give $F = mg \tan\theta$ ✓ (or by triangle or parallelogram methods) $\tan\theta \left(= \frac{F}{mg}\right) = \frac{1.28 \times 10^{-3}}{4.8 \times 10^{-4} \times 9.81}$ (= 0.272) ✓ gives θ = 15(.2) (°) ✓	**3**
		Total	**8**

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Question 5		
(a) (i)	(vertically) downwards ✓	**1**
(a) (ii)	force F is perpendicular to both B and I [**or** equivalent correct explanation using Fleming LHR] ✓ magnitude of F changes as size of current changes ✓ force acts in opposite direction when current reverses [**or** ac gives alternating force] ✓ continual reversal of ac means process is repeated ✓	**max 3**
(b)	appreciation that maximum force corresponds to peak current ✓ peak current = $2.4 \times \sqrt{2}$ = 3.39 (A) ✓ F_{max} (= $B I_{pk} L$) = 0.22 × 3.39 × 55 × 10^{-3} ✓ (= 4.10 × 10^{-2} N)	**3**
(c)	wavelength (λ) of waves $= \left(= \frac{c}{f}\right) = \frac{64}{80}$ = 0.80 (m) ✓ length of wire is $\lambda/2$ causing fundamental vibration ✓ [**or** λ of waves required for fundamental (= 2 × 0.40) = 0.80 m ✓ natural frequency of wire $\left(= \frac{c}{\lambda}\right) = \frac{64}{0.80}$ = 80 (Hz) ✓] wire resonates (at frequency of ac supply) [**or** a statement that fundamental frequency (or a natural frequency) of the wire is the same as applied frequency] ✓	**3**
	Total	**10**

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Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

General Certificate of Education
Advanced Level Examination
June 2010

Physics A PHYA4/1

Unit 4 Fields and Further Mechanics
Section A

Friday 18 June 2010 9.00 am to 10.45 am

In addition to this paper you will require:
- an objective test answer sheet
- a black ink or black ball-point pen
- a calculator
- a question paper/answer book for Section B (enclosed)
- a Data and Formulae Booklet.

Time allowed
- The total time for both sections of this paper is 1 hour 45 minutes. You are advised to spend approximately 45 minutes on this section.

Instructions
- Use black ink or black ball-point pen. Do **not** use pencil.
- Answer **all** questions in this section.
- For each question there are four responses. When you have selected the response which you think is the most appropriate answer to a question, mark this response on your answer sheet.
- Mark all responses as instructed on your answer sheet. If you wish to change your answer to a question, follow the instructions on your answer sheet.
- Do all rough work in this book **not** on the answer sheet.

Information
- The maximum mark for this section is 25.
- Section A and Section B of this paper together carry 20% of the total marks for Physics Advanced.
- All questions in Section A carry equal marks. No deductions will be made for incorrect answers.
- A *Data and Formulae Booklet* is provided as a loose insert.
- The question paper/answer book for Section B is enclosed within this question paper.

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Multiple choice questions

Each of Questions **1** to **25** is followed by four responses, **A**, **B**, **C** and **D**. For each question select the best response and mark its letter on the answer sheet.

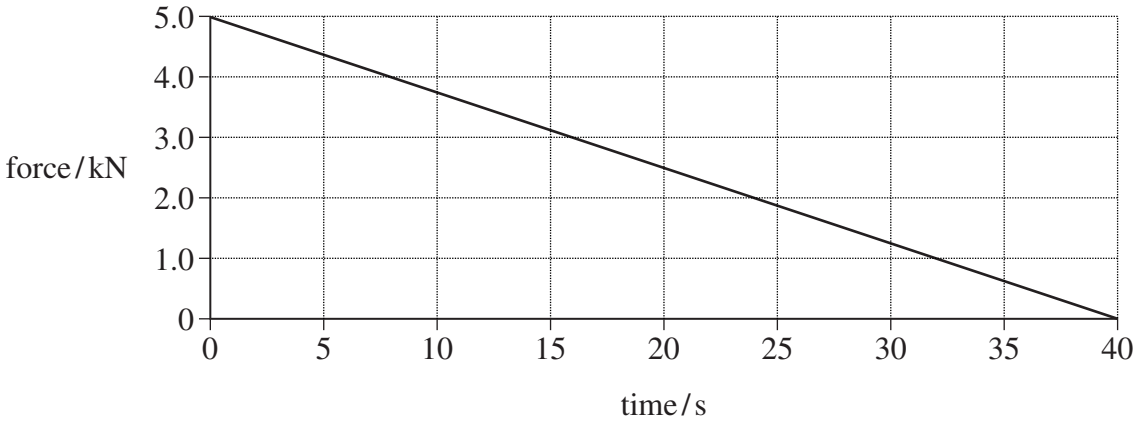
You are advised to spend approximately **45 minutes** on this section.

1 Which one of the following statements is correct?

The force acting on an object is equivalent to

A its change of momentum.
B the impulse it receives per second.
C the energy it gains per second.
D its acceleration per metre.

2 The graph shows how the force on a glider of mass 2000 kg changes with time as it is launched from a level track using a catapult.



Assuming the glider starts at rest what is its velocity after 40 s?

A 2.5 $m\,s^{-1}$
B 10 $m\,s^{-1}$
C 50 $m\,s^{-1}$
D 100 $m\,s^{-1}$

3 A gas molecule of mass m in a container moves with velocity v. If it makes an elastic collision at right angles to the walls of the container, what is the change in momentum of the molecule?

A zero
B $\frac{1}{2}mv$
C mv
D $2mv$

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4 A mass on the end of a string is whirled round in a horizontal circle at increasing speed until the string breaks. The subsequent path taken by the mass is

A a straight line along a radius of the circle.
B a horizontal circle.
C a parabola in a horizontal plane.
D a parabola in a vertical plane.

5 A particle of mass m moves in a circle of radius r at uniform speed, taking time T for each revolution. What is the kinetic energy of the particle?

A $\frac{\pi^2 mr}{T^2}$

B $\frac{\pi^2 mr^2}{T^2}$

C $\frac{2\pi^2 mr^2}{T}$

D $\frac{2\pi^2 mr^2}{T^2}$

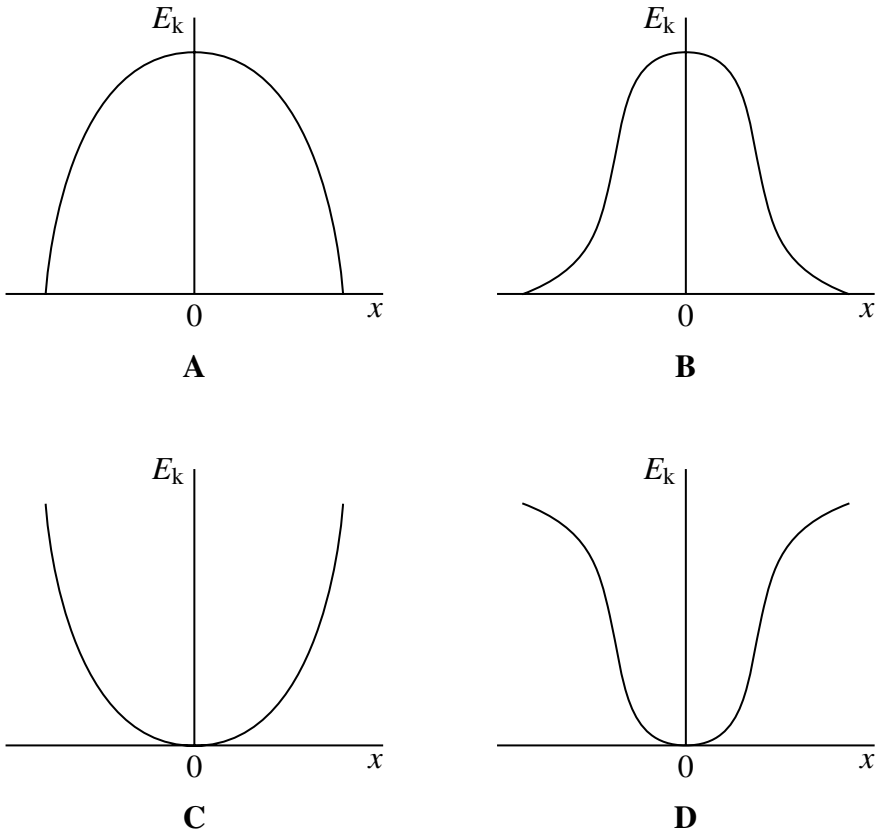
6 A body moves with simple harmonic motion of amplitude 0.90 m and period 8.9 s. What is the speed of the body when its displacement is 0.70 m?

A $0.11\ \text{m s}^{-1}$
B $0.22\ \text{m s}^{-1}$
C $0.40\ \text{m s}^{-1}$
D $0.80\ \text{m s}^{-1}$

Turn over for the next question

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7 Which graph, **A** to **D**, shows the variation of the kinetic energy, E_k, with displacement x for a particle performing simple harmonic motion?



8 The time period of oscillation of a simple pendulum of length l is the same as the time period of oscillation of a mass M attached to a vertical spring. The length and mass are then changed. Which row, **A** to **D**, in the table would give a simple pendulum with a time period twice that of the spring oscillations?

	new pendulum length	**new mass on spring**
A	$2l$	$2M$
B	$2l$	$\frac{M}{2}$
C	$\frac{l}{2}$	$2M$
D	$\frac{l}{2}$	$\frac{M}{2}$

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9 A projectile moves in a gravitational field. Which one of the following is a correct statement about the gravitational force acting on the projectile?

A The force is in the direction of the field.
B The force is in the opposite direction to that of the field.
C The force is at right angles to the field.
D The force is at an angle between 0° and 90° to the field.

10 The gravitational potential difference between the surface of a planet and a point P, 10 m above the surface, is $8.0\,J\,kg^{-1}$. Assuming a uniform field, what is the value of the gravitational field strength in the region between the planet's surface and P?

A $0.80\,N\,kg^{-1}$

B $1.25\,N\,kg^{-1}$

C $8.0\,N\,kg^{-1}$

D $80\,N\,kg^{-1}$

11 An artificial satellite of mass m is in a stable circular orbit of radius r around a planet of mass M. Which one of the following expressions gives the speed of the satellite? G is the universal gravitational constant.

A $\left(\frac{Gm}{r}\right)^{\frac{1}{2}}$

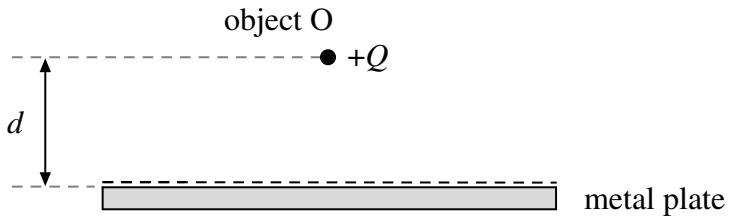
B $\left(\frac{GM}{r}\right)^{\frac{1}{2}}$

C $\frac{Gm}{r}$

D $\left(\frac{Gm}{r}\right)^{\frac{3}{2}}$

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12 A small object O carrying a charge $+Q$ is placed at a distance d from a metal plate that has an equal and opposite charge. The object is acted on by an electrostatic force F.



Which one of the following expressions has the same unit as F?

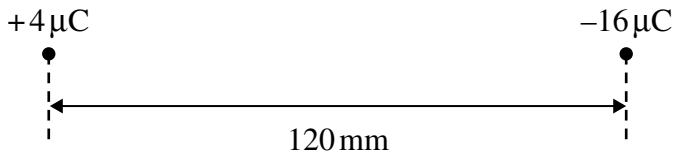
A $\dfrac{\varepsilon_0 Q^2}{d}$

B $\dfrac{\varepsilon_0 Q^2}{d^2}$

C $\dfrac{Q^2}{\varepsilon_0 d}$

D $\dfrac{Q^2}{\varepsilon_0 d^2}$

13

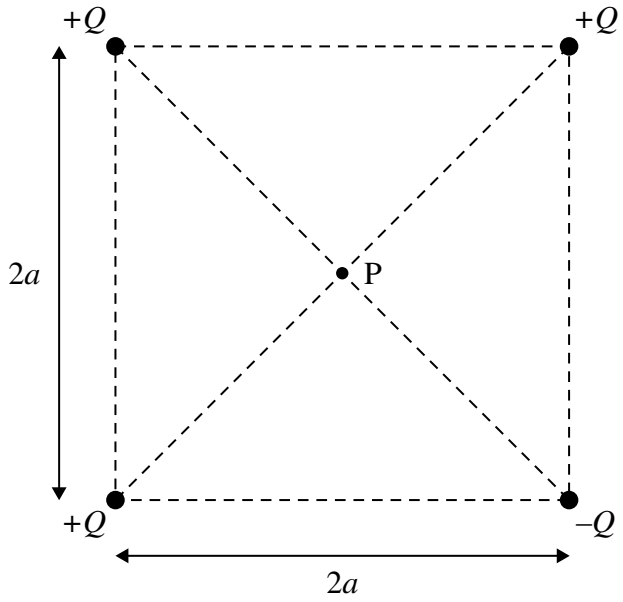


The diagram shows two charges, +4 μC and −16 μC, 120 mm apart. What is the distance from the +4 μC charge to the point between the two charges where the resultant electric potential is zero?

A 24 mm
B 40 mm
C 80 mm
D 96 mm

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14 The diagram shows four point charges at the corners of a square of side $2a$. What is the electric potential at P, the centre of the square?



A $\dfrac{Q}{2\sqrt{2}\pi\varepsilon_0 a}$

B $\dfrac{Q}{\sqrt{2}\pi\varepsilon_0 a}$

C $\dfrac{Q}{2\pi\varepsilon_0 a}$

D $\dfrac{Q}{4\pi\varepsilon_0 a}$

15 A 1 μF capacitor is charged using a **constant** current of 10 μA for 20 s. What is the energy finally stored by the capacitor?

A 2×10^{-3} J

B 2×10^{-2} J

C 4×10^{-2} J

D 4×10^{-1} J

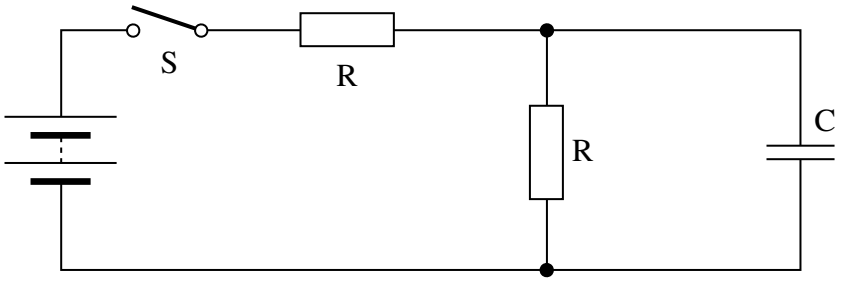
16 A 2.0 mF capacitor, used as the backup for a memory unit, has a potential difference of 5.0 V across it when fully charged. The capacitor is required to supply a constant current of 1.0 μA and can be used until the potential difference across it falls by 10%. How long can the capacitor be used for before it must be recharged?

A 10 s
B 100 s
C 200 s
D 1000 s

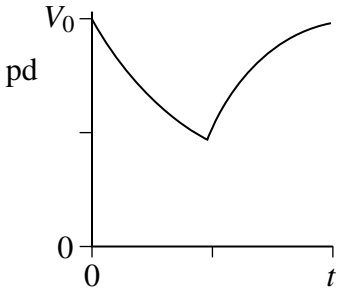
Turn over ▶

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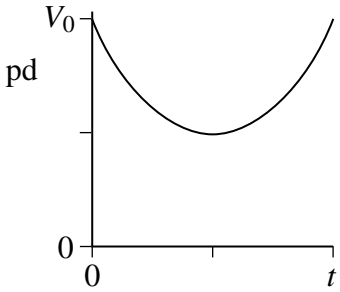
17 When switch S in the circuit is closed, the capacitor C is charged by the battery to a pd V_0. The switch is then opened until the capacitor pd decreases to $0.5\,V_0$, at which time S is closed again. The capacitor then charges back to V_0.



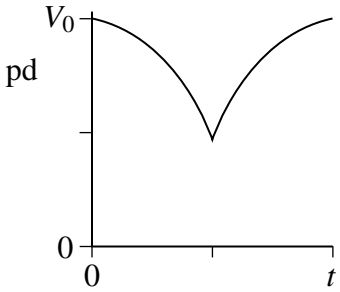
Which graph best shows how the pd across the capacitor varies with time, t, after S is opened?



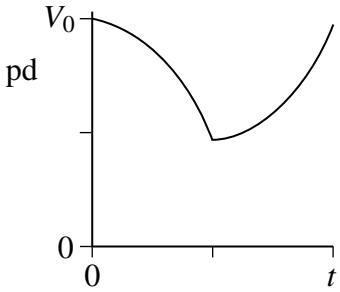
A



B



C



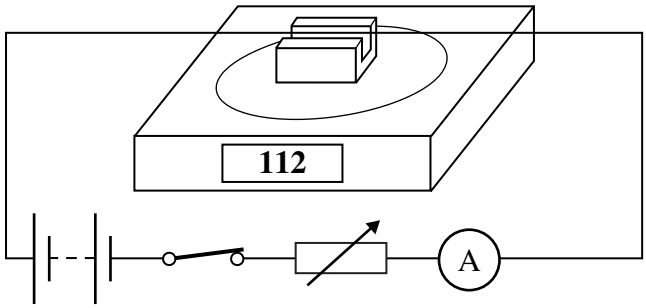
D

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18 When a capacitor discharges through a resistor it loses 50% of its charge in 10 s. What is the time constant of the capacitor-resistor circuit?

A 0.5 s
B 5 s
C 14 s
D 17 s

19 The diagram shows a rigidly-clamped straight horizontal current-carrying wire held mid-way between the poles of a magnet on a top pan balance. The wire is perpendicular to the magnetic field direction.



The balance, which was zeroed before the switch was closed, reads 112 g after the switch is closed. If the current is reversed and doubled, what will be the new reading on the balance?

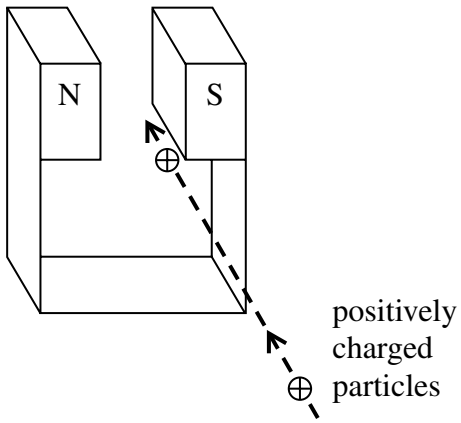
A –224 g
B –112 g
C zero
D 224 g

20 An electron moving with a constant speed enters a uniform magnetic field in a direction at right angles to the field. What is the subsequent path of the electron?

A A straight line in the direction of the field.
B A straight line in a direction opposite to that of the field.
C A circular arc in a plane perpendicular to the direction of the field.
D An elliptical arc in a plane perpendicular to the direction of the field.

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21 A jet of air carrying positively charged particles is directed horizontally between the poles of a strong magnet, as shown in the diagram.



In which direction are the charged particles deflected?

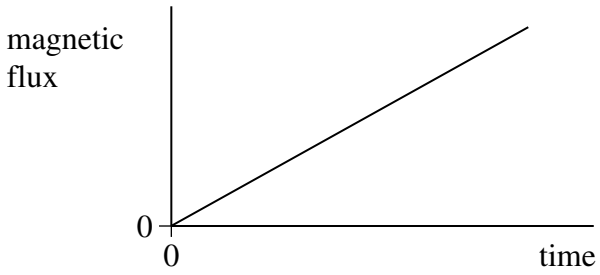
A upwards
B downwards
C towards the N pole of the magnet
D towards the S pole of the magnet

22 Which one of the following could **not** be used as a unit of force?

A $\mathrm{A\,T\,m}$
B $\mathrm{W\,s^{-2}}$
C $\mathrm{kg\,m\,s^{-2}}$
D $\mathrm{J\,m^{-1}}$

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23 The graph shows how the magnetic flux passing through a loop of wire changes with time.



What feature of the graph represents the magnitude of the emf induced in the coil?

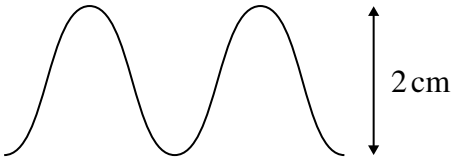
A the area enclosed between the graph line and the time axis
B the area enclosed between the graph line and the magnetic flux axis
C the inverse of the gradient of the graph
D the gradient of the graph

24 A coil rotating in a magnetic field produces the following voltage waveform when connected to an oscilloscope.



With the same oscilloscope settings, which one of the following voltage waveforms would be produced if the coil were rotated at twice the original speed?

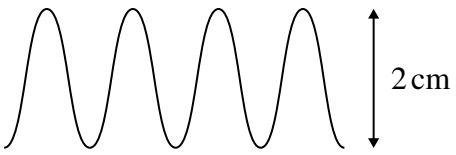
A



B



C



D



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25 A 230 V, 60 W lamp is connected to the output terminals of a transformer which has a 200 turn primary coil and a 2000 turn secondary coil. The primary coil is connected to an ac source with a variable output pd. The lamp lights at its normal brightness when the primary coil is supplied with an alternating current of 2.7 A.

What is the percentage efficiency of the transformer?

A 3%

B 10%

C 97%

D 100%

END OF QUESTIONS

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Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
5	
TOTAL	

General Certificate of Education
Advanced Level Examination
June 2010

Physics A PHYA4/2

Unit 4 Fields and Further Mechanics Section B

Friday 18 June 2010 9.00 am to 10.45 am

For this paper you must have:
- a calculator
- a ruler
- a Data and Formulae Booklet.

Time allowed
- The total time for both sections of this paper is 1 hour 45 minutes. You are advised to spend approximately one hour on this section.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Answers written in margins or on blank pages will not be marked.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this section is 50.
- You are expected to use a calculator where appropriate.
- A *Data and Formulae Booklet* is provided as a loose insert.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use specialist vocabulary where appropriate.

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Do not write outside the box

Answer **all** questions.

You are advised to spend approximately **one hour** on this section.

1 (a) State Newton's law of gravitation.

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(2 marks)

1 (b) In 1798 Cavendish investigated Newton's law by measuring the gravitational force between two unequal uniform lead spheres. The radius of the larger sphere was 100 mm and that of the smaller sphere was 25 mm.

1 (b) (i) The mass of the smaller sphere was 0.74 kg. Show that the mass of the larger sphere was about 47 kg.

density of lead = 11.3×10^3 kg m^{-3}

(2 marks)

1 (b) (ii) Calculate the gravitational force between the spheres when their surfaces were in contact.

answer = ... N

(2 marks)

Do not write outside the box

1 (c) Modifications, such as increasing the size of each sphere to produce a greater force between them, were considered in order to improve the accuracy of Cavendish's experiment. Describe and explain the effect on the calculations in part (b) of doubling the radius of both spheres.

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(4 marks)

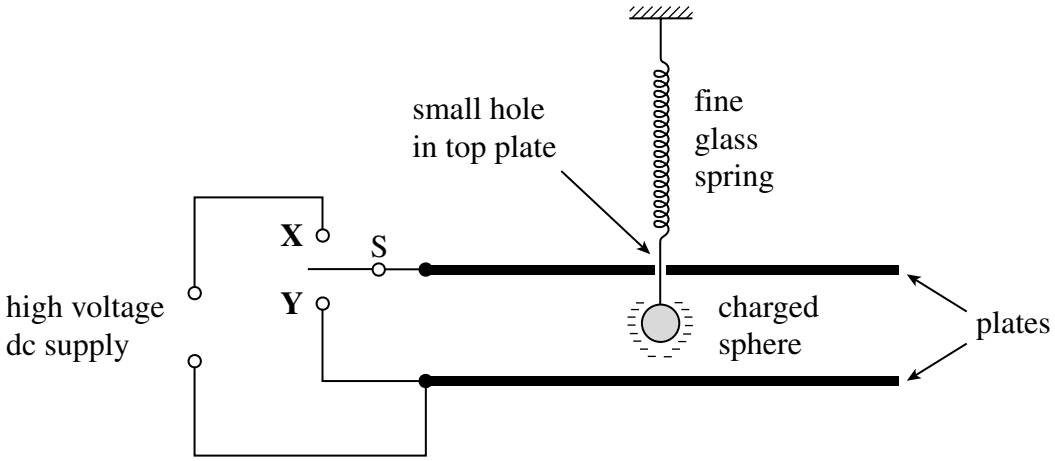
10

Turn over for the next question

Do not write outside the box

2 A small negatively charged sphere is suspended from a fine glass spring between parallel horizontal metal plates, as shown in **Figure 1**.

Figure 1



2 (a) Initially the plates are uncharged. When switch S is set to position **X**, a high voltage dc supply is connected across the plates. This causes the sphere to move vertically upwards so that eventually it comes to rest 18 mm higher than its original position.

2 (a) (i) State the direction of the electric field between the plates.

.....

(1 mark)

2 (a) (ii) The spring constant of the glass spring is $0.24\,\text{N}\,\text{m}^{-1}$. Show that the force exerted on the sphere by the electric field is $4.3 \times 10^{-3}\,\text{N}$.

(1 mark)

Do not write outside the box

2 (a) (iii) The pd applied across the plates is 5.0 kV. If the charge on the sphere is -4.1×10^{-8} C, determine the separation of the plates.

answer = ... m

(3 marks)

2 (b) Switch S is now moved to position **Y**.

2 (b) (i) State and explain the effect of this on the electric field between the plates.

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(2 marks)

2 (b) (ii) With reference to the forces acting on the sphere, explain why it starts to move with simple harmonic motion.

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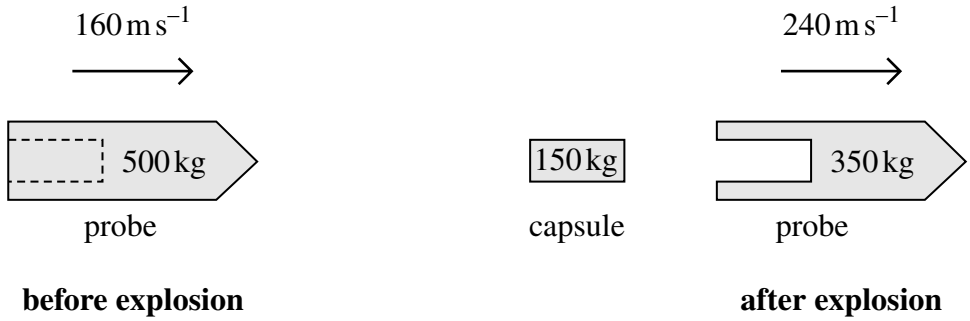
(3 marks)

10

Do not write outside the box

3 Deep space probes often carry modules which may be ejected from them by an explosion. A space probe of total mass 500 kg is travelling in a straight line through free space at 160 m s^{-1} when it ejects a capsule of mass 150 kg explosively, releasing energy. Immediately after the explosion the probe, now of mass 350 kg, continues to travel in the original straight line but travels at 240 m s^{-1}, as shown in **Figure 2**.

Figure 2



3 (a) Discuss how the principles of conservation of momentum and conservation of energy apply in this instance.

The quality of your written communication will be assessed in this question.

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(6 marks)

Do not write outside the box

3 (b) (i) Calculate the magnitude of the velocity of the capsule immediately after the explosion and state its direction of movement.

magnitude of velocity = ... $m\,s^{-1}$

direction of movement .....

(3 marks)

3 (b) (ii) Determine the total amount of energy given to the probe and capsule by the explosion.

answer = ... J

(4 marks)

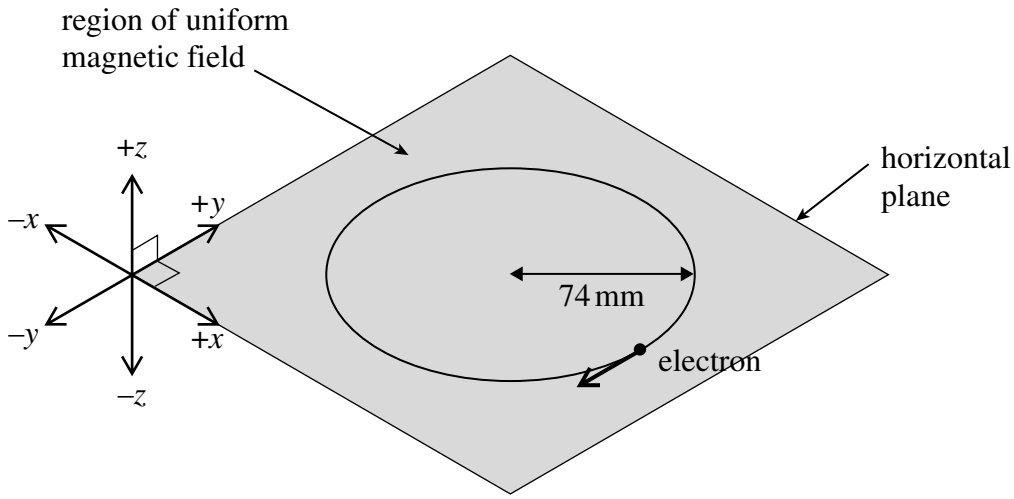
13

Turn over for the next question

Do not write outside the box

4 When travelling in a vacuum through a uniform magnetic field of flux density 0.43 mT, an electron moves at constant speed in a horizontal circle of radius 74 mm, as shown in **Figure 3**.

Figure 3



4 (a) When viewed from vertically above, the electron moves clockwise around the horizontal circle. In which one of the six directions shown on **Figure 3**, $+x$, $-x$, $+y$, $-y$, $+z$ or $-z$, is the magnetic field directed?

direction of magnetic field .....

(1 mark)

4 (b) Explain why the electron is accelerating even though it is travelling at constant speed.

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(2 marks)

Do not write outside the box

4 (c) (i) By considering the centripetal force acting on the electron, show that its speed is $5.6 \times 10^6\,\text{m}\,\text{s}^{-1}$.

(2 marks)

4 (c) (ii) Calculate the angular speed of the electron, giving an appropriate unit.

answer = ...

(2 marks)

4 (c) (iii) How many times does the electron travel around the circle in one minute?

answer = ...

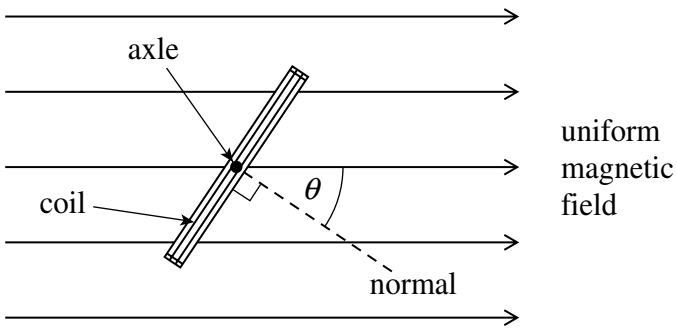
(2 marks)

9

Do not write outside the box

5 **Figure 4** shows an end view of a simple electrical generator. A rectangular coil is rotated in a uniform magnetic field with the axle at right angles to the field direction. When in the position shown in **Figure 4** the angle between the direction of the magnetic field and the normal to the plane of the coil is θ.

Figure 4



5 (a) The coil has 50 turns and an area of $1.9 \times 10^{-3}\,m^2$. The flux density of the magnetic field is $2.8 \times 10^{-2}\,T$. Calculate the flux linkage for the coil when θ is 35°, expressing your answer to an appropriate number of significant figures.

answer = ... Wb turns

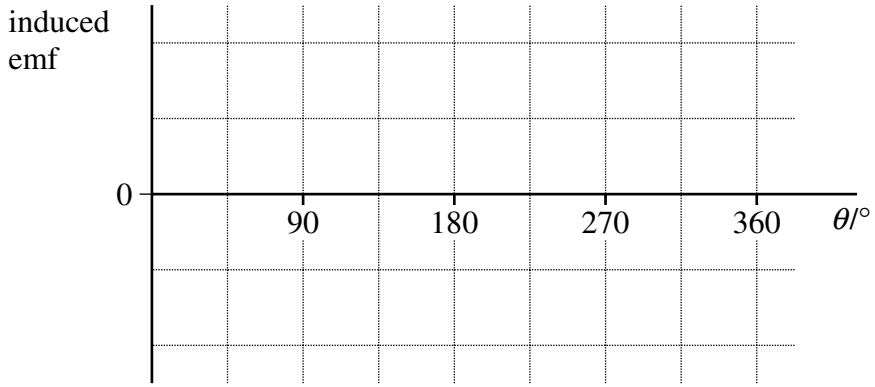
(3 marks)

Do not write outside the box

5 (b) The coil is rotated at constant speed, causing an emf to be induced.

5 (b) (i) Sketch a graph on the outline axes to show how the induced emf varies with angle θ during one complete rotation of the coil, starting when $\theta = 0$. Values are not required on the emf axis of the graph.

(1 mark)



5 (b) (ii) Give the value of the flux linkage for the coil at the positions where the emf has its greatest values.

answer = ... Wb turns

(1 mark)

5 (b) (iii) Explain why the magnitude of the emf is greatest at the values of θ shown in your answer to part (b)(i).

.....

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.....

(3 marks)

END OF QUESTIONS

8

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There are no questions printed on this page

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Version 1.0



General Certificate of Education
June 2010

Physics A PHYA4

Fields and Further Mechanics

Unit 4

Final

Mark Scheme

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Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation meeting attended by all examiners and is the scheme which was used by them in this examination. The standardisation meeting ensures that the mark scheme covers the candidates' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for the standardisation meeting each examiner analyses a number of candidates' scripts: alternative answers not already covered by the mark scheme are discussed at the meeting and legislated for. If, after this meeting, examiners encounter unusual answers which have not been discussed at the meeting they are required to refer these to the Principal Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of candidates' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

Further copies of this Mark Scheme are available to download from the AQA Website: www.aqa.org.uk

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Instructions to Examiners

1 Give due credit for alternative treatments which are correct. Give marks for what is correct in accordance with the mark scheme; do not deduct marks because the attempt falls short of some ideal answer. Where marks are to be deducted for particular errors, specific instructions are given in the marking scheme.

2 Do not deduct marks for poor written communication. Refer the scripts to the Awards meeting if poor presentation forbids a proper assessment. In each paper, candidates are assessed on their quality of written communication (QWC) in designated questions (or part-questions) that require explanations or descriptions. The criteria for the award of marks on each such question are set out in the mark scheme in three bands in the following format. The descriptor for each band sets out the expected level of the quality of written communication of physics for each band. Such quality covers the scope (eg relevance, correctness), sequence and presentation of the answer. Amplification of the level of physics expected in a good answer is set out in the last row of the table. To arrive at the mark for a candidate, their work should first be assessed holistically (ie in terms of scope, sequence and presentation) to determine which band is appropriate then in terms of the degree to which the candidate's work meets the expected level for the band.

QWC	descriptor	mark range
Good - Excellent	*see specific mark scheme*	**5-6**
Modest - Adequate	*see specific mark scheme*	**3-4**
Poor - Limited	*see specific mark scheme*	**1-2**
The description and/or explanation expected in a good answer should include a coherent account of the following points: *see specific mark scheme*		

Answers given as bullet points should be considered in the above terms. Such answers without an 'overview' paragraph in the answer would be unlikely to score in the top band.

3 An arithmetical error in an answer will cause the candidate to lose one mark and should be annotated AE if possible. The candidate's incorrect value should be carried through all subsequent calculations for the question and, if there are no subsequent errors, the candidate can score all remaining marks.

4 The use of significant figures is tested **once** on each paper in a designated question or part-question. The numerical answer on the designated question should be given to the same number of significant figures as there are in the data given in the question or to one more than this number. All other numerical answers should not be considered in terms of significant figures.

5 Numerical answers **presented** in non-standard form are undesirable but should not be penalised. Arithmetical errors by candidates resulting from use of non-standard form in a candidate's working should be penalised as in point 3 above. Incorrect numerical prefixes and the use of a given diameter in a geometrical formula as the radius should be treated as arithmetical errors.

6 Knowledge of units is tested on designated questions or parts of questions in each a paper. On each such question or part-question, unless otherwise stated in the mark scheme, the mark scheme will show a mark to be awarded for the numerical value of the answer and a further mark for the correct unit. No penalties are imposed for incorrect or omitted units at intermediate stages in a calculation or at the final stage of a non-designated 'unit' question.

7 All other procedures including recording of marks and dealing with missing parts of answers will be clarified in the standardising procedures.

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GCE Physics, Specification A, PHYA4, Fields and Further Mechanics

Section A

This component is an objective test for which the following list indicates the correct answers used in marking the candidates' responses.

	Keys to Objective Test Questions	
	1 B **2** C **3** D **4** D **5** D **6** C **7** A **8** B **9** A **10** A **11** B **12** D **13** A **14** A **15** B **16** D **17** A **18** C **19** A **20** C **21** B **22** B **23** D **24** C **25** C	

Section B

Question 1		
(a)	force of attraction between two point masses (or particles) ✓ proportional to product of masses ✓ inversely proportional to square of distance between them ✓ [**alternatively** quoting an equation, $F = \frac{GM_1M_2}{r^2}$ with all terms defined ✓ reference to point masses (or particles) **or** *r* is distance between centres ✓ F identified as an attractive force ✓]	**max 2**
(b) (i)	mass of larger sphere $M_L (= \frac{4}{3}\pi r^3\rho) = \frac{4}{3} \pi \times (0.100)^3 \times 11.3 \times 10^3$ ✓ = 47(.3) (kg) ✓ [**alternatively** use of $M \propto r^3$ gives $\frac{M_L}{0.74} = \left(\frac{100}{25}\right)^3$ ✓ (= 64) and M_L = 64 × 0.74 = 47(.4) (kg) ✓]	**2**
(b) (ii)	gravitational force F $\left(= \frac{GM_L M_S}{x^2}\right) = \frac{6.67 \times 10^{-11} \times 47.3 \times 0.74}{0.125^2}$ ✓ = 1.5×10^{-7} (N) ✓	**2**
(c)	for the spheres, mass ∝ volume (or $\propto r^3$, or $M = \frac{4}{3}\pi r^3\rho$) ✓ mass of either sphere would be 8 × greater (378 kg, 5.91 kg) ✓ this would make the force 64 × greater ✓ but separation would be doubled causing force to be 4 × smaller ✓ net effect would be to make the force (64/4) = 16 × greater ✓ (ie 2.38×10^{-6} N)	**max 4**
	Total	**10**

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Question 2			
(a)	(i)	(vertically) downwards [**or** top to bottom, or down the page] ✓	**1**
(a)	(ii)	force on sphere $F\ (=kx)$ = $0.24 \times 18 \times 10^{-3}$ ✓ (= 4.32×10^{-3} N)	**1**
(a)	(iii)	**use of** $F = EQ$ gives $E = \frac{4.32 \times 10^{-3}}{41 \times 10^{-9}}$ ✓ (= 1.05×10^{5} V m^{-1}) **use of** $E = \frac{V}{d}$ gives separation $d = \frac{5.0 \times 10^{3}}{1.05 \times 10^{5}}$ ✓ = 4.8×10^{-2} (m) ✓ (4.76×10^{-2})	**3**
(b)	(i)	electric field becomes zero (or ceases to exist) ✓ flow of charge (or electrons) from one plate to the other [**or** plates discharge] ✓ (until) pd across plates becomes zero [**or** no pd across plates, **or** plates at same potential] ✓	**max 2**
(b)	(ii)	net downward force on sphere (when E becomes zero) [**or** gravitational force acts on sphere, **or** force is weight] ✓ this force extends spring ✓ force (or acceleration) is proportional to (change in) extension of spring ✓ acceleration is in opposite direction to displacement (or towards equilibrium) ✓ for shm, acceleration ∝ (–) displacement [**or** for shm, force ∝ (–) displacement] ✓	**max 3**
		Total	**10**

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Question 3		
(a)	**The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.** The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. **High Level (Good to excellent): 5 or 6 marks** The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. The candidate states that momentum is conserved, supported by reasoning to explain why the conditions required for momentum conservation are satisfied in this case. The candidate also gives a statement that total energy is conserved, giving detailed consideration of the energy conversions which take place, described in the correct sequence, when there is an explosion on a body that is already moving. **Intermediate Level (Modest to adequate): 3 or 4 marks** The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. The candidate states that momentum is conserved, but the reasoning is much more limited. **and/or** There is a statement that (total) energy is conserved, with basic understanding that some energy is released by the explosion. **Low Level (Poor to limited): 1 or 2 marks** The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. The candidate indicates that either momentum or energy is conserved, or that both are conserved. There are very limited attempts to explain either of them.	**max 6**

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		The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences in this case. **Momentum** • momentum is conserved because there are no external forces acting on the overall system (probe plus capsule) – or because it's free space • they are moving in free space and are therefore so far from large masses that gravitational forces are negligible • during the explosion, there are equal and opposite forces acting between the probe and the capsule • these are internal forces that act within the overall system • because momentum has to be conserved, and it is a vector, the capsule must move along the original line of movement after the explosion **Energy** • total energy is always conserved in any physical process because energy can be neither created nor destroyed • however, energy may be converted from one form to another • the probe is already moving and has kinetic energy • in the explosion, some chemical energy is converted into kinetic energy (and some energy is lost in heating the surroundings) • the system of probe and capsule has more kinetic energy than the probe had originally, because some kinetic energy is released by the explosion	
(b)	(i)	conservation of momentum gives $(500 \times 160) = 150\ v + (350 \times 240)$ ✓ from which $v = (-)26(.7)$ (m s^{-1}) ✓ direction: opposite horizontal direction to larger fragment [**or** to the left, **or** backwards] ✓	**3**
(b)	(ii)	initial $E_k = ½ \times 500 \times 160^2$ ✓ (= 6.40×10^6 J) final $E_k = (½ \times 350 \times 240^2) + (½ \times 150 \times 26.7^2)$ ✓ (= 1.01×10^7 J) energy released by explosion = final E_k – initial E_k ✓ = 3.7×10^6 (J) ✓	**4**
		Total	**13**

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Question 4		
(a)	magnetic field direction: $-z$ ✓	**1**
(b)	direction changes meaning that velocity is not constant ✓ acceleration involves change in velocity (or acceleration is rate of change of velocity) ✓ [**alternatively** magnetic force on electron acts perpendicular to its velocity ✓ ∴force changes direction of movement causing acceleration ✓]	**2**
(c) (i)	$BQv = \frac{mv^2}{r}$ ✓ gives $v \left(= \frac{BQr}{m}\right)$ $= \frac{0.43 \times 10^{-3} \times 1.60 \times 10^{-19} \times 74 \times 10^{-3}}{9.11 \times 10^{-31}}$ ✓ (= 5.59×10^6 m s^{-1})	**2**
(c) (ii)	angular speed $\omega \left(= \frac{v}{r}\right) = \frac{5.59 \times 10^6}{74 \times 10^{-3}} = 7.5(5) \times 10^7$ ✓ *unit*: rad s^{-1} ✓ (accept s^{-1})	**2**
(c) (iii)	frequency of electron's orbit $f \left(= \frac{\omega}{2\pi}\right) = \frac{7.55 \times 10^7}{2\pi}$ ✓ (= 1.20×10^7 s^{-1}) number of transits min^{-1} = $1.20 \times 10^7 \times 60 = 7.2 \times 10^8$ ✓ [**alternatively** orbital period $\left(= \frac{2\pi r}{v}\right) = \frac{2\pi \times 74 \times 10^{-3}}{5.59 \times 10^6}$ [**or** $\left(= \frac{2\pi}{\omega}\right) = \frac{2\pi}{7.55 \times 10^{-7}}$] ✓ (= 8.32×10^{-8} s) number of transits min^{-1} = $\frac{60}{8.32 \times 10^{-8}} = 7.2 \times 10^8$ ✓]	**2**
	Total	**9**

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Question 5		
(a)	flux linkage $(= N\phi = BAN\cos\theta)$ $= 2.8 \times 10^{-2} \times 1.9 \times 10^{-3} \times 50 \times \cos 35°$ ✓ $= 2.2 \times 10^{-3}$ (Wb turns) ✓ answer must be to **2 sf** only ✓	**3**
(b) (i)	reasonable sine curve drawn on axes, showing just one cycle, starting at emf = 0 ✓	**1**
(b) (ii)	the flux linkage in these positions is **zero** ✓	**1**
(b) (iii)	induced emf $\propto$ (or =) rate of change of flux (linkage) ✓ flux (linkage) through the coil changes as it is rotated ✓ from maximum at θ = 0, 180° to zero at 90° and 270° ✓ rate of change is greatest when plane of coil is parallel to *B* [**or** reference to $\varepsilon = BAN\omega \sin \omega t$, **or** $\varepsilon = BAN\omega \sin \theta$] ✓ because coil then cuts flux lines perpendicularly [**or** $\varepsilon = BAN\omega \sin \omega t$ shows ε is greatest when ωt = 90° or 270°] ✓	**max 3**
	Total	**8**

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Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

General Certificate of Education
Advanced Level Examination
January 2010

Physics A PHYA4/1

Unit 4 Fields and Further Mechanics
Section A

Thursday 28 January 2010 1.30 pm to 3.15 pm

In addition to this paper you will require:
- an objective test answer sheet
- a black ink or black ball-point pen
- a calculator
- a question paper/answer book for Section B (enclosed).

Time allowed
- The total time for both sections of this paper is 1 hour 45 minutes. You are advised to spend approximately 45 minutes on this section.

Instructions
- Use black ink or black ball-point pen. Do **not** use pencil.
- Answer **all** questions in this section.
- For each question there are four responses. When you have selected the response which you think is the most appropriate answer to a question, mark this response on your answer sheet.
- Mark all responses as instructed on your answer sheet. If you wish to change your answer to a question, follow the instructions on your answer sheet.
- Do all rough work in this book **not** on the answer sheet.

Information
- The maximum mark for this section is 25.
- Section A and Section B of this paper together carry 20% of the total marks for Physics Advanced.
- All questions in Section A carry equal marks. No deductions will be made for incorrect answers.
- A *Data and Formulae Booklet* is provided as a loose insert.
- The question paper/answer book for Section B is enclosed within this question paper.

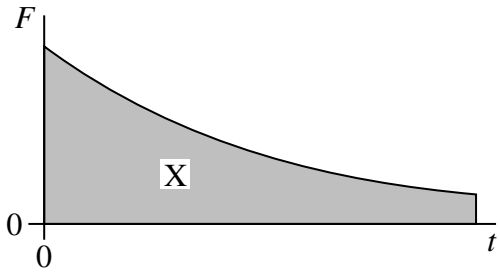
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Multiple choice questions

Each of Questions **1** to **25** is followed by four responses, **A**, **B**, **C** and **D**. For each question select the best response and mark its letter on the answer sheet.

You are advised to spend approximately **45 minutes** on this section.

1 The graph shows the variation with time, t, of the force, F, acting on a body.



What physical quantity does the area X represent?

A the displacement of the body
B the acceleration of the body
C the change in momentum of the body
D the change in kinetic energy of the body

2 Water of density $1000\,\text{kg}\,\text{m}^{-3}$ flows out of a garden hose of cross-sectional area $7.2 \times 10^{-4}\,\text{m}^2$ at a rate of $2.0 \times 10^{-4}\,\text{m}^3$ per second. How much momentum is carried by the water leaving the hose per second?

A $5.6 \times 10^{-5}\,\text{N s}$
B $5.6 \times 10^{-2}\,\text{N s}$
C $0.20\,\text{N s}$
D $0.72\,\text{N s}$

3 Which row, **A** to **D**, in the table correctly shows the quantities conserved in an inelastic collision?

	mass	**momentum**	**kinetic energy**	**total energy**
A	conserved	not conserved	conserved	conserved
B	not conserved	conserved	conserved	not conserved
C	conserved	conserved	conserved	conserved
D	conserved	conserved	not conserved	conserved

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4 What is the angular speed of a point on the Earth's equator?

A $7.3 \times 10^{-5}\,\text{rad}\,\text{s}^{-1}$
B $4.2 \times 10^{-3}\,\text{rad}\,\text{s}^{-1}$
C $2.6 \times 10^{-1}\,\text{rad}\,\text{s}^{-1}$
D $15\,\text{rad}\,\text{s}^{-1}$

5 Which one of the following does **not** involve a centripetal force?

A an electron in orbit around a nucleus
B a car going round a bend
C an α particle in a magnetic field, travelling at right angles to the field
D an α particle in a electric field, travelling at right angles to the field

6 Which one of the following gives the phase difference between the particle velocity and the particle displacement in simple harmonic motion?

A $\frac{\pi}{4}$ rad

B $\frac{\pi}{2}$ rad

C $\frac{3\pi}{4}$ rad

D 2π rad

7 A mass *M* hangs in equilibrium on a spring. *M* is made to oscillate about the equilibrium position by pulling it down 10 cm and releasing it. The time for *M* to travel back to the equilibrium position for the first time is 0.50 s. Which row, **A** to **D**, in the table is correct for these oscillations?

	amplitude / cm	**period / s**
A	10	1.0
B	10	2.0
C	20	2.0
D	20	1.0

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8 Which one of the following statements concerning forced vibrations and resonance is correct?

A An oscillating body that is not resonating will return to its natural frequency when the forcing vibration is removed.
B At resonance, the displacement of the oscillating body is 180° out of phase with the forcing vibration.
C A pendulum with a dense bob is more heavily damped than one with a less dense bob of the same size.
D Resonance can only occur in mechanical systems.

9 Two identical spheres exert a gravitational force F on each other. What is the gravitational force between two spheres, each twice the mass of one of the original spheres, when the separation of their centres is twice the original separation?

A F
B $2F$
C $4F$
D $8F$

10 A planet of mass M and radius R rotates so rapidly that loose material at the equator only just remains on the surface. What is the period of rotation of the planet?

G is the universal gravitational constant.

A $2\pi\sqrt{\frac{R}{GM}}$

B $2\pi\sqrt{\frac{R^2}{GM}}$

C $2\pi\sqrt{\frac{GM}{R^3}}$

D $2\pi\sqrt{\frac{R^3}{GM}}$

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11 The radius of a certain planet is x times the radius of the Earth and its surface gravitational field strength is y times that of the Earth.

Which one of the following gives the ratio $\left(\frac{\text{mass of the planet}}{\text{mass of the Earth}}\right)$?

A xy

B x^2y

C xy^2

D x^2y^2

12 Which one of the following could be a unit of gravitational potential?

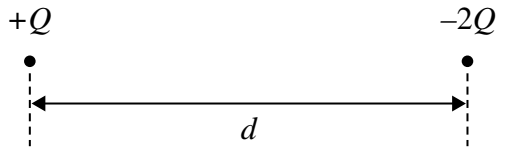
A N

B J

C N kg^{-1}

D J kg^{-1}

13



The diagram shows two particles at a distance d apart. One particle has charge $+Q$ and the other $-2Q$. The two particles exert an electrostatic force of attraction, F, on each other. Each particle is then given an additional charge $+Q$ and their separation is increased to a distance $2d$. Which one of the following gives the force that now acts between the two particles?

A an attractive force of $\frac{F}{4}$

B a repulsive force of $\frac{F}{4}$

C an attractive force of $\frac{F}{2}$

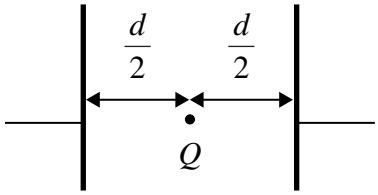
D a repulsive force of $\frac{F}{2}$

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14 Which one of the following statements about a charged particle in an electric field is correct?

A No work is done when a charged particle moves along a field line.
B No force acts on a charged particle when it moves along a field line.
C No work is done when a charged particle moves along a line of constant potential.
D No force acts on a charged particle when it moves along a line of constant potential.

15 Two parallel metal plates separated by a distance d have a potential difference V across them. What is the magnitude of the electrostatic force acting on a charge Q placed midway between the plates?



A $\frac{2VQ}{d}$

B $\frac{VQ}{d}$

C $\frac{VQ}{2d}$

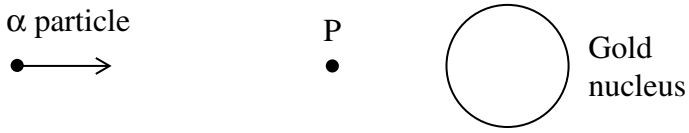
D $\frac{Qd}{V}$

16 Which one of the following statements about *electric field strength* and *electric potential* is **incorrect**?

A Electric potential is a scalar quantity.
B Electric field strength is a vector quantity.
C Electric potential is zero whenever the electric field strength is zero.
D The potential gradient is proportional to the electric field strength.

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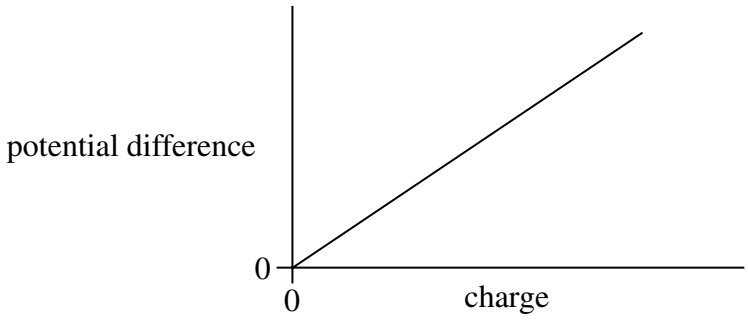
17



An α particle travels towards a gold nucleus and at P reverses its direction.
Which one of the following statements is **incorrect**?

A The electric potential energy of the α particle is a maximum at P.
B The kinetic energy of the α particle is a minimum at P.
C The total energy of the α particle is zero.
D The total energy of the α particle has a constant positive value.

18 The graph shows how the potential difference across a capacitor varies with the charge stored by it.



Which one of the following statements is correct?

A The gradient of the line equals the capacitance of the capacitor.
B The gradient of the line equals the energy stored by the capacitor.
C The reciprocal of the gradient equals the energy stored by the capacitor.
D The reciprocal of the gradient equals the capacitance of the capacitor.

19 An initially uncharged capacitor of capacitance 10 μF is charged by a **constant** current of 200 μA. After what time will the potential difference across the capacitor be 2000 V?

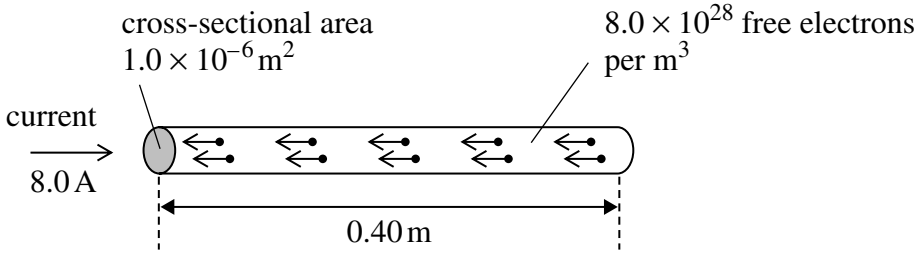
A 50 s
B 100 s
C 200 s
D 400 s

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20 A 1000 μF capacitor, X, and a 100 μF capacitor, Y, are charged to the same potential difference. Which row, **A** to **D**, in the table gives correct ratios of charge stored and energy stored by the capacitors?

	$\frac{\text{charge stored by X}}{\text{charge stored by Y}}$	$\frac{\text{energy stored by X}}{\text{energy stored by Y}}$
A	1	1
B	1	10
C	10	1
D	10	10

21



A current of 8.0 A is passed through a conductor of length 0.40 m and cross-sectional area $1.0 \times 10^{-6}\,m^2$. The conductor contains 8.0×10^{28} free electrons per m^3. When the conductor is at right angles to a magnetic field of flux density 0.20 T, it experiences a magnetic force. What is the average magnetic force that acts on **one** of the free electrons in the wire?

A 8.0×10^{-30} N

B 5.0×10^{-29} N

C 8.0×10^{-24} N

D 2.0×10^{-23} N

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22 An electron moves due North in a horizontal plane with uniform speed. It enters a uniform magnetic field directed due South in the same plane. Which one of the following statements concerning the motion of the electron in the magnetic field is correct?

A It accelerated due West.
B It slows down to zero speed and then accelerates due South.
C It continues to move North with its original speed.
D It is accelerated due North.

23 Particles of mass m, each carrying charge Q and travelling with speed v, enter a magnetic field of flux density B at right angles. Which one of the following changes would produce an increase in the radius of the path of the particles?

A an increase in Q
B an increase in m
C a decrease in v
D an increase in B

24 The magnetic flux through a coil of N turns is increased uniformly from zero to a maximum value in a time t. An emf, E, is induced across the coil.
What is the maximum value of the magnetic flux through the coil?

A $\frac{Et}{N}$

B $\frac{N}{Et}$

C EtN

D $\frac{E}{Nt}$

25 An aircraft, of wing span 60 m, flies horizontally at a speed of $150\,\text{m}\,\text{s}^{-1}$, If the vertical component of the Earth's magnetic field in the region of the plane is 1.0×10^{-5} T, what emf is induced across the wing tips of the plane?

A 0.09 V
B 0.90 V
C 9.0 V
D 90 V

END OF QUESTIONS

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Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
TOTAL	

General Certificate of Education
Advanced Level Examination
January 2010

Physics A PHYA4/2

Unit 4 Fields and Further Mechanics
Section B

Thursday 28 January 2010 1.30 pm to 3.15 pm

For this paper you must have:
- a calculator
- a ruler
- a Data and Formulae Booklet.

Time allowed
- The total time for both sections of this paper is 1 hour 45 minutes. You are advised to spend approximately one hour on this section.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Answers written in margins or on blank pages will not be marked.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this section is 50.
- You are expected to use a calculator where appropriate.
- A *Data and Formulae Booklet* is provided as a loose insert.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use specialist vocabulary where appropriate.

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Answer **all** questions.

You are advised to spend approximately **one hour** on this section.

1 (a) Describe the energy changes that take place as the bob of a simple pendulum makes one complete oscillation, starting at its maximum displacement.

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(2 marks)

1 (b)

Figure 1

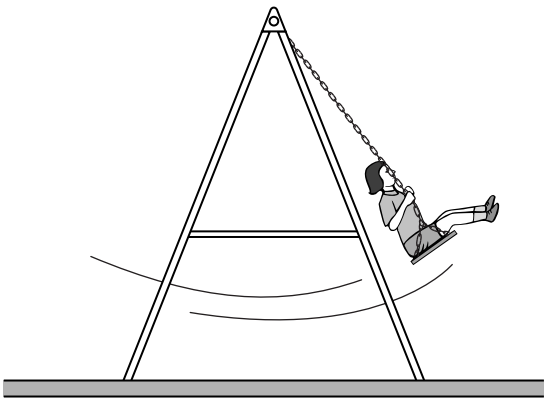


Figure 1 shows a young girl swinging on a garden swing. You may assume that the swing behaves as a simple pendulum. Ignore the mass of chains supporting the seat throughout this question, and assume that the effect of air resistance is negligible. 15 complete oscillations of the swing took 42s.

1 (b) (i) Calculate the distance from the top of the chains to the centre of mass of the girl and seat. Express your answer to an appropriate number of significant figures.

answer = ... m

(4 marks)

Areas outside the box will not be scanned for marking

1 (b) (ii) To set her swinging, the girl and seat were displaced from equilibrium and released from rest. This initial displacement of the girl raised the centre of mass of the girl and seat 250 mm above its lowest position. If the mass of the girl was 18 kg, what was her kinetic energy as she first passed through this lowest point?

answer = ... J

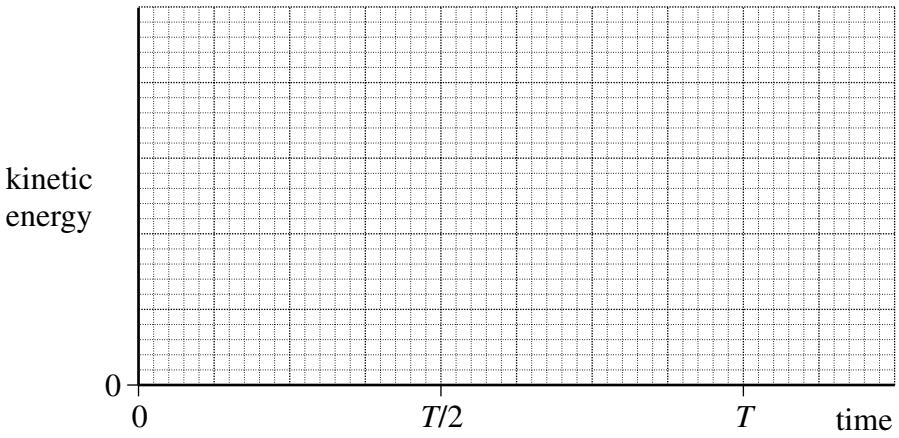
(2 marks)

1 (b) (iii) Calculate the maximum speed of the girl during the first oscillation.

answer = ... $m\,s^{-1}$

(1 mark)

1 (c) **Figure 2**



On **Figure 2** draw a graph to show how the kinetic energy of the girl varied with time during the first complete oscillation, starting at the time of her release from maximum displacement. On the horizontal axis of the graph, *T* represents the period of the swing. You do not need to show any values on the vertical axis.

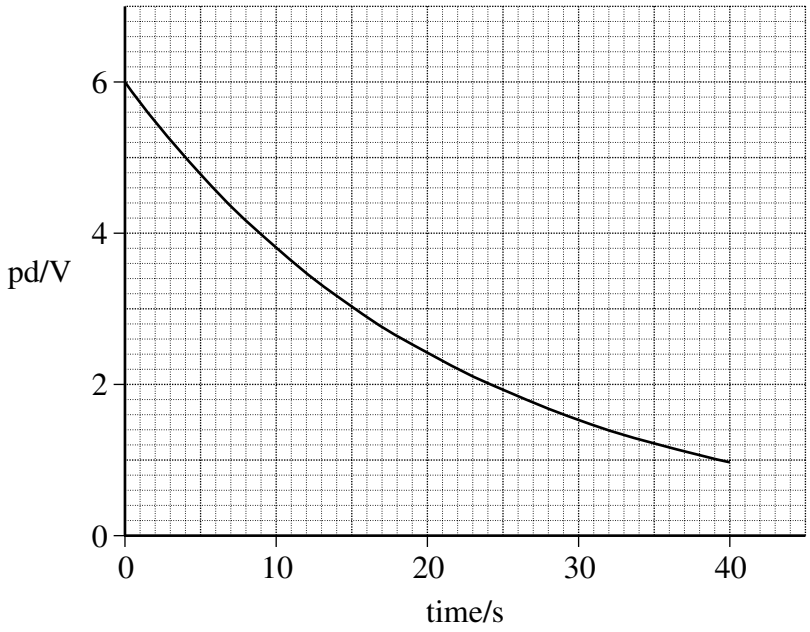
(3 marks)

12

Turn over ▶

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2 (a) A capacitor, initially charged to a pd of 6.0 V, was discharged through a 100 kΩ resistor. A datalogger was used to record the pd across the capacitor at frequent intervals. The graph shows how the pd varied with time during the first 40 s of discharge.



2 (a) (i) Calculate the initial discharge current.

answer = ... A

(1 mark)

2 (a) (ii) Use the graph to determine the time constant of the circuit, giving an appropriate unit.

answer = ...

(4 marks)

Areas outside the box will not be scanned for marking

2 (a) (iii) Hence calculate the capacitance of the capacitor.

answer = ... μF

(1 mark)

2 (a) (iv) Show that the capacitor lost 90% of the energy it stored originally after about 25 s.

(3 marks)

2 (b) In order to produce a time delay, an intruder alarm contains a capacitor identical to the capacitor used in the experiment in part (a). This capacitor is charged from a 12 V supply and then discharges through a 100 kΩ resistor, similar to the one used in the experiment.

2 (b) (i) State and explain the effect of this higher initial pd on the energy stored by this capacitor initially.

.....

.....

.....

(2 marks)

2 (b) (ii) State and explain the effect of this higher initial pd on the time taken for this capacitor to lose 90% of its original energy.

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(1 mark)

12

Turn over ▶

Areas outside the box will not be scanned for marking

3 (a) (i) State the relationship between the *gravitational potential energy*, E_p, and the *gravitational potential*, V, for a body of mass m placed in a gravitational field.

.....

.....

(1 mark)

3 (a) (ii) What is the effect, if any, on the values of E_p and V if the mass m is doubled?

value of E_p .....

value of V .....

(2 marks)

3 (b)

Figure 3

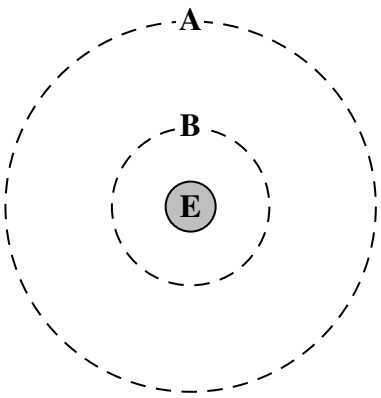


Figure 3 shows two of the orbits, **A** and **B**, that could be occupied by a satellite in circular orbit around the Earth, **E**.
The gravitational potential due to the Earth of each of these orbits is:

orbit **A** $-12.0\ \text{MJ kg}^{-1}$
orbit **B** $-36.0\ \text{MJ kg}^{-1}$.

3 (b) (i) Calculate the radius, from the centre of the Earth, of orbit **A**.

answer = ... m

(2 marks)

Areas outside the box will not be scanned for marking

3 (b) (ii) Show that the radius of orbit **B** is approximately 1.1×10^4 km.

(1 mark)

3 (b) (iii) Calculate the centripetal acceleration of a satellite in orbit **B**.

answer = ... m s^{-2}

(2 marks)

3 (b) (iv) Show that the gravitational potential energy of a 330 kg satellite decreases by about 8 GJ when it moves from orbit **A** to orbit **B**.

(1 mark)

3 (c) Explain why it is not possible to use the equation $\Delta E_p = mg\Delta h$ when determining the change in the gravitational potential energy of a satellite as it moves between these orbits.

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(1 mark)

10

Turn over ▶

Areas outside the box will not be scanned for marking

4 (a) (i) Outline the essential features of a step-down transformer when in operation.

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(2 marks)

4 (a) (ii) Describe **two** causes of the energy losses in a transformer and discuss how these energy losses may be reduced by suitable design and choice of materials.
The quality of your written communication will be assessed in this question.

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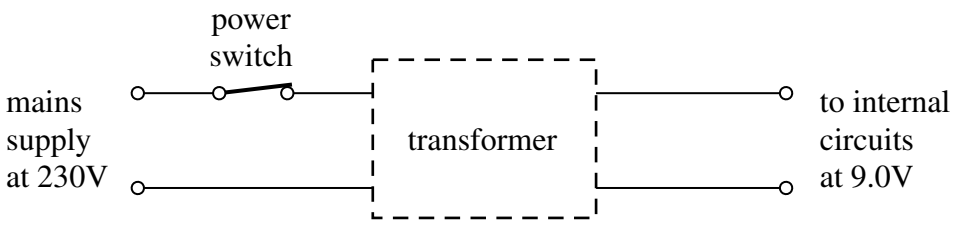
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(6 marks)

4 (b) Electronic equipment, such as a TV set, may usually be left in 'standby' mode so that it is available for instant use when needed. Equipment left in standby mode continues to consume a small amount of power. The internal circuits operate at low voltage, supplied from a transformer. The transformer is disconnected from the mains supply only when the power switch on the equipment is turned off. This arrangement is outlined in **Figure 4**.

Figure 4



When in standby mode, the transformer supplies an output current of 300 mA at 9.0 V to the internal circuits of the TV set.

4 (b) (i) Calculate the power wasted in the internal circuits when the TV set is left in standby mode.

answer = ... W

(1 mark)

Question 4 continues on the next page

Turn over ▶

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4 (b) (ii) If the efficiency of the transformer is 0.90, show that the current supplied by the 230 V mains supply under these conditions is 13 mA.

(2 marks)

4 (b) (iii) The TV set is left in standby mode for 80% of the time. Calculate the amount of energy, in J, that is wasted in one year through the use of the standby mode.

$$1 \text{ year} = 3.15 \times 10^7 \text{ s}$$

answer = ... J

(1 mark)

4 (b) (iv) Show that the cost of this wasted energy will be about £4, if electrical energy is charged at 20 p per kWh.

(2 marks)

4 (c) The power consumption of an inactive desktop computer is typically double that of a TV set in standby mode. This waste of energy may be avoided by switching off the computer every time it is not in use. Discuss **one** advantage and **one** disadvantage of doing this.

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(2 marks)

END OF QUESTIONS

16

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Version 1.0: 0310

ASSESSMENT and QUALIFICATIONS ALLIANCE

General Certificate of Education

Physics 2451

Specification A

PHYA4 Fields and Further Mechanics

Mark Scheme

2010 examination - January series

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Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation meeting attended by all examiners and is the scheme which was used by them in this examination. The standardisation meeting ensures that the mark scheme covers the candidates' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for the standardisation meeting each examiner analyses a number of candidates' scripts: alternative answers not already covered by the mark scheme are discussed at the meeting and legislated for. If, after this meeting, examiners encounter unusual answers which have not been discussed at the meeting they are required to refer these to the Principal Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of candidates' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

Further copies of this Mark Scheme are available to download from the AQA Website: www.aqa.org.uk

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Dr Michael Cresswell Director General

Instructions to Examiners

1 Give due credit for alternative treatments which are correct. Give marks for what is correct in accordance with the mark scheme; do not deduct marks because the attempt falls short of some ideal answer. Where marks are to be deducted for particular errors, specific instructions are given in the marking scheme.

2 Do not deduct marks for poor written communication. Refer the scripts to the Awards meeting if poor presentation forbids a proper assessment. In each paper, candidates are assessed on their quality of written communication (QWC) in designated questions (or part-questions) that require explanations or descriptions. The criteria for the award of marks on each such question are set out in the mark scheme in three bands in the following format. The descriptor for each band sets out the expected level of the quality of written communication of physics for each band. Such quality covers the scope (eg relevance, correctness), sequence and presentation of the answer. Amplification of the level of physics expected in a good answer is set out in the last row of the table. To arrive at the mark for a candidate, their work should first be assessed holistically (ie in terms of scope, sequence and presentation) to determine which band is appropriate then in terms of the degree to which the candidate's work meets the expected level for the band.

QWC	descriptor	mark range
Good - Excellent	*see specific mark scheme*	**5-6**
Modest - Adequate	*see specific mark scheme*	**3-4**
Poor - Limited	*see specific mark scheme*	**1-2**
The description and/or explanation expected in a good answer should include a coherent account of the following points: *see specific mark scheme*		

Answers given as bullet points should be considered in the above terms. Such answers without an 'overview' paragraph in the answer would be unlikely to score in the top band.

3 An arithmetical error in an answer will cause the candidate to lose one mark and should be annotated AE if possible. The candidate's incorrect value should be carried through all subsequent calculations for the question and, if there are no subsequent errors, the candidate can score all remaining marks.

4 The use of significant figures is tested **once** on each paper in a designated question or part-question. The numerical answer on the designated question should be given to the same number of significant figures as there are in the data given in the question or to one more than this number. All other numerical answers should not be considered in terms of significant figures.

5 Numerical answers **presented** in non-standard form are undesirable but should not be penalised. Arithmetical errors by candidates resulting from use of non-standard form in a candidate's working should be penalised as in point 3 above. Incorrect numerical prefixes and the use of a given diameter in a geometrical formula as the radius should be treated as arithmetical errors.

6 Knowledge of units is tested on designated questions or parts of questions in each a paper. On each such question or part-question, unless otherwise stated in the mark scheme, the mark scheme will show a mark to be awarded for the numerical value of the answer and a further mark for the correct unit. No penalties are imposed for incorrect or omitted units at intermediate stages in a calculation or at the final stage of a non-designated 'unit' question.

7 All other procedures including recording of marks and dealing with missing parts of answers will be clarified in the standardising procedures.

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GCE Physics, Specification A, PHYA4, Fields and Further Mechanics

Section A

This component is an objective test for which the following list indicates the correct answers used in marking the candidates' responses.

	Keys to Objective Test Questions	
	1 C **2** B **3** D **4** A **5** D **6** B **7** B **8** A **9** A **10** D **11** B **12** D **13** A **14** C **15** B **16** C **17** C **18** D **19** B **20** D **21** D **22** C **23** B **24** A **25** A	

Section B

Question 1		
(a)	(grav) potential energy → kinetic energy → (grav) potential energy → kinetic energy → gravitational potential energy ✓ energy lost to surroundings in overcoming air resistance ✓	**2**
(b) (i)	period $T = \left(\frac{42}{15}\right) = 2.8\,\text{s}$ ✓ use of $T = 2\pi\sqrt{\frac{l}{g}}$ gives length $l = \left(= \frac{T^2 g}{4\pi^2}\right) = \frac{2.8^2 \times 9.81}{4\pi^2}$ ✓ giving distance from pt of support to c of m, l = 1.9 (m) or 1.95 (m) ✓ answer must be to **2 or 3 sf** only ✓	**4**
(b) (ii)	$E_k = mg\Delta h$ stated or used ✓ gives E_k of girl at lowest point = 18 × 9.81 × 0.25 = 44 (J) ✓	**2**
(b) (iii)	½ mv^2 = 44.1 gives max speed of girl $v = \sqrt{\frac{2 \times 44.1}{18}} = 2.2\,(\text{m s}^{-1})$ ✓ [**alternatively**: $A^2 = (3.9 - 0.25) \times 0.25$ gives $A = 0.955\,(\text{m})$ and $v_{max} = 2\pi f A = (2\pi/2.8) \times 0.955 = 2.1\,(\text{m s}^{-1})$ ✓]	**1**
(c)	graph drawn on **Figure 2** which: shows E_k = 0 at t = 0, $T/2$ and T ✓ has 2 maxima of similar size (some attenuation allowed) at $T/4$ and $3T/4$ ✓ is of the correct general shape ✓	**3**
	Total	**12**

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Question 2		
(a) (i)	initial discharge current $\left(= \frac{V}{R} = \frac{6.0}{1.0 \times 10^5}\right)$ = 6.0 × 10^{-5} (A) ✓	**1**
(a) (ii)	time constant is time for V to fall to (1/e) [or 0.368] of initial value ✓ pd falls to (6.0/e) = 2.21 V when t =time constant ✓ reading from graph gives time constant = 22 (± 1) ✓ unit: s ✓ (ΩF not acceptable) [**alternatively** accept solutions based on use of $V = V_0 e^{-t/RC}$ eg 1.5 = 6.0 $e^{-30/RC}$ ✓ gives $RC = \frac{30}{\ln(6.0/1.5)}$ ✓= 22 ✓ s✓]	**4**
(a) (iii)	capacitance of capacitor $C = \left(\frac{\text{time constant}}{\text{R}} = \frac{22}{1.0 \times 10^5}\right)$ = 2.2 × 10^{-4} (F) = 220 (μF) ✓	**1**
(a) (iv)	energy ∝ V^2 (or energy = ½ CV^2) ✓ ∴ $\frac{E_2}{E_1}$ = 0.10 gives = $\frac{V_2}{V_1}$ $(0.10)^{1/2}$ ✓ (= 0.316) ∴ V_2 = 0.316 × 6.0 = 1.90 (V) ✓ reading from graph gives V_2 = 1.90 V when t = 25 s ✓ [**alternatively** accept reverse argument: ie when t = 25 s, V_2 = 1.9 V from graph ✓ final energy stored = ½ × 2.2 × 10^{-4} × 1.9^2 = 3.97 × 10^{-4} (J) and initial energy stored = 3.96 × 10^{-3} (J) ✓ which is 10 × greater, so 90% of initial energy has been lost ✓] [**alternatively**, using exponential decay equation: use of $V = V_0 e^{-t/R}$ with t = 25 s and RC = 22 s gives V = 1.93 V ✓ energy ∝ V^2 (or energy = ½ CV^2) gives $\frac{E_2}{E_1} = \left(\frac{1.93}{6.0}\right)^2$ = 0.103 ✓ ∴ fraction of stored energy that is lost = $\frac{E_2 - E_1}{E_1}$ = 1 – $\frac{E_2}{E_1}$ = 0.90 ✓]	**3**
(b) (i)	initial energy stored is 4 × greater ✓ because energy ∝ V^2 (and V is doubled) ✓	**2**
(b) (ii)	time to lose 90% of energy is unchanged because time constant is unchanged (or depends only on R and C) ✓	**1**
	Total	**12**

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Question 3		
(a) (i)	relationship between them is $E_p = mV$ (allow $\Delta E_p = m\Delta V$) [or V is energy per unit mass (or per kg)] ✓	**1**
(a) (ii)	value of E_p is doubled ✓ value of V is unchanged ✓	**2**
(b) (i)	use of $V = -\frac{GM}{r}$ gives $r_A = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{12.0 \times 10^6}$ ✓ $= 3.3(2) \times 10^7$ (m) ✓	**2**
(b) (ii)	since $V \propto (-)\frac{1}{r}$ $\left(or\ \frac{r_A}{r_B} = \frac{V_B}{V_A} = \frac{36.0}{12.0} = 3\right)$ $r_B = \frac{3.32 \times 10^7 m}{3}$ ✓ (which is ≈ 1.1×10^4 km)	**1**
(b) (iii)	centripetal acceleration $g_B = \frac{GM}{r_B^2} = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{(1.11 \times 10^7)^2}$ ✓ [allow use of 1.1×10^7 m from (b)(ii)] $= 3.2$ (m s^{-2}) ✓ [**alternatively**, since $g_B = (-)\frac{V_B}{V_a}$, $g_B = \frac{36.0 \times 10^6}{1.11 \times 10^7}$ ✓ $= 3.2$ (m s^{-2}) ✓]	**2**
(b) (iv)	use of $\Delta E_p = m\Delta V$ gives $\Delta E_p = 330 \times (-12.0 - (-36.0)) \times 10^6$ ✓ (which is 7.9×10^9 J or ≈ 8 GJ)	**1**
(c)	g is not constant over the distance involved (**or** g decreases as height increases **or** work done per metre decreases as height increases **or** field is radial and/or not uniform) ✓	**1**
	Total	**10**

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Question 4		
(a) (i)	primary coil with more turns than secondary coil ✓ (wound around) a core **or** input is ac ✓	**2**
(a) (ii)	the mark scheme for this part of the question includes an overall assessment for the Quality of Written Communication	
QWC	**descriptor**	**mark range**
good - excellent	Two causes of energy losses are clearly identified, correct measures to indicate how these two losses may be reduced are stated and a detailed physical explanation of why these measures are effective is given. eg **any two** from the following four 1 When a transformer is in operation, there are ac currents in the primary and secondary coils. The coils have some resistance and the currents cause **heating of the coils**, causing some energy to be lost. This loss may be reduced by using **low resistance wire** for the coils. This is most important for the high current winding (the secondary coil of a step-down transformer). Thick copper wire is used for this winding, because thick wire of low resistivity has a low resistance. 2 The ac current in the primary coil magnetises, demagnetises and re-magnetises the core continuously in opposite directions. Energy is required both to **magnetise and to demagnetise the core** and this energy is wasted because it simply heats the core. The energy wasted may be reduced by choosing a material for the core which is easily magnetised and demagnetised, ie a **magnetically soft material** such as iron, or a special alloy, rather than steel. 3 The magnetic flux passing through the core is changing continuously. The metallic core is being cut by this flux and the continuous change of flux induces emfs in the core. In a continuous core these induced emfs cause currents known as **eddy currents**, which heat the core and cause energy to be wasted. The eddy current effect may be reduced by laminating the core instead of having a continuous solid core; the laminations are separated by very thin layers of insulator. Currents cannot flow in a conductor which is discontinuous (or which has a very high resistance). 4 If a transformer is to be efficient, as much as possible of the magnetic flux created by the primary current must pass through the secondary coil. This will not happen if these coils are widely separated from each other on the core. **Magnetic losses** may be reduced by adopting a design which has the two coils close together, eg by **better core design**, such as winding them on top of each other around the same part of a common core which also surrounds them.	**5 - 6**
modest - adequate	Up to two sources of energy losses are stated and there is an indication of how these may be minimised by suitable features or materials. There is no clear appreciation of an understanding of the physical principles to explain why these measures are effective.	**3 - 4**
poor - limited	Up to two sources of energy losses are given, but the answer shows no clear understanding of the measures required to minimise them.	**1 – 2**
incorrect, inappropriate or no response	There is no answer or the answer presented is irrelevant or incorrect.	**0**
	Answers which address only **one** acceptable energy loss should be marked using the same principles, but to max 3.	

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(b)	(i)	power wasted internally (= I V) = 0.30 × 9.0 = 2.7 (W) ✓	**1**
(b)	(ii)	input power $\left(=\frac{2.7}{0.90}\right)$ = 3.0 (W) ✓ mains current $\left(=\frac{3.0}{230}\right)$ ✓ (= 1.30 × 10^{-2} A)	**2**
(b)	(iii)	energy wasted per year (= P t) = 3.0 × 0.80 × 3.15 × 10^7 = 7.5(6) × 10^7 (J) ✓	**1**
(b)	(iv)	energy wasted = $\frac{7.56 \times 10^7}{3.6 \times 10^6}$ = 21.0 (kWh) ✓ cost of wasted energy = 21.0 × 20 = 420p (£4.20) ✓	**2**
(c)		answers should refer to: an advantage of switching off ✓ • cost saving, saving essential fuel resources, reduced global warming etc a disadvantage of switching off ✓ • inconvenience of waiting, time taken for computer to reboot etc • risk of computer failure increased by repeated switching on and off • energy required to reboot may exceed energy saved by switching off	**2**
		Total	**16**

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