mock papers 1-SECTION A

In this section each item consists of a question or an incomplete statement followed by four suggested answers or completions. You are to select the most appropriate answer in each case. You are advised to spend about **30 minutes** on this section.

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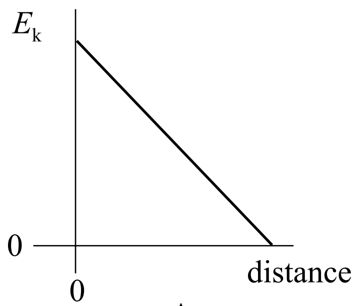
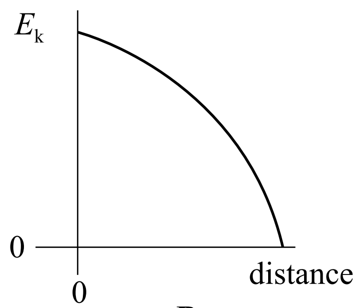
1 Which one of the following statements is true when an object performs simple harmonic motion about a central point O?

- **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.

2 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



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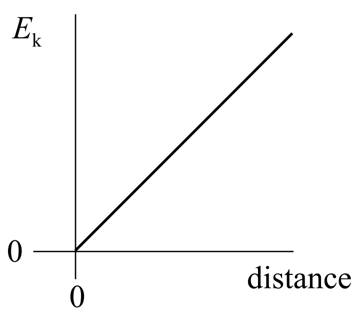

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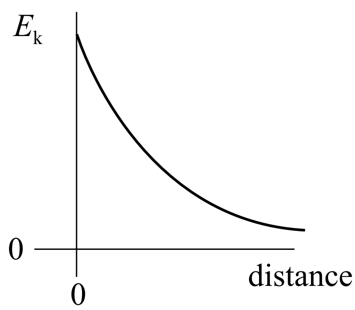


D

3 The displacement (in mm) of the vibrating cone of a large loudspeaker can be represented by the equation $x = 10\cos(150t)$, where t is the time in s. Which line, **A** to **D**, in the table gives the amplitude and frequency of the vibrations.

	amplitude/mm	**frequency/Hz**
A	5	$\frac{10}{2\pi}$
B	10	150
C	10	$\frac{150}{2\pi}$
D	20	$\frac{150}{2\pi}$

4 A wave of frequency 5 Hz travels at $8\,\text{km}\,\text{s}^{-1}$ through a medium. What is the phase difference between two points 2 km apart?

A zero

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

C π rad

D $\frac{3\pi}{2}$ rad

5 Interference fringes are produced on a screen by illuminating a double slit with monochromatic light. Which one of the following changes would reduce the separation of these fringes?

A increasing the separation of the slits
B increasing the distance from the screen to the slits
C increasing the wavelength of the light
D increasing the width of an individual slit

6 Two coherent sources produce waves which are 180° out of phase. What is a possible value for the path difference of the two waves when they meet at a point of constructive interference, if the wavelength is λ?

A 0

B $\frac{\lambda}{4}$

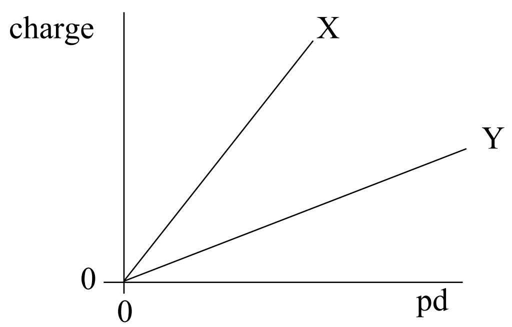
C $\frac{\lambda}{2}$

D λ

7 Light of wavelength λ is incident normally on a diffraction grating of slit separation 4 λ. What is the angle between the second order maximum and third order maximum of the diffracted light?

A 14.5°
B 18.6°
C 48.6°
D 71.4°

8 The graph shows how the charge stored by each of two capacitors, X and Y, increases as the pd across them increases.



Which one of the following statements is correct?

A The capacitance of X is equal to that of Y.
B The capacitance of Y is greater than that of X.
C The capacitance of Y is less than that of X.
D The capacitances of both X and Y are increasing.

9 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?

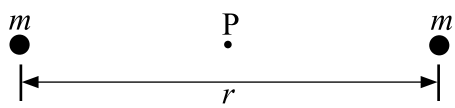
A $\sqrt{\frac{gr}{2}}$

B $\frac{g}{r}$

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

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

10 The diagram shows two objects of equal mass m separated by a distance r.



Which line, **A** to **D**, in the table gives the correct values of the gravitational field strength and gravitational potential at the mid-point P between the two objects?

	gravitational field strength	**gravitational potential**
A	$-\frac{8Gm}{r^2}$	$-\frac{4Gm}{r}$
B	$-\frac{8Gm}{r^2}$	0
C	0	$-\frac{4Gm}{r}$
D	0	0

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

A $-13\,\mathrm{MJ\,kg^{-1}}$
B $-25\,\mathrm{MJ\,kg^{-1}}$
C $-95\,\mathrm{MJ\,kg^{-1}}$
D $-320\,\mathrm{MJ\,kg^{-1}}$

12 When two point charges, each $+Q$, are distance r apart, the force between them is F. What is the force between point charges of $+Q$ and $+2Q$ when they are distance $\frac{r}{2}$ apart?

A F
B $2F$
C $8F$
D $16F$

13 Variables x and y are defined by

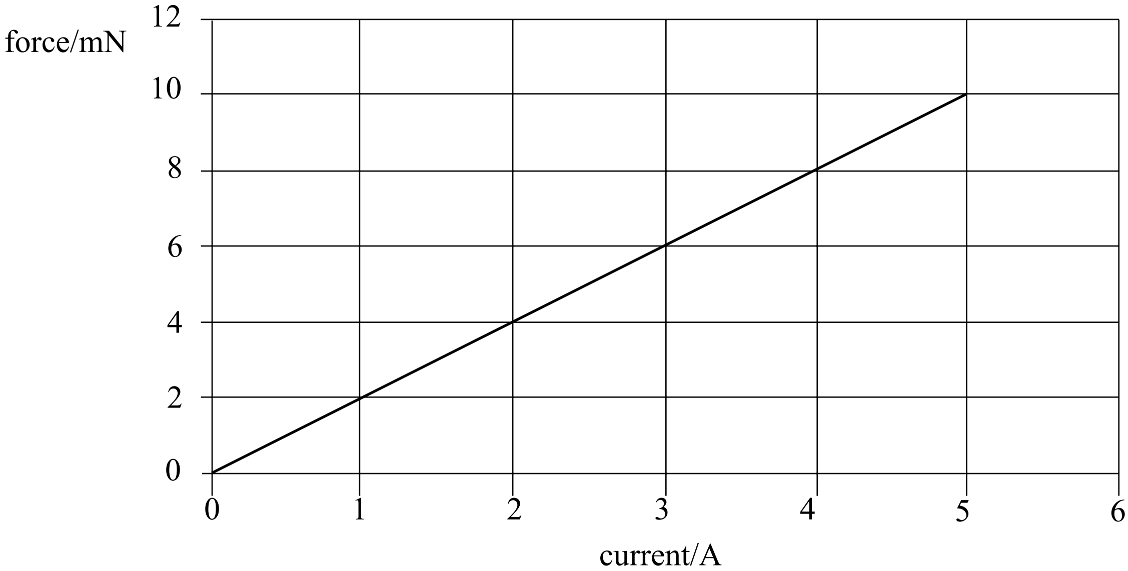
$$x = \frac{\alpha z}{r} \quad \text{and} \quad y = \frac{\beta z}{r^2},$$

where r is a distance, z is either a mass or a charge, and α and β are constants.

Which line, **A** to **D**, in the table shows correctly the meaning of the symbols when used in this way?

	gravitational field	**electric field**
A	$\alpha = G$	y = potential
B	$\beta = \frac{1}{G}$	x = potential
C	x = field strength	$\beta = 4\pi\varepsilon_0$
D	y = field strength	$\alpha = \frac{1}{4\pi\varepsilon_0}$

14 A wire of length 0.50 m, forming part of a complete circuit, is positioned at right angles to a uniform magnetic field. The graph shows how the force acting on the wire due to the magnetic field varies as the current through the wire is increased.



What is the flux density of the magnetic field?

A 2 mT
B 4 mT
C 15 mT
D 25 mT

15 Which one of the following materials, if introduced into the core of an overheated nuclear fission reactor, would be most effective in reducing the rate of fission reactions?

A boron
B carbon
C nitrogen
D carbon dioxide

END OF SECTION A

Answer **all** questions.

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

1 (a) (i) State **two** conditions which have to be satisfied for the formation of a stationary wave.

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(ii) When a stationary wave is formed on a string that is stretched between two fixed points, what additional condition concerning the length of the string must be satisfied?

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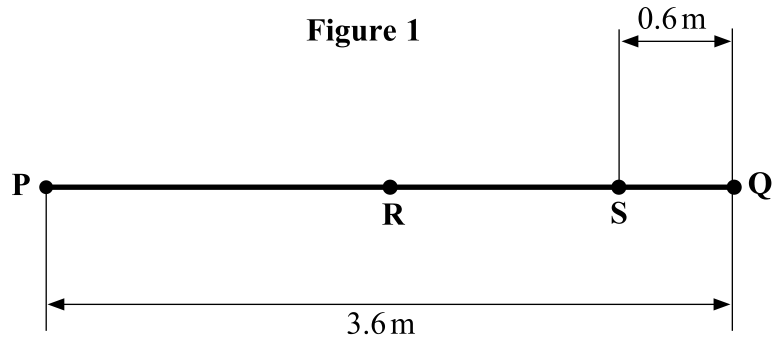
(3 marks)

(b) **Figure 1** shows the undisturbed position of a string stretched between the two points, **P** and **Q**, which are 3.6 m apart. The string is vibrated transversely at a frequency of 30 Hz, causing waves to travel along it at a speed of 72 m s^{-1}.

Figure 1



(i) Calculate the wavelength of the waves on the string.

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(ii) Draw on **Figure 1** the appearance of the stationary wave formed under these conditions.

(iii) Compare the vibrations of the mid-point **R** of the string with those of point **S**, which is 0.6 m from **Q**, with reference to amplitude, frequency and phase.

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(4 marks)

7

Turn over for the next question

2 (a) An experiment is to be carried out to determine the capacitance of a capacitor by measuring the potential difference V across it at various times t as it discharges through a resistor. The timing is to be carried out using a stopwatch. If the capacitance is known to be about $30\,\mu F$, suggest a suitable value for the resistance of the resistor, and explain why you have chosen this value.

You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer.

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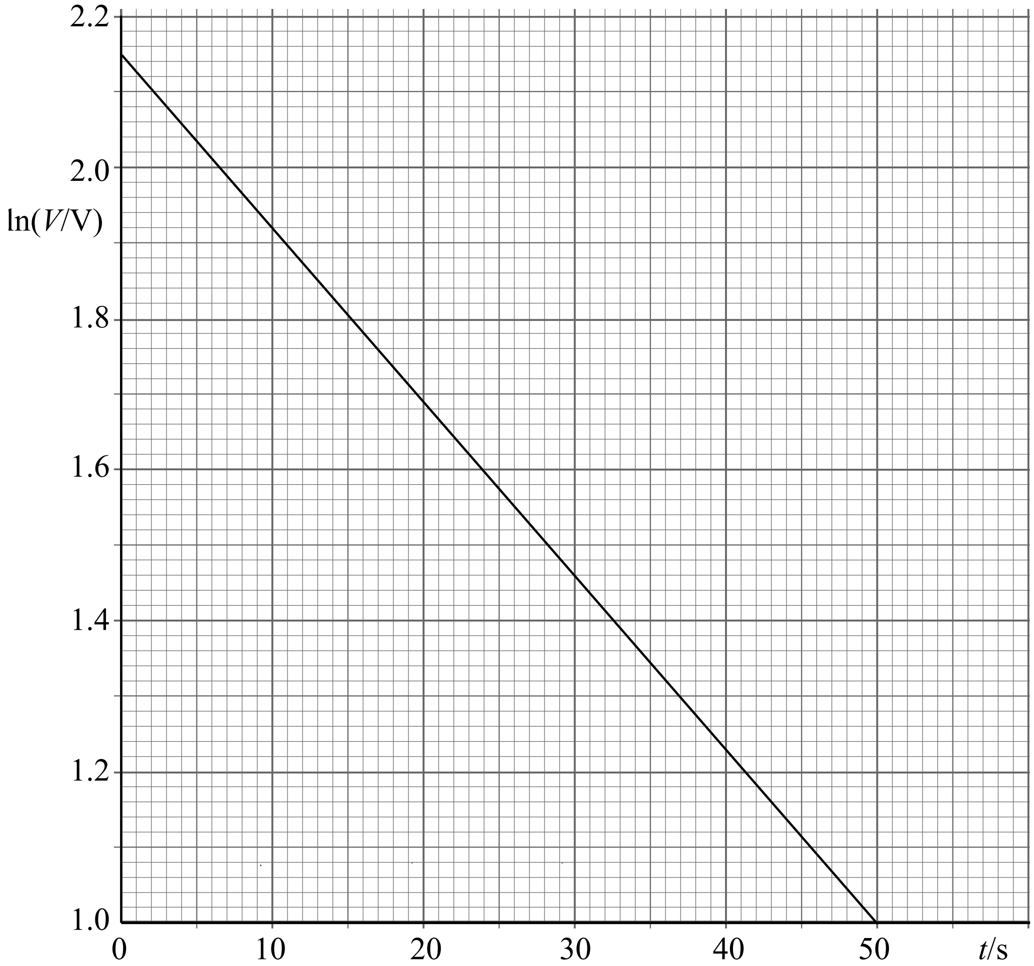
(3 marks)

(b) A similar experiment, in which the resistor had a resistance of $91\,k\Omega$, gave the graph of $\ln V$ against t shown on the opposite page.



Use this graph to calculate

(i) the pd across the capacitor when $t = 0$,

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(ii) the time constant for the discharging circuit,

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(iii) the capacitance of the capacitor used in this experiment.

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(5 marks)

8

3 (a) Electrons experience forces in electric fields. In each of the following cases, state the direction of the force that acts on a moving electron, and describe and explain the electron's subsequent motion.

You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer.

(i) An electron enters a uniform electric field that is directed at right angles to the electron's velocity at the point of entry.

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(ii) An electron enters a uniform electric field whose direction is the same as that of the electron's velocity at the point of entry.

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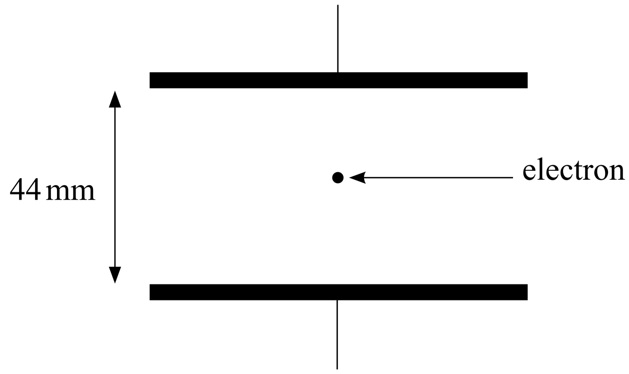
(5 marks)

(b) **Figure 2** shows two parallel metal plates, 44 mm apart, which have a pd of 110 V applied across them, with an electron between them.

Figure 2



Calculate

(i) the electric field strength between the plates,

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(ii) the magnitude of the force on the electron when it is between the plates,

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(iii) the kinetic energy, in J, that is gained by the electron when it starts from rest at one plate and crosses to the other plate.

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(4 marks)

9

4 (a) In order for fusion of two nuclei to take place, they have to be brought together to a separation of about 2 fm.

(i) Show that the electrostatic potential energy of a system consisting of two deuterium (^2_1H) nuclei at a separation of 2 fm is about 1×10^{-13} J.

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(ii) Two deuterium nuclei may be brought to this separation by causing them to collide with equal and opposite velocities. Calculate the minimum speed required by **each** nucleus for the system to have the potential energy calculated in part (a)(i).

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(5 marks)

(b) One reaction that can occur when deuterium nuclei undergo fusion is

$$^{2}_{1}H + ^{2}_{1}H \rightarrow ^{3}_{1}H + ^{1}_{1}p$$

(i) Calculate the energy released, in J, by this reaction.

mass of $^{2}_{1}H$ nucleus = 2.01355 u

mass of $^{3}_{1}H$ nucleus = 3.01550 u

mass of proton = 1.00728 u

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(ii) How much energy is released, in J, from 1 kg of reactant in the above fusion reaction?

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(4 marks)

(c) State **two** reasons why fusion reactions would be preferable to fission reactions as an energy resource, provided the necessary conditions required for continuous fusion could be maintained.

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(2 marks)

11

5 (a) By considering the force equation for a satellite of mass m in an orbit of radius r around a planet of mass M, show that the orbital time period T of the satellite does not depend upon m.

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(3 marks)

(b) One of the moons of Jupiter, Ganymede, is the largest satellite in the solar system. Its orbital period is equal to 7.15 Earth days and the radius of its orbit is 1.07×10^6 km.

Calculate

(i) the angular speed of Ganymede in its orbit,

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(ii) the centripetal acceleration of Ganymede in its orbit,

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(iii) the mass of Jupiter.

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(5 marks)

8

Quality of Written Communication *(2 marks)*

2

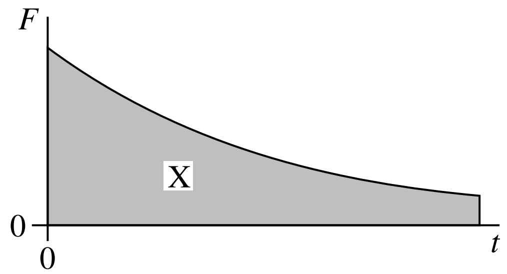
END OF QUESTIONS

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

4 What is the angular speed of a point on the Earth's equator?

A $7.3 \times 10^{-5}\,\text{rad s}^{-1}$
B $4.2 \times 10^{-3}\,\text{rad s}^{-1}$
C $2.6 \times 10^{-1}\,\text{rad s}^{-1}$
D $15\,\text{rad s}^{-1}$

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

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 $2\pi\sqrt{\dfrac{R}{GM}}$

B $2\pi\sqrt{\dfrac{R^2}{GM}}$

C $2\pi\sqrt{\dfrac{GM}{R^3}}$

D $2\pi\sqrt{\dfrac{R^3}{GM}}$

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 $\left(\dfrac{\text{mass of the planet}}{\text{mass of the Earth}}\right)$?

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?

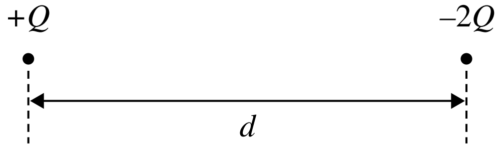
A N

B J

C $\mathrm{N\,kg^{-1}}$

D $\mathrm{J\,kg^{-1}}$

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 $\dfrac{F}{4}$

B a repulsive force of $\dfrac{F}{4}$

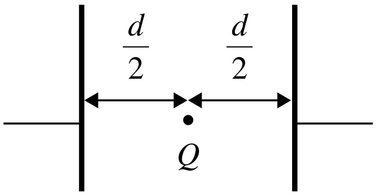
C an attractive force of $\dfrac{F}{2}$

D a repulsive force of $\dfrac{F}{2}$

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 $\frac{VQ}{d}$

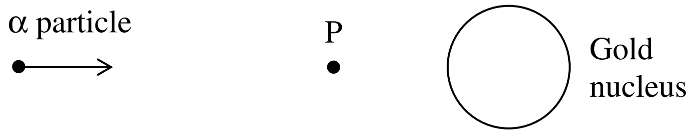
C $\frac{VQ}{2d}$

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.

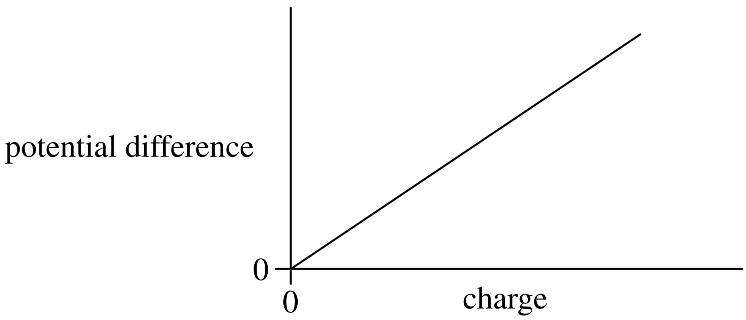
17



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.

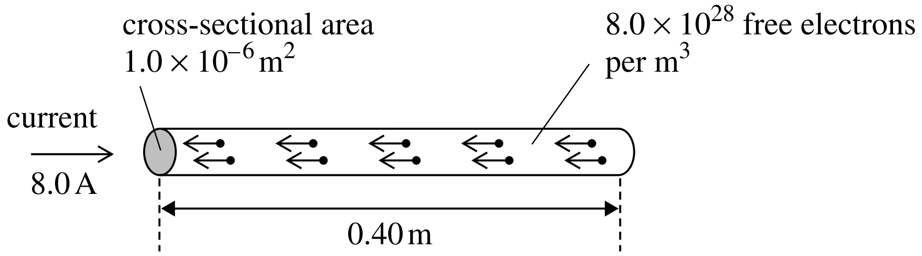
19 An initially uncharged capacitor of capacitance 10 μF is charged by a **constant** current of 200 μA. After what time will the potential difference across the capacitor be 2000 V?

A 50 s
B 100 s
C 200 s
D 400 s

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?

	$\dfrac{\textbf{charge stored by X}}{\textbf{charge stored by Y}}$	$\dfrac{\textbf{energy stored by X}}{\textbf{energy stored by Y}}$
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

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 $\dfrac{Et}{N}$

B $\dfrac{N}{Et}$

C EtN

D $\dfrac{E}{Nt}$

25 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 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

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**

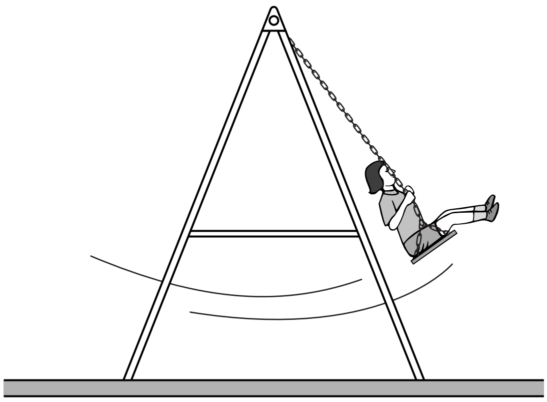


Figure 1 shows a young girl swinging on a garden swing. You may assume that the swing behaves as a simple pendulum. Ignore the mass of chains supporting the seat throughout this question, and assume that the effect of air resistance is negligible. 15 complete oscillations of the swing took 42s.

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)

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?

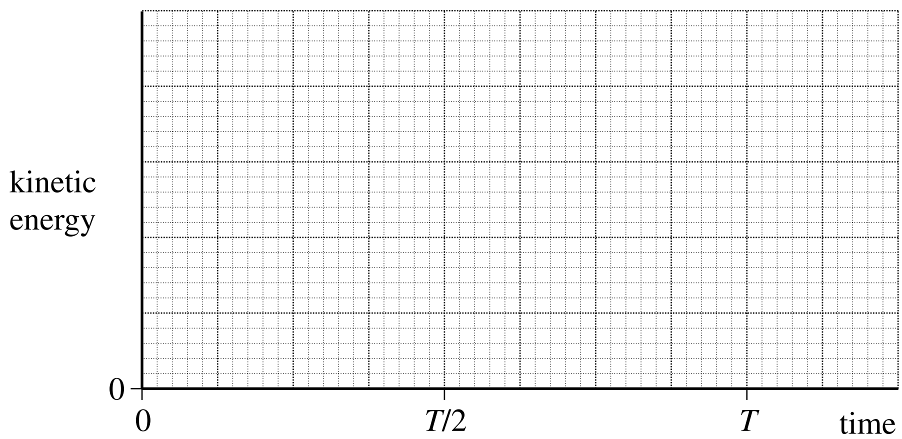
answer = ... J
(2 marks)

1 (b) (iii) Calculate the maximum speed of the girl during the first oscillation.

answer = ... m s^{-1}
(1 mark)

1 (c)

Figure 2



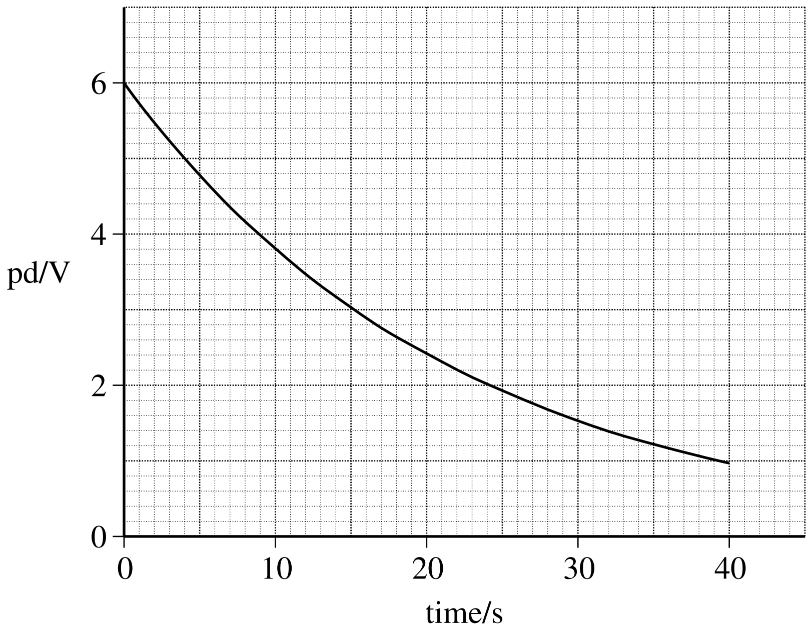
On **Figure 2** draw a graph to show how the kinetic energy of the girl varied with time during the first complete oscillation, starting at the time of her release from maximum displacement. On the horizontal axis of the graph, *T* represents the period of the swing. You do not need to show any values on the vertical axis.

(3 marks)

12

Turn over ▶

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)

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.

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(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

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.

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(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**

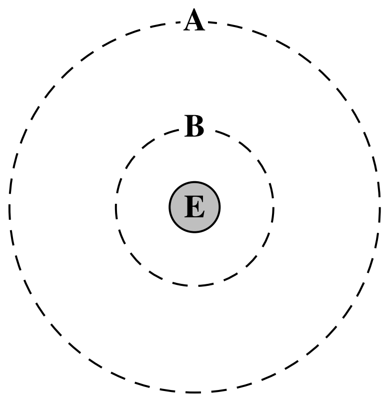

Figure 3 shows two of the orbits, **A** and **B**, that could be occupied by a satellite in circular orbit around the Earth, **E**.
The gravitational potential due to the Earth of each of these orbits is:

orbit **A** $-12.0\ \mathrm{MJ\,kg^{-1}}$
orbit **B** $-36.0\ \mathrm{MJ\,kg^{-1}}$.

3 (b) (i) Calculate the radius, from the centre of the Earth, of orbit **A**.

answer = ... m

(2 marks)

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 = ... $\mathrm{m\,s^{-2}}$

(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

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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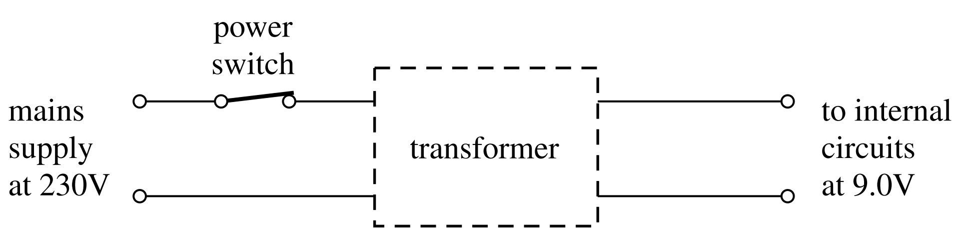
(6 marks)

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 ▶

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

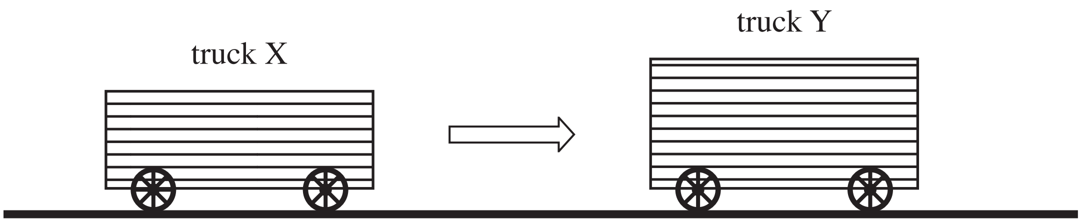
16

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.

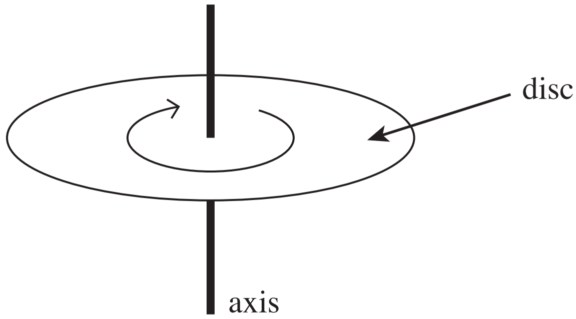
1 A rail truck X travels along a level track and collides with a stationary truck Y. The two trucks move together at the same velocity after the collision.



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

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^{o} in 20 ms. What is the average speed of a point on the edge of the disc during this time?

A $0.5\pi\,\mathrm{m\,s^{-1}}$

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

C $1.5\pi\,\mathrm{m\,s^{-1}}$

D $2\pi\,\mathrm{m\,s^{-1}}$

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?

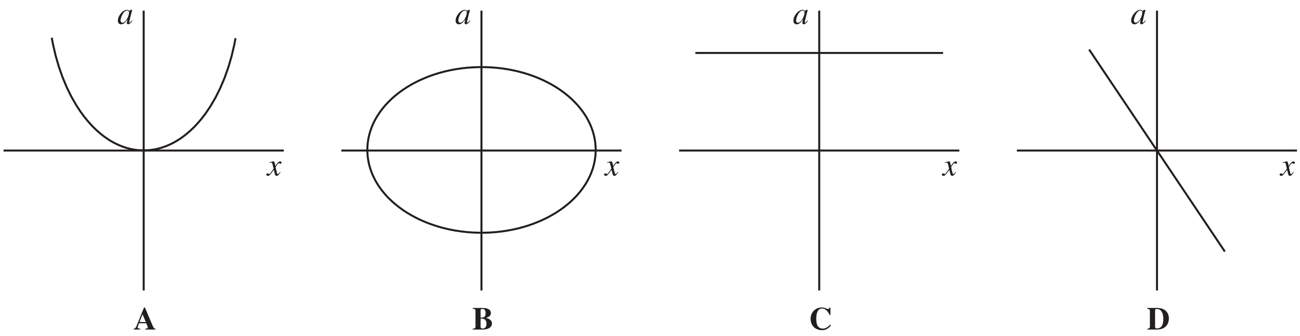
A $\dfrac{mf^2r^2}{4\pi^2}$

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 ▶

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?

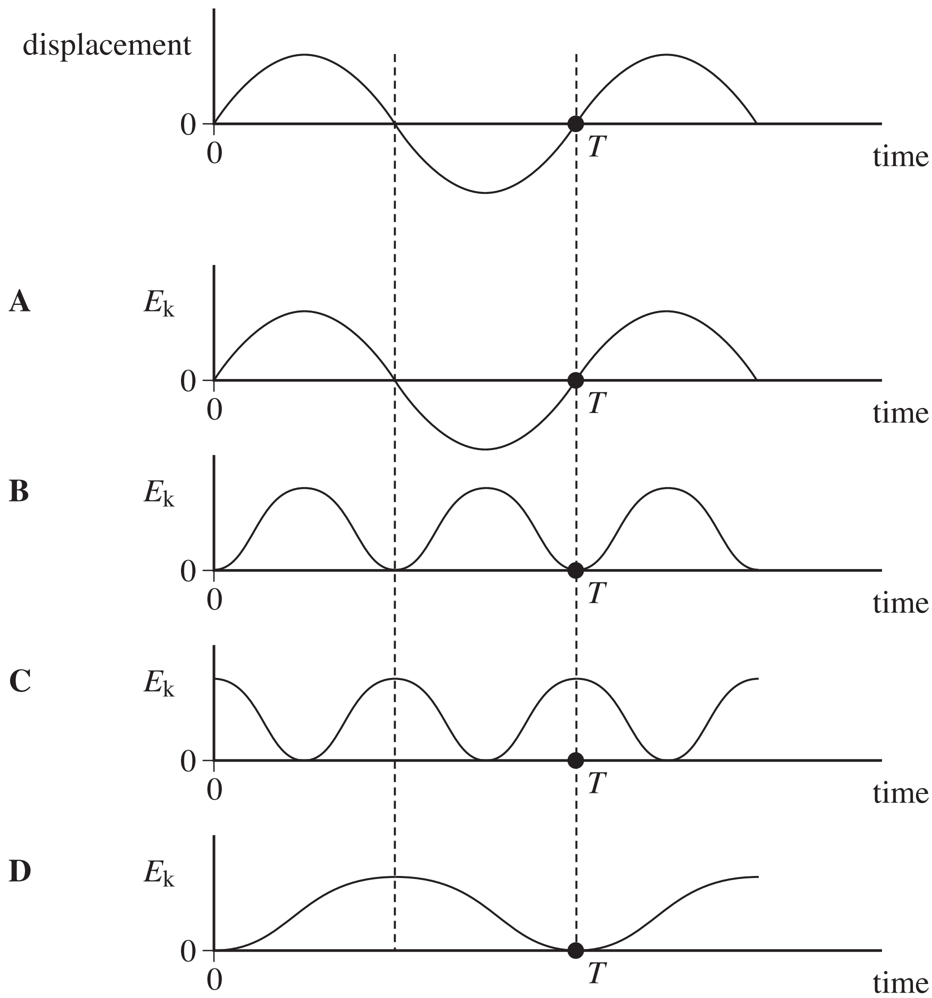
A zero

B $4\pi^2 A b^2$

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?



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?

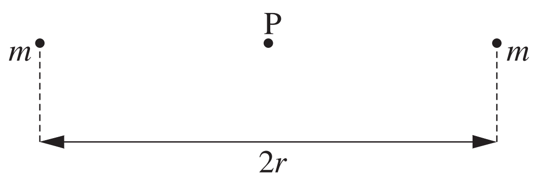
A 0.043 kg

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 $\frac{4Gm}{r^2}$

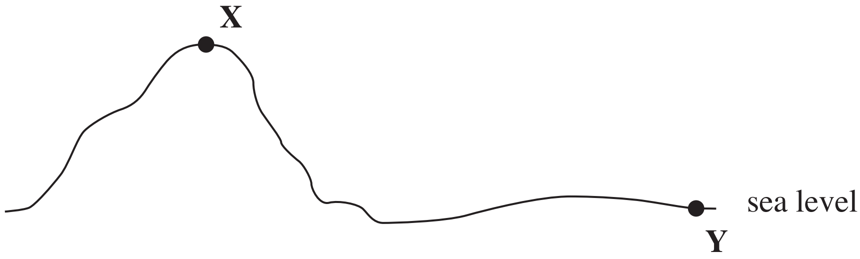
B $\frac{2Gm}{r^2}$

C $\frac{Gm}{2r^2}$

D zero

Turn over ►

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.

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 V m^{-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}

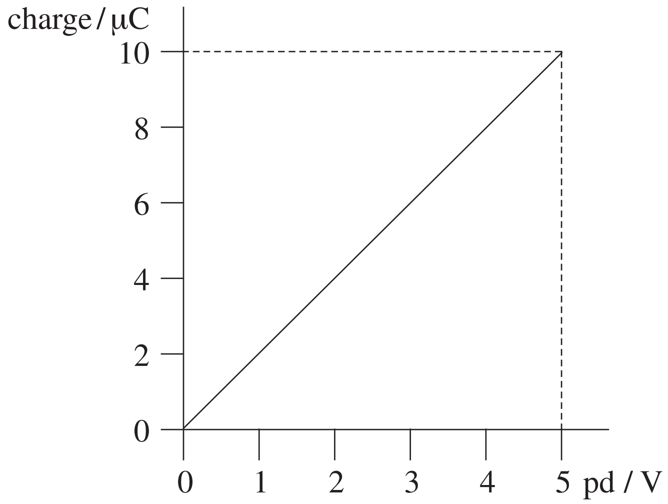
B 10^{30}

C 10^{36}

D 10^{42}

Turn over ▶

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

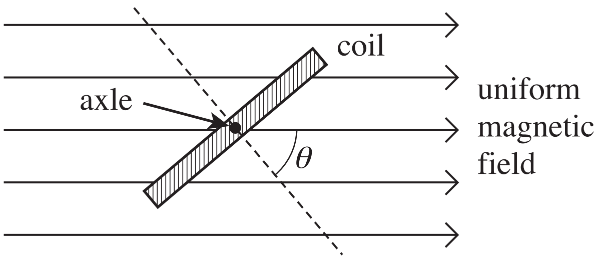
19 A negatively charged particle moves at right angles to a uniform magnetic field. The magnetic force on the particle acts

A in the direction of the field.
B in the opposite direction to that of the field.
C at an angle between 0^o and 90^o 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 $\theta = 0^o$?

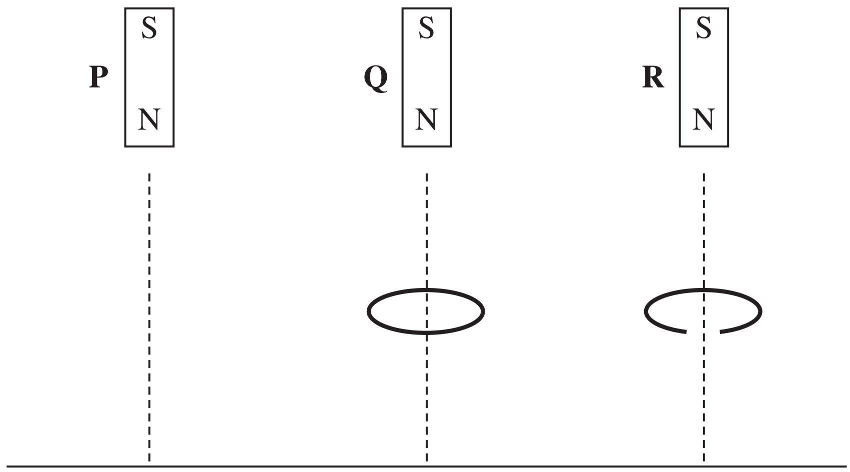
A The flux linkage decreases by 2.1×10^{-3} Wb turns.
B The flux linkage increases by 2.1×10^{-3} Wb turns.
C The flux linkage decreases by 3.8×10^{-3} Wb turns.
D The flux linkage increases by 3.8×10^{-3} Wb turns.

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 $1.0 \times 10^{-5}T$, 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 ▶

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?

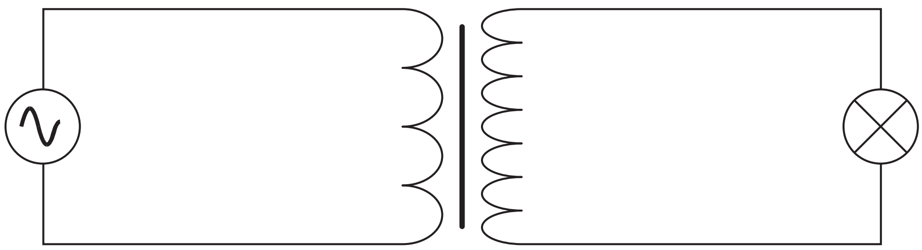
A **P** and **R** arrive together followed by **Q**.

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?

	$\dfrac{\textbf{secondary magnetic flux linkage}}{\textbf{primary magnetic flux linkage}}$	$\dfrac{\textbf{secondary current}}{\textbf{primary current}}$
A	>1	<1
B	<1	<1
C	>1	>1
D	<1	>1

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

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

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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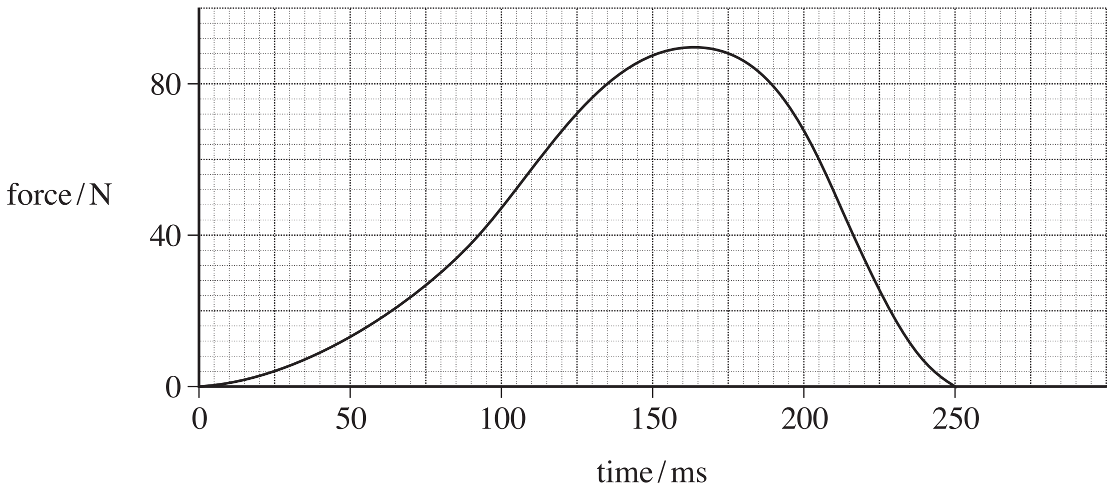
(1 mark)

2 (b) A football of mass 0.42 kg is moving horizontally at $10\,\mathrm{m\,s^{-1}}$ 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)

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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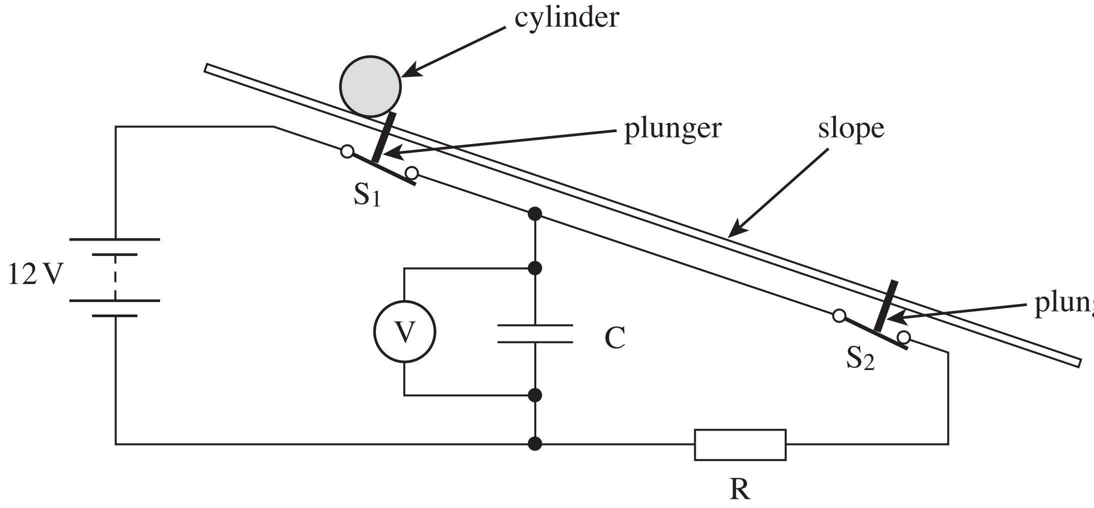
(3 marks)

13

Turn over ▶

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?

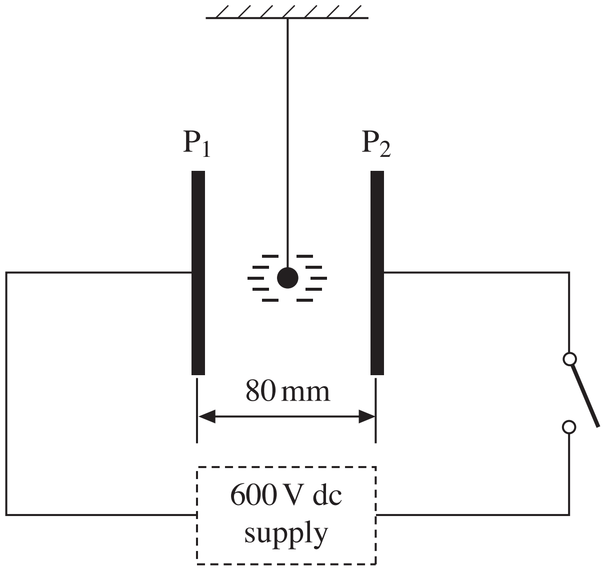
answer = ...m s^{-2}

(2 marks)

11

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.

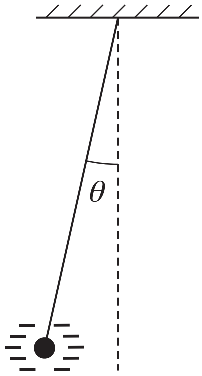
answer = ...V m^{-1}
(2 marks)

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)

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

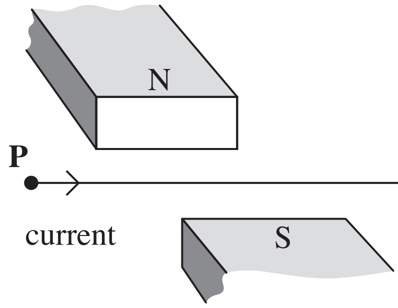
(3 marks)

8

Turn over ▶

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**.

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(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)

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

Multiple-choice questions

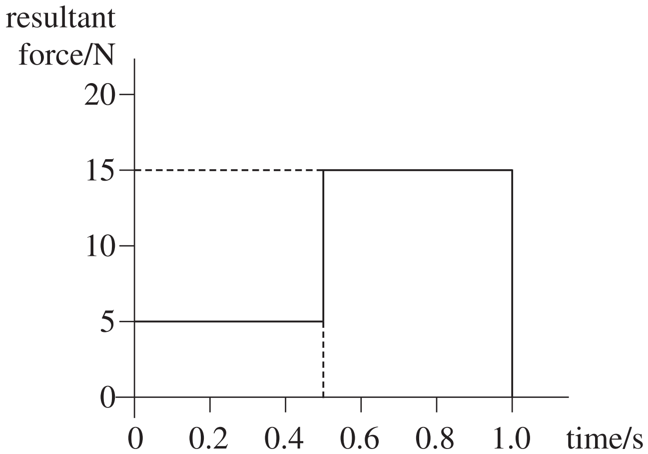
Each of Questions **1** to **25** is followed by four responses, **A**, **B**, **C**, and **D**. For each question select the best response and mark its letter on the answer sheet.

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 $2.5\,\mathrm{m\,s^{-1}}$
B $5.0\,\mathrm{m\,s^{-1}}$
C $7.5\,\mathrm{m\,s^{-1}}$
D $10\,\mathrm{m\,s^{-1}}$

3 Which of the following is a possible unit for rate of change of momentum?

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

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 $3.0\,\text{rad s}^{-1}$. 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

Turn over ▶

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 $1.6\,\mathrm{N\,kg^{-1}}$
B $5.0\,\mathrm{N\,kg^{-1}}$
C $10\,\mathrm{N\,kg^{-1}}$
D $20\,\mathrm{N\,kg^{-1}}$

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	$\frac{W}{16}$	$\frac{V}{3}$

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?

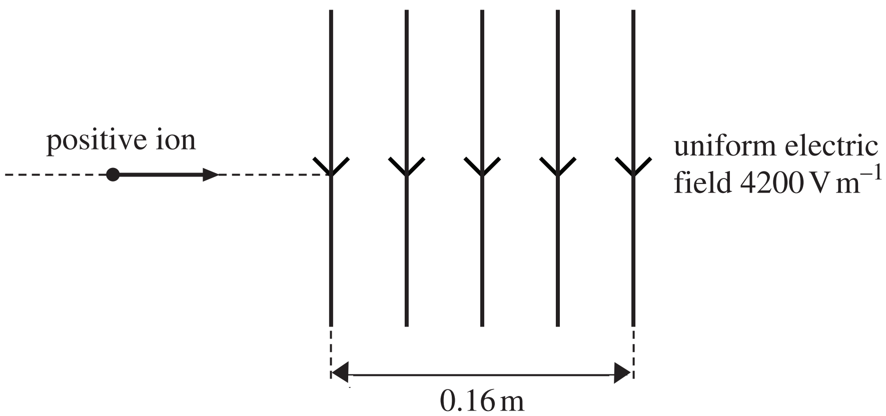
A $+2.3 \times 10^{-18}$ J

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.

Turn over ▶

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

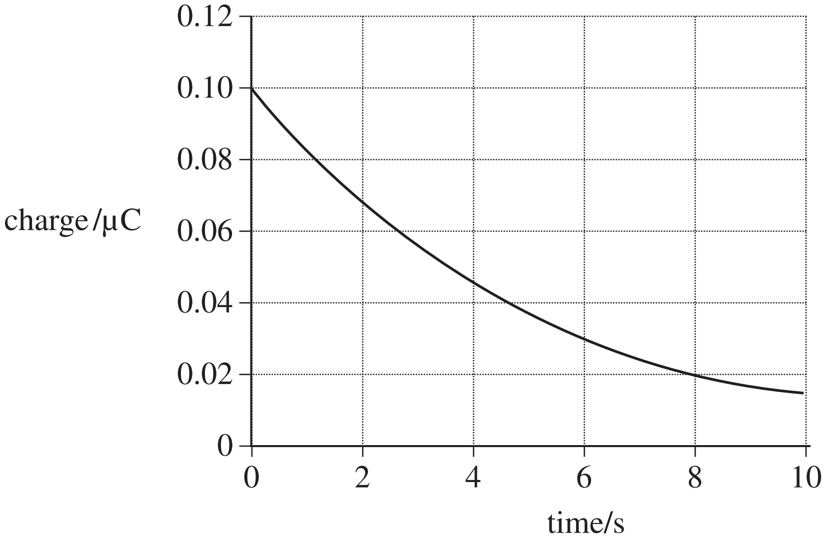
18 A capacitor of capacitance C stores an amount of energy E when the pd across it is V. Which line, **A** to **D**, in the table gives the correct stored energy and pd when the charge is increased by 50%?

	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.

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?

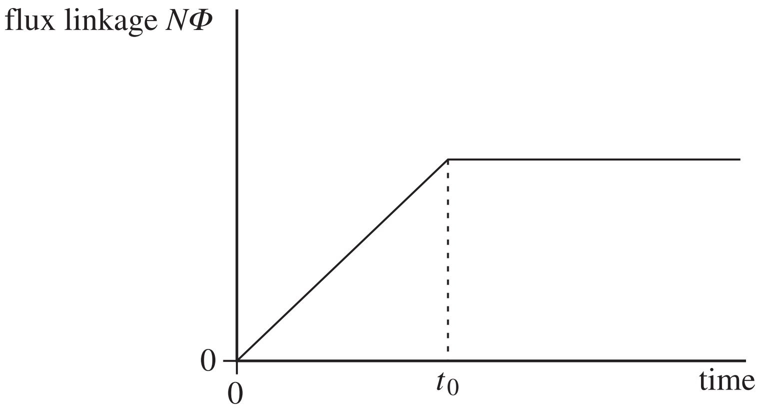
A $T_P = T_Q$

B $T_P > T_Q$

C $T_P < T_Q$

D $T_P - T_Q = 1$

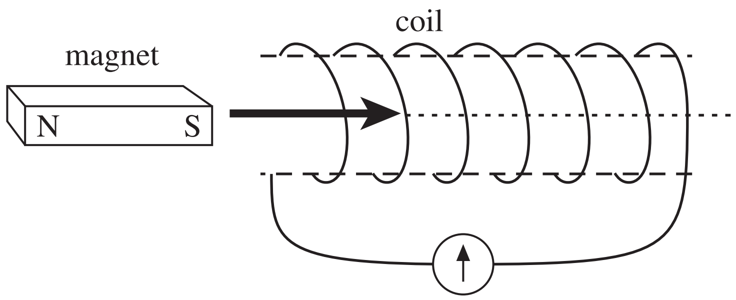
22 The graph shows how the flux linkage, $N\Phi$, through a coil changes when the coil is moved into a magnetic field.



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.

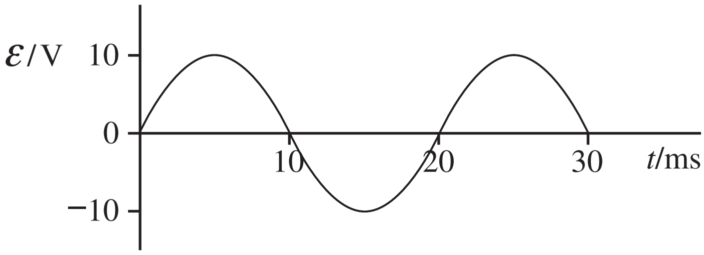
23 A bar magnet is pushed into a coil connected to a sensitive ammeter, as shown in the diagram, until it comes to rest inside the coil.



Why does the ammeter briefly show a non-zero reading?

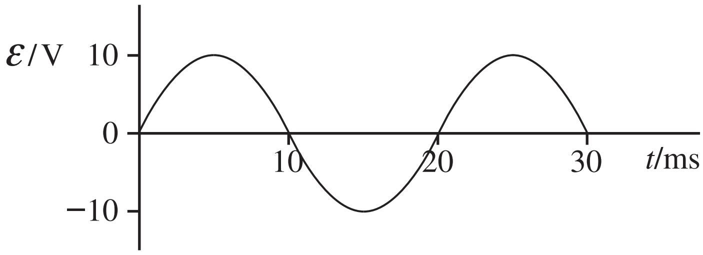
A The magnetic flux linkage in the coil increases then decreases.
B The magnetic flux linkage in the coil increases then becomes constant.
C The magnetic flux linkage in the coil decreases then increases.
D The magnetic flux linkage in the coil decreases then becomes constant.

24

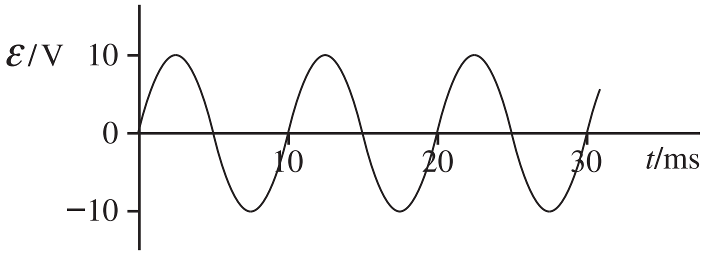


The above graph shows how the output emf, $\mathcal{E}$, varies with time, t, for a coil rotating at angular speed ω in a uniform magnetic field of flux density B. Which one of the following graphs shows how $\mathcal{E}$ varies with t when the same coil is rotated at angular speed 2ω in a uniform magnetic field of flux density 0.5 B?

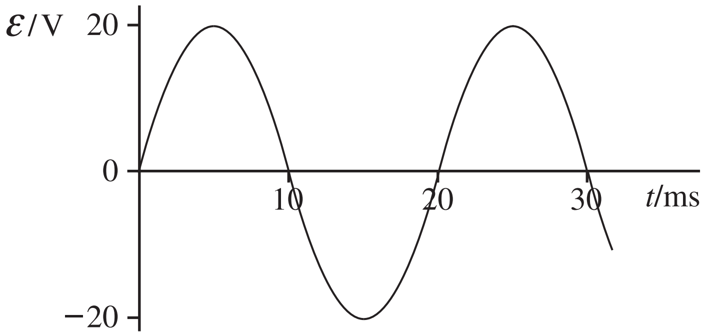
A



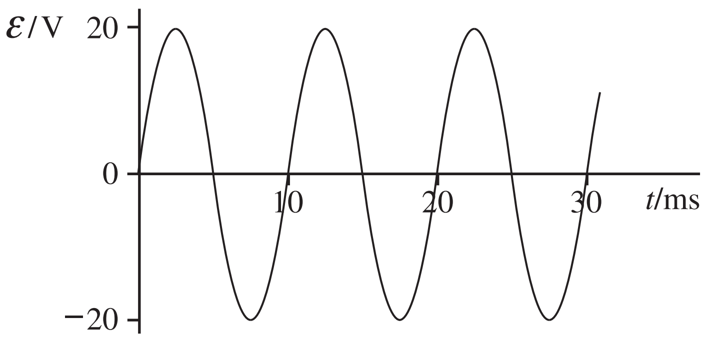
B



C



D



Turn over ▶

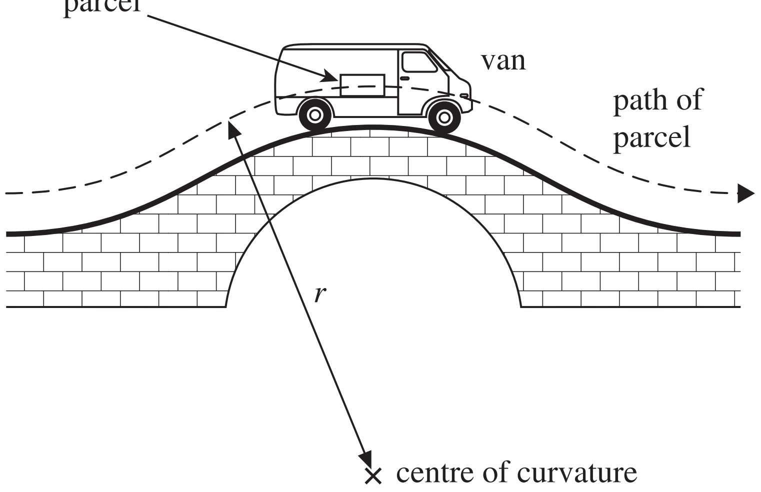
25 Which one of the following is **not** a cause of energy loss in a transformer?

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

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.

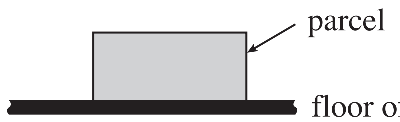
Figure 1



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)

1 (a) (iii) Calculate R if $m = 12\,kg$, $r = 23\,m$, and $v = 11\,m\,s^{-1}$.

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 $15\,m\,s^{-1}$? Support your answer with a calculation.

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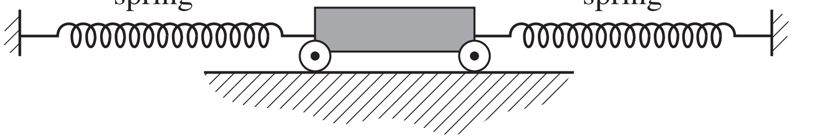
(3 marks)

7

Turn over ▶

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)

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.

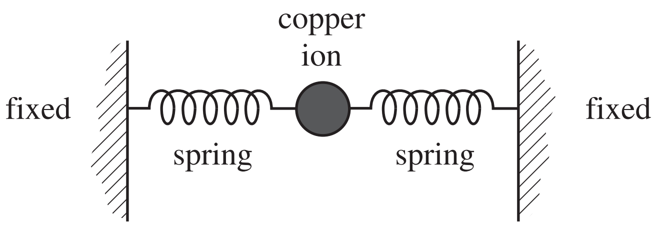
answer = ...

(3 marks)

Turn over ▶

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 $200\,\mathrm{N\,m^{-1}}$. 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 = ...$\mathrm{m\,s^{-1}}$

(1 mark)

2 (c) (iii) Estimate the maximum kinetic energy of the copper ion.

answer = ...J

(1 mark)

12

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

4 (a) The equation $F = B\,Q\,v$ may be used to calculate magnetic forces.

4 (a) (i) State the condition under which this equation applies.

....

....
(1 mark)

4 (a) (ii) Identify the physical quantities that are represented by the four symbols in the equation.

F ....

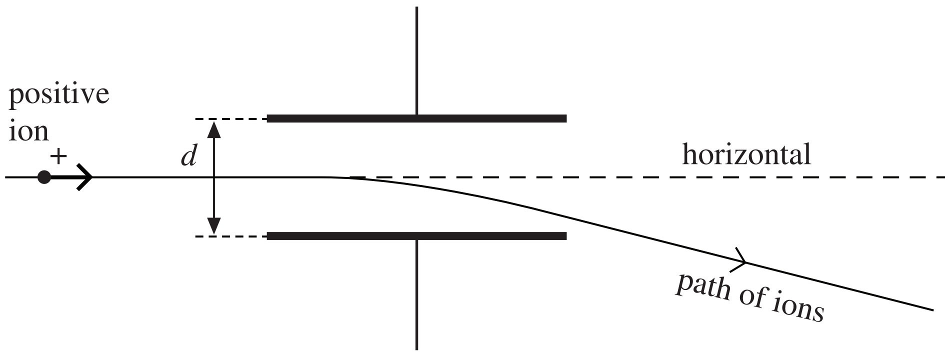
B ....

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)

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 $1.7 \times 10^5\,\text{m s}^{-1}$. 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 $1.7 \times 10^5\,\text{m s}^{-1}$ when they pass between the plates at a time when the conditions in part (b)(iii) have been established.

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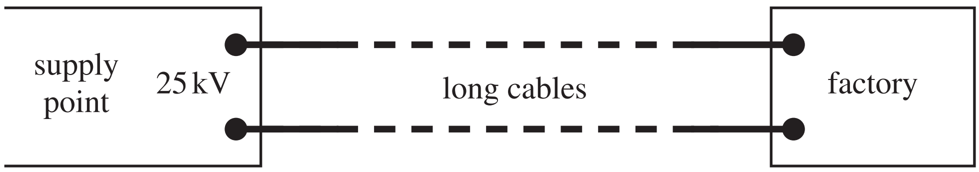
(2 marks)

11

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)

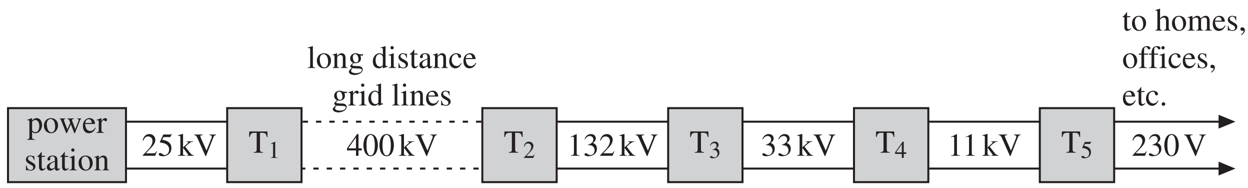
5 (a) (iii) Calculate the efficiency with which power is transmitted by the cables from the input at the supply point to the factory.

answer = ...%

(1 mark)

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

Turn over ▶

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

Answer **all** the questions.

1 **(a)** Fig. 1.1 shows a circuit consisting of two parallel plates **A** and **B** connected to a high voltage power supply.

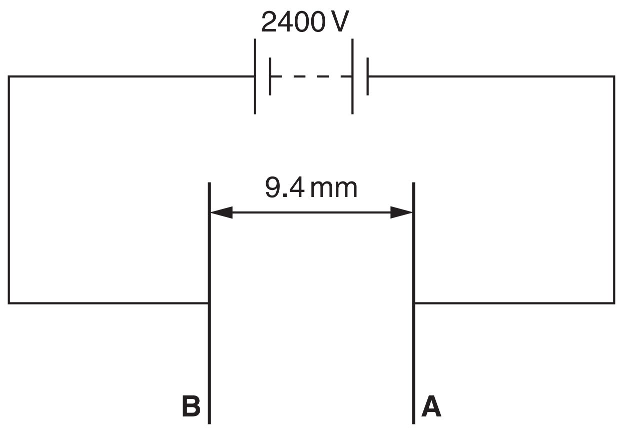

Fig. 1.1

The separation of the plates is 9.4 mm and the p.d. across the plates is 2400 V. There is a vacuum between the plates. Electrons are accelerated from plate **A** to plate **B**.

Calculate

(i) the force acting on an electron when it is between the plates

force = ... N **[2]**

(ii) the gain in kinetic energy of an electron when it travels from **A** to **B**

kinetic energy = ... J **[2]**

(iii) the speed of the electron when it reaches plate **B**. Assume that the speed of the electron is initially zero at plate **A**.

speed = ... m s^{-1} **[1]**

(b) The separation between the plates is doubled but the p.d. across the plates is kept the same. Explain how this would affect the answer to **(a)(ii)**.

....

....

....

.... **[2]**

[Total: 7]

2 **(a)** Define the *farad*.

.... **[1]**

(b) Fig. 2.1 shows a capacitor **C** of capacitance 5.4 nF connected to a battery. The switch $\mathbf{S_1}$ is closed and the capacitor is charged to a p.d. of 12 V.

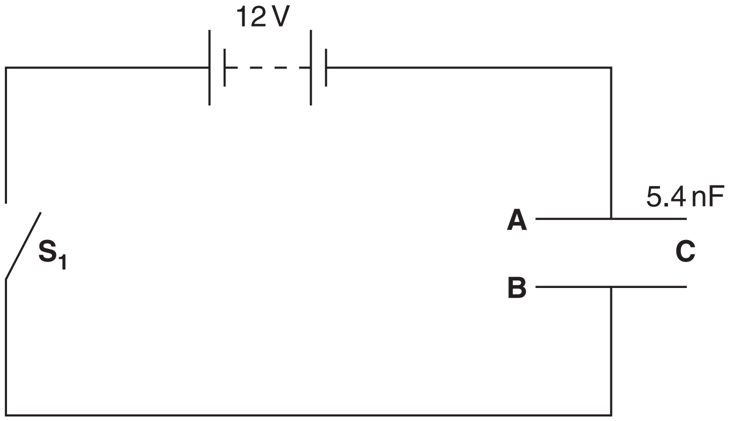

Fig. 2.1

The plates of the capacitor are labelled **A** and **B**.

(i) Explain how the plates of the capacitor become charged in terms of the movement of charged particles in the circuit.

....

....

....

.... **[2]**

(ii) Calculate

1 the charge stored by the capacitor

charge = ... C **[1]**

2 the energy transferred to the capacitor.

energy = ... J **[1]**

(c) Fig. 2.2 shows the capacitor **C** connected to a resistor **R**.

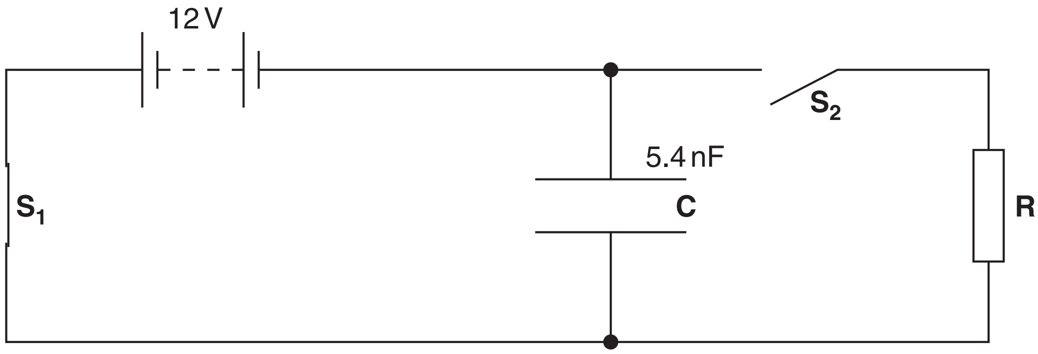

Fig. 2.2

The switch $\mathbf{S_1}$ is now opened and switch $\mathbf{S_2}$ is closed. The current in the resistor **R** is monitored. The initial current through **R** is 3.24 μA.

(i) Show that the resistance of the resistor **R** is 3.7 MΩ.

[1]

(ii) Calculate the current through **R** after a time t = 0.080 s.

current = ... μA **[2]**

(d) Explain the effect on the initial rate of discharge of the capacitor when a second resistor of resistance 3.7 MΩ is connected in parallel with the resistor **R**.

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....

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.... **[2]**

Total: [10]

3 Fig. 3.1 shows part of an accelerator used to produce high-speed protons. The protons pass through an evacuated tube that is shown in the plane of the paper.

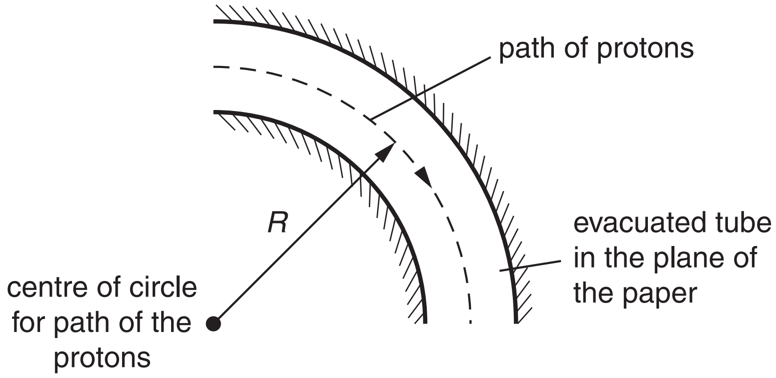

Fig. 3.1

The protons are made to travel in a circle of radius R by a magnetic field of flux density B.

(a) State clearly the direction of the magnetic flux density B that produces the circular motion of the protons.

.... **[1]**

(b) Show that the relationship between the velocity v of the protons and the radius R is given by $v = \dfrac{BQR}{m}$ where Q and m are the charge and mass of a proton respectively.

[1]

(c) Calculate the magnetic flux density B of the magnetic field needed to keep protons in a circular orbit of radius 0.18 m. The time for one complete orbit is 2.0×10^{-8} s.

B = ... T **[3]**

(d) Explain why the magnetic field does not change the speed of the protons.

....

....

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.... **[2]**

[Total: 7]

4 **(a)** State Hubble's Law.

....

.... **[1]**

(b) The dark lines of the spectrum observed from a distant galaxy are red-shifted by 15% of their normal wavelengths.

The Hubble constant is estimated to be 65 $km\,s^{-1}\,Mpc^{-1}$. One parsec = 3.1×10^{16} m.

(i) Show that the speed of the galaxy is $4.5 \times 10^{7}\,m\,s^{-1}$.

[1]

(ii) Estimate the distance of the galaxy from the Earth.

distance = ... m **[2]**

(iii) Estimate the age of the universe in years.

1 year = 3.2×10^{7} s

age = ... y **[2]**

(c) The age of the universe is calculated from the time of the big bang. Describe **two** observations that directly support the idea of the big bang.

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.... **[2]**

[Total: 8]

5 **(a)** Define the *parsec*. Draw a diagram to illustrate your answer.

....

.... **[2]**

(b) The star Tau Ceti has a parallax of 0.275 seconds of arc.

Calculate the distance of Tau Ceti from Earth

(i) in parsec (pc)

distance = ... pc **[1]**

(ii) in light year (ly).

1 pc = 3.1×10^{16} m

distance = ... ly **[2]**

[Total: 5]

Turn over

6 (a) (i) Describe the formation of a star such as our Sun and its most probable evolution.

In your answer you should make clear how the steps in the process are sequenced.

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.... [6]

(ii) Describe the probable evolution of a star that is much more massive than our Sun.

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.... [2]

(b) The present mass of the Sun is 2.0×10^{30} kg. The Sun emits radiation at an average rate of $3.8 \times 10^{26}\,J\,s^{-1}$. Calculate the time in years for the mass of the Sun to decrease by one millionth of its present mass.

$1\ y = 3.2 \times 10^{7}\,s$

time = ... y **[3]**

(c) The following nuclear equation summarises a typical fusion reaction cycle that occurs in the Sun.

$$4\,{}^{1}_{1}H \rightarrow {}^{4}_{2}He + 2\,{}^{0}_{1}e + 2\nu$$

(i) Explain the process of nuclear fusion in the core of the Sun. In your explanation refer to the conditions necessary for fusion to occur.

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.... **[4]**

(ii) Name two forms of energy produced in thermonuclear reactions.

1. ....

2. .... **[2]**

(iii) The binding energy per nucleon of ${}^{1}_{1}H$ and ${}^{4}_{2}He$ are 0 and 7.2 MeV respectively. Calculate the energy produced in joules for the fusion reaction above.

energy = ... J **[2]**

[Total: 19]

Turn over

7 **(a)** Describe the *piezoelectric effect*.

....

.... **[1]**

(b) Describe how ultrasound scanning is used to obtain diagnostic information about internal structures of a body. In your description include the differences between an A-scan and a B-scan.

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.... **[4]**

(c) Fig. 7.1 shows the speed of ultrasound, density and acoustic impedance for muscle and bone.

material	speed of ultrasound / $m\,s^{-1}$	density / $kg\,m^{-3}$	acoustic impedance / $10^6\,kg\,m^{-2}\,s^{-1}$
muscle	1590	1080	1.72
bone	4080	1750	7.14

Fig. 7.1

(i) Show that the unit for acoustic impedance is $kg\,m^{-2}\,s^{-1}$.

[1]

(ii) An ultrasound pulse is incident at right angles to the boundary between bone and muscle. Calculate the fraction of reflected intensity of the ultrasound.

fraction of reflected intensity = ... **[2]**

(iii) What is meant by *acoustic impedance matching*? Explain why a gel is used to produce an effective ultrasound image.

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.... **[2]**

(iv) The frequency of the ultrasound in the muscle is 1.2 MHz. Calculate the wavelength of the ultrasound in millimetres (mm).

wavelength = ... mm **[2]**

(v) Suggest why it is desirable to have ultrasound of short wavelength for a scan.

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.... **[1]**

[Total: 13]

8 **(a)** Describe the use of image intensifiers and contrast media when X-rays are used to produce images of internal body structures.

In your answer, you should make clear how the appearance of the image is linked to the techniques used.

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.... **[5]**

(b) A student suggests an image intensifier uses the photoelectric effect. Explain why this suggestion is **incorrect**.

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.... **[1]**

(c) **(i)** Explain how the production of a CAT scan image differs from that of a simple X-ray image.

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.... **[2]**

(ii) Describe the advantages of a CAT scan compared to an X-ray image.

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.... **[2]**

Total: [10]

9 **(a)** **(i)** Complete Fig. 9.1 to show the quark composition and charge for neutrons and protons.

	quark composition	charge
neutron		
proton		

Fig. 9.1

[2]

(ii) Complete Fig. 9.2 to show the composition of quarks.

quark	charge	baryon number	strangeness
up		+ 1/3	
down			0

Fig. 9.2

[2]

(b) When a neutron decays it can produce particles that include an electron.

(i) Complete the decay equation below for a neutron.

$^{1}_{0}n \rightarrow$

[2]

(ii) Name the interaction responsible for the decay of the neutron.

.... **[1]**

(iii) Electrons and neutrons belong to different groups of particles. Name the group of particles to which each belongs.

electrons ....

neutrons .... **[1]**

[Total: 8]

10 **(a)** Describe what is meant by the **spontaneous** and **random** nature of radioactive decay of unstable nuclei.

....

....

....

.... **[2]**

(b) Define the *decay constant*.

....

.... **[2]**

(c) Explain the technique of radioactive carbon-dating.

....

....

....

....

....

.... **[4]**

(d) The activity of a sample of living wood was measured over a period of time and averaged to give 0.249 Bq. The same mass of a sample of dead wood was measured in the same way and the activity was 0.194 Bq. The half-life of carbon-14 is 5570 years.

(i) Calculate

1 the decay constant in y^{-1} for the carbon-14 isotope

decay constant = ... y^{-1} **[1]**

2 the age of the sample of dead wood in years.

age = ... y **[2]**

(ii) Suggest why the activity was measured over a long time period and then averaged.

....

.... **[1]**

(iii) Explain why the method of carbon-dating is not appropriate for samples that are greater than 10^5 years old.

....

.... **[1]**

[Total: 13]

END OF QUESTION PAPER