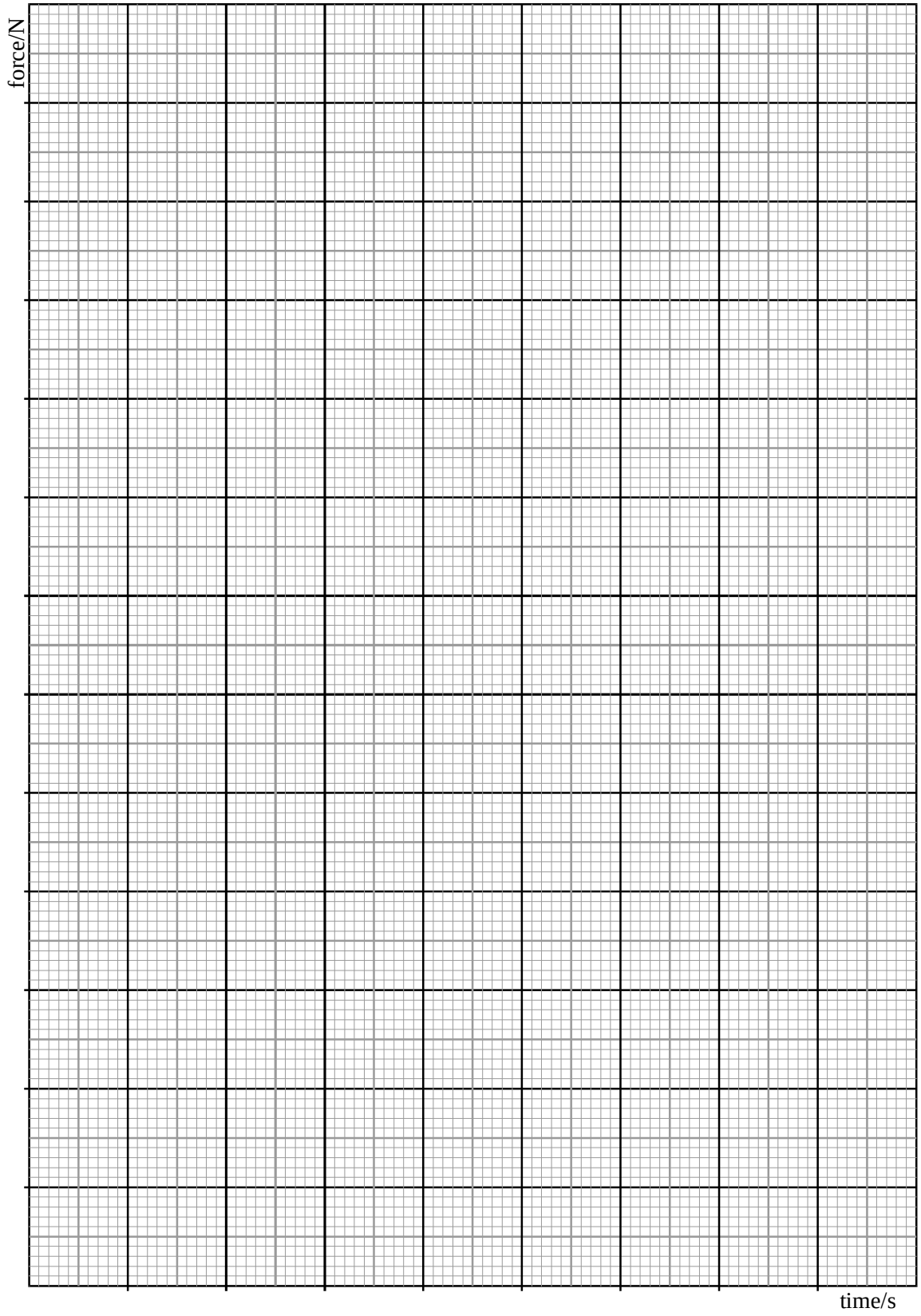
1. A toy locomotive of mass 0.50kg is initially at rest on a horizontal track. The locomotive is powered by a twisted rubber band which, as it unwinds, exerts a force which varies with time as shown in the table.

time/s	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0
force/N	0.20	0.18	0.15	0.12	0.10	0.08	0.05	0.02	0.00

(a) (i) On the grid below plot a graph of force against time for the rubber band power source.



(ii) State what is given by the area between the graph and the time axis.

.....

(4)

(b) The rubber band is wound up and released to power the locomotive. Use your graph to show that the speed of the locomotive 8.0s after the twisted rubber band is released is l.6 m s^{-1}. Ignore the effects of air resistance and energy losses due to friction.

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(2)

(c) 8.0s after release the locomotive collides with and couples to a toy truck, initially at rest, which has a mass of 1.50kg.

(i) Calculate the speed of the coupled locomotive and truck after collision.

.....

.....

(ii) Calculate the combined kinetic energy of the locomotive and truck immediately after collision.

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(iii) Show, with the aid of a calculation, whether or not the collision is elastic.

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(5)
(Total 11 marks)

2. A 10 μF capacitor is connected across the terminals of a 100 V d.c. power supply and allowed to charge fully.

(a) Calculate

(i) the charge on the capacitor,

.....

.....

(ii) the energy stored by the capacitor.

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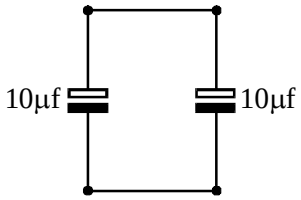
.....

(2)

(b) The fully-charged capacitor is disconnected from the power supply and connected via two wires across the terminals of an uncharged 10 μF capacitor as shown.



The charge on the original 10 μF capacitor is shared equally between the capacitors in the parallel combination.

(i) Calculate the potential difference across the terminals of each capacitor.

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(ii) Calculate the total energy stored by the two capacitors.

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(iii) Account for the difference between the energy stored by the two capacitors in parallel and that stored by the original single 10 μF capacitor.

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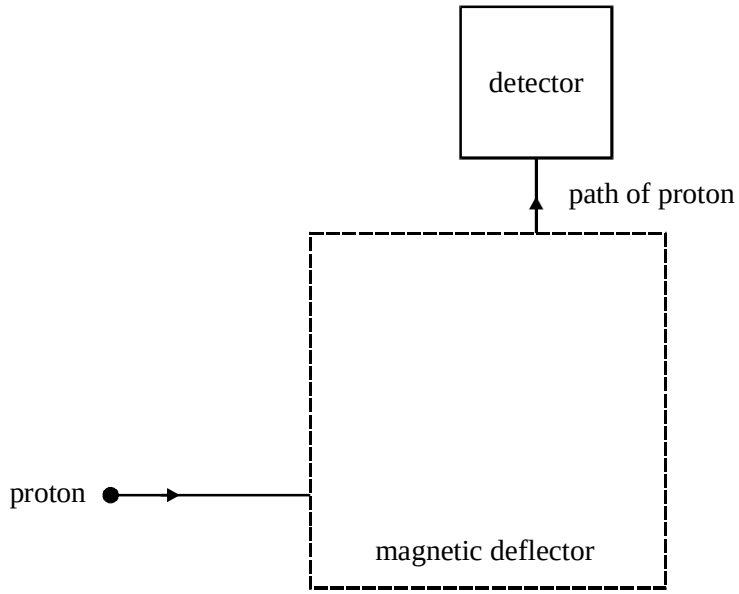
(4)
(Total 6 marks)

3. The diagram shows an arrangement in a vacuum to deflect protons into a detector using a magnetic field, which can be assumed to be uniform within the square shown and zero outside it.
The motion of the protons is in the plane of the paper.



(a) Sketch the path of a proton through the magnetic deflector. At any point on this path draw an arrow to represent the magnetic force on the proton. Label this arrow F.

(2)

(b) State the direction of the uniform magnetic field causing this motion.

.....

(1)

(c) The speed of a proton as it enters the deflector is $5.0 \times 10^6 ms^{-1}$. If the flux density of the magnetic field is 0.50T, calculate the magnitude of the magnetic force on the proton.

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.....

.....

(2)

(d) If the path were that of an electron with the same velocity, what **two** changes would need to be made to the magnetic field for the electron to enter the detector along the same path?

.....

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(2)
(Total 7 marks)

4. (a) (i) Define *electric field strength*, and state whether it is a scalar quantity or a vector quantity.

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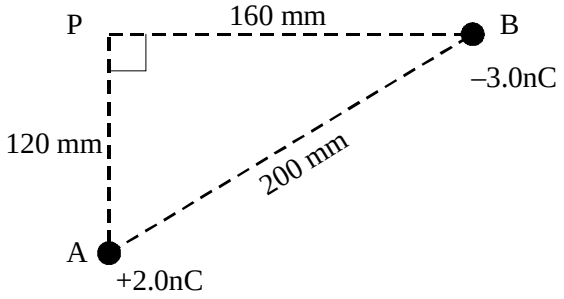
.....

(ii) Complete the diagram below to show the electric field lines in the region around two equal positive point charges. Mark with a letter N the position of any point where the field strength is zero.

(6)

(b) Point charges A, of +2.0 nC, and B, of –3.0 nC, are 200 mm apart in a vacuum, as shown by the figure. The point P is 120 mm from A and 160 mm from B.



(i) Calculate the component of the electric field at P in the direction AP.

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.....

(ii) Calculate the component of the electric field at P in the direction PB.

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(iii) Hence calculate the magnitude and direction of the resultant field at P.

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(6)

(c) (i) Explain why there is a point X on the line AB in part (b) at which the **electric potential** is zero.

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(ii) Calculate the distance of the point X from A.

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(4)
(Total 16 marks)

5. (a) State, in words, Newton's law of gravitation.

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(2)

(b) Some of the earliest attempts to determine the gravitational constant, *G*, were regarded as experiments to "weigh" the Earth. By considering the gravitational force acting on a mass at the surface of the Earth, regarded as a sphere of radius *R*, show that the mass of the Earth is given by

$$M = \frac{gR^2}{G},$$

where *g* is the value of the gravitational field strength at the Earth's surface.

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(2)

(c) In the following calculation use these data.

radius of the Moon	= 1.74×10^6 m
gravitational field strength at Moon's surface	= 1.62 N kg^{-1}
mass of the Earth *M*	= 6.00×10^{24} kg
gravitational constant *G*	= 6.67×10^{-11} Nm^2 kg^{-2}

Calculate the mass of the Moon and express its mass as a percentage of the mass of the Earth.

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(3)
(Total 7 marks)

6. A parallel plate capacitor consists of two smooth square metal plates with sides of length 0.35 m. The gap between the plates is filled completely with a sheet of mica of thickness 0.15mm. The plates of the capacitor are connected across the terminals of a 1.2 kV supply. Refer to the Data Sheet for any additional information.

(a) Calculate

(i) the magnitude of the charge on the capacitor,

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(ii) the resistance of the mica sheet, i.e. the resistance between the plates.

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(6)

(b) When the capacitor is disconnected from the supply there is a leakage current through the mica sheet and the charge reduces to zero in about 3 hours. Calculate the mean current flowing during the loss of charge from the capacitor.

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(2)

(c) Explain why there is a limit to the magnitude of the potential difference that may be applied between the plates of the capacitor.

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(3)
(Total 11 marks)

7. A camera flashgun uses the discharge of a capacitor to provide the energy to produce a single flash. In a particular flashgun a 4700 μF capacitor is initially charged from a 90 V supply.

(a) Calculate

(i) the charge stored by the capacitor when it is fully charged,

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(ii) the energy stored by the fully-charged capacitor,

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.....

(iii) the average current which flows if total discharge of the capacitor takes place effectively in 30 ms.

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(3)

(b) During a partial discharge of the capacitor the potential difference between its terminals falls from 90 V to 80 V. Calculate the energy discharged to the flashgun.

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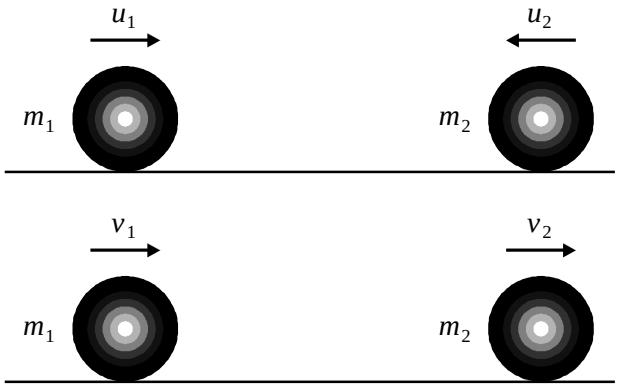
(2)
(Total 5 marks)

8. (a) (i) Give an equation showing how the principle of conservation of momentum applies to the colliding snooker balls shown in the diagram.



.....

(ii) State the condition under which the principle of conservation of momentum applies.

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(3)

(b) A trolley, A, of mass 0.25 kg and a second trolley, B, of mass 0.50 kg are held in contact on a smooth horizontal surface. A compressed spring inside one of the trolleys is released and they then move apart. The speed of A is 2.2 m s^{-1}.

(i) Calculate the speed of B.

.....

.....

.....

(ii) Calculate a minimum value for the energy stored in the spring when compressed.

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.....

.....

(4)

(c) The rotor blades of a helicopter sweep out a cross-sectional area, *A*. The motion of the blades helps the helicopter to hover by giving a downward velocity, v, to a cylinder of air, density ρ. The cylinder of air has the same cross-sectional area as that swept out by the rotor blades.

Explaining your reasoning,

(i) derive an expression for the mass of air flowing downwards per second, and

.....

.....

.....

(ii) derive an expression for the momentum given per second to this air.

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.....

(iii) Hence show that the motion of the air results in an upward force, F, on the helicopter given by

$$F = \rho A v^2.$$

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(5)

(d) A loaded helicopter has a mass of 2500 kg. The area swept out by its rotor blades is $180 m^2$. If the downward flow of air supports 50% of the weight of the helicopter, what speed must be given to the air by the motion of the rotor blades when the helicopter is hovering? Take the density of air to be 1.3 kg m^{-3}.

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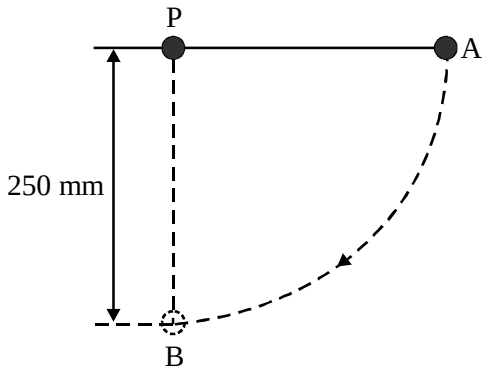
(3)
(Total 15 marks)

9.



A 150 g mass is attached to one end of a light inextensible string and the other end of the string is fixed at a point P as shown in the diagram above. The mass is held at point A so that the string is taut and horizontal. The mass is released so that it moves freely along a circular arc of 250 mm radius.

When the string moves through the vertical position, the mass is at point B. Neglecting the effect of air resistance, calculate

(i) the kinetic energy of the mass,

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.....

.....

(ii) the velocity of the mass,

.....

.....

(iii) the centripetal force acting on the mass,

.....

.....

(iv) the tension in the string.

.....

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(Total 6 marks)

10. (a) A capacitor is made from two parallel metal plates of the same area, separated by an air gap. It is connected across a battery of constant e.m.f.

The plates are moved further apart, maintaining the same area of overlap, whilst the battery remains connected. State and explain what change, if any, occurs to

(i) the potential difference across the plates,

.....

(ii) the capacitance of the capacitor,

.....

(iii) the charge on each plate of the capacitor,

.....

(iv) the energy stored by the capacitor.

.....

(4)

(b) A thunder cloud and the earth beneath it can be considered to form a parallel plate capacitor. The area of the cloud is 8.0 km^2 and it is 0.75 km above the earth.

(i) Calculate the energy stored if the potential difference between the cloud and the earth is 200 kV.

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(ii) The air suddenly conducts, allowing all the charge to flow to earth in 120 μs. Calculate the mean current flowing between the cloud and the earth when this happens.

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(6)

(Total 10 marks)

11. The gravitational field strength at the surface of a planet, X, is 19 N kg^{-1}.

(a) (i) Calculate the gravitational potential difference between the surface of X and a point 10 m above the surface, if the gravitational field can be considered to be uniform over such a small distance.

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.....

(ii) Calculate the minimum amount of energy required to lift a 9.0 kg rock a vertical distance of 10m from the surface of X.

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(iii) State whether the minimum amount of energy you have found in part (a)(ii) would be different if the 9.0 kg mass were lifted a vertical distance of 10 m from a point near the top of the highest mountain of planet X. Explain your answer.

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.....

(3)

(b) Calculate the gravitational field strength at the surface of another planet, Y, that has the same mass as planet X, but twice the diameter of X.

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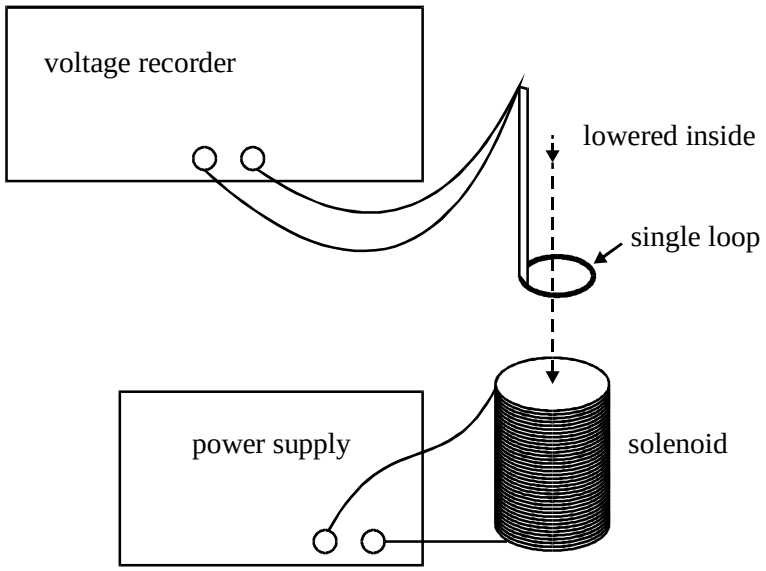
(2)
(Total 5 marks)

12. An experiment is performed to investigate the magnetic field inside a 100 mm long solenoid of 500 turns. A small single loop of wire attached to a voltage recorder (data logger) is lowered coaxially inside the solenoid, as shown in the diagram, until it is at the centre of the solenoid.



The solenoid is supplied with a steady current of 0.50 A.

The magnetic flux density at a point on the axis well inside a long solenoid is given by

$$B = \frac{\mu_0 NI}{l},$$

where N is the number of turns on the solenoid and l is its length. μ_0 and I have their usual meanings.

(i) Calculate the approximate value of the flux density at the centre of the solenoid on its axis.

.....

.....

(ii) The single loop of wire is positioned at the centre of the solenoid so that it is at right angles to the magnetic field. If the loop has an area of 160 mm^2, calculate the magnetic flux through the loop.

(Total 3 marks)

13. Take the acceleration due to gravity, g_E, as 10 m s^{-2} on the surface of the Earth.

The acceleration due to gravity on the surface of the Moon is $\frac{g_E}{6}$. An object whose weight on Earth is 5.0 N is dropped from rest above the Moon's surface. What is its momentum after falling for 3.0s?

A 2.5 kg m s^{-1}

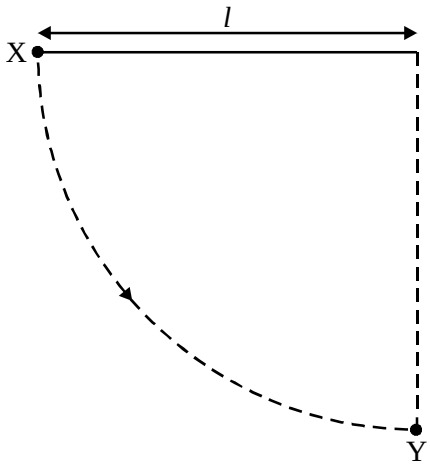
B 6.2 kg m s^{-1}

C 15 kg m s^{-1}

D 25 kg m s^{-1}

(Total 1 mark)

14.



A simple pendulum consists of a bob of mass *m* on the end of a light string of length *l*. The bob is released from rest at X when the string is horizontal. When the bob passes through Y its velocity is υ and the tension in the string is *T*. Which one of the following equations gives the correct value of *T*?

A $T = mg$

B $T = \frac{m\upsilon^2}{l}$

C $T + mg = \frac{m\upsilon^2}{l}$

D $T - mg = \frac{m\upsilon^2}{l}$

(Total 1 mark)

15. In experiments to pass a very high current through a gas, a bank of capacitors of total capacitance 50 μF is charged to 30 kV. If the bank of capacitors could be discharged completely in 5.0 ms what would be the mean power delivered?

A 9.0 MW

B 4.5 MW

C 110 kW

D 22 kW

(Total 1 mark)

16. (a) (i) Give an equation showing how the principle of conservation of momentum applies to the colliding snooker balls shown in the diagram.

before collision

after collision

.....

(ii) State the condition under which the principle of conservation of momentum applies.

.....

.....

(3)

(b) A trolley, A, of mass 0.25 kg and a second trolley, B, of mass 0.50 kg are held in contact on a smooth horizontal surface. A compressed spring inside one of the trolleys is released and they then move apart. The speed of A is 2.2 m s^{-1}.

(i) Calculate the speed of B.

.....

.....

.....

(ii) Calculate a minimum value for the energy stored in the spring when compressed.

.....

.....

.....

(4)

(c) The rotor blades of a helicopter sweep out a cross-sectional area, *A*. The motion of the blades helps the helicopter to hover by giving a downward velocity, v, to a cylinder of air, density ρ. The cylinder of air has the same cross-sectional area as that swept out by the rotor blades.

Explaining your reasoning,

(i) derive an expression for the mass of air flowing downwards per second, and

.....

.....

.....

(ii) derive an expression for the momentum given per second to this air.

.....

.....

(iii) Hence show that the motion of the air results in an upward force, F, on the helicopter given by

$$F = \rho A v^2.$$

.....

.....

.....

(5)

(d) A loaded helicopter has a mass of 2500 kg. The area swept out by its rotor blades is 180 m^2. If the downward flow of air supports 50% of the weight of the helicopter, what speed must be given to the air by the motion of the rotor blades when the helicopter is hovering? Take the density of air to be 1.3 kg m^{-3}.

.....

.....

.....

(3)
(Total 15 marks)

17. (a) State what is meant by

(i) a free vibration,

.....

.....

(ii) a forced vibration.

.....

.....

(2)

(b) A car and its suspension can be treated as a simple mass-spring system. When four people of total weight 3000 N get into a car of weight 6000 N, the springs of the car are compressed by an extra 50 mm.

(i) Calculate the spring constant, *k*, of the system.

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.....

(ii) Show that, when the system is displaced vertically and released, the time period of the oscillations is 0.78 s.

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(3)

(c) The loaded car in part (b) travels at 20 ms^{-1} along a road with humps spaced 16 m apart.

(i) Calculate the time of travel between the humps.

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(ii) Hence, state and explain the effect the road will have on the oscillation of the car.

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(3)
(Total 8 marks)

18. A metal aircraft with a wing span of 42m flies horizontally with a speed of 1000 km h^{-1} in a direction due east in a region where the vertical component of the flux density of the Earth's magnetic field is 4.5 ×

10^{-5} T.

(i) Calculate the flux cut per second by the wings of the aircraft.

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(ii) Determine the magnitude of the potential difference between the wing tips, stating the law which you are applying in this calculation.

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(iii) What would be the change in the potential difference, if any, if the aircraft flew due west?

.....

.....

(Total 6 marks)

19. (a) For a capacitor of capacitance C, sketch graphs of charge, *Q*, and energy stored, *E*, against potential difference, *V*.

graph A

graph B

What is represented by the slope of graph A?

.....

(3)

(b) A capacitor of capacitance 0.68 F is charged to 6.0 V. Calculate

(i) the charge stored by the capacitor,

.....

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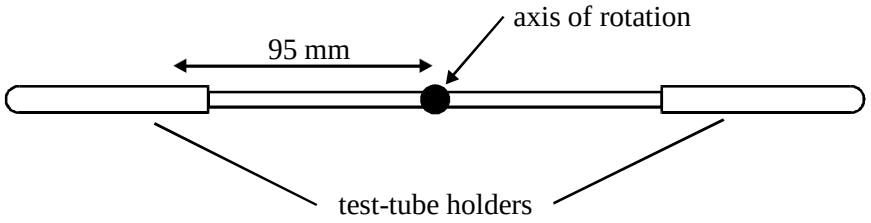
(ii) the energy stored by the capacitor.

.....

.....

(2)
(Total 5 marks)

20. A chemical centrifuge consists of two test-tube holders which can be spun round in a horizontal circular path at very high speed as shown. The centrifuge runs at a steady speed of 3000 revolutions per minute and the test-tube holders are horizontal.



(i) Calculate the angular speed of the centrifuge in rad s^{-1}

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.....

(ii) Calculate the magnitude of the acceleration at a point on the centrifuge 95 mm from the axis of rotation.

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(iii) State the direction of the acceleration in part (ii).

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(Total 5 marks)

21. (a) A vibrating system which is experiencing *forced vibrations* may show *resonance.*

Explain what is meant by

forced vibrations .....

.....

resonance.....

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.....

.....

(3)

(b) (i) Explain what is meant by *damping.*

.....

.....

(ii) What effect does damping have on resonance?

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(2)
(Total 5 marks)

22. Both gravitational and electric field strengths can be described by similar equations written in the form

$$a = \frac{bc}{d^2}.$$

(a) Complete the following table by writing down the names of the corresponding quantities, together with their SI units, for the two types of field.

symbol	*gravitational field* quantity	SI unit	*electrical field* quantity	SI unit
a	gravitational field strength			
b			$\frac{1}{4\pi\varepsilon_0}$	m F^{-1}
c				
d				

(4)

(b) Two isolated charged objects, A and B, are arranged so that the gravitational force between them is equal and opposite to the electric force between them.

(i) The separation of A and B is doubled without changing their charges or masses. State and explain the effect, if any, that this will have on the resultant force between them.

.....

.....

(ii) At the original separation, the mass of A is doubled, whilst the charge on A and the mass of B remain as they were initially. What would have to happen to the charge on B to keep the resultant force zero?

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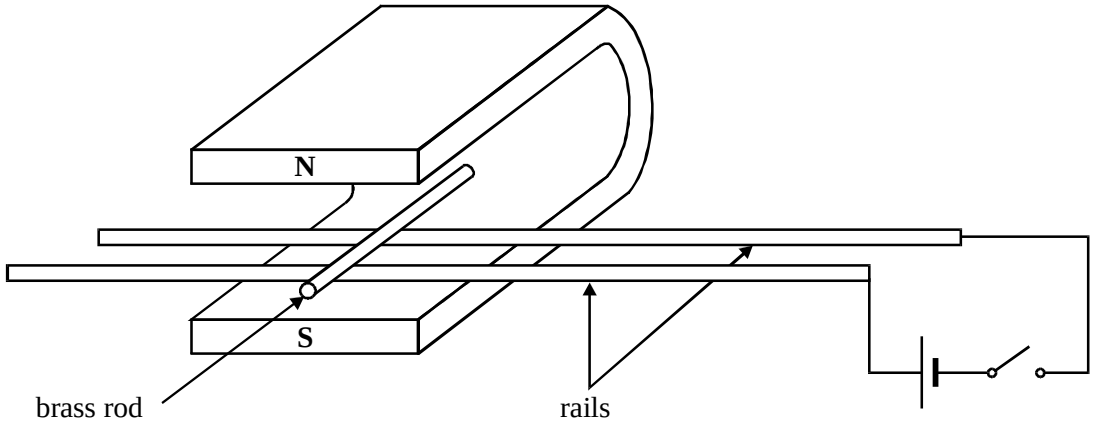
(3)
(Total 7 marks)

23. The diagram shows a current-carrying conductor which is free to move between the poles of a horseshoe magnet. The conductor is a brass rod resting on two conducting parallel rails.



(a) Draw an arrow on the diagram to show the direction of the force on the rod due to the magnetic field when the switch is closed. Label it F.

(1)

(b) Using the information below, calculate the magnitude of the force F.

The e.m.f. of the cell is 2.0 V.
The flux density of the magnetic field in the region of the rod is 0.080 T.
The total resistance of the circuit is 0.40 Ω.
The rails are 60 mm apart.

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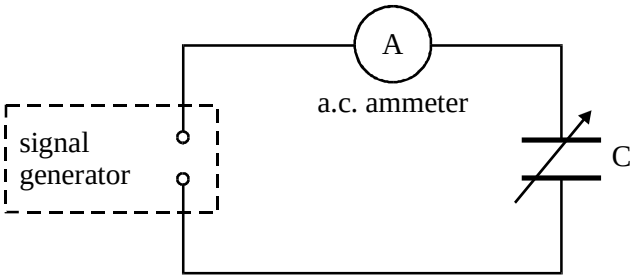
(2)
(Total 3 marks)

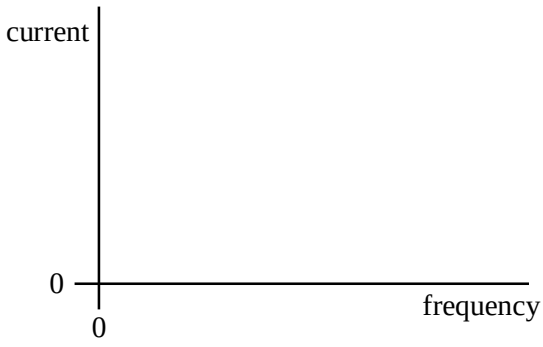
24. A student is investigating the effect of capacitors in a.c. circuits. He connects up the circuit shown in the diagram. The variable frequency signal generator supplies a sinusoidal a.c. output at constant r.m.s. voltage. C is a capacitor whose capacitance, *C*, may be altered.



(a) The student measures the r.m.s. current for several different frequencies when *C* is constant. He then plots graphs of current against frequency.

(i) Sketch, using the axes below, the graph you would expect him to obtain.
Label this graph F.

(ii) Also sketch, using the same axes, the graph expected when the capacitance is half the value in part (i). Label it S.



(iii) Show how the value of the capacitance of C can be calculated from the gradient of the graph and the r.m.s. voltage of the signal generator output.

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(5)

(b) The output from the signal generator was 7.8 V r.m.s. At a particular frequency the r.m.s. current was 90 mA. Calculate the reactance of the capacitor at this frequency.

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(2)

(Total 7 marks)

25. A spring, which obeys Hooke's law, hangs vertically from a fixed support and requires a force of 2.0 N to produce an extension of 50mm. A mass of 0.50kg is attached to the lower end of the spring. The mass is pulled down a distance of 20mm from the equilibrium position and then released.

(a) (i) Show that the time period of the simple harmonic vibrations is 0.70 s.

.....

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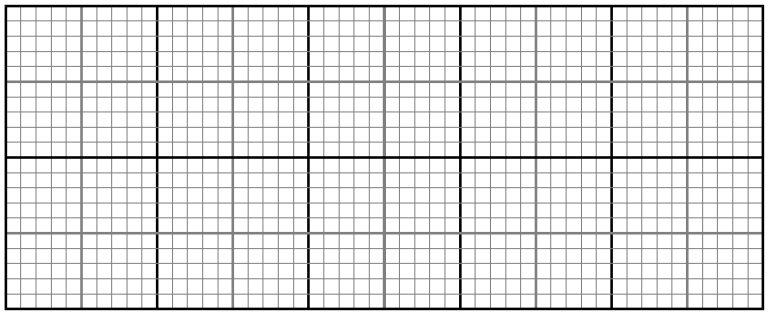
(ii) Sketch the displacement of the mass against time, starting from the moment of release and continuing for two oscillations. Show appropriate time and distance scales on the axes.



(5)

(b) The mass-spring system described in part (a) is attached to a support which can be made to vibrate vertically with a small amplitude. Describe the motion of the mass-spring system with reference to frequency and amplitude when the support is driven at a frequency of

(i) 0.5 Hz**,**

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(ii) 1.4 Hz.

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(3)
(Total 8 marks)

26. (a) Figure 1 shows a pair of parallel metal plates, A and B, fixed vertically 20 mm apart with a potential difference of 1500 V between them.

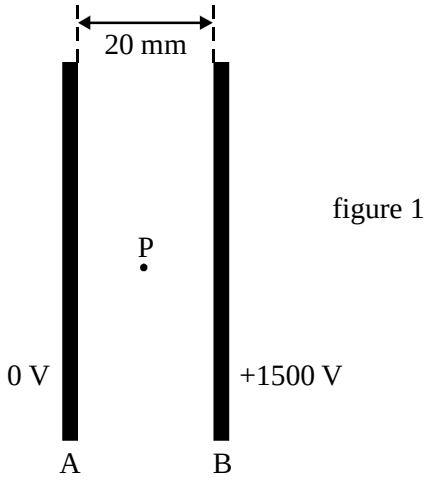
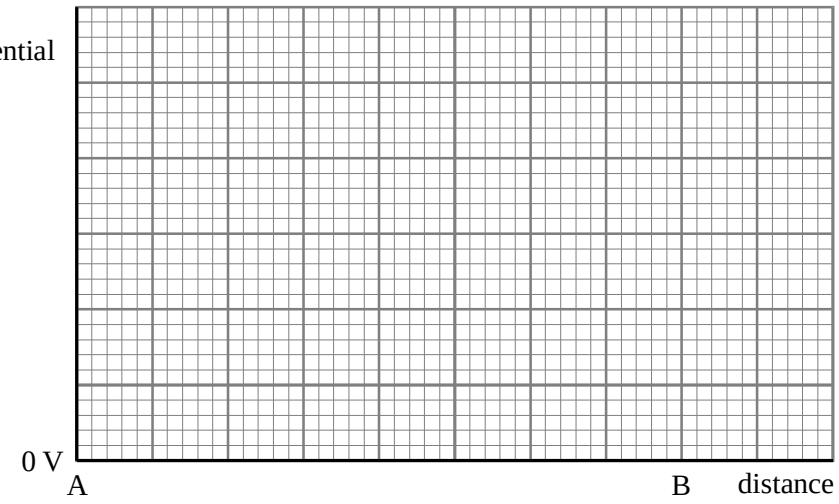


figure 1

(i) Draw the electric field lines in the space between the plates and calculate the electric field strength at P.

(ii) Sketch a graph showing the potential at different points in the space between the plates.



(5)

(b) Figure 2 shows a polystyrene ball of mass 5.0×10^{-4} kg suspended midway between the plates by a long insulating thread. The ball has a conducting surface and carries an initial charge of –3.0 nC.

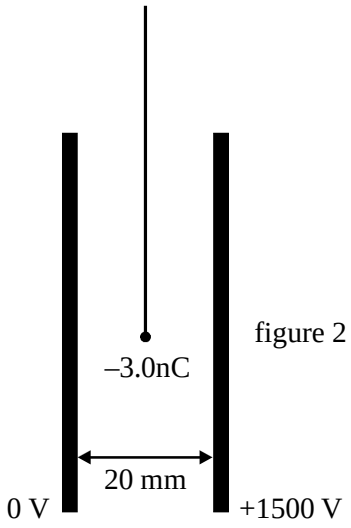


figure 2

(i) Calculate the force on the ball due to the electric field and hence show that the ball, when released from rest, will take a time of approximately 0.2 s to reach one conducting plate. State the direction of motion of the ball.

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(ii) Explain why the ball will subsequently shuttle backwards and forwards between the plates.

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(6)

(c) The same charged ball described in part (b) is suspended at rest between the poles of a magnet. State the magnitude and direction of the force (if any) on the ball and explain your answer.

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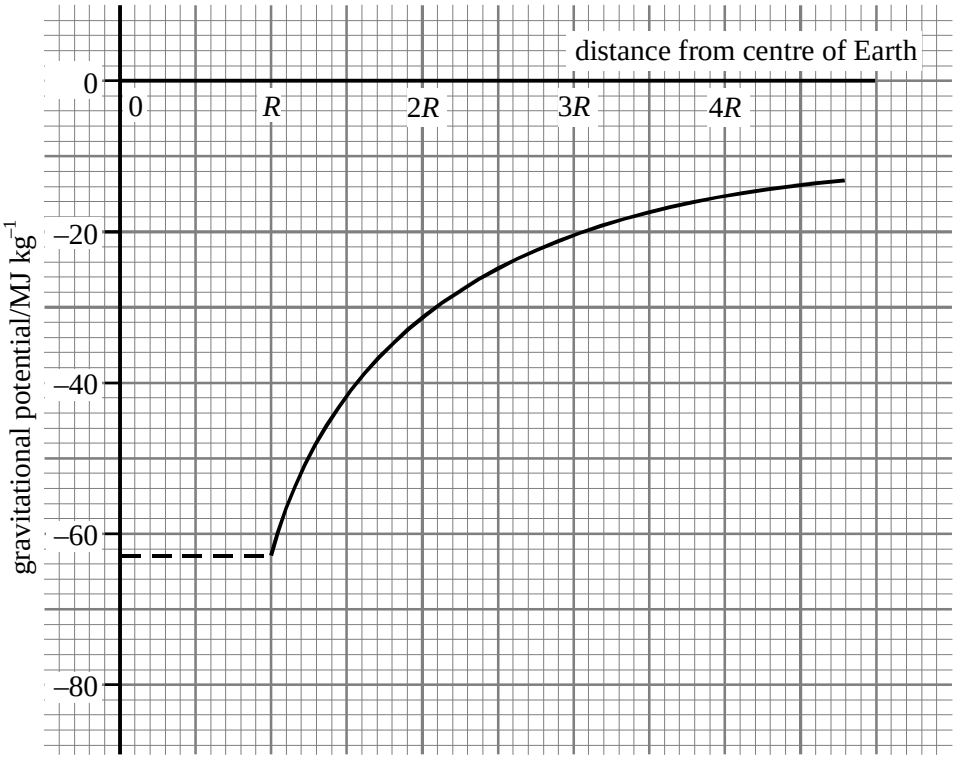
(2)
(Total 13 marks)

27. (a) The graph shows how the gravitational potential varies with distance in the region above the surface of the Earth. *R* is the radius of the Earth, which is 6400 km. At the surface of the Earth, the gravitational potential is –62.5 MJ kg^{-1}



Use the graph to calculate

(i) the gravitational potential at a distance 2*R* from the centre of the Earth,

.....

(ii) the increase in the potential energy of a 1200kg satellite when it is raised from the surface of the Earth into a circular orbit of radius 3*R*.

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(4)

(b) (i) Write down an equation which relates gravitational field strength and gravitational potential.

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(ii) **By use of the graph** in part (a), calculate the gravitational field strength at a distance 2*R* from the centre of the Earth.

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(iii) Show that your result for part (b)(ii) is consistent with the fact that the surface gravitational field strength is about 10 N kg^{-1}.

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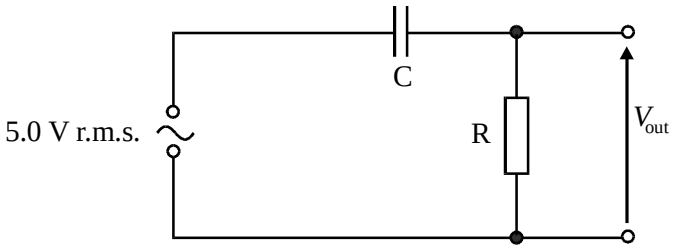
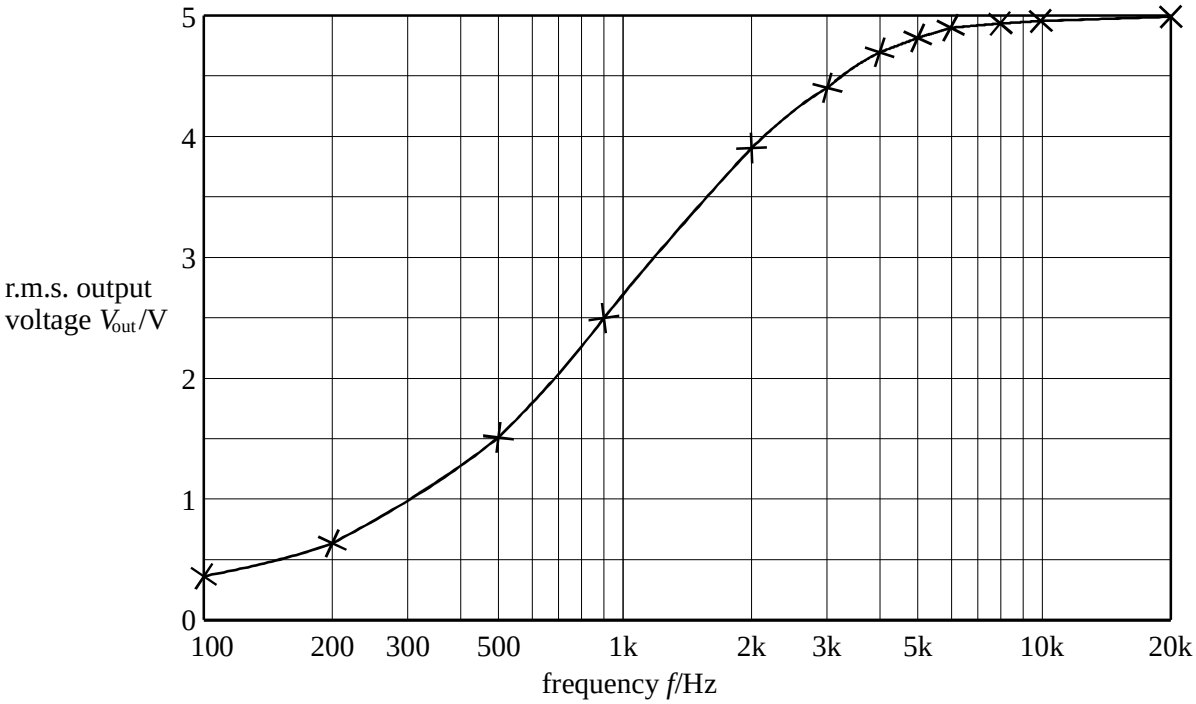
(5)
(Total 9 marks)

28. The curve on the graph is the measured frequency response of the audio-frequency filter shown in the circuit diagram. A fixed voltage of 5.0V r.m.s. is applied across the input of the filter using a sinusoidal signal generator of neglible internal resistance, and the r.m.s. output voltage V of the filter is measured using an oscilloscope.





(a) Explain, without writing down any formulae, why the response curve takes this form.

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(3)

(b) A current of 0.5 mA r.m.s. flows in the circuit when the frequency of the supply is 20 kHz. Estimate the resistance of the resistor R.

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(1)

(c) By considering the value of *V* at a frequency of 900 Hz, show that the capacitance of the capacitor C is approximately 10 nF.

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(3)

(d) Using the frequency response curve of the filter, estimate the frequency at which the power dissipated by the resistor R is half its maximum value.

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(2)
(Total 9 marks)

29. The following data refer to two planets.

	radius/km	density/kg m^{-3}
planet P	8000	6000
planet Q	16000	3000

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

A 3.4 N kg^{-1}

B 13.4 N kg^{-1}

C 53.6 N kg^{-1}

D 80.4 N kg^{-1}

(Total 1 mark)

30. A body is in simple harmonic motion of amplitude 0.50 m and period 4π seconds. What is the speed of the body when the displacement of the body is 0.30 m?

A 0.10 m s^{-1}

B 0.15 m s^{-1}

C 0.20 m s^{-1}

D 0.40 m s^{-1}

(Total 1 mark)

31. 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.

(Total 1 mark)

32. (a) Figure 1 shows a pair of parallel metal plates, A and B, fixed vertically 20 mm apart with a potential difference of 1500 V between them.

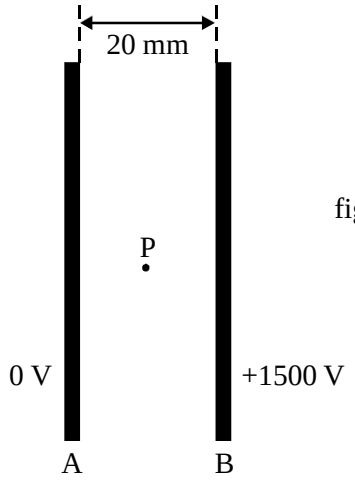

figure 1

(i) Draw the electric field lines in the space between the plates and calculate the electric field strength at P.

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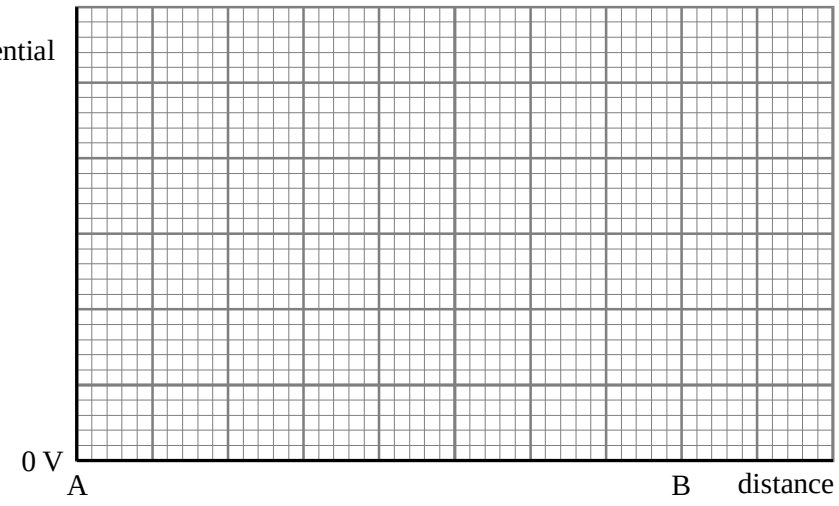
(ii) Sketch a graph showing the potential at different points in the space between the plates.



(5)

(b) Figure 2 shows a polystyrene ball of mass 5.0×10^{-4} kg suspended midway between the plates by a long insulating thread. The ball has a conducting surface and carries an initial charge of –3.0 nC.

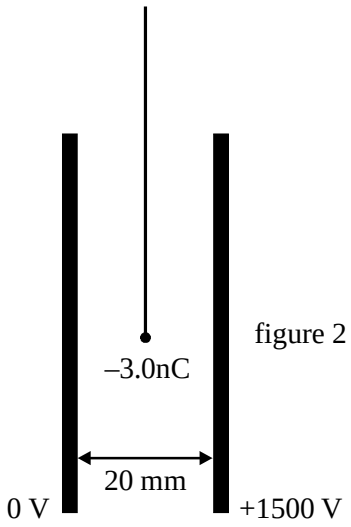


figure 2

(i) Calculate the force on the ball due to the electric field and hence show that the ball, when released from rest, will take a time of approximately 0.2 s to reach one conducting plate. State the direction of motion of the ball.

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(ii) Explain why the ball will subsequently shuttle backwards and forwards between the plates and discuss whether or not you consider this motion to be simple harmonic.

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(8)

(c) The same charged ball described in part (b) is suspended at rest between the poles of a magnet. State the magnitude and direction of the force (if any) on the ball and explain your answer.

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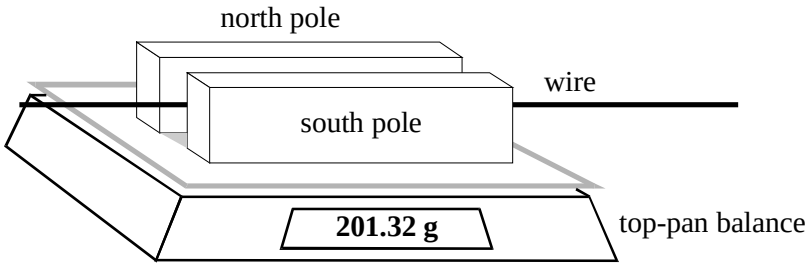
(2)
(Total 15 marks)

33. The diagram shows a magnet placed on a top-pan balance. A fixed horizontal wire, through which a current can flow, passes centrally through the magnetic field parallel to the pole-pieces.
With no current flowing, the balance records a mass of 201.32g. When a current of 5.0A flows, the reading on the balance is 202.86 g.



(a) (i) Explain why the reading on the balance increased when the current was switched on.

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(ii) State the direction of current flow and explain your answer.

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(iii) If the length of the wire in the magnetic field is 60 mm, estimate the flux density of the magnetic field.

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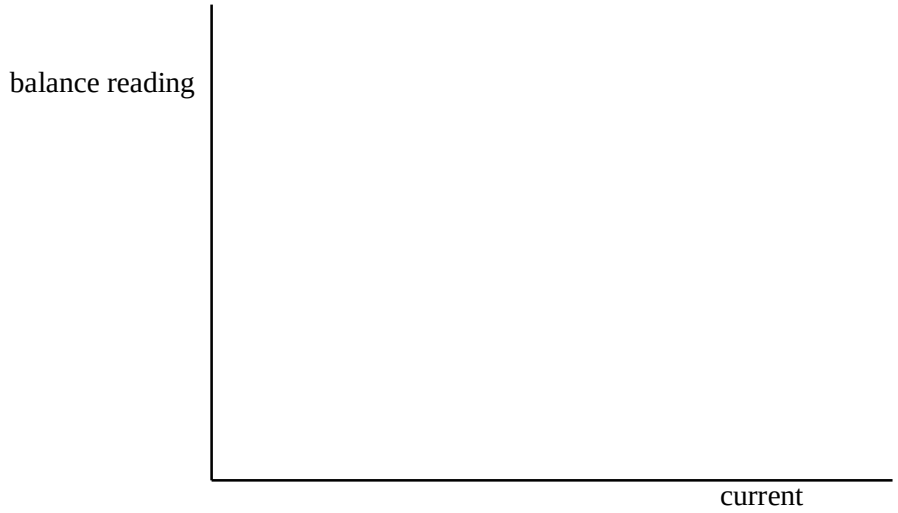
(6)

(b) Sketch a graph to show how you would expect the balance reading to change if the current through the wire was changed.



(2)
(Total 8 marks)

34. (a) State the principle of conservation of linear momentum for two colliding bodies.

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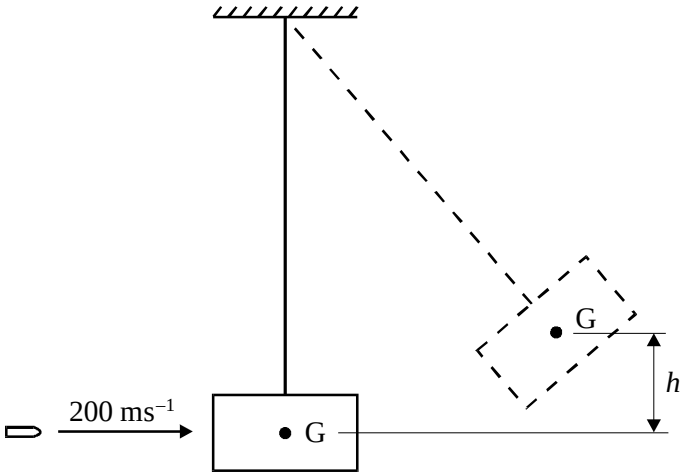
(2)

(b)



A bullet of mass 0.010 kg travelling at a speed of 200 m s^{-1} strikes a block of wood of mass 0.390 kg hanging at rest from a long string. The bullet enters the block and lodges in the block. Calculate

(i) the linear momentum of the bullet before it strikes the block,

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(ii) the speed with which the block first moves from rest after the bullet strikes it.

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(4)

(c) During the collision of the bullet and block, kinetic energy is converted into internal energy which results in a temperature rise.

(i) Show that the kinetic energy of the bullet before it strikes the block is 200 J.

.....

(ii) Show that the kinetic energy of the combined block and bullet immediately after the bullet has lodged in the block is 5.0 J.

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(iii) The material from which the bullet is made has a specific heat capacity of 250 J kg^{-1} K^{-1}. Assuming that all the lost kinetic energy becomes internal energy in the bullet, calculate its temperature rise during the collision.

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(5)

(d) The bullet lodges at the centre of mass G of the block. Calculate the vertical height *h* through which the block rises after the collision.

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(2)
(Total 13 marks)

35. (a) Collisions can be described as *elastic* or *inelastic*. State what is meant by an inelastic collision.

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(1)

(b) A ball of mass 0.12 kg strikes a stationary cricket bat with a speed of 18 m s^{-1}. The ball is in contact with the bat for 0.14 s and returns along its original path with a speed of 15 m s^{-1}.

Calculate

(i) the momentum of the ball before the collision,

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(ii) the momentum of the ball after the collision,

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(iii) the total change of momentum of the ball,

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(iv) the average force acting on the ball during contact with the bat,

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.....

(v) the kinetic energy lost by the ball as a result of the collision,

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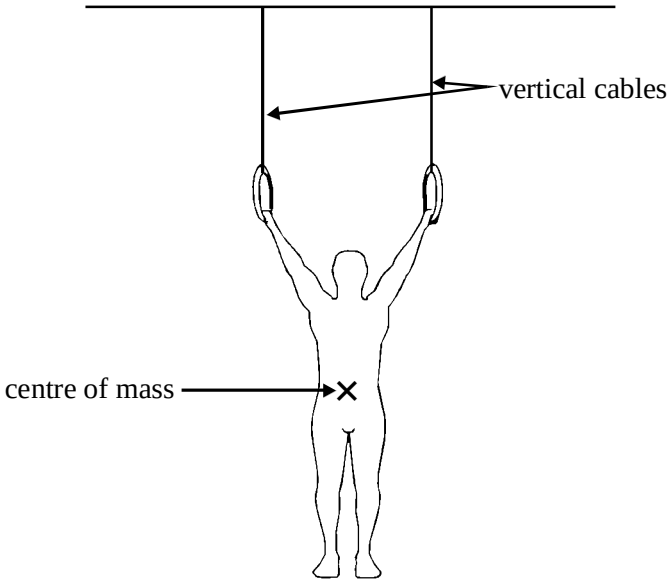
(6)
(Total 7 marks)

36. The diagram shows a gymnast of weight 720N hanging centrally from two rings, each attached to cables which hang vertically.

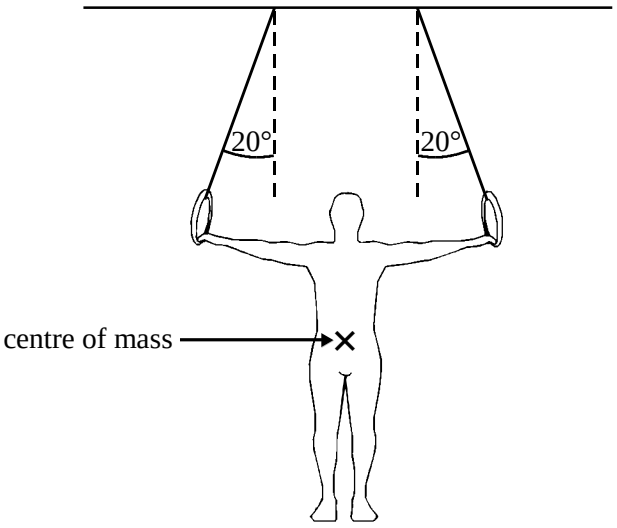


(a) State the tension in each cable.

.....

(1)

(b) The diagram shows the gymnast after he has raised his body so that his centre of mass moves through a vertical distance of 0.60 m.



Calculate

(i) the increase in gravitational potential energy of the gymnast,

.....

.....

(ii) the tension in each cable.

.....

.....

(3)

(c) The gymnast now raises his legs so that they become horizontal, without raising the rest of his body. State and explain whether his gravitational potential energy is changed by this manoeuvre.

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(2)
(Total 6 marks)

37. 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**, 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	decrease	decrease
B	increase	increase
C	no change	decrease
D	increase	no change

(Total 2 marks)

38. 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

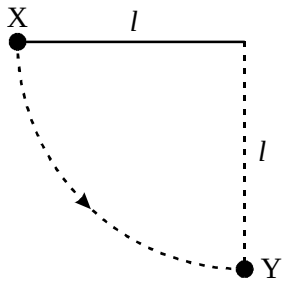
B $4\pi^2Ab^2$

C Ab^2

D $\frac{4\pi^2 A}{b^2}$

(Total 2 marks)

39.



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 υ. 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 $T = \frac{m\upsilon^2}{l} - mg$

B $T - mg = \frac{m\upsilon^2}{l}$

C $mg - T = \frac{m\upsilon^2}{l}$

D $T + \frac{m\upsilon^2}{l} = mg$

(Total 2 marks)

40. 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}

(Total 2 marks)

41. If the potential difference between a pair of identical, parallel, conducting plates is known, what is the only additional knowledge required to determine the electric field strength between the plates?

A the permittivity of the medium between the plates

B the separation and area of the plates

C the separation and area of the plates and the permittivity of the medium between the plates

D the separation of the plates

(Total 2 marks)

42. 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.

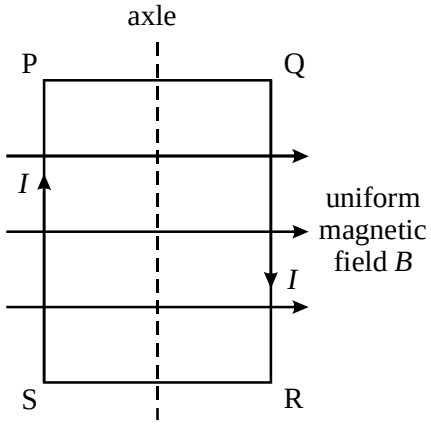
(Total 2 marks)

43. Which line, **A** to **D**, gives correct units for both magnetic flux and magnetic flux density?

	magnetic flux	magnetic flux destiny
A	Wb m^{-2}	Wb
B	Wb	T
C	Wb m^{-2}	T m^{-2}
D	T m^{-2}	Wb m^{-2}

(Total 2 marks)

44.



A coil, mounted on an axle, has its plane parallel to the flux lines of a uniform magnetic field *B*, as shown. When a current *I* is switched on, and before the coil is allowed to move,

A there are no forces due to *B* on the sides SP and QR.

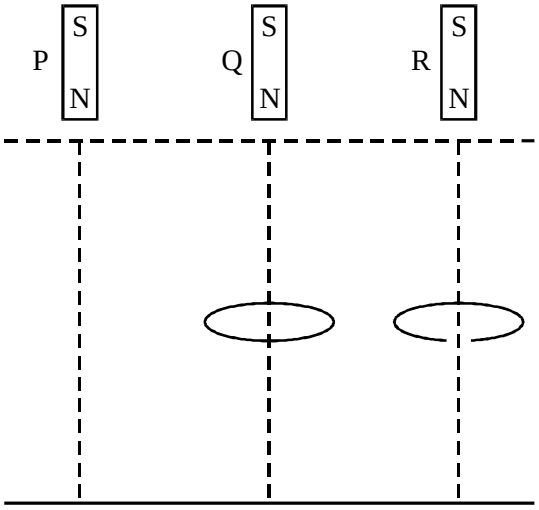
B there are no forces due to *B* on the sides PQ and RS.

C sides SP and QR tend to attract each other.

D sides PQ and RS tend to attract each other.

(Total 2 marks)

45.



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 describes 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, followed by Q which is followed by R.

D All three magnets arrive simultaneously.

(Total 2 marks)

46.

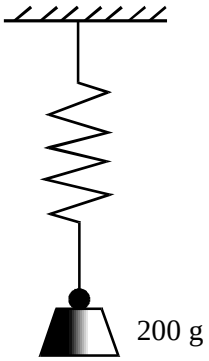


Figure 1

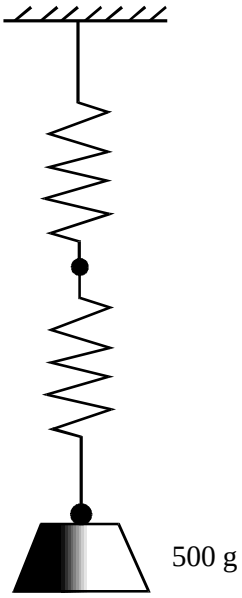


Figure 2

(a) When a 200 g mass is suspended from a spring, as in **Figure 1**, it produces an extension of 3.5 cm. Calculate the spring constant, *k*, for this spring.

.....

.....

(2)

(b) A spring identical to that in part (a) is joined to the lower end of the original one and a 500 g mass is suspended from the combination, as shown in **Figure 2.**

(i) State the value of the new spring constant for this combination of two springs.

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(ii) When the 500 g mass is displaced it performs small vertical oscillations. Calculate the number of oscillations made in one minute.

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(3)
(Total 5 marks)

47. (a) A 2.0 μF capacitor is charged through a resistor from a battery of emf 4.5 V. Sketch a graph on the axes below to show how the charge stored, *Q*, varies with the potential difference, *V*, across the capacitor during the charging process. Mark appropriate values on the axes of the graph.

(2)

(b) (i) Show that the energy stored by a charged capacitor is given by $E = \frac{1}{2} QV$.

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(ii) Calculate the energy stored by the capacitor in part (a) when the potential difference across it is 1.5 V.

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(5)
(Total 7 marks)

48. (a) An electron moves parallel to, but in the opposite direction to, a uniform electric field, as shown in **Figure 1**.

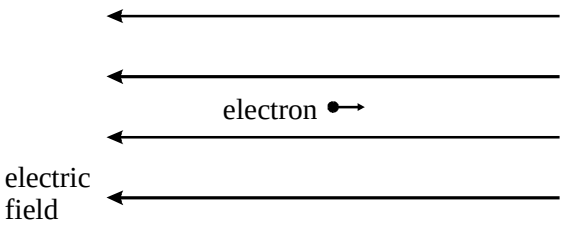

Figure 1

(i) State the direction of the force that acts on the electron due to the electric field.

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(ii) What is the effect of this force on the motion of the electron?

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.....

(2)

(b) An electron, which is travelling in a horizontal path at constant speed, enters a uniform vertical electric field as shown in **Figure 2**.

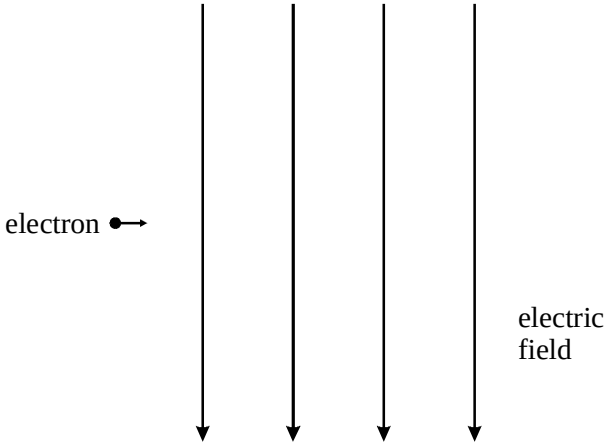

Figure 2

(i) Sketch on **Figure 2** the path followed by the electron.

(ii) Explain the motion of the electron whilst in this field.

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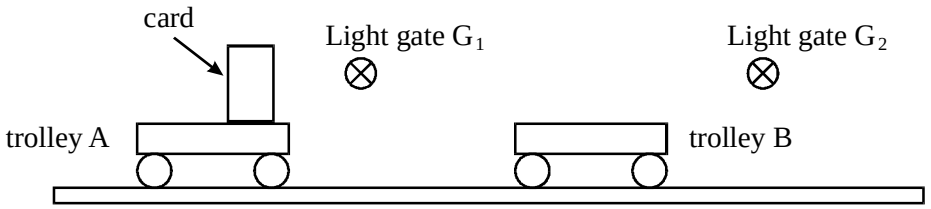
(3)
(Total 5 marks)

49. The simplified diagram shows an experimental arrangement to investigate the collision of two trolleys.



In the experiment, trolley A is travelling at speed *v*. It collides with and sticks to, the initially stationary trolley B.

(a) State the measurements you would need to take so that you could determine the speed of

(i) trolley A before the collision,

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(ii) trolleys A and B after the collision.

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(3)

(b) Explain how you would verify that momentum was conserved in this collision, indicating what other measurements would be required.

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(2)

(c) State and explain what you would do to minimise the effects of friction on the motion of the trolleys.

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(2)

(Total 7 marks)

50. 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 line, **A** to **D**, 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

(Total 2 marks)

51. A wave motion has period *T*, frequency *f*, wavelength λ and speed υ. Which one of the following equations is **incorrect**?

A $1 = Tf$

B $T = \frac{\upsilon}{\lambda}$

C $\lambda = \frac{\upsilon}{f}$

D $T\upsilon = \lambda$

(Total 2 marks)

52. 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 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.

(Total 2 marks)

53. A girl of mass 40 kg stands on a roundabout 2.0 m from the vertical axis as the roundabout rotates uniformly with a period of 3.0 s. The horizontal force acting on the girl is approximately

A zero.

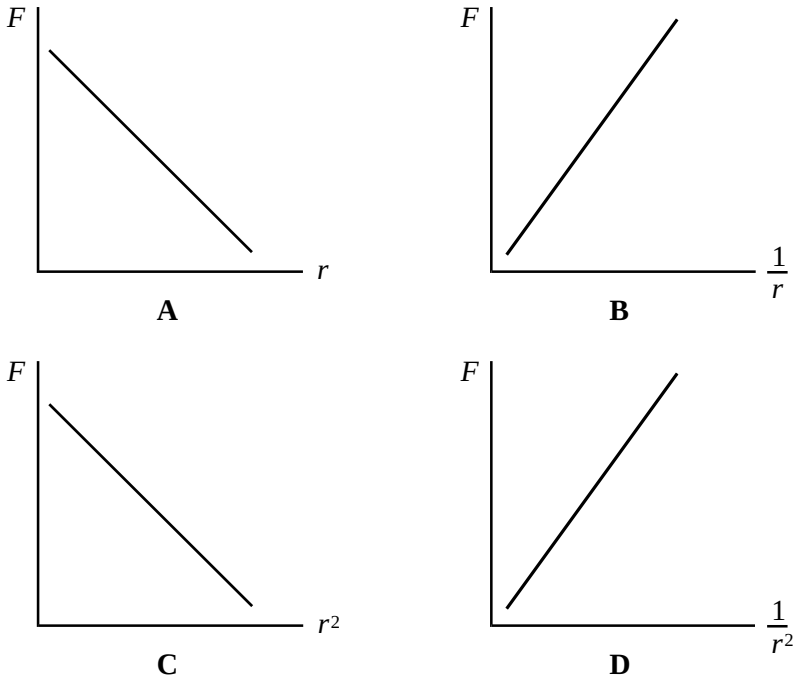
B 3.5×10^2 N.

C 7.2×10^2 N.

D 2.8×10^4 N.

(Total 2 marks)

54. Which one of the following graphs correctly shows the relationship between the gravitational force, F, between two masses and the distance, r, between them?



(Total 2 marks)

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

A The velocity of the particle is constant.

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

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

D The kinetic energy of the particle is constant.

(Total 2 marks)

56. 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 $\sqrt{\frac{GM(R+h)}{R}}$

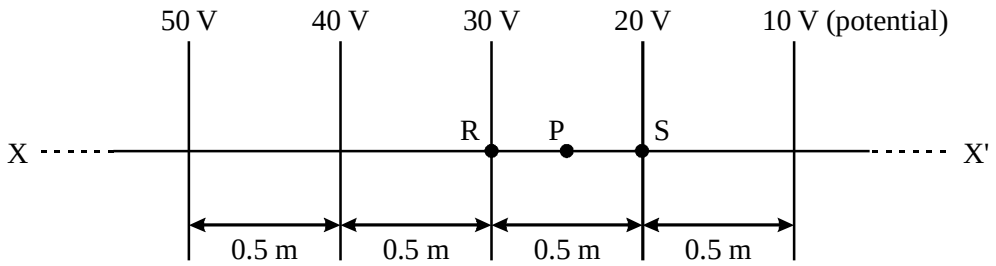
B $\frac{\sqrt{GM(R+h)}}{R}$

C $\sqrt{\frac{GM}{(R+h)}}$

D $\frac{\sqrt{GM}}{(R+h)}$

(Total 2 marks)

57.



The diagram shows how the electric potential varies along a line XX' in an electric field. What will be the electric field strength at a point P on XX' which is mid-way between R and S?

A 5.0 V m^{-1}

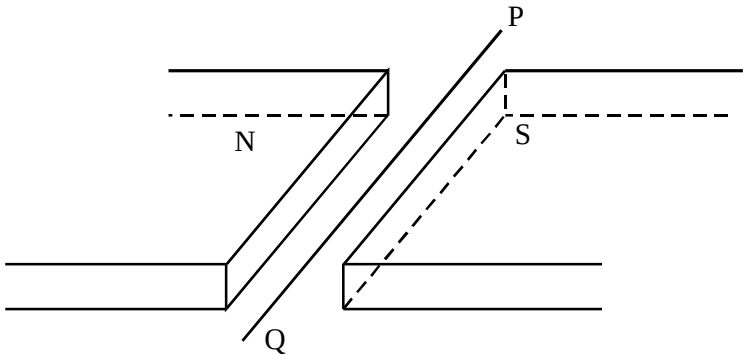
B 10 V m^{-1}

C 20 V m^{-1}

D 30 V m^{-1}

(Total 2 marks)

58.



A wire lies perpendicularly across a horizontal uniform magnetic field of flux density 20×10^{-3} T so that 0.30 m of the wire is effectively subjected to the field. If the force exerted on this length of wire due to a current in it is 30×10^{-3} N downward, what is the current in the wire?

A 0.45 A from P to Q

B 0.45 A from Q to P

C 5.0 A from P to Q

D 5.0 A from Q to P

(Total 2 marks)

59. 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 continues to move North with its original speed.

B It slows down to zero speed and then accelerates due South.

C It is accelerated due West.

D It is accelerated due North.

(Total 2 marks)

60. To celebrate the Millennium in the year 2000, a footbridge was constructed across the River Thames in London. After the bridge was opened to the public it was discovered that the structure could easily be set into oscillation when large numbers of pedestrians were walking across it.

(a) What name is given to this kind of physical phenomenon, when caused by a periodic driving force?

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(1)

(b) Under what condition would this phenomenon become particularly hazardous? Explain your answer.

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(4)

(c) Suggest **two** measures which engineers might adopt in order to reduce the size of the oscillations of a bridge

measure 1 .....

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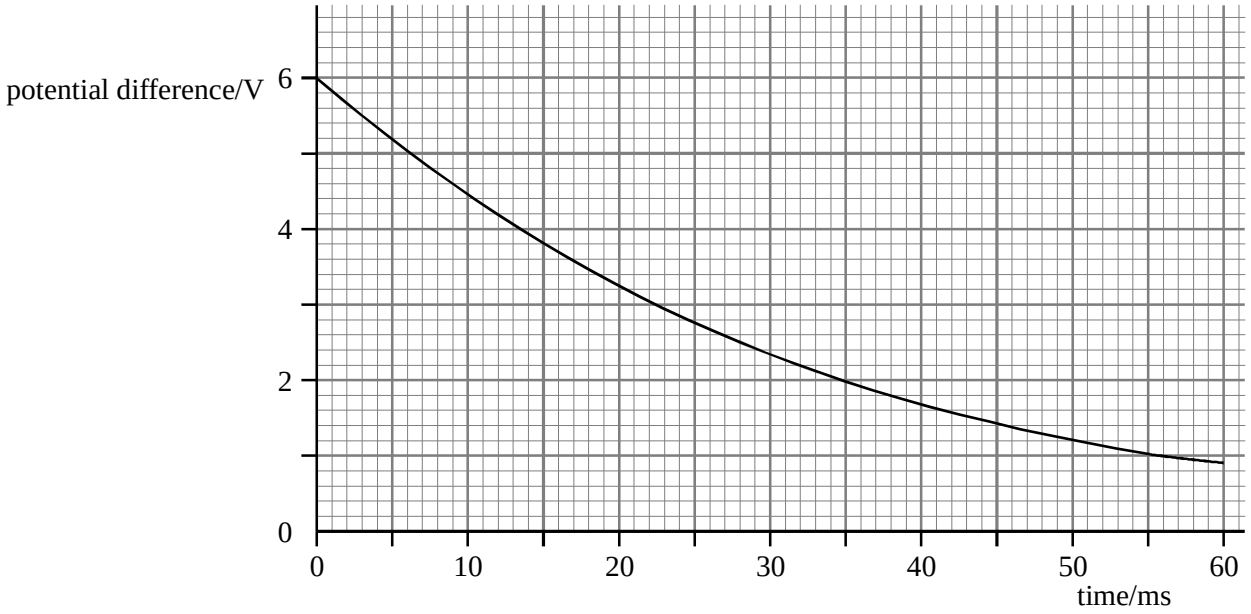
measure 2 .....

.....

(2)

(Total 7 marks)

61. A student used a voltage sensor connected to a datalogger to plot the discharge curve for a 4.7 μF capacitor. She obtained the following graph.



Use data from the graph to calculate

(a) the initial charge stored,

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(2)

(b) the energy stored when the capacitor had been discharging for 35 ms,

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(3)

(c) the time constant for the circuit,

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(3)

(d) the resistance of the circuit through which the capacitor was discharging.

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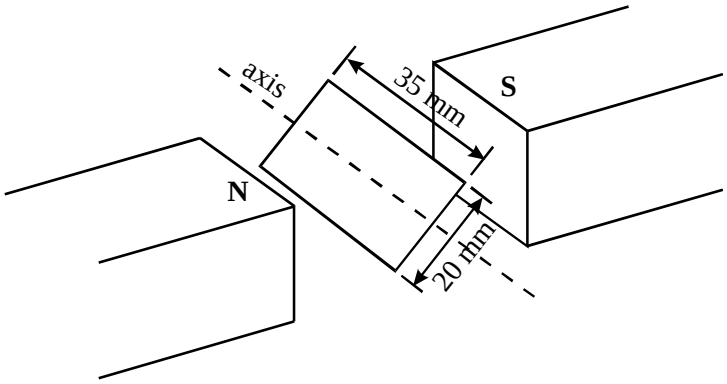
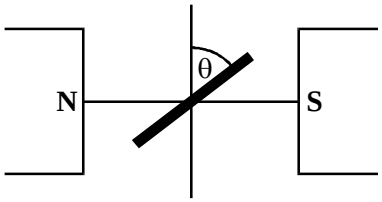
(2)
(Total 10 marks)

62. A rectangular coil measuring 20 mm by 35 mm and having 650 turns is rotating about a horizontal axis which is at right angles to a uniform magnetic field of flux density 2.5×10^{-3} T. The plane of the coil makes an angle θ with the vertical, as shown in the diagrams.





front view

(a) State the value of θ when the magnetic flux through the coil is a minimum.

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(1)

(b) Calculate the magnetic flux passing through the coil when θ is 30°.

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(2)

(c) What is the maximum *flux linkage* through the coil as it rotates?

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(2)
(Total 5 marks)

63. (a) When an α particle is emitted from a nucleus of the isotope $^{212}_{83}\text{Bi}$, a nucleus of thallium, Tl, is formed. Complete the equation below.

$$^{212}_{83}\text{Bi} \quad \rightarrow \quad \alpha \quad + \quad \text{Tl}$$

(2)

(b) The α particle in part (a) is emitted with 6.1 MeV of kinetic energy.

(i) The mass of the α particle is 4.0 u. Show that the speed of the α particle immediately after it has been emitted is 1.7×10^{-7} m s^{-1}. Ignore relativistic effects.

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(ii) Calculate the speed of recoil of the daughter nucleus immediately after the α particle has been emitted. Assume the parent nucleus is initially at rest.

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(6)
(Total 8 marks)

64. Protons and pions are produced in a beam from a target in an accelerator. The two types of particles can be separated using a magnetic field.

(a) State the quark composition of

(i) a proton,

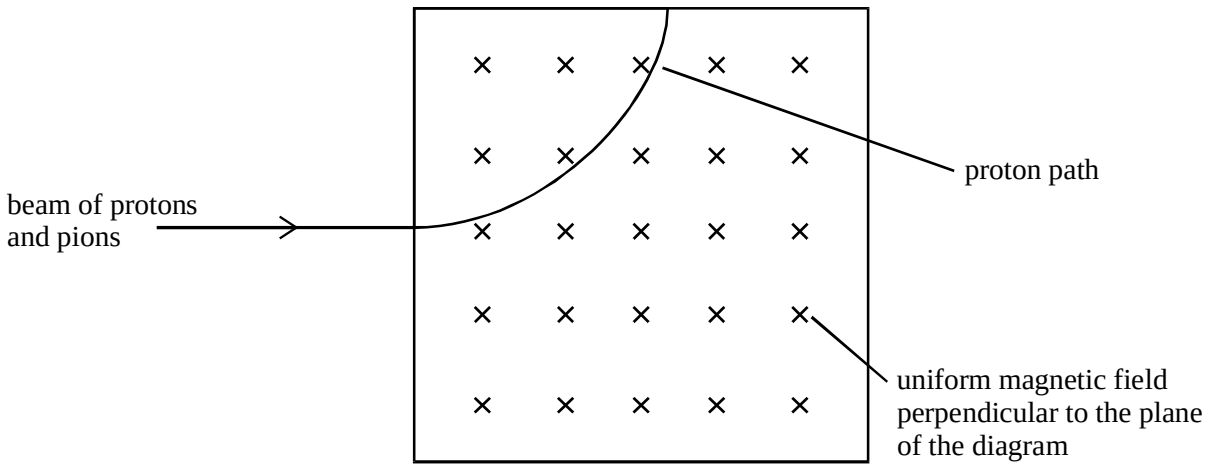
.....

(ii) a positive pion, π^+.

.....

(2)

(b) A narrow beam consisting of protons and positive pions, all travelling at a speed of $1.5 \leftrightarrow 10^7$ m s^{-1}, is directed into a uniform magnetic field of flux density 0.16 T, as shown in the diagram.



(i) Calculate the radius of curvature of the path of the protons in the field.

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(ii) Sketch, on the diagram above, the path of the pions from the point of entry into the field to the point of exit from the field.

(iii) If the magnetic field were increased, how would this affect the paths of the particles?

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(7)
(Total 9 marks)

65. (a) A satellite moves in a circular orbit at constant speed. Explain why its speed does not change even though it is acted on by a force.

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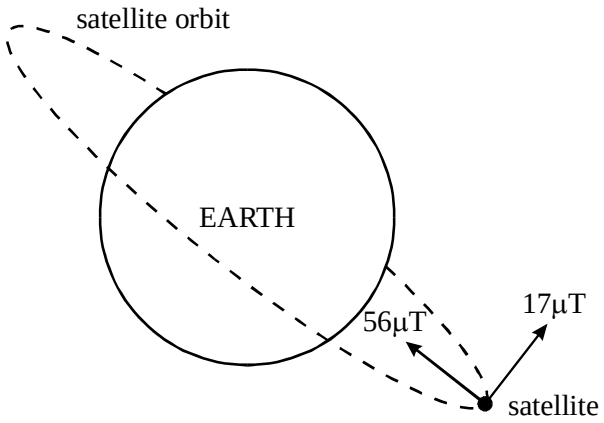
(3)

(b) At a certain point along the orbit of a satellite in uniform circular motion, the Earth's magnetic flux density has a component of 56 μT towards the centre of the Earth and a component of 17 μT in a direction perpendicular to the plane of the orbit.



(i) Calculate the magnitude of the resultant magnetic flux density at this point.

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(ii) The satellite has an external metal rod pointing towards the centre of the Earth. Calculate the angle between the direction of the resultant magnetic field and the rod.

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(iii) Explain why an emf is induced in the rod in this position.

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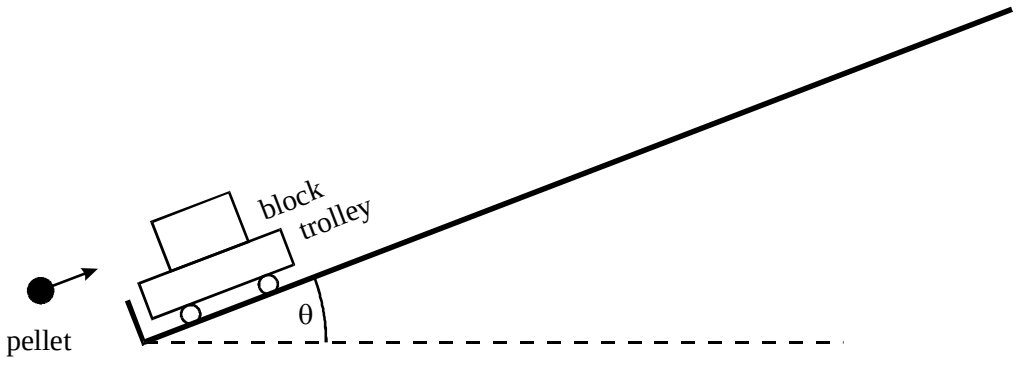
(4)
(Total 7 marks)

66. The diagram represents part of an experiment that is being used to estimate the speed of an air gun pellet.



The pellet which is moving parallel to the track, strikes the block, embedding itself. The trolley and the block then move along the track, rising a vertical height, *h*.

(a) Using energy considerations explain how the speed of the trolley and block immediately after it has been struck by the pellet, may be determined from measurements of *h.* Assume frictional forces are negligible.

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(3)

(b) The following data is collected from the experiment

mass of trolley and block	0.50 kg
mass of pellet	0.0020 kg
speed of trolley and block immediately after impact	0.40 m s^{-1}

Calculate

(i) the momentum of the trolley and block immediately after impact,

.....

.....

(ii) the speed of the pellet just before impact.

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(4)

(c) (i) State what is meant by an inelastic collision.

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(ii) Use the data from part (b) to show that the collision between the pellet and block is inelastic.

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(4)
(Total 11 marks)

67. A girl kicks a ball along the ground at a wall 2.0 m away. The ball strikes the wall normally at a velocity of 8.0 m s^{-1} and rebounds in the opposite direction with an initial velocity of 6.0 m s^{-1}. The girl, who has not moved, stops the ball a short time later.

(a) Explain why the final displacement of the ball is not 4.0 m.

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(1)

(b) Explain why the average velocity of the ball is different from its average speed.

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(2)

(c) The ball has a mass of 0.45 kg and is in contact with the wall for 0.10 s. For the period of time the ball is in contact with the wall,

(i) calculate the average acceleration of the ball.

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(ii) calculate the average force acting on the ball.

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(iii) state the direction of the average force acting on the ball.

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(5)
(Total 8 marks)

68. 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

(Total 2 marks)

69. A particle oscillates with undamped simple harmonic motion. Which one of the following statements about the acceleration of the oscillating particle is true?

A It is least when the speed is greatest.

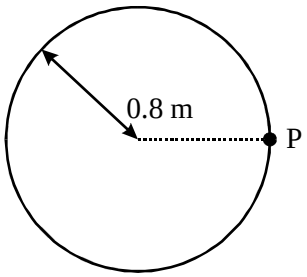
B It is always in the opposite direction to its velocity.

C It is proportional to the frequency.

D It decreases as the potential energy increases.

(Total 2 marks)

70.



A model car moves in a circular path of radius 0.8 m at an angular speed of $\frac{\pi}{2}$ rad s^{-1}.

What is its displacement from point P, 6 s after passing P?

A zero

B 1.6 m

C 0.47π m

D 1.6π m

(Total 2 marks)

71. 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. If its distance from the mass m_1 is r_1 and its distance from the mass 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 $\sqrt{\frac{m_2}{m_1}}$

(Total 2 marks)

72. Which one of the following has different units to the other three?

A gravitational potential

B gravitational field strength

C force per unit mass

D gravitational potential gradient

(Total 2 marks)

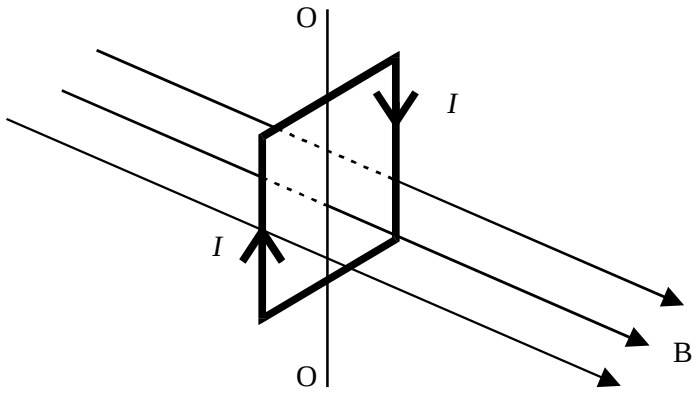
73. Two horizontal parallel plate conductors are separated by a distance of 5.0 mm in air. The lower plate is earthed and the potential of the upper plate is + 50 V.

Which line, **A** to **D**, 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	1×10^4 upwards	25
B	1×10^4 downwards	25
C	1×10^4 upwards	50
D	1×10^4 downwards	50

(Total 2 marks)

74. The diagram shows a vertical square coil whose plane is at right angles to a horizontal uniform magnetic field B. A current, *I*, flows in the coil, which can 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', it will remain in position.

(Total 2 marks)

75. An α particle and a β^- particle both enter the same uniform magnetic field, which is perpendicular to their direction of motion. If the β^- particle has a speed 15 times that of the α particle, what is the value of the ratio

$$\frac{\text{magnitude of force on } \beta^- \text{ particle}}{\text{magnitude of force on } \alpha \text{ particle}} ?$$

A 3.7

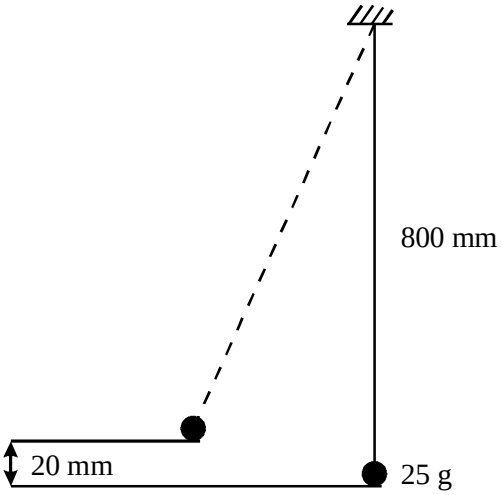
B 7.5

C 60

D 112.5

(Total 2 marks)

76. A simple pendulum consists of a 25 g mass tied to the end of a light string 800 mm long. The mass is drawn to one side until it is 20 mm above its rest position, as shown in the diagram. When released it swings with simple harmonic motion.



(a) Calculate the period of the pendulum.

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.....

(2)

(b) Show that the initial amplitude of the oscillations is approximately 0.18 m, and that the maximum speed of the mass during the first oscillation is about 0.63 m s^{-1}.

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(4)

(c) Calculate the magnitude of the tension in the string when the mass passes through the lowest point of the first swing.

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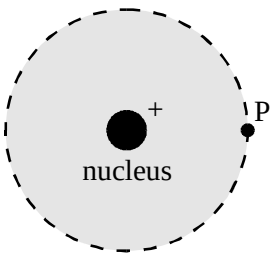
(2)
(Total 8 marks)

77. The mass of the nucleus of an isolated copper atom is 63 u and it carries a charge of +29 *e*. The diameter of the atom is 2.3×10^{-10} m.

P is a point at the outer edge of the atom.



(a) Calculate

(i) the electric field strength at P due to the nucleus,

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.....

(ii) the gravitational potential at P due to the nucleus.

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.....

.....

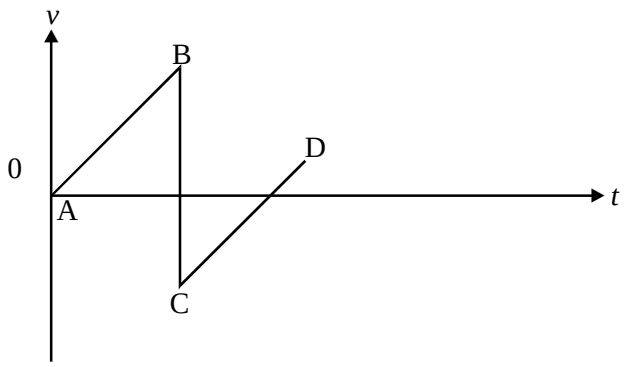
(5)

(b) Draw an arrow on the above diagram to show the direction of the electric field at the point P.

(1)

(Total 6 marks)

78. The diagram shows the velocity-time graph for a vertically bouncing ball, which is released above the ground at A and strikes the floor at B. The effects of air resistance have been neglected.



(a) (i) What does the gradient of a velocity-time graph represent?

.....

(ii) Explain why the gradient of the line CD is the same as line AB.

.....

.....

(iii) What does the area between the line AB and the time axis represent?

.....

(iv) State why the velocity at C is negative.

.....

.....

(v) State why the speed at C is less than the speed at B.

.....

.....

.....

(5)

(b) The ball has a mass of 0.15 kg and is dropped from an initial height of 1.2 m. After impact the ball rebounds to a height of 0.75 m.

Calculate

(i) the speed of the ball immediately before impact,

.....

.....

(ii) the speed of the ball immediately after impact,

.....

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(iii) the change in momentum of the ball as a result of the impact,

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.....

(iv) the magnitude of the resultant average force acting on the ball during impact if it is in contact with the floor for 0.10 s.

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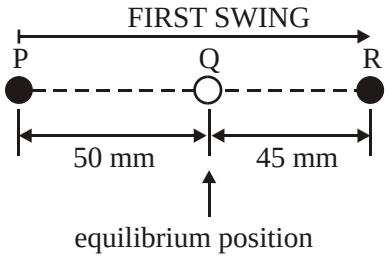
(8)
(Total 13 marks)

79. A particle, whose equilibrium position is at Q, is set into oscillation by being displaced to P, 50 mm from Q, and then released from rest. Its subsequent motion is simple harmonic, but subject to damping. On the first swing, the particle comes to rest momentarily at R, 45 mm from Q.



During this first swing, the greatest value of the acceleration of the particle is when it is at

A P.

B Q.

C R.

D P and R.

(Total 2 marks)

80. A particle of mass 5.0×10^{-3} kg performing simple harmonic motion of amplitude 150 mm 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

(Total 2 marks)

81. When the length of a simple pendulum is decreased by 600 mm, the period of oscillation is halved. What is the original length of the pendulum?

A 800mm

B 1000mm

C 1200mm

D 1400mm

(Total 2 marks)

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

A 0

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

C π

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

(Total 2 marks)

83. A 10 mF capacitor is charged to 10 V and then discharged completely through a small motor. During this 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

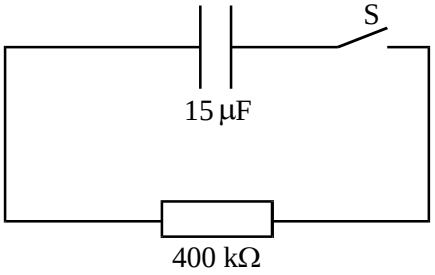
B 0.10 m

C 0.50 m

D 1.00 m

(Total 2 marks)

84. A capacitor of capacitance 15 μF is fully charged and the potential difference across its plates is 8.0V. It is then connected into the circuit as shown.



The switch S is closed at time $t = 0$. Which one of the following statements is correct?

A The time constant of the circuit is 6.0 ms.

B The initial charge on the capacitor is 12 μC.

C After a time equal to twice the time constant, the charge remaining on the capacitor is Q_0e^2, where Q_0 is the charge at time $t = 0$.

D After a time equal to the time constant, the potential difference across the capacitor is 2.9 V.

(Total 2 marks)

85. A fairground roundabout makes nine revolutions in one minute. What is the angular speed of the roundabout?

A 0.15 rad s^{-1}

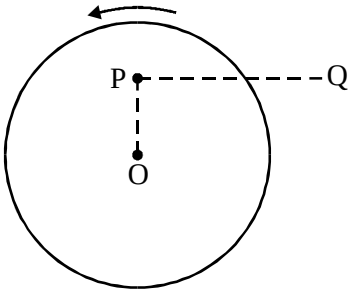
B 0.34 rad s^{-1}

C 0.94 rad s^{-1}

D 2.1 rad s^{-1}

(Total 2 marks)

86.



A small mass is placed at P on a horizontal disc which has centre 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?

A the weight of the mass

B a frictional force directed away from O

C a frictional force directed towards O

D a frictional force directed from P to Q

(Total 2 marks)

87. 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 $\frac{F}{3r}$

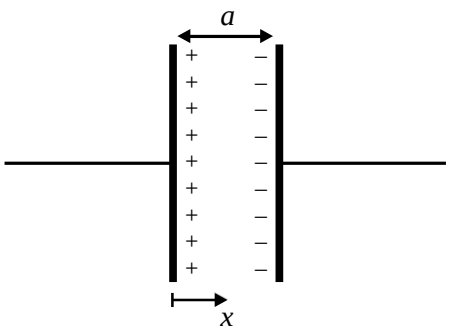
B $\frac{F}{9r}$

C $\frac{F}{3}$

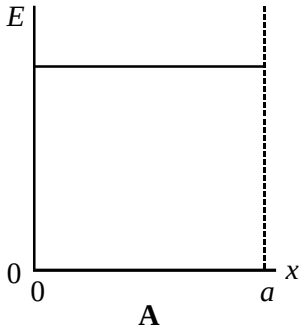
D $\frac{F}{9}$

(Total 2 marks)

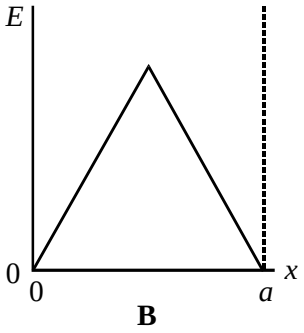
88.



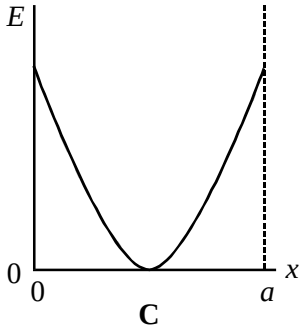
Two parallel metal plates of separation *a* carry equal and opposite charges. Which one of the following graphs, **A** to **D**, best represents how the electric field strength *E* varies with the distance *x* in the space between the plates?



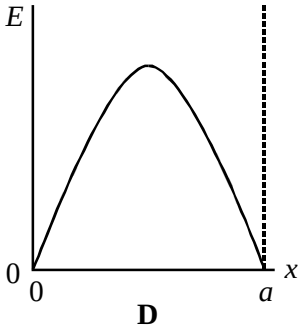
A



B



C



D

(Total 2 marks)

89. Communications satellites are usually placed in a *geo-synchronous orbit*.

(a) State **two** features of a geo-synchronous orbit.

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.....

(2)

(b) Given that the mass of the Earth is 6.00×10^{24} kg and its mean radius is 6.40×10^{7} m,

(i) show that the radius of a geo-synchronous orbit must be 4.23×10^{7} m,

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(ii) calculate the increase in potential energy of a satellite of mass 750 kg when it is raised from the Earth's surface into a geo-synchronous orbit.

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(6)
(Total 8 marks)

90. (a) The equation $F = BIl$, where the symbols have their usual meanings, gives the magnetic force that acts on a conductor in a magnetic field.

Given the unit of each of the quantities in the equation.

F ..... *B* .....

I ..... *l* .....

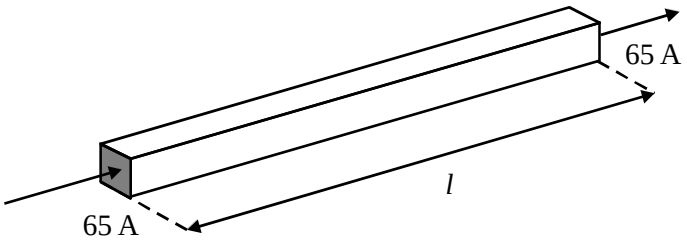
State the condition under which the equation applies.

.....

.....

(2)

(b) The diagram shows a horizontal copper bar of 25 mm × 25 mm square cross-section and length l carrying a current of 65 A.



(i) Calculate the minimum value of the flux density of the magnetic field in which it should be placed if its weight is to be supported by the magnetic force that acts upon it.

density of copper = 8.9×10^3 kg m^{-3}

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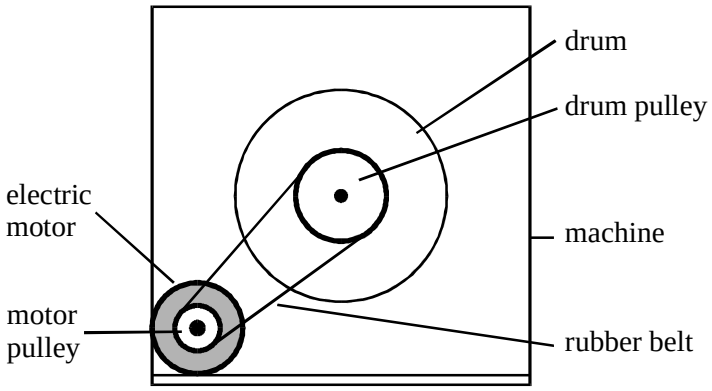
(ii) Draw an arrow on the diagram above to show the direction in which the magnetic field should be applied if your calculation in part (i) is to be valid. Label this arrow M.

(5)
(Total 7 marks)

91. An electric motor in a machine drives a rotating drum by means of a rubber belt attached to pulleys, one on the motor shaft and one on the drum shaft, as shown in the diagram below.



(a) The pulley on the motor shaft has a diameter of 24 mm. When the motor is turning at 50 revolutions per second, calculate

(i) the speed of the belt,

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(ii) the centripetal acceleration of the belt as it passes round the motor pulley.

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(5)

(b) When the motor rotates at a particular speed, it causes a flexible metal panel in the machine to vibrate loudly. Explain why this happens.

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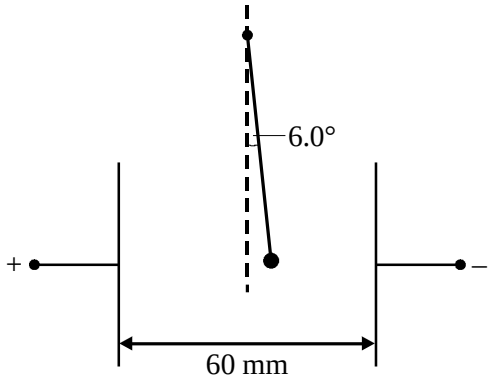
(2)
(Total 7 marks)

92. A small charged sphere of mass 2.1×10^{-4} kg, suspended from a thread of insulating material, was placed between two vertical parallel plates 60 mm apart. When a potential difference of 4200 V was applied to the plates, the sphere moved until the thread made an angle of 6.0° to the vertical, as shown in the diagram below.



(a) Show that the electrostatic force F on the sphere is given by

$$F = mg \tan 6.0°$$

where m is the mass of the sphere.

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(3)

(b) Calculate

(i) the electric field strength between the plates,

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(ii) the charge on the sphere.

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(3)
(Total 6 marks)

93. A body moves in 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 m s^{-1}

B 0.22 m s^{-1}

C 0.40 m s^{-1}

D 0.80 m s^{-1}

(Total 2 marks)

94. To find a value for the acceleration of free fall, g, a student measured the time of oscillation, T, of a simple pendulum whose length, l, is changed. The student used the results to plot a graph of T^2 (y axis) against l (x axis) and found the slope of the line to be S. It follows that g is

A $\frac{4\pi^2}{S}$.

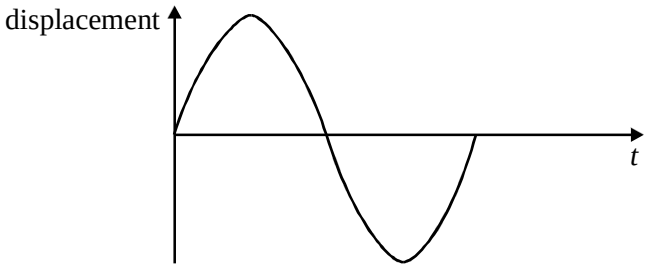
B $4\pi^2 S$.

C $\frac{2\pi}{S}$.

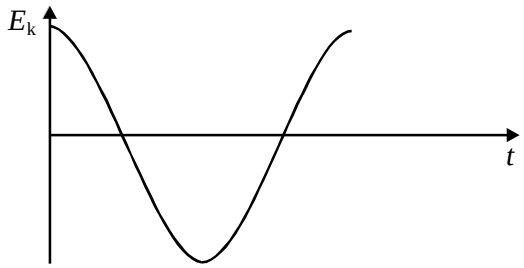
D $2\pi S$.

(Total 2 marks)

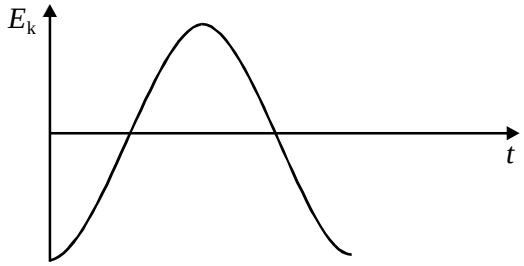
95. The top graph is a displacement/time graph for a particle executing simple harmonic motion. Which one of the other graphs shows correctly how the kinetic energy, E_k, of the particle varies with time?



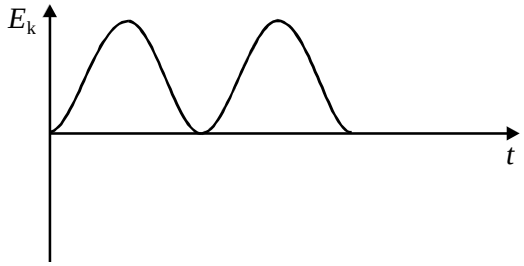
A



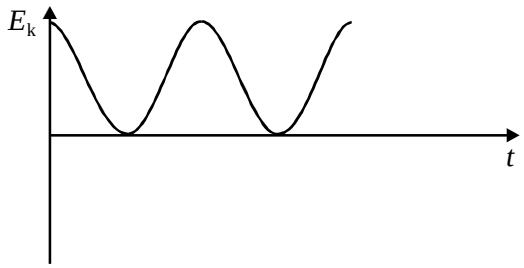
B



C



D



(Total 2 marks)

96. What is the angular speed of a satellite in a geo-synchronous orbit around the Earth?

A 7.3×10^{-5} rad s^{-1}

B 2.6×10^{-1} rad s^{-1}

C 24 rad s^{-1}

D 5.0×10^{6} rad s^{-1}

(Total 2 marks)

97. An object moving at constant speed in a circle experiences a force that is

A in the direction of motion.

B outwards and at right angles to the direction of motion.

C inwards and at right angles to the direction of motion.

D opposite to the direction of motion.

(Total 2 marks)

98. A planet has a radius half of 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}

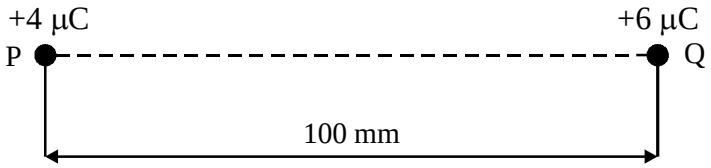
(Total 2 marks)

99. 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**, 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	$\frac{E}{4}$	$\frac{V}{4}$

(Total 2 marks)

100. Two charges, P and Q, are 100 mm apart.



X is a point on the line between P and Q. If the potential at X is 0 V, what is the distance from P to X?

A 40 mm

B 45 mm

C 50 mm

D 60 mm

(Total 2 marks)

101. Which line, **A** to **D**, correctly describes the trajectory of charged particles which enter, at right angles, (a) a uniform electric field, and (b) a uniform magnetic field?

	(a) uniform electric field	(b) uniform magnetic field
A	circular	circular
B	circular	parabolic
C	parabolic	circular
D	parabolic	parabolic

(Total 2 marks)

102. (a) Complete the table of quantities related to fields. In the second column, write an SI unit for each quantity. In the third column indicate whether the quantity is a scalar or a vector.

quantity	SI unit	scalar or vector
gravitational potential		
electric field strength		
magnetic flux density		

(3)

(b) (i) A charged particle is held in equilibrium by the force resulting from a vertical electric field. The mass of the particle is 4.3×10^{-9} kg and it carries a charge of magnitude 3.2×10^{-12} C. Calculate the strength of the electric field.

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(ii) If the electric field acts upwards, state the sign of the charge carried by the particle

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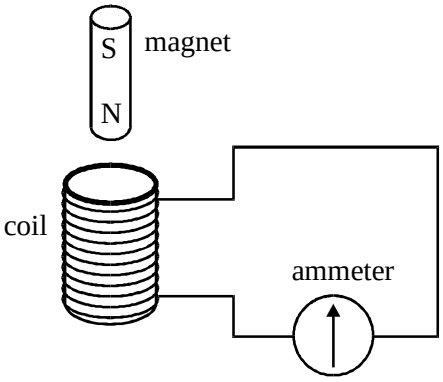
(3)
(Total 6 marks)

103. A coil is connected to a centre zero ammeter, as shown. A student drops a magnet so that it falls vertically and completely through the coil.



(a) Describe what the student would observe on the ammeter as the magnet falls through the coil.

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(2)

(b) If the coil were not present the magnet would accelerate downwards at the acceleration due to gravity. State and explain how its acceleration in the student's experiment would be affected, if at all,

(i) as it entered the coil,

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(ii) as it left the coil.

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(4)

(c) Suppose the student forgot to connect the ammeter to the coil, therefore leaving the circuit incomplete, before carrying out the experiment. Describe and explain what difference this would make to your conclusions in part (b).

You may be awarded marks for the quality of written communication provided in your answer.

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(3)
(Total 9 marks)

104. A capacitor of capacitance 330 μF is charged to a potential difference of 9.0 V. It is then discharged through a resistor of resistance 470 kΩ.

Calculate

(a) the energy stored by the capacitor when it is fully charged,

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(2)

(b) the time constant of the discharging circuit,

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(1)

(c) the p.d. across the capacitor 60 s after the discharge has begun.

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(3)
(Total 6 marks)

105. In a vehicle impact, a car ran into the back of a lorry. The car driver sustained serious injuries, which would have been much less had the car been fitted with a driver's air bag.

(a) Explain why the effect of the impact on the driver would have been much less if an air bag had been fitted and had inflated in the crash.

You may be awarded marks for the quality of written communication in your answer.

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(4)

(b) Calculate the deceleration of the car if it was travelling at a speed of 18 m s^{-1} when the impact occurred and was brought to rest in a distance of 2.5 m.

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(2)
(Total 6 marks)

106. A golf club undergoes an *inelastic* collision with a golf ball and gives it an initial velocity of 60 m s^{-1}. The ball is in contact with the club for 15 ms and the mass of the ball is 4.5×10^{-2} kg.

(a) Explain what is meant by an inelastic collision.

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(1)

(b) Calculate

(i) the change in momentum of the ball,

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(ii) the average force the club exerts on the ball.

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(4)

(c) (i) State the value of the force exerted by the ball on the club and give its direction.

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(ii) Explain how your answer to part (i) follows from an appropriate law of motion.

You may be awarded marks for the quality of written communication in your answer.

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(4)
(Total 9 marks)

107. A body is in simple harmonic motion of amplitude 0.50 m and period 4π seconds. What is the speed of the body when the displacement of the body is 0.30 m?

A 0.10 m s^{-1}

B 0.15 m s^{-1}

C 0.20 m s^{-1}

D 0.40 m s^{-1}

(Total 2 marks)

108. Which one of the following statements about an oscillating mechanical system at resonance, when it oscillates with a constant amplitude, is **not** correct?

A The amplitude of oscillations depends on the amount of damping.

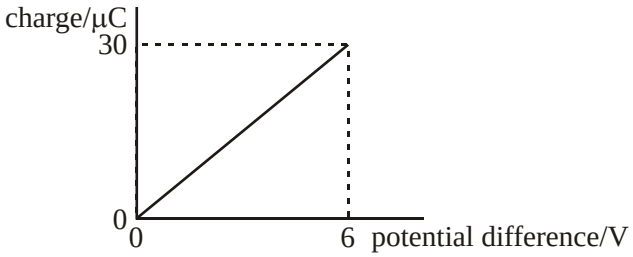
B The frequency of the applied force is the same as the natural frequency of oscillation of the system.

C The total energy of the system is constant.

D The applied force prevents the amplitude from becoming too large.

(Total 2 marks)

109. The graph shows how the charge stored by a capacitor varies with the potential difference across it as it is charged from a 6 V battery.



Which one of the following statements is **not** correct?

A The capacitance of the capacitor is 5.0 μF.

B When the potential difference is 2 V the charge stored is 10 μC.

C When the potential difference is 2 V the energy stored is 10 μJ.

D When the potential difference is 6 V the energy stored is 180 μJ.

(Total 2 marks)

110. 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 increase if *R* is increased.

B The time constant will decrease if *C* 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.

(Total 2 marks)

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

A 7.3×10^{-5} rad s^{-1}

B 4.2×10^{-3} rad s^{-1}

C 2.6×10^{-1} rad s^{-1}

D 15 rad s^{-1}

(Total 2 marks)

~~*right*~~**112.** The following data refer to two planets.

	radius/km	density/kg m^{-3}
planet P	8 000	6 000
planet Q	16 000	3 000

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

A 3.4 N kg^{-1}

B 13.4 N kg^{-1}

C 53.6 N kg^{-1}

D 80.4 N kg^{-1}

(Total 2 marks)

113. Near the surface of a planet the gravitational field is uniform and for two points, 10 m apart vertically, the gravitational potential difference is 3 J kg^{-1}. How much work must be done in raising a mass of 4 kg vertically through 5 m?

A 3 J

B 6 J

C 12 J

D 15 J

(Total 2 marks)

(c) the p.d. across the capacitor 60 s after the discharge has begun.

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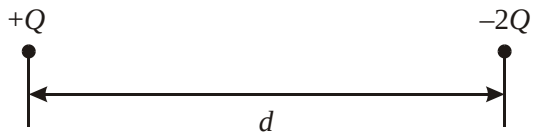
(3)

(Total 6 marks)

114.



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 of $2d$. 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 $\frac{F}{2}$

(Total 2 marks)

115. The electrical field strength, E, and the electrical potential, V, at the surface of a sphere of radius r carrying a charge Q are given by the equations

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

A school van de Graaff generator has a dome of radius 100 mm. Charge begins to leak into the air from the dome when the electric field strength at its surface is approximately 3×10^6 V m^{-1}.
What, approximately, is the maximum potential to which the dome can be raised without leakage?

A 3×10^4 V

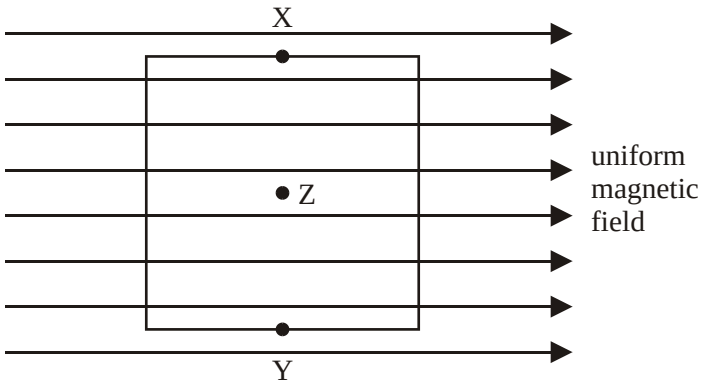
B 3×10^5 V

C 3×10^6 V

D 3×10^7 V

(Total 2 marks)

116.



The diagram shows a square coil with its plane parallel to a uniform magnetic field. Which one of the following would induce an emf in the coil?

A movement of the coil slightly to the left

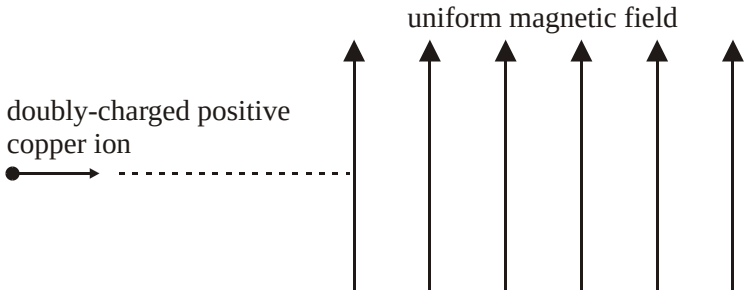
B movement of the coil slightly downwards

C rotation of the coil about an axis through XY

D rotation of the coil about an axis perpendicular to the plane of the coil through Z

(Total 2 marks)

117. (a)



The diagram above shows a doubly-charged positive ion of the copper isotope $^{63}_{29}Cu$ that is projected into a vertical magnetic field of flux density 0.28 T, with the field directed upwards. The ion enters the field at a speed of 7.8×10^5 m s^{-1}.

(i) State the initial direction of the magnetic force that acts on the ion.

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(ii) Describe the subsequent path of the ion as fully as you can.
Your answer should include both a qualitative description and a calculation.

mass of $^{63}_{29}Cu$ ion = 1.05×10^{-25} kg

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(5)

(b) State the effect on the path in part (a) if the following changes are made separately.

(i) The strength of the magnetic field is doubled.

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(ii) A singly-charged positive $^{63}_{29}Cu$ ion replaces the original one.

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(3)
(Total 8 marks)

118. (a) The Moon's orbit around the Earth may be assumed to be circular. Explain why no work is done by the gravitational force that acts on the Moon to keep it in orbit around the Earth.

You may be awarded marks for the quality of written communication provided in your answer.

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(3)

(b) Give an example of a situation where a body

(i) travels at constant speed but experiences a continuous acceleration,

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(ii) experiences a maximum acceleration when its speed is zero.

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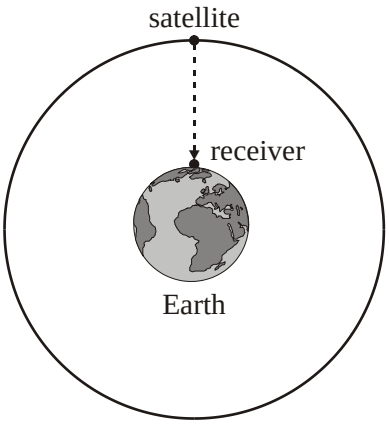
(2)
(Total 5 marks)

119. The Global Positioning System (GPS) is a system of satellites that transmit radio signals which can be used to locate the position of a receiver anywhere on Earth.



(a) A receiver at sea level detects a signal from a satellite in a circular orbit when it is passing directly overhead as shown in the diagram above.

(i) The microwave signal is received 68 ms after it was transmitted from the satellite. Calculate the height of the satellite.

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(ii) Show that the gravitational field strength of the Earth at the position of the satellite is 0.56 N kg^{-1}.

mass of the Earth = 6.0×10^{24} kg
mean radius of the Earth = 6400 km

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(4)

(b) For the satellite in this orbit, calculate

(i) its speed,

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(ii) its time period.

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(5)
(Total 9 marks)

120. 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 opposite direction to the velocity.

C It is in the same direction as the displacement.

D It is proportional to the displacement.

(Total 2 marks)

121. A 1.0 μF capacitor is charged by means of a **constant** current of 10 μA for 20s.
What is the energy finally stored in the capacitor?

A 4.0×10^{-4} J

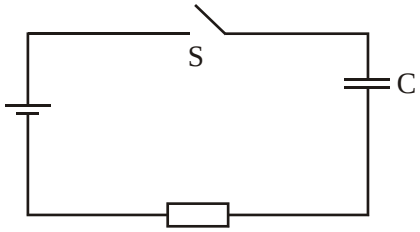
B 2.0×10^{-3} J

C 2.0×10^{-2} J

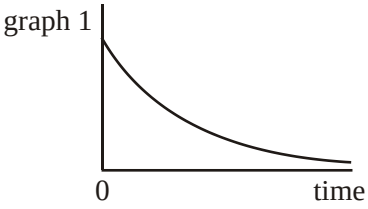
D 4.0×10^{-2} J

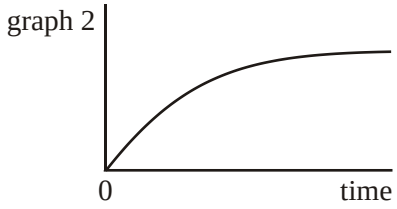
(Total 2 marks)

122. In the circuit shown, the capacitor C is charged to a potential difference *V* when the switch S is closed.



Which line, **A** to **D**, in the table gives a correct pair of graphs showing how the charge and current 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

(Total 2 marks)

123. 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.

(Total 2 marks)

124. Two isolated point charges are separated by 0.04 m and attract each other with a force of 20 μN. If the distance between them is increased by 0.04 m, what is the new force of attraction?

A 40 μN

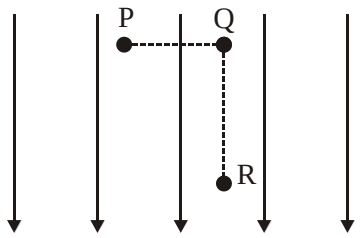
B 20 μN

C 10 μN

D 5 μN

(Total 2 marks)

125.



The diagram shows a uniform electric field of strength 10 V m^{-1}

A charge of 4 μC is moved from P to Q and then from Q to R. If the distance PQ is 2 m and QR is 3 m, what is the change in potential energy of the charge when it is moved from P to R?

A 40 μJ

B 50 μJ

C 120 μJ

D 200 μJ

(Total 2 marks)

126. (a) A body is moving with simple harmonic motion. State **two** conditions that must be satisfied concerning the *acceleration* of the body.

condition 1 .....

.....

condition 2 .....

.....

(2)

(b) A mass is suspended from a vertical spring and the system is allowed to come to rest. When the mass is now pulled down a distance of 76 mm and released, the time taken for 25 oscillations is 23 s.

Calculate

(i) the frequency of the oscillations,

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(ii) the maximum acceleration of the mass,

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(iii) the displacement of the mass from its rest position 0.60 s after being released. State the direction of this displacement.

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(6)

(c)

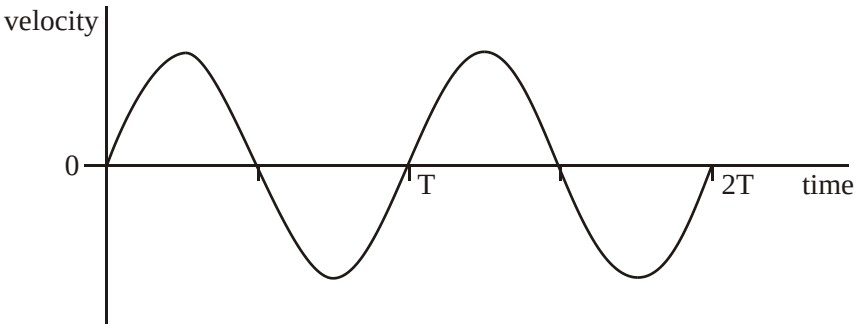

Figure 1

Figure 1 shows qualitatively how the velocity of the mass varies with time over the first two cycles after release.

(i) Using the axes in **Figure 2**, sketch a graph to show qualitatively how the displacement of the mass varies with time during the same time interval.

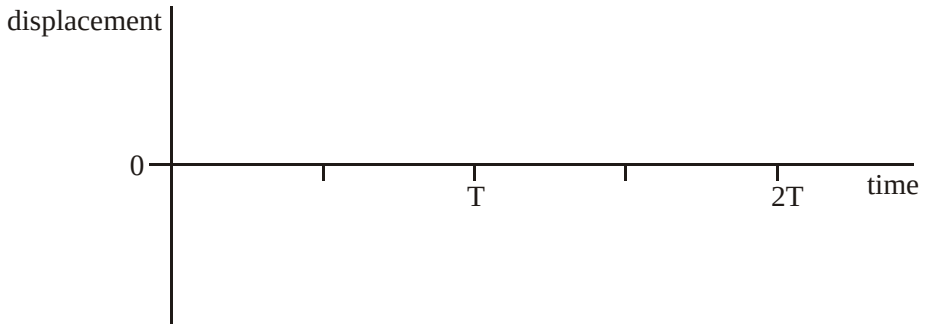

Figure 2

(ii) Using the axes in **Figure 3**, sketch a graph to show qualitatively how the potential energy of the mass-spring system varies with time during the same time interval.

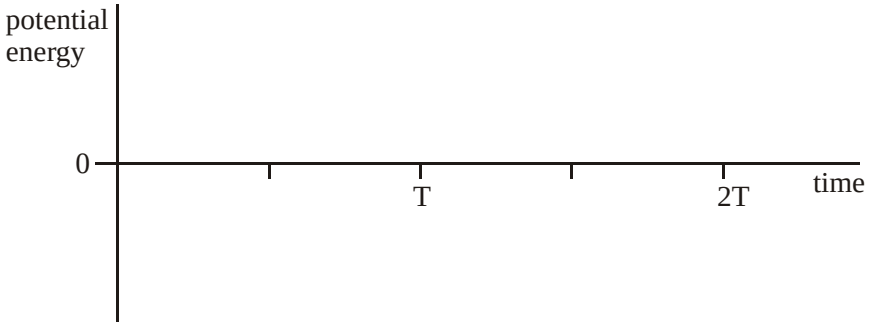

Figure 3

(4)
(Total 12 marks)

127. (a) Explain what is meant by the *gravitational potential* at a point in a gravitational field.

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(2)

(b) Use the following data to calculate the gravitational potential at the surface of the Moon.

mass of Earth = 81 × mass of Moon
radius of Earth = 3.7 × radius of Moon
gravitational potential at surface of the Earth = –63 MJ kg^{-1}

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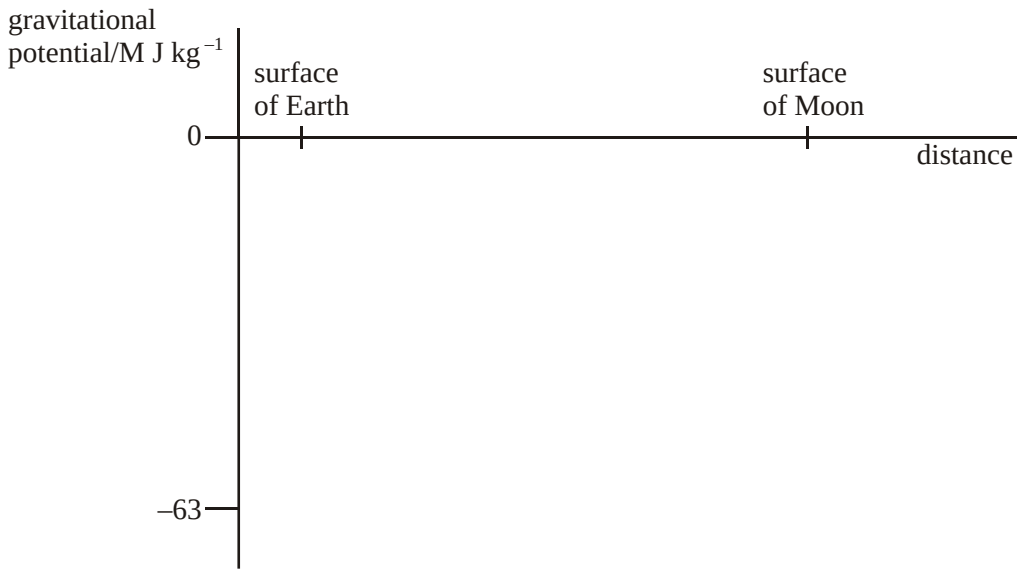
(3)

(c) Sketch a graph on the axes below to indicate how the gravitational potential varies with distance along a line outwards from the surface of the Earth to the surface of the Moon.



(3)
(Total 8 marks)

128.

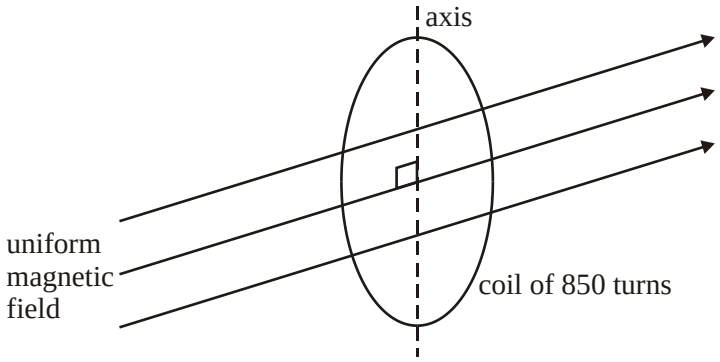


Figure 1

A circular coil of diameter 140 mm has 850 turns. It is placed so that its plane is perpendicular to a horizontal magnetic field of uniform flux density 45 mT, as shown in **Figure 1**.

(a) Calculate the magnetic flux passing through the coil when in this position.

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(2)

(b) The coil is rotated through 90° about a vertical axis in a time of 120 ms.

Calculate

(i) the change of magnetic flux linkage produced by this rotation,

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(ii) the average emf induced in the coil when it is rotated.

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(4)
(Total 6 marks)

129. In a football match, a player kicks a stationary football of mass 0.44 kg and gives it a speed of 32 m s^{-1}.

(a) (i) Calculate the change of momentum of the football.

.....

(ii) The contact time between the football and the footballer's boot was 9.2 m s. Calculate the average force of impact on the football.

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(3)

(b) A video recording showed that the toe of the boot was moving on a circular arc of radius 0.62 m centred on the knee joint when the football was struck. The force of the impact slowed the boot down from a speed of 24 m s^{-1} to a speed of 15 m s^{-1}.

Figure 1

(i) Calculate the deceleration of the boot along the line of the impact force when it struck the football.

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(ii) Calculate the centripetal acceleration of the boot just before impact.

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(iii) Discuss briefly the radial force on the knee joint before impact and during the impact.

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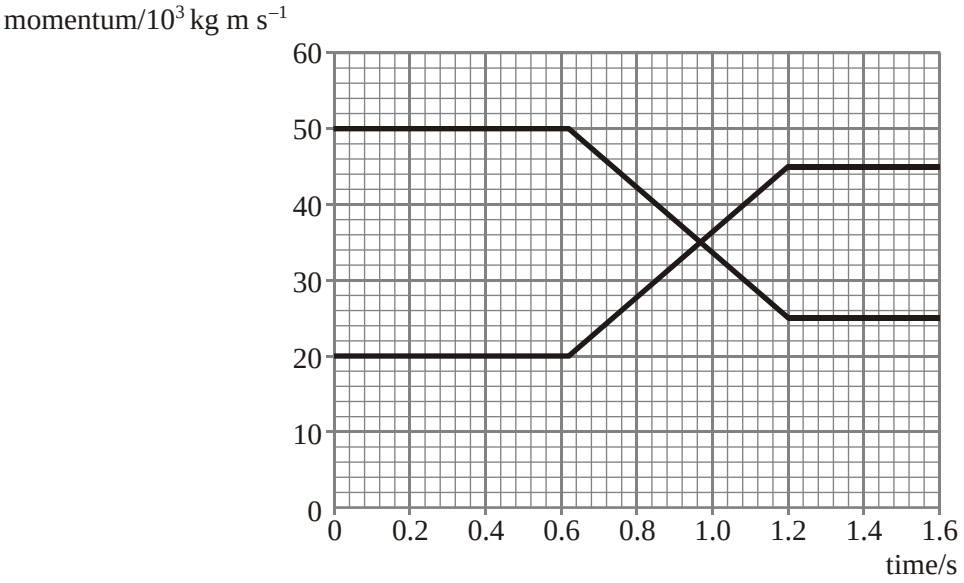
(4)
(Total 7 marks)

130. The graph shows how the momentum of two colliding railway trucks varies with time. Truck **A** has a mass of 2.0×10^4 kg and truck **B** has a mass of 3.0×10^4 kg. The trucks are travelling in the same direction.



(a) Calculate the change in momentum of

(i) truck **A**,

.....

(ii) truck **B.**

.....

(4)

(b) Complete the following table.

	Initial velocity/m s^{-1}	Final velocity/m s^{-1}	Initial kinetic energy/J	Final kinetic energy/J
truck **A**				
truck **B**				

(4)

(c) State and explain whether the collision of the two trucks is an example of an elastic collision.

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(3)
(Total 11 marks)

131. A spring is suspended from a fixed point. A mass attached to the spring is set into vertical undamped simple harmonic motion. When the mass is at its lowest position, which one of the following has its minimum value?

A the potential energy of the system

B the kinetic energy of the mass

C the acceleration of the mass

D the tension in the spring

(Total 2 marks)

132. The time period of a simple pendulum is doubled when the length of the pendulum is increased by 3.0 m. What is the original length of the pendulum?

A 1.0 m

B 1.5 m

C 3.0 m

D 6.0 m

(Total 2 marks)

133. The Earth has density ρ and radius R. The gravitational field strength at the surface is g. What is the gravitational field strength at the surface of a planet of density 2ρ and radius $2R$?

A g

B $2\,g$

C $4\,g$

D $16\,g$

(Total 2 marks)

134. 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 $\dfrac{\pi^2 m r}{T^2}$

B $\dfrac{\pi^2 m r^2}{T^2}$

C $\dfrac{2\pi^2 m r^2}{T}$

D $\dfrac{2\pi^2 m r^2}{T^2}$

(Total 2 marks)

135. Two protons, each of mass m and charge e, are a distance d apart. Which one of the following expressions correctly gives the ratio $\left(\frac{\text{electrostatic force}}{\text{gravitational force}}\right)$ for the forces acting between them?

A $\frac{4\pi\varepsilon_0 e^2}{Gm^2}$

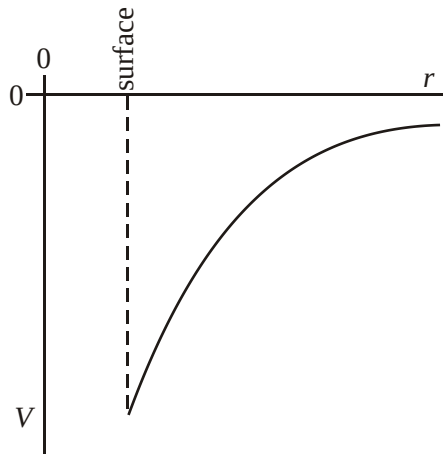
B $\frac{Ge^2}{4\pi\varepsilon_0 m^2}$

C $\frac{e^2 m^2}{4\pi\varepsilon_0 G}$

D $\frac{e^2}{4\pi\varepsilon_0 Gm^2}$

(Total 2 marks)

136. The graph shows how the gravitational potential, V , varies with the distance, r , from the centre of the Earth.



What does the gradient of the graph at any point represent?

A the magnitude of the gravitational field strength at that point

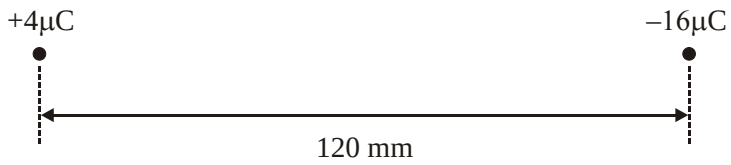
B the magnitude of the gravitational constant

C the mass of the Earth

D the potential energy at the point where the gradient is measured

(Total 2 marks)

137.



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

(Total 2 marks)

138. An electron travelling at constant speed enters a uniform electric field at right angles to the field. While the electron is in the field it accelerates in a direction which is

A in the same direction as the electric field.

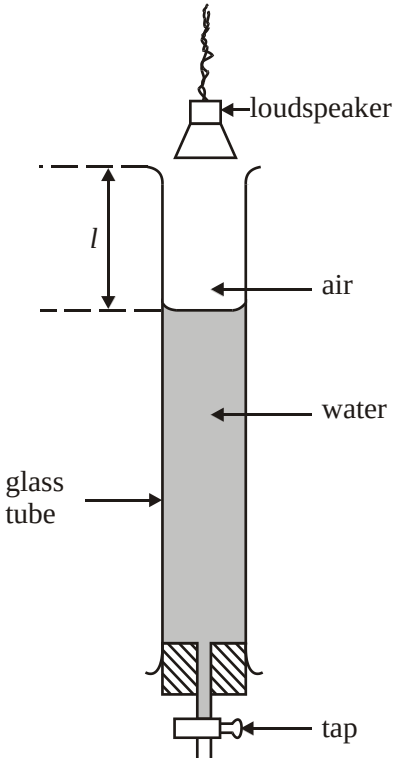
B in the opposite direction to the electric field.

C in the same direction as the motion of the electron.

D in the opposite direction to the motion of the electron.

(Total 2 marks)

139.



A small loudspeaker emitting sound of constant frequency is positioned a short distance above a long glass tube containing water. When water is allowed to run slowly out of the tube, the intensity of the sound heard increases whenever the length *l* (shown above) takes certain values.

(a) Explain these observations by reference to the physical principles involved.

You may be awarded marks for the quality of written communication in your answer.

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(4)

(b) With the loudspeaker emitting sound of frequency 480 Hz, the effect described in part (a) is noticed first when l = 168 mm. It next occurs when l = 523 mm.

Use both values of l to calculate

(i) the wavelength of the sound waves in the air column,

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(ii) the speed of these sound waves.

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(4)
(Total 8 marks)

140. (a) As a capacitor was charged from a 12 V supply, a student used a coulomb meter and a voltmeter to record the charge stored by the capacitor at a series of values of potential difference across the capacitor. The student then plotted a graph of pd (on the *y*-axis) against charge (on the *x*-axis).

(i) Sketch the graph obtained.

(ii) State what is represented by the gradient of the line.

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(iii) State what is represented by the area enclosed by the line and the *x*-axis of the graph.

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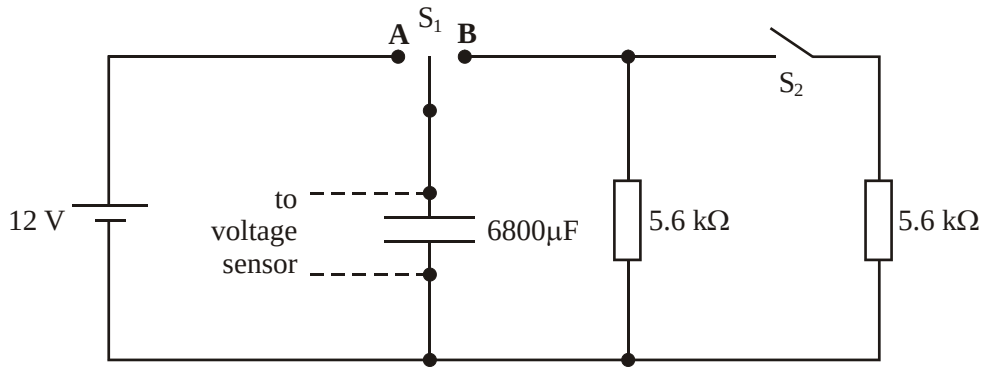
(3)

(b) The student then connected the capacitor as shown in the diagram below to carry out an investigation into the discharge of the capacitor.



The student used a voltage sensor, datalogger and computer to obtain values for the pd across the capacitor at various times during the discharge.

(i) At time $t = 0$, with switch S_2 open, switch $S_1$was moved from position **A** to position **B**. Calculate the pd across the capacitor when $t = 26$ s.

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(ii) At time $t = 26$ s, as the discharge continued, the student closed switch S_2. Calculate the pd across the capacitor 40 s after switch S_1 was moved from position **A** to position **B**.

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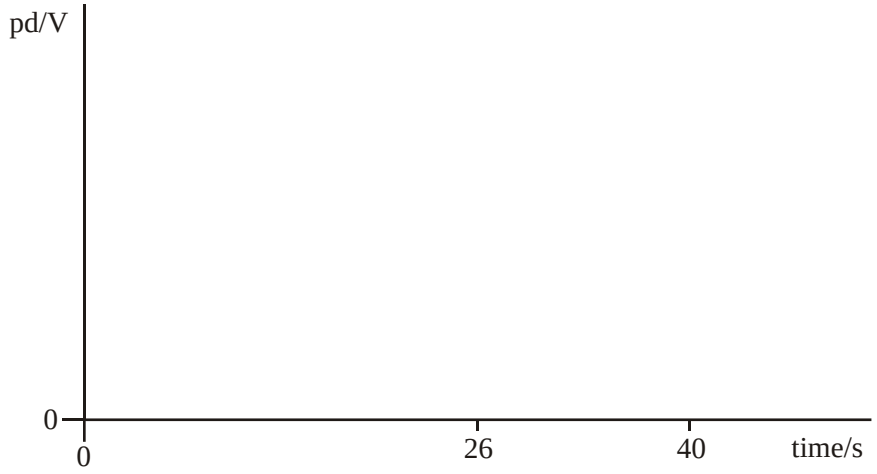
(iii) Sketch a graph of pd against time for the student's experiment described in parts (b)(i) and (b)(ii).



(7)
(Total 10 marks)

141. (a) State, in words, Newton's law of gravitation.

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(3)

(b) By considering the centripetal force which acts on a planet in a circular orbit, show that $T^2 \propto R^3$, where T is the time taken for one orbit around the Sun and R is the radius of the orbit.

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(3)

(c) The Earth's orbit is of mean radius 1.50×10^{11} m and the Earth's year is 365 days long.

(i) The mean radius of the orbit of Mercury is 5.79×10^{10} m. Calculate the length of Mercury's

year.

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(ii) Neptune orbits the Sun once every 165 Earth years.

Calculate the ratio $\frac{\text{distance from Sun to Neptune}}{\text{distance from Sun to Earth}}$.

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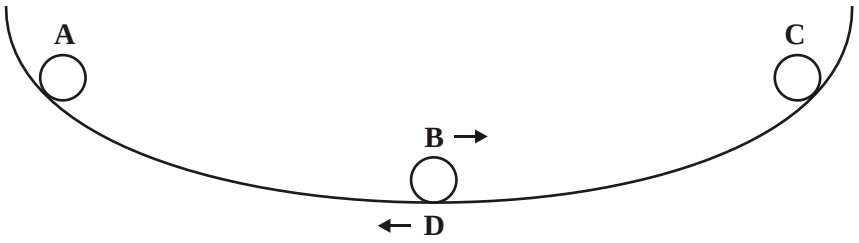
(4)
(Total 10 marks)

142. A ball bearing rolls on a concave surface, as shown in the diagram, in approximate simple harmonic motion. It is released from **A** and passes through the lowest point **B** before reaching **C**. It then returns through the lowest point **D**. At which stage, **A**, **B**, **C** or **D**, does the ball bearing experience maximum acceleration to the left?



(Total 2 marks)

143. 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 $\frac{4\pi^2 A}{b^2}$

(Total 2 marks)

144. 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

(Total 2 marks)

145. What is the value of the angular velocity of a point on the surface of the Earth?

A 1.2×10^{-5} rad s^{-1}

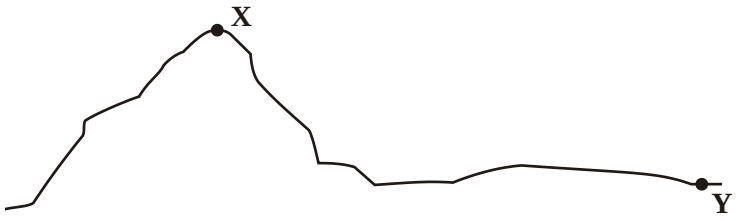
B 7.3×10^{-5} rad s^{-1}

C 2.6×10^{-1} rad s^{-1}

D 4.6×10^{2} rad s^{-1}

(Total 2 marks)

146. The diagram shows two positions, **X** and **Y**, at different heights on the surface of the Earth.



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

(Total 2 marks)

147. A projectile moves in a gravitational field. Which one of the following is a correct statement for the gravitational force acting on the projectile?

A The force is in the direction of the field.

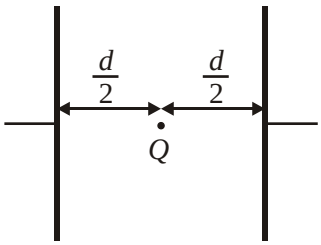
B The force is in the opposite direction to that of the field.

C The force is at right angles to the field.

D The force is at an angle between 0° and 90° to the field.

(Total 2 marks)

148. 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 $\frac{2VQ}{d}$

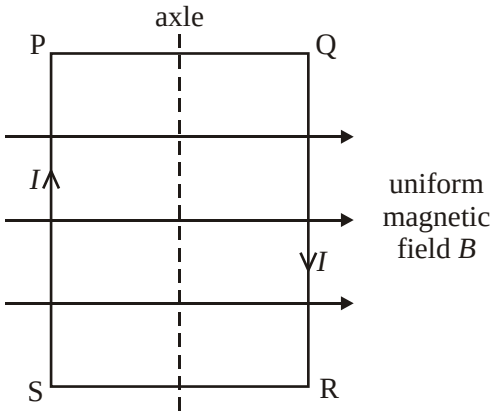
B $\frac{VQ}{2d}$

C $\frac{VQ}{d}$

D $\frac{Qd}{V}$

(Total 2 marks)

149.



A coil, mounted on an axle, has its plane parallel to the flux lines of a uniform magnetic field *B*, as shown. When a current I is switched on, and before the coil is allowed to move,

A there are no forces due to *B* on the sides PQ and RS.

B there are no forces due to *B* on the sides SP and QR.

C sides SP and QR attract each other.

D sides PQ and RS attract each other.

(Total 2 marks)

150. Protons, each of mass *m* and charge *e*, follow a circular path when travelling perpendicular to a magnetic field of uniform flux density *B*. What is the time taken for one complete orbit?

A $\frac{2\pi eB}{m}$

B $\frac{m}{2\pi eB}$

C $\frac{eB}{2\pi m}$

D $\frac{2\pi m}{eB}$

(Total 2 marks)

151. (a) A spring, which hangs from a fixed support, extends by 40 mm when a mass of 0.25 kg is suspended from it.

(i) Calculate the spring constant of the spring.

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(ii) An additional mass of 0.44 kg is then placed on the spring and the system is set into vertical oscillation. Show that the oscillation frequency is 1.5 Hz.

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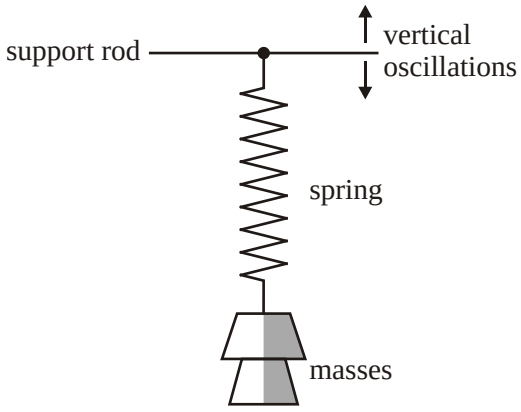
(4)

(b) With both masses still in place, the spring is now suspended from a horizontal support rod that can be made to oscillate vertically, as shown in the figure below, with amplitude 30 mm at several different frequencies.



Describe fully, with reference to amplitude, frequency and phase, the motion of the masses suspended from the spring in each of the following cases.

(i) The support rod oscillates at a frequency of 0.2 Hz.

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(ii) The support rod oscillates at a frequency of 1.5 Hz.

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(iii) The support rod oscillates at a frequency of 10 Hz.

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(6)
(Total 10 marks)

152. A 680 μF capacitor is charged fully from a 12 V battery. At time $t = 0$ the capacitor begins to discharge through a resistor. When $t = 25$ s the energy remaining in the capacitor is one quarter of the energy it stored at 12 V.

(a) Determine the pd across the capacitor when $t = 25$s.

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(2)

(b) (i) Show that the time constant of the discharge circuit is 36 s.

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(ii) Calculate the resistance of the resistor.

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(4)
(Total 6 marks)

153. (a) Artificial satellites are used to monitor weather conditions on Earth, for surveillance and for communications. Such satellites may be placed in a *geo-synchronous* orbit or in a low polar orbit.

Describe the properties of the geo-synchronous orbit and the advantages it offers when a satellite is used for communications.

You may be awarded marks for the quality of written communication in your answer.

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(3)

(b) A satellite of mass m travels at angular speed ω in a circular orbit at a height h above the surface of a planet of mass M and radius R.

(i) Using these symbols, give an equation that relates the gravitational force on the satellite to the centripetal force.

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(ii) Use your equation from part (b)(i) to show that the orbital period, T, of the satellite is given by

$$T^2 = \frac{4\pi^2(R+h)^3}{GM}$$

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(iii) Explain why the period of a satellite in orbit around the Earth cannot be less than 85 minutes. Your answer should include a calculation to justify this value.

mass of the Earth = 6.00×10^{24} kg
kg radius of the Earth = 6.40×10^{6} m

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(6)

(c) Describe and explain what happens to the speed of a satellite when it moves to an orbit that is closer to the Earth.

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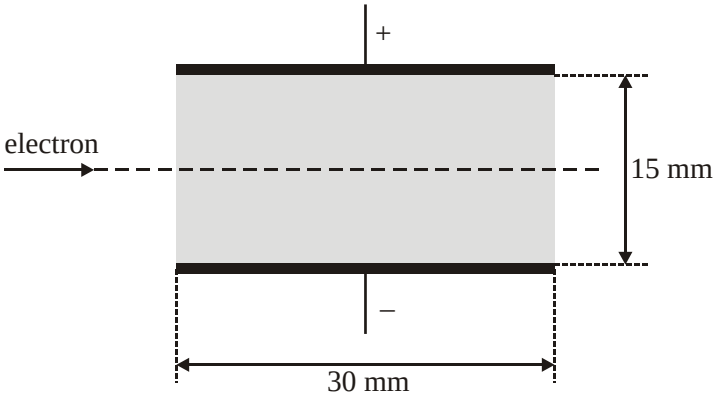
(2)
(Total 11 marks)

154. (a) An electron travels at a speed of 3.2×10^7 ms^{-1} in a horizontal path through a vacuum. The electron enters the uniform electric field between two parallel plates, 30 mm long and 15 mm apart, as shown in the figure below. A potential difference of 1400 V is maintained across the plates, with the top plate having positive polarity. Assume that there is no electric field outside the shaded area.



(i) Show that the electric field strength between the plates is 9.3×10^4 Vm^{-1}.

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(ii) Calculate the time taken by the electron to pass through the electric field.

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(iii) Show that the acceleration of the electron whilst in the field is 1.6×10^{16} m s^{-2} and state the direction of this acceleration.

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(5)

(b) Determine the magnitude and direction of the velocity of the electron at the point where it leaves the field.

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(3)
(Total 8 marks)

155. (a) State **two** quantities that are conserved in an elastic collision.

quantity 1: .....

quantity 2: .....

(2)

(b) A gas molecule makes an elastic collision with the walls of a gas cylinder. The molecule is travelling at 450 m s^{-1} at right angles towards the wall before the collision.

(i) What is the magnitude and direction of its velocity after the collision?

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(ii) Calculate the change in momentum of the molecule during the collision if it has a mass of 8.0×10^{-26} kg.

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(4)

(c) Use Newton's laws of motion to explain how the molecules of a gas exert a force on the wall of a container.

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

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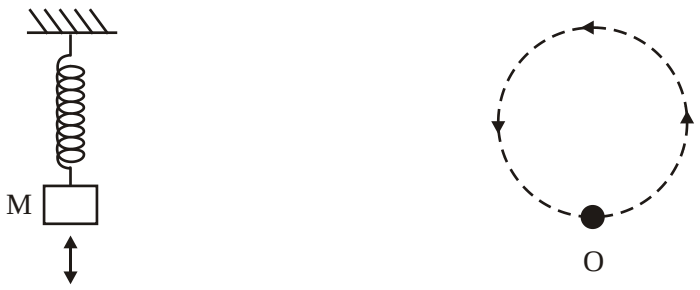
(4)
(Total 10 marks)

156. A mass M on a spring oscillates along a vertical line with the same period *T* as an object O in uniform circular motion in a vertical plane. When M is at its highest point, O is at its lowest point.



What is the least time interval between successive instants when the acceleration of M is exactly in the opposite direction to the acceleration of O?

A $\frac{T}{4}$

B $\frac{T}{2}$

C $\frac{3T}{4}$

D T

(Total 2 marks)

157. A particle of mass m oscillates with amplitude A at frequency f. What is the maximum kinetic energy of the particle?

A $\frac{1}{2}\pi^2 mf^2A^2$

B $\pi^2 mf^2A^2$

C $2\pi^2 mf^2A^2$

D $4\pi^2 mf^2A^2$

(Total 2 marks)

158. A 1000 μF capacitor, initially uncharged, is charged by a steady current of 50 μA. How long will it take for the potential difference across the capacitor to reach 2.5 V?

A 20 s

B 50 s

C 100 s

D 400 s

(Total 2 marks)

159. In experiments to pass a very high current through a gas, a bank of capacitors of total capacitance 50 μF is charged to 30 kV. If the bank of capacitors could be discharged completely in 5.0 m s what would be the mean power delivered?

A 22 kW

B 110 kW

C 4.5 MW

D 9.0 MW

(Total 2 marks)

160. For a particle moving in a circle with uniform speed, which **one** of the following statements is correct?

A The displacement of the particle is in the direction of the force.

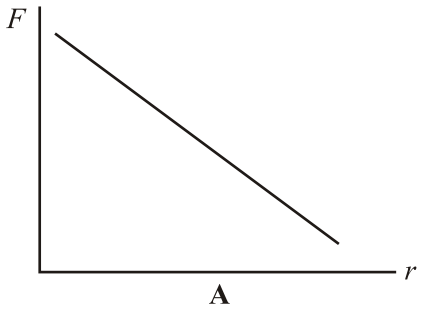
B The force on the particle is in the same direction as the direction of motion of the particle.

C The momentum of the particle is constant.

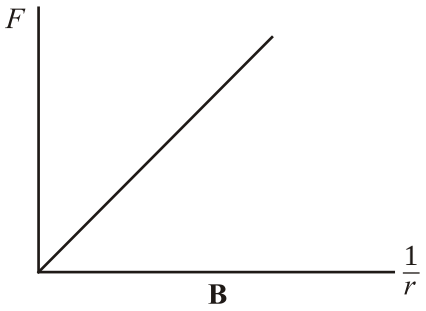
D The kinetic energy of the particle is constant.

(Total 2 marks)

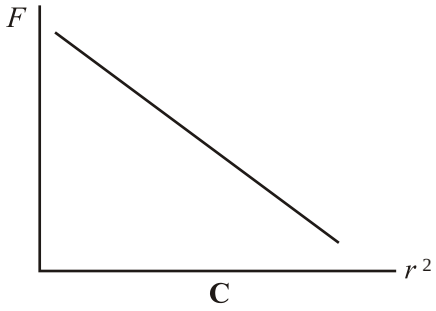
161. Which one of the following graphs correctly shows the relationship between the gravitational force, F, between two masses and their separation r.



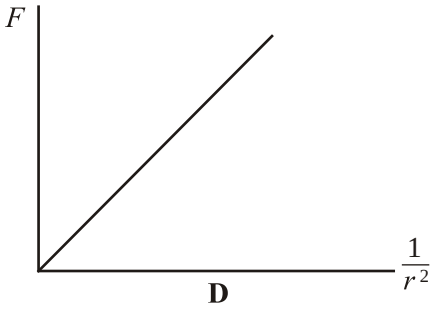
A



B



C



D

(Total 2 marks)

162. When at the surface of the Earth, a satellite has weight W and gravitational potential energy $-U$. It is projected into a circular orbit whose radius is equal to twice the radius of the Earth. Which line, **A** to **D**, in the table shows correctly what happens to the weight of the satellite and to its gravitational potential energy?

	weight	**gravitational potential energy**
A	becomes $\frac{W}{2}$	increases by $\frac{U}{2}$
B	becomes $\frac{W}{4}$	increases by $\frac{U}{2}$
C	remains W	increases by U
D	becomes $\frac{W}{4}$	increases by U

(Total 2 marks)

163. 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?

A 10^{23}

B 10^{30}

C 10^{36}

D 10^{42}

(Total 2 marks)

164. Particles of mass *m* carrying a charge *Q* travel in a circular path of radius *r* in a magnetic field of flux density *B* with a speed *v*. How many of the following quantities, if changed one at a time, would change the radius of the path?

- *m*
- *Q*
- *B*
- *v*

A one

B two

C three

D four

(Total 2 marks)

165. (a) Give an equation for the frequency, *f*, of the oscillations of a simple pendulum in terms of its length, *l*, and the acceleration due to gravity, *g*.

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State the condition under which this equation applies.

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(2)

(b) The bob of a simple pendulum, of mass 1.2×10^{-2} kg, swings with an amplitude of 51 mm. It takes 46.5 s to complete 25 oscillations. Calculate

(i) the length of the pendulum,

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(ii) the magnitude of the restoring force that acts on the bob when at its maximum displacement.

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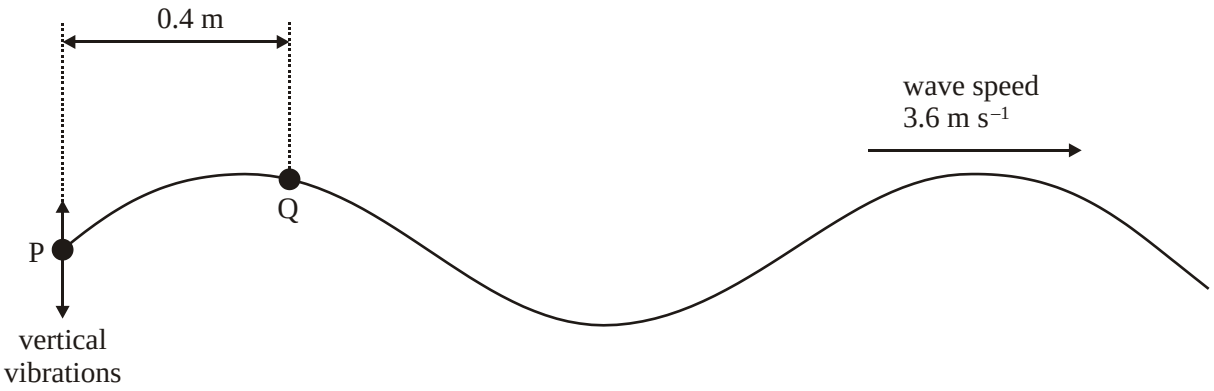
(6)
(Total 8 marks)

166. Progressive waves are generated on a rope by vibrating vertically the end, P, in simple harmonic motion of amplitude 90 mm, as shown in the figure below. The wavelength of the waves is 1.2 m and they travel along the rope at a speed of 3.6 m s^{-1}. Assume that the wave motion is not damped.



(a) Point Q is 0.4 m along the rope from P. Describe the motion of Q in as much detail as you can and state how it differs from the motion of P. Where possible, give quantitative values in your answer.

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

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(5)

(b) Calculate the maximum speed of point P.

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(3)
(Total 8 marks)

167. (a) (i) Define the *electric field strength*, *E*, at a point in an electric field.

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(ii) State whether *E* is a scalar or a vector quantity.

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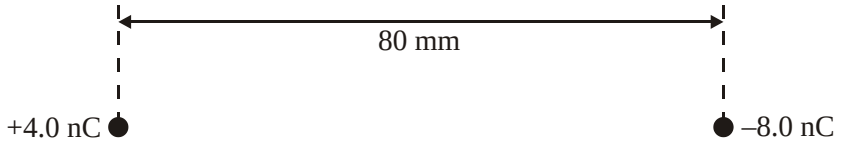
(3)

(b) Point charges of +4.0 nC and –8.0 nC are placed 80 mm apart, as shown in the figure below.



P

(i) Calculate the magnitude of the force exerted on the +4.0 nC charge by the –8.0 nC charge.

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(ii) Determine the distance from the +4.0 nC charge to the point, along the straight line between the charges, where the electric potential is zero.

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(4)

(c) Point **P** in the figure above is equidistant from the two charges.

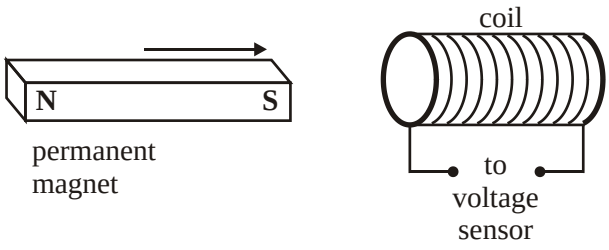
(i) Draw two arrows on the figure above at **P** to represent the directions and relative magnitudes of the components of the electric field at **P** due to each of the charges.

(ii) Hence draw an arrow, labelled **R**, on the figure above at **P** to represent the direction of the resultant electric field at **P**.

(3)
(Total 10 marks)

168. (a) In an experiment to illustrate electromagnetic induction, a permanent magnet is moved towards a coil, as shown in **Figure 1**, causing an emf to be induced across the coil.

Figure 1



Using Faraday's law, explain why a larger emf would be induced in this experiment if a stronger magnet were moved at the same speed.

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

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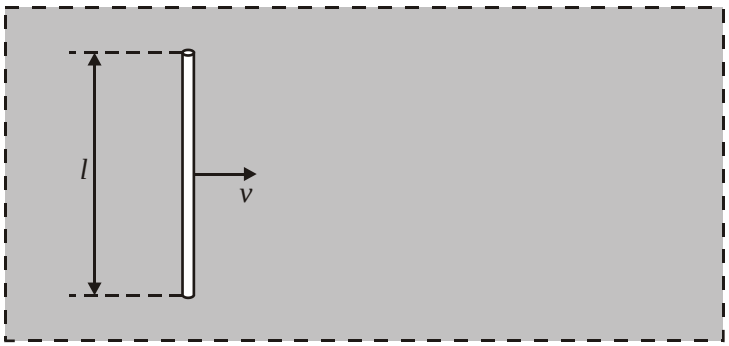
(3)

(b) A conductor of length l is moved at a constant speed v so that it passes perpendicularly through a uniform magnetic field of flux density B, as shown in **Figure 2**.

Figure 2



(i) Give an expression for the area of the magnetic field swept out by the conductor in time Δt.

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(ii) Show that the induced emf, $\in$, across the ends of the conductor is given by

$$\in = Blv.$$

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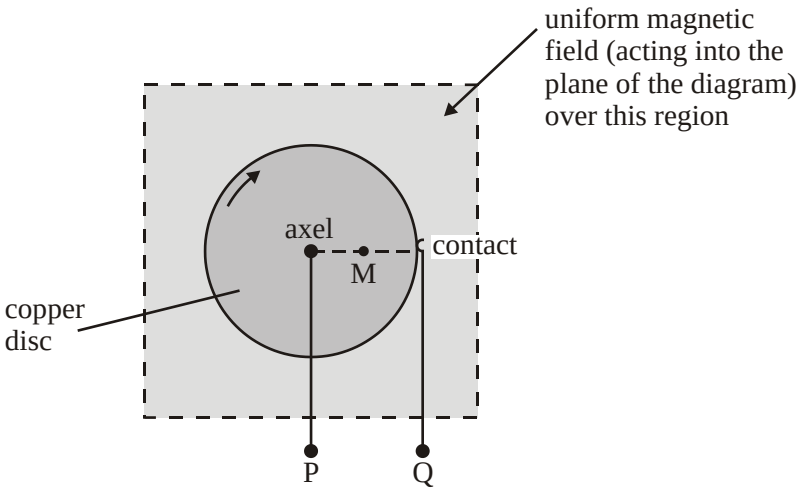
(3)

(c) A simple electrical generator can be made from a copper disc, which is rotated at right angles to a uniform magnetic field, directed into the plane of the diagram (**Figure 3**). An emf is developed across terminals P (connected to the axle) and Q (connected to a contact on the edge of the disc).

Figure 3



The radius of the disc is 64 mm and it is rotated at 16 revolutions per second in a uniform magnetic field of flux density 28 mT.

(i) Calculate the angular speed of the disc.

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(ii) Calculate the linear speed of the mid-point M of a radius of the disc.

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(iii) Hence, or otherwise, calculate the emf induced across terminals P and Q.

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(5)
(Total 11 marks)

169. For the two physical quantities, impulse and force, which one of the following is correct?

A Impulse is a scalar and force is a scalar.

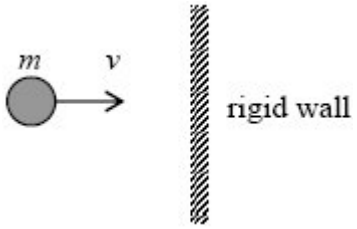
B Impulse is a scalar and force is a vector.

C Impulse is a vector and force is a scalar.

D impulse is a vector and force is a vector.

(Total 1 mark)

170. A particle of mass *m* strikes a rigid wall perpendicularly from the left with velocity *v*.



If the collision is perfectly elastic, the change in momentum of the particle which occurs as a result of the collision is

A 2*mv* to the right.

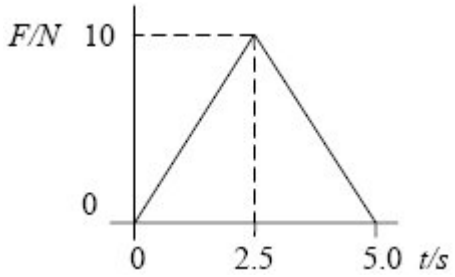
B 2*mv* to the left.

C *mv* to the left.

D zero.

(Total 1 mark)

171.



A force, *F*, varies with time, *t*, as shown by the graph and is applied to a body initially at rest on a smooth surface. What is the momentum of the body after 5.0 s?

A zero.

B 12.5 N s.

C 25 N s.

D 50 N s.

(Total 1 mark)

172. The rate of change of momentum of a body falling freely under gravity is equal to its

A weight.

B power.

C kinetic energy.

D potential energy.

(Total 1 mark)

173. What is the value of the angular velocity of a point on the surface of the Earth?

A 1.2×10^{-5} rad s^{-1}

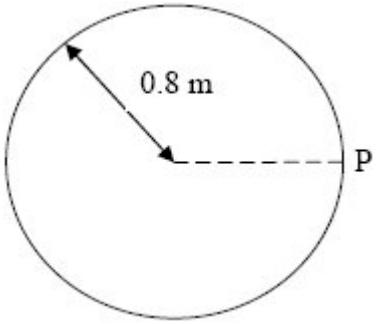
B 7.3×10^{-5} rad s^{-1}

C 2.6×10^{-1} rad s^{-1}

D 4.6×10^{2} rad s^{-1}

(Total 1 mark)

174.



A model car moves in a circular path of radius 0.8 m at an angular speed of $\frac{\pi}{2}$ rad s^{-1}. What is its displacement from point P, 6 s after passing P?

A zero

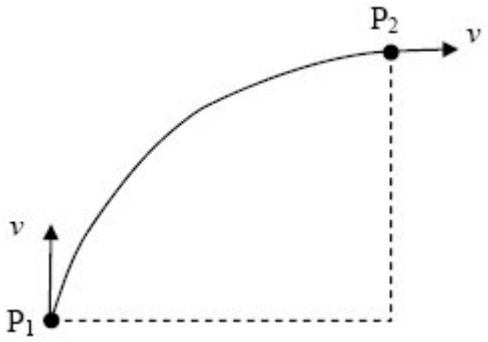
B 1.6 m

C 0.4 πm

D 1.6 πm

(Total 1 mark)

175. A particle of mass *m* moves horizontally at constant speed *v* along the arc of a circle from P_1 to P_2 under the action of a force. What is the work done on the particle by the force during this displacement?



A zero

B $\frac{\pi mv^2}{2}$

C $mv^2\sqrt{2}$

D $2\,mv^2$

(Total 1 mark)

176. A body moves with simple harmonic motion of amplitude 0.50 m and period 4π seconds.
What is the speed of the body when the displacement of the body from the equilibrium position is 0.30 m?

A 0.10 m s^{-1}

B 0.15 m s^{-1}

C 0.20 m s^{-1}

D 0.40 m s^{-1}

(Total 1 mark)

177. The time period of a simple pendulum is doubled when the length of the pendulum is increased by 3.0 m. What is the original length of the pendulum?

A 1.0 m

B 1.5 m

C 3.0 m

D 6.0 m

(Total 1 mark)

178. Which one of the following statements is not true for a body vibrating in simple harmonic motion when damping is present?

A The damping force is always in the opposite direction to the velocity.

B The damping force is always in the opposite direction to the displacement.

C The presence of damping gradually reduces the maximum potential energy of the system.

D The presence of damping gradually reduces the maximum kinetic energy of the system.

(Total 1 mark)

179. The Earth has density ρ and radius R. The gravitational field strength at the surface is g. What is the gravitational field strength at the surface of a planet of density 2ρ and radius $2R$?

A g

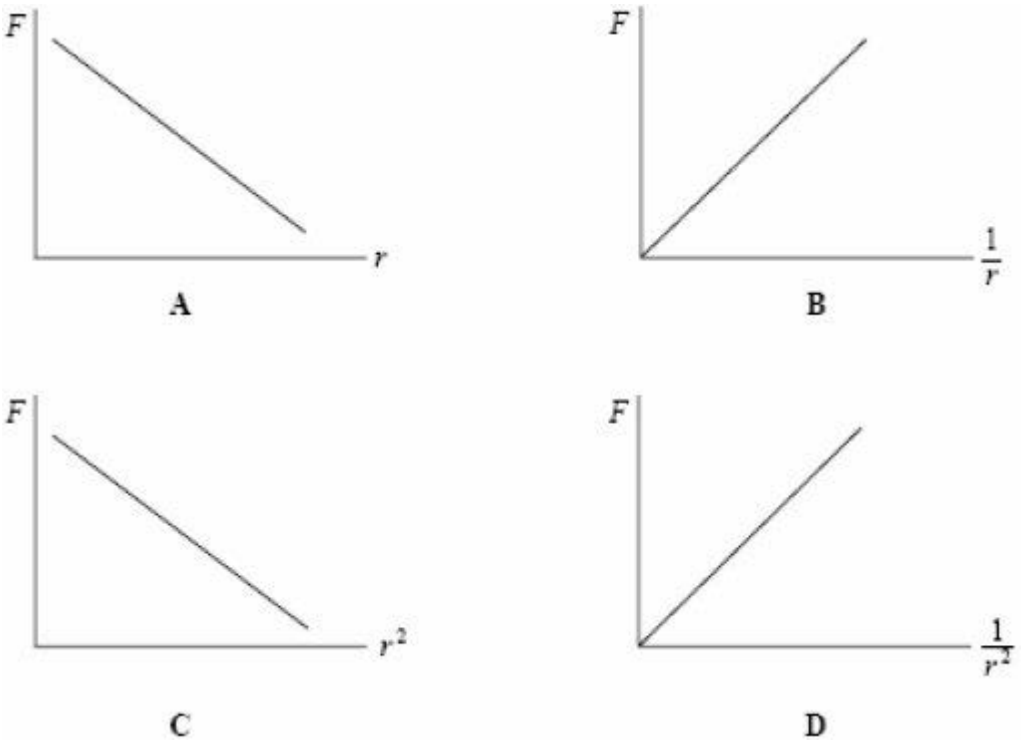
B $2g$

C $4g$

D $16g$

(Total 1 mark)

180. Which one of the following graphs correctly shows the relationship between the gravitational force, *F*, between two masses and their separation, *r*?



(Total 1 mark)

181. Near the surface of a planet the gravitational field strength is uniform and for two points, 10 m apart vertically, the gravitational potential difference is 3 J kg^{-1}. How much work must be done in raising a mass of 4 kg vertically through 5 m?

A 3 J

B 6 J

C 12 J

D 15 J

(Total 1 mark)

182. Two isolated point charges are separated by 0.04 m and attract each other with a force of 20 μN. If the distance between them is increased by 0.04 m, what is the new force of attraction?

A 5 μN

B 10 μN

C 20 μN

D 40 μN

(Total 1 mark)

183. Two protons, each of mass *m* and charge *e*, are a distance *d* apart. Which one of the following expressions correctly gives the ratio $\left(\frac{\text{electrostatic force}}{\text{gravitational force}}\right)$ for the forces acting between them?

A $\frac{4\pi\varepsilon_0 e^2}{Gm^2}$

B $\frac{Ge^2}{4\pi\varepsilon_0 m^2}$

C $\frac{e^2 m^2}{4\pi\varepsilon_0 G}$

D $\frac{e^2}{4\pi\varepsilon_0 Gm^2}$

(Total 1 mark)

184. An electron travelling at constant speed enters a uniform electric field at right angles to the field. While the electron is in the filed it accelerates in a direction which is

A in the same direction as the electric field

B in the opposite direction to the electric field

C in the same direction as the motion of the electron

D in the opposite direction to the motion of the electron 7

(Total 1 mark)

185. Which one of the following statements about electric potential and electric field strength is correct?

A electric potential is zero whenever the electric field strength is zero

B electric field strength is a scalar quantity

C electric potential is a vector quantity

D electric potential due to a point charge varies as (l/*r*) where *r* is the distance from the point charge

(Total 1 mark)

186. A 1000 μF capacitor and a 10 μF capacitor are charged so that the potential difference across each of them is the same. The charge stored in the 100 μF capacitor is Q_1 and the charge stored in the 10 μF capacitor is Q_2. What is the ratio $\frac{Q_1}{Q_2}$?

A 100

B 10

C 1

D $\frac{1}{100}$

(Total 1 mark)

187. In experiments to pass a very high current through a gas, a bank of capacitors of total capacitance 50 μF is charged to 30kV. If the bank of capacitors could be discharged completely in 5.0 ms, what would be the mean power delivered?

A 22 kW

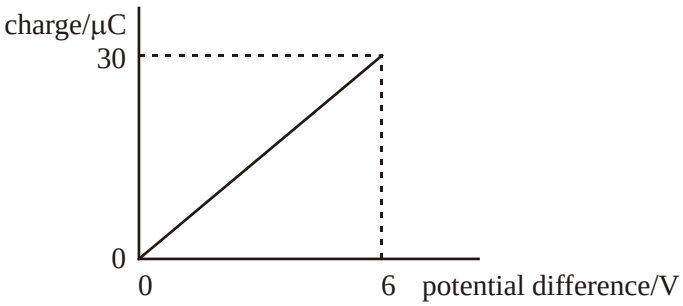
B 110 kW

C 4.5 MW

D 9.0 MW

(Total 1 mark)

188. The graph shows how the charge stored by a capacitor varies with the potential difference across it as it is charged from a 6 V battery.



Which one of the following statements is **not** correct?

A The capacitance of the capacitor is 5.0 μF.

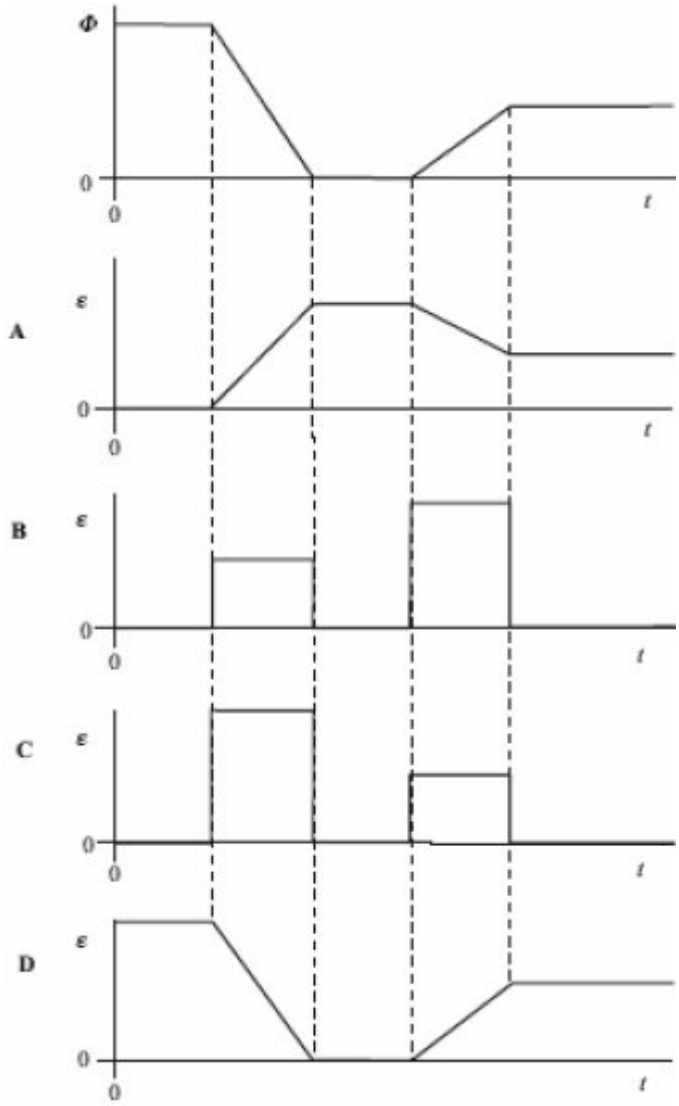
B When the potential difference is 2 V the charge stored is 10 μC.

C When the potential difference is 2 V the energy stored is 10 μJ.

D When the potential difference is 6 V the energy stored is 180 μJ.

(Total 1 mark)

189. The magnetic flux, Φ, through a coil varies with time, t, as shown by the first graph. Which one of the following graphs, A to D, best represents how the magnitude, $\in$, of the induced emf varies in this same period of time?



(Total 1 mark)

190. Protons, each of mass *m* and charge *e*, follow a circular path when travelling perpendicular to a magnetic field of uniform flux density *B*. What is the time taken for one complete orbit?

A $\frac{2\pi eB}{m}$

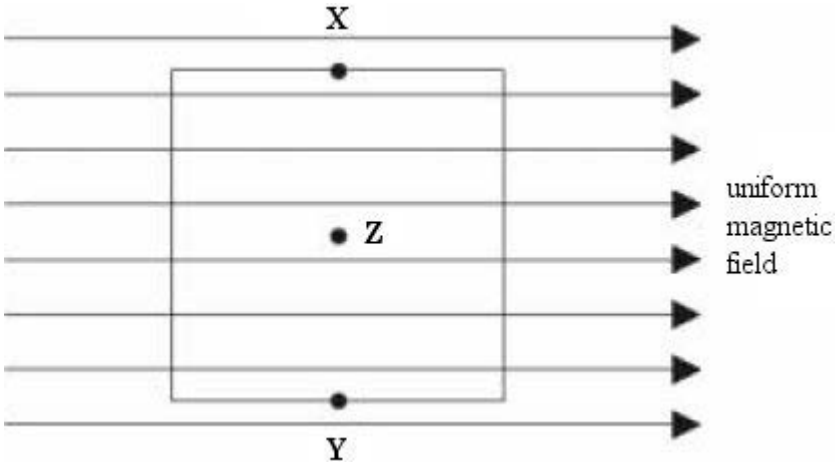
B $\frac{m}{2\pi eB}$

C $\frac{eB}{2\pi m}$

D $\frac{2\pi m}{eB}$

(Total 1 mark)

191.



The diagram shows a square coil with its plane parallel to a uniform magnetic field.
Which one of the following would induce an emf in the coil?

A movement of the coil slightly to the left

B movement of the coil slightly downwards

C rotation of the coil about an axis through XY

D rotation of the coil about an axis perpendicular to the plane of the coil through Z

(Total 1 mark)

192. The primary winding of a perfectly efficient transformer has 200 turns and the secondary has 1000 turns. When a sinusoidal pd of rms value 10 V is applied to the input, there is a primary current of rms value 0.10 A rms. Which line in the following table, **A** to **D**, gives correct rms output values obtainable from the secondary when the primary is supplied in this way?

	rms output emf/V	**rms output current/A**
A	50	0.10
B	50	0.02
C	10	0.10
D	10	0.02

(Total 1 mark)

193. Why, when transporting electricity on the National Grid, are high voltages and low currents used?

A The energy lost by radiation from electromagnetic waves is reduced.

B The electrons move more rapidly.

C The heat losses are reduced.

D The resistance of the power lines is reduced.

(Total 1 mark)

194. A golf club undergoes an *inelastic* collision with a stationary golf ball and gives it an initial velocity of 60 m s^{-1}. The ball is in contact with the club for 15 ms and the mass of the ball is 4.5×10^{-2} kg.

(a) Explain what is meant by an inelastic collision.

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(1)

(b) Calculate

(i) the change in momentum of the ball,

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(ii) the average force the club exerts on the ball.

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(4)
(Total 5 marks)

195. (a) A spring, which hangs from a fixed support, extends by 40 mm when a mass of 0.25 kg is suspended from it.

(i) Calculate the spring constant of the spring.

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(ii) An additional mass of 0.44 kg is then placed on the spring and the system is set into vertical oscillation. Show that the oscillation frequency is 1.5 Hz.

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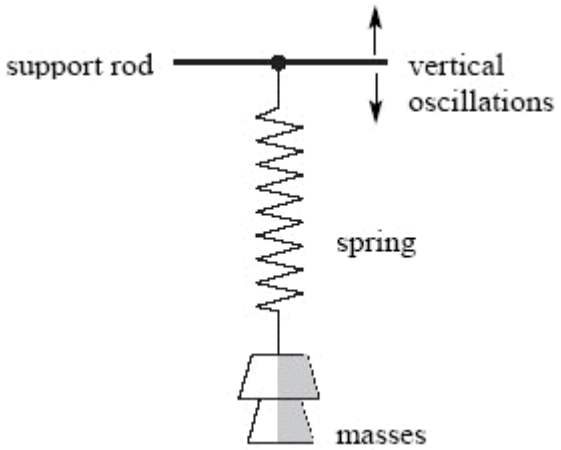
(4)

(b) With both masses still in place, the spring is now suspended from a horizontal support rod that can be made to oscillate vertically, as shown in the diagram below, with amplitude 30 mm at several different frequencies.



The response of the masses suspended from the spring to the vertical oscillations of the support rod varies with frequency. Describe and explain, as fully as you can, the motion of the masses when the support rod oscillates at a frequency of (i) 0.2 Hz, (ii) 1.5 Hz and (iii) 10 Hz.

The quality of your written answer will be assessed in this question.

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(6)
(Total 10 marks)

196. Communications satellites are usually placed in a *geo-synchronous* orbit.

(a) State two features of a geo-synchronous orbit.

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(2)

(b) The mass of the Earth 6.00×10^{24} kg and its mean radius is 6.40×10^{6} m.

(i) Show that the radius of a geo-synchronous orbit must be 4.23×10^{7} m,

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(ii) Calculate the increase in potential energy of a satellite of 750 kg when it is raised from the Earth's surface into a geo-synchronous orbit.

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(6)

(c) Satellites in orbits nearer the Earth than geo-synchronous satellites may be used in the future to track road vehicles.

(i) State and explain **one** reason why geo-synchronous satellites would not be suitable for such a purpose.

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(ii) Give **two** points you would make in arguing for or against tracking road vehicles. Explain your answers.

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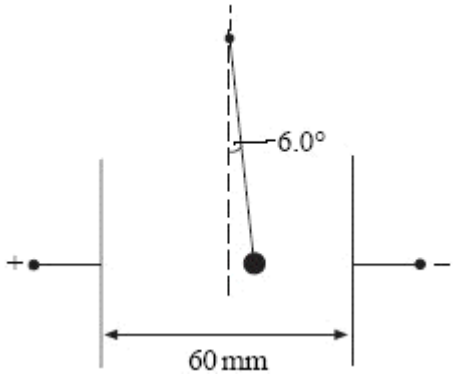
(4)
(Total 12 marks)

197. A small charged sphere of mass 2.1×10^{-4} kg, suspended from a thread of insulating material, was placed between two vertical parallel plates 60 mm apart. When a potential difference of 4200 V was applied to the plates, the sphere moved until the thread made an angle of 6.0º to the vertical, as shown in the diagram below.



(a) Show that the electrostatic force F on the sphere is given by $F = mg \tan 6.0^{\circ}$, where m is the mass of the sphere.

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(3)

(b) Calculate the charge on the sphere.

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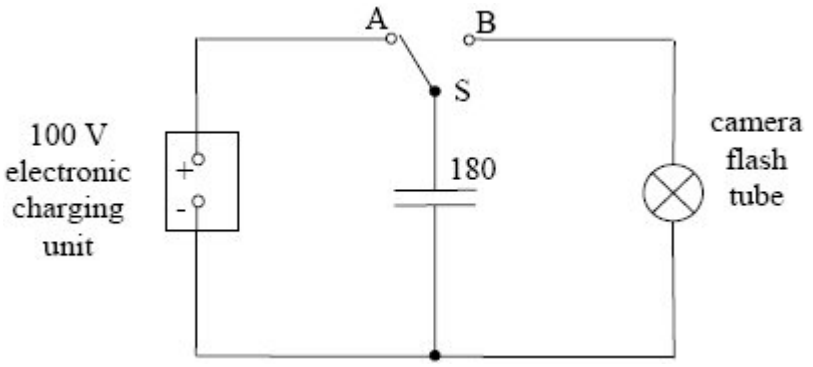
(3)
(Total 6 marks)

198. The flash tube in a camera produces a flash of light when a 180 μF capacitor is discharged across the tube.



(a) The capacitor is charged to a pd of 100 V from an electronic charging unit in the camera, as shown in the diagram above.
Calculate,

(i) the energy stored in the capacitor,

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(ii) the work done by the battery.

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(2)

(b) When a photograph is taken, switch S in the diagram above is automatically moved from A to B and the capacitor is discharged across the flash tube. The discharge circuit has a resistance of 1.5 Ω. Emission of light from the flash tube ceases when the pd falls below 30 V.

(i) Calculate the duration of the light flash.

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(ii) The capacitor in the circuit in the diagram above is replaced by a capacitor of greater capacitance. Discuss the effect of this change on the photograph image of a moving object.

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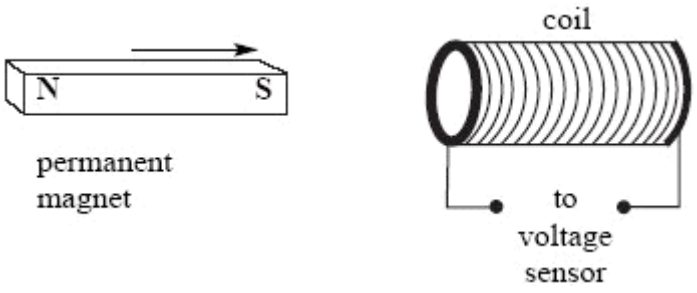
(4)
(Total 6 marks)

199. (a) In an experiment to illustrate electromagnetic induction, a permanent magnet is moved towards a coil, as shown in **Figure 1**, causing an emf to be induced across the coil.

Figure 1



Using Faraday's law, explain why a larger emf would be induced in this experiment if a stronger magnet were moved at the same speed.

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(3)

(b) A conductor of length l is moved at constant speed v so that is passes perpendicularly through a uniform magnetic field of flux density B, as shown in **Figure 2**.

Figure 2

Show that the induced emf, $\in$, across the ends of the conductor is given by

$$\in = Blv.$$

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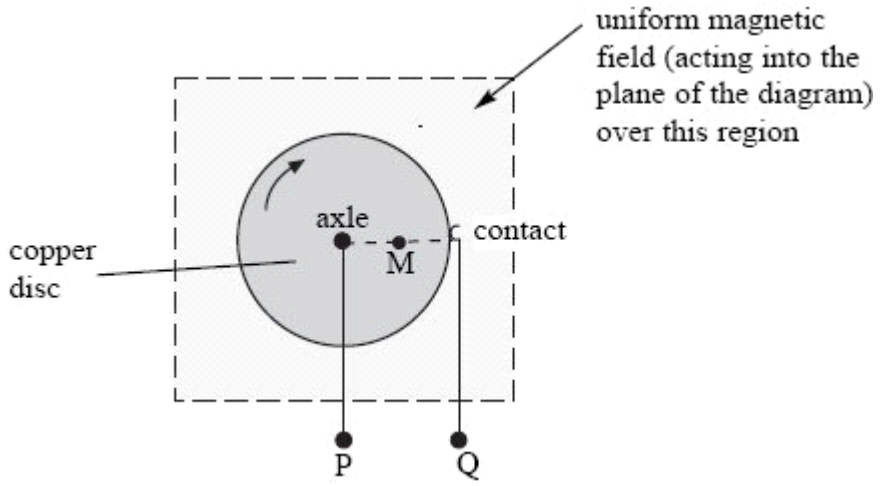
(3)

(c) A simple electrical generator can be made from a copper disc, which is rotated at right angles to a magnetic field, directed into the plane of the diagram (**Figure 3**). An emf is developed across the terminals P (connected to the axle) and Q (connected to a contact on the edge of the disc).

Figure 3



The radius of the disc is 64 mm and it is rotated at 16 revolutions per second in a uniform magnetic field of flux density 28 mT.

(i) Calculate the angular speed of the disc.

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(ii) Calculate the linear speed of mid-point M of a radius of the disc.

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(iii) Hence, or otherwise, calculate the emf induced across the terminals P and Q.

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(5)
(Total 11 marks)