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1. (a) State **in words** the formula which gives the electric force between two charged particles.

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(2)

- (b) What are the base units of the constant in this formula?

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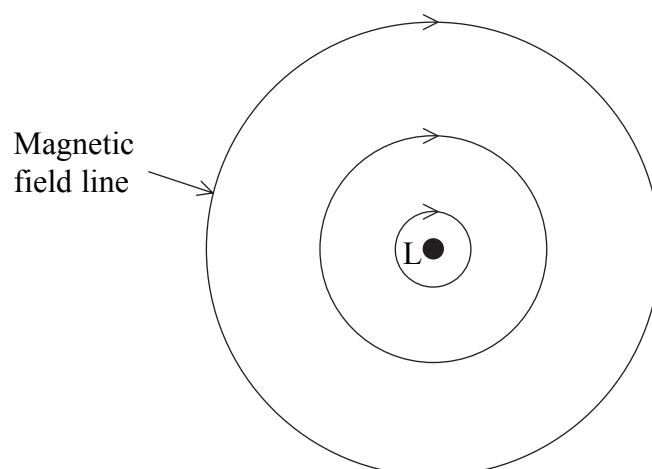
(3)

Q1

(Total 5 marks)



2. The diagram below shows the magnetic field due to a current in a long straight wire L, in a plane perpendicular to the wire.



- (a) (i) State the direction of the current in L.

..... (1)

- (ii) What feature of the magnetic field shown in the diagram indicates that there are no other magnetic fields close to the wire?

..... (1)

- (b) A second wire carrying a current of the same size is placed parallel and near to L. The magnetic field along a line joining the wires is investigated and it is found that at a certain distance from L, no magnetic field can be detected. Explain this observation.

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 (3)

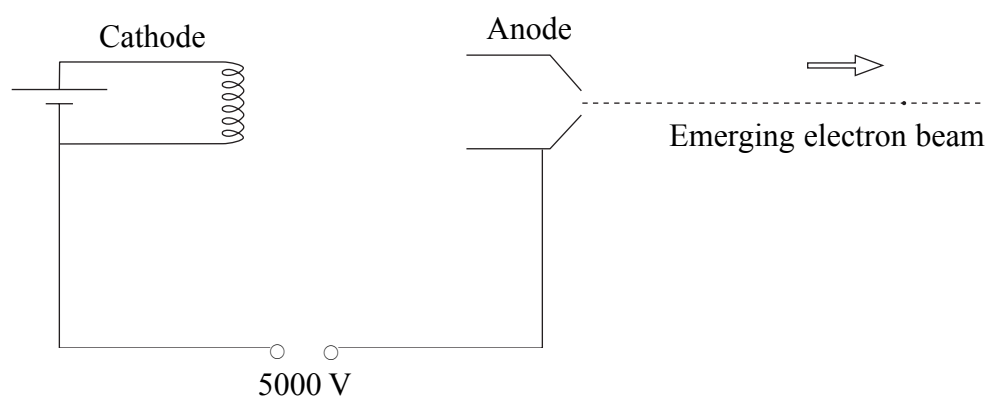
(Total 5 marks)

Q2



3. Electrons are accelerated from rest from the cathode to the anode of a vacuum tube through a potential difference of 5000 V.

Figure 1



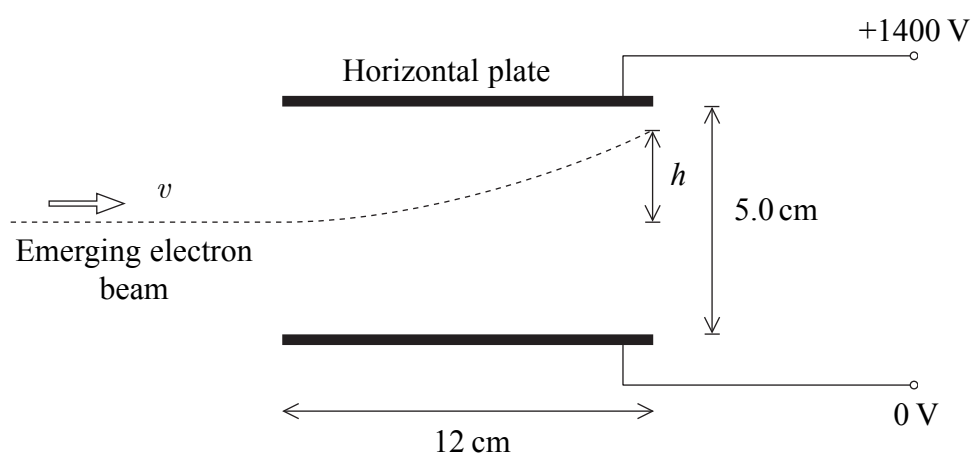
- (a) Show that the speed v of an electron as it leaves the anode is approximately $4 \times 10^7 \text{ m s}^{-1}$.

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 (3)

- (b) The emerging beam of electrons follows a parabolic path as it passes between a pair of horizontal parallel plates 5.0 cm apart with a potential difference of 1400 V between them.

Figure 2



- (i) Calculate the strength E of the uniform electric field between the horizontal plates.

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 $E =$
 (1)



(ii) Hence determine the force F exerted by this field on each electron.

.....
.....

$$F = \text{.....} \quad \textbf{(1)}$$

(c) An electron experiences an upward acceleration a as it travels between the plates. Its vertical displacement h after a time t is given by

$$h = \frac{1}{2} at^2$$

Calculate the value of h as the electron leaves the plates.

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$$h = \text{.....} \quad \textbf{(4)}$$

(d) (i) Add to Figure 2 the path that the electron beam would follow if the potential difference between the horizontal plates were decreased. Label this path A. **(1)**

(ii) Add to Figure 2 the path that the electron beam would follow if the potential difference between the cathode and the anode were decreased. Label this path B. **(1)**

(Total 11 marks)

Q3

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4. (a) State Newton's law for the gravitational force between two point masses.

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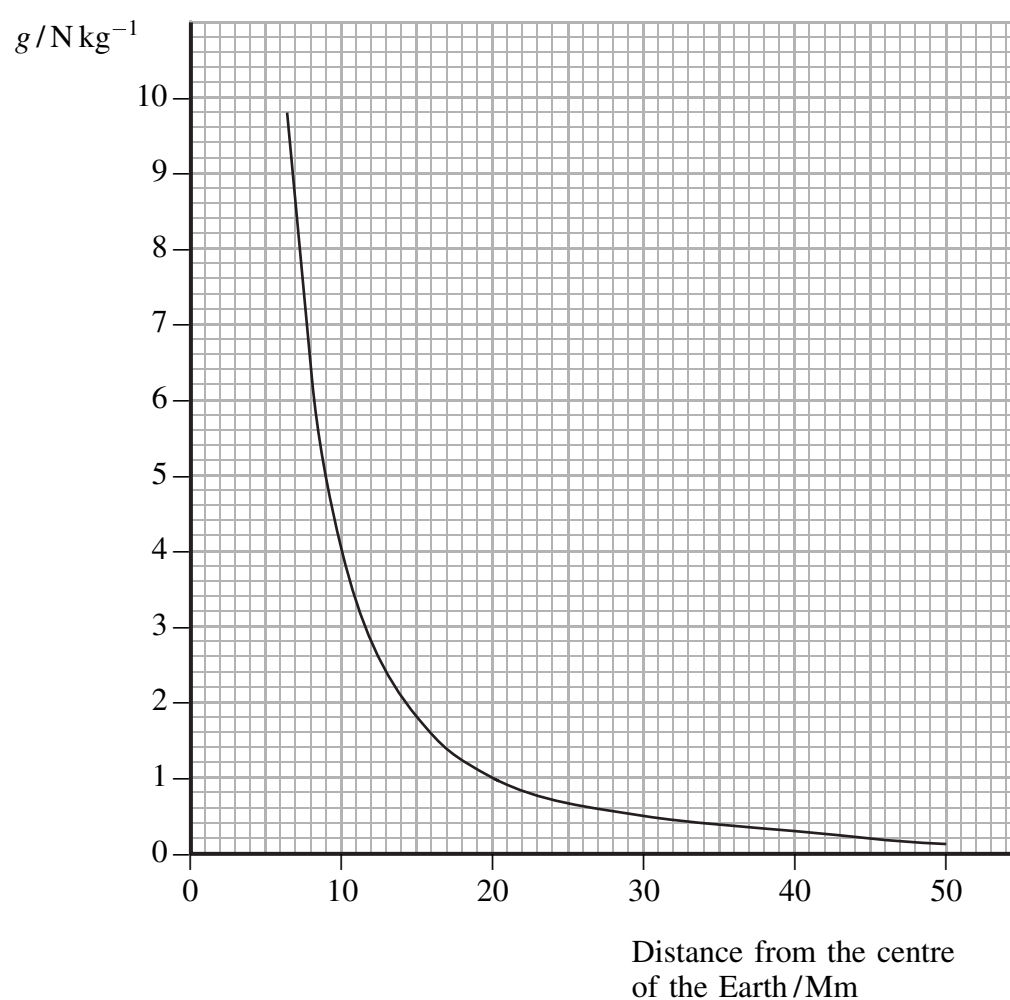
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(2)

- (b) The graph shows how the gravitational field strength g above the Earth's surface varies with the distance from its centre.



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- (i) Use the graph to demonstrate that the relationship between g and distance from the centre of the Earth obeys an inverse square law.

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(3)

- (ii) The average distance between the centre of the Moon and the centre of the Earth is 380 Mm. Use information from the graph to determine the Earth's gravitational field strength at this distance.

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Gravitational field strength =

(2)

- (c) What effect, if any, does the Earth's gravitational field have on the Moon?

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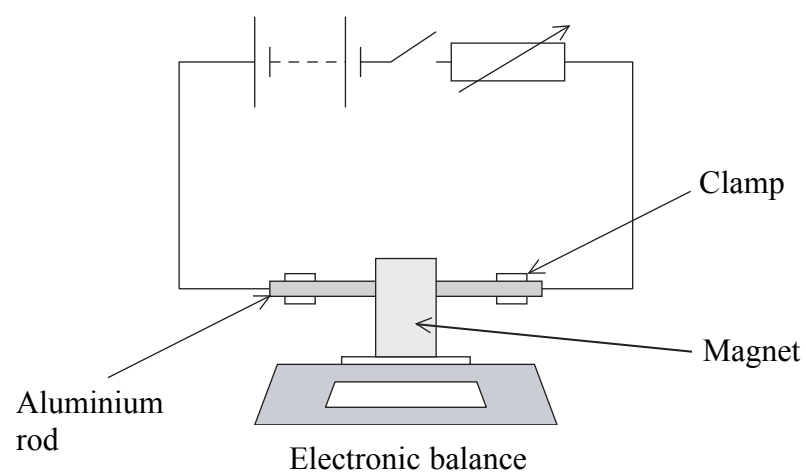
(1)

Q4

(Total 8 marks)



5. A U-shaped permanent magnet of mass 85.0 g rests on an electronic balance as shown in the diagram. An aluminium rod connected in a circuit is supported between the opposite poles of the magnet so that it is unable to move.



The switch is closed. The reading on the balance increases to 85.4 g.

- (a) (i) Calculate the additional force on the magnet when there is current in the circuit.

.....

Force =
(1)

- (ii) Explain how this additional force originates. You may be awarded a mark for the clarity of your answer.

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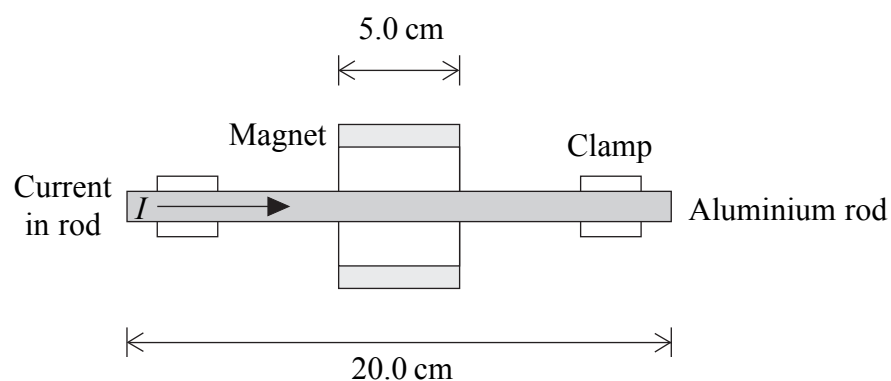
(4)



(b) The diagram below shows a plan view of the rod and the poles of the magnet.

- (i) On the diagram **label the poles of the magnet** to indicate the direction of field needed to produce a downward force on the magnet.

VIEW AS SEEN FROM ABOVE



(1)

- (ii) The rod is 20.0 cm long and the magnet is 5.0 cm wide. The magnetic flux density of the magnet is 30.0 mT. Calculate the current in the rod.

.....

Current =
 (3)

- (iii) The direction of the current is reversed. What would be the new reading on the balance?

.....

Balance reading =
 (2)

Q5

(Total 11 marks)

TOTAL FOR PAPER: 40 MARKS

END



List of data, formulae and relationships

Data

Speed of light in vacuum	$c = 3.00 \times 10^8 \text{ m s}^{-1}$	
Gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$	
Acceleration of free fall	$g = 9.81 \text{ m s}^{-2}$	(close to the Earth)
Gravitational field strength	$g = 9.81 \text{ N kg}^{-1}$	(close to the Earth)
Elementary (proton) charge	$e = 1.60 \times 10^{-19} \text{ C}$	
Electronic mass	$m_e = 9.11 \times 10^{-31} \text{ kg}$	
Electronvolt	$1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$	
Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$	
Unified atomic mass unit	$u = 1.66 \times 10^{-27} \text{ kg}$	
Molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$	
Permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$	
Coulomb Law constant	$k = 1/4\pi\epsilon_0$ $= 8.99 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$	
Permeability of free space	$\mu_0 = 4\pi \times 10^{-7} \text{ N A}^{-2}$	

Rectilinear motion

For uniformly accelerated motion:

$$v = u + at$$

$$x = ut + \frac{1}{2}at^2$$

$$v^2 = u^2 + 2ax$$

Forces and moments

Moment of F about O = $F \times$ (Perpendicular distance from F to O)

Sum of clockwise moments about any point in a plane = Sum of anticlockwise moments about that point

Dynamics

Force $F = m \frac{\Delta v}{\Delta t} = \frac{\Delta p}{\Delta t}$

Impulse $F\Delta t = \Delta p$

Mechanical energy

Power $P = Fv$

Radioactive decay and the nuclear atom

Activity $A = \lambda N$ (Decay constant λ)

Half-life $\lambda t_{\frac{1}{2}} = 0.69$



Electrical current and potential difference

Electric current	$I = nAQv$
Electric power	$P = I^2R$

Electrical circuits

Terminal potential difference	$V = \mathcal{E} - Ir$	(E.m.f. \mathcal{E} ; Internal resistance r)
Circuit e.m.f.	$\Sigma \mathcal{E} = \Sigma IR$	
Resistors in series	$R = R_1 + R_2 + R_3$	
Resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$	

Heating matter

Change of state:	energy transfer = $l\Delta m$	(Specific latent heat or specific enthalpy change l)
Heating and cooling:	energy transfer = $mc\Delta T$	(Specific heat capacity c ; Temperature change ΔT)
Celsius temperature	$\theta/^{\circ}\text{C} = T/\text{K} - 273$	

Kinetic theory of matter

Temperature and energy	$T \propto$ Average kinetic energy of molecules
Kinetic theory	$p = \frac{1}{3} \rho \langle c^2 \rangle$

Conservation of energy

Change of internal energy	$\Delta U = \Delta Q + \Delta W$	(Energy transferred thermally ΔQ ; Work done on body ΔW)
Efficiency of energy transfer	$= \frac{\text{Useful output}}{\text{Input}}$	
Heat engine	maximum efficiency = $\frac{T_1 - T_2}{T_1}$	

Circular motion and oscillations

Angular speed	$\omega = \frac{\Delta \theta}{\Delta t} = \frac{v}{r}$	(Radius of circular path r)
Centripetal acceleration	$a = \frac{v^2}{r}$	
Period	$T = \frac{1}{f} = \frac{2\pi}{\omega}$	(Frequency f)
Simple harmonic motion:	displacement $x = x_0 \cos 2\pi ft$	
	maximum speed = $2\pi f x_0$	
	acceleration $a = -(2\pi f)^2 x$	
For a simple pendulum	$T = 2\pi \sqrt{\frac{l}{g}}$	



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Waves

Intensity $I = \frac{P}{4\pi r^2}$ (Distance from point source r ; Power of source P)

Superposition of waves

Two slit interference $\lambda = \frac{xS}{D}$ (Wavelength λ ; Slit separation s ; Fringe width x ; Slits to screen distance D)

Quantum phenomena

Photon model $E = hf$ (Planck constant h)

Maximum energy of photoelectrons $= hf - \phi$ (Work function ϕ)

Energy levels $hf = E_1 - E_2$

de Broglie wavelength $\lambda = \frac{h}{p}$

Observing the Universe

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

Hubble law $v = Hd$ (Hubble constant H)

Gravitational fields

Gravitational field strength $g = F / m$

for radial field $g = Gm/r^2$, numerically (Gravitational constant G)

Electric fields

Electrical field strength $E = F / Q$

for radial field $E = kQ / r^2$ (Coulomb law constant k)

for uniform field $E = V/d$

For an electron in a vacuum tube $e\Delta V = \Delta(\frac{1}{2}m_e v^2)$

Capacitance

Energy stored $W = \frac{1}{2}CV^2$

Capacitors in parallel $C = C_1 + C_2 + C_3$

Capacitors in series $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

Time constant for capacitor to charge or discharge $= RC$



Magnetic fields

Force on a wire	$F = BIl$	
Magnetic flux density (Magnetic field strength)		
in a long solenoid	$B = \mu_0 nI$	(Permeability of free space μ_0)
near a long wire	$B = \mu_0 I / 2\pi r$	
Magnetic flux	$\Phi = BA$	
E.m.f. induced in a coil	$\mathcal{E} = -\frac{N\Delta\Phi}{\Delta t}$	(Number of turns N)

Accelerators

Mass-energy	$\Delta E = c^2 \Delta m$
Force on a moving charge	$F = BQv$

Analogies in physics

Capacitor discharge	$Q = Q_0 e^{-t/RC}$
	$\frac{t_{\frac{1}{2}}}{RC} = \ln 2$
Radioactive decay	$N = N_0 e^{-\lambda t}$
	$\lambda t_{\frac{1}{2}} = \ln 2$

Experimental physics

$$\text{Percentage uncertainty} = \frac{\text{Estimated uncertainty} \times 100\%}{\text{Average value}}$$

Mathematics

	$\sin(90^\circ - \theta) = \cos \theta$	
	$\ln(x^n) = n \ln x$	
	$\ln(e^{kx}) = kx$	
Equation of a straight line	$y = mx + c$	
Surface area	cylinder = $2\pi r h + 2\pi r^2$	
	sphere = $4\pi r^2$	
Volume	cylinder = $\pi r^2 h$	
	sphere = $\frac{4}{3}\pi r^3$	
For small angles:	$\sin \theta \approx \tan \theta \approx \theta$	(in radians)
	$\cos \theta \approx 1$	



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