SOLUTONS

JUNE 2001

1.Heat lost by calorimeter and water= heat absorbed by ice to change state plus heat used in warming the melted ice

i.e $m_c c_c(\theta_R - \theta) + m_w c_w(\theta_R - \theta) = m_i l_f + m_i c_w(\theta - 273)$, with $\theta = 282.7K$

Simplifying the above expression gives

$$\theta_R = \frac{m_i l_f + m_i c_w(\theta - 273)}{m_c c_c + m_w c_w} + \theta \Rightarrow \theta_R = \frac{0.05(3.25 \times 10^5) + (0.05)(4200)(282.7 - 273)}{0.1(380) + 0.3(4200)} + 282.7$$

$\Rightarrow \theta_R = 14.088 + 282.7 = 296.8K$

2. This question has a problem with the formulation. Now the question says "the source S supplies 300 W to the resistors R_1, R_2 and 100 Ω respectively". This means the total power supply of the cell is 900 W

total current supply from the cell= $1.5A + 1.5\ A = 3.0\ A$

(i) $P = IV \Longrightarrow V = \frac{900}{3} = 300V$. This is the emf of the cell. Since S, R_1, 100Ω and R_2 are in parallel,

$V_{R1} = V_{R2} = V_{100\Omega} = 300V$

(ii) $R_2 = \frac{V_{R2}}{I_{R2}} = \frac{300}{1.5} = 200\Omega$

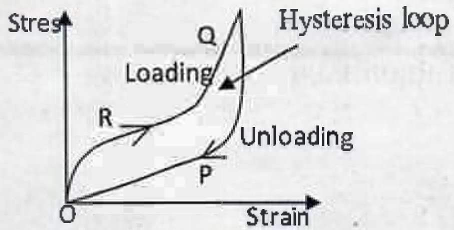
3.The solution of this problem is beyond the scope of advanced level physics

4.(a) From the lens equation $\frac{1}{f} = \frac{1}{v} + \frac{1}{u} \Rightarrow \frac{v}{f} = 1 + \frac{v}{u} \Rightarrow \frac{v}{f} = 1 + m \Rightarrow m = \frac{v}{f} - 1$, so a graph of m against v gives slope $\frac{1}{f}$. From the graph, slope $= \frac{2.5}{13} = 0.19\text{cm}^{-1} \Rightarrow f = \frac{1}{0.19} = 5.3\text{cm}$

(b) Advantages of optical fibres over copper wires

- optical fibres have a larger bandwidth ie is they have a large information carrying capacity
- Transmission security is more enhanced since it is impossible to tap information from the fibre without breaking it.
- The glass of which the optical fibres are made is considerably cheaper than copper cables.
- Optical fibres are free from electrical interference
- Fewer amplifiers are required
- There is little or no risk (electrical accidents) with optical fibre since they do not carry electricity.

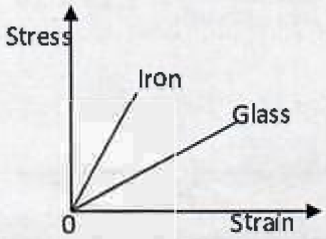
5.(a)



During loading, energy is supplied to the wire and released during unloading. The area under ORQ represents the work done per unit volume during the loading process. The area under the curve OPQ represents the energy per unit volume released during the unloading process. The area of the loop OPQRO represents the energy lost in the form of heat during the loading and unloading process.

(b) This is because the car tyre should not get hot faster when the car is in motion and get exploded. The small area of hysteresis means that less mechanical energy is converted to heat energy and as such fuel consumption is also minimized.

(c)



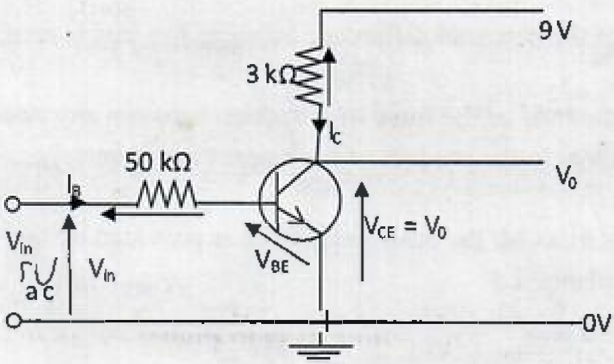
6. $Q = AC(1 - e^{\frac{-t}{BC}})$

Units of AC = units of Q $\Rightarrow$ units of A = $\frac{\text{units of Q}}{\text{units of C}}$

$$\Rightarrow \text{units of A} = \frac{\text{units of V} \times \text{units of C}}{\text{units of C}} = \text{units of V} = \text{volt}$$

$$\text{units of BC} = \text{units of t} \Rightarrow \text{units of B} = \frac{\text{units of t}}{\text{units of C}} = \frac{\text{units of Q/units of I}}{\text{units of Q /units of V}} = \frac{\text{units of V}}{\text{units of I}} = \text{ohm}$$

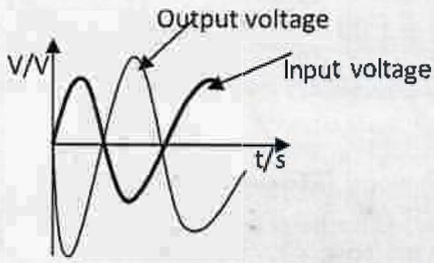
7.



(i) Applying Kirchhoff's voltage law, $V_{in} - I_B R_B - V_{Be} = 0 \Rightarrow I_B = \frac{V_{in} - V_{Be}}{R_B}$, assuming the transistor is a made from silicon, $V_{Be} = 0.6\ V \Rightarrow I_B = \frac{2.0 - 0.6}{50 \times 10^3} \Rightarrow I_B = 2.8 \times 10^{-5} A$

(ii) $\beta = \frac{I_c}{I_B} \Rightarrow I_C = \beta I_B = 60 \times 2.8 \times 10^{-5} = 1.68 \times 10^{-3} A$

(iii) Applying Kirchhoff's voltage law, $V_{CE} = V_{cc} - I_C R_L = 9 - (0.00168 \times 3000) = 3.96V$



Since the transistor is a current amplifier, the amplitude of the output is greater the input. Also, the transistor is an inverter so the input and output are 180^0 out of phase.

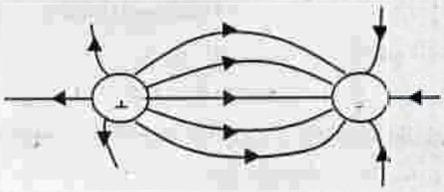
8. (a) (i) Coulomb's law states that the magnitude of the force between two electrically charged bodies is directly proportional to the product of the charges and inversely proportional to the square of their separation.

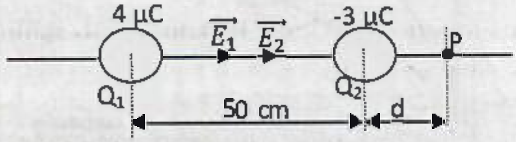
(ii) By coulomb's law, $F = \frac{Q^2}{4\pi\varepsilon r^2} = \frac{1}{r^2}\cdot\frac{Q^2}{4\pi\varepsilon}$, since the charges are of the same magnitudes. From the equation, a graph of F against $\frac{1}{r^2}$ gives a straight line with slope$=\frac{Q^2}{4\pi\varepsilon} \Longrightarrow \varepsilon = \frac{Q^2}{4\pi \times slope}$

From the graph, slope$= \frac{4-0}{(3.0-0)\,10^{-5}} = 1.333 \times 10^5 Nm^2 \Longrightarrow \varepsilon = \frac{(4.4\times10^{-3})^2}{4\pi\times1.33\times10^5} = 1.15 \times 10^{-11} Fm^{-1}$

(iii) Dielectric constant, $\varepsilon_r = \frac{\varepsilon}{\varepsilon_0} = \frac{1.33\times10^{-11}}{8.85\times10^{-12}} = 1.5$

(b)(i)





(ii) Between the two charges, the fields created by both charges are in the same direction. Hence there is no point between the two charges that the resultant field can be zero. Since $Q_1>Q_2$, the resultant field can only be zero to the right of Q_2, say at the point P, a distance d from Q_2.

At the point P, $\overrightarrow{E_1} + \overrightarrow{E_2} = \vec{0} \Longrightarrow E_1 = E_2 \Longrightarrow \frac{Q_1}{4\pi\varepsilon(0.5+d)^2} = \frac{Q_2}{4\pi\varepsilon d^2} \Longrightarrow d = \frac{0.5\sqrt{\frac{Q_2}{Q_1}}}{1-\sqrt{\frac{Q_2}{Q_1}}} \Longrightarrow d = \frac{0.5\sqrt{\frac{4}{3}}}{1-\sqrt{\frac{4}{3}}}$

$\Longrightarrow d = 0.32$ m

(c) The bird is on an equipotential surface. Hence the potential difference between the legs is zero, no current flows and the bird remain unelectricuted.

(d) (i) Newton's law of gravitation states the magnitude of the force of attraction between any two particles in the universe is directly proportional to the product of the masses and inversely proportional to the square of their separation.

(ii) For a planet of mass m, circling the sun with mass M, the centripetal force is provided by the gravitational attraction between the sun and the planet. i.e

Centripetal force = gravitational attraction $\frac{GMm}{r^2} = m\omega^2 r \Rightarrow \frac{GM}{\omega^2} = r^3$, but $\omega = \frac{2\pi}{T} \Rightarrow r^3 = \frac{GM}{\left(\frac{2\pi}{T}\right)^2}$

$\Rightarrow r^3 = \frac{GM}{4\pi^2} T^2$ as required to demonstrate

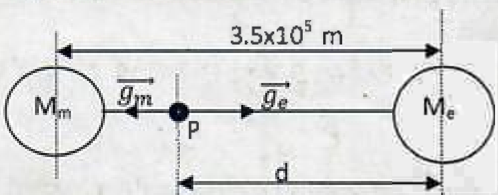
(iii) From the above relation, $T = \sqrt{\frac{4\pi^2 r^3}{GM}} \Rightarrow T = \sqrt{\frac{4\pi^2(3.5\times10^8)^3}{1.67\times10^{-11}\times6.0\times10^{24}}} \Rightarrow T = 2.1 \times 10^6 s$

(e) From $r^3 = \frac{GM}{4\pi^2}T^2 \Rightarrow T^2 = \frac{4\pi^2}{GM} r^3$. This implies that a graph of T^2 against r^3 is a straight line passing through the origin with slope$\frac{4\pi^2}{GM}$

From the graph, slope$= \frac{(1.2-0.2)10^{12}}{(1.4-0.1)10^{27}} = 1.692 \times 10^{-16} \Longrightarrow \frac{4\pi^2}{GM} = 1.692 \times 10^{-16} \Longrightarrow G = \frac{4\pi^2}{1.692\times10^{-16} M}$

$\Longrightarrow G = \frac{4\pi^2}{1.692\times10^{-16}\times7.0\times10^{26}} = 7.33 \times 10^{-11} kg^{-1}s^{-2}m^3$

(f)



Let the gravitational field strength be zero at P, then $\overrightarrow{g_e} + \overrightarrow{g_m} = \vec{0}$ at the point P i.e $g_m = g_e$

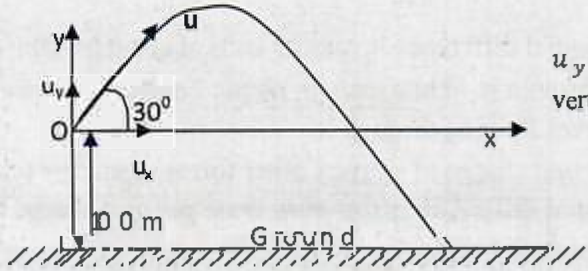
$\Longrightarrow \frac{GM_m}{(3.5\times10^5 - d)^2} = \frac{GM_e}{d^2}$

Solving the above equation gives d= 3.1×10^5 m

9.(a) (i) When the ball is thrown, the vertical component of the velocity decreases to zero at the top of the motion and thereafter it increases until the ball strikes the ground. Since there is no acceleration in the horizontal direction, the horizontal component of the velocity stays constant throughout the motion.

(ii) Air resistance will reduce the maximum horizontal range of the ball, since air resistance opposes motion.

(b) (i)



$u_y = u\sin\theta, u_x = u\cos\theta$, $\theta = 30^0$, u=300 ms^{-1}. The vertical displacement of the bullet is given by

$$y = ut\sin\theta - \frac{1}{2}gt^2$$

When the ball strikes the ground, y = -100 m

$$\Rightarrow -100 = 300t\sin30^o - \frac{1}{2}gt^2 \Rightarrow -100 = 150 - 4.9t^2 \Rightarrow 4.9t^2 - 150t - 100 = 0$$

Solving the above equation gives t =-0.65 s or t=31.3 s. Since time is never negative, we take t=31.3 s and discard t = -0.65s.

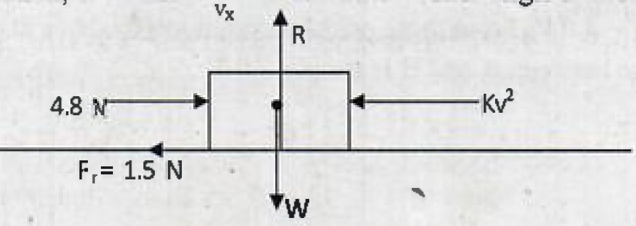
Distance of bullet from the cliff, $x = u_x t \Rightarrow x = (300\cos30^o)(31.3) \Rightarrow x = 8132$ m

(ii) $v_x = u\cos\theta \Rightarrow v_x = 300\cos30 \Rightarrow v_x = 259.8$ ms^{-1}, $v_y = u\sin\theta - gt$

$$\Rightarrow v_y = 300\sin30 - 9.8 \times 31.3 \Rightarrow v_y = -156.74 \text{ ms}^{-1} \Rightarrow v = \sqrt{v_y^2 + v_x^2} \Rightarrow v = 300 \text{ m}^{-1}$$

Direction, $\alpha = \tan^{-1}\frac{v_y}{v_x} \Rightarrow \alpha = 31.1^0$. This angle is below the horizontal

(c) (i)



(ii) By Newton's second law, $4.8 - 1.5 - Kv^2 = 0 \Rightarrow v = \sqrt{\frac{3.3}{6.0\times10^{-2}}} \Rightarrow v = 7.4$ ms^{-1}

(d) (i) The zeroth law of thermodynamics states that if bodies X and Y are separately in thermal equilibrium with body Z then X and Y are in thermal equilibrium with each other.

(ii) Temperature tells us in which way heat will flow if two bodies are brought in contact with each other.

(e) (i) Primary sources of energy are those which used in form in which the occur naturally e.g wood, coal, etc

(ii) These are sources of energy which are obtained by converting other forms of energy into the required form.

(f) (i)$P = \frac{GPE}{time} = \frac{mg(\frac{h}{2})}{time} = \frac{\frac{1}{2}\rho Vh}{t} = \frac{\frac{1}{2}\rho Ah^2}{t} = \frac{\frac{1}{2}\times1100\times4.0\times10^7\times10^2}{12\times3600} = 5.0\times 10^{12}$ W

(ii) The variation of water level with seasons will lead to fluctuations in the output. Also, the cost of trapping water is very high.

10. (a) Consult your notebooks

(b) (i) Radioisotopes are radioactive isotopes produced as a result of bombardment of nuclei with fast moving particles such as alpha particles, neutron, beta particles etc.

The half life is the time taken for half the number particles present in a given sample to decay.

(ii) $N = N_0e^{-\lambda t} = N_0e^{-\frac{\ln 2}{T_{1/2}}t} = 8.0\ mg e^{-\frac{\ln 2\times 12}{30}} = 6.1\ mg$

(c) (i) mass defect, $\Delta m = (3.345 + 5.008) \times 10^{-27} - (6.647 + 1.675) \times 10^{-27} = 0.031 \times 10^{-27}$

Energy released, $\Delta E = \Delta mc^2 = 0.031 \times 10^{-27} \times (3.0 \times 10^8)^2 = 2.79 \times 10^{-12}J$

(ii) Number of moles of 1 kg of deuterium, $n = \frac{1}{0.002} = 500$

Number of atoms $= 500 \times 6.02 \times 10^{23} = 3.01 \times 10^{26}$

Thus the energy released per kilogram $= 3.01 \times 10^{26} \times 2.79 \times 10^{-12}J = 8.40 \times 10^{14}J$

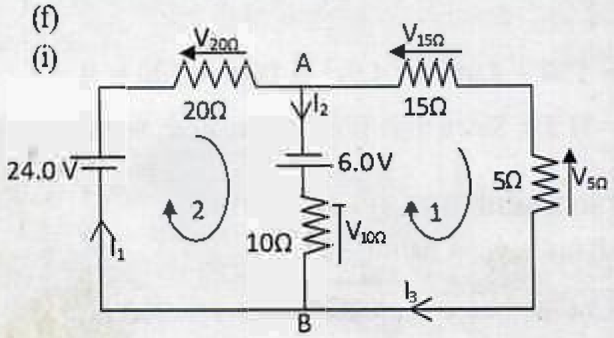
(d) Consult your notebooks

(e) (i) An ohmic conductor is one whose potential difference across its ends at constant temperature is directly proportional to the current flowing through it. While a non – ohmic conductor is one whose p.d across its does not vary linearly with the current flowing through it.

(ii) Electromotive force is the work done per unit charge to convertother forms of energy (chemical or mechanical) to electrical energy, while potential difference is the work done per unit charge to convert electrical energy into other forms of energy such as heat.

(f)

(i)



(i) KCL: $I_1 = I_2 + I_3$ ------------- (1)

KVL loop 1: $10I_2 - 6 - 15I_3 - 5I_3 = 0$

$\Rightarrow 10I_2 - 20I_3 = 6 \Rightarrow 5I_2 - 10I_3 = 3$ -----(2)

KVL loop 2: $6 - 10I_2 + 24 - 20I_1 = 0$

$\Rightarrow 2I_1 + I_2 = 3$ -------------------(1)

Solving the above equations,

$I_1 = 1.05\ A,\ I_2 = 0.9\ A,\ I_3 = 0.15A$

(ii) $V_{AB} = 6.0 - 10I_2 = 6.0 - 10(0.9) = -3.0\ V$. From these calculations, it implies A is at a higher potential than B i.e the potential difference between A and B is simply 3.0 V