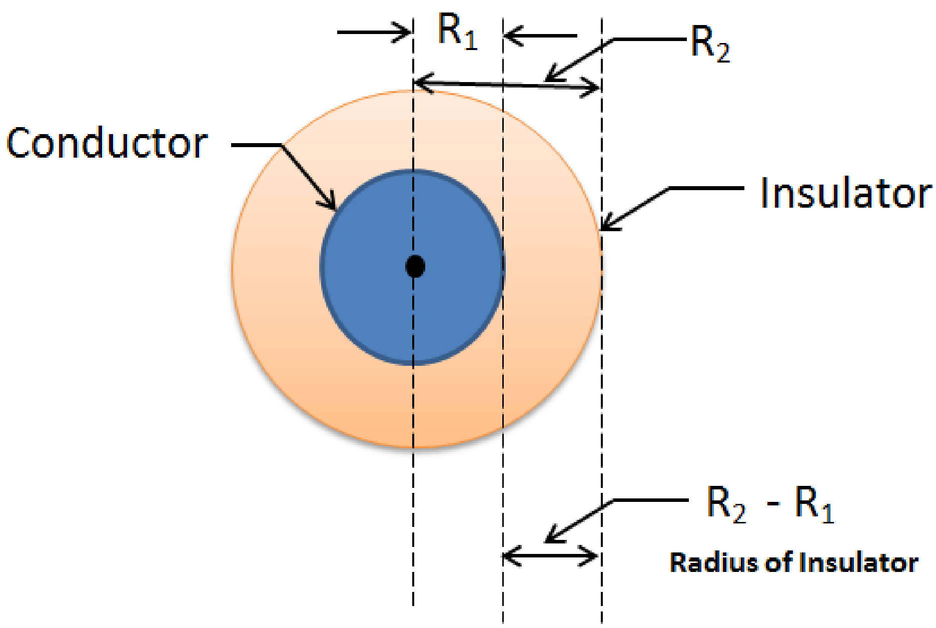
Model Question and Answer
Fundamentals of Electrical Engineering (2022 course)

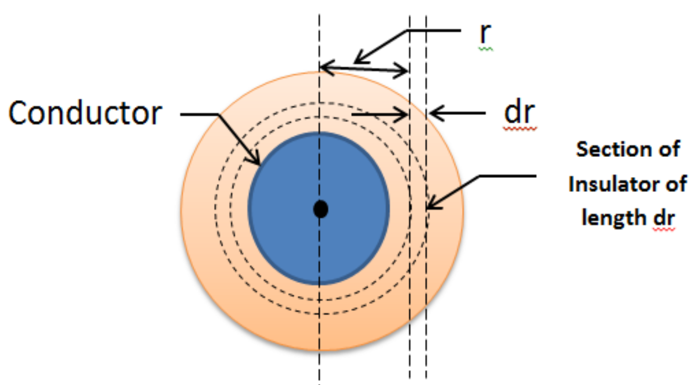
Unit 01: Work Power Energy and Batteries

Q1:	Derive the expression for insulation resistance of a cable	(6)

Ans

The level or degree of ***insulation resistance of a cable*** depends on the purpose for which the cable was designed for. Apart from saving energy from being lost or dissipated to the surrounding, one paramount reason **why cables are insulated** is to save us from the danger of being electrocuted.





Length = dr and cross sectional area = $2\pi rl$

$$\therefore\ dR_i = \rho \times \frac{length\ of\ path\ followed\ by\ leakage\ current}{Area}$$

$$\therefore\ dR_i = \rho \times \frac{dr}{2\pi r l}$$

Where $l = length\ of\ the\ cable$

The total insulation resistance R_{ins} can be obtained by integrating "dR_i" over the entire radius of the insulating material i.e. from R_1 to R_2

$$\therefore \boldsymbol{R_i = \int_{R_1}^{R_2} dR_i = \int_{R_1}^{R_2} \frac{\rho dr}{2\pi r l} = \frac{\rho}{2\pi l} \int_{R_1}^{R_2} \frac{dr}{r} = \frac{\rho}{2\pi l} [log_e r]_{R_1}^{R_2}}$$

$$\boldsymbol{R_i = \frac{\rho}{2\pi l} [log_e R_2 - log_e R_1]}$$

$$\boldsymbol{R_i = \frac{\rho}{2\pi l} log_e [R_2/R_1]\ \Omega}$$

i.e.

$$\boldsymbol{R_{ins} = \frac{\rho}{2\pi l} [log_e \frac{r_2}{r_1}]}$$

Where,

$\boldsymbol{R_2 = Radius\ of\ the\ cable\ including\ the\ Conductor\ \&\ Insulator}$

$\boldsymbol{R_1 = Radius\ of\ the\ conductor}$

Q2:	What are the factors affecting the resistance of the conductor?	(4)

Ans

The mathematical expression for resistance is,

$$\boldsymbol{R = \frac{\rho l}{a}}$$

1. The **temperature** of the conductor.
   As temperature increases resistance of conductor increase.
2. The cross-sectional area of the conductor.
   As cross sectional area increases resistance decrease
3. Length of the conductor.
   As length will increase resistance increase
4. Nature of the material of the conductor.

Q3:	An immersion heater is used for heating 9 litres of water. It's resistance is 50 ohm and efficiency of 83.6%. How much time is required to heat water from 20^0C to 70^0,C when connected to 250 V supply ? Specific capacity of water is 4180 J/kg-K	(6)

Ans	**Given :** $m = 9$ kg, $R = 50\ \Omega$, $\eta = 0.836$, $t_1 = 20°C$, $t_2 = 70°C$, $V = 250$ Volts, $S = 4180$ J/kg-K **To find :** Time. **Step 1 : Calculate heat energy (H) :** $H = m \times S \times (\Delta T) = 9 \times 4180 \times (70 - 20) = 1881000$ J **Step 2 : Input energy (E_i) :** $E_i = H / \eta = \frac{1881000}{0.836} = 2250000$ J $E_i = P \times t = \frac{V^2}{R} \times t$ $\therefore\ t = \frac{E_i \times R}{V^2} = \frac{2250000 \times 50}{(250)^2} = 1800$ sec $= 0.5$ hours ...**Ans.**	
Qu 4:	A coil has resistance of 40 ohm at 25^0C. When its temperature is increased to 110^0C the resistance increases to 50 ohm. Calculate the temperature resistance of coil material at 1) 25^0C 2) 110^0C 3) 0^0C	
Ans.	**Given :** $R_{t_1} = 40\ \Omega$, $t_1 = 25°C$, $R_{t_2} = 50\ \Omega$, $t_2 = 110°C$ **To find :** 1. $\alpha_{25°}$ 2. $\alpha_{110°}$ 3. $\alpha_{0°}$ **Step 1 : RTC at 25°C :** $R_{t_2} = R_{t_1}\ [1 + \alpha_{t_1}\ (t_2 - t_1)]$ $50 = 40\ [1 + \alpha_{t_1}\ (110 - 25)]$ $\frac{50}{40} - 1 = \alpha_{t_1}\ (85)$	

	$\alpha_{25} = 2.94 \times 10^{-3} /^{\circ}C$ ...**Ans.** **Step 2 : RTC at 110°C :** $\alpha_{t_2} = \frac{\alpha_{t_1}}{1+\alpha_{t_1}(t_2 - t_1)}$ $\alpha_{110} = \frac{\alpha_{25}}{1+\alpha_{25}(110-25)}$ $\alpha_{110} = \frac{2.94 \times 10^{-3}}{1+(2.94 \times 10^{-3}) \times 85} = 2.353 \times 10^{-3}$ ...**Ans.** **Step 3 : RTC at 0°C :** $\alpha_{25} = \frac{\alpha_0}{1+\alpha_0(25)}$ $2.94 \times 10^{-3} = \frac{\alpha_0}{1+\alpha_0(25)}$ $2.94 \times 10^{-3}(1+\alpha_0(25)) = \alpha_0$ $2.94 \times 10^{-3} + (0.0735)\alpha_0 = \alpha_0$ $2.94 \times 10^{-3} = \alpha_0(1-0.0735)$ $2.94 \times 10^{-3} = \alpha_0(0.9265)$ $\alpha_0 = 3.17 \times 10^{-3} /^{\circ}C$ ...**Ans.**	
Qu 5:	A bucket contains 15-Liters of water at 20^0C. A 2-KW immersion heater is used to raise the temperature of water to 95^0C. The overall efficiency of the process is 90% and the specific heat capacity of water is 4187 J/kg-K. Find the time required for the process.	
Ans.	**Given :** $m_w = 15$ kg., $T_1 = 20°C$, $T_2 = 95°C$, $P_i = 2$ kW, $\eta = 0.9$ Specific heat capacity of water $S_w = 4187$ J/kg K., t = ? **Step 1 : Calculate the heat energy :** The heat energy required to raise the temperature of 15 kg water is given by, $H = m_w \times S_w \times (T_2 - T_1) = 15 \times 4187 \times (95-20)$ ...(1) $\therefore H = 4710375$ J ...(2) **Step 2 : Calculate the input energy :** Energy at the input $E_i = H/\eta = 4710375/0.9 = 5233750$ J But 1 Joule = 1 Watt-sec. $\therefore$ Electrical energy at the input, E_i = 5233750 Watt-sec. **Step 3 : Calculate time :** Input energy E_i = Input power $P_i \times$ time t $\therefore t = \frac{E_i}{P_i} = \frac{5233750 \text{ W sec.}}{2 \times 10^3 \text{ W}} = 2616.875$ sec. = 2616.875 sec. or 43.61 min ...**Ans.**	
Qu 6:	A resistance of 0.025 ohm carries a current of 60 A for hours. Determine the velocity with which a mass of 2 tonnes must be move in order that its kinetic energy shall be equal in amount to that the energy dissipated in the resistance.	

Ans.	**Given :** $R = 0.025\ \Omega$, $I = 60$ A, $t = 2$ hour $= 2 \times 60 \times 60 = 7200$ sec. $m = 2$ tonnes $= 2000$ kg. **Step 1 : Calculate energy dissipated in the resistor :** $E = V \times I \times t = I^2Rt = (60)^2 \times 0.025 \times 7200 = 648000$ Joules **Step 2 : Calculate the velocity :** Kinetic energy $= \frac{1}{2}mv^2 = 648000$ $\therefore \frac{1}{2} \times 2000 \times v^2 = 648000, \quad \therefore v = 25.46$ m/sec.	
Qu.7:	The filament of 240 V of metal filament lamp is to be constructed from wire having a diameter of 0.03 mm and a resistivity of 4.3 μΩ-cm. If the RTC of the filament material is 0.005^0C at 20^0C, what length of the filament is necessary for the lamp to dissipate 60 W at a filament temperature of 2420^0C. Assume room temperature s 20^0C.	
Ans.	**Given :** $V = 240$ Volts $\quad d = 0.03$ mm. $\quad \therefore r = 0.015$ mm, $\quad \rho = 4.3\ \mu\Omega$-cm. $\alpha_{20} = 0.005\ /°C \quad P = 60$ W, $\quad T_2 = 2420°C \quad T_1 = 20°C$ **To find :** length of filament l. **Step 1 : Find hot filament current I_2 :** At $T_2 = 2420°C$, with the filament hot, $P = 60$ W and $V = 240$ volt. $\therefore$ hot filament current $I_2 = \frac{P}{V} = \frac{60}{240} = 0.25$ A. **Step 2 : Find hot filament resistance :** $R_{hot} = \frac{V}{I_2} = \frac{240}{0.25} = 960\Omega$ **Step 3 : Find the filament length l :** $R_{hot} = \rho \frac{l}{a} = \rho \frac{l}{\pi r^2}$ $\therefore l = R_{hot} \times \frac{\pi r^2}{\rho} = 960 \times \frac{\pi \times (0.015 \times 10^{-3})^2}{43 \times 10^{-6} \times 10^{-2}\ \Omega - m}$ $\therefore l = 1.578$ m **...Ans.**	
Qu. 8	What is trickle charging? Explain? Or Why Trickle charging is necessary?	(6)
Ans.	**Trickle charging** is necessary to keep the battery fully charged always • When a battery is kept as an emergency reserve, it is necessary to ensure that it is fully charged all the time and ready for the service at any time. • The charged battery always losses some of its charge due to internal leakage and other open circuit losses. • In order to compensate for such a loss of charge the battery is kept on trickle charging. • Trickle charging takes place at a very small charging rate i.e. charging current is very small. • Typically, the trickle charging current is less than 1% of the normal charging current of the battery.	

Qu. 9 An average water head of 200 m is available for a hydroelectric power station operating at an overall efficiency of 80%. Calculate the volume of water required to generate one unit of electricity **(6)**

Ans.

Given : $h = 200$ m, $\eta = 0.8$, Output energy $E_o = 1$ unit $= 1$ kWh.

To find : Volume of water.

Step 1 : Draw the illustrative diagram.

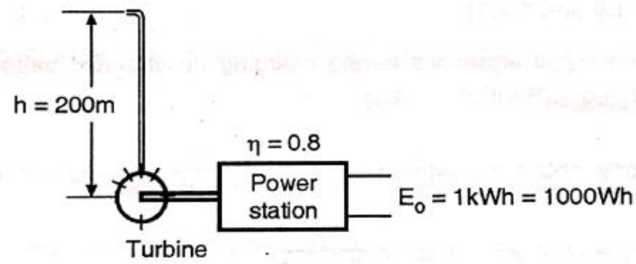


Fig. P. 1.26.9

Step 2 : Convert E_o into Joule i.e. W-sec.

Output energy $E_o = 1 \text{ unit} = 1 \text{ kWh} = 1000 \text{ Wh}$

$\therefore \quad E_o = 1000 \text{ W} \times 3600 \text{ sec} = 36 \times 10^5 \text{ W-sec.} = 36 \times 10^5 \text{ J}$

Step 3 : Calculate the volume of water.

$$\text{Input energy } E_i = \frac{E_o}{\eta} = \frac{36 \times 10^5}{0.8} = 45 \times 10^5 \text{ J}$$

$$\text{But } E_i = m \times g \times h$$

$$\therefore \quad 45 \times 10^5 = m \times 9.8 \times 200$$

$$\therefore \quad m = 2295.92 \text{ kg}$$

Assuming 1 kg = 1 litre we get,

Volume of water = 2295.92 litre

Qu. 10 Discuss the testing procedure for lead acid cell batteries **(4)**

Ans.

1. Remove the dirt and tighten the connection at the terminals.
2. Check the specific gravity and it to the adequate level by adding distilled water. The specific gravity should be between 1.18 to 1.28. If it found less than 1.18 then charging is essential.
3. Check the voltage per cell. It should not be less than 1.8 V or higher than 2.4 V. If it is less than 1.8 V then the battery needs charging and if it is greater than 2.4 V then battery is overcharged.
4. Make the physical inspection of the battery.