Q 5. Incandescent bulbs are designed by keeping in mind that the resistance of their filament increases with increase in temperature. If at room temperature, 100 W, 60 W and 40 W bulbs have filament resistances R_{100}, R_{60} and R_{40}, respectively, the relation between these resistances is (2010)

(A) $\frac{1}{R_{100}} = \frac{1}{R_{40}} + \frac{1}{R_{60}}$ (B) $R_{100} = R_{40} + R_{60}$

(C) $R_{100} > R_{60} > R_{40}$ (D) $\frac{1}{R_{100}} > \frac{1}{R_{60}} > \frac{1}{R_{40}}$

Sol. The power of a bulb having resistance R and operating at voltage V is given by $P = V^2/R$. Let the three bulbs operate at temperatures T_{100}, T_{60} and T_{40} above room temperature. The resistances and powers of three bulbs at operating temperatures are given by

$$R'_{100} = R_{100}(1 + \alpha T_{100}), \qquad V^2/R'_{100} = 100,$$
$$R'_{60} = R_{60}(1 + \alpha T_{60}), \qquad V^2/R'_{60} = 60,$$
$$R'_{40} = R_{40}(1 + \alpha T_{40}), \qquad V^2/R'_{40} = 40,$$

where α is the thermal coefficient of resistance. Eliminate R'_{100}, R'_{60}, and R'_{40} to get

$$\frac{1}{R_{100}} = \frac{100}{V^2}(1 + \alpha T_{100}),$$
$$\frac{1}{R_{60}} = \frac{60}{V^2}(1 + \alpha T_{60}),$$
$$\frac{1}{R_{40}} = \frac{40}{V^2}(1 + \alpha T_{40}).$$

We expect the higher power bulb to have a higher temperature i.e., $T_{100} > T_{60} > T_{40}$. This gives us, $\frac{1}{R_{100}} > \frac{1}{R_{60}} > \frac{1}{R_{40}}$ and $\frac{1}{R_{100}} \neq \frac{1}{R_{60}} + \frac{1}{R_{40}}$. We encourage you to measure the resistance of a bulb (by using a multimeter etc.) at room temperature, calculate resistance at operating temperature, and get some estimates of α and operating temperature.

Ans. D ⊡