CURRENT ELECTRICITY

ELECTRICAL ENERGY, POWER

ELECTRICAL POWER:

The energy liberated per second in a device is called its power, the electrical power P delivered by an electrical device is given by

$$P = \frac{dp}{dt}V = VI$$

Power consumed by a resistor

$$P = VI \quad = I^2R \quad = \frac{V^2}{R}\,watt$$

The power P is in watts when I is in amperes, R is in ohms and V is in volts. The practical unit of power is 1 kW = 1000 W
The formula for power

$$P = I^2R = VI = \frac{V^2}{R}$$

is true only when all the electrical power is dissipated as heat and not converted into mechanical work, etc. simultaneously.

If the current enters the higher potential point of the device, then electric power is consumed by it (i.e. acts as load). If the current enters the lower potential point, then the device supplies power (i.e. acts as source.)

(A) JOULE'S LAW OF ELECTRICAL HEATING:

When an electric current flows through a conductor electrical energy is used in overcoming the resistance of the wire. If the potential difference across a conductor of resistance R is V volt and if a current of I ampere flows the energy expanded in time t seconds is given by

$$W = VIt joule$$

$$= I^2Rt joule = \frac{V^2}{R}t$$

The electrical energy so expanded is converted into heat energy and this conversion is called the heating effect of electric current.

The heat generated in joules when a current of I amperes flows through a resistance of R ohm for t seconds is given by

$$H = I^2 Rt joule = \frac{I^2 Rt}{4.2} cal.$$

This relation is known as Joule's law of electrical heating.

Ex. If bulb rating is 100 watt and 220 V then determine

(a) Resistance of filament

(b) Current through filament

(c) If bulb operate at 110volt power supply then find power consume by Bulb

Sol. Bulb rating in 100 W and 220 V bulb means when 220 V potential difference is applied between the two ends then the power consume is 100 W

Here V = 220

P = 100

$$\frac{V^2}{R} = 100$$

So, R= 484 Ω

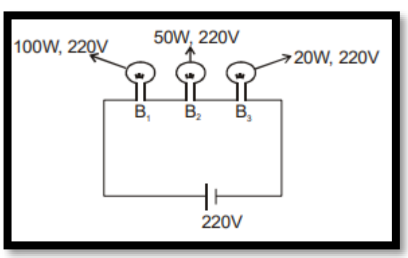
Since Resistance depends only on material hence it is constant for bulb

$$i = \frac{V}{R} = \frac{220}{22 \times 22} = \frac{5}{11} Amp.$$

power consumed at 110 V

Power consumed $= \dfrac{110 \times 110}{484} = 25W$

Ex. In the following figure, grade the bulb in order of their brightness:



Sol. $$P_{rated} = \frac{V_{rated}^2}{R}$$

$$R = \frac{V_{rated}^2}{P_{rated}}$$

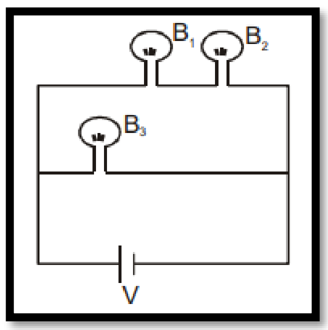
$$\therefore \ R3 > R2 > R1$$

Power $= i2R$

As current passing through every bulb is same

$\therefore$ Brightness order is B3 > B2 > B

Ex. The above configuration shows three identical bulbs, Grade them in order of their brightness.

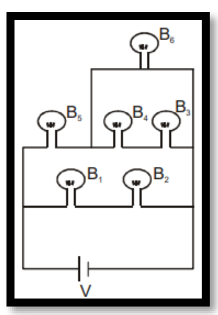


Sol. B_1 & B_2 withdraw less current as compared to B_3 because in series they give 2R resistance whereas R is the resistance du to B_3.

Power = i2R

Brightness order: $B_3 > B_2 = B_1$.

Ex. Grade the bulbs in order of their brightness (All bulbs are identical)



Sol. As $$i \alpha \frac{1}{R}$$

$$i_1 : i_2 = \frac{3}{5R} : \frac{1}{2R} = 6:5$$

$$\therefore i_1 = \frac{6i}{11},\ i_2 = \frac{5i}{11}$$

$$i_3 : i_4 = \frac{1}{2R} : \frac{1}{R} = 1:2$$

As $$i_3 + i_4 = i_1$$

$$\therefore i_3 = \frac{2i}{11},\ i_4 \frac{4i}{11}$$

power = i^2R

Order of Brightness: $B_5 > B_1 = B_2 > B_6 > B_4 = B_3$

(b) Maximum power transfer theorem:

Let E be emf and r internal resistance of the battery. It is supplying current to an external resistance R current in circuit

$$I = \frac{E}{(R = r)}$$

The power absorbed by load resistor R is

$$P = I^2 R = \left(\frac{E}{R+r}\right)^2 R$$

For maximum power transfer we take the derivative of P w.r.t R, set it equal to zero and solve the equation for R.

$$\frac{dP}{dR} = 0$$

$$\frac{dP}{dR} = E^2 \frac{(R+r)^2 - R\left[2(R+r)\right]}{(R+r)^2} = 0$$

Solving for R, we have

$(R + r)\ 2 - R\ (2)\ (R + r) = 0$

$(R + r) - 2R = 0\ R = r$

For a given real battery the load resistance maximizes the power if it is equal to the internal resistance of the battery. The maximum power transfer theorem in general, holds for any real voltage source. The resistance R may be a single resistor or R may be the equivalent resistance of a collection of resistors.