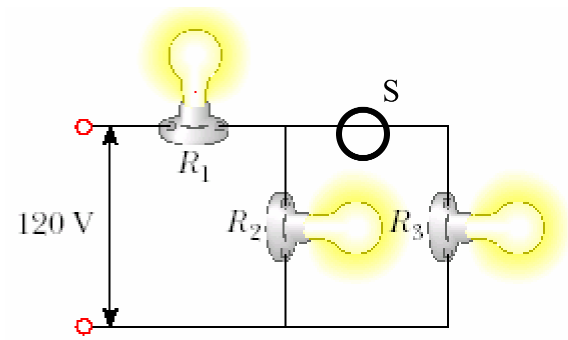
232 Lecture supplement 12

67. Three 60.0-W, 120-V lightbulbs are connected across a 120-V power source, as shown in Figure P28.67. Find
(a) the total power delivered to the three bulbs and
(b) the voltage across each. Assume that the resistance of each bulb is constant (even though in reality the resistance might increase markedly with current).
(c) Now the switch S is opened. Compare the brightness of bulbs R1, R2 and R3 before and after the switch is opened.



P28.67 (a) First determine the resistance of each light bulb: $\mathcal{P} = \frac{(\Delta V)^2}{R}$

$$R = \frac{(\Delta V)^2}{\mathcal{P}} = \frac{(120\text{ V})^2}{60.0\text{ W}} = 240\ \Omega .$$

We obtain the equivalent resistance R_{eq} of the network of light bulbs by identifying series and parallel equivalent resistances:

$$R_{eq} = R_1 + \frac{1}{(1/R_2)+(1/R_3)} = 240\ \Omega + 120\ \Omega = 360\ \Omega .$$

The total power dissipated in the 360 Ω is

$$\mathcal{P} = \frac{(\Delta V)^2}{R_{eq}} = \frac{(120\text{ V})^2}{360\ \Omega} = \boxed{40.0\text{ W}} .$$

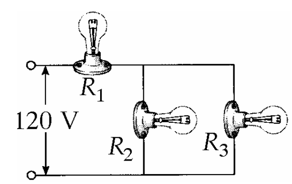


FIG. P28.67

(b) The current through the network is given by $\mathcal{P} = I^2 R_{eq}$:

$$I = \sqrt{\frac{\mathcal{P}}{R_{eq}}} = \sqrt{\frac{40.0\text{ W}}{360\ \Omega}} = \frac{1}{3}\text{ A} .$$

The potential difference across R_1 is

$$\Delta V_1 = IR_1 = \left(\frac{1}{3}\text{ A}\right)(240\ \Omega) = \boxed{80.0\text{ V}} .$$

The potential difference ΔV_{23} across the parallel combination of R_2 and R_3 is

$$\Delta V_{23} = IR_{23} = \left(\frac{1}{3}\text{ A}\right)\left(\frac{1}{(1/240\ \Omega)+(1/240\ \Omega)}\right) = \boxed{40.0\text{ V}}.$$

You can also determine ΔV_{23} by using:

$$120V = \Delta V_{23} + \Delta V_1$$

$$\Rightarrow \Delta V_{23} = 120 - 80 = 40V$$

(c) The power dissipated in each bulb before S is opened:

$$P_1 = \frac{(\Delta V_1)^2}{R_1} = \frac{80^2}{240}W = 26.67\quad W$$

$$P_2 = P_3 = \frac{(\Delta V_{23})^2}{R_2} = \frac{40^2}{240}W = 6.67\quad W$$

When the switch is opened R3 is off. Now R1 and R2 are in series and the equivalent resistance is R1+R2 = 480 Ω. And the current through both bulbs:

$$I = \frac{\Delta V}{R_{eq}} = \frac{120}{480} = 0.25A$$

So now the new potential differences and power dissipated for R1 and R2:

$$\Delta V_1 = IR_1 = 0.25.240 = 60\quad V$$

$$\Delta V_2 = IR_2 = 0.25.240 = 60\quad V$$

$$P_1 = P_2 = \frac{(\Delta V_1)^2}{R_1} = \frac{(\Delta V_2)^2}{R_2} = \frac{60^2}{240}W = 15\quad W$$

So when S is opened R1 becomes less bright while R2 becomes brighter.