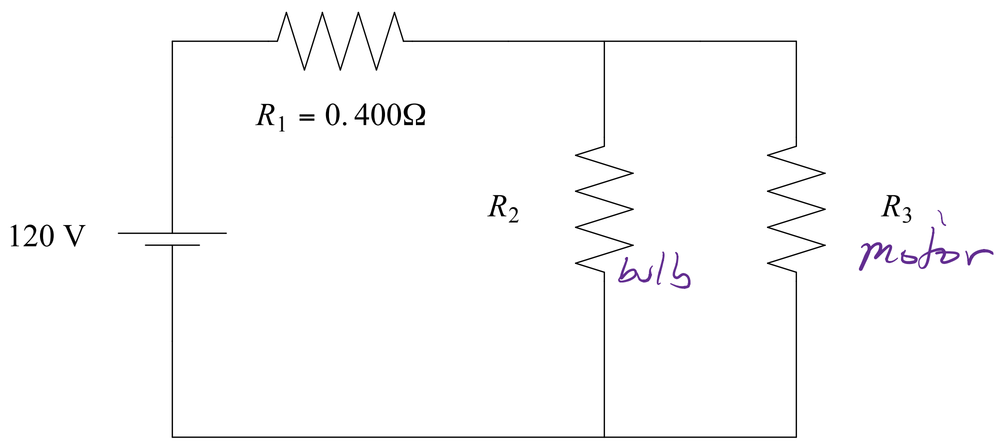
Physics 133

Sample Test Problem

Problem 1. (30 pts.) When a powerful appliance switches on, the lights on the same circuit often dim noticeably. In this problem, you will calculate this effect for the following idealized simplified circuit. Resistance R_1 represents the total resistance in the wires and connections, R_2 is a light bulb, and R_3 is a motor. (For the purposes of this problem, assume that all these resistances are fixed, constant values.)

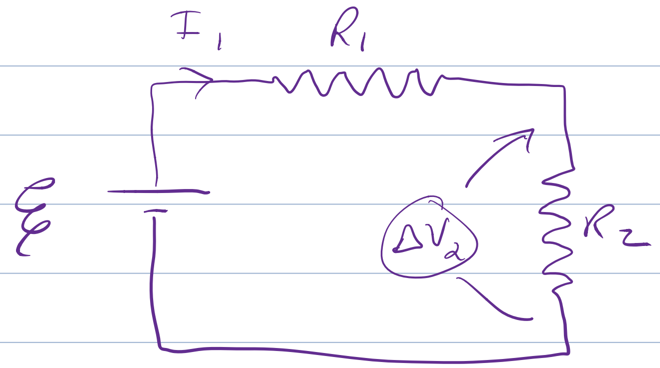


a. (15 pts.) When the motor is off (or disconnected), a total current of 0.626 A passes through R_1. What is the power dissipated by the light bulb?

b. (5 pts.) When the motor is on, a total current of 30.0 A passes through R_1. What is the voltage across R_1?

c. (10 pts.) When the motor is on, what is the power dissipated by the light bulb?

(a) Redraw the circuit with the motor disconnected



$\mathcal{E} = 120\,V$
$R_1 = 0.400\,\Omega$
$R_2 = \ ?$
$I_1 = 0.626\,A$

Since R_1 and R_2 are in series,

$$I_1 = \frac{\mathcal{E}}{R_1 + R_2} \Rightarrow R_1 + R_2 = \frac{\mathcal{E}}{I_1}$$

$$R_2 = \frac{\mathcal{E}}{I_1} - R_1 = \frac{120\,V}{0.626\,A} - 0.400\,\Omega \simeq 191.3\,\Omega$$

To calculate P_2 (how "bright" is the bulb?) we can use $P_2 = I_2(\Delta V_2)$ or $I_2^2 R_2$.

what is ΔV_2 ?

$$\Delta V_2 = I_2 R_2 = I_1 R_2 = 119.75\,V$$

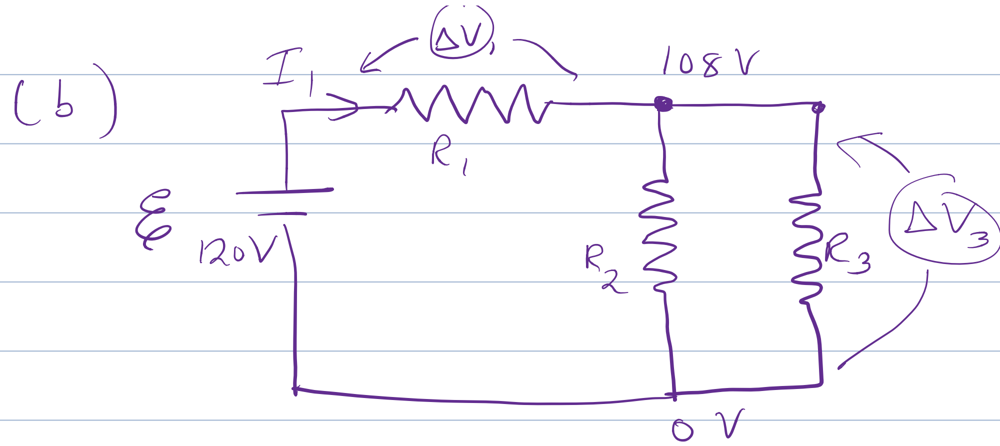
note: $\Delta V_1 = I_1 R_1 = 0.25\,V$

Then $P_2 = I_2\, \Delta V_2 = (0.626\,A)(119.75\,V)$

$$\boxed{P_2 = 75\,W}$$

Now that we know R_2 (bulb) return to the full circuit

(b)



$\mathcal{E} = 120V$ $\quad$ $R_2 = 191.3\,\Omega$

$R_1 = 0.400\,\Omega$ $\quad$ $R_3 = ?$

$I_1 = 30.0\,A$

$\Delta V_1 = I_1 R_1 = (30.0A)(0.400\,\Omega)$

$\Delta V_1 = 12.0\,V$

(c) what is P_2?

$$P_2 = I_2 (\Delta V_2) = \left(\frac{\Delta V_2}{R_2}\right)(\Delta V_2) = \frac{(\Delta V_2)^2}{R_2}$$

what is ΔV_2?

$\mathcal{E}$ is 120 V

ΔV_1 is 12 V

$\therefore \Delta V_2$ is 108V

KVL:

$\mathcal{E} - \Delta V_1 - \Delta V_2 = 0$

$\Delta V_2 = \mathcal{E} - \Delta V_1$

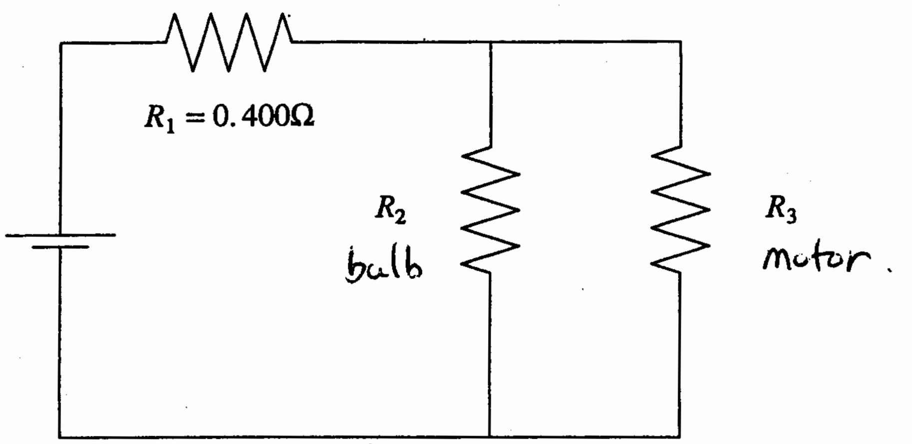
$= 120\,V - 12\,V$

$\Delta V_2 = 108\,V$

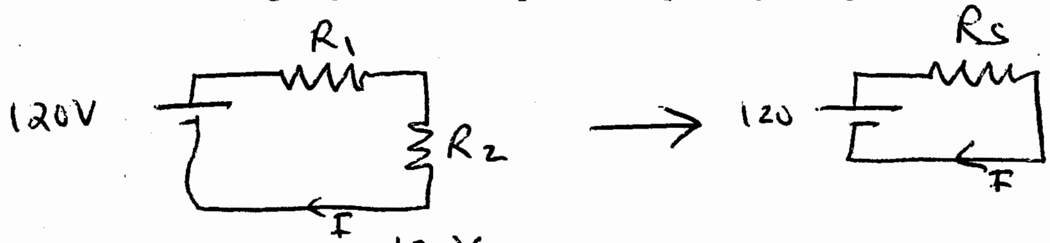
$$P_2 = \frac{(108V)^2}{191.3\,\Omega} = \boxed{61.0W}$$

The bulb dims.

4. (30 pts.) When a powerful appliance switches on, the lights on the same circuit often dim noticeably. In this problem, you will calculate this effect for the following idealized simplified circuit. Resistance R_1 represents the total resistance in the wires, R_2 is a light bulb, and R_3 is a motor. (For the purposes of this problem, assume that all these resistances are fixed, constant values.)



a. (15 pts.) When the motor is off (or disconnected), a total current of 0.626 A passes through R_1. What is the power dissipated by the light bulb?



$$I = \frac{120V}{R_s}$$

$$0.626\ A = \frac{120V}{R_s} \Rightarrow R_s = \frac{120V}{0.626A} = 191.7\Omega$$

Now $R_s = R_1 + R_2 \Rightarrow R_2 = R_s - R_1 = 191.7 - 0.4$

$$R_2 = 191.3\Omega$$

Lastly $P_2 = V_2 I_2 = (I_2 R_2) I_2 = I_2^2 R_2$

$$P_2 = (0.626)^2 (191.3) = \boxed{75.0W}$$

b. (5 pts.) When the motor is on, a total current of 30.0 A passes through R_1. What is the voltage across R_1?

$$V_1 = I_1 R_1 = (30A)(0.400\,\Omega) = 12V$$

c. (10 pts.) When the motor is on, what is the power dissipated by the light bulb?

$$P_2 = V_2 I_2 = V_2\left(\frac{V_2}{R_2}\right) = \frac{V_2^2}{R_2}$$

$$V_2 = 120V - 12V \quad (KVL) = 108V$$

$$P_2 = \frac{(108)^2}{191.3} = \boxed{61.0W}$$