Ch 28 Solutions

2 The EMF will equal the terminal voltage when there is no load on the battery. The terminal voltage will exceed the EMF when current is driven backwards through the battery.

9 The equivalent resistance will remain the same, but the power dissapated by each resistor will be ¼ that of a single resistor.

11 The birds sit only on one wire. The potential difference between the bird's feet is almost zero (the wire is a conductor), therefore very little current goes through the bird.

13 The brightness of a bulb depends on the current running through it. The bulb also functions as a resistor, making this similar to an RC circuit. Thus, the bulb will shine brightly at first, but slowly dim as the capacitor charges. When the capacitor is fully charged the light will not shine.

16 The resistance becomes significant because it dissapates power. Over long distances this adds up. P = I^2 R. dissapation of the energy depends on the square of the current, thus we want to minimize current.

17 The headlights in a car are wired in parallel. This way if one burns out the other stays lit at the original brightness.

19 P = V ^2 / R. The highest powered bulb has the lowest resistance. In series they all carry the same current. P = I^2 R. If current is constant the bulb with the highest resistance will output the most power, ie more light. This is why the 60 W bulb is brightest in series. In parallel the 200 W bulb will shine brightest.

28.1) $P = \frac{\Delta V^2}{r}$

$R = \frac{(11.6V)^2}{20.0W} = 6.73\Omega$

$\Delta V = IR$ $\quad$ $I = 1.72A$

$\varepsilon = IR + Ir$

$15.0V = 11.6V + (1.72A)r$

$r = 1.97\Omega$

28.3) $3.00V = I(r_1 + r_2 + R_{Lamp})$

$I = 600mA$

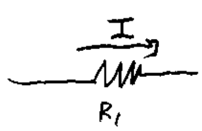
$r_1 = .153\Omega$

$r_2 = .255\Omega$

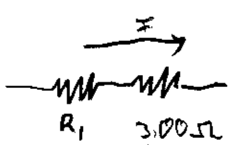
$\Longrightarrow R_{lamp} = 4.59\Omega$ $\quad$ $R_{total} = 5.00\Omega$

$\frac{P_{bat}}{P_{total}} = \frac{.408\Omega I^2}{5.00\Omega I^2} = 8.16\%$

28.5)



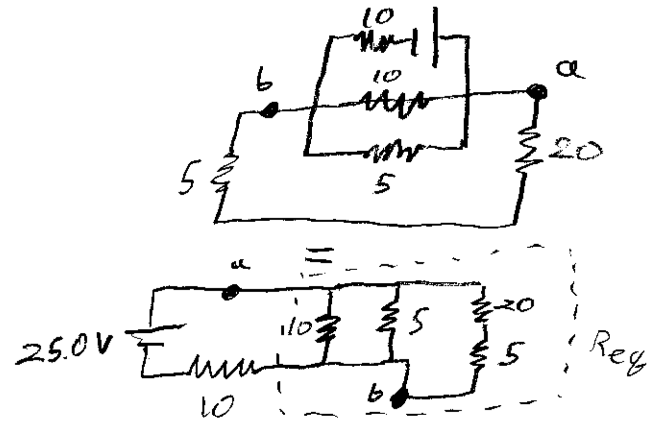
$I = 2A$ $\quad$ $\Delta V =$ constant



$I = 1.6A$ $\quad$ $R_1(2.00A) = \Delta V = (R_1 + 3\Omega)\,1.60A$

$R_1 = 12.0\Omega$

28.9) a)



R in Ohms

$$R_{eq} = \left(\frac{1}{10\Omega} + \frac{1}{5\Omega} + \frac{1}{25\Omega} \right)^{-1}$$

$$= \frac{50}{17}\ \Omega$$

$$R_{total} = \frac{220}{17}\ \Omega \qquad V = 25.0\,V$$

$$I = \frac{25.0\,V}{\frac{220}{17}\Omega} = 1.93\,A$$

this is I leaving battery

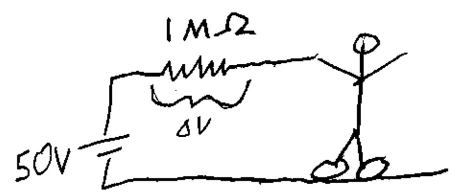
ΔV across the resistor not in R_{eq} : $(1.93\,A)(10\,\Omega) = 19.3\,V$

$\Rightarrow \boxed{\Delta V_{ab} = 5.7\,V}$ (part b)

To find current through $20\,\Omega$ resistor, find current through the $20\,\Omega$ and $5\,\Omega$ series, it will be the same.

$$I = \frac{V}{R} = \frac{5.7\,V}{25\,\Omega} = \boxed{.227\,A}$$

28.10) $I = \dfrac{\Delta V}{1M\Omega}$



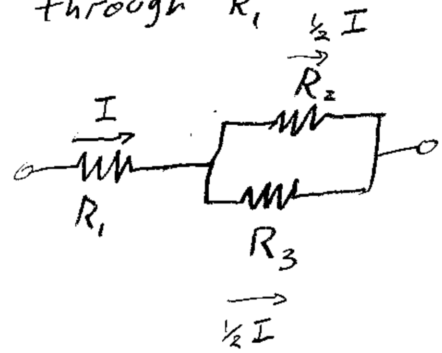
$$V_{set} = \Delta V + I R_s$$

$$\frac{50V - \Delta V}{\left(\frac{\Delta V}{1M\Omega}\right)} = R_s$$

b) assume $R_{body} = 0\,\Omega$

$I = \dfrac{V}{R} = \dfrac{50V}{1M\Omega} = 50.0\,\mu A$ we're safe

28.11) $P = I^2 R$ current will be highest through R_1



$$\sqrt{\frac{25\,W}{100\,\Omega}} = I_{max} = .5A$$

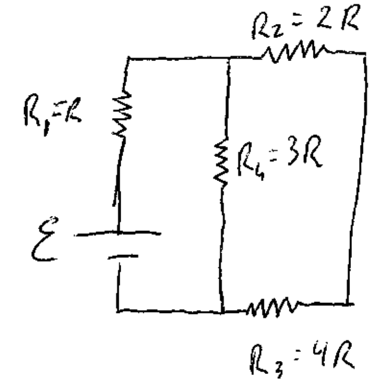
$$R_{eq} = 100\,\Omega + \left(\frac{1}{100\,\Omega} + \frac{1}{100\,\Omega}\right)^{-1} = 150\,\Omega$$

$$\Delta V = R_{eq} I_{max} = 150\,\Omega\,(.5A) = 75\,V$$

$$P_1 = 25\,W$$
$$P_2 = P_3 = (.25A)^2 (100\,\Omega) = 6.25\,W$$

$$P_{total} = P_1 + P_2 + P_3 = 37.5\,W$$

28.19) a) The voltage across series resistors divides in proportion to the resistances, while the voltage across parallel resistors is the same.



This means that $V_4 = V_2 + V_3 > V_2, V_3$ and $V_3 > V_2$. R_1 is in series with the parallel combination of R_4, R_2, and R_3, which has effective resistance

$$R_{eff} = \frac{(3R)(4R+2R)}{3R+(4R+2R)} = 2R$$

This means that $V_1 = \frac{V_4}{2}$. Since $V_2 + V_3 = V_4$ and $V_3 > V_2$, $V_3 > \frac{V_4}{2} > V_2$.

Thus, the potential differences are, from largest to smallest:

$$\boxed{V_4 > V_3 > V_1 > V_2}$$

b) From (a), we know that $V_4 = 2V_1$, since V_4 is the same as the voltage drop across the full parallel combination of R_2, R_3, and R_4. This also means that $V_1 + V_4 = \mathcal{E}$. So:

$$V_1 + 2V_1 = \mathcal{E} \Rightarrow \boxed{V_1 = \frac{\mathcal{E}}{3}}$$

$$V_4 = \mathcal{E} - V_1$$
$$= \mathcal{E} - \frac{\mathcal{E}}{3} \Rightarrow \boxed{V_4 = \frac{2\mathcal{E}}{3}}$$

We also know that $V_4 = V_2 + V_3$. And, since voltage drops across series resistors divide in proportion to resistance, $\frac{V_2}{2} = \frac{V_3}{4}$ (or, $V_2 = \frac{V_3}{2}$). So:

$$V_2 + 2V_2 = \frac{2\mathcal{E}}{3} \Rightarrow \boxed{V_2 = \frac{2\mathcal{E}}{9}}$$
$$V_3 = 2V_2 \Rightarrow \boxed{V_3 = \frac{4\mathcal{E}}{9}}$$

c) The current through series resistors will be the same, while the currents through parallel resistor divide in proportion to the inverse of the resistances.

It follows that $I_2 = I_3$, $I_1 = I_2 + I_4 > I_2, I_4$, and $3I_4 = 6I_2$. So:

$$\boxed{I_1 > I_4 > I_2 = I_3}$$

d) The full current from the battery passes through R_1. So

$$\boxed{I_1 = I}$$

This current divides to pass through the two branches of the parallel resistors, meaning that $I = I_2 + I_4$. Since $3I_4 = 6I_2$:

$$I_2 + 2I_2 = I \Rightarrow \boxed{I_2 = \frac{I}{3}}$$

$$I_4 = 2I_2 \Rightarrow \boxed{I_4 = \frac{2I}{3}}$$

Finally, the current through R_2 and R_3 is the same:

$$I_3 = I_2 \Rightarrow \boxed{I_3 = \frac{I}{3}}$$

e) Increasing R_3 increases the total resistance in the circuit. Since a battery is a constant voltage source, this will cause the total current flowing from the battery to decrease. This means that I_1 must decrease. Due to the increase in resistance along the R_2/R_3 path, the current through this path must decrease. Finally, since the effective of the parallel resistors increases, the current through R_4 must increase, since its resistance is unchanged. In summary:

$$I_1 \downarrow, \; I_2 \downarrow, \; I_3 \downarrow, \; I_4 \uparrow$$

f) In the original circuit, the total effective resistance is:

$$R_{tot} = R_1 + \frac{R_4 (R_2 + R_3)}{R_4 + (R_2 + R_3)} = 3R$$

Thus, the battery's emf and the original current are related by:

$$\mathcal{E} = 3RI \Rightarrow I = \frac{\mathcal{E}}{3R}$$

Since the effective resistance of the parallel portion of the circuit obeys $\frac{1}{R_{eff}} = \frac{1}{R_4} + \frac{1}{R_2+R_3}$, as $R_3 \to \infty$, $\frac{1}{R_2+R_3} \to 0$. So, $R_{eff} \to R_4$. This means that the total effective resistance in the circuit becomes:

$$R_{tot} \to R_1 + R_4 = 4R$$

The total current is now:

$$I' = \frac{\mathcal{E}}{4R} = \frac{3\cancel{R}}{4\cancel{R}} I = \frac{3}{4} I$$

The current through R_1 will still be the total current:

$$\boxed{I_1' = \frac{3}{4} I}$$

With R_3 infinite, it would take an infinite emf to drive a current through R_2 and R_3. Since $\mathcal{E} < \infty$:

$$\boxed{I_2' = I_3' = 0}$$

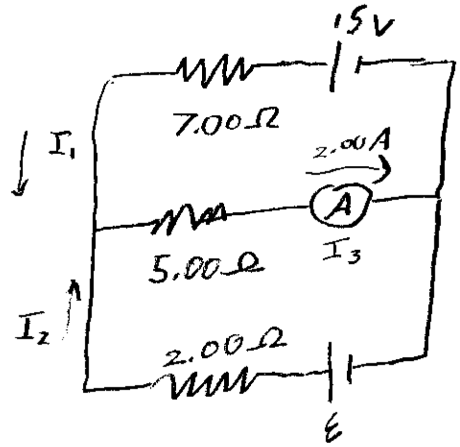
If no current passes through R_2 and R_3, the total current must pass through R_4:

$$\boxed{I_4' = \frac{3}{4} I}$$

28.20) upper loop:

$15V = I_1(7.00\Omega) + 2.00A(5.00\Omega)$

$I_1 = \frac{5}{7}A = .714A$



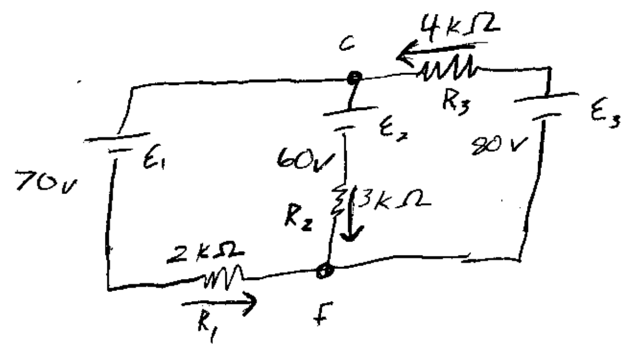
$I_2 + I_1 = I_3$

$I_2 = 1.29A$

$\varepsilon = I_2(2.00\Omega) + 10V$

$\varepsilon = 12.6V$

28.24



$\varepsilon_3 - I_3R_3 - \varepsilon_2 - I_2R_2 = 0$

$\varepsilon_1 - \varepsilon_2 - I_1R_1 + I_2R_2 = 0$

$I_3 = I_1 + I_2$

3 equations, 3 unknowns

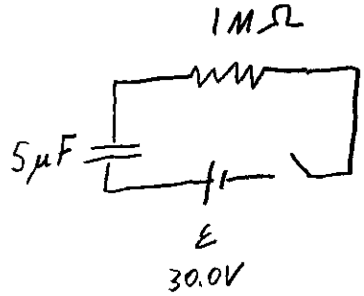
$I_1 = -.385\ mA$

$I_2 = 2.96\ mA$

$I_3 = 3.08\ mA$

$\Delta V_{cf} = 60V + I_2R_2 = -69.2V$ c is higher

28,31)



$\tau = RC = 5.0$ seconds

$Q_{max} = CV = 5\mu F \; 30.0V$
$= 150 \mu C$

$$I(t) = \frac{\varepsilon}{R} e^{-t/RC} = \frac{30V}{1M\Omega} e^{-10s/5s} = 4.06 \mu A$$

28.34) $Q(t) = (1 - e^{-t/RC}) Q_{max}$

$$(1 - e^{-t/RC}) = .6$$

$$e^{-t/RC} = .4$$

$$-t = RC \ln .4$$

$$RC = \frac{-.90s}{\ln .4} = .982 s$$

28.49) $1500W + 750W + 1000W = 3250W$

$V = 120V$

$P = IV$

$$I = \frac{P}{V} = \frac{3250W}{120V} = 27.1A$$

Heater	12.5A
Toaster	6.25A
Grill	8.33 A