Section	Group	Name	Signature
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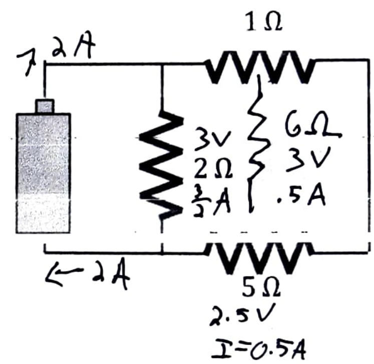
After this activity you should know: • *basic techniques for approaching resistor circuits.*

1. The open circuit voltage of the real battery shown is 4.5 Volts (when nothing is connected to it). The voltage across the 5 Ω resistor is 2.5 Volts when the resistors are connected to the battery as shown.

   a. What is the voltage across battery terminals when the resistors are connected?



$\boxed{3V}$

   b. What is the internal resistance of the battery?

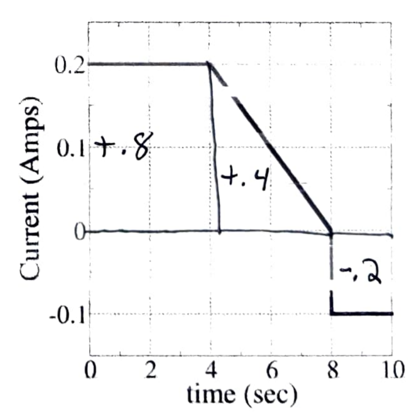
$V = IR$

$1.5V = 2A \cdot R_I$

$\boxed{\frac{3}{4}\Omega = R_I}$

2. The graph shows the current entering the positive plate of a capacitor. Negative current means the current is leaving the positive plate. The charge on the capacitor at $t = 0$ is $0.3\ C$. What is the charge on the capacitor after 10 s? *Hint: we know that $I = dQ/dt$. What is the inverse of differentiation?*

$1 + .3 = 1.3\ C$



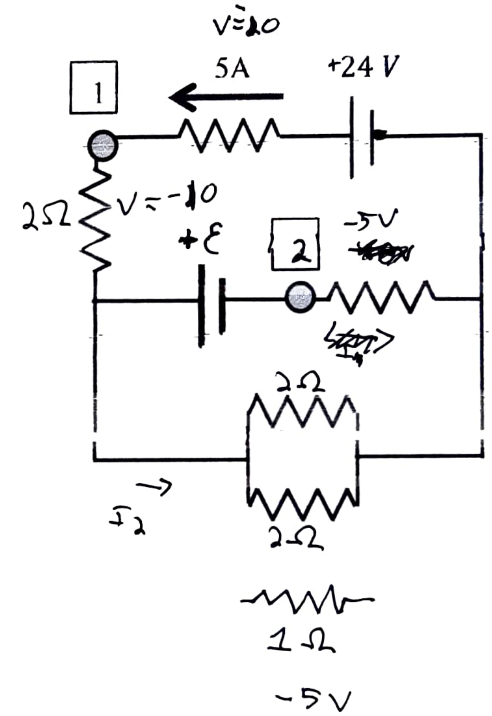
$= 1$

3. An electric lawn mower requires 4.8 Amps to run. The resistance of the lawn mower is 22 Ohms. Your household outlet is 110 Volts and you use an extension cord which has a resistance per length of 0.02 $\Omega/meter$. What is the maximum length extension cord you can use with the lawn mower?

$$110 - 4.8 \cdot 22 = 4.4V = 4.8A \cdot .02(m)$$

$$= 45\tfrac{5}{6}\,m$$

4. All the resistances are 2Ω and the EMFs can be treated as ideal.



   a. Determine the power provided by the unknown EMF. Is this EMF transferring power to the current or receiving power from the current? *Hint: simplify circuit and set up three equations for the unknown $\mathcal{E}$ and the currents I_2 and I_3 through the middle and bottom branches. Using the outside branch of the simplified circuit will make the equations easier to solve.*

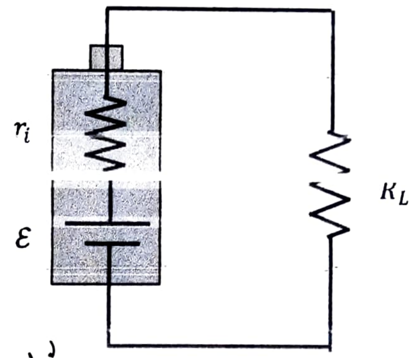
$$+24V - 10V \overset{-10V}{\cancel{-10V}} + \mathcal{E}V \overset{+5V}{\cancel{+10V}} = 0$$

$$\mathcal{E} =$$

   b. What is the voltage difference $V_2 - V_1$ between points 1 and 2?

5. (BONUS 4 pts): **What is the maximum power you can get from a power supply (such as an old stereo amplifier)?** We have a power supply with an open circuit voltage $\mathcal{E}$ and an internal resistance r_i. We want to determine the load resistance R_L that we would connect to the real power supply to get the maximum power output.

a. Write an expression for the power provided by the real power supply in terms of ideal EMF $\mathcal{E}$, the internal resistance r_i, and the load resistance R_L. *Comment: the power provided by the power supply is the same as the power dissipated in the load resistor.*



$$\mathcal{E} = I(r_i + R_L)$$

$$I = \frac{\mathcal{E}}{r_i + R_L}$$

$$P = I^2 R_L = \left(\frac{\mathcal{E}}{r_i + R_L}\right)^2 \cdot R_L$$

b. Using what you learned in Math 140, determine the value of the load resistance R_L such that will maximize the power provided, i.e., find the value of R_L that maximize the expression you found in part (a). Your answer should be in terms of r_i and/or $\mathcal{E}$.

$$P = \frac{\mathcal{E}^2 R_L}{(r_i + R_L)^2}$$

$$\frac{\partial P}{\partial R_L} = \mathcal{E}\,\frac{(r_i + R_L)^2 - 2R_L(r_i + R_L)}{(r_i + R_L)^4}$$

$$(r_i + R_L)^{\cancel{2}} - 2R_L\cancel{(r_i + R_L)} = 0 \qquad r_i + R_L - 2R_L = 0 \qquad \boxed{r_i = R_L}$$

Setting your load resistance to maximize the power output is called impedance matching.

c. Using your answer from (a) and (b), determine the maximum power that can be provided by the power supply. Your answer should be in terms of r_i and/or $\mathcal{E}$.

$$\frac{\mathcal{E}^2 \cdot r_i}{(2r_i)^2} = \boxed{\frac{\mathcal{E}^2}{4r_i}}$$