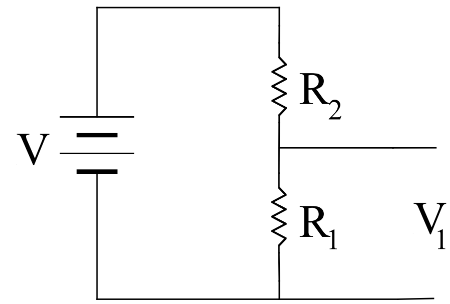
Physics 517/617 Homework 1 (Due June 29th)

Reading: Practical Electronics for Inventors: p 1-80, 159-164.

1) The circuit shown to the right is a "voltage divider."



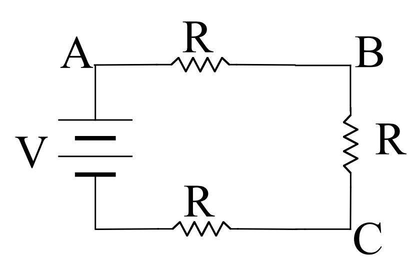
a) Show that the voltage, V, from the supply splits across the two resistors according to the fraction of the total resistance in each segment. In particular: $V_1 = \frac{R_1}{R_1 + R_2} V$.

Loop current= I
Voltage across resistor 1: $V_1 = IR_1$
Loop equation: $V - IR_1 - IR_2 = 0 \Rightarrow V = (R_2 + R_1)$
Voltage divider relation: $\frac{V_1}{V} = \frac{R_1}{R_1 + R_2}$

b) This circuit is a convenient way to generate voltages for use in a circuit. For example, suppose we had a device that required 2 V and had a 10 V supply. Then we could generate 2 V by picking the $R_2 : R_1$ in the ratio $8:2$. If we model the device by a "load" resistance, R_L, and consider placing it across the terminals at V_1, what condition must R_L satisfy so as not to significantly change V_1?

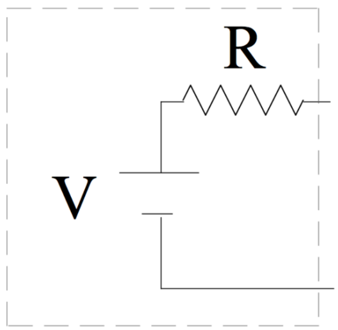
The load resistance should not load down the circuit. $R_L \gg R_1$ so that much less current flows thru R_L than R_1

2) For the circuit at the right, calculate the voltage at points A, B, and C, if (a) A is grounded, (b) B is grounded, (c) C is grounded.



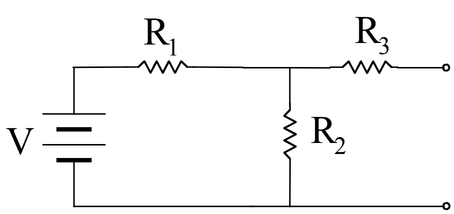
	A grounded	B grounded	C grounded
V_A	0	$\frac{V}{3}$	$2\frac{V}{3}$
V_B	$-\frac{V}{3}$	0	$\frac{V}{3}$
V_C	$-2\frac{V}{3}$	$-\frac{V}{3}$	0

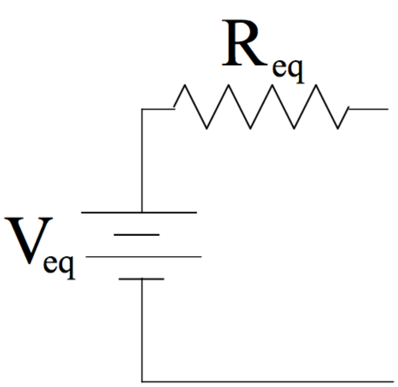
3) An automobile battery has a terminal voltage of 12.8 V with no load. When the starter motor (which draws 90 A) is being turned over by the battery, the terminal voltage drops to 11 V. Calculate the internal resistance of the battery.



The equivalent circuit for the battery is shown at the left. The voltage drop across the resistor with a 90 A load is 12.8-11=1.8V. This is equal to IR where I=90. The internal resistance of the battery is $R = \frac{V_R}{I} = \frac{1.8}{90} = 0.02\,\Omega$.

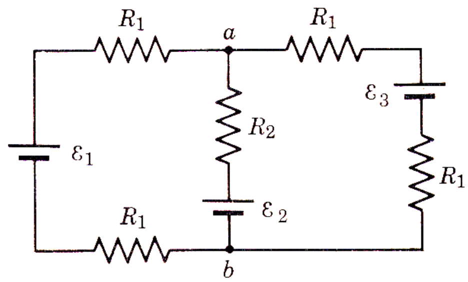
4) Calculate the Thevenin equivalent circuit:





The Thevenin equivalent circuit is show at the right. V_{eq} is th open circuit voltage which in this case is $V_{eq} = \frac{R_2}{R_1 + R_2} V$. R_{eq} is found by shorting all of the voltage sources and calculating the equivalent resistance. For this circuit, this is R_3 in series with the parallel combination of R_1 and R_2: $R_{eq} = R_3 + \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}}$.

5) (*Fundamentals of Physics*, *Haliday&Resnick 9-45)* Calculate the current through each voltage sources assuming R_1=1.0Ω, R_2=2.0Ω, ε_1=2.0V, ε_2=4.0V, and ε_3=4.0V. Indicate which batteries are charging and which are discharging.



Let I_1 and I_2 be the loop currents for the left and right internal loops in the circuit. Take them to be circulating clockwise.

Then the two loop equations are:

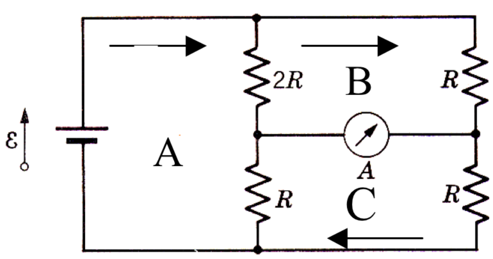
$$\varepsilon_1 - R_1 I_1 - R_2 I_1 + R_2 I_2 - \varepsilon_2 - R_1 I_1 = 0 \quad \Rightarrow \quad 2 - I_1 - 2I_1 + 2I_2 - 4 - I_1 = 0 \quad \Rightarrow \quad I_1 = \frac{1}{2}(I_2 - 1)$$

$$\varepsilon_2 - R_2 I_2 + R_2 I_1 - R_1 I_2 - \varepsilon_3 - R_1 I_2 = 0 \quad \Rightarrow \quad 4 - 2I_2 + 2I_1 - I_2 - 4 - I_2 = 0 \quad \Rightarrow \quad I_1 = 2I_2$$

Solving these gives: $I_1 = -\frac{2}{3}$ $I_2 = -\frac{1}{3}$. I.e. ε_1 is charging at $-I_1 = \frac{2}{3}$ A,

ε_2 is discharging at $I_2 - I_1 = \frac{1}{3}$ A and ε_3 is discharging at $-I_2 = \frac{1}{3}$ A.

6) (*Fundamentals of Physics*, *Haliday&Resnick 9-47P)* What current, in terms of ε and R, does the ammeter below read? Indicate the current direction on the diagram. (Assume that A has zero resistance.)



Identify loop currents for loops A, B, and C. Currents convention: clockwise = positive.

The "answer" is $I_{meter} = I_C - I_B$, where convention is current flows from left to right.

Loop equations:

$$\varepsilon + 2R(-I_A + I_B) + R(-I_A + I_C) = 0$$

$$\left.\begin{array}{l} 2R(I_A - I_B) - RI_B = 0 \quad \Rightarrow \quad I_B = \frac{2}{3} I_A \\ \\ R(I_A - I_C) - RI_C = 0 \quad \Rightarrow \quad I_C = \frac{1}{2} I_A \end{array}\right\} \Rightarrow I = -\frac{1}{6} I_A$$

Solving and substituting for I_A: $I_A = \frac{6}{7}\frac{\varepsilon}{R}$ and $I = -\frac{1}{7}\frac{\varepsilon}{R}$.

7) Review of complex math complex math. In electronics, the square root of -1 is written as "*j*" --- the symbol "*i*" is reserved for currents. Complex numbers can be written either in terms of their real and imaginary parts or the magnitude and phase angle of a "phasor:"

$$X + jY = R \cdot e^{j\theta}$$

Find the magnitude and phase angles for the following pure numbers:

a) 3 b) 2*j* c) -4 d) -4*j*

a) 3, 0 b) 2, $\frac{\pi}{2}$ c) 4, π d) 4, $-\frac{\pi}{2}$.

and the following complex numbers:

e) 2+4*j* f) 2 - 4*j* e) -2+4*j* f) -2 – 4*j*.

e) magnitude= $\sqrt{2^2+4^2} = 2\sqrt{5}$ angle= $\tan^{-1}\left(\frac{4}{2}\right) = 1.11$

f) $2\sqrt{5}$, -1.11

e) $2\sqrt{5}$ 2.034 $(= \pi - 1.11)$

f) $2\sqrt{5}$ -2.034

8) The error on page 66 of "Practical Electronics for Inventors" is in the real model of a voltmeter. The very large input resistance should be *in parallel* with the ideal voltmeter NOT in series with it as shown in Fig. 2.55.