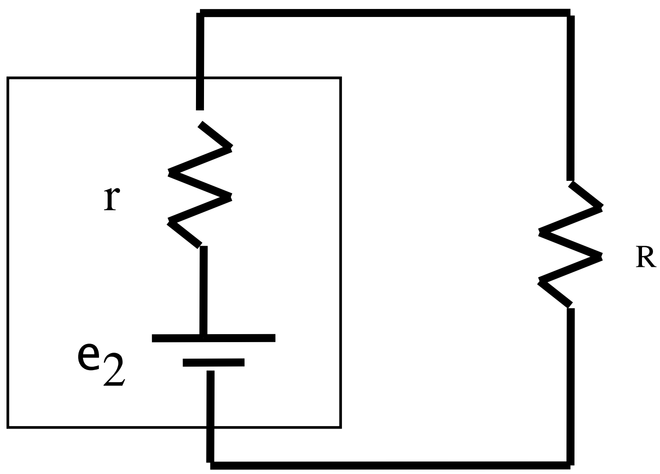
**Exam 3**
**Physics 132**

**Short Answer Section. Please answer all of the questions.**

1. What is the current in the circuit shown below? Take r=10 Ohms, R=1000 Ohms, and the emf to be 12 V. What is the power in r? If r=0, what current would flow through R?




$$V = i(r+R)$$

$$i = \frac{V}{r+R} = \frac{12V}{10\Omega + 1000\Omega} = 1.19 \times 10^{-2} A$$

$$P = i^2 r = (1.19 \times 10^{-2} A)^2 \cdot (10\Omega) = 1.42 \times 10^{-3} W$$

$$i = \frac{V}{r+R} = \frac{12V}{0\Omega + 1000\Omega} = 1.2 \times 10^{-2} A$$

2. How is a real battery different from an ideal battery

An ideal battery maintains its voltage no matter what current is required. It never loses voltage over time. Real batteries cannot do these things. The voltage sags if we draw too much current and real batteries lose voltage as they age.

3. State Kirchoff's two laws clearly.

1. The sum of the voltage differences around any closed loop in a circuit must be zero.
2. The net flow of current into a junction must equal the net flow of current out of the junction.

4. State the voltage convention that is used with Kirchoff's voltage law.

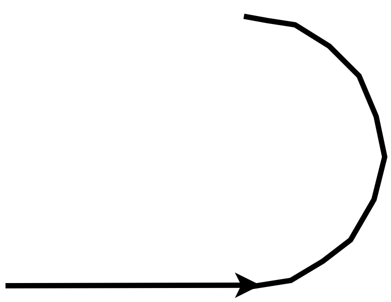
1. If the analysis path crosses a resistor in the *same* direction as the current flows through the resistor, then $V = -iR$

2. If the analysis path crosses a resistor in the *opposite* direction as the current flows through the resistor, then $V = iR$

3. If the analysis path crosses an emf from the short (negative) side to the long (positive) side, then $V = +\varepsilon$.

4. If the analysis path crosses an emf from the long (positve) side to the short (negative) side, then $V = -\varepsilon$.

5. An oxygen nucleus enters a region of uniform magnetic field. If the radius of curvature of the oxygen nucleus is 1 m and the field strength was 2T perpendicular to the velocity, what velocity did the nucleus have. Draw a picture of this event, and be sure to include the direction of the velocity (to the right) when it enters the field region, the force it experiences, and the field direction. Take the charge of the nucleus to be $q = +8e, m = 16 \cdot 1.66 \times 10^{-27} kg$



$$\frac{mv^2}{r} = qvB$$
$$\frac{mv}{r} = qB$$
$$v = \frac{qrB}{m} = \frac{(8 \cdot 1.6 \times 10^{-19}) \cdot 1m \cdot 2T}{16 \cdot 1.66 \times 10^{-27} kg} = 9.64 \times 10^{7} m/s$$

Field is into paper.

6. A straight wire of length 6 m carries a 2 A current of in $-\hat{i}$ direction. This wire is in a magnetic field given by $\vec{B} = 3\hat{j} + 4\hat{k}$. What force vector does the wire experience?

$$\begin{aligned}\vec{F} &= i\vec{l} \times \vec{B} = 2(-6\hat{i}) \times (3\hat{j} + 4\hat{k}) \\ &= -36\hat{k} + -48(-\hat{j}) \\ &= 48\hat{j} - 48\hat{k}\end{aligned}$$

7. A square loop of wire is composed of 10 turns and it has side length 0.2 m. It is placed in a magnetic field of strength 0.5 T at an angle of 30 degrees and it experiences a torque of 2 Nm. What current must be present in the wire?

$$\tau = \mu B \sin\theta = NiAB\sin\theta$$

$$i = \frac{\tau}{NAB\sin\theta} = \frac{2Nm}{10\cdot(0.2m)^2(0.5T)\sin 30} = 20A$$

8. An RC circuit has a time constant $\tau = 2s$. If the resistance in the circuit is 2000 Ohms, what is the capacitance? If the capacitor is fully charged at t=0 and it begins discharging, what charge will be left on the capacitor in 4s?

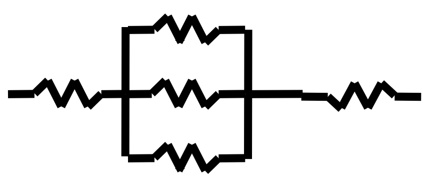
$$\tau = RC$$

$$C = \frac{\tau}{R} = \frac{2s}{2000\Omega} = 0.001F$$

$$q(t) = q_0 e^{-t/\tau}$$

$$q(4) = q_0 e^{-4s/2s} = q_0 e^{-4s/2s} = q_0 e^{-2}$$

9. Resistors are arranged as show below. Each resistor is 6 Ohms. What is the equivalent resistance?



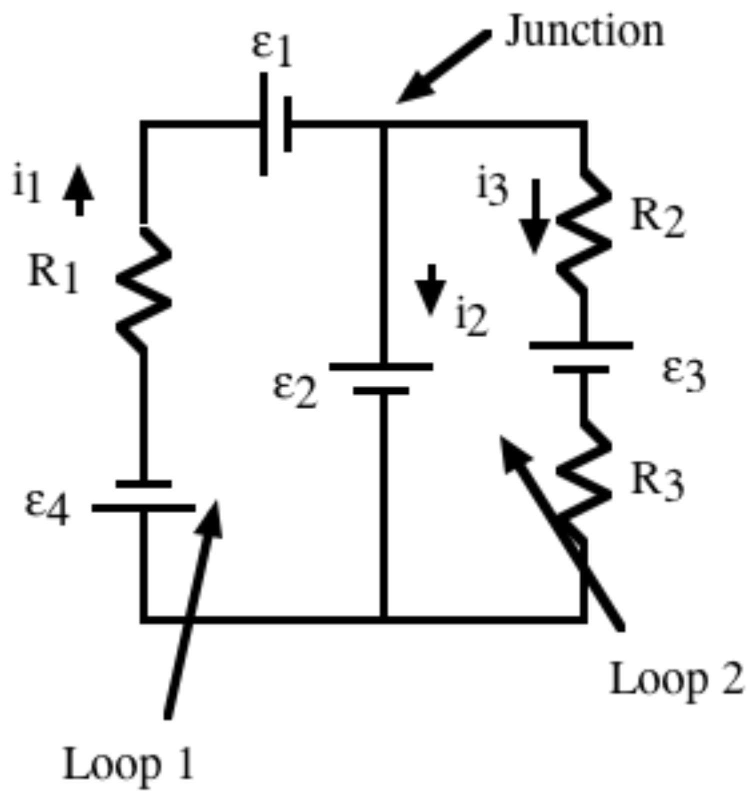
$$\frac{1}{R_{eqCenter}} = \frac{1}{6} + \frac{1}{6} + \frac{1}{6} = \frac{3}{6}$$

$$R_{eqCenter} = 2\Omega$$

$$R_{eq} = 6\Omega + 2\Omega + 6\Omega = 14\Omega$$

**Problems. Please work 2 of three problems**

**1.** Consider the circuit below




$R_1$ =200 Ohms, $R_2$ = 300 Ohms, $R_3$ = 400 Ohms, $e_1$ =40 V, $e_2$ = 20 V, $e_3$ =10V, $e_4$ = 30 V.

a) Using the loops indicated, write Kirchoff's voltage loop rule for each loop.

Loop 1: $-\varepsilon_4 - i_1 R_1 - \varepsilon_1 - \varepsilon_2 = 0$
Loop 2: $\varepsilon_2 - i_3 R_2 - \varepsilon_3 - i_3 R_3 = 0$

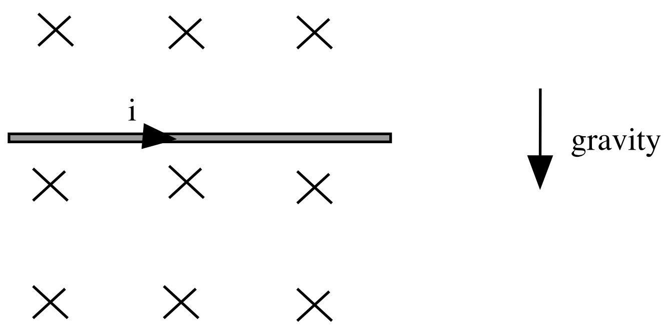
b) Apply Kirchoff's junction law to the junction indicated.

$$i_1 = i_2 + i_3$$

c) Solve for the currents.

$$-\varepsilon_4 - i_1 R_1 - \varepsilon_1 - \varepsilon_2 = 0$$
$$i_1 R_1 = -\varepsilon_4 - \varepsilon_1 - \varepsilon_2$$
$$i_1 = \frac{-\varepsilon_4 - \varepsilon_1 - \varepsilon_2}{R_1} = \frac{-30V - 40V - 20V}{200\Omega} = -0.45A$$
$$\varepsilon_2 - i_3 R_2 - \varepsilon_3 - i_3 R_3 = 0$$
$$i_3(R_2 + R_3) = \varepsilon_2 - \varepsilon_3$$
$$i_3 = \frac{\varepsilon_2 - \varepsilon_3}{(R_2 + R_3)} = \frac{20V - 10V}{(300\Omega + 400\Omega)} = 1.429 \times 10^{-2} A$$
$$i_1 = i_2 + i_3$$
$$i_2 = i_1 - i_3 = -0.45A - 1.429 \times 10^{-2} A = -0.464A$$

2. A magnetic levitation train uses the force on a current conducting wire to allow a train to float just above a track, as shown below. The rod below has a mass 2 kg and a length of 2m. B=2T




a) What current is necessary to get the rod to just float?

$$mg = ilB$$
$$i = \frac{mg}{lB} = \frac{2kg \cdot 9.8m/s^2}{2m \cdot 2T} = 4.9A$$

b) Taking the resistance of the rod to have a resistance of just 0.1 Ohms, what battery voltage would be necessary to drive this current in simple loop circuit.

$$V = iR = 4.9A \cdot 0.1\Omega = 0.49V$$

c) Draw the simple loop circuit and compute the power in the rod as resistor.

Simple loop of battery and resistor. $P = i^2 R = (4.9A)^2 \cdot 0.1\Omega = 2.4W$

d) You would need to be able to support the battery as well as the rod in a real train. If the mass of the battery, wires, and all the other stuff needed to build this device had a mass of 4 kg, how much more current would you need to support it. What voltage battery would you now need?

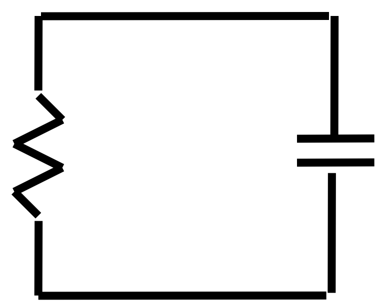
$$mg = ilB$$

$$i = \frac{mg}{lB} = \frac{4kg \cdot 9.8m/s^2}{2m \cdot 2T} = 9.8A$$

$$V = iR = 9.8A \cdot 0.1\Omega = 0.98V$$

The problem is that the battery would be much heavier than this.

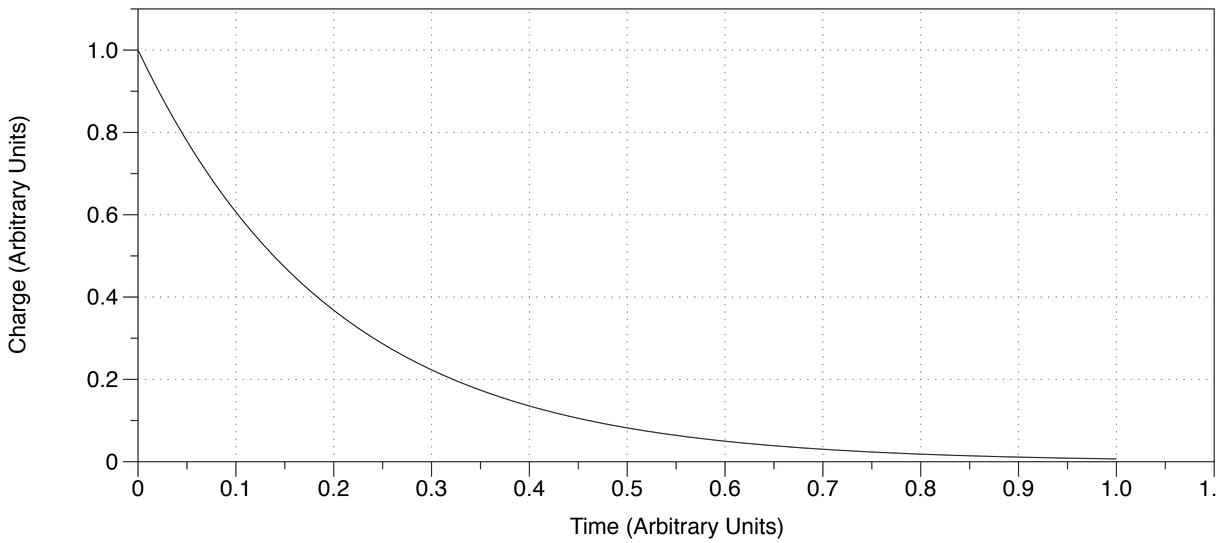
**3.** A simple RC circuit is shown below. The resistance is known to be 20,000 Ohms, but the capacitance is unknown.



The capacitor is initially charged to a voltage of 12 Volts. It discharges through the resistor and reaches a voltage of 8 volts in 5s.

a) Sketch the discharge and write the equation that describes the discharge.

$$q = q_0 e^{-t/RC} = CV_0 e^{-t/RC}$$




b) Given the information that you have, find the time constant for the decay.

$$q = q_0 e^{-t/RC} = CV_0 e^{-t/RC}$$
$$CV = CV_0 e^{-t/RC}$$
$$V(t) = V_0 e^{-t/RC}$$
$$\tau = RC$$
$$8 = 12e^{-5/\tau}$$
$$e^{-5/\tau} = \frac{8}{12}$$
$$-\frac{5}{\tau} = \ln(\frac{8}{12})$$
$$\tau = -\frac{5}{\ln(\frac{8}{12})} = 12.33s$$

c) What is the capacitance?

$$\tau = RC$$
$$C = \frac{\tau}{R} = 6.17 \times 10^{-4} F$$

d) Now that you have the time capacitance, what was the original charge on the capacitor?

$$q_0 = CV_0 = 7.404 \times 10^{-3} C$$