Test 1 Review, Tahan (I'm not reposible for anything that's mistyped below.)

Chapter 18

- Protons and electrons, which are the foundation of all matter, have *electric charge*.
  - The smallest unit of charge is $\mathbf{e = 1.6 \times 10^{-19}}$ C (in Coulombs).
  - An electron has charge $-e$ and mass m_e, and a proton has charge $+e$ and mass m_p.
  - Any quantity of charge, q, comes in units of e: $q = (\# \text{ of electrons or protons}) \times e$

- LIKE CHARGES REPEL.
  UNLIKE CHARGES ATTRACT.

  ⇒ This *force* between charges is mathematically characterized by **Coulomb's Law:**

  $$\boxed{\vec{F} = \frac{kq_1q_2}{r^2}},$$

  which has a magnitude and a direction (is a vector) and is measured in Newtons (N).

- Charged matter (either positive or negative) creates an **electric field**, $\vec{E}$, given by $\boxed{\vec{E} = \frac{kq}{r}}$, which is also a vector and has units of N/C or V/m. And, playing with the equations, we get:

$$\vec{F} = q\vec{E}.$$

- The direction of the electric field, $\vec{E}$, is *defined* as the direction a positive "test" charge will go.
- We *visualize* this electric field, $\vec{E}$, via the use of **electric field lines**, which:
  - Begin on positive charge.
  - End on negative charge.
  - The number of field lines you draw is arbitrary, but the number must be *proportional to the charge* (e.g. if you choose 4 field lines to begin on a positive charge of $+q$, then 8 must begin on a positive charge of $+2q$: $\frac{1 \text{ charge}}{4 \text{ lines}} = \frac{2 \text{ charges}}{8 \text{ lines}}$).
  - Electric field lines *never overlap.*
- Conductors: materials where charge is free to move easily.
  - Charge will always go to the surface of a conductor and spread out evenly (remeber, like charges repel).
  - When two conductors touch (this is called induction), the charges mix, i.e., the final charge on both afterwards will be the same and equal to: $q_f = (q_1 + q_2)/2$ (including sign).
  - Electric field lines always begin or end perpindicular to a conductor's surface.
- Notes on solving problems:
  - $\vec{F}$ and $\vec{E}$ are vectors, so you have to add individual forces or electric fields vectorially. For example, if you have 3 charges and you're asked to calculate the electric field at some point in space, calculate $\vec{E}_1$, $\vec{E}_2$, and $\vec{E}_3$ seperately then add them up (with x and y components, you know the drill: $\vec{E}_{\text{tot}} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3$).
  - Don't do to much work: once you have the electric field at a point, $\vec{E}_{\text{tot}}$, you can calculate the force on a charge, q, placed at that point with just $\vec{F} = q\vec{E}$ (still in the same direction as $\vec{E}$).
  - Determine the direction of $\vec{F}$ and $\vec{E}$ with your knowledge of physics (likes repel, unlikes attract) then solve with the magnitudes with the equations.

- Gauss's Law: Gauss's law is easy. It allows you to calculate the electric flux, Φ, and the magnitude of the electric field, E, going through some *imaginary* surface A.

$$\Phi = EA = Q_{in}/\epsilon_0$$

- Q_{in} is the charge inside A—and that's it—it doesn't matter what shape it is...
- For example, if your imaginary surface is a spherical surface of $A = 4\pi r^2$ and inside it is a metal ball of radius $R < r$ and charge Q: it doesn't matter one bit how big the ball is, except that it's entirely in A and has charge Q. So $Q_{in} = Q$ and your problem is solved.
- If you have oppositely charged things inside A, just add them (with signs).
- If Q_{in} is positive, the electric field points out. If Q_{in} is negative, the electric field points in.

Chapter 19

- Electric potential energy and electric potential
  - Just as gravitational potential energy (mgh) is associated with the conservative force of gravity ($\vec{F}_G = m\vec{g}$), **electric potential energy**, EPE, is associated with the electrostatic force ($\vec{F}_E = q\vec{E}$).
  - Just as charge generates an electric field, $\vec{E}$, so to does it generate an **electric potential**, $\boxed{V = \frac{kq}{r}}$.
    - The potential, V, depends only on distance—it's just a scalar not a vector.
    - This means that V is just a number (with no direction). So, for example, if you want to calculate the potential V_{tot} at a point in space due to three charges q_1, q_2, and q_3 distances r_1, r_2, and r_3 away, all you need to do is add!: $V_{\text{tot}} = V_1 + V_2 + V_3 = \frac{kq_1}{r_1} + \frac{kq_2}{r_2} + \frac{kq_3}{r_3}$.
    - $\boxed{EPE = qV}$
- The change in energy needed to do something is equal to the work needed to do that: $\Delta E = W$.
- So the work done by the electric force is $W_{AB} = EPE_A - EPE_B$ from the point A to B.
  - If the work done by the electric force, W, is positive, then energy is gained in the process (the system wanted to do that).
  - If W is negative, the system didn't want to do that, it *required* energy.
- Notes: Just as with $\vec{E}$ and $\vec{F}$, don't do to much work. Once you have V, EPE is just qV.
- Remember:
  - Power = energy/time
  - $F = ma$
  - $E_{kinetic} = \frac{1}{2}mv^2$, $E_{potential} = mgh$
  - Conservation of energy: $E_{initial} = E_{final}$
- **Equipotenital lines** (think equal-potential) are regions (lines, surfaces) where V is the same.
  - They're always perpindicular to $\vec{E}$-field lines.
  - They're always loops; they never end or begin.
- A relation between E and V: $\boxed{\vec{E} = -\frac{\Delta V}{\Delta s}}$
- Capacitors:
  - The electric field between two parallel plates of area A and charge q is uniform and points from the positive side to the negative side.
  - q is the charge on one of the plates; $-q$ is the charge on the other plate.
  - $\boxed{q = CV}$ where C is the capacitance (measured in farads, F).
  - Dielectrics:
    - Add a dielectric, κ, to a capacitor and the electric field between the plates decreases; $\kappa = \frac{E_o}{E_f}$.
    - The capacitance is given by: $\boxed{C = \frac{\kappa \epsilon_0 A}{d}}$. Without the dielectric (vacuum), $\kappa = 1$.
    - Energy of a capacitor: $\boxed{E = \frac{1}{2}CV^2}$.

Chapter 20

- Electric Circuits
  - When a circuit is connected to a power supply, a potential difference V (: one side plus, one side minus) causes positive charges to move away from the + end: this causes a current to flow,

    $$I = \frac{\Delta q}{\Delta t},$$

    equal to the amount of charge going through a slice of the wire over some period of time.
  - Current, I, is measured in amperes (or, in slang, amps), $A = C/s$.
  - A battery (with an **electric motive force**, emf) or a **dc** (direct current) **power supply** produce a constant voltage and thus a constant current (dc current).
    * In practice, $\mathcal{E}$ is the same thing as V (it's just the V for a battery) and it works in all the equations you know just like V does: $\mathcal{E} = IR$, etc.
  - The wall outlets and other **ac power supplies** produce a voltage that varies in time and looks like a sin() wave (this results in ac current).
    * To make sense of this we speak of the average or "root mean square" voltage, $V_{\text{rms}} = V_0/\sqrt{2}$, which equals the peak voltage V_0 (the top of the sine wave) over the square root of two.
    * For ac circuits ($V = V_0 \sin 2\pi f t$), use the same equations, just sub in V_{rms} for V.

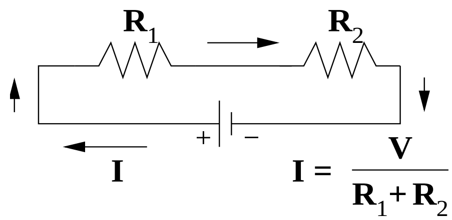
- The golden rule of circuits: Ohm's Law: $\boxed{V = IR}$
  - The voltage drop or voltage across or voltage difference across (they all mean the same thing save for maybe a minus sign) a resistor is equal to the current going through the resistor times its resistance.

- The resistance R of a material can be calculated with $R = \rho \frac{L}{A}$ where $\rho \equiv$ resistivity ($\Omega \cdot m$), $L =$ length, and $A =$ cross sectional area.
  - Resistance can also depend on temperature: $\rho = \rho_0[1 + \alpha(T - T_0)]$ where α is the **temperature coeffecient of resistivity** for the particular material in question.
    * If α is positive, the resistance, R, increases with temperature, T.
    * If α is negative, R decreases with T.

- Electric Power: $\boxed{P = IV = I^2R = V^2/R}$
  - Usually, in a circuit, the voltage is held constant. So if you're comparing two circuits both driven by a battery at $+10V$ by looking at the ratio P_1/P_2, the V's are the same so they cancel.
  - Again, for ac circuits:
    * The average power, $\bar{P} = I_{\text{rms}}V_{\text{rms}} = \frac{I_0}{\sqrt{2}}\frac{V_0}{\sqrt{2}} = \frac{1}{2}I_0V_0$

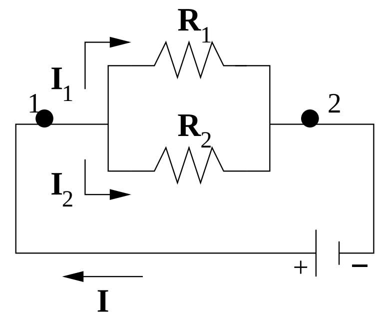
- Reducing circuits with resistors only.
  - All circuits with just resistors and *one* power supply can be reduced to a ciruit with the same one power supply and one resistor of equivalent resistance, R_{eq}.
  - To find R_{eq}, work from the inside out using the resistor combination rules:
    * series resistors: $R_{\text{eq}} = R_1 + R_2 + \ldots$
    * parallel resistors: $R_{\text{eq}} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \ldots}$

- More difficult ciruits.

– 

The current going through resistors in series *is the same.*

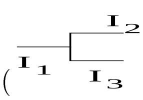
– When a wire splits though, so can the current... Some of the current, I, in the circuit to the right will go through the top—I_1—some of it will go through the bottom—I_2.



* To solve a simple parallel problem like this one, you have to realize that the potential drop across both R_1 and R_2 is the same.
* So the voltage difference between points 1 and 2 equals the voltage across R_1 *and* across R_2.
* Then, if you know $V_{12} = V$, R_1 and R_2, you're in business:

$$\text{(in this case)} \qquad V_{12} = V = I_1 R_1 = I_2 R_2 \Rightarrow \frac{I_1}{I_2} = \frac{R_2}{R_1}$$

* What does this tell us? It tells us that *current always goes through the path of least resistance.*

- Even more difficult circuits: multiple power supplies scattered God knows where.
  - You must use **Kirchhoff's Rules**:
    * *Loop Rule:* The sum of all voltage gains and drops equals zero around a "closed loop" (meaning you start and stop at the same place - and no figure 8s) in a circuit.
    * *Junction Rule:* The sum of the currents going into a junction () equals the sum of the currents goint out. (In this case, $I_1 = I_2 + I_3$.)
    * The METHOD:

      Step 1: Identify the different wire segments in the circuit and label them I_1, I_2, ... on the circuit diagram (they each will have a different current which you will eventually solve for). (A wire segment goes from junction to junction without any splits.)

      Step 2: Try to guess the direction of I_1, I_2, ... and draw it on your diagram with an arrow, this is important. When guessing, remember:
      · current goes from + to −,
      · if you choose wrong, it's OK—you will know at the end because one of your I's will be negative (you can just switch the arrow then, everything else will still be right).

      Step 3: Find enough equations to match the number of currents (e.g. 3 equations for I_1, I_2, and I_3).
      · Use the loop and junction rules. Use the junction rule (pick any junction) for 1 equation, then use the loop rule for the other equations.

        i) Pick your loops: a circle, no figure 8s.

        ii) Start at a point on your loop, move clockwise.
        → When you come to a *power source*: if you're going from − to +, you gain voltage: write down "$+V$"; if you're going from + to −, you lose voltage: write down "$-V$".
        → When you come to a *resistor*, R_i: if you're going **in the direction of the current**, $I_{i=1,2,or...}$, you **lose** voltage (voltage drop) equal to $I_i R_i = V_{\text{drop}}$: write down "$-I_i R_i$"; if you're going **against the current, you gain voltage**, $V_{\text{gain}} = I_i R_i$: write down "$+I_i R_i$".
        → When you get back to where you started, you're done, write down "$= 0$".

Step 4: Solve for the current you need: use substitution and a lot of algebra.

- Notes on problem solving:
  - Redraw complicated circuits in simpler form.
  - Kirchhoff's rules and Ohm's law *don't work for capacitors*. Don't even try.
- Reducing circuits with capacitors only.
  - Capicitor combination works exactly reverse to resistor combination:
    * series capacitors: $C_{\text{eq}} = \frac{1}{\frac{1}{C_1}+\frac{1}{C_2}+\ldots}$
    * parallel capacitors: $C_{\text{eq}} = C_1 + C_2 + \ldots$
- RC circuits (real brief)
  - A resistor, R, and a capacitor, C, are both in a circuit. It takes time to charge up or discharge the capacitor. The goal here is to figure the percentage of charge q/q_0 left on the capacitor at any given time, t.
  - capacitor charging: The capacitor is gaining charge eventually to reach some maximum value $q = CV$. The percentage will increase as time proceeds (t gets bigger).

$$\frac{\text{final charge}}{\text{initial charge}} = \frac{q}{q_0} = 1 - e^{-t/RC}$$

  - capacitor discharging: The capacitor is losing charge eventually to reach $q = 0$. The percentage decreases as time proceeds.

$$\frac{\text{final charge}}{\text{initial charge}} = \frac{q}{q_0} = e^{-t/RC}$$