Chapter 17

Problems will be from sections 1-5, 7 and 9

Electric Potential Energy: The electric force is conservative, so we can define a electric potential energy. The change in potential energy in moving a charge from a location a to a location b is

$$PE_b - PE_a = -W_E,$$

where W_E is the work done by the electric forces. The electric potential energy stored in two point charges, q and Q separated by a distance r is

$$PE = k\frac{qQ}{r}$$

If we imagine the charge Q placed at the origin and then move the charge q in from very far away, then the formula above is equal to the minimum work needed by an external agent to move the charge to the position r.

Electrical Potential: The electric potential or *potential* is the electric potential energy per charge. If a charge q is moved from one point to another and the electric potential energy changes by an amount $\Delta PE = PE_b - PE_a$ then the potential difference between the positions b and a is

$$\Delta V_{ba} = V_b - V_a \equiv \frac{PE_b - PE_a}{q} = -\frac{W_E}{q}$$

Or, in reverse, if the potential difference between two points in space is known, then the change in electric potential energy due to moving a charge q between the two points is

$$\Delta PE = q\Delta V$$

Move a charge a short distance Δx in an electric field $\mathbf{E}$. The force is

$$\mathbf{F}_E = q\mathbf{E}$$

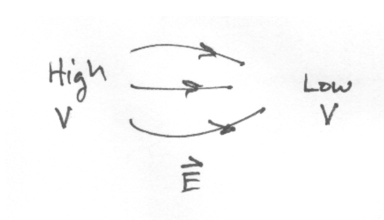
and the work done by the electric field in moving along the direction of the electric field is

$$W_E = qE\Delta x = -\Delta PE \longrightarrow -\Delta PE = -q\Delta V$$

From this it follows that

$$E = -\frac{\Delta V}{\Delta x}$$

The negative sign indicates that the electric field points from high to low potential:



A positive charge is pushed by the electric field from high to low potential, while a negative charge is pushed from low to high potential. Alternatively, the electric potential energy of a positive (negative) charge decreases its potential energy moving from high to low (low to high).

Electric Potential of Point Charges: If we declare the potential is zero at infinity, then the electric potential a distance r from a single point charge q is

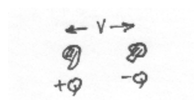
$$V = k\frac{q}{r}$$

If there are multiple point charges, the individual potentials due to each one at a point just add together:

$$V_{tot} = \sum V_i$$

Be able to compute the potential due to a collection of point charges and use the electric potential to compute the potential energy.

Capacitance: Two conductors carrying equal and opposite charges constitute a capacitor:

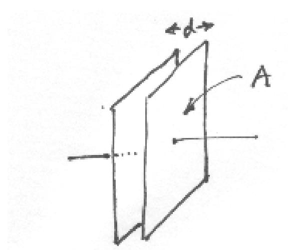


The capacitance is defined as

$$C = \frac{Q}{V},$$

where Q is the magnitude of the charge on one of the conductors (note the net charge on the capacitor is zero) and V is the magnitude of the potential difference between the conductors.

For two large parallel plates of area A, separated by a distance d:



the capacitance is

$$C = \epsilon_0 \frac{A}{d}$$

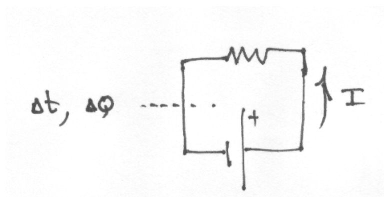
Between the plates, there is a constant electric field pointing from the positive to the negative plate:

$$E = \frac{V}{d}$$

Chapter 18

Problems will be from sections 1-3 and 5-7

Electric Current: Connect a battery to a lightbulb, and current will flow:



If a net amount of positive charge ΔQ moves past a point in the wire during a time interval Δt, the electric current is

$$I \equiv \frac{\Delta Q}{\Delta t}$$

The current flows in the direction that the net positive charge is moving. If a negative charge is moving, then the amount of charge is computed using the net negative charge that moves past the point in a direction opposite the current.

The net amount of charge that moves past a point in time Δt is

$$\Delta Q = I \Delta t$$

Ohm's Law: A device for which the current flowing through it is proportional to the potential difference across its ends is called an ohmic device. The resistance R of an ohmic device is defined by

$$V = IR$$

This is called Ohm's law.

Electric Power: In electric circuits, energy can be dissipated (resistors, light bulbs) or produced (batteries[1], power supplies, generators). The rate that energy is dissipated or produced is

$$P = \frac{W}{t} = IV,$$

where I is the current through the device and V is the potential difference across the device. For a resistor:

$$P = IV = I(IR) = I^2 R$$

Or in terms of voltage:

$$P = IV = \left(\frac{V}{R}\right) V = \frac{V^2}{R}$$

Alternating Current: The voltage in a household wall socket oscillates in time:

$$V(t) = V_0 \sin \omega t$$

If a resistance R is connected to this voltage, the current that flows is also oscillating:

$$I(t) = I_0 \sin \omega t,$$

[1] Batteries can also dissipate energy when being charged

where

$$I_0 = \frac{V_0}{R}$$

Since the average voltage and current are zero for sinusoidal voltages and currents, we define the root-mean-square values:

$$V_{rms} = \frac{V_0}{\sqrt{2}}$$

$$I_{rms} = \frac{I_0}{\sqrt{2}}$$

The instantaneous power in a circuit is

$$P = IV,$$

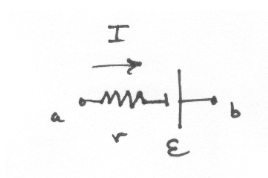
which varies in time. The average power is

$$\langle P \rangle = I_{rms} V_{rms} = \frac{1}{2} I_0 V_0$$

Chapter 19

Problems will be from sections 1-3

Batteries: An ideal battery or emf maintains a constant potential between its terminals–it does not matter how much current flows through it. However, a real battery does change the potential between its terminals changes in response to current flowing. A simple model for a real battery is



If the battery is delivering power to the circuit (as shown above):

$$V_{ba} = \varepsilon - Ir,$$

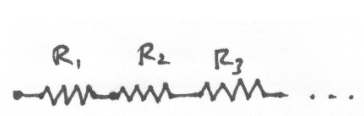
and the terminal voltage V_{ba} drops.

If the battery is being charged by the circuit:

$$V_{ba} = \varepsilon + Ir,$$

since the current flows from the high to the low terminal, and the terminal voltage increases in magnitude.

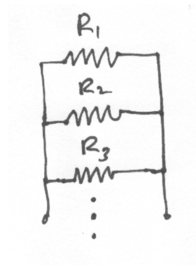
Equivalent Resistance: Resistors in series:



The equivalent resistance is

$$R_{eq} = R_1 + R_2 + R_3 + \cdots$$

Resistors in parallel:



The inverse of the equivalent resistance is

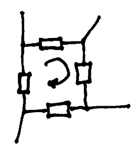
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$$

It is also possible to construct a network of resistances using combinations of parallel and series components. Be able to analyze such a configuration.

Kirchhoff's rules

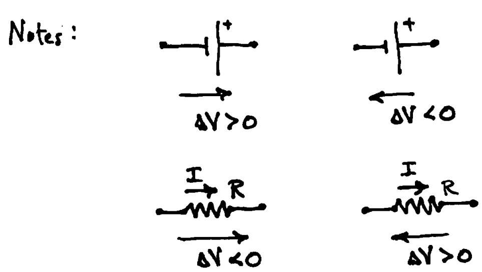
For a complex circuit (multiple resistors and more than one battery) Kirchhoff's rules are used. Kirchhoff's first rule is a consequence of energy conservation:

1. The sum of voltages around a closed loop add to zero:

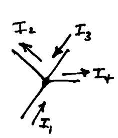


$$\sum \Delta V_i = 0$$

Here is a summary of the possible voltage differences:



2. The current into a junction point is equal to the current out of the junction point:



$$I_{in} = I_{out}$$

To solve circuit problems requiring Kirchhoff's rules begin by labeling the currents.

Chapter 20

Problems will be from sections 1-3

The simplest magnetic fields are analogous to electric dipole fields. The Earth's magnetic field points from geographic south to geographic north. Magnetic north is 11 degrees from geographic north.

The magnitude of a force on a current carrying wire in a magnetic field is

$$F_B = I\ell B \sin\theta$$

The direction is given by the Right Hand Rule: