# ELECTRIC FIELD AND POTENTIAL

1. **Coulomb's Law** - electrostatic force between two charges

$$\mathbf{F = kq_1q_2 / r^2}$$

2. **Electric Field** - force experienced by **<u>positive</u>** test charge $q_o$

$$\mathbf{E = F / q_o}$$

a. Force on charge in electric field:

$$\mathbf{F = qE}$$

b. Direction of field lines (<u>tangent to curve</u>) <u>indicates direction of force</u> experienced by positive test charge.

c. **<u>Number</u>** of field lines in given area indicates **<u>intensity</u>** of field.

d. **<u>Field lines</u> begin on +, end on -**

3. **Flux –** number of field lines passing through given area.

$$\Phi_E = \mathbf{E \bullet A}$$

$$\Phi_B = \mathbf{B \bullet A}$$

(**A** is a vector perpendicular to surface.)

# ELECTRIC FIELD AND POTENTIAL

4. **Electric Potential**

$$V = U / q_o \qquad \text{(joule/coulomb = volt)}$$

$$\Delta V = \Delta U / q_o$$

a. A **potential difference** means that **a charge will lose or gain** a certain amount of **potential energy** as it goes from spot to another.

b. For a test charge moving in the field of a **point charge**, its potential is

$$V_{pt\ chg} = kq / r$$

c. **Equipotential lines** - contours of equal potential. Field will be perpendicular to these lines.

PROBLEM 1

# ELECTRICAL CIRCUITS

1. **Capacitors**- device for storing charge; capacity depends on geometry, materials

   **$C = Q / V$** (coulomb/volt = **farad**)

   a. Combinations of capacitors

   **Series** **$1 / C_{eq} = (1 / C1 + 1 / C2 + ... )$**

   **Parallel** **$C_{eq} = C1 + C2 + ...$**

   b. Energy is stored in capacitors:

   **$U = 1/2\ CV^2$**

   c. The capacitance of a capacitor can be changed by inserting a material between the plates which has a high **dielectric constant ($\kappa$).**

   **$C' = \kappa C$**

   ($\kappa$ of vacuum is 1, for air ~ 1)

2. **Resistors** - objects that resist flow of charge in circuit

   **$R = V / i$** (for elements that obey Ohm's law)

   a. Combinations of resistors

   **Series** **$R_{eq} = R1 + R2 + ...$**

   **Parallel** **$1 / R_{eq} = (1 / R1 + 1 / R2 + ...)$**

   b. **Power dissipated** in resistors: **$P = i^2R = VI = V^2/R$**

# ELECTRICAL CIRCUITS

2. **Resistors** (continued)

   c. **Resistivity** - inherent property of materials

   **($R = \rho L / A$)** (water analogy)

3. **Batteries** - supply **emf** (**electromotive force**) to circuit; somehow they "pump up" the energy of charges so that they are capable of making a round trip through the circuit

   a. Supplies power at rate **$P = \varepsilon i$**

   b. Often has **internal resistance r** to be considered.

   c. emfs are **added if in series**

4. **DC Circuits**

   **a. Current** **$i = \Delta q / \Delta t$** (ampere - 1 coulomb/s)

   1) **junction rule**

      sum of currents = sum of currents out

   2) **conventional current** is flow of **positive** charge carriers

   3) **current density**

   **$J = i/A$**

# ELECTRICAL CIRCUITS

4. **DC Circuits** (continued)

**b. Ohm's Law**

$$\mathbf{V = IR} \quad \text{or} \quad E = \rho J$$

(does not work for all materials)

<u>Resistance increases with increasing temperature</u>

c. **<u>Loop rule</u>** - sum of potential differences must sum to zero

1) go with current - lose potential
2) go from - to + on emf source, increase potential

d. **<u>RC circuits</u>** show time-dependent behavior:

$$\mathbf{i = \varepsilon / R\ e^{-t/RC} = i_o\ e^{-t/RC}} \quad \text{(discharging capacitor)}$$

What fraction of the original current remains after one time constant has passed? Could you draw the curve?

5. **AC Circuits**

a. The voltage varies

$$\varepsilon = \varepsilon_o \sin(\omega t)$$

# ELECTRICAL CIRCUITS

5. **AC Circuits** (continued)

b. The current can be calculated using the emf and the impedance (Z)

$$\mathbf{i = \varepsilon / Z}$$

(the current will also have a sinusoidal behavior)

c. Since the direction of current varies, **$i^2$ is averaged** in order to average power:

$$\mathbf{P_{av}=i^2_{rms}R}$$

Average power is 1/2 maximum power

(because average of $\sin^2\theta$ is ½)

PROBLEM 3

# MAGNETIC FIELDS

1. **<u>Magnetic fields are created by moving charges</u>**. They can also exert a force on moving charges:

$$\mathbf{F = q\ v \times B}$$

   right hand rule

   fingers point along v, curl toward B; thumb points along F

   a. The **<u>force always acts ⊥</u>** to v and B

   b. mks unit of magnetic field is the **<u>Tesla</u>**

   1 tesla (T) = 10000 Gauss (Ga)

2. Because of the nature of the force, **<u>B never increases the speed</u>** of charges, only **<u>changes their direction</u>**.

3. **<u>Currents</u>** also feel a force in a magnetic field

$$\mathbf{F = i\ L \times B}$$

4. **<u>Right hand rules</u>**

   a. **magnetic field** of a **current carrying wire**

   thumb - i; fingers – B

   b. **magnetic field** of a **current loop or solenoid**

   fingers - i; thumb - B

# MAGNETIC FIELDS

5. **<u>Magnetic field lines</u>** do not have beginning/ending points; they **<u>are loops</u>**.

    a. **Bar magnets** do have a **<u>north and south pole</u>**.

    b. Field lines run **<u>externally from north to south</u>**, internally from south to north.

6. **<u>Electromagnetic Induction</u>** - a **changing magnetic field** can induce an emf

PROBLEM 2