Physics Lecture 7 - Electricity and Magnetism

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Charge (q, Coulombs)

Coulomb's law: force between two charges $F = k\frac{q_1 q_2}{r^2}$

Remember that like charges repel, opposite charges attract
Center of charge: can treat entire collection of charges as single charge at that point

Electric Field (E, N/C or V/m)
Field lines: point in direction of field, or from (+) to (-) charges
-> Denser = higher field strength
Force due to electric field: $F = qE$
Potential energy due to position in electric field: $U = qEd$
Point charge: $E = k\frac{q}{r^2}$, $U = k\frac{q_1 q_2}{r}$

Voltage/Potential (V, Volts or J/C)
How much potential work an electric field must do to move a charge a certain distance
Stronger electric field = more potential for work
More distance = more work
so $V = Ed$, for a point charge $V = k\frac{q}{r}$
Note that $U = qV$, or for a specific charge its potential energy is related to the voltage
Equipotential surfaces: perpendicular to field lines, moving a charge along these surfaces requires no work

Charge Movement
Conductor: electrons can move easily i.e. metals
Resistors/insulators: electrons can't really move i.e. diamond, glass
Induction: charged things can cause charge to move in other things

Current (I, Amps or C/s)
Defined as opposite direction of flow of electrons (= flow of positive charge)

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<u>Batteries</u> supply an *electromotive force* or voltage across two points

<u>Resistors</u>
Resistance (R, OhmsΩ): how much a substance resists charge flow

-> $R = \rho \frac{L}{A}, \rho$ is resistivity

<u>Capacitors</u>
Stores energy by separating positive + negative charges
Capacitance (C, Farads F): how much energy the capacitor can potentially store
Formula: $C = \frac{Q}{V}$, so high capacitance = more charge stored at lower voltage

Parallel plate capacitor: $C \propto K \frac{A}{d}$

Energy stored in capacitor: $U = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$

Dielectric constant: material between plates on capacitor, some material can give capacitor more potential for storing energy

-> Vacuum has $K = 1$, if a capacitor has $K = 4$ then the capacitor has 4 times the capacitance so can store 4 times the amount of energy

<u>Circuits</u>
Ohm's Law: $V = iR$
Kirchoff's First Law: amount of current flowing into any point = amount of current flowing out
Kirchoff's Second Law: sum of voltage changes around a path in a closed circuit = 0
Series: current goes into one, then the other

-> $R_{eff} = R_1 + R_2 + \ldots, \ \frac{1}{C_{eff}} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots$

Parallel: current splits, part of current goes into one, other part goes into other

-> $\frac{1}{R_{eff}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots, \ C_{eff} = C_1 + C_2 + \ldots$

<u>Power</u>
Either power circuit can supply, or power dissipated by resistor; $P = iV = i^2R = V^2 / R$

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<u>AC Current</u>
Oscillates sinusoidally
$V_{max} = \sqrt{2}V_{rms}$, $i_{max} = \sqrt{2}i_{rms}$, so $P_{max} = 2P_{rms}$

<u>Magnetism</u>
Magnetic fields are created by magnetic dipoles in the material
-> Can also be created by a changing electric field
Symbol is B, units are tesla (T)
Field lines go from north to south
Created by wire: $B = \frac{\mu_0 i}{2\pi r}$, circles around wire (right hand rule tells direction)
Magnetic force (created by moving charge): $F = qvB\sin\theta$
-> Direction perpendicular to both charge velocity AND magnetic field
-> Find direction using RHR

APPLICATIONS:
Particle moving in magnetic field: set force equal to centripetal force to find *v*
We can also find whether wires are attracted to or repel each other

Faraday's law: changing magnetic field creates an electric field
-> So changing magnetic field creates a current
-> Current always goes AGAINST change in magnetic field
-> Loop of wire: if magnetic field decreases, current will be created to increase it back