



Unit 1 Electrostatics

- Law of conservation of charge
- Conductors
 - Charge distributes evenly throughout, does not hold its charge
 - Inside has zero net charge
- Insulator:
 - Charge will not distribute evenly, holds charge in one spot
- Grounded: object touches earth through conductor, electrons balance
- Ways to induce charge: friction, conduction, induction
- Coulomb's Law: $F_e = kq_1q_2/r^2$
 - Positive F_e : repel, Negative F_e : attract
- Electric fields: $E = F/q$, $E = kQ/r^2$ for a point charge
- Density of electric field lines proportional to magnitude of field, direction is direction of a positive charge
- Electric Field due to a continuous charge distribution: $E = \oint dE$
 - $dE = k/r^2 dq$
- Charge Densities:
 - $dq = \lambda dx$, $dq = \sigma dA$, $dq = \rho dV$
- Gauss' Law: Flux of an electric field: $\Phi = E \cdot A \cos \theta = \oint E dA = 4\pi k Q_{enclosed}$
- Gaussian Surfaces:
 - Symmetries: planar, cylindrical, spherical
 - Field needs to be tangent/perpendicular
- Electric Potential Energy:
 - Electric field is doing work on particle, goes from high potential to low potential energy, gaining KE, losing U
 - Must be a conservative force, $\Delta U = -Fd$
- Electric Potential: electric potential energy per unit charge in an area of space, positive plate is always high potential
 - $V_o = U_o/q$
- Potential Difference (voltage): $\Delta V = -W/q = \Delta U/q = -\int E dx$
 - $V = k \int dq/r$, V is a scalar!
- Equipotential Lines/Surfaces: perpendicular to electric field, regions of space at same electric potential
 - $E_s = -dV/ds$
 - If two charges are the same, pulling them apart increases potential energy, pushing them together decreases potential energy and vice versa for same charges

Unit 2 Conductors, Capacitors, & Dielectrics

- Capacitor: device that stores electric charge and energy, made up of two conductors separated by an insulator
 - $Q = C\Delta V$
- Parallel Plate Capacitor: $C = \epsilon_0 A/d$
- Isolated Sphere: $C = 4\pi\epsilon_0 a$
- Multiple Capacitors:
 - Parallel: $C_{eq} = C_1 + C_2 + \dots$
 - Series: $1/C_{eq} = 1/C_1 + 1/C_2 + \dots$
- Energy Storage: $\Delta U = QV/2 = Q^2/2C = Cv^2/2$
 - $U = \frac{1}{2} \epsilon_0 E^2 Ad$
 - Stored energy density: $\mu = \frac{1}{2} \epsilon_0 E^2$
- Dielectrics: nonconducting materials become ionized at dielectric breakdown 3×10^6
 - Since capacitors are limited by dielectric strength of air we introduce dielectrics to increase capacitance
 - They increase the electric field strength or increase the charge on the plates if there is a battery
 - $C = K C_{air}$
 - $\epsilon = k\epsilon_0$ = permittivity of material
 - $K > 1$ for capacitor with a dielectric
 - If a battery is connected, constant voltage
 - If grounded, constant charge

Unit 4 Magnetic Fields

- Magnetic Force: $F_m = q(v \times B)$
 - $r = mv/qB$ when $\sin \theta = 1$
 - Magnetic fields do no work because velocity never changes, only direction
- Right Hand Rule: thumb is velocity, fingers are magnetic field, palm is direction of force
- Current Carrying Wires: $dF = dq (dl/dt) \times B$
 - $F\mu = \int I dl \times B$
 - $B = \mu_0 I / 2\pi r$
- Biot-Savart's Law: when you can't use Ampere's law because the B-field is not constant
 - $dB = \mu_0 I dx / 4\pi r^2$
- Ampere's Law: basically Gauss's law, draw an amperian loop
 - $\oint B dl = \mu_0 I$
- Solenoids: bunch of tightly wound wires
 - $B = N \mu_0 I / l = B_s = \mu_0 I$

Unit 3 Electric Circuits

- Current: $I = dq/dt$
 - Current Density: $J = I/A$, $I = \oint J dA$
 - $J = neVd$
- Resistance: $R = V/I$, $R = L\rho/A$
 - $\rho = E/J$
- Ohm's Law: $V = IR$
- Power: describes brightness
 - $P = dW/dt = IV = I^2R$
- Electromotive force: $\epsilon = dW/dq$
- Kirchhoff's Loop Rule: $\Delta V = 0$ for closed loops
- Kirchhoff's Junction Rule: $I_{in} = I_{out}$ for any junction
- Emf = $V = \epsilon$ -ir, internal resistance of the source
- RC Circuits Resistor + Capacitor
 - Charging: $q = C\epsilon(1 - e^{-(t/RC)})$
 - $I = I_0 e^{-(t/RC)}$
 - Discharging: $q = q_0 e^{-(t/RC)}$
 - $I = I_0 e^{-(t/RC)}$
- Capacitors in Circuits:
 - Initial State: $t = 0$
 - $Q = 0$, $V_c = 0$, $I = V_b/R$
 - Steady State: $t = \infty$
 - $Q = CV_b$, $V_c = V_b$, $I = 0$

Unit 5 Electromagnetism

- Electromagnetic induction means generating electricity by using a magnetic field to produce a voltage
- Magnetic Flux: $\Phi = B \cdot A \cos \theta = \oint B dA$
 - Can be changed in three ways:
 - Changing magnetic field, loop area, angle
- Lenz's Law: fixes negative sign in Faraday by finding direction of induced current
- Faraday's Law: $\epsilon = -d\Phi/dt = -N d\Phi/dt$
- Inductors: typically a solenoid
 - $VI = 1/2 Li^2$, $\epsilon = -L di/dt$
 - $\Phi = LI$
 - Act open at $t = 0$
- LC Circuit: cycle between charged for each at opposite times
- LR Circuit: same as RC but time constant is R/L
- Maxwell's equations: changing E-field induces magnetic field and vice versa
 - Gauss' Law + Ampere's Law + Faraday