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Electrostatics
Unit 1 ↓

- 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: Fe = kq1q2/r^2
  - Positive Fe: repel, Negative Fe: 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 = ∮dE
  - dE = k/r^2 dq
- Charge Densities:
  - dq= λ dx, dq= σ dA, dq= ρ dV
- Gauss' Law: Flux of an electric field: Φ = E*A cos θ = ∮EdA = 4πkQenclosed
- 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, Δ U = -Fd
- Electric Potential: electric potential energy per unit charge in an area of space, positive plate is always high potential
  - Vo = Uo/q
- Potential Difference (voltage): ΔV = -W/q = ΔU/q = -∫Edx
  - V = k ∫ dq/r, V is a scalar!
- Equipotential Lines/Surfaces: perpendicular to electric field, regions of space at same electric potential
  - Es = -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

Conductors, Capacitors, Dielectrics
Unit 2 ↓

- Capacitor: device that stores electric charge and energy, made up of two conductors separated by an insulator
  - Q = CΔV
- Parallel Plate Capacitor: C = Eo A/d
- Isolated Sphere: C = 4πEoa
- Multiple Capacitors:
  - Parallel: Ceq = C1 +C2 +...
  - Series: 1/Ceq = 1/C1 +1/C2 +...
- Energy Storage: ΔU = QV/2 = Q^2/2C = Cv^2/2
  - U = ½ Eo E^2 Ad
  - Stored energy density: μ = ½ Eo 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 Cair
  - ε= kεo = permittivity of material
  - K > 1 for capacitor with a dielectric
  - If a battery is connected, constant voltage
  - If grounded, constant charge

Electric Circuits
Unit 3 ↓

- Current: I = dq/dt
  - Current Density: J = I/A, I = ∮J dA
    - J = neVd
- Resistance: R = V/I, R= Lρ/A
  - ρ=E/J
- Ohm's Law: V = IR
- Power: describes brightness
  - P = dW/dt = IV = I^2 R
- Electromotive force: = ε= dW/dq
- Kirchhoff's Loop Rule: ΔV = 0 for closed loops
- Kirchhoff's Junction Rule: In = Iout for any junction
- Emf= V=ε -ir, internal resistance of the source
- RC Circuits Resistor + Capacitor
  - Charging: q = Cε(1- e^(-t/RC)
    - I = Ioe^(-t/RC)
  - Discharging: q = qo e^(-t/RC)
    - I = Ioe^(-t/RC)
- Capacitors in Circuits:
  - Initial State: t = 0
    - Q = 0
    - Vc = 0
    - I = Vb/R
  - Steady State: t = ∞
    - Q = CVb
    - Vc =Vb
    - I =0

Magnetic Fields
Unit 4 ↓

- Magnetic Force: Fm = q(v xB)
  - r=mv/qB when sinθ = 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)xB
  - Fμ = ∫I dl xB
  - B = μoI/2πr
- Biot-Savart's Law: when you can't use Ampere's law because the B-field is not constant
  - dB = μoIdlxr/4πr^2
- Ampere's Law: basically Gauss's law, draw an amperian loop
  - ∮B dl = μoI
- Solenoids: bunch of tightly wound wires
  - B = N μoI/l = Bs = μoI

Electromagnetism
Unit 5 ↓

- Electromagnetic induction means generating electricity by using a magnetic field to produce a voltage
- Magnetic Flux: Φ = B*A cos θ = ∮BdA
  - 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: ε= -dΦ/dt = -N dΦ/d
- Inductors: typically a solenoid
  - Vl = 1/2Li^2, ε=-LdI/dt
  - Φ=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's Law
  - ∮B dl = μoI+ μo ε (dΦe/dt)

Test Tips

- Electrostatics is the most tested unit!
- Always list your givens at the start of the problem (m, v, a, F, etc.)
- If you are given a graph, do that problem first!
- Make sure you know how to integrate and differentiate (i.e. u-sub)
- Make relationships between variables clear
- Visualize, draw a picture, and draw your gaussian surfaces and amperian loops
- Apply all your laws!