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Review (→ in-class exam #1 on 2/27, covering Giordano ch.17-20)

- understand class notes
- understand text (key chapter sections noted on course webpage)
- tutorial problems
- HW problems

□ Have covered a wide range of topics so far, so we'll try to distill down the key concepts into a salient narrative here

$\boxed{1}$ Electric Forces + Fields (ch.17)

- charge is a fundamental property of matter
- protons, electrons, ions, ... → $e = 1.60 \times 10^{-19}$ C
- charge exerts force on charge → Coulomb's Law

$$\bar{F} = \frac{q_1 q_2}{4\pi\epsilon_0 r^2}\hat{r} = K\frac{q_1 q_2}{r^2}\hat{r} \quad \left(K = 9.0\times10^{9}\ \frac{Nm^2}{C^2}\right)$$

$\epsilon_0 = 8.85\times10^{-12}\ C^2/N\cdot m^2$

- superposition of forces → remember that force is a Vector (magnitude and direction)
- notion of a dipole (+ and − charge separated by a fixed dist.)
- notion of an electric field (think of analogy to gravity!)

$$\bar{F} = q\bar{E} \qquad (\bar{E} \text{ is a vector; } q \text{ is a 'test charge'})$$

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- Conductors vs. Insulators: How does charge move about?
- Electric Flux (think of water/pipe analogy!)

$$\Phi_E = \bar{E}\cdot\bar{A} \qquad (\text{dot product, } \underset{\downarrow}{\bar{A}} \text{ is area vector}$$
$$= EA\cos\theta \qquad \rightarrow \text{notion of a 'surface'})$$

- Gauss' Law: $\Phi_E = \underset{\substack{\uparrow \\ \text{sum over a} \\ \text{'closed surface'}}}{\sum} \bar{E}\cdot d\bar{A} = \oint_S \bar{E}\cdot d\bar{A} = \frac{Q_{enclosed}}{\underset{\substack{\nearrow \\ \text{charge contained inside} \\ \text{the closed surface}}}{\epsilon_0}}$

→ when symmetries exist (e.g. we can choose a surface over which $\bar{E}\cdot d\bar{A}$ is const./zero), Gauss' Law gives us a powerful tool for calculating electric fields

<u>NOTE</u>: remember that Gauss' Law sums the flux over the <u>entire</u> surface of the closed shape

$\boxed{2}$ <u>Electric Potential (ch.18)</u>

- energy stored as a result of electrostatic forces (think analogy to gravitational potential energy)
- potential energy is energy 'stored' due to work

e.g. energy between two point charges: $U_{el} = k\frac{q_1 q_2}{r}$

[things to think about: conservation of energy, superposition, conservative forces, ...]

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- Potential energy vs. 'potential': $V(\bar{r}) = \frac{U_{el}(\bar{r})}{q_0}$ ← 'test charge'

  → potential is created by some distribution of charge, but we often describe it in terms of how it would affect an (arbitrary) 'test charge'

  → we call V a 'voltage'

- Distinction between a 'potential' (V) and a 'potential difference' (ΔV)

  → a reference is sometimes important (hence the need for 'ground' when dealing w/ circuits)

- Field lines (e.g. equipotential lines)

- Capacitors $\Delta V = \frac{Q}{C}$ ($C = \frac{\epsilon_0 A}{d}$ for p.p. capac.)
  - storage of energy ($U_{el} = \frac{1}{2}C\Delta V^2 = \frac{1}{2}\frac{Q^2}{C}$)
  - different geometries (e.g. parallel-plates)
  - dielectrics ($C = K_0 C_0$)
  - capacitors in series vs. parallel

  → think in analogy to a mechanical spring

$\boxed{3}$ Electric Circuits (ch. 19)

- Current ($I = \frac{dq}{dt}$) → has a clearly defined direction.

  NOTE: positive charge moving L to R is same as negative charge R to L

- Battery: creates a potential difference (think of escalator analogy)

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$$R = \rho \frac{L}{A}$$

- Resistance (R)
  - conduction electrons and drift velocity → material property
  - resistivity (ρ)
  - notion of an 'ideal wire'

- Ohm's Law: $\Delta V = IR$ → resistance leads to power dissipation! ($P = I^2 R = I\Delta V = \frac{V^2}{R}$)

- Circuit Basics
  - ideal wires
  - junctions
  - circuit elements: batteries, resistors, capacitors
  - notion of 'ground'
  - elements in series vs. parallel
  - voltmeter, current meter (ammeter)
  - resistors in series, parallel

- Kirchoff's Laws

  a) Junction Law: $\sum I_{in} = \sum I_{out}$ (Conservation of charge)

  b) Loop Law: $\Delta V_{loop} = \sum_i \Delta V_i = 0$ (conservation of energy)

  → practice, practice, practice! Also make sure its clear how these 'laws' relate to changes in electric potential as one moves around a circuit

- RC circuits ⇝ things can now change w/ time!

  - simple RC circuit in series: $\Delta V_B - \underset{\substack{\uparrow \\ \Delta V_R}}{IR} - \underset{\substack{\nwarrow \\ \Delta V_c}}{\frac{Q}{c}} = 0$

  where $V_c(t) = \frac{Q(t)}{c}$

  → $I(t) = I_0 e^{-t/\tau}$ ($\tau = RC$)

4] Magnetism (ch.20)

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- basics of magnets — field lines flow in **loops**
  - no magnetic monopbles (i.e. there is always a S and a N)
  - earth has a magnetic field → compass
  - certain materials are 'magnetic' (e.g. iron)
  [etc....] incl. electromagnets

- Current-carrying → magnetic field
  - Right-hand rule (RHR)
  - convention for drawing things (x = into page, etc...)

- Ampére's Law
  - means to determine $|\bar{B}|$ (magnetic field 'strength')
  - notion of a 'line Integral'

$$\sum_{\substack{\text{closed}\\\text{path}}} B_{\parallel} \Delta L = \oint_c \bar{B} \cdot d\bar{s} = \mu_0 I_{\text{enclosed}}$$

$$\mu_0 = 4\pi \times 10^{-7} \ \text{T}\cdot\text{m/A} \quad (\text{permeability of free space})$$

→ provides us w/ a means to determine the magnetic field strength (given certain symmetries are satisfied, otherwise the math can be difficult)

- Loops vs. Coils vs. solenoids vs. straight wire : $B_{\text{wire}} = \dfrac{\mu_0 I}{2\pi r}$

$$B_{\text{loop}} = \frac{\mu_0 I}{2R} \qquad B_{\text{coil}} = N\frac{\mu_0 I}{2R} \qquad B_{\text{solenoid}} = \frac{\mu_0 N I}{L} \quad (L >> R)$$

- Magnetic forces ⇝ $\overset{\text{cross-product}}{\text{use RHR \#2!}}$ $\bar{F}_m = q(\bar{v} \times \bar{B})$
  - current carrying wires
  - moving charges in magnetic field
  - Hall effect