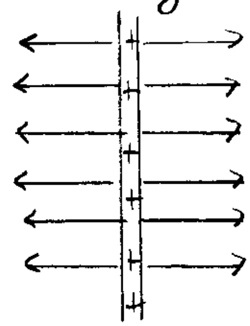
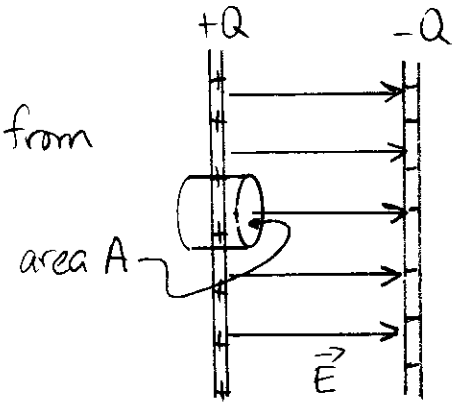
GENERAL REVIEW

1) Finding Electric Fields.

- For point charges use Coulombs Law $\vec{E} = \left(\frac{1}{4\pi\epsilon_0}\right)\frac{q}{r^2}\hat{r}$
- Field lines originate on + charges and end on − charges.
- Use symmetry: for example, for an infinite plane of + charge the electric field is outward:



- $|\vec{E}|$ is strongest where lines are close together ⇒ in this example $\vec{E}$ is independent of distance from the plane



- In simple geometry we can often find $\vec{E}$ from Gauss's Law. $\Phi = Q_{inside}/\epsilon_0$

  Here

  $\Phi = A \cdot E$ charge per unit area

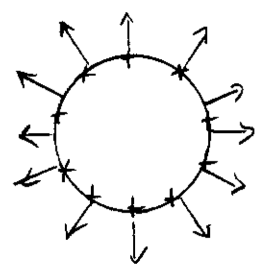
  $Q_{in} = \sigma \cdot A$

  ⇒ $A \cdot E = \frac{\sigma A}{\epsilon_0} \Rightarrow E = \sigma/\epsilon_0$

- Uniform spherical shell of charge

  Inside $E = 0$

  Outside E = same as point charge

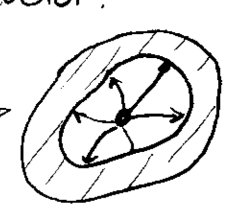


- **CONDUCTORS**: $E = 0$ everywhere within the conductor.

  E is always $\perp$ to the surface outside.

  Point charge inside a hollow conductor →

  ⇒ all field lines end on inner surface



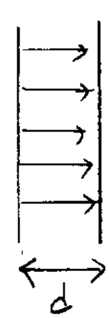
2) Electric Potential (Voltages).

$\vec{E}$ points "downhill" from higher V to lower V.

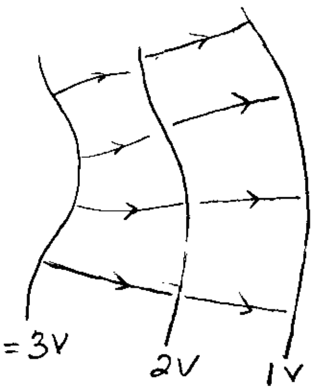
E can be written in volts/m. For ∥ plates

$$\Delta V = E \cdot d$$

$\Delta V = E \cdot d$ applies over any region where $E \simeq$ constant.



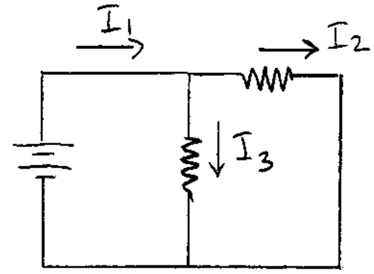
- Remember about equipotentials
  $\vec{E} \perp$ to equipotential surfaces



- Voltage and Potential Energy
  U = electric potential energy of a point charge $= q \cdot V$

Releasing a particle at higher voltage $\Rightarrow$ PE converted to KE.

3) CIRCUITS.



Resistors: currents flow from higher V to lower V.

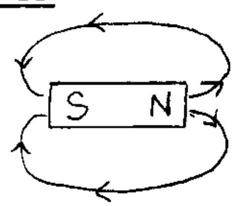
Kirchhoff's Rules

- At each node sum of currents in = sum of currents out
  $I_1 = I_2 + I_3$ in circuit above
- Sum of the voltage changes around any closed loop = 0

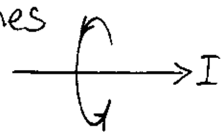
I stands for current passing through a given element

V stands for voltage difference across an element

4) Sources of Magnetic Fields

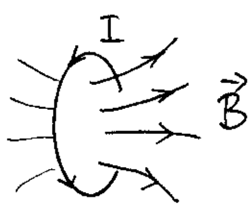


- Straight wire $\Rightarrow$ Field lines circle the wire



$B = \frac{\mu_0 I}{2\pi r}$ for infinitely long wire

- Loop



↳ Right-hand rule – with thumb along I, fingers show direction of B.

- Solenoid is a nice way to make a uniform B.

5) Magnetic Forces

- Force on a moving charge $= \vec{F} = q\vec{v} \times \vec{B}$
  Gives circular motion for constant $\vec{B}$.
- Force on a length of wire: $\vec{F} = I\,d\vec{\ell} \times \vec{B}$
- Magnetic dipoles $|\vec{\mu}| = NIA \Rightarrow$ dipoles orient along $\vec{B}$ like a compass needle

6) EM Induction

- A changing magnetic field generates an induced EMF. We get an induced current as well if there is a conduction path.
- $\Phi = BA\cos\theta$ or $\Phi = \int \vec{B}\cdot\hat{n}\,dA$
- Faraday's Law
$$\mathcal{E} = -\frac{d\Phi_m}{dt}$$
- We can change Φ_m by changing i) B, ii) A, iii) θ.
- Motional EMF: $\mathcal{E} = vBL$.

7)

- Inductors $V = L\frac{dI}{dt}$ $\quad U = \frac{1}{2}LI^2$
- Capacitors: $Q = CV$ $\quad U = \frac{1}{2}CV^2$

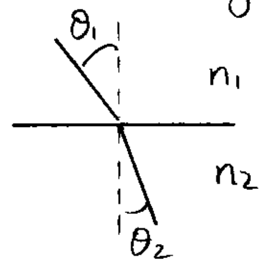
- AC circuits: Inductors and capacitors have an effective resistance of $X_L = \omega L$ and $X_C = 1/\omega C$

8) EM WAVES:

$\vec{E} \perp \vec{B}$ with $E = cB$ $\quad c = \frac{1}{\sqrt{\epsilon_0\mu_0}}$

- u = stored energy = $\frac{1}{2}\epsilon_0 E^2 + \frac{1}{2\mu_0}B^2$
- $I \propto E^2$
- $\lambda \cdot f = c$ with $\lambda = 400$-$700\,nm$ for visible light.

9) Ray Optics



- Law of refraction $n_1\sin\theta_1 = n_2\sin\theta_2$

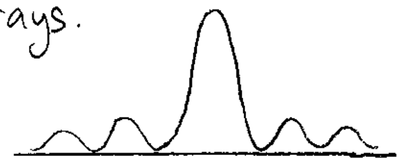
- Lenses + mirrors $\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$

$$M = \text{magnification} = -\frac{q}{p} = \frac{\text{image size}}{\text{object size}}$$

- m = magnifying power relates to how big the image is on the retina of our eyes

10) <u>Wave Optics</u>

- Constructive interference $\Rightarrow$ waves in phase at point of observation
  pathlength difference $\delta = (\text{integer}) \cdot \lambda$
- Double slit $\delta = d \sin\theta = m\lambda$
- Diffraction grating $d \sin\theta = m\lambda$
- Thin films $\delta = 2t$ for $\perp$ rays.
- Diffraction : minima @
  $\sin\theta = m\lambda / a$

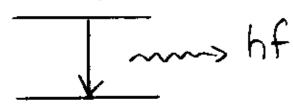


11) <u>Photons</u> $E = hf$ $p = E/c$ like zero-mass particles

- photoelectric effect : $K_{max} = hf - \phi$
- blackbody spectrum
- Compton scattering : energy and momentum conserved.

12) <u>deBroglie waves</u>: $\lambda = h/p$ where $p = mv$

- Schrodinger's Equation $\Rightarrow$ energy quantization
- Probability Distribution $P(x) = |\psi(x)|^2$



- Quantum Numbers for Hydrogen

$n \longrightarrow$ energy

$\ell \longrightarrow$ magnitude of $\vec{L}$ $\quad L = [\ell(\ell+1)]^{\frac{1}{2}} \hbar$

$m \longrightarrow L_z$ $\quad L_z = m\hbar$

$\ell = 0, 1, \cdots, n-1$

$m = -\ell, \cdots, +\ell$

13) <u>Relativity:</u>

Time dilation $\Delta t = \gamma \Delta t_p$

Momentum $p = \gamma m v$

Kinetic Energy $KE = (\gamma - 1) mc^2$ $\quad E_0$ = rest energy $= mc^2$

Rel. Velocities $u' = (u - v)/(1 - vu/c^2)$

14) <u>Radioactivity</u> $A = \lambda N$

$N = N_0 e^{-\lambda t}$ $\quad t_{1/2} = \ln 2 / \lambda$.