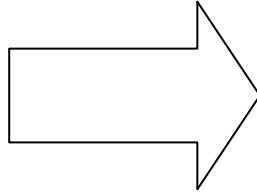


2nd Semester AP Physics (Ashwin Jacob)

Electrostatics

3 Rules of Electrostatics

1. Like charges Repel
2. Opposite charges attract
3. Charges Objects attract neutral objects

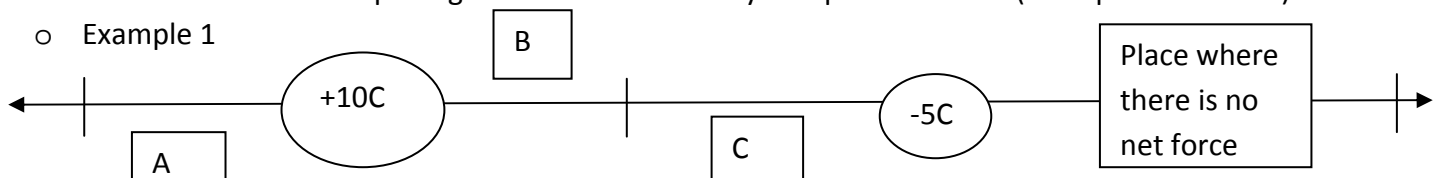


Only transfer of electrons that produce charging!

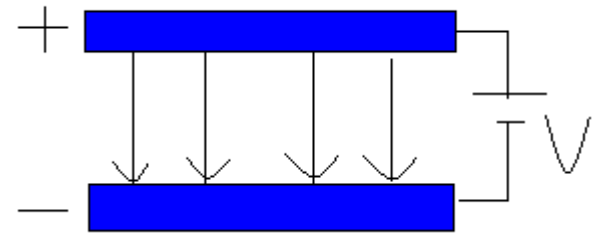
- Insulators- Keep charge in place
 - Example: When you charge a balloon. It has charge only on the surface area that you charged it on; the other surface areas have neutral charges.
- There are two types of charges
 - Charge by Contact (Example: Friction)
 - Induction(Example: Redistribute and separate or grounding)
 - The electrons in the top of electroscope move down to the bottom, the electroscope is temporarily polarized, with the top positive and the bottom negative when your hand touches the top of the electroscope, the electrons flow from the bottom into your hand, and when you take your hand away, the entire electroscope becomes positive(Julia Wang's Example)

Vector	Scalar(Sign matter)
$\vec{F}_e = k \frac{ q_1 Q_2 }{r^2}$	$U_e = k \frac{qQ}{r}$
$\vec{E} = k \frac{ Q }{r^2}$	$V = k \frac{Q}{r}$
$\vec{F} = q\vec{E}$	$W = -\Delta U_e = -q\Delta V$

- Please note that in vectors the sign do not matter because you are using directions
- **Coulomb's Law:** The force of attraction or repulsion between two point charges is directly proportional to the product of the two charges and inversely proportional to the square of the separation between the charges.
- If you see "μC", the symbol mean micro-coulombs, so you multiply your value by ___ *10⁻⁶
- Electric Fields go way if positive and electric field go towards if negative(this is for a positive electric field which makes sense with the **3 laws**)
- If they ask you to find the Electric Field first, then they ask you to find the Force, just use $\vec{F} = q\vec{E}$ to find F
 - If the value of q is negative then make sure you flip the direction(Example NW → SW)



- Example 1 shows where there is a neutral charge in the electric field
- Formula for finding total charge
 - $Q = Ne^-$
 - $e^- = 1.6 * 10^{-19} \text{ C}$
- Parallel Plate Apparatus
 - No matter where the electron is, the value of the Electric field is the same
 - Electric Field Formula(ONLY for Parallel Plate)
 - **Please note that this formula only applies to parallel plate and other formulas do not work in this situation**
 - $\vec{E} = \Delta V/d$
 - Please note that if the electron was suspended
 - Then the electron's weight would equal to F_e
- Accelerating Plates
 1. $\vec{F}_{net} = ma$
 2. $a = \frac{\vec{F}_{net}}{m}$
 3. $a = \frac{q\vec{E}}{m}$
 4. $\vec{a} = \frac{qV}{md}$
- Deflecting Plates
 - If you had a problem with electricity to calculate the distance it travels vertically, then you can use kinematics
 - $y_f = \frac{1}{2}at^2$
 - $x = v_x t \rightarrow$ This equation can help you find "t"

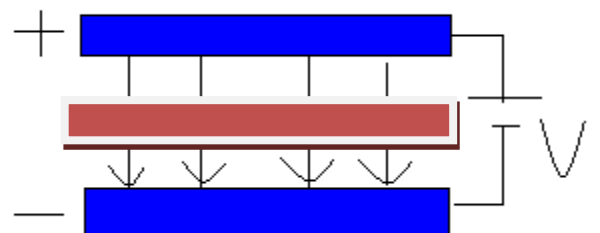


Scalars

****SIGNS MATTER****

- You can use Electric Potential Energy to find the speed of an electron or proton or whatever the question states using $U_e = K$
- K is still $\frac{1}{2}mv^2$
- Electric field lines are perpendicular to equipotential lines(Red Line in Picture 1)
- If the problem contains the word potential energy it is U, but if it contain the word potential without energy it is V
- Voltage is stationary and a static quantity
- Charge is a movement because of voltage
- High Voltage always wants to move to low current
- Voltage is Joules per Coulomb of Charge

Scalar(Sign matter)
$U_e = k \frac{qQ}{r}$
$V = k \frac{Q}{r}$
$W = -\Delta U_e = -q\Delta V$



Picture 1

Capacitance

- Stores Charge between 2 Plates

$$Q = CV \quad C = \epsilon_0 k \frac{A}{d} \quad U_e = \frac{1}{2} QV = \frac{1}{2} CV^2$$

Q= Charge

C= Capacitance (**CONSTANT VALUE**)

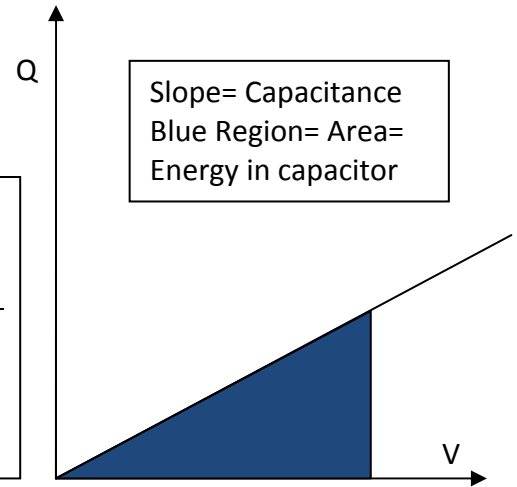
V= Voltage

$$\epsilon_0 = 8.85 \times 10^{-12}$$

K= Dielectric Constant Air (if without k then it's air because A=1)

A= Area of capacitor

d= Distance between capacitor



- Parallel Capacitor Rules (Means that each capacitor has equal access to power supply)

1. Voltage is Same

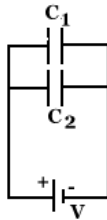
$$V_T = V_1 = V_2 = V_3 = \dots$$

2. Total Charge Displaced

$$Q_T = Q_1 + Q_2 + Q_3$$

3. Capacitance

$$C_T = C_1 + C_2 + C_3 + \dots$$

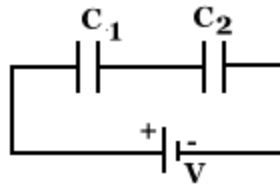


- Series Capacitor Rules

1. $Q_T = Q_1 = Q_2 = Q_3 = \dots$

2. $V_T = V_1 + V_2 + V_3 + \dots$

$$3. \frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots$$



Resistors

- Friction that regulates the flow of charge in a circuit ($R = e \frac{L}{A}$)
- Measured in OHMS
- Current- Rate that charges move! (Amount of energy moving at time)

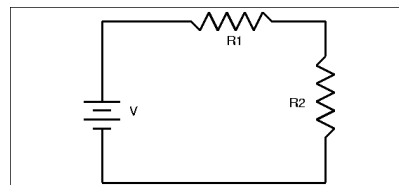
$$I = \frac{Q}{t} = 1 \text{ AMP!}$$

1. Series Resistors Rules

$$2. I_T = I_1 = I_2 = I_3 = \dots$$

$$3. V_T = V_1 + V_2 + V_3 + \dots$$

$$4. R_T = R_1 + R_2 + R_3 + \dots$$



- Parallel resistors

$$1. V_T = V_1 = V_2 = V_3 = \dots$$

$$2. I_T = I_1 + I_2 + I_3 + \dots$$

$$3. \frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$$

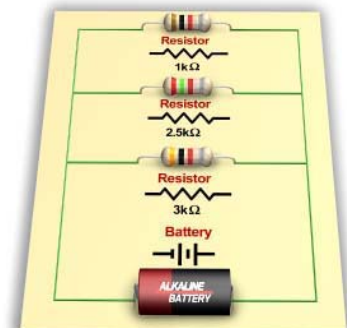


Figure 4

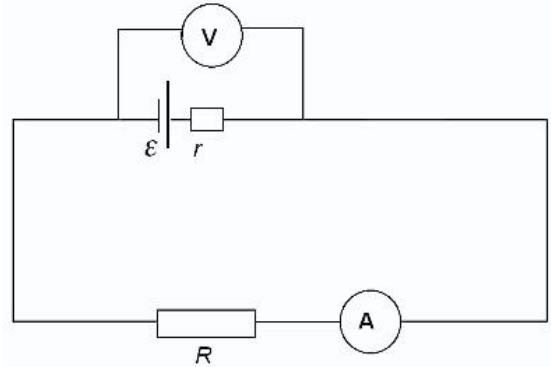
Circuits

- Power Equations

$$1. p = \frac{W}{t} = \frac{qV}{t}$$

2. $P = IV$
3. $P = I^2R$
4. $P = \frac{V^2}{R}$

- If you have a current and a resistor in one circuit, then after a long period of time the resistors will have no current because of the capacitors
- Battery's Job is to flow energy from + \rightarrow -
- Internal Resistance
 - Friction in the battery
- Terminal Voltage
 - Operating Voltage
 - Same number that charges it by a little bit
 - $V_T = \varepsilon \pm iR$
 - E = Stamped value or given value of Voltage (EMF)
 - I = internal Resistance
 - R = current thru battery
 - "Negative" if current flows from Negative to Positive thru the Battery(1 Battery or if battery working together)
 - "Positive" if current flows from Positive to Negative thru Battery (Hooking up another battery)



Magnetism

- Earth's Geographic North(South) = Magnetic South(North)
- Force acting on a current bearing wire in B field
 1. Current(I)
 2. B Field(T)
 3. Length of wire in the B-field(m)
 4. Result: $\vec{F}_b = \vec{B}il \sin \theta$
 - $B = \frac{F}{il} = T$
- Right Hand Rule
 - ✎ Finger: Magnetic Directional Field (N \rightarrow S) aka B-Field
 - ✎ Thumb: Wire, Current, or charge
 - ✎ Palm: Force
 - ✎ "X" means into the paper(Magnetic Direction) while circles means out of the paper(Magnetic Field)
- **The force on a charged particle in a magnetic field is always perpendicular, so no work is done in this case. They ask this on just about every AP test somewhere.**
- Magnetic Force moving in a B-Field
 1. $\vec{F} = \vec{B}il \sin \theta$
 2. $\vec{F} = \vec{B} \frac{q}{t} l \sin \theta$

$$3. \vec{F} = qv\vec{B} \sin \theta$$

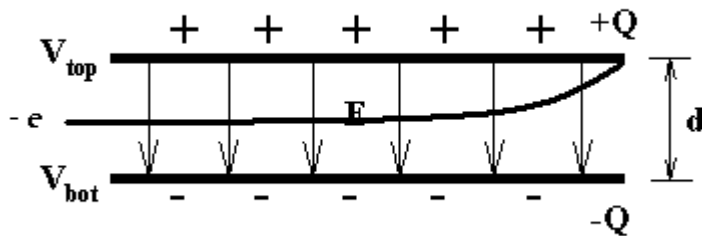
- Charge Moving in a Magnetic Field

$$1. \vec{F}_B = \vec{F}_c$$

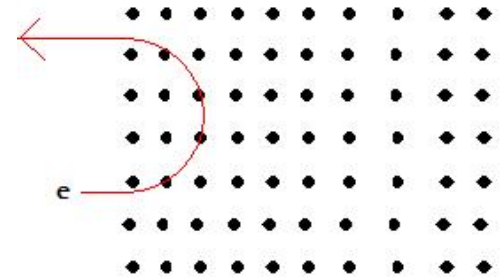
$$2. qv\vec{B} = \frac{mv^2}{r}$$

$$3. r = \frac{mv}{q\vec{B}}$$

- Charge moving in a magnetic field moves in a circular path while a charge moving in a parallel plate moves in a parabolic path



Picture 3- Parallel Plate



Picture 2a- Magnetic Field

- Velocity Selector

$$\circ \vec{F}_B = \vec{F}_E$$

$$\circ qv\vec{B} = q\vec{E}$$

$$\circ v = \frac{\vec{E}}{\vec{B}}$$

- 2nd Right hand Rule

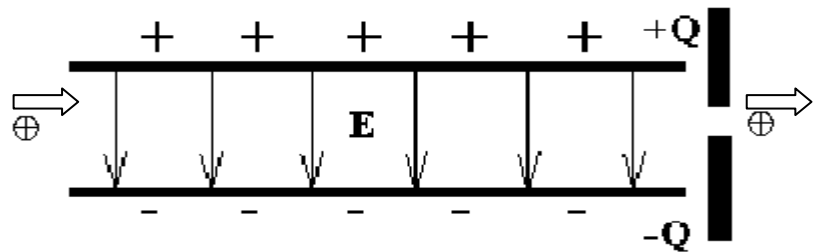
- Determines the direction that the B-Field circulates around current bearing wire
- Point thumb to direction of current or I and curve fingers around the B-field

- Ampere's Law

$$\circ \sum B_H \Delta l = \mu I$$

$$\circ \vec{B} = \frac{\mu I}{2\pi r}$$

$$\blacksquare \text{ Where } \mu = 4\pi * 10^{-7}$$



Faraday's Law of E/M Induction

$$\bullet \Phi_B = \vec{B}\vec{A}$$

$$\bullet \frac{\Delta\Phi_B}{\Delta t} = \text{Volt}$$

$$\bullet \varepsilon = -N \frac{\Delta\Phi_B}{\Delta t}$$

$$1. \varepsilon = -N \frac{\Delta A}{t} B$$

$$2. \varepsilon = -N \frac{\Delta B}{t} A$$

- 3rd right hand Rule

- Wrap around in direction of current

- Lenz Law- The Induced current in a conductor must flow in a direction such that the induced magnetic Field opposes the changing flux that created it in the 1st place!
 1. Is the Flux Increasing or Decreasing? Then take the opposite of that for the magnetic field
 2. What direction is the flux? Same direction for magnetic field
- $B = n\mu_0 I$ (Another Equation for B-Field)

Harmonics

- Period-Time it take, in seconds, to complete 1 cycle (T) sec.
 - $T = 2\pi \sqrt{\frac{l}{g}}$
 - $T = 2\pi \sqrt{\frac{m}{k}}$
- Frequency- The number of cycles completed in 1 second (f) Hertz (1/s)
- Frequency and Period are reciprocals $T=1/f$
- $E_t = U_e = 1/2kA^2$
 - A= Amplitude
- $v(x) = \sqrt{\frac{K(A^2-x^2)}{m}}$

Hooke's Law

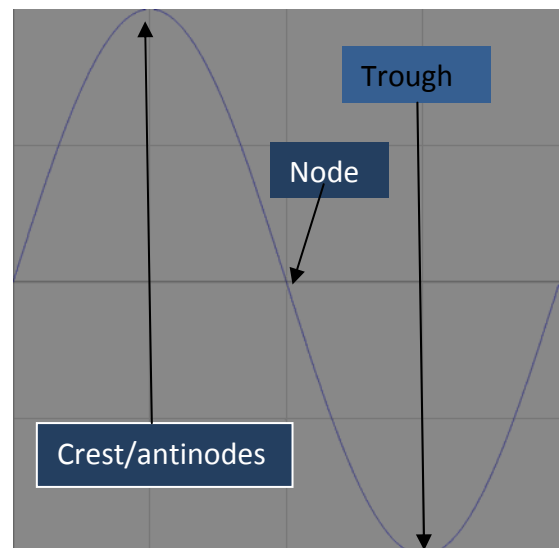
- $F = -kx$
- $ma = -kx$
- $a = -\frac{k}{m}x$

Other Notes

- Longitudinal Waves: Travels same direction as medium; Example: Sound
- Transversal Waves: Travels perpendicular to medium; Example: Light
- In Phase: Crest to Crest/ Trough to Trough
- Wave- Energy moving at 1 point to another via a medium

Waves and Sounds

- Wavelength is the distance between successive points on a wave(m)
- $v = f\lambda$
- $v_{string} = \sqrt{T/\mu}$
 - μ = mass/ length
- $f_n = \frac{nv}{2L}$, $n=1,2,3,4,\dots$
- Standing wave- interference patterns between incoming (Incident) waves and reflected waves that produce Constructive (antinodes) and destructive interferences (Nodes)



- $v_{\text{sound}} = 330 + (C)(0.6)$ where C= Degrees Celsius
- Closed Wave
 - $f_n = \frac{nv}{2L}$ where n= odd integers
- **Overtone**- harmonic after fundamental series
- Speed depends on the mediums elasticity. When a wave travels from one medium to a different medium the speed & wavelength change. However the **frequency** remains the same.
- **Open Tubes**: Same as strings, multiples of $\frac{1}{2}$ waves. But the waves look a little different, since the ends aren't fixed.
- **Closed Tubes**: Closed tubes hold multiples of $\frac{1}{4}$ waves.
- **Strings**: Only multiples of $\frac{1}{2}$ wavelengths can fit on a vibrating string that is held fixed at each end.

Resonance

- Resonance- when a system is made to vibrate at its natural frequency

Doppler Effect

- Sound is clicking so many times that we think it is continuous
- Pitch is correlated with frequency
- Trains is creating more and more as it is moving → crushing of waves and Greater Frequency
- $\lambda' = \lambda \pm v_s T$
- $f' = f \left(\frac{v}{v \pm v_s} \right)$
 - Positive- source moving away from observer
 - Negative- Source moving towards observer
- $f' = f \frac{v \pm v_0}{v}$
- Results of the two: $f' = f \frac{v \pm v_0}{v \pm v_s}$

Beats Frequency

- $f_b = |f_1 - f_2|$
- Difference between 2 waves
- Number of cycles(of beats) per second

Torque

- 1st Condition of Equilibrium
 - $\sum F_x = 0 \rightarrow T_x = F_x$
- 2nd Condition of Equilibrium
 - $\sum F_y = 0 \rightarrow T_y = F_y$
- 3rd condition
 - $\sum T = 0$
- $\tau = \vec{F} \times \vec{l}$
 - The "L" is a moment arm- vector that measures from axis of rotation to force

Reflection

- Any angles are given by the Normal
- Law of Reflection
 - $\theta_i = \theta_r$

Refraction

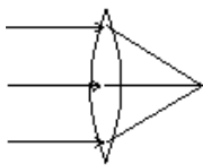
- Refraction- the bending of light as it enters the new medium
 - Light Bends
 - The Speed of Light is different in the new medium
- Law of Refraction (Robert Snell's Law)
- - $n_1 \sin \theta = n_2 \sin \theta$
 - Optical Density goes with Physical Density (n_1)
 - n_1 also equals Index of refraction
- $v_x = c/n_x$
 - $C = 3 * 10^8$ m/s
- Critical Angle
 - $\theta_c = \sin^{-1} n_2/n_1$
 - Critical Angle is when $n_1 > n_2$
 - If θ_i (incident angle) $> \theta_c$ then it reflects
 - If $\theta_c > \theta_i$ then Gone with the air
- Another equation for Refraction: $\lambda_2 \sin \theta_1 = \lambda_1 \sin \theta_2$

From a less dense to more dense medium	From a more dense to less dense medium
Light moves <i>slower</i>	Light moves <i>faster</i>
The frequency is unchanged	The frequency is unchanged
So wavelength is shorter	So wavelength is longer
So light <i>bends toward</i> the normal	So light <i>bends away from</i> the normal

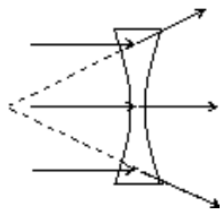
Mirrors

Converging	Diverging
Concave Mirror ---(Convex Lens	Convex Mirror ---) Concave Lens

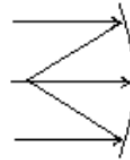
Converging Lens
Convex Lens



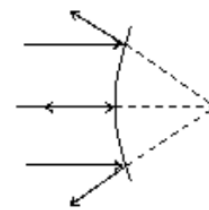
Diverging Lens
Concave Lens



Converging Mirror
Concave Mirror

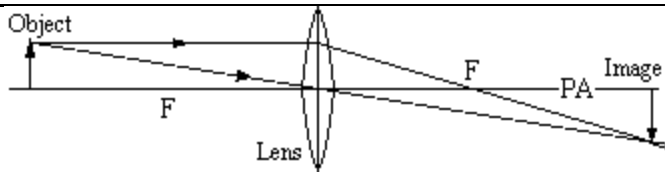


Diverging Mirror
Convex Mirror



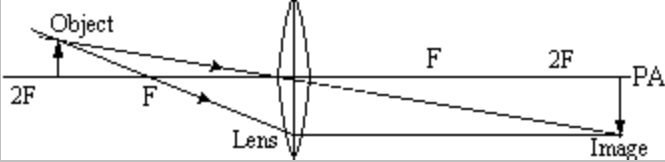
Images Formed by Converging Lens

Image	Description
<p>Distant Object</p>	<ol style="list-style-type: none"> 1. Real 2. Inverted 3. Size(Smaller)



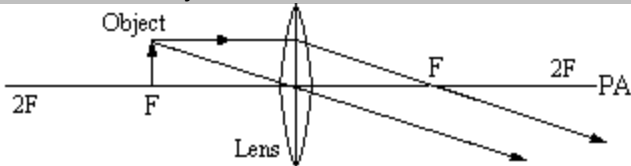
1. Real
2. Inverted
3. Same Size

Object at 2f



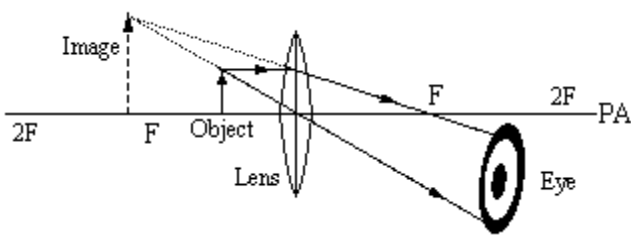
1. Real
2. Inverted
3. Larger

Object between 2F and F



1. No Image
2. (Blank)
3. (Blank)

Object at F



1. Virtual
2. Upright
3. Larger

Object between F and lens

Images formed by Diverging Lens

- Always Virtual, Upright and Smaller

Equations

- $\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$

➤ f = "+" if convergent; "-" if diverging (Measured from f to center)

➤ d_i = "-" if virtual; "+" if real

➤ d_o = always positive

- $M = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$

➤ Heights = "+" if right side up; "-" if down

Steps

Converging

Convex Lenses

1. Draw incident ray from object parallel to principle axis & refracting through focal point of opposite side
2. Draw incident ray from object traveling through focal point refracting through lens to be parallel to the principal axis
3. Draw incident ray from object through center of lens w/o refraction

Concave Mirror

1. Draw incident ray from object parallel to principle axis & reflecting through F at lens
2. Draw incident ray from object through F & reflecting parallel to principle axis at lens

Diverging

Concave Lens

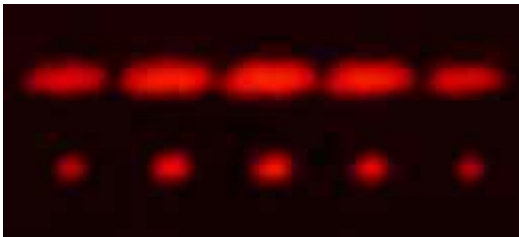
1. Draw incident ray from object parallel to principle axis & refracting imaginarily to F on object side
2. Draw incident ray from object towards F on opposite side but refracting parallel to principal axis at the lens, extend the horizontal line backwards towards the object
3. Draw incident ray from object through center of lens

Convex Mirror

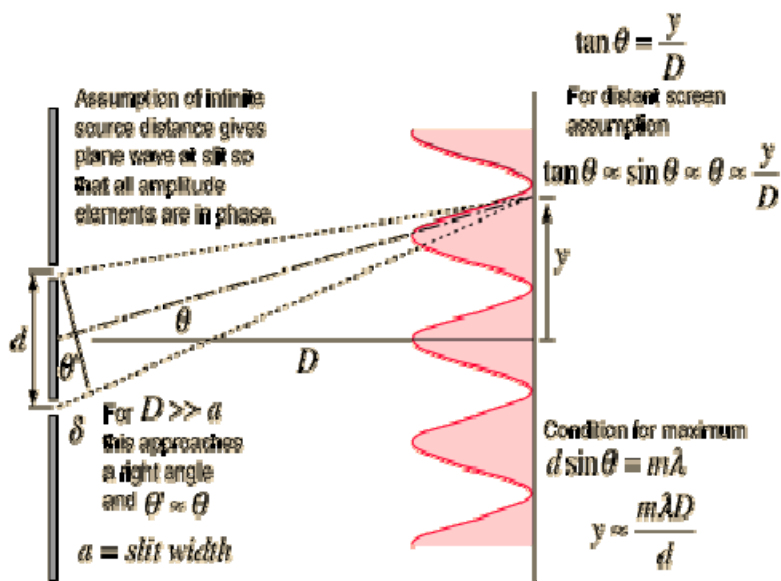
1. Draw incident ray from object towards F on opposite side but refracting parallel to principal axis at the mirror
2. Draw incident ray from object parallel to principal axis refracting at the lens towards F on the opposite side

Diffraction

➤ Definition: The unique ability of waves to bend around corners and obstacles



Example of Diffraction Splits



➤ For small θ ,

○ $\lambda = \frac{dx}{ln}$

○ Good for Light

➤ For all types of problems

○ $d \sin \theta = n \lambda$

➤ Straight across beam it is the brightest, then as it goes upwards it becomes dimmer

➤ Min. Path=1 Wavelength

➤ And the n refers to the order of the slit

Thin-Film Interference

➤ Review of Vocab

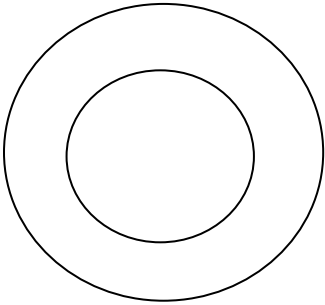
- Hard Reflection: Changes wave from crest \leftrightarrow Trough (Low to High " n ")
- Soft Reflection: High " n " to low " n "

➤ A reflected ray will change phase by 180° when going from a medium with a low n to a medium with a high n .

🔪 To find Constructive or destructive interferences you set $2T$ (which T =Thickness of thin film) and set that equal to λ over n or $2n$

- Deciding upon n or counts on the thin film Problem

🔪 Example 1 : Soft Bubble; Hard Reflection then Soft Reflection; $n=1$ then $n=1.33$ then $n=1$



First, you know that Hard Reflection = out of phase and Soft Reflection= In Phase. So a constructive interference means that $2t=\lambda/2n$ and $2T= \lambda/n$ for destructive interference. Remember all you need to remember are the definitions and setting up a constructive and destructive interferences.

Modern Physics

Max Planck

$$E = hf = h\left(\frac{c}{\lambda}\right)$$

🔪 E = Energy of the **photon**

🔪 H = Planck's constant

🔪 F = frequency

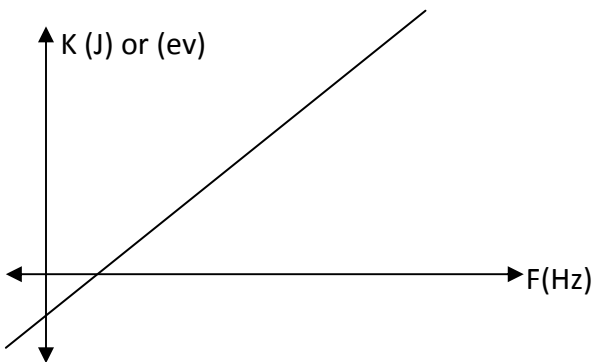
Photoelectric Effect

🔪 Applied to Plank's Theory

🔪 Einstein's Photoelectric effect formula

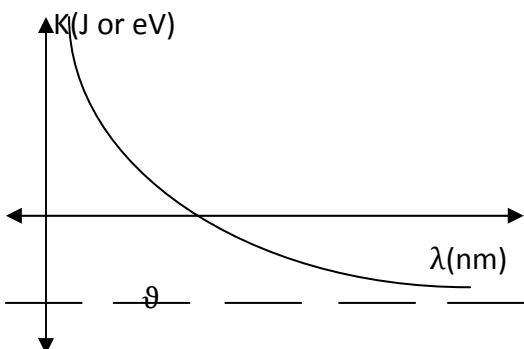
- $K = hf - \phi = h\left(\frac{c}{\lambda}\right) - \phi$

- ϕ = work function(electron absorption to break away)



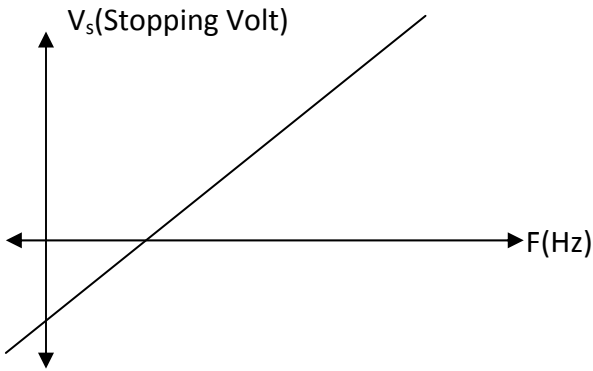
Y-Axis Intersection: Work Function
X-Axis Intersection: $f_c = \phi/h$ this is cutoff frequency
Slope: h (Planck's constant)

🔪 Note that $1\text{eV}=U_e=e^- \cdot 1.6 \cdot 10^{-19} \text{J}$



Asymptote is the work function

X-Axis: $\lambda_t = \frac{hc}{\phi}$ (Threshold Wavelength) anything longer does not produce photons



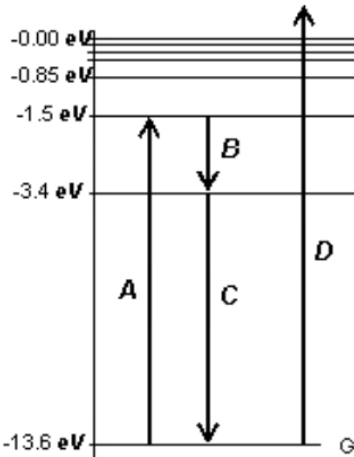
Same thing as Graph 1, but this time we notice that the Value of V_s is equal to the K of the photoelectron in eV!!!!

Light/Wave Duality

- ⚡ Plank's Theory connects Particles and waves
- ⚡ D'Broy Wavelength $\lambda = \frac{h}{p}$
 - $P=mv$ also
- ⚡ Wave= Precise Wavelength \rightarrow Precise Momentum
- ⚡ Adding waves \rightarrow Range of Momentum

Spectrum

- $R=109,677.58 \text{ cm}^{-1}$
- HYDROGEN Spectrum: $\frac{1}{\lambda} = R\left(\frac{1}{m^2} - \frac{1}{n^2}\right)$
- $|E_1 - E_2| = hf \rightarrow$ shows idea that electron jump \rightarrow Photon



- $E_n = \frac{-13.6 \text{ eV}}{n^2} (Z^2)$
 - Equation used to calculate energy associated with certain levels
- Downward Arrows= Emission Lines(Higher Energy to Lower Energy)
- Upward Arrows= Absorbtion Lines (Lower Energy to Higher)
- $r = n^2 r_0$
 - This only works for Hydrogen and other hydrogen like atoms
- Any kind of Binding Energy= negative energy

Nuclear Physics



- A- Nuclear #= Protons plus Neutrons
- Z- Atomic #= # of protons
- Neutron Number = A-Z

- **Binding Energy:** Total mass of a stable nucleus is less than the component protons and neutrons
- ***Binding Energy= Time Consuming Problem****