Final Exam Review

Monday, December 07, 2009
11:21 AM

Maxwell's Equations

$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{in}}{\epsilon_0}$	Gauss's law
$\oint \vec{B} \cdot d\vec{A} = 0$	Gauss's law for magnetism
$\oint \vec{E} \cdot d\vec{s} = -\frac{d\Phi_m}{dt}$	Faraday's law
$\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{through} + \epsilon_0\mu_0 \frac{d\Phi_e}{dt}$	Ampère-Maxwell law

Lorentz Force Law:

$$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$$

Biot-Savart Law

$$d\vec{B} = \frac{\mu_0}{4\pi} \frac{I\, d\vec{s} \times \hat{r}}{r^2}$$

Chapter 33:

$$\vec{F} = q\vec{v} \times \vec{B}$$

$d\vec{F} = I\, d\vec{s} \times \vec{B}$, Force on current segment

$\vec{F} = I_0 \int d\vec{s} \times \vec{B}$ Force on wire

$\vec{F} = I\vec{L} \times \vec{B}$, Force on straight wire in uniform B-field

$\vec{\tau} = \vec{\mu} \times \vec{B}$, $\vec{\mu} = I\vec{A}$, $U = -\vec{\mu} \cdot \vec{B}$

$$d\vec{B} = \frac{\mu_0}{4\pi} \frac{I\, d\vec{s} \times \hat{r}}{r^2}$$

1. B-field from finite straight wire
2. B-field from ∞-ite " "
3. B-field from circular arc (@ r=0)
4. B-field from hoop on-axis (r=0)

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{enc}$$

1. ∞-ite straight wire
2. ∞-ite straight wire, finite thickness
3. Solenoid
4. toroid

Applications:
- Force between two straight current carrying wires
- Hall effect

Chapter 34:

$F = qE + q\vec{v}\times\vec{B}$

Motional Emf:

- Bar being dragged through uniform B-field @ Constant Velocity:

  $qE = qvB$, $\mathcal{E} = E\ell \Rightarrow \mathcal{E} = vB\ell$

$\oint E\cdot ds = -\frac{d\Phi_B}{dt}$

- $\Phi_B = \underset{\text{\# of turns}}{N}\int \vec{B}\cdot d\vec{a}$, $\oint \vec{E}\cdot d\vec{s} \equiv \mathcal{E}$
- Lenz's Law
- $\frac{dB}{dt}$, $\frac{dA}{dt}$, angle between $\vec{B}$ + $\vec{A}$ changes with time
- E-field Exists without physical "ring"
- Back Emf for inductor, transformers

Applications:

Inductors + self inductance

$\mathcal{E}_{back} = -N\frac{d\Phi_B}{dt}$, $\Phi_B = BA$, $B \propto I$ for solenoid

$\Rightarrow \mathcal{E}_{back} \propto \frac{dI}{dt} \Rightarrow \mathcal{E}_{back} = -\underbrace{L}_{\text{defines Self inductance}}\frac{dI}{dt}$

Calculating L for ∞-ite Solenoid:

$\oint B\cdot ds = \mu_0 I_{enc} \Rightarrow B\cdot \ell = \mu_0\left(\frac{N}{L} I_0 \ell\right) \Rightarrow B = \mu_0 \underset{N/L}{n} I_0$

$\mathcal{E}_{back} = -N\frac{d\Phi_B}{dt} = \underbrace{-N\mu_0 n A_\perp}_{\equiv L = \mu_0 n^2 V}\frac{dI}{dt}$

Energy stored in inductor (B-field):

$\frac{dW}{dt} = \frac{dq}{dt}\mathcal{E} = IL\frac{dI}{dt} \Rightarrow dW = L\, I\, dI$

$\Rightarrow W = L\int_0^I I dI = \frac{1}{2}L I^2$, $B = \mu_0 n I \Rightarrow I = \frac{B}{\mu_0 n}$

$\Rightarrow u_B = \frac{W}{V} = \frac{1}{2}\mu_0 n^2 I^2 = \frac{1}{2\mu_0}B^2$

Energy stored in capacitor (E-field):

$$V = E d \;,\; \oint E \cdot d\vec{a} = \frac{Q_{enc}}{\varepsilon_0} \Rightarrow E\, a = \frac{1}{\varepsilon_0} \underbrace{\frac{Q}{A}}_{\sigma} a \Rightarrow E = \frac{1}{\varepsilon_0} \frac{Q}{A}$$

$$C = \frac{Q}{V} = \frac{(\varepsilon_0 A) E}{E d} = \frac{\varepsilon_0 A}{d}$$

$$dW = dq\, V = dq\, \frac{q}{C} \Rightarrow W = \frac{d}{\varepsilon_0 A} \int_0^{q} q\, dq = \frac{d}{\varepsilon_0 A} \frac{1}{2} q^2$$

or

$$dW = dq\, V = dq\, E d = \frac{d}{\varepsilon_0 A}\, dq\, q \Rightarrow W = \frac{d}{\varepsilon_0 A} \frac{1}{2} q^2$$

$$q^2 \rightarrow (\varepsilon_0 A E)^2$$

$$\Rightarrow W = \frac{1}{2} \varepsilon_0 \underbrace{A d}_{V} E^2 \Rightarrow u_E = \frac{1}{2} \varepsilon_0 E^2$$

More Applications:

RC Circuits: $-IR - L \frac{dI}{dt} = 0$ Discharge

$$\Rightarrow \frac{dI}{dt} = \frac{-R}{L} I \Rightarrow \underline{I = I_0 e^{-t/\tau}} \;;\; I_0 = \mathcal{E}/R$$

$$\Rightarrow -\frac{1}{\tau} = \frac{-R}{L} \Rightarrow \underline{\tau = L/R}$$

$$\mathcal{E} - IR - L \frac{dI}{dt} = 0$$ charging

$$\Rightarrow \frac{\mathcal{E}}{R} - I - \tau \frac{dI}{dt} = 0 \;;\; X = \frac{\mathcal{E}}{R} - I \Rightarrow \frac{dx}{dt} = -\frac{dI}{dt}$$

$$\Rightarrow \frac{dx}{dt} = -\frac{1}{\tau} X \Rightarrow X = X_0 e^{-t/\tau} \;;\; @\, t=0 \;\; I = 0 \Rightarrow X_0 = \mathcal{E}/R$$

$$\Rightarrow \frac{\mathcal{E}}{R} - I = \frac{\mathcal{E}}{R} e^{-t/\tau} \Rightarrow I = \frac{\mathcal{E}}{R}(1 - e^{-t/\tau})$$

LC Circuits: Charge circuit: $C = \frac{Q}{\mathcal{E}} \Rightarrow Q_0 = \mathcal{E} C$

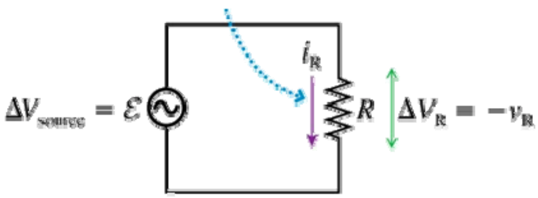
$$-\frac{Q}{C} - L \frac{dI}{dt} = 0 \Rightarrow \frac{d^2 Q}{dt^2} = \frac{-1}{LC} Q$$

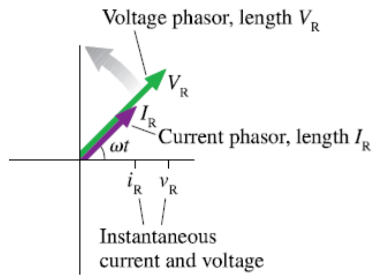
$$\Rightarrow Q = A \cos \omega t \;,\; Q_0 = \mathcal{E} C = A \;;\; \frac{d^2 Q}{dt^2} = -\omega^2 Q$$

$$\Rightarrow \omega^2 = \frac{1}{LC} \;,\; \omega = \sqrt{1/LC} \;,\; Q = \mathcal{E} C \cos \omega t$$

Chapter 36: More circuits

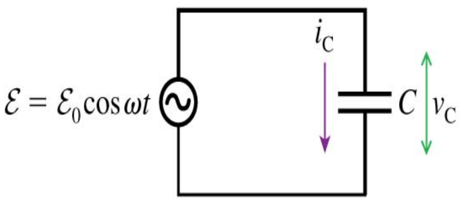
Last Time

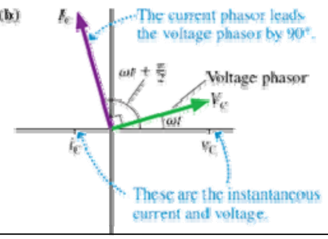




$V_R = i_R R$

$V_R = R I_R$

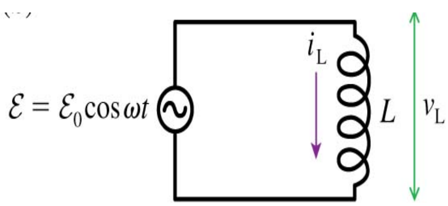


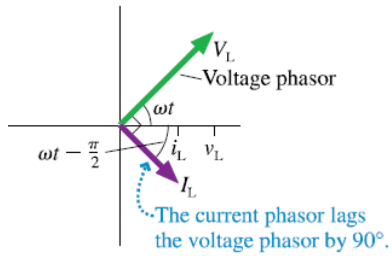


$v_C \neq X_C i_C$

$V_C = X_C I_C$

$X_C = \frac{1}{\omega C}$



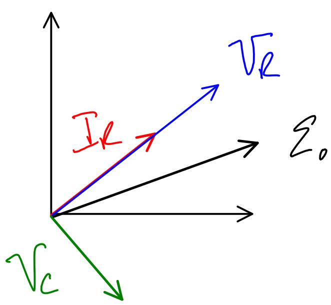


$v_L \neq X_L i_L$

$V_L = X_L I_L$

$X_L = \omega L$

RC filters:



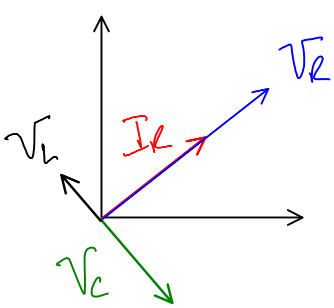
$$\mathcal{E}_0^2 = V_R^2 + V_C^2$$
$$= I^2 \underbrace{(R^2 + X_C^2)}_{Z^2} \Rightarrow I = \frac{\mathcal{E}_0}{Z} = \frac{\mathcal{E}_0}{\sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}}$$

$$V_C = I X_C = \frac{\mathcal{E}_0 (1/\omega C)}{\sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}}, \quad V_R = IR = \frac{\mathcal{E}_0 R}{\sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}}$$

As $\omega \to 0 \Rightarrow V_C = \mathcal{E}_0, \; V_R \to 0$

$\omega \to \infty \Rightarrow V_C \to 0, \; V_R = \mathcal{E}_0$

LRC Filter:



$$\mathcal{E}_0^2 = I^2 \left(V_R^2 + (V_L - V_C)^2\right)$$
$$= I^2 \underbrace{\left(R^2 + (\omega L - 1/\omega C)^2\right)}_{Z^2}$$

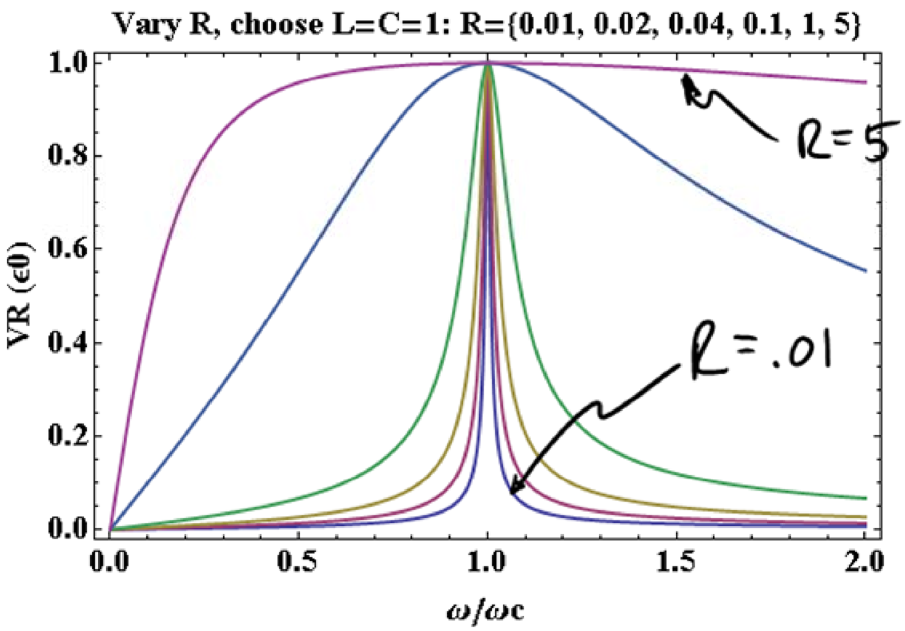
$$\Rightarrow I = \frac{\mathcal{E}_0}{Z}; \quad V_R = IR = \frac{\mathcal{E}_0 R}{Z}$$

$$V_C = I X_C = \frac{\mathcal{E}_0 (1/\omega C)}{Z}, \quad V_L = I X_L = \frac{\mathcal{E}_0}{Z}(\omega L)$$

$$V_R = \frac{\mathcal{E}_0 R}{\sqrt{R^2 - (X_L - X_C)^2}}$$ Max when $X_L = X_C \Rightarrow \frac{1}{\omega L} = \omega C$

or $\omega_0 = \sqrt{\frac{1}{LC}}$

V_R Max $\Rightarrow$ I_R max $\Rightarrow$ $P_R = I_R V_R$ Max @ ω_0



Final Exam review II

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Chapter 35:

$F = q\vec{E} + q\vec{v}\times\vec{B}$ yields:

Galilean Transformation of E + B - fields ($v << c$)

$\vec{E}' = \vec{E} - \vec{v}\times\vec{B}$

$\vec{B}' = \vec{B} - \frac{\vec{v}}{c^2}\times\vec{E}$

- Biot-Savart Law derivable from $\vec{E}$-field of pt. charge

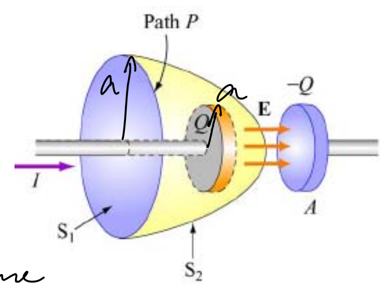
$\oint \vec{B}\cdot d\vec{a} = 0$ Magnetic Gauss's Law, No magnetic monopoles

$\oint B\cdot d\vec{s} = \mu_0 (I_{enc} + I_d)$, Displacement Current.

For capacitor:

$\oint E\cdot da = \frac{q_{enc}}{\varepsilon_0} \Rightarrow E = \frac{Q}{A\varepsilon_0}$

$\oint B\cdot ds = B\cdot 2\pi a = \mu_0 \underbrace{I_{enc}}_{= I}$, blue surface



Yellow surface, require: $B\cdot 2\pi a = \mu_0 I_d$

$\frac{d\Phi_E}{dt} = A\frac{dE}{dt} = \frac{1}{\varepsilon_0}\frac{dQ}{dt} = \frac{1}{\varepsilon_0} I_d \Rightarrow I_d = \varepsilon_0 \frac{d\Phi_E}{dt}$

$\oint \vec{B}\cdot d\vec{s} = \mu_0 I_{enc} + \mu_0\varepsilon_0 \frac{d\Phi_E}{dt}$

- Direction of $\vec{B}$ found from "opposite of Lenz's Law"

E + M Plane waves, free space

- Meaning of plane wave:

- $\vec{E} = E_0 \cos(kx - \omega t)\ \hat{y}$

$\Rightarrow \vec{B} = B_0 \cos(kx - \omega t)\ \hat{z}$

$\frac{\partial^2 E_y}{\partial x^2} = \mu_0\varepsilon_0 \frac{\partial^2 E_y}{\partial t^2}, \quad \frac{\partial^2 B_z}{\partial x^2} = \mu_0\varepsilon_0 \frac{\partial^2 B_z}{\partial t^2}$

$B_0 = \frac{E_0}{c}$, $v = c \equiv \sqrt{\frac{1}{\mu_0 \varepsilon_0}}$

- Flow of energy: Poynting vector is Intensity = Power/Area

  $\vec{S} = \frac{1}{\mu_0} \vec{E} \times \vec{B}$, instantaneous , $\vec{S}_{avg} = \frac{1}{2}\left(\frac{1}{\mu_0}\right) \vec{E}_0 \times \vec{B}_0$

- $\underbrace{E = pc}_{E^2 - (pc)^2 = E_0^2}$ for $m_0 = 0$ $\Rightarrow$ $p = E/c$

  $\text{Pressure} = \frac{\text{Force}}{\text{Area}} = \frac{\Delta P / \Delta t}{\text{Area}} = \frac{1}{c} \underbrace{\frac{\Delta E}{\Delta t \cdot \text{Area}}}_{\text{Intensity}} = \frac{S}{c}$ absorber

  $= \frac{2S}{c}$ reflector

- Polarization , $E = E_0 \cos\theta$ through Polarizer

  $I = I_0 \cos^2\theta$ Malus's Law

Final exam review iii optics

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Chapter 22 : Physical Optics

$E_1 = E_0 \cos(kx_1 - \omega t + \phi_{10})$, $E_2 = E_0 \cos(kx_2 - \omega t + \phi_{20})$

$$E_1 + E_2 = 2E_0 \boxed{\cos\left(\frac{\Delta\Phi}{2}\right)} \cos(k x_{avg} - \omega t_{avg})$$

$$\Delta\Phi = (kx_2 - \omega t + \phi_{20}) - (kx_1 - \omega t + \phi_{10})$$

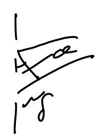
$$\boxed{\Delta\Phi = k\delta + \Delta\phi \quad , \delta = x_2 - x_1 \quad , \Delta\phi = \phi_{20} - \phi_{10}}$$

Assume $\Delta\phi = 0$;

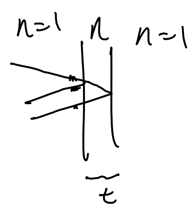
Constructive $\Rightarrow \cos\frac{k\delta}{2} = \pm 1 \Rightarrow \frac{k\delta}{2} = m\pi \Rightarrow \delta = m\lambda$

Destructive $\Rightarrow \cos\frac{k\delta}{2} = 0 \Rightarrow \frac{k\delta}{2} = (m+\frac{1}{2})\pi \Rightarrow \delta = (m+\frac{1}{2})\frac{\lambda}{2}$

$$I_{avg} = I_{0_{avg}} \cos^2\left(\frac{\Delta\Phi}{2}\right)$$

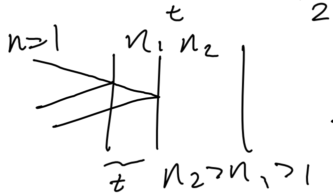
- Double slit : d{  $\delta = d\sin\theta$, $I_{avg} = I_0 \cos^2\left(\frac{dy}{L}\frac{\pi}{\lambda}\right)$

  or $\sin\theta \approx \tan\theta \approx \frac{y}{L}$

- Thin film in air : 

  $\Phi_1 = \pi$, $\Phi_2 = k' \cdot 2t$, $k' = \frac{2\pi}{\lambda/n} = nk_0$

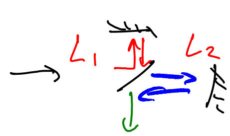
  $\frac{\Delta\Phi}{2} = \frac{k_0 2nt - \pi}{2}$

- AR Coating : 

  $\Phi_1 = \pi$, $\Phi_2 = k_1 \cdot 2t + \pi$, $k_1 = \frac{2\pi}{\lambda} n_2$

  $\Rightarrow \frac{\Delta\Phi}{2} = \frac{k_0 2n_1 t}{2} = (m+\frac{1}{2})\pi$

  $\Rightarrow t = \frac{\lambda_0}{n_1} 2\pi (m+\frac{1}{2})$

- Michelson Interferometer : 

  $\Phi_1 = k\,2L_1$, $\Phi_2 = k\,2L_2$

  $k = \frac{2\pi}{\lambda}$

- Single Slit: $I = I_0 \left(\frac{\sin\beta}{\beta}\right)^2$, $\beta = \left(\frac{y}{L}\right)\pi \frac{a}{\lambda}$

  Short Cut destructive interference: $\frac{a}{2}(\sin\theta) = \delta = \lambda/2$

  $\longrightarrow \frac{a}{2m} \sin\theta = \frac{\lambda}{2}$

- Resolution: Max of 1 = Min of original peak

  Angle to first Min: $\frac{a}{2}\sin\Delta\theta = \frac{\lambda}{2} \Rightarrow \sin\Delta\theta \approx \frac{\lambda}{a}$ Slit

  $\sin\Delta\theta = 1.22\frac{\lambda}{a}$ hole

Chapter 23:

$\theta_i = \theta_F$, Law of Reflection

$V = \frac{c}{n}$, velocity of light in medium of index n

$n_1 \sin\theta_1 = n_2 \sin\theta_2$, Snell's Law,

Critical angle & total internal reflection ($\theta_2 \Rightarrow 90°$ for $n_2 < n_1$)

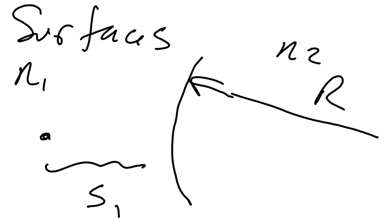
Dispersion: $n(\omega) \longrightarrow$ Prisms

Applications:

Image formation from

- Flat mirror
- n_1, n_2 Flat interface
- Image @ Refractory Spherical Surfaces

$$\frac{n_1}{s_1} + \frac{n_2}{s_2} = \left(\frac{n_2 - n_1}{R}\right)$$



Base Case, $S_1 > 0$, $R > 0$

Note: Flat surface from $R \to \infty$

- Thin lens: 2 Refracting Surfaces

$$\frac{n_1}{S_1} + \frac{n_1}{S_2} = (n_2 - n_1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

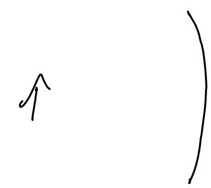
$$\Rightarrow \frac{1}{S_1} + \frac{1}{S_2} = \left(\frac{n_2 - n_1}{n_1}\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$f = S_2$ when $S_1 \to \infty$ $\Rightarrow$ $\frac{1}{f} = \frac{(n_2 - n_1)}{n_1}\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$$\Rightarrow \frac{1}{S_1} + \frac{1}{S_2} = \frac{1}{f}$$

- Spherical mirrors:

$$\frac{1}{S_1} + \frac{1}{S_2} = \frac{1}{f}, \quad \frac{1}{f} = \frac{2}{R}$$



Base case, $R > 0$, $S_1 > 0$, $S_2 > 0$ ...

Ray Tracing for <u>All</u> <u>Cases</u>

Chapter 24: Lens systems

- Camera - Zoom lenses, $f/\# = \frac{f}{D}$, $I \propto \frac{D^2}{f^2}$,
  Exposure $= I \Delta t$, Depth of Field
- Farsighted / Hyperopia, Nearsighted / myopia
  How to find corrective lenses: find lens that moves object placed @ ∞ or N.P. to an image where the person can see it.
  Power of Lens $= \frac{1}{f}$, Diopter $\left(\frac{1}{m}\right)$
- Angular Magnification: $M = \frac{\theta_2}{\theta_1}$
- Eyepiece, telescope, microscope
- $NA = n \sin\alpha_0 = \frac{D/2}{f}$

- Diffraction from Lens

$$\frac{a}{2}\sin\theta = \frac{\lambda}{2}, \quad \sin\theta = \frac{w/2}{f} \Rightarrow w = 2f\sin\theta = 2f\frac{\lambda}{a}$$

for "Slit" like lens

$$\Rightarrow w = 1.22\left(\frac{2f\lambda}{a}\right)$$ for Circular lens

Smallest Spot Size

Chapter 25

- $p = \hbar k$, de Broglie
- X-ray Diffraction

Final exam iv relativity

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Chapter 37

- Galilean transformation

$$x' = (x - vt) \qquad \frac{dx'}{dt'} = \frac{dx}{dt} - v \Rightarrow u' = u - v$$
$$t' = t \qquad \frac{\partial^2 x'}{\partial t^2} = \frac{d^2 x}{dt^2} \Rightarrow F' = F$$

C is the same in all reference frames
Laws of physics the same in all reference frames

- Peggy & Ryan example
  - Simultenaity is relative
  - Derived Length Contraction : $L = L_0/\gamma$, L_0 proper length
- Light Clock → analysis of time dilation

$$\Delta t = \Delta\tau\,\gamma \qquad \Delta\tau \text{ proper time}$$

- Twin paradox : Earth measures proper time
- Invariant h in light clock

$$\rightarrow \quad s^2 = c^2(\Delta t)^2 - (\Delta x)^2$$

- Lorentz transformation (implicit 1st event is Coordinate system origin lining up @ $t = t' = 0$)

$$x' = \gamma(x - vt), \quad t' = \gamma\left(t - \frac{v}{c^2}x\right)$$

$$dx' = \gamma(dx - v\,dt), \quad dt' = \gamma\left(dt - \frac{v}{c^2}dx\right)$$

$$\Rightarrow \frac{dx'}{dt'} = \frac{dx - v\,dt}{dt - (v/c^2)\,dx} = \frac{dx/dt - v}{1 - \frac{v}{c^2}\frac{dx}{dt}}$$

$$\Rightarrow u' = \frac{u - v}{1 - \frac{uv}{c^2}}$$

- Conservation of momentum requires:

$$p \equiv \gamma_p m_0 u \,, \quad \gamma_p = \frac{1}{\sqrt{1 - \left(\frac{u}{c}\right)^2}}$$

- Using invariant s^2

$$\Rightarrow \gamma_p m_0 c^2 - (pc)^2 = \text{invariant}$$

Choose frame where $p' = 0$, $u' = 0$ ($\Rightarrow \gamma_p \to 1$)

$$\Rightarrow \underbrace{\gamma_p m_0 c^2}_{\equiv E} - (pc)^2 = \underbrace{m_0 c^2}_{\equiv E_0}$$

$$\Rightarrow \boxed{E - (pc)^2 = E_0}$$

or $E = E_0 + KE \Rightarrow KE = E - E_0 \Rightarrow \boxed{KE = (\gamma_p - 1) m_0 c^2}$

Final exam v quantum

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Chapters 38 & 39

Quantization : photons ($E = \hbar\omega$, $p = \hbar k$), Charge
$p = E/c = \hbar\omega/c$

- J. J. Thompson, crossed field experiment $\rightarrow \frac{e}{m}$ electrons
- Milikan oil drop : quantized charge
- mass spectrometer
- Photo electric effect : $h\nu = eV_{stop} + \Phi \rightarrow$ Concept of photon validation
  - KE of e^-'s $\propto \nu$, not I
- Planck's Black Body radiation $\longrightarrow$ Energy of walls quantized

Defn : 1eV ; $\underset{1e}{q}\ \underset{1V}{V} = 1eV = 1.6\cdot 10^{-19}J$

- Particle in a Box: $\sin k_n L = 0 \Rightarrow k_n = \frac{n\pi}{L}$
  & $P_n = \hbar k_n$, & $E_n = \frac{P_n^2}{2m} = \frac{(\hbar k_n)^2}{2m}$

- Bohr Model of atom:
  ① $F = m\frac{v^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$ ② $p = mv = \hbar k$

  ③ Stationary state : $2\pi r = m\lambda$

  $\Rightarrow r_n = a_B n^2$, $V_n = \frac{1}{n}V_0$, $E_n = \frac{-R_y}{n^2}$, $L_n = n\hbar$

  $\lambda = \frac{\lambda_0}{(\frac{1}{m})^2 + (\frac{1}{n})^2}$

Chapter 40:

- Prob (in dx at x) = $\underbrace{P(x)}_{\text{Probability density}}\, dx$, $P(x) = |\psi|^2$

- Normalization : $\int |\psi(x)|^2\, dx = 1$

- wave packet : $\Delta f \Delta t \approx 1 \Rightarrow \Delta\omega \Delta t = 2\pi$

- Heisenberg Uncertainty : $\Delta k \Delta x \approx 2\pi \Rightarrow \Delta x \Delta p \approx h$

$$\Delta x \Delta p_x \geq \frac{\hbar}{2}$$

  - Single Slit diffraction $\Rightarrow \Delta x \Delta p_x \approx h$

Chapter 41

- Schrodinger's Equation :

$$i\hbar \frac{\partial \psi}{\partial t} = \frac{-\hbar^2}{2m} \frac{\partial^2 \psi}{\partial x^2} + U \psi$$

If U independent of time :

$$\Rightarrow \quad E\,\psi(x) = -\frac{\hbar^2}{2m} \frac{\partial^2 \psi}{\partial x^2} + U\psi$$

$$\Rightarrow \quad -\frac{\hbar^2}{2m} \frac{\partial^2 \psi}{\partial x^2} = \left(E - U(x)\right)\psi$$

- ψ + ψ' cts
- ψ normalizable

- If U = Constant , $\psi = Ae^{bx} \Rightarrow$

$$-\frac{\hbar^2}{2m} b^2 = E - U \Rightarrow b = \sqrt{-\frac{2m}{\hbar^2}(E-U)}$$

$$\Rightarrow b = \begin{cases} \pm ik & E > U \\ \pm K & E < U \end{cases} \qquad k = K = \sqrt{\frac{2m}{\hbar^2}|E-U|}$$

- ∞-ite well: $\psi = Ae^{ikx} + Be^{-ikx}$
$= A' \cos kx + B' \sin kx$

$\Rightarrow \sin kx = 0$ @ $x = 0$ & $x = L$

$\Rightarrow kL = n\pi$ or $k_n = \frac{n\pi}{L}$

$p_n = \hbar k_n$ & $E_n = \frac{p_n^2}{2m} = \frac{(\hbar k_n)^2}{2m}$

Normalization: $\int \psi^2 dx = \int_0^L (B' \sin kx)^2 dx = 1 \Rightarrow$
$B' = \sqrt{\frac{2}{L}}$

- Correspondence Principle
- Finite potential well, Harmonic Oscillator
- Penetration depth: $\eta = \frac{1}{K}$
- Sketching $\psi(x)$ for different $U(x)$
  - $KE = E - U = \frac{p^2}{2m} \sim \frac{1}{\lambda^2}$ $\therefore$ $KE\uparrow \Rightarrow \lambda\downarrow, k\uparrow$
  - If $KE\uparrow$, Amplitude $\downarrow$

  - Capacitor, Harmonic Oscillator
- H_2^+ : Bonding & Antibonding bonds
- Quantum Tunneling: $\psi(x) = e^{-Kx}$ inside barrier

Chapter 42:

- $E_n = \frac{-R_y}{n^2}$, $L = \sqrt{l(l+1)}\,\hbar$ $l = 0, \ldots, n-1$
$L_z = m\hbar$, $m = -l, \ldots, l$

- $P(r) = (4\pi r^2 dr)\, R_{n\ell}^{2}(r)$
- Stern Gerlach + electron Spin : $S_z = \pm\frac{1}{2}\hbar$
- Pauli Exclusion Principle
- Multi Electron Atom
- Optical Selection Rules : $\Delta \ell = \pm 1$
- Lifetimes : $\frac{N}{N_0} = e^{-t/\tau}$
- Stimulated Emission

- Copenhagen vs Realist : What is a measurement
- Stern Gerlach filters
- EPR Experiment
- Bell's Inequality: What does it prove in Context of EPR?