PHY207MFC FINAL Exam Formular Sheet

05/05/2005

Chapter 14

traveling wave
$$z(x, t) = z_0 \sin(kx - \omega t + \varphi)$$

standing wave
$$z(x, t) = z_0 \sin(kx + \alpha) \cdot \cos(\omega t + \beta)$$

wave equation
$$\frac{\partial^2 z}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2 z}{\partial t^2}$$

$$\lambda \cdot f = v$$

$$\omega = \frac{2\pi}{\tau} = \frac{2\pi}{\lambda}v = 2\pi f$$

$v = \sqrt{\frac{T}{\mu}}$ for waves on strings $\quad \langle P \rangle = \frac{1}{2}\mu\omega^2 A^2 v$

$v = \sqrt{\frac{\gamma p_0}{p_0}}$ for sound waves

$$\beta = 10\log\left(\frac{I}{I_0}\right) \quad \text{where} \quad I_0 = 10^{-12}\frac{\mathrm{W}}{\mathrm{m}^2}$$

$$f' = \frac{v'}{\lambda'} = f_0\left(\frac{v - v_r}{v - v_s}\right)$$

$$\sin(a \pm b) = \sin a \cdot \cos b \pm \sin b \cdot \cos a$$

$$\cos(a \pm b) = \cos a \cdot \cos b \mp \sin a \cdot \sin b$$

$A = \pi R^2$ area of circle

$A = 4\pi R^2$ area of sphere

$A = \frac{4}{3}\pi R^3$ volume of sphere

averaging over one period

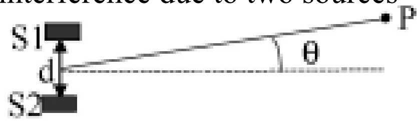
$$\langle \cos^2\theta \rangle = \langle \sin^2\theta \rangle = \frac{1}{2}$$

Chapter 15

beat frequency
$$f_{\text{beat}} = \frac{1}{2}(f_1 - f_2)$$

pulse frequency
$$f_{\text{pulse}} = 2 \cdot f_{\text{beat}}$$

interference due to two sources



Path difference at point P:
$$\Delta L = d\sin\theta$$

if S1 and S2 in phase:

$\Delta L = n\lambda$ max. constr. interference

$\Delta L = \left(n + \frac{1}{2}\right)\lambda$ max. destructive interference

$$n = 0, \pm 1, \pm 2, \ldots$$

Chapter 34

EM wave traveling in z direction, polarized in x direction:

$$E_x(x, t) = E_0\cos(kz - \omega t + \varphi)$$

$$B_y(x, t) = B_0\cos(kz - \omega t + \varphi)$$

speed of light in vacuum $v = \sqrt{\frac{1}{\mu_0\varepsilon_0}} = c = 3.00\times 10^8\frac{\mathrm{m}}{\mathrm{s}}$

wave equation $\frac{\partial^2 z}{\partial x^2} = \mu_0\varepsilon_0\frac{\partial^2 z}{\partial t^2}$

$E = c \cdot B \quad \vec{E} \cdot \vec{B} = 0$

$u = \frac{1}{\varepsilon_0}(c^2B^2 + E^2) \quad \vec{S} = \frac{1}{\mu_0}\vec{E}\times\vec{B}$

$$I = \frac{\langle P \rangle}{A} = \langle S \rangle = \frac{1}{2}c\varepsilon_0 E_0^2$$

energy density of EM waves $\langle u \rangle = \frac{\varepsilon}{2}E_0^2 = \frac{1}{2\mu_0}B_0^2$

$\frac{S}{c^2} = \frac{u}{c}$ momentum density

radiation pressure (when totally absorbed) $\frac{F}{A} = \frac{\langle S \rangle}{c} = \langle u \rangle$

Intensity of dipole radiation $S \propto \frac{\sin^2\theta}{R^2}$

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

$\tan\theta_B = n$ Brewster's angle

$E = hf$ photon energy

$p = \frac{E}{c} = \frac{hf}{c} = \frac{h}{\lambda}$ photon momentum

Chapter 35

Law of reflection
$$\theta_{\text{incident}} = \theta_{\text{reflect}}$$

Snell's law
$$n_1\sin\theta_1 = n_2\sin\theta_2$$

Total internal reflection when $\theta \geq \theta_c$

$\sin\theta_c = \frac{n_2}{n_1}$ (note that $n_1 > n_2$)

EM waves:
$$\lambda \cdot f = v = \frac{c}{n}$$

$$\omega = \frac{2\pi}{\tau} = \frac{2\pi}{\lambda}v = 2\pi f$$

distance=v $\cdot$ t

$$\sin(a \pm b) = \sin a \cdot \cos b \pm \sin b \cdot \cos a$$

$$\cos(a \pm b) = \cos a \cdot \cos b \mp \sin a \cdot \sin b$$

averaging over one period

$$\langle \cos^2\theta \rangle = \langle \sin^2\theta \rangle = \frac{1}{2}$$

speed of light in vacuum $v = \frac{1}{\mu_0\varepsilon_0} = c = 3.00\times 10^8\frac{\mathrm{m}}{\mathrm{s}}$

Physical constants

$\pi = 3.1415927\ldots$

$c = 3.00\times 10^8\frac{\mathrm{m}}{\mathrm{s}}$ $\quad h = 6.63\times 10^{-34}\mathrm{Js}$ $\quad \varepsilon_0 = 8.85\times 10^{-12}\frac{\mathrm{C}^2}{\mathrm{N}\cdot\mathrm{m}^2}$ $\quad \mu_0 = 4\pi\times 10^{-7}\frac{\mathrm{T}\cdot\mathrm{m}}{\mathrm{A}}$

$R_\infty = 1.0974\times 10^7\ \mathrm{m}^{-1}$ $\quad m_e = 9.11\times 10^{-31}\mathrm{kg}$ $\quad m_p \cong m_n = 1.67\times 10^{-27}\mathrm{kg}$ $\quad 1eV = 1.6022\times 10^{-19}\mathrm{J}$

Chapter 36

Plane mirror

$$i = -s$$

Spherical mirror (radius R)

$$f = \frac{R}{2}$$

$$\frac{1}{s} + \frac{1}{i} = \frac{1}{f} \quad \text{(also true for thin lenses)}$$

$$M = -\frac{i}{s} = \frac{f}{f-s}$$

Spherical boundary (radius R) between n_1 and n_2

$$\frac{n_1}{s} + \frac{n_2}{i} = \frac{n_2 - n_1}{R}$$

Thin lens in air

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{s} + \frac{1}{i} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Sign conventions (lenses & mirrors)

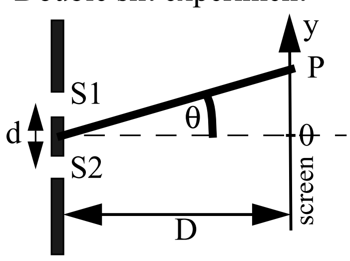
Side **A**: the side from which the light originates

Side **B**: the side to which the light passes

s > 0: object on side A (real object)
s < 0: object opposite side A (virtual)
i > 0: image on side B (real image)
i < 0: image opposite side B (virtual)
R > 0: C on side B
R < 0: C opposite side B

Chapter 37

Double slit experiment



Path difference at point P:
if S1 and S2 in phase:

$$\Delta L = d\sin\theta$$

$$\Delta L = n\lambda \quad \text{max. constr. interference}$$

$$\Delta L = \left(n + \frac{1}{2}\right)\lambda \quad \text{max. destructive interference}$$

$$n = 0, \pm1, \pm2, \ldots$$

Intensity pattern of double slit:
I_0: Intensity for a single slit

$$I = 4I_0\left[\cos\left(\frac{\pi d}{\lambda}\sin\theta\right)\right]^2$$

Phase difference between rays reflecting in air gaps or thin films

$$\Phi = \Phi_{\text{path difference}} + \Phi_{\text{reflections}}$$

$$\Phi_{\text{path difference}} = \frac{\Delta L}{\lambda_{\text{medium}}}2\pi$$

max. constr. interference

$$\Phi = n \cdot 2\pi \qquad n = 0, 1, 2, \ldots$$

max. destr. interference

$$\Phi = \left(n + \frac{1}{2}\right) \cdot 2\pi \qquad n = 0, 1, 2, \ldots$$

Chapter 38

Multiple slits (# of slits N, separation d between slits):
principal maxima:

$$d\sin\theta = m\lambda \quad \text{where order: } m = 0, \pm1, \pm2, \ldots$$

$$I = I_0\left[\frac{\sin(N\beta)}{\sin\beta}\right]^2 \quad \text{where: } \beta = \frac{\pi d\sin\theta}{\lambda}$$

angular dispersion: $\frac{\Delta\theta}{\Delta\lambda} = \frac{m}{d\cos\theta}$

resolving power: $R = \frac{\lambda}{\Delta\lambda} = mN$

Single Slit (width a):
destructive interference:

$$\sin\theta = \frac{m\lambda}{a} \quad \text{where: } m = \pm1, \pm2, \ldots$$

$$I = I_{max}\frac{(\sin\alpha)^2}{\alpha^2} \quad \text{where: } \alpha = \frac{\pi a\sin\theta}{\lambda}$$

minima (single slit) in terms of α:

$$\alpha = n\pi \quad \text{where: } n = \pm1, \pm2, \ldots$$

Multiple slits (width a, separation d):

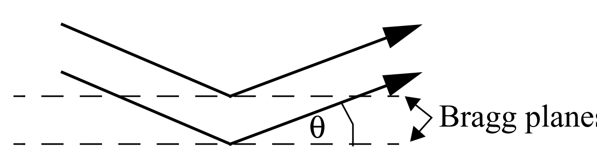
$$I_{\text{total}} = I_{\text{multiple slit}} \cdot I_{\text{single slit}}$$

Apertures:

$$\theta_{\text{min}} = \frac{\lambda}{D} \qquad S_{\text{min}} = s\theta_{\text{min}}$$

Bragg's Law:

$$2d\sin\theta = n\lambda \quad \text{where: } n = 1, 2, \ldots$$



Chapter 40

$$\lambda = \frac{h}{p} \qquad h = 6.63\times10^{-34}\,\text{Js}$$

Photons: $E = hf \qquad p = \frac{E}{c}$

Particles with mass:

low energy $E = \frac{p^2}{2m}$ high energy $E = pc$

Tunneling:
fraction getting through $\approx e^{\left[-\frac{2}{\hbar}a\sqrt{2m(\langle U\rangle - E)}\right]}$

$$\Delta x\Delta p > \hbar \qquad \hbar = \frac{h}{2\pi} = 1.05\times10^{-34}\,\text{Js}$$

$$\Delta E\Delta t > \hbar$$

Photoelectric effect:

$$E = \frac{1}{2}mv^2 = hf - W$$

Compton effect: $\lambda' - \lambda = \frac{h}{mc}(1 - \cos\theta)$

Chapter 41

Bohr Model (hydrogen atom):

$$L = n\hbar \quad \text{where: } n = 1, 2, \ldots$$

$$E_n = -\frac{m_e}{2n^2}\left(\frac{e^2}{4\pi\varepsilon_0\hbar}\right)^2 = \frac{-13.6\text{eV}}{n^2}$$

$$\frac{1}{\lambda} = \frac{E_i - E_f}{hc} = R_\infty\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right)$$

$$hf = E_i - E_f$$

True hydrogen atom (Heisenberg-Schroedinger):
principal quantum number n
angular momentum L

$$L^2 = l(l+1)\hbar^2 \quad \text{where: } l = 0, 1, 2, \ldots, (n-1)$$

projection of L onto the z-axis:

$$L_z = m_l\hbar \quad \text{where: } m_l = -l, \ldots, -1, 0, 1, \ldots, l$$

electron spin s: $s = \frac{1}{2}$

projection of s onto the z-axis: $m_s = -\frac{1}{2}, \frac{1}{2}$