Summary III - Optics + Light

1) We have now seen all four of Maxwell's Equations.

$$\oint \vec{E}\cdot d\vec{a} = \frac{q_{in}}{\epsilon_0} \qquad \oint \vec{E}\cdot d\vec{s} = -\frac{d\Phi_B}{dt}$$

$$\oint \vec{B}\cdot d\vec{a} = 0 \qquad \oint \vec{B}\cdot d\vec{s} = \mu_0 I + \mu_0\epsilon_0 \frac{d\Phi_E}{dt}$$

$$\mu_0 = 4\pi \times 10^{-7} \frac{T\cdot m}{Amp} \qquad \epsilon_0 = 8.854 \times 10^{-12} \frac{C^2}{N\cdot m^2}$$

you should know what these equations are & how to use them.

2) We learned that light is an electromagnetic wave (transverse) with velocity $c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$, $\vec{E} \perp \vec{B}$, $\frac{E_{max}}{B_{max}} = c$

3) Poynting vector $\vec{S} = \frac{1}{\mu_0}\vec{E}\times\vec{B}$

$$[S] = J/m^2\cdot sec$$

4) Intensity, $I = S_{avg} = \frac{E_{max}^2}{2\mu_0 c} = \frac{c B_{max}^2}{2\mu_0}$

5) Light carries momentum. The pressure on a completely:
absorbing surface is $P = \frac{S}{c}$
reflecting surface is $P = \frac{2S}{c}$

6) for waves: $v = \lambda f$, $\omega = vk$, $k = \frac{2\pi}{\lambda}$, $\omega = 2\pi f$

7) Know some basic properties of the electromagnetic spectrum, such as typical λ & f values for visible light, X-rays, microwaves, radio waves.

Geometrical optics

8) reflection: $\theta_i = \theta_r$

refraction $n_1 \sin\theta_1 = n_2 \sin\theta_2$

or

$v_2 \sin\theta_1 = v_1 \sin\theta_2$ with $v = \frac{c}{n}$

9) Know about total internal reflection

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

10) Be familiar with the mirror/lens equation and know ray tracing techniques (i.e. know the rules for which rays to draw)

$$\boxed{\frac{1}{p} + \frac{1}{q} = \frac{1}{f}}$$

· Know the sign conventions for p, q, and f, for mirrors and lenses.

11) Magnification $m = -\frac{q}{p}$. Know the meaning of m, and what it tells you about whether images are real or virtual, and inverted or upright.

12) The eye: Know the definitions of near point & far point, and how to correct for "near-sighted" and "far sighted" vision.

$P = \frac{1}{f}$ where P is in Diopters, and f is in meters.

13) Know how to analyze combinations of lenses.

Interference / Wave Optics

14) Wave period $T = \frac{1}{F}$. Wave travels one wavelength in one period ($\lambda F = c = \frac{\lambda}{T}$)

$\frac{\text{path difference}}{\lambda} \cdot 2\pi$ = phase shift

15) when we add waves (superposition) that are coherent - i.e. have well defined phase relationships - then we can get:

a) in phase ⇒ constructive interference ⇒ bright spots

b) out of phase ⇒ destructive interference ⇒ dark spots

16) reflective phase changes: when light reflects at an interface with $n_{incident} < n_{transmitted}$ the reflection introduces a $\frac{\lambda}{2}$ or π phase shift.

(this does not happen for $n_{incident} > n_{transmitted}$)

17) Know how to work with various examples that generate interference patterns such as:

a) Double Slit - bright fringes $d\sin\theta = m\lambda$; $y = L\frac{m\lambda}{d}$

dark fringes $d\sin\theta = (m+\frac{1}{2})\lambda$; $y = L(m+\frac{1}{2})\frac{\lambda}{d}$

b) Thin Films:

Know why these are different

One phase change (#16) — dark: $2nt = m\lambda$; bright: $2nt = (m+\frac{1}{2})\lambda$

phase change @ each surface — dark: $2nt = (m+\frac{1}{2})\lambda$; bright: $2nt = m\lambda$

18) Intensity for double slit interference pattern:

$$I = I_{max} \cos^2\left[\frac{\pi d \sin\theta}{\lambda}\right]$$

Diffraction & Polarization

19) Single slit diffraction: minima for $\sin\theta = \frac{m\lambda}{a}$
(for slit width a)

or $y = \frac{m\lambda L}{a}$

20) Diffraction Grating: $d \sin\theta_{bright} = m\lambda$

21) For circular apertures, $\theta_{min} = 1.22\frac{\lambda}{D}$

22) Polarization refers to the orientation of the electric field. Light transmitted through a polarizer is attenuated according to Malus' Law:

$$I = I_{max} \cos^2\theta$$

23) Light can be polarized by reflection

$$\tan\theta_p = \frac{n_2}{n_1}$$

(θ_p also called Brewster's angle)

24) Know the orientation of polarization for reflected light, and know how polarized sunglasses work.