Week 4:

**Energy and momentum** is carried by waves and particles:

For photons: \( E = h f \) and momentum, \( p = h / \lambda \)

The EM wave consists of a transverse wave, with perpendicular electric and magnetic field waves that are in phase with each other and whose magnitudes are related by: \( E_0 = c B_0 \) and whose speed in vacuum is given by \( c = 1 / \sqrt{\varepsilon_0 \mu_0} \)

For waves, the Poynting vector gives us the average energy per time per unit area [also called intensity or irradiance] carried by an electromagnetic wave:

\[
\langle S \rangle = \frac{1}{2} \varepsilon_0 c E_0^2 = \frac{c}{2 \mu_0} B_0^2 = \frac{1}{2 \mu_0} E_0 B_0
\]

and momentum transferred per time per unit area = Irradiance / \( c \)

----back to Geometrical Optics------

**Total Internal Reflection** [TIR] occurs when the light in the more (optically) dense medium bends away from the normal to the surface. If the incident angle is large enough, \( \geq \theta_c \), the critical angle, then no light is transmitted, all is reflected, and we have TIR. We derive the equation for the critical angle by saying that the refracted (transmitted angle) = 90°:

\[
n_1 \sin \theta_c = n_2 \sin 90°
\]

\[
sin \theta_c = n_2 / n_1
\]

Week 5:

Reflections from curved surfaces = mirrors:

Mirror Equations

\[
1/u + 1/v = 2/r = 1/f
\]

magnification \( m = h_i / h_o = -v / u \)

Mirror [and lens] Sign conventions: all based on incoming light coming from the left

- \( u, v, \) and \( r \) (and hence \( f \)) are negative when the object, image, center of curvature is left of the vertex (point where the mirror intersects the axis) and positive otherwise
- \( h \) is positive when the object/image is above the (horizontal) axis

Fiber Optics:

**For step-index fibers**

Numerical Aperture = N.A. = \( n_o \) \( \sin \theta_m = \sqrt{n_1^2 - n_2^2} \)

Skip distance = \( L_s = n_2 d / \sqrt{n_1^2 - n_2^2} \) where \( d \) is the diameter of the fiber core, \( n_1 \) is the index of the core, and \( n_2 \) of the cladding