Chapter 35 - Images

1. Both spherical mirrors and thin lenses satisfy the same equation
$$\frac{1}{f} = \frac{1}{p} + \frac{1}{i}.$$

2. The magnification is
$$m = \frac{h_i}{h_o} = -\frac{i}{p}.$$

3. The key to solving problems is to understand the sign conventions:
   (a) p is positive for real objects (usually the case), negative for virtual objects (only can occur with more than one optical instrument).
   (b) i is positive for real images, negative for virtual images. Real images can be projected on a screen and are in front of the mirror or behind the lens.
   (c) f is positive for concave mirrors and converging lenses, negative for convex mirrors and diverging lenses.
   (d) h_o is positive if the object is upright (usually the case).
   (e) h_i is positive if the image is upright (usually a virtual image), negative if the image is inverted (usually a real image).

4. Geometry affects the focal length. For concave mirrors, $f = R/2$, and for convex mirrors $f = -R/2$. For lenses, we use the lens maker's equation
$$\frac{1}{f} = (n-1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right).$$
The radii of curvature are positive if the surface facing the object is convex and negative if the surface is concave.

5. Some facts about single mirrors.
   (a) Convex mirrors always give virtual, upright, reduced images.
   (b) Concave mirrors give a virtual, upright, enlarged image when the object is between the focus and the mirror ($p < f$).
   (c) Concave mirrors give a real, inverted image when the object is outside the focus ($p > f$). The image is enlarged if the object is between the center of curvature ($2f$) and the focus. The image is reduced of the object is outside the center of curvature.

6. Some facts about single lenses.
   (a) Diverging lenses always give virtual, upright, reduced images.
   (b) Converging lenses give a virtual, upright, enlarged image when the object is between the focus and the lens ($p < f$). This is how a magnifying glass works.
   (c) Converging lens give a real, inverted image when the object is outside the focus ($p > f$). The image is enlarged if $p < 2f$ and reduced if $p > 2f$.

Chapter 36 - Interference

1. Huygen's principle asserts that all points on a wavefront serve as point sources of spherical secondary wavelets. After a time, the new position of the wavefront will be that of a surface tangent to these secondary wavelets.
2. Light travels slower in a medium than it does in a vacuum
$$v = \frac{c}{n}$$
because the wavelength is smaller
$$\lambda_n = \frac{\lambda}{n}.$$
3. The phase difference (Δ) between two waves can change if
   (a) the waves travel through different materials having different indices of refraction.
   (b) the waves travel along paths of different lengths.
   (c) one or both of the waves are reflected.
4. Light undergoes a $\lambda/2$ phase shift when it reflects from an interface between an optically less dense (lower index of refraction) medium and an optically more dense (higher index of refraction) medium.
5. For constructive interference (maxima), $\Delta = m\lambda$. For destructive interference (minima), $\Delta = (m + 1/2)\lambda$.
6. Thin films can exhibit interference. We have to consider
   (a) that the wavelength of the light is reduced in the film.
   (b) that there can be additional phase shifts if reflection occurs at a low-to-high index of refraction interface.

7. *A soap film (low-high-low film)* of thickness t has a path difference $\Delta_{overall} = 2t + \Delta_1 + \Delta_2 = 2t + \lambda/2 + 0 = 2t + \lambda/2$.

   (a) Therefore, constructive interference (or maxima) ($\Delta = m\lambda$)

   $$2t = \left(m - \frac{1}{2}\right)\frac{\lambda}{n}$$

   (b) and destructive interference (or minima) ($\Delta = (m + 1/2)\lambda$)

   $$2t = m\frac{\lambda}{n}.$$

8. Interference in Young's double slit experiment occurs because of the path difference $\Delta = d\sin\theta$. The slits are d apart, the screen is L away from the slits, and the pattern is y from the central maximum.

   (a) Constructive interference (maxima) occurs when

   $$\Delta = d\sin\theta = d\frac{y}{L} = m\lambda.$$

   (b) Destructive interference (minima) occurs when

   $$\Delta = d\sin\theta = d\frac{y}{L} = \left(m + \frac{1}{2}\right)\lambda.$$

Chapter 37 - Diffraction

1. When waves encounter an edge of an obstacle or aperture with a size comparable to the wavelength of the waves, those waves spread in their direction of travel and undergo interference. This is called diffraction.

2. The minima in a single slit diffraction experiment are located at angles θ from the central axis that satisfy

   $$W\sin\theta = \frac{y}{L} = m\lambda$$

   where $m = 1, 2, 3, \ldots$ (Notice that $m \neq 0$!)

3. The central maximum appears at $\theta = 0$ and is twice as wide as the other maxima. The other maxima are located approximately at

   $$W\sin\theta = (m + \frac{1}{2})\lambda.$$

4. The width of a maximum is found by taking the difference of the positions of the bounding minima. For example, the width of the $m = 1$ maximum is found from the positions of the $m = 1, 2$ minima.

5. Diffraction by a circular aperture or a lens with diameter D produces a central maximum and concentric maxima and minima. The first minimum is found at an angle θ given my

$$\sin\theta = 1.22\frac{\lambda}{D}.$$

6. A diffraction grating is a series of "slits" used to separate an incident wave into its component wavelengths by separating and displaying their diffraction maxima. It behaves similarly to a double slit interference device and has maxima located at

$$d\sin\theta = m\lambda.$$

   The grating spacing d is the reciprocal of the number of slits per unit length.