Physics 122 Test 1 study guide

This is intended to be a study guide for your first test. This list is to help you decide what to concentrate on and what you can skip when studying each chapter. (Book = Giancoli’s “Physics for Scientists and Engineers,” 4th ed.)

Chapter 32: Read sections 1–2, and 4–7. (You may skim the material on curved mirrors.)

Concentrate on:
Definitions of real and virtual images: an image is real if the light rays actually converge at the location of the image, and is virtual if the light rays only appear to come from its location. A real image may actually be seen by placing a screen (white paper) at its location; for a virtual image, the location is only apparent and nothing will be seen if a screen is placed there.
Flat (plane) mirrors: image is always virtual, upright, and the same size as the object.
Speed of light in material with index of refraction \(n\) is \(c/n\)

Angles of reflection and refraction:
Convention: angles are measured from the normal to the surface in all formulae
Angle of incidence = angle of reflection \(\theta_{\text{inc}} = \theta_{\text{refl}}\).
Reflected (transmitted) angle obeys Snell’s Law: \(n_1 \sin \theta_1 = n_2 \sin \theta_2\)
No refracted (transmitted) wave happens for incident angles greater than the critical angle:
\[
\sin \theta_C = \frac{n_2}{n_1}
\]
where we must have \(n_2 < n_1\). This is responsible for the phenomenon of total internal reflection, which we exploit in designing fiber optics.

Chapter 33: Read sections 1, 2, and 7. (You will not be responsible for the “lensmaker’s equation.”)

Curved mirrors and thin lenses obey the thin lens equation:
\[
\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}
\]
where \(s\) is the distance from the mirror or lens to the object, \(s'\) is the distance to the image, and \(f\) is the focal length of the mirror or lens. Note that the plane mirror is a special case of this, with \(f \to \infty\) for a flat mirror. Do not confuse the thin lens equation with the lensmaker’s equation (used for thicker lenses), which you will not be responsible for in this class. Conventions: for a mirror, \(s'\) and \(f\) are positive if the image (or focal point) is on the same side of the mirror as the object; we expect the light to be reflected. For a lens, we expect the light to go through, so \(s'\) and \(f\) are positive if they are on the opposite side of the lens from the object.

Magnification of a mirror, lens, or compound optical system is given by
\[
M = -s'/s
\]
where a negative magnification means that the image is inverted. Magnitude of the magnification gives the factor by which the size of the object is increased (or decreased, if $|M| < 1$).

**Chapter 15:** You may skip/skim section 15.3; read the rest.

Concentrate on: definition of a wave, transverse vs. longitudinal waves (transverse: particle motion is perpendicular to wave travel direction, and longitudinal: particle motion is parallel to wave travel direction).

Definition of $D(x, t)$ for a longitudinal wave: particle which is at $x$ in equilibrium is at the location $x + D(x, t)$ when the wave is passing by.

Definitions of period $T =$ time per cycle, frequency $f$, angular freq. $\omega$, and the relations between them:

$f = 1/T \quad \omega = 2\pi f$ (use: converts time to radians)

definition of wavelength: $\lambda =$ spatial distance per cycle

definition of wavenumber $k = 2\pi/\lambda$ (converts distance to radians... NOT to be confused with spring constant $k$!)

$$\frac{\partial^2 D}{\partial x^2} = \frac{1}{v_{\text{wave}}^2} \frac{\partial^2 D}{\partial t^2}$$ The wave equation

Note that $v_{\text{wave}} = \lambda f = \lambda/T = \omega/k$, and that $v_{\text{wave}}$ is a property of the medium which is carrying the waves (only), and not a property of any specific wave solution.

String with tension $F_T$ and mass/length $\mu$: $v_{\text{wave}} = \sqrt{F_T/\mu}$

Harmonic motion solutions of wave equation:

$$D(x, t) = A \cos(kx + \omega t + \phi)$$

where $A$ is the amplitude; $-$ sign means moving in the positive $x$ direction, and $+$ sign means moving in the negative $x$ direction.

Note the difference between the wave speed, $v_{\text{wave}}$, and the particle speed $v_D = \partial D/\partial t$: $v_{\text{wave}}$ is fixed, but $v_D$ depends upon the wave amplitude and also oscillates in time.

**Chapter 16:** Read sections 6 and 7 and skim sections 1 and 4; You may skip the rest.

$$f_L = \frac{v_{\text{wave}} \pm v_L}{v_{\text{wave}} \mp v_S} f_S$$

(Doppler effect; upper signs for motion towards each other, and lower signs for motion away; L means “Listener” and S means “Source”)

General interference of two waves in phase: constructive if $L_2 - L_1 = m\lambda$, and destructive if $L_2 - L_1 = (m + 1/2)\lambda$, where $L_1$ and $L_2$ are the distances to the two sources, $m$ is any integer, and $\lambda$ is the wavelength.
Principle of superposition: if $D_1$ and $D_2$ both satisfy the wave equation, so does $D_1 + D_2$.

Standing waves with node at $x = 0$: 

$$y(x, t) = A_{SW} \sin(kx) \sin(\omega t)$$

where $\omega/k = v_{wave}$, even though standing wave does not travel.

- $f_n = nv_{wave}/(2L); n = 1, 2, 3, \ldots$ (Standing waves on string with fixed ends)
- $f_n = nv/(2L), n = 1, 2, 3, \ldots$ (open pipe SW modes; just like string)
- $f_n = nv/(4L), n = 1, 3, 5, \ldots$ (half-open pipe SW modes)

Beats: $f_{\text{beat}} = |f_1 - f_2|

Chapter 34: Read sections 1, 2, and 4–7.

$L_2 - L_1 = n\lambda$ (constructive interference, for any wave with two sources in phase)

$L_2 - L_1 = (n + 1/2)\lambda$ (destructive) $(n = 0, \pm 1, \pm 2, \ldots)$

For sources out of phase, simply switch “constructive” with “destructive” above.

Reflected waves are flipped in phase when reflecting off a higher value of $n$ (slower-wave material). They reflect with the same phase when reflecting off a lower value of $n$.

So, we have two cases for thin-film interference:

If one surface has $n$ increasing and the other has $n$ decreasing, then bright reflections whenever $2nd = (m + 1/2)\lambda$, where $d$ is the film width, and $\lambda$ is the wavelength in vacuum (and so $\lambda/n$ is the wavelength in the film, which has index of refraction $n$).

If both surfaces have $n$ increasing or both have $n$ decreasing, then bright reflections are whenever $2nd = m\lambda$ instead.

For other cases (e.g., transmission instead of reflection), the specific setup should be analyzed to determine whether the two sources are in or out of phase with one another, and then the appropriate formula above should be used.

2-slit interference patterns for small wavelengths: just replace $L_2 - L_1$ with the approximate value $d\sin\theta$, where $d$ is the distance between the two slits:

- dark spots at angle $\theta$ from the normal whenever $d\sin\theta = (m + 1/2)\lambda$, where $d$ is the distance between the slits, and $m = 0, \pm 1, \pm 2, \ldots$
- bright spots whenever $d\sin\theta = m\lambda$, with $m = 0, \pm 1, \pm 2, \ldots$ (also true for $N$ slits when $N \geq 2$)

Dark spots for $N$ slits: $d\sin\theta = m\lambda/N$, with $m = 0, \pm 1, \pm 2, \ldots$ but $m$ not a multiple of $N$

Chapter 35: Read sections 1, 7, and 11.

1-slit diffraction: dark spots at angle $\theta$ from the normal whenever $a\sin\theta = \pm m\lambda$, where $a$ is the slit width and $m = 1, 2, 3, 4, \ldots$; note that $m = 0$ is never a dark spot but is always bright (the central maximum).

In all of the above formulae, we are usually interested in the case when the imaging screen is much farther away than the distances between spots. In that
case, we may replace $\sin \theta$ with $y/L$ (which is actually $\tan \theta$), where $y$ is the position of the spot on the screen and $L$ is the distance to the screen.

Polarization: concentrate on types of polarization possible (linear, circular, elliptic), and what they mean (direction of electric field wiggles, in plane perpendicular to the direction the light is traveling).

Important property of polarizers: any light which makes it through becomes polarized in the new direction.

Malus’ law for linear polarizers: intensity $I = I_0 \cos^2 \theta$ when passing through a new polarizer at angle $\theta$ to the original linear polarization direction (classical light only! Not true for individual photons).

For unpolarized light passing through a polarizer, $I = I_0/2$. The factor of $1/2$ comes from averaging $\cos^2 \theta$ over all possible angles $\theta$. 