CHAPTER 22 (Knight, 2nd edition)

(SCROLL DOWN FOR BOOK-RELATED PRE-READING)

COMPUTER SIMULATION:

Got to http://vsg.quasihome.com/interfer.htm
play with the different settings. Notice the changes to the interference pattern on the screen as you adjust the different parameters. It's good to get a sense of the what wavelengths are associated with the different colors, particularly red, green, and blue.

Q1. Comp SIM
What happens in the sim if you move from pink light to orange light? Choose ALL that apply.
1. **The distance from the central maximum to the first fringe increases.**
2. The distance from the central maximum to the first fringe decreases.
3. **The distance between bright fringes increases.**
4. The distance between bright fringes decreases.
5. **Less fringes appear on the screen.**
6. More fringes appear on the screen.

Feedback: play with the sim here: http://vsg.quasihome.com/interfer.htm
Also you can look at p.674-675, particularly eqn. 22.6 is helpful here.

Q2. Comp SIM
What happens in the sim if you increase the distance between the two slits? Choose ALL that apply.
1. The distance from the central maximum to the first fringe increases.
2. **The distance from the central maximum to the first fringe decreases.**
3. The distance between bright fringes increases.
4. **The distance between bright fringes decreases.**
5. Less fringes appear on the screen.
6. **More fringes appear on the screen.**

Feedback: play with the sim here: http://vsg.quasihome.com/interfer.htm
Also you can look at p.674-675, particularly eqn. 22.6 is helpful here.

Q3. Comp SIM
What happens in the sim if you mover the two slits closer to the screen (i.e., you decrease L)? Choose ALL that apply.
1. The distance from the central maximum to the first fringe increases.
2. **The distance from the central maximum to the first fringe decreases.**
3. The distance between bright fringes increases.
4. **The distance between bright fringes decreases.**
5. Less fringes appear on the screen.
6. **More fringes appear on the screen.**

Feedback: play with the sim here: http://vsg.quasihome.com/interfer.htm
Also you can look at p.674-675, particularly eqn. 22.6 is helpful here.

22.1 Light and Optics - This section is interesting but optional.
NO QUESTIONS

22.2 The Interference of Light. We started discussing this on Friday. Read this section carefully and try to see how the geometry and the concept of path length difference leads to the conditions stated for constructive and destructive interference.
This is similar to interference in two dimensions we discussed when looking at sound. For the subsection on intensity of the double slit, think about how the total energy is related to A^2.

22.2 Q1. Look at Fig 22.3. What would happen to the interference fringes if the viewing screen was moved farther away from the double slit?

1. The fringes get brighter but otherwise do not change.
2. The fringes get brighter and closer together.
3. The fringes get brighter and farther apart.
4. The fringes get dimmer and closer together.
5. **The fringes get dimmer and farther apart.**

Feedback: review p.673 and equation 22.6.
If you picture moving a screen further away, the intensity will decrease (sort of like sound at farther distances). Also less of the interference pattern can 'fit' on the screen.

22.2 Q2. What conditions must be met to allow for the correct application of the small-angle approximation in equations 22.2 -22.6? (Chose ALL that apply)

1. **The angle must be 1° or less.**
2. The angle must be in the range 0 - 15°.
3. **The distance between the slits (d) must be much less (<<) than the distance to the screen (L), i.e., d << L.**
4. The distance between the slits (d) must be much more (>>) than the distance to the screen (L), i.e., d >> L.
5. The distance between the slits (d) must be equal to the distance to the screen (L), i.e., d = L.
6. **The wavelength must be much smaller than the distance between the slits. In practice, this is the case for light waves but NOT for sound waves.**
7. The wavelength should be similar to the distance between the slits. In practice, this is the case for BOTH light waves and sound waves.

Feedback: review p. 674-675. For the pendulum example, we could assume a small angle to be less than 15 degrees, but NOT here; for the light rays to be NEARLY PARALLEL the angle must be close to 1 degree.
The wavelength must be much smaller than the distance between the slits. This works really well for visible light waves, where wavelengths are on the order of 10^-9 m vs. slit distance on the order of 10^-3m. Sound waves are moving at 340 m/s with the distance between sources (analogous to slit distance) on the order of meters (does not work in approximation).
This is the same argument about the order of magnitude difference needed between the slit separation distance (d) and the distance to the screen (L).

22.2 Q3. Which one of these quantities does not influence the separation between two adjacent bright fringes?
1. Slit separation, d.
2. Wavelength, λ.
3. Distance to screen, L.
4. **Fringe number, m.**
5. All of the above have an influence.
*Feedback: The key word here is *adjacent* fringes. The width of fringes, or separation distance between two adjacent fringes, remains CONSTANT in a double slit experiment. (you can't just look at equation 22.6 -- you need to know what the formula describes PHYSICALLY!).*

22.2 Q4. Light of wavelength λ1 illuminates a double slit, and interference fringes are observed on a screen behind the slits. When the wavelength is changed to λ2, the fringes spread farther apart. How large is λ2 relative to λ1?
1. **λ2 is larger (longer) than λ1.**
2. You cannot tell from this information.
3. λ2 is smaller (shorter) than λ1.
Feedback: review p. 674-675. The relationship of the wavelength and the slit distance plays a role in determining the distance between fringes, see equation 22.6.

22.3 - Diffraction Grating. This section will help you in lab next week(s). This is mostly conceptual. Try to reason through the text; take a minute-break while reading to picture what the text is talking about.

22.3 Q1. Which statements below are TRUE about a diffraction grating? (check ALL that apply).

1. "lines per millimeter" refer to the number that appear on a screen some distance away from a diffraction grating.
2. The fringes get more narrow and distinct, but do NOT get any brighter when the N number of slits increases.
3. **The fringes get more narrow and distinct when the N number of slits increases.**
4. **The fringes get brighter when the N number of slits increases.**
5. **"lines per millimeter" refer to the number of slits per millimeter on a diffraction grating.**
6. **You can NOT use the small angle approximation for diffraction gratings, which you can use for two-slit interference.**
7. You can use the small angle approximation for diffraction gratings, which you can use for two-slit interference.
8. The fringes get brighter when the N number of slits increases, but do NOT get more narrow and distinct.

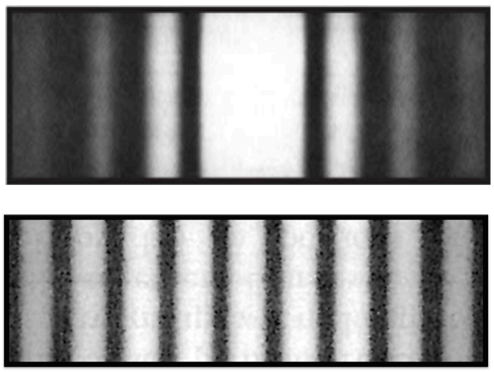
Feedback: Review p. 678-679 -- all the information is there (re-read it!).

22.4 Single-Slit diffraction. Read this section *carefully*. Equation 22.20 is often confusing for students, as it would imply MAXIMUM interference for a DOUBLE slit (m), BUT IS A DARK MINIMUM for a SINGLE-slit diffraction (p). Also compare the width of the central fringe for a single-slit and double-slit interference pattern.

22.4 Q1. There are two patterns of light intensity below. Pattern A is a result of .... and pattern B is a result of ...

A.

B.



1. two-slit interference, diffraction from a grating
2. **diffraction from a single slit, two-slit interference**
3. diffraction from a grating, two-slit interference
4. two-slit interference, diffraction from a single slit
5. diffraction from a single slit, diffraction from a grating
6. diffraction from a grating, diffraction from a single slit

Feedback: review the figures 22.2, 22.3 (p.672-673), and Fig. 22.8 (p.679), and Fig. 22.10 (p.681).
Pattern A is from a single-slit, since the central band is a broad bright fringe. Pattern B is from two-slit interference since the fringes are evenly spaced, with more bright appearing than dark. A pattern from a diffraction grating (see p.679) has narrow bright fringes with wider dark bands in between.

22.4 Q2. The figure in Stop to Think 22.4 shows two single-slit diffraction patterns. The distance between the slit and viewing screen is the same in both cases. Which of the following statements could be true? (Perhaps more than one *could be* true, just not simultaneously true.

1. The wavelengths are the same for both; a1 < a2.
2. **The wavelengths are the same for both; a2 < a1.**
3. **The slits are the same for both; λ1 < λ2.**
4. The slits are the same for both; λ2 < λ1.

Feedback: review p. 681- 683. The width of the central maxima, which is proportional to λ/a, has increased. This could occur EITHER because λ has INCREASED or the slit width, a, has decreased.

22.4 Q3. The equation for complete destructive interference for diffraction from a single-slit is

1. **$a\sin\theta = p\lambda$, where p = 1, 2, 3**
2. $a\sin\theta = p\lambda$, where p = 0, 1, 2
3. $d\sin\theta = m\lambda$, where m = 0, 1, 2
4. $d\sin\theta = (m+1/2)\lambda$, where m = 0, 1, 2
5. $d\sin\theta = m\lambda$, where m = 1, 2, 3
6. $a\sin\theta = (p+1/2)\lambda$, where p = 1, 2, 3

Feedback: review p. 682-683, particularly eqn. 22.19. This is CRUCIAL! SINGLE-SLIT diffraction the complete destructive interference when $a\sin\theta = p\lambda$, where p = 1, 2, 3. This is because of the paris of rays that cancel each other. (Two-slit interference is only considered to be 2 rays, and so follows analogous to sound interference from two speakers).

22.5 Circular-Aperture Diffraction -- only p.685 (including example 22.6). Interference still occurs from a pinhole, but the geometry of the slit changes the shape of the interference pattern. Equation 22.23 tells us the 'Rayleigh criterion': the limit for distinguishing small details of an object. This is important for resolving power of microscopes, telescopes, and our own eyes.
There is a good *short* summary of this here:
http://hyperphysics.phy-astr.gsu.edu/hbase/phyopt/raylei.html

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22.5 Q1. Which statement is FALSE about the width of the central maximum of a circular-aperture diffraction.

1. If the distance to the screen (L) increases, then the circular spot increases in size (i.e., increases in diameter).
2. If the distance to the screen (L) increases, then the circular spot increases in size in the same way the width of the central maximum increases in single slit diffraction.
3. If the size of the aperture (D) is increased, then the circular spot decreases in size (i.e., decreases in diameter).
4. **If the size of the aperture (D) is increased, then the circular spot increases in size (i.e., increases in diameter).**

Feedback: review p. 684-685. Compare equations 22.22 and 22.24 and the text surrounding.

**I usually include a few subsections from chap 20 & 21 here, as it matches thematically, as well as Chap 34 Giancolli:*

20.5, subsection The Index of Refraction (p.618-619). We have already discussed this in class, but make sure you understand the change to properties of a light wave inside a medium. These formulas are not difficult, but be sure you understand where they come from. Looking at Fig. 21. 8 (p.639), you see that a traveling wave reflected from a higher μ-rope (analogous to a higher n-value) the REFLECTED wave will be pi-shifted. But if the wave travels to a smaller μ-rope (analogous to a smaller n-value), there is NO phase shift to the reflected wave.

20.5 Q1. Looking at the Figure in the Stop to Think 20.5, rank in order, from largest to smallest, the speed of the wave inside the material.
1. v_b > v_c > v_a
2. v_c > v_a > v_b
3. v_a > v_b > v_c
4. v_a > v_c > v_b
*5. **v_b > v_a > v_c***
feedback: review p. 618-619. The higher the index of refraction, the SLOWER the light moves. If v goes down, then wavelength goes down (frequency is CONSTANT), so a shorter wavelength corresponds to a slower speed.

20.5 Q2. Think about light passing through a fish tank. A light wave traveling in air (n = 1.0) will be ..... phase shifted when reflected off of the glass (n=1.5). The reflected light from the backside of the glass passing into the water (n = 1.33) will be ..... phase shifted.
Fill in the blanks.
1. pi, also pi
*2. **pi, zero***
3. zero, also zero
4. zero, pi
Feedback: review p. 652. Light reflected from a medium with a HIGHER index of refraction will ALWAYS be pi-shifted. otherwise there is NO shift.

*21.6, subsection Application: Thin-Film Optical Coating. This interference is a mix of BOTH phase difference (from the reflection) and path difference (distance traveled inside the film). It is *important* to note that the wavelength INSIDE the film will change.*

This needs to be carefully taken into account.

GIANCOLLI: 34.5 - Interference in Thin Films (posted on VISTA for those of you that do not have the custom edition text). This is a much more thorough explanation of thin-flim interference. Make sure you can follow their arguments now that we have covered this in lecture. Look carefully at example 34.6 and 34.7.

34.5 Q1. Looking at example 34.7, what is the minimum thickness of a soap bubble to create constructive interference?

1. λ/2
2. 3λ/2
3. λ
*4. **λ/4***

Feedback: review p. 910-913, particularly looking at p. 912. If the REFLECTION of the two rays are initially OUT of phase, then destructive interference will occur at mλ=2t. So in order to get constructive interference, the path difference needs to be (m+1/2)λ. The minimum thickness would be λ/4, so that the path difference would be λ/2 (into the film a distance λ/4 and out of the film a distance λ/4).