A.P. Physics – B

UNIT 11 TEST REVIEW

Light and Optics: Chapters 22-24

*** In studying for your test, make sure to study this review sheet <u>along with your quizzes and homework assignments.</u>**

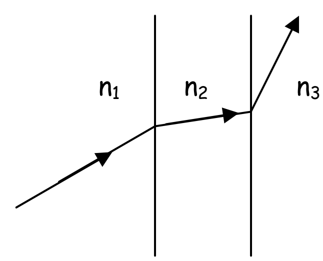
Multiple Choice Review: **On this portion of the test, you will not be allowed to use your calculator or AP formula sheet. (You may, however, use your AP table of information.) Approximate $g=10m/s^2$ for simplicity of calculations. No partial credit will be given.**

1. A physics student places an object 6.0cm from a converging lens of focal length 9.0cm. What is the magnitude of the magnification of the image produced?

a. 0.6 **b.** 1.5 **c.** 2.0 **d.** 3.0 **e.** 3.6

2. A light ray moves across two interfaces as shown in the figure. Which of the following relations is true for the three indices of refraction?

a. $n_1 > n_2$, $n_2 > n_3$, $n_1 > n_3$
b. $n_1 < n_2$, $n_2 > n_3$, $n_1 < n_3$
c. $n_1 > n_2$, $n_2 > n_3$, $n_1 < n_3$
d. $n_1 < n_2$, $n_2 > n_3$, $n_1 > n_3$
e. $n_1 < n_2$, $n_2 < n_3$, $n_1 < n_3$



3. A concave mirror with a radius of curvature of 1.0m is used to collect light from a distant star. The distance between the mirror and image is most nearly

a. 0.25m **b.** 0.50m **c.** 0.75m **d.** 1.0m **e.** 2.0m

4. Which of the following is characteristic of both sound and light waves?

a. They are longitudinal waves.
b. They are transverse waves.
c. They travel with the same velocity.
d. They can be easily polarized.
e. They give rise to interference effects.

5. When light passes from air into water, the frequency of the light remains the same. What happens to the speed and wavelength of light as it crosses the boundary in going from air into water?

	Speed	Wavelength
a.	Increases	Remains the same
b.	Remains the same	Decreases
c.	Remains the same	Remains the same
d.	Decreases	Increases
e.	Decreases	Decreases

6. An object is placed in front of a converging thin lens at a distance from the center of the lens equal to half the focal length. Compared to the object, the image is…

a. upright and larger.
b. upright and smaller.
c. inverted and larger.
d. inverted and smaller.
e. inverted and the same size.

7. A radio station broadcasts on a carrier frequency of 100MHz. The wavelength of this radio wave is most nearly…

a. 0.003m **b.** 1.0m **c.** 3.0m **d.** 3.3m **e.** 3×10^6m

8. When monochromatic light is passed through a slit of a particular width, a diffraction pattern is formed on a screen. Which one of the following happens when the width of the slit is decreased?

a. The bands of the diffraction pattern spread apart on the screen.
b. The bands of the diffraction pattern squeeze together on the screen.
c. The color of the bands in the diffraction pattern changes.
d. The intensity of the bands in the diffraction pattern changes.
e. There is no change in the diffraction pattern.

9. An object is placed on the axis of a converging thin lens of focal length 2cm, at a distance of 8cm from the lens. The distance between the image and the lens is most nearly…

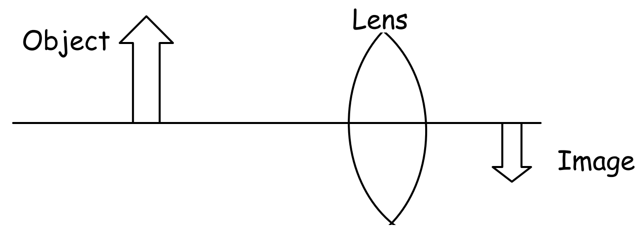
a. 0.4cm **b.** 0.8cm **c.** 1.6cm **d.** 2.0cm **e.** 2.7cm

10. Monochromatic light of wavelength 500nm falls upon two slits spaced 5μm apart. How far from the central maximum does the first bright fringe appear on a screen that is 4m from the slit-plate? (Hint: For very small angles, tanθ and sinθ are basically equal.)

a. 4mm **b.** 4cm **c.** 8cm **d.** 40cm **e.** 80cm

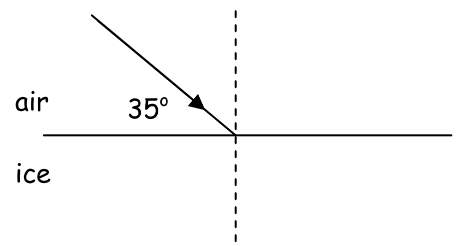
11. For the diagram, the image formed by the ___________lens is a ___________ image and the image distance is ___________.

a. converging, real, positive
b. converging, real, negative
c. converging, virtual, positive
d. diverging, virtual, negative
e. diverging, virtual, negative



Problem Review: On this portion of the test, you may use your calculator, AP formula sheet, and AP table of information. Partial credit will be given on these problems.

12. A ray of monochromatic 500nm-wavelength light traveling through air is incident upon ice (n=1.309) as shown.



a. What is the speed of the light in the ice?

b. What is the wavelength of the light in the cube of ice?

c. What is the angle between the reflected and refracted rays as they leave the boundary?

d. If the light had been approaching from inside the ice, what would be the maximum angle from the normal at which it could have approached, in order to pass into the air, rather than be totally internally reflected?

13. A 10cm-tall object is placed 12cm in front of a convex mirror that has a radius of curvature of 35cm. First sketch a ray diagram to predict the approximate image position and height. Then calculate the image position and height, and state whether the image is real or virtual, and upright or inverted.

14. A concave mirror with a focal length of 10cm produces an upright image to the right of the mirror, that is magnified by a factor of 1.3. Where is the object located?

15. A 7cm-tall object is placed 15cm in front of a diverging lens that has a focal length of 10cm. First sketch a ray diagram to predict the approximate image position and height. Then calculate the image position and height, and state whether the image is real or virtual, and upright or inverted.

16. Light of wavelength 550nm falls on two slits spaced 0.4mm apart, and an interference pattern is observed on a screen 1.9m from the slits. Find the angle between the second-order maximum and the third-order minimum.

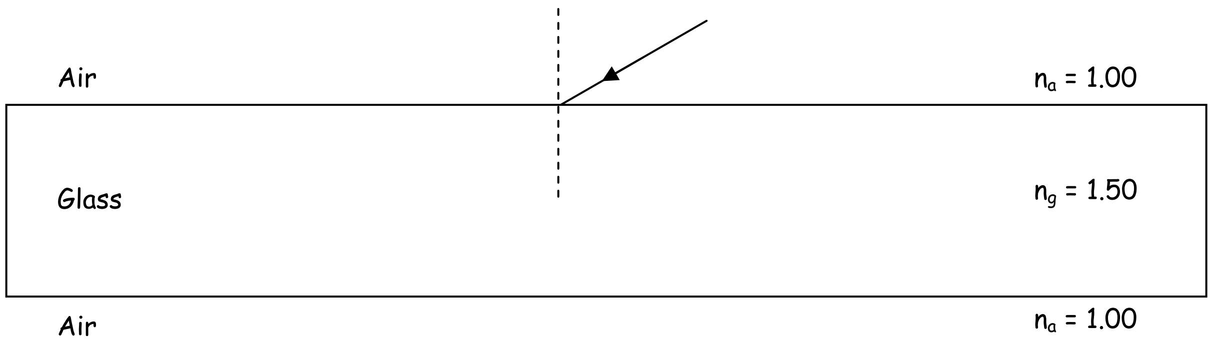
17. Light of wavelength 480nm falls on a single 0.5mm-wide slit and forms a diffraction pattern on a screen 2.3m away. Find the width of the central maximum.

18. A diffraction grating with 1200 lines/cm is illuminated with light of wavelength 420nm. What is the highest order-number that can be observed with this grating?

19. Actual A.P. Physics B Free-Response Question (2000):

A sheet of glass has an index of refraction $n_g = 1.50$. Assume that the index of refraction for air is $n_a = 1.00$.

a. Monochromatic light is incident on the glass sheet, as shown in the figure below, at an angle of incidence of 60°. On the figure, sketch the path the light takes the first time it strikes each of the parallel surfaces. Calculate and label the size of each angle (in degrees) on the figure, including angles of incidence, reflection, and refraction at each of the two parallel surfaces shown.



b. Next, a thin film of material is to be tested on the glass sheet for use in making reflective coatings. The film has an index of refraction $n_f = 1.38$. white light is incident normal to the surface of the film. It is observed that at a point where the light is incident on the film, light reflected from the surface appears green (λ = 525nm).

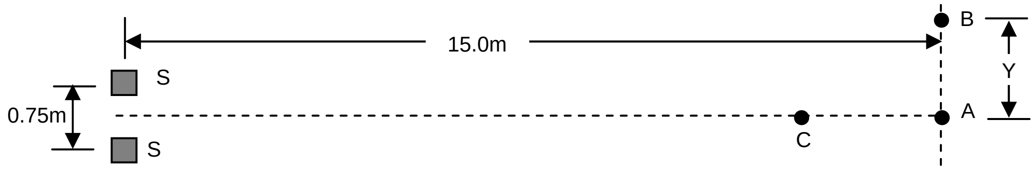
i. What is the frequency of the green light in air?

ii. What is the frequency of the green light in the film?

iii. What is the wavelength of the green light in the film?

iv. Calculate the minimum thickness of film that would produce this green reflection.

20. Actual A.P. Physics B Free-Response Question, sort of (2004):



Two small speakers S are positioned at a distance of 0.75m from each other, as shown in the diagram above. The two speakers are each emitting a constant 2500Hz tone, and the sound waves from the speakers are in phase with each other. A student is standing at point A, which is a distance of 15.0m from the midpoint between the speakers, and hears a maximum from constructive interference of the sound waves, as expected. Use 345m/s for the speed of sound, if it is needed.

a. Calculate the wavelength of the sound waves produced by the speakers.

b. The student moves a distance Y to point B, and notices that the sound intensity has decreased to a minimum, because of destructive interference between the sound waves. Calculate the shortest distance Y the student could have moved to hear this minimum.

ANSWERS:

12.a. $n = c/v$ so $v = 3\times10^8 / 1.309 = 2.29\times10^8$ m/s

b. Because frequency doesn't change, when the light changes speed, its wavelength must change by the same factor. So… $\lambda = \frac{500nm}{1.309} = 382nm$

c. Use Snell's law for the following: $(1)(\sin 55^\circ) = (1.309)(\sin\theta_r)$ so $\theta_r = 38.7^o$
Then find the angle between the reflected ray (which reflects at 55° to the normal) and the refracted ray (which travels at 38.7° to the normal) by taking 180-(55+38.7) = 86.3°.

d. You're really being asked for the critical angle, which can be found by…

$$\sin\theta_C = \frac{n_2}{n_1} \quad \text{so} \quad \theta_C = \sin^{-1}\frac{n_2}{n_1} = \sin^{-1}\frac{1}{1.309} = 49.8^\circ$$

13. After you sketch your ray diagram, use the mirror equation (with f=-17.5cm) to find that the image distance s_i = -7.12cm. And find magnification M = +0.59 so height h_i = 5.9cm. Because image distance is negative, it's virtual, and because image height is positive, it's upright.

14. Solve two equations simultaneously, the mirror equation and the magnification equation. Magnification gives you that $s_i = -1.3s_o$. Plug this into the mirror equation to get $\frac{1}{s_o} + \frac{1}{-1.3s_o} = \frac{1}{10}$. Solve to get s_o = 2.308cm left of mirror.

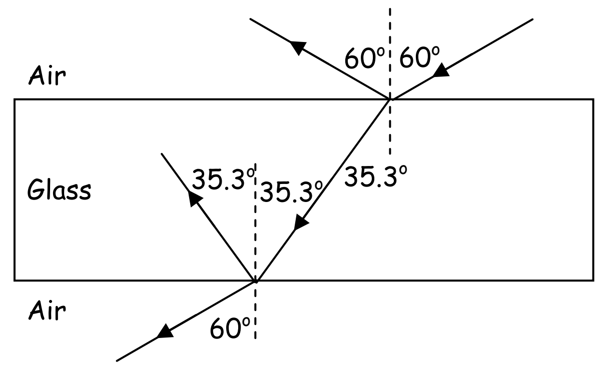
15. After you sketch your ray diagram, use the thin-lens equation (same as the mirror equation, but with different sign conventions) and the magnification equation. If you use f = -10cm, you find that s_i = -6cm, and M = +0.4. So this virtual image is found 6cm in front of the lens. The image is also upright and 2.8cm tall.

16. For 550nm light waves, plug into the interference equation twice, for m=2 and for m=3.5. Solve for θ both times, and then subtract to find the angular separation to be 0.1181°.

17. For a single-slit experiment, remember that the interference equation still applies, but with integral m-values predicting the location of <u>dark</u> fringes. Also remember that the width of a bright fringe will just be the distance from one dark fringe to the next dark fringe. So for this problem, find θ=0.055° out from central max to the first dark fringe. The distance out from the central max is just found then by x = (2.3)(tan0.055°) = 2.208mm. So the width of the central max is just twice this value, 4.416mm.

18. For diffraction grating problems, remember that the interference equation works for again predicting locations of bright fringes. Also remember that 1200lines/cm is d^{-1}. Lastly, remember that the limiting factor on observable order-numbers is that $\theta < 90^\circ$. Using all of this with the interference equation gives m = 19.8, so the highest that can actually be observed is 19.

19.a. Your drawing should include the angle of reflection at each interface (just equal to angle of incidence), and angle of refraction upon entering each new substance (calculated with Snell's law). It should look like this…



b.i. Use $c=f\lambda$ to get $f = 5.71E^{14}$ Hz.

ii. Frequency doesn't change when it enters a new substance.

iii. The wavelength changes by the same factor that the speed changes by upon entering the new substance - n_g. So $\lambda' = 525/1.38 = 380$nm

iv. Because both waves are inverted upon reflection at the two interfaces, the waves are in phase with each other, and the second wave needs to travel $m\lambda$ farther than the first one while in the film. So…

$2T = m\lambda = (1)(380\text{nm})$ and $T = 190$nm.

20.a. Don't be freaked out that this is a sound wave problem in the optics chapter- because ALL waves can undergo diffraction. For part a, just use $v=f\lambda$ to arrive at $\lambda = 0.138$m

b. This is really asking for the location of the 1st "dark" fringe (though it's actually a "quiet" fringe). Use $d\sin\theta=(0.5)\lambda$ to find θ, and then use $Y = L\tan\theta$ to find Y = 1.39m.

20. White light is incident upon a thin film of oil (n=1.18) covering a piece of glass (n=1.52). What would need to be the minimum thickness of the oil film for a wavelength of 600nm to be most strongly reflected?

21. Two glass plates (n=1.46) are separated at one end by a very thin wire of diameter $3.15\mu m$, leaving a thin film of air (of changing thickness) between the plates. When the plates are illuminated by light of wavelength 720nm, how many dark bands appear on the surface of the top plate because of destructive interference?

Answers

20. First, think about whether the inversion of the light ray(s) needs to be considered. The rule says that the waves will be inverted upon reflection if attempting to enter into a higher-n material, so inversion happens in this case at both interfaces. Therefore, you don't need to worry about inversion on this problem. Next, think about how much farther the second wave needs to travel in order for constructive interference to happen, and the answer is that it needs to travel $m\lambda$ farther than the first wave. So $2T = m\lambda$, and T = 254nm. (Don't forget that λ refers to wavelength in the film.)

21. The number of dark lines is directly linked to the m-value (number of wavelengths) at that thickest part of the film. Start by realizing that inversion will happen at one interface, so the waves will start by being 180^o out of phase. This means that you need the second wave to travel $m\lambda$ farther than the first one for destructive interference to occur. So $2T = m\lambda$ and m=8.75 at the thickness of the wire. So this means the 8^{th}-order dark fringe is the one that occurs closest to the wire. But there would be a total of 9 dark bands, because there would be a dark band for the 0^{th}-order (corresponding to a path difference of 0 between the two waves).