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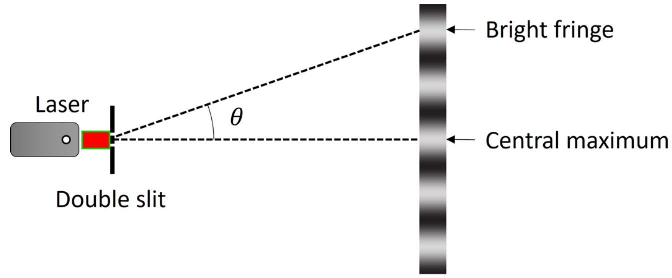
I. Lecture Multi Choices (60 points)

1) (5 pts.) In a double-slit interference experiment using red laser light, the slit separation is 150 times the light's wavelength. What is the angle between the central maximum and the bright fringe indicated by an arrow in the provided diagram?

A. 0.007^o
B. 0.013^o
C. 0.38^o
D. 0.76^o
E. 1.52^o



$$\theta_m \approx \frac{m\lambda}{d} \rightarrow \Rightarrow \Delta\theta = \theta_2 - \theta_0 = 2\frac{\lambda}{d} = \frac{2}{150} = 0.0133\, rad = 0.76^o$$

2) (5 pts.) In a single-slit diffraction experiment, which of these individual changes would widen the central maximum on the screen?
i) Use a laser with a higher frequency.
ii) Make the slit narrower.
iii) Place the screen farther away from the slit.

A. (i)
B. (ii)
C. (iii)
D. More than one of the choices above
E. None of the choices above

$w = \frac{2\lambda L}{a}$ Broader W, means larger wavelength λ, lower frequency f, narrower slit a, farther away L
Answer ii and iii are correct. Therefore, correct answer is D

3) (5 pts.) In a single-slit diffraction setup, a 0.30-mm-wide aperture is illuminated by infrared light with a 3 µm wavelength. At what angle, in degrees, does the first dark fringe appear?
A. 0.01^o
B. 0.012^o
C. 0.57^o
D. 0.69^o
E. 1.38^o

$$\theta = \frac{1.22\lambda}{D} = 1.22 \times \frac{3E-6}{0.3E-3} = 0.0122\, rad = 0.699^o$$

4) (5 pts.) In a diffraction grating experiment, how does increasing only the number of slits affect the interference pattern on the screen? All other factors, including slit spacing, remain constant.

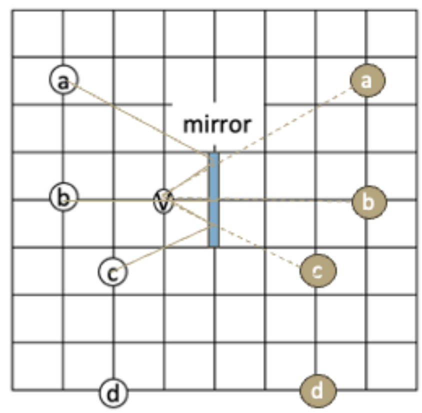
Select all correct statements from the following options:

A. The fringes stay the same brightness.
B. The fringes get brighter and narrower.
C. The fringes get dimmer and wider.
D. The fringes get closer together. The fringes get farther apart.
E. There are more than two answers above.

$d \sin\theta_m = m\lambda$, $y = L \tan\theta$ the slit spacing doesn't change and the wave length doesn't change. The diffraction angle stays the same. In this case, the only effect is brighter and narrower, answer B

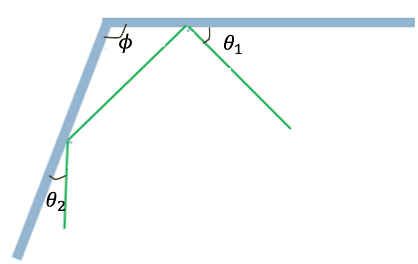
5) (5 pts.) An observer stands at point V facing a flat mirror. Multiple light sources are positioned in the vicinity. Which of these light sources will the observer see reflected in the mirror?

A. (b) only
B. (b) and (c) only
C. (a) and (b) only
D. (a), (b) and (c) only
E. All four of them



Draw ray diagrams and conclude (a), (b), (c) only. Ray to reach d would have to reflect off a place where the mirror is not.

6) (5 pts.) Two mirrors are positioned to form a vertex with an angle ϕ between their reflecting surfaces. A light ray strikes the first mirror at an angle θ_1 = 40° from the horizontal plane. The reflected ray then hits the second mirror and is reflected at an angle θ_2 = 30° from its surface. Calculate the angle ϕ between the two mirrors. (Note: The accompanying figure is not drawn to scale.



A. 70^o
B. 90^o
C. 100^o
D. 110^o
E. 145^o

From the law of reflection we know that the angles inside the triagle are the same as the incident angles. $\phi = 180 - 40 - 30 = 110$ (C)

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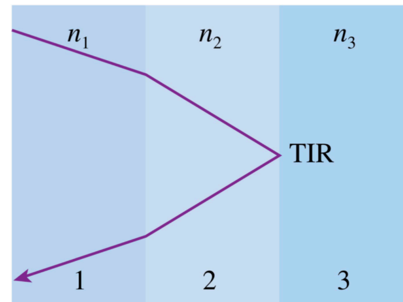
7) (6 pts.) A laser beam undergoes two refractions at the interface between medium 1 and 2, and total internal reflection (TIR) at the interface between medium 2 and medium 3 as shown. Rank the indices of refraction of media 1, 2, and 3.



A. $n_1 < n_2 < n_3$
B. $n_1 < n_3 < n_2$
C. $n_2 < n_1 < n_3$
D. $n_2 < n_3 < n_1$
E. $n_3 < n_2 < n_1$

In 1-2 boundary, theta_1 is less than theta_2, therefor n1>n2
In 2-3 boundary, TIR occurs, the condition is n2>n3
n3<n2<n1. Solution is (E)

8) (6 pts.) An object is positioned in front of a concave lens at a distance less than the lens's focal length. Describe the characteristics of the resulting image.

A. Diminished, Upright, Virtual
B. Diminished, Inverted, Virtual
C. Enlarged, Upright, Virtual
D. Enlarged, Inverted, Virtual
E. Enlarged, Upright, Real

For a concave lens, the image is always diminished, upright, virtual. Key is A. Could draw ray diagram to check answer.

9) (6 pts.) A person whose near-point distance is 42 cm can focus on an object 24 cm from her eyes with the aid of a pair of contact glasses. Find the refractive power of her glasses.

A. $0.15\ D$
B. $0.56\ D$
C. $1.79\ D$
D. $6.54\ D$
E. $13\ D$

It is important to note that the distance we need to put the object to be seen is at the near-point distance. So s' = -0.42. Negative because it is virtual.

$$\frac{1}{0.24} + \frac{1}{-0.42} = \frac{1}{f} \rightarrow f = \left(\frac{1}{0.24} + \frac{1}{-0.42}\right)^{-1} = 0.56\ m.$$

$$P = \frac{1}{f} = \frac{1}{0.56\ m} = 1.786\ D.\ Key\ is\ (\ C\ )$$

Use the scenario below for the next two questions.

An object is placed near the axis at a distance of 10 cm in front of a mirror, forming an image at 5.0 cm behind the mirror.

10) (6 pts.) What is the magnitude of the focal length of the mirror? Is this a diverging or converging

A. 0.1 cm, diverging
B. 3.3 cm, converging
C. 3.3 cm, diverging
D. 10 cm, converging
E. 10 cm, diverging

$\frac{1}{s}+\frac{1}{s'}=\frac{1}{f}$, s = 10cm, s' = -5 cm f= -10cm . It's a diverging mirror (convex mirror) with |f|= 10cm. Key is (E)

11) (6 pts.) Which of the following statement is true about the image ?

A. The image is the same size and upright compared to the object.
B. The image is double the size and upright compared to the object.
C. The image is double the size and inverted compared to the object.
D. The image is half the size and upright compared to the object.
E. The image is half the size and inverted compared to the object.

magnification m = -s'/s=5/10= ½. It's half the size. It's positive and therefore upright. Key is (D).

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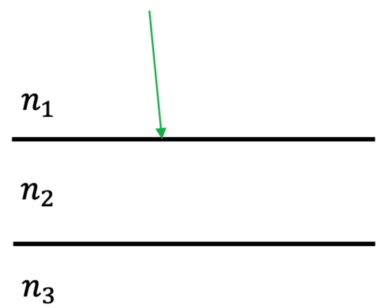
II. Lecture free response (20 points)

(6 pts.) Consider a stack of three transparent materials with different refractive indices: n_1 = 1.43 (top layer), n_2 = 2.33 (middle layer), and n_3 = 1.33 (bottom layer). Light with a wavelength of 400 nm in vacuum is incident normally (perpendicular to the surface) from above onto the top layer. Your task is to calculate the minimum thickness of the middle layer (n_2) that will result in maximum light transmission into the bottom layer (n_3).



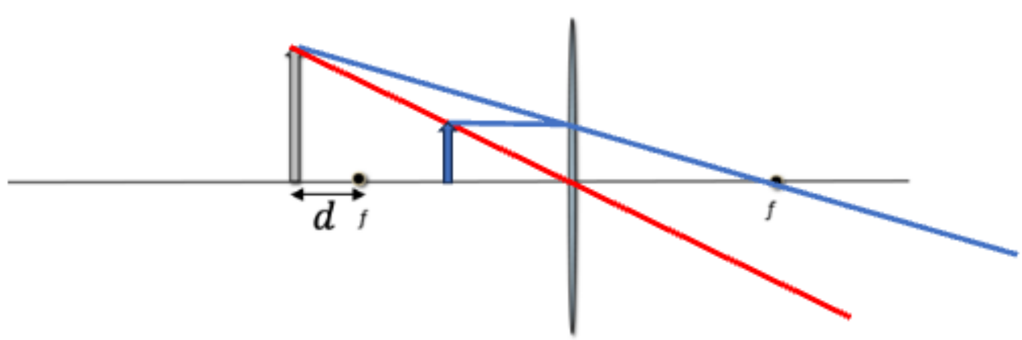
The transmitted rays from boundary 1→2→3,and the transmitted rays from 2→reflection,2→1 reflection and 2→3 transmission has no phase shift due to reflection. The only phase shifts come from travel thickness

$$2t = \frac{\lambda}{n_2} \to t = \frac{400}{2 * 2.33} = 86nm$$

(7 pts.) The virtual image of an object formed by a convex lens is shown.

(a) Use a ray diagram to find the approximate location of the object.

(b) Consider focal length 10 cm and the distance of image to the nearest focal point d is 2.5 cm, calculate the object distance.



$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \to \frac{1}{s} + \frac{1}{-12.5} = \frac{1}{10} \to s = 5.55\ cm$$

12) (7 pts.) A dentist employs a curved mirror to examine the back surfaces of teeth on the upper jaw. She requires specific conditions for optimal viewing: the mirror must be positioned 1.0 cm from a tooth, produce an upright image, and magnify the tooth's appearance by a factor of 3. For the purposes of this problem, assume that the tooth (object) and its image are aligned along a straight line. Given these parameters, determine the necessary properties and configuration of the curved mirror to achieve the dentist's desired viewing conditions.

(a) Is it a concave mirror or convex mirror?

(b) What is its focal length?

$$m = -\frac{s'}{s} = 3$$

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

$f = \left(\frac{1}{s} + \frac{1}{s'}\right)^{-1} = \left(\frac{1}{3cn} - \frac{1}{-3*1cm}\right)^{-1} = 1.5\ cm$. The focal length is positive. It's a concave mirror.

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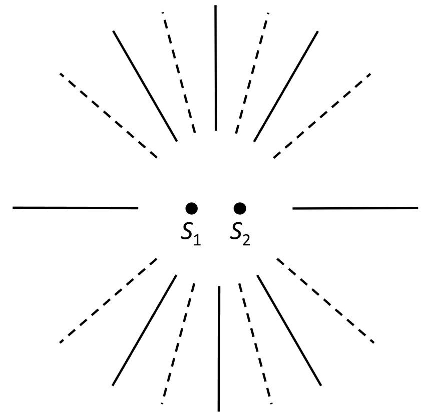
III. Tutorial free response (20 points)

Two point sources (S_1 and S_2) separated by a distance d generate periodic waves of wavelength λ_o by tapping the surface of the water with frequency f_o. The diagram at right shows the interference created far away from the sources: **antinodal lines** are represented by **solid lines** and *nodal lines* are represented by *dashed lines*.

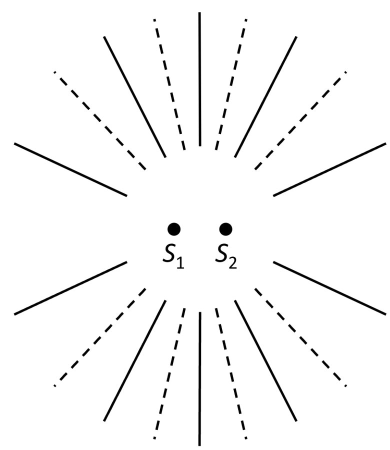


13) (6 pts) Determine the source separation in terms of the wavelength? Explain.

+2 2lambda
+2 Number of lines is related to separation distance
+1 Max separation determined by horizontal

Horizontal line has delta R of 2lambda which must be the source separation because the vertical line is equal to source separation.

14) (7 pts) A change is made to the frequency of the sources and as a result the interference pattern is changed, as shown at right. Is the new frequency *greater than*, *less than*, or *equal to* f_o? Explain.



+3 Greater Than
+2 Uses V=f*lambda equation
+2 Says pattern looks like separation increased
Because the biggest line is no longer on the horizontal we know that largest delta R is bigger than that line. That means that the separation must have increased between the sources relative to lambda. That must mean lambda got small so F must have gotten larger.

15) (7 pts) A mask with two holes directly above each other is placed in front of a screen. A red bulb is placed in front of the mask at the same height as the bottom hole, and a blue blub is placed directly above the red bulb, at the same height as the top hole, as shown at right. The holes are large enough that you can ignore diffraction. In the space below, draw what you see on the screen. Be sure to label the color of what you see.