Midterm 4
Exam Review
(Lecture #25)

INDEX OF REFRACTION
(v is the speed of light in the material)

$$n = \frac{c}{v} = \frac{\text{velocity light in vacuum}}{\text{velocity light in material}}$$

Equation 34-4 Physics for Engineers and Scientists 3/e

WAVELENGTH IN MATERIAL

$$f_{vacuum} = f_{material}$$

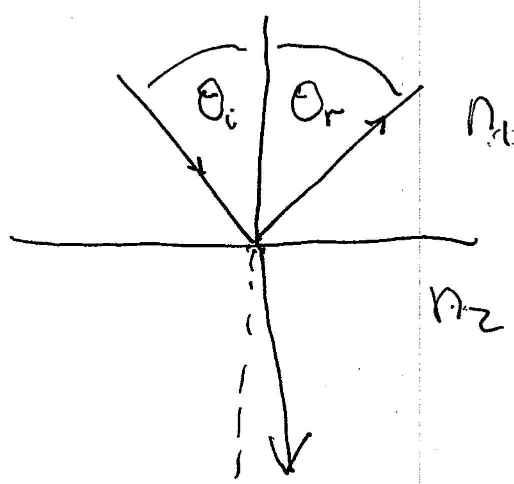
$$f\lambda = v = \frac{c}{n}$$

$$\lambda_{mat} = \frac{\lambda_{vac}}{n}$$

Equation 34-7 Physics for Engineers and Scientists 3/e

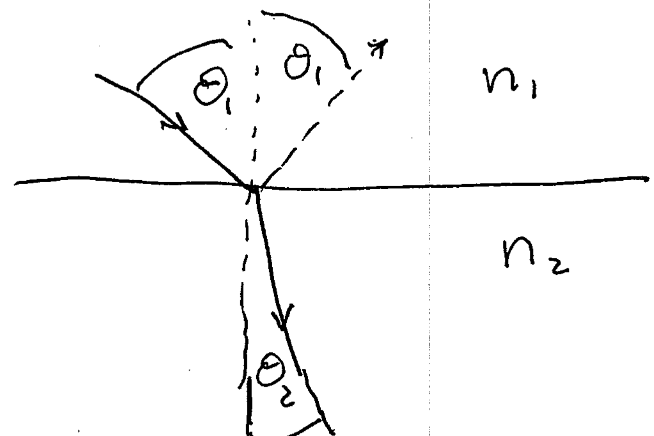
LAW OF REFLECTION

$$\theta_{\text{incident}} = \theta_{\text{reflected}}$$



Equation 34-1 Physics for Engineers and Scientists 3/e

LAW OF REFRACTION (SNELL'S LAW)

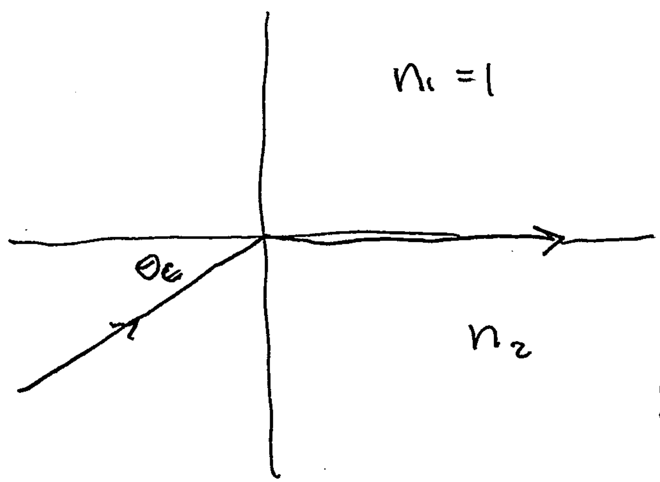


$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

small angles

$$n_1 \theta_1 = n_2 \theta_2$$

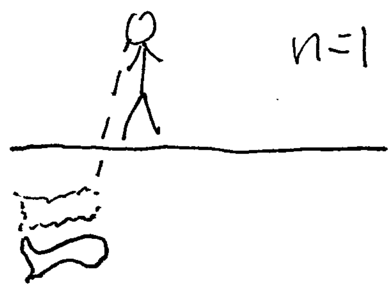
CRITICAL ANGLE FOR TOTAL INTERNAL REFLECTION



$$\sin\theta_{\text{crit}} = \frac{1}{n}$$

APPARENT DEPTH

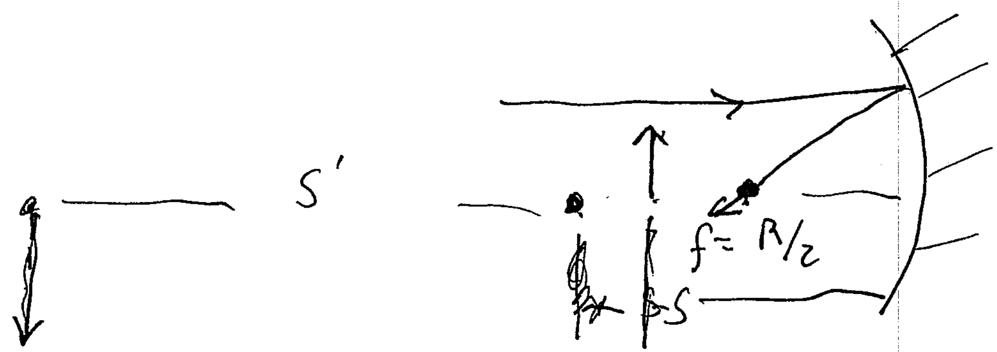
when viewing from air



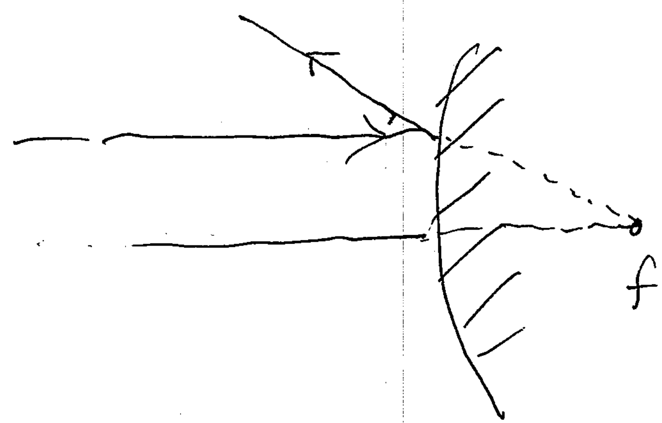
$$[\text{apparent depth}] = \frac{[\text{actual depth}]}{n}$$

Equation 34-15 Physics for Engineers and Scientists 3/e

FOCAL LENGTH OF SPHERICAL MIRROR



$$f = \pm\frac{1}{2}R$$



MIRROR AND LENS EQUATION

But there is a difference in notation between mirror and lens

$$\frac{1}{s}+\frac{1}{s'}=\frac{1}{f}; \quad M=\frac{-s'}{s}$$

<u>MIRROR</u>; $s > 0$ on left;

<u>real image</u> (inverted)

$s' > 0$, s' on left

$f = R/2 > 0$, converging concave mirror

<u>virtual upright image</u>

<u>$s' < 0$ on right</u>

$f = R/2 < 0$, diverging convex mirror

<u>LENS;</u> $s > 0$ on left

<u>real image</u> (inverted)

$s' > 0$, s' on right

$1/f = (n-1)(1/R_1 + 1/R_2) > 0$, converging convex lens

<u>virtual upright image</u>

<u>$s' < 0$, on left</u>

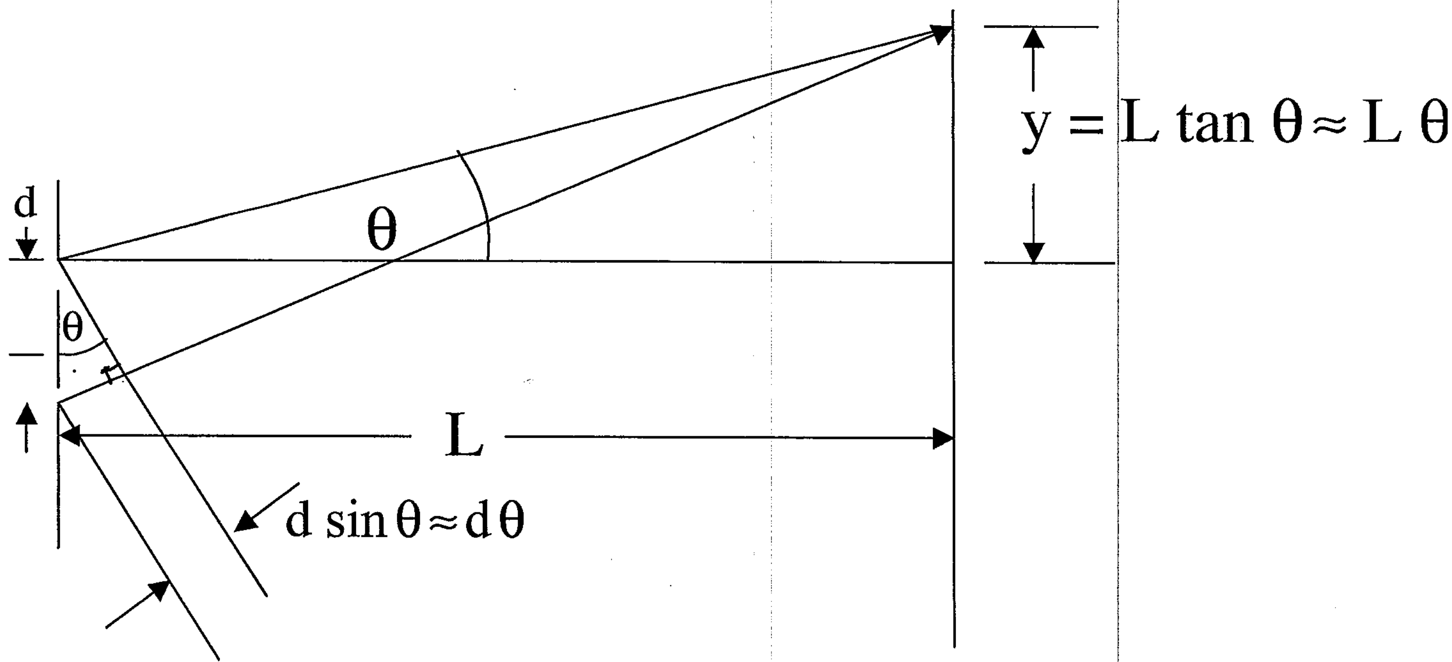
$1/f = (n-1)(1/R_1 + 1/R_2) < 0$, diverging concave mirror

LINEAR MAGNIFICATION

$$M = -\frac{s'}{s}$$

Equation 34-30 Physics for Engineers and Scientists 3/e

TWO-SLIT INTERFERENCE PATTERN



For maxima with small angle $\theta = y/L$

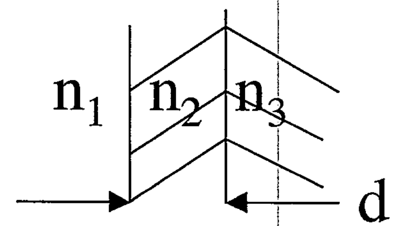
$d\,\theta = n\,\lambda \;(n = 0, \pm 1, \pm 2, \ldots) = d\,y_n/L$

For minima with small angle $\theta = y/L$

$d\,\theta = (n+1/2)\,\lambda \;(n = 0, \pm 1, \pm 2, \ldots) = d\,y_{n+1/2}/L$

THIN-FILM INTERFERENCE

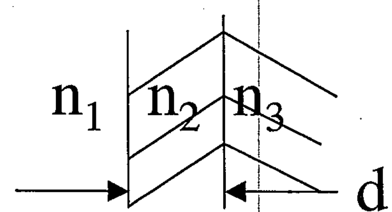
When $1 = n_1 < n_2 < n_3$



Maxima: $2d = \lambda_1/n_2,\ 2\lambda_1/n_2,\ 3\lambda_1/n_2 \ldots.$

Minima: $2d = \lambda_1/2n_2,\ 3\lambda_1/2n_2,\ 5\lambda_1/2n_2 \ldots$

When $1 = n_1 < n_2 > n_3$



Maxima: $2d = \lambda_1/2n_2,\ 3\lambda_1/2n_2,\ 5\lambda_1/2n_2 \ldots$

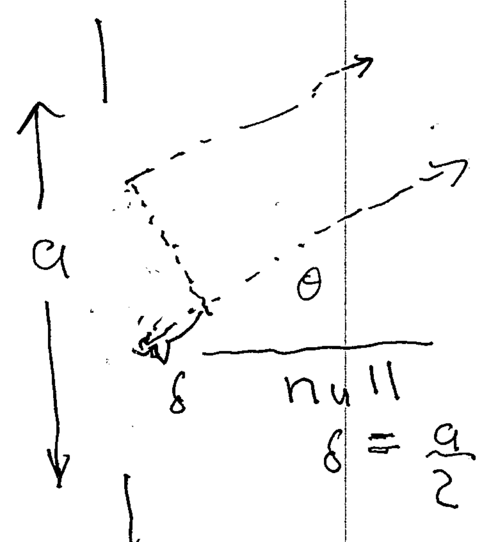
Minima: $2d = \lambda_1/n_2,\ 2\lambda_1/n_2,\ 3\lambda_1/n_2 \ldots.$

MINIMA FOR SINGLE-SLIT DIFFRACTION PATTERN

$$a \sin\theta = \lambda,\ 2\lambda,\ 3\lambda, \ldots$$

$\approx a\,\theta =$

small angles



$\delta = \frac{a}{2}\,\theta = (m+\tfrac{1}{2})\,\lambda$

FIRST MINIMUM FOR CIRCULAR APERTURE

$$\sin\theta = 1.22\frac{\lambda}{a} \approx \theta$$

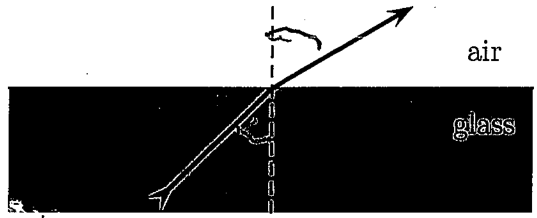
Equation 35-27 Physics for Engineers and Scientists 3/e

$$\overline{u}_E = \frac{1}{2}\,\epsilon_0\,\overline{[E_{max}\,\cos(k\,x-\omega\,t)]^2}$$
$$= \frac{1}{4}\,\epsilon_0\,E_{max}^2\,.$$

Similarly, $\overline{u}_B = \dfrac{1}{4\,\mu_0}\,B_{max}^2$. Since $\overline{u}_E = \overline{u}_B$, we have

$$I = 2\,\overline{u}_E\,c = \boxed{\frac{1}{2}\,\epsilon_0\,c\,E_{max}^2},$$
$$= 2\,\overline{u}_B\,c = \boxed{\frac{1}{2\,\mu_0}\,c\,B_{max}^2}, \quad \text{and}$$
$$= (\overline{u}_E + \overline{u}_B)\,c$$
$$= \boxed{\frac{1}{4}\,\epsilon_0\,c\,E_{max}^2 + \frac{1}{4\,\mu_0}\,c\,B_{max}^2}.$$

4.



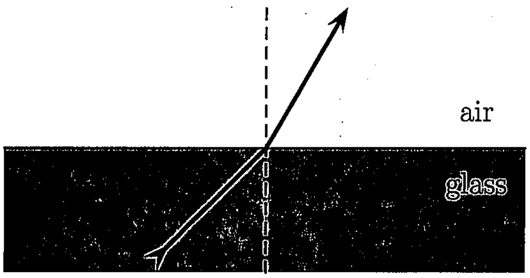
Question 6, chap 34, sect 3.

part 1 of 2 0 points
Refraction 02 (5800)

Given: A ray approaching an interface.

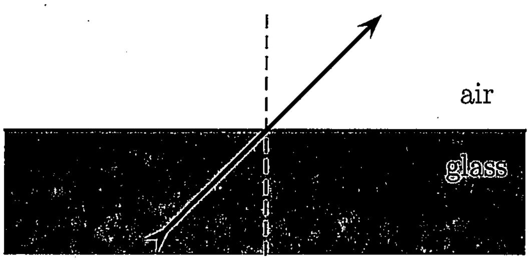
What is the approximate refracted ray?

1.



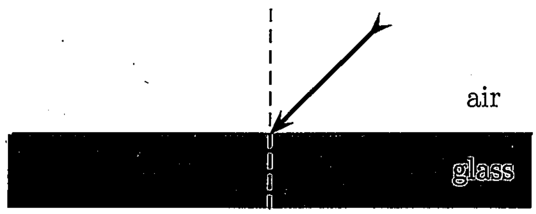
2. None of these

3.



Question 7, chap 34, sect 3.

part 2 of 2 0 points
Refraction 02 (5800)

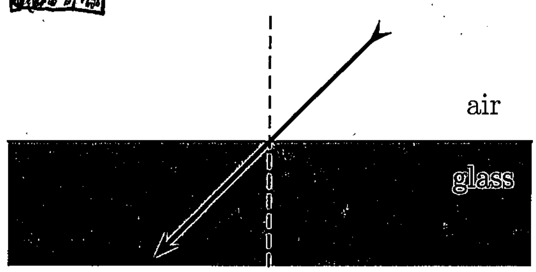


What is the approximate refracted ray?

1. None of these

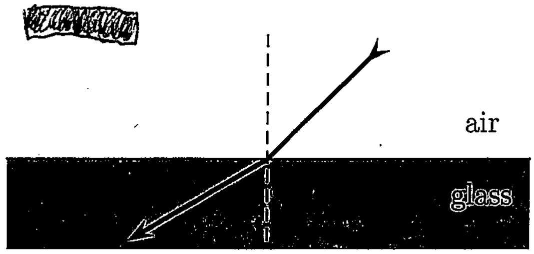
[redacted]

2.



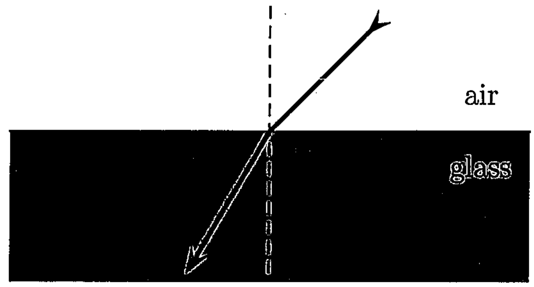
[redacted]

3.



[redacted]

4.

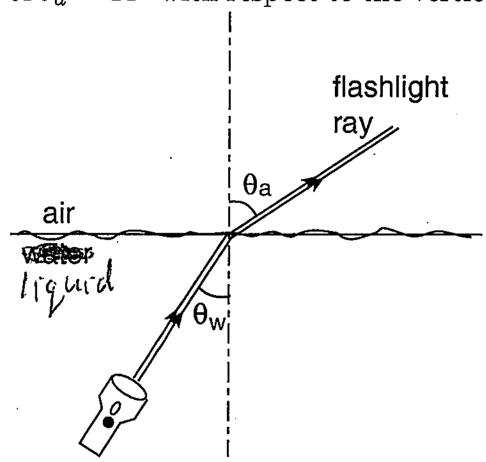


[redacted]

Question 8, chap 34, sect 3.
part 1 of 2 0 points
Flashlight Under Water (2546)

Given: The index of refraction of transparent liquid (similar to water but with a different index of refraction) is 1.33.

A flashlight held under the transparent liquid shines out of the transparent liquid in a swimming pool. This beam of light exiting the surface of the transparent liquid makes an angle of $\theta_a = 44°$ with respect to the vertical.



At what angle θ_w (with respect to the vertical) is the flashlight being held under transparent liquid?

Correct answer: 31.4866 ° (tolerance ± 1 %).

Explanation:

Basic Concepts: Snell's Law:

$$n_a \sin\theta_a = n_w \sin\theta_w\,,$$

where n_a and n_w are the indices of refraction for each substance and θ_a and θ_w are the incident angles to the boundary in each medium, respectively.

Solution: This is a straightforward application of Snell's law. We assume that the surface of the transparent liquid is a level horizontal plane, thus each angle with respect to the vertical represents the incident angle in each medium.

The index of refraction of air is (nearly) $n_a = 1.0$ while the index of refraction of transparent liquid is given as $n_w = 1.33$. The incident angle in the air is given to be $\theta_a = 44°$. Hence

$$\frac{\sin\theta_w}{\sin\theta_a} = \frac{n_a}{n_w}$$
$$\frac{\sin\theta_w}{\sin(44°)} = \frac{1}{1.33}$$
$$\sin\theta_w = \frac{0.694659}{1.33}$$
$$\theta_w = \arcsin(0.5223)$$
$$\theta_w = \boxed{31.4866°}\,.$$

Question 9, chap 34, sect 3.
part 2 of 2 0 points
Flashlight Under Water (2546)

The flashlight is slowly turned away from the vertical direction.

At what angle will the beam no longer be visible above the surface of the pool?

Correct answer: 48.7534 ° (tolerance ± 1 %).

Explanation:

This is solved in the same fashion as Part 1. When the light ceases to be visible outside the transparent liquid, then $\theta_a \geq 90°$. The $\sin 90° = 1$. Hence (from above),

$$\sin\theta_w = \frac{n_a}{n_w}$$
$$\theta_w = \arcsin\left(\frac{1}{1.33}\right)$$
$$\theta_w = \boxed{48.7534°}\,.$$

Question 10, chap 34, sect 3.
part 1 of 1 0 points
Coin in a Beaker (1186)

Mirror and

THIN-LENS EQUATION

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

Equation 34-28 Physics for Engineers and Scientists 3/e

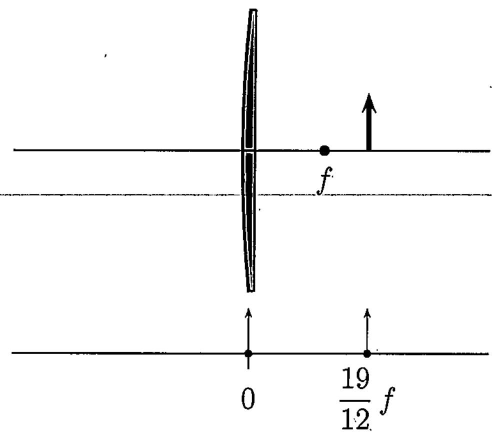
LENS MAKER'S FORMULA

Focal length of a lens

$$\frac{1}{f} = (n - 1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

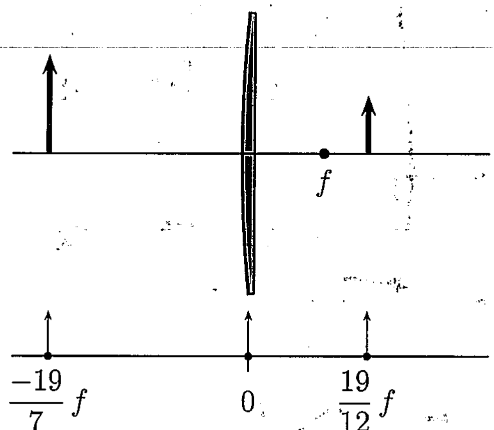
Equation 34-27 Physics for Engineers and Scientists 3/e

Given: A virtual object is located to the right of a divergent mirror. The object's distance from the mirror and its focal length are shown in the figure below.

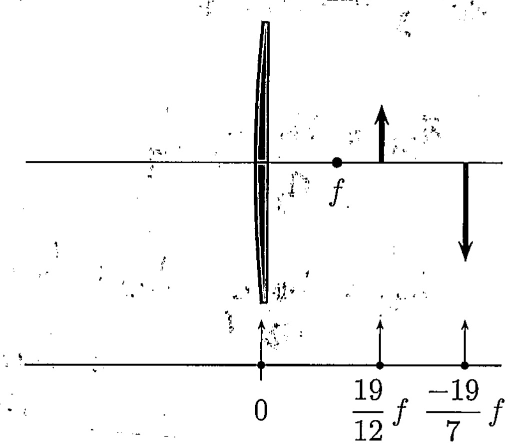


Which diagram correctly shows the image?

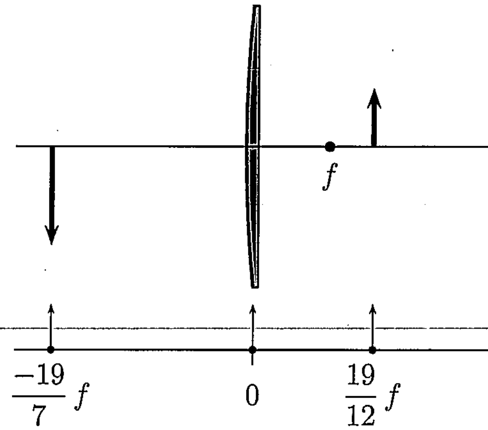
1.



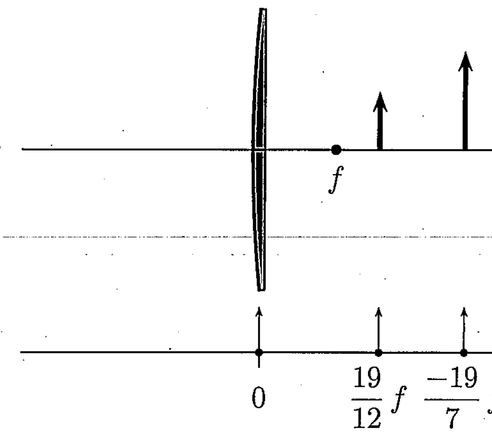
2.



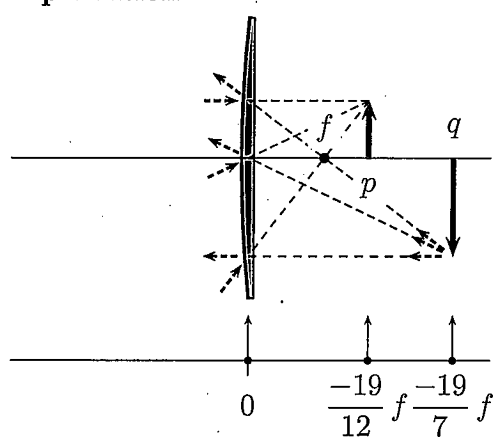
3.



4.



Explanation:



Basic Concepts:

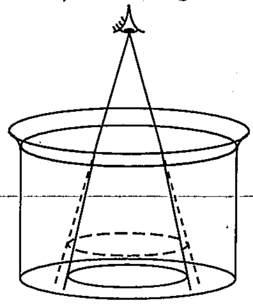
$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f},$$

where $f<0$ for a divergent mirror.

Solution:

$$\begin{aligned}\frac{1}{q_1} &= -\frac{1}{p_1}-\frac{1}{f}\\ &= -\frac{(-12)}{19\,f}-\frac{1}{f}\end{aligned}$$

A coin is at the bottom of a beaker. The beaker is filled with 3.5 cm of water ($n_1 = 1.33$) covered by 2.5 cm of liquid ($n_2 = 1.4$) floating on the water.



How deep does the coin appear to be from the upper surface of the liquid (near the top of the beaker)?

Correct answer: 4.41729 cm (tolerance ± 1 %).

Explanation:

Basic Concept: Snell's Law

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 .$$

For small angles

$$\sin\theta \approx \tan\theta = \frac{x}{\ell} .$$

The appearance of the width of the coin x remains the same. From Snell's Law, we have

$$n_i \frac{x}{\ell_i} = n_f \frac{x}{\ell_f}$$

Therefore

$$\ell_f = \frac{\ell_i}{n_i} ,$$

since $n_f \approx 1$ for air and the apparent distance $d = \ell_f$.

Solution:

$$\begin{aligned} d &= \frac{l_2}{n_2} + \frac{l_1}{n_1} \\ &= \frac{2.5 \text{ cm}}{1.4} + \frac{3.5 \text{ cm}}{1.33} \\ &= (1.78571 \text{ cm}) + (2.63158 \text{ cm}) \\ &= 4.41729 \text{ cm} . \end{aligned}$$

The coin appears to be closer to the surface by

$$\begin{aligned} &(3.5 \text{ cm}) + (2.5 \text{ cm}) - (4.41729 \text{ cm}) \\ &= 1.58271 \text{ cm} . \end{aligned}$$

Alternate Solution: Light coming straight up from the coin falls on each interface at 0° and continues straight up. Consider light making a 1° angle (therefore we can use the small angle approximation) with the vertical in the water. It enters the liquid a distance

$$\begin{aligned} (3.5 \text{ cm}) \tan 1^\circ &\simeq (3.5 \text{ cm}) \times \theta_1 u \\ &= 0.0610865 \text{ cm} \end{aligned}$$

from the vertical ray. In the liquid its angle with the vertical is given by

$$1.33 \sin 1^\circ = 1.4 \sin\theta_2$$

$$\theta_2 = 0.950001^\circ$$

This same ray reaches air at distance

$$\begin{aligned} &(0.0610865 \text{ cm}) + (2.5 \text{ cm}) \tan(0.950001^\circ) \\ &= 0.102538 \text{ cm} , \end{aligned}$$

from the vertical ray, and the angle of refraction is found from

$$1.4 \sin(0.950001^\circ) = 1 \sin\theta_3$$

$$\theta_3 = 1.33^\circ$$

Your brain automatically finds the intersection of this ray with the vertical ray, at an apparent depth of

$$\begin{aligned} \frac{0.102538 \text{ cm}}{\tan(1.33^\circ)} &\simeq \frac{0.102538 \text{ cm}}{0.0232129 \text{ rad}} \\ &= 4.41729 \text{ cm} . \end{aligned}$$

Rays for all other small angles with the vertical appear to diverge from the image of the coin at this depth.

Question 11, chap 34, sect 4.
part 1 of 1 0 points
Mirror Divergent Diagram (5004)

Hint: The convergent mirror in this problem is a part of a lens/mirror system so the object in this problem may be either real or virtual. Construct a ray diagram.

$$
\begin{aligned}
&= \frac{-(19) - (-12)}{19\, f} \\
&= \frac{-7}{19\, f} \\
q_1 &= \frac{-19}{7}\, f\,.
\end{aligned}
$$

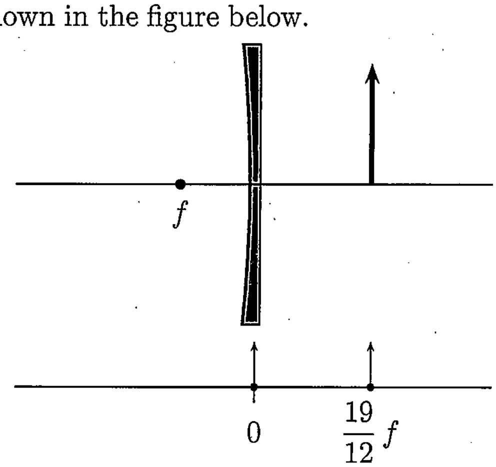
The magnification m of this mirror is

$$
\begin{aligned}
m &= -\frac{q_1}{p_1} \\
&= -\frac{\frac{19}{-7}\, f}{\frac{19}{-12}\, f} \\
&= -\frac{-12}{-7} \\
&= \frac{-12}{7}
\end{aligned}
$$

Question 12, chap 34, sect 4.
part 1 of 1 0 points
Mirror Convergent Diagram (5002)

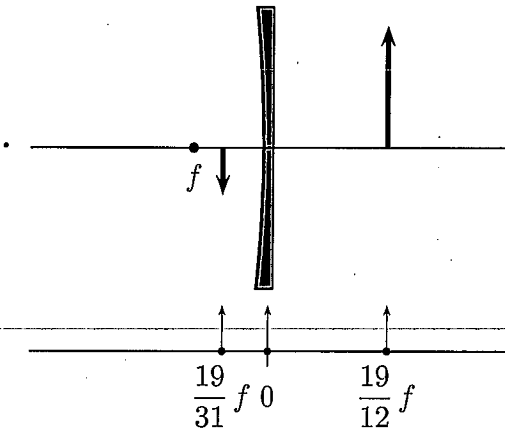
Hint: The convergent mirror in this problem is a part of a lens/mirror system so the object in this problem may be either real or virtual. Construct a ray diagram.

Given: A virtual object is located to the right of a convergent mirror. The object's distance from the mirror and its focal length are shown in the figure below.



Which diagram correctly shows the image?

1.



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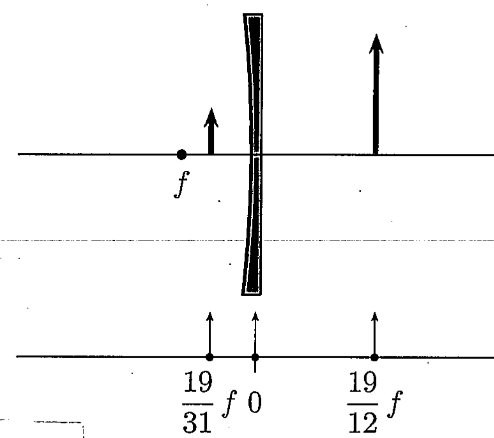

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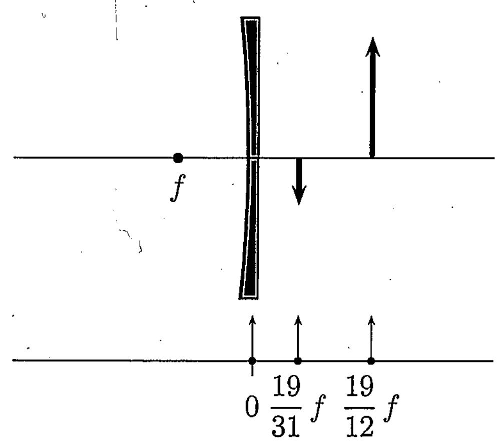

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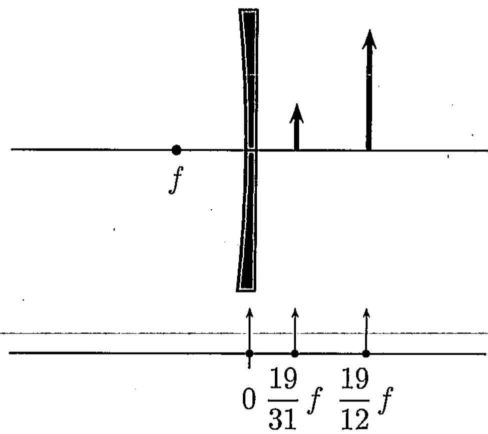
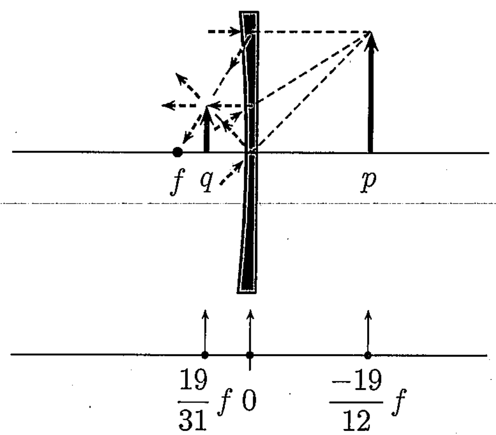


Explanation:



Basic Concepts:

$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f},$$

where $0<f$ for a convergent mirror.

Solution:

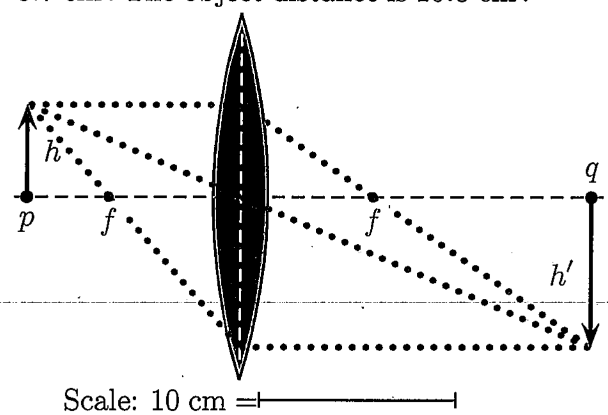
$$\begin{aligned}\frac{1}{q}&=-\frac{1}{p}+\frac{1}{f}\\ &=-\frac{(-12)}{19\,f}+\frac{1}{f}\\ &=\frac{-(-12)+(19)}{19\,f}\\ &=\frac{31}{19\,f}\\ q&=\frac{19}{31}\,f\,.\end{aligned}$$

The magnification m of this mirror is

$$\begin{aligned}m&=-\frac{q_1}{p_1}\\ &=-\frac{\frac{19}{31}\,f}{\frac{19}{-12}\,f}\\ &=-\frac{-12}{31}\\ &=\frac{12}{31}\,.\end{aligned}$$

Question 13, chap 34, sect 5.
part 1 of 2 0 points
Lens A 01 (4699)

A convergent lens has a focal length of 6.7 cm . The object distance is 10.8 cm .



Find the distance of the image from the center of the lens.
Correct answer: 17.6488 cm (tolerance ± 1 %).

Explanation:

$\frac{1}{p}+\frac{1}{q}=\frac{1}{f}$		$M=\frac{h'}{h}=-\frac{q}{p}$
Convergent Lens		$f>0$
$\infty>p>f$	$f<q<\infty$	$0>M>-\infty$

Note: The focal length for a convergent lens is positive, $f=6.7$ cm.
Solution: Substituting these values into the lens equation

$$\begin{aligned}q&=\frac{1}{\frac{1}{f}-\frac{1}{p}}\\ &=\frac{1}{\frac{1}{(6.7\text{ cm})}-\frac{1}{(10.8\text{ cm})}}\\ &=\boxed{17.6488\text{ cm}}\,.\end{aligned}$$

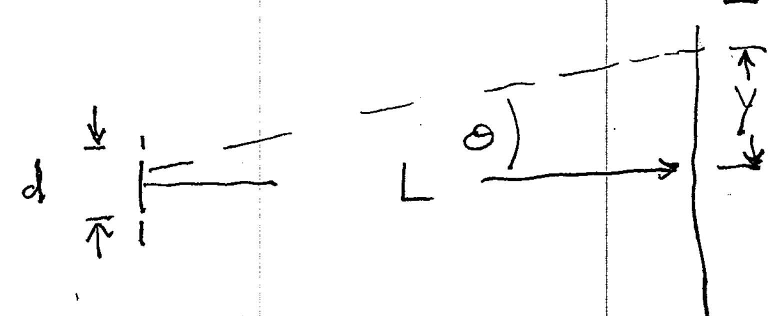
INTERSITY FOR TWO-SLIT INTERFERENCE PATTERN

$$= I_{max} \cos^2(\phi/2)$$

$$I = I_{\max} \cos^2\left(\frac{\pi d}{\lambda}\sin\theta\right)$$

for small angles

$$\sin\theta \simeq \tan\theta \sim \theta \sim Y/L$$



Question 14, chap 34, sect 5.
part 2 of 2 0 points
Lens A 01 (4699)

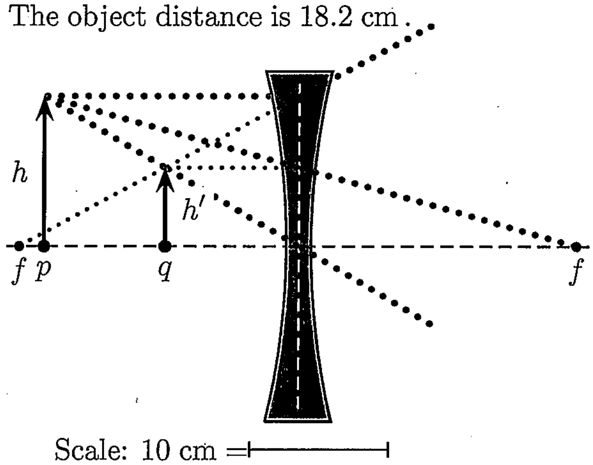
Find the magnification.
Correct answer: −1.63415 (tolerance ± 1 %).

Explanation:

$$M = -\frac{q}{p} = -\frac{(17.6488\text{ cm})}{(10.8\text{ cm})} = \boxed{-1.63415}.$$

Question 15, chap 34, sect 5.
part 1 of 2 0 points
Lens A 02 (4700)

A divergent lens has a focal length of 20 cm. The object distance is 18.2 cm.



Find the distance of the image from the center of the lens.
Correct answer: 9.5288 cm (tolerance ± 1 %).

Explanation:

$\frac{1}{p}+\frac{1}{q}=\frac{1}{f}$	$M=\frac{h'}{h}=-\frac{q}{p}$	
Divergent Lens	$f<0$	
$\infty>p>0$	$f<q<0$	$0<M<1$

Note: The focal length for a divergent lens is negative, $f = -20$ cm.
Solution: Substituting these values into the lens equation

$$q = \frac{1}{\frac{1}{f}-\frac{1}{p}} = \frac{1}{\frac{1}{(-20\text{ cm})}-\frac{1}{(18.2\text{ cm})}} = -9.5288\text{ cm}$$

$$|q| = \boxed{9.5288\text{ cm}}.$$

Question 16, chap 34, sect 5.
part 2 of 2 0 points
Lens A 02 (4700)

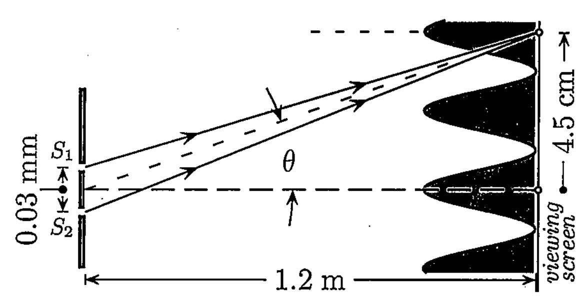
Find the magnification.
Correct answer: 0.52356 (tolerance ± 1 %).

Explanation:

$$M = -\frac{q}{p} = -\frac{(-9.5288\text{ cm})}{(18.2\text{ cm})} = \boxed{0.52356}.$$

Question 17, chap 35, sect 3.
part 1 of 1 0 points
Double Slits 02 JMS (2053)

The second-order bright fringe ($m = 2$) is 4.5 cm from the center line.

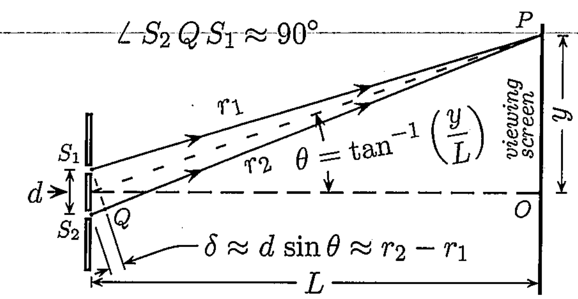


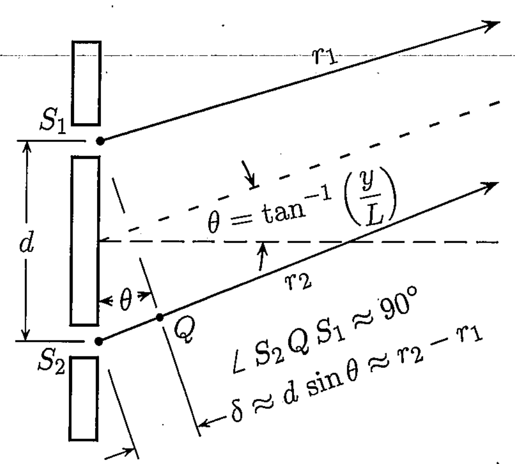
Determine the wavelength of the light. Be sure to use the small angle approximation, $sin(\theta) \approx \theta$

Correct answer: 562.5 nm (tolerance ± 1 %).

Explanation:

$$\text{Let}: \quad y = 4.5 \text{ cm}, \quad L = 1.2 \text{ m}, \quad \text{and} \quad d = 0.03 \text{ mm},$$





For constructive interference

$$y_{\text{bright}} = \frac{\lambda L}{d} m, \tag{1}$$

with $m = 2$, $y_2 = 0.045$ m, $L = 1.2$ m, and $d = 3 \times 10^{-5}$ m

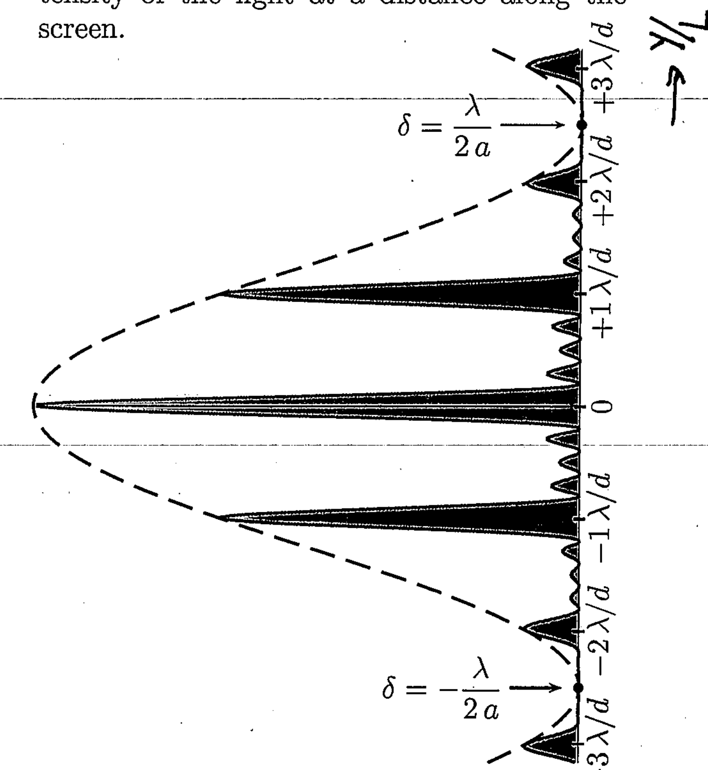
$$\begin{aligned} \lambda &= \frac{d\, y_2}{m\, L} \\ &= \frac{(3 \times 10^{-5} \text{ m})\,(0.045 \text{ m})}{(2)\,(1.2 \text{ m})} \\ &= 5.625 \times 10^{-7} \text{ m} \\ &= 562.5 \text{ nm}. \end{aligned}$$

Question 18, chap 35, sect 4.
part 1 of 1 0 points
Multiple Slits (5086)

In a diffraction/interference experiment, identical slits are illuminated by a laser beam.

The intensity pattern shown in the figure is observed on a screen a large distance from the slits.

The figure below, shows a plot of the intensity of the light at a distance along the screen.



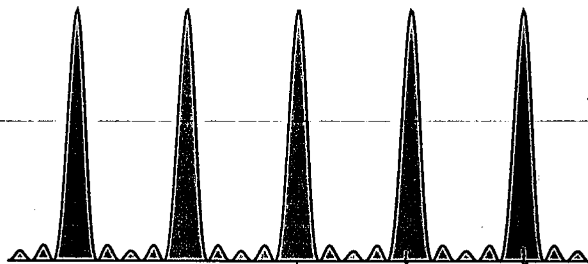
How many slits are illuminated?

1. four slits
2. seven slits
3. eight slits
4. five slits
5. one slit
6. six slits
7. three slits
8. two slits
9. more than eight slits

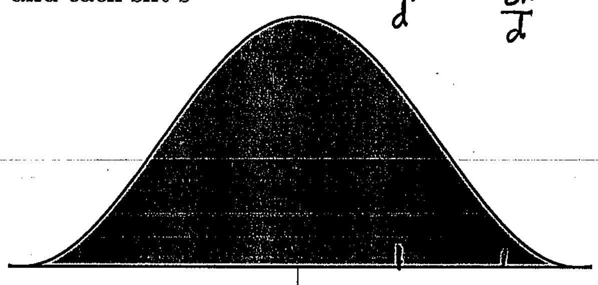
Explanation:

Basic Concepts: Multiple Slit Interference and Single Slit Diffraction

This interference pattern (shown in the question) is the combination of a multiple five slit interference pattern



and each slit's

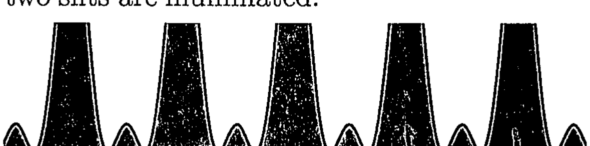


single slit diffraction pattern.

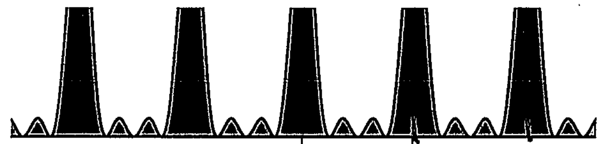
Solution: If only one slit was illuminated, the intensity pattern is the envelope of the peak maxima as shown in the figure above, which is single slit "Fraunhofer" diffraction.

If two slits were illuminated, the intensity pattern is the envelope of the peak maxima as shown in the figure below, which is double slit "Fresnel" interference.

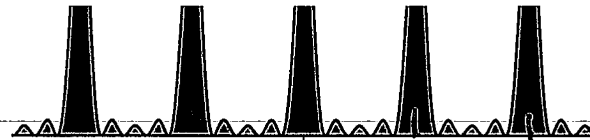
Secondary maxima occur when more than two slits are illuminated. λ/d 2λ/d



If there was one secondary maximum between the central peak and the first large peak, three slits are illuminated. λ/d 2λ/d



If there were two secondary maxima, four slits are illuminated. λ/d 2λ/d



If there were three secondary maxima, five slits are illuminated, *etc.* λ/d 2λ/d

Consequently, in this problem (as shown in the question) there are three secondary minima which indicates that there are five slits illuminated.

Question 19, chap 35, sect 1.
part 1 of 2 0 points
Coating on a Camera Lens (1167)

A thin film of cryolite ($n_c = 1.35$) is applied to a camera lens ($n_g = 1.5$). The coating is designed to reflect wavelengths at the blue end of the spectrum and transmit wavelengths in the near infrared.

What minimum thickness gives high reflectivity at 450 nm?

Correct answer: 166.667 nm (tolerance ± 1 %). ×2

Explanation:

For camera lens coating of cryolite ($n_c = 1.35$) over glass ($n_g = 1.5$), high reflectivity is achieved for

$$2\, n_c\, t_1 = m\, \lambda_1 \,.$$

Here we have taken into account that high reflectivity is achieved for constructive interference. The phase changes at both the "air-cryolite" and the "cryolite-glass" surfaces is $\phi = 180°$ ($n_{air} = 1 < n_c < n_g$).

Note: Two phase changes of 180°.

For minimum thickness $m = 1$

$$\begin{aligned} t_1 &= \frac{\lambda_1}{2\, n_c} \\ &= \frac{450\ \text{nm}}{2 \times 1.35} \\ &= 166.667\ \text{nm}\,. \end{aligned}$$

Question 20, chap 35, sect 1.
part 2 of 2 0 points
Coating on a Camera Lens (1167)

What minimum thickness gives high transmission at 900 nm?
Correct answer: 166.667 nm (tolerance ± 1 %).

Explanation:
Under the same conditions low reflectivity is achieved for

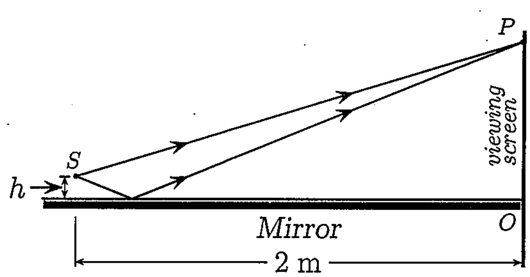
$$2\,n_c\,t = \left(m + \frac{1}{2}\right)\,\lambda_2\,.$$

For minimum thickness $m = 0$

$$t_2 = \frac{\lambda_2}{4\,n_c} = \frac{900\text{ nm}}{4 \times 1.35} = 166.667\text{ nm}\,.$$

Question 21, chap -1, sect -1.
part 1 of 1 0 points
Lloyds Mirror 01 (4793)

Interference fringes are produced at point P on a screen as a result of direct rays from a 606 nm wavelength source and reflected rays off the Lloyd's mirror as in the figure. Fringes 1.2 mm apart are formed on a screen 2 m from the source S.



Find the vertical distance h of the source above the reflecting surface.
Correct answer: 0.505 mm (tolerance ± 1 %).

Explanation:
Basic Concepts: Intensity maxima occur when the two waves have a phase difference

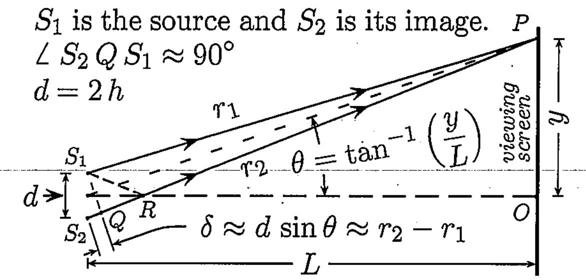
$$\phi = 0,\ 2\,\pi,\ 4\,\pi,\ \cdots = \phi_{path} + \phi_{reflection}\,,$$

where $\phi_{reflection} = \pi$.

$$\begin{aligned} Let:\quad L &= 2\text{ m} \\ h &= \frac{d}{2} \\ \Delta y &= 1.2\text{ mm}\,. \end{aligned}$$

Solution: If the difference in path length is δ, the phase difference due to the unequal path lengths is

$$\phi_{path} = k\,\delta = \frac{2\,\pi}{\lambda}\,\delta\,. \tag{1}$$



This diagram shows the similarity between the Lloyd's mirror apparatus and Young's double slit experiment. The difference between the two experiments is that there is a 180° phase change at the reflecting mirror.

$$\sin\theta = \frac{\delta}{2\,h} = \frac{y}{L}\,. \tag{2}$$

In the small angle approximation

$$\theta \approx \frac{\delta}{2\,h} \approx \frac{y}{L}$$

$$h = \frac{\delta}{2\,y}\,L\,, \tag{3}$$

where the height of the light source above the mirror is $h = \dfrac{d}{2}$.

So maxima occur at

$$\begin{aligned} \phi_{path} &= \frac{2\,\pi}{\lambda}\,\delta = \phi - \phi_{reflection} \\ &= (0,\ 2\,\pi,\ 4\,\pi,\ \cdots) - \pi \\ &= -\pi\ (\text{below } O) \\ &\quad \pi\ (1^{\text{st}}\text{ max}) \\ &\quad 3\,\pi\ (2^{\text{nd}}\text{ max}),\ \cdots. \end{aligned}$$

The central minimum (at the bottom of the mirror) is a dark fringe, since the reflected light produces a 180° phase change.
Solution: The separation between maximum (or minima) on the screen is given in the problem $\Delta y = 1.2$ mm, and the separation in path difference is

$$\delta = \frac{\lambda}{2\pi}\,2\pi = \lambda\,.$$

Solving Eq. (3) for h, we have

$$\begin{aligned} h &= \frac{m\,\delta}{2\,\Delta y}\,L \\ &= \frac{m\,\lambda}{2\,\Delta y}\,L \\ &= \frac{1\,6.06\times 10^{-7}\text{ m}}{2\,(0.0012\text{ m})}\,(2\text{ m}) \\ &= 0.505\text{ mm}, \end{aligned}$$

where $m = 1$.