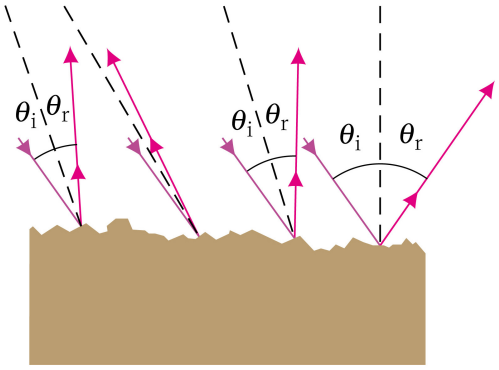
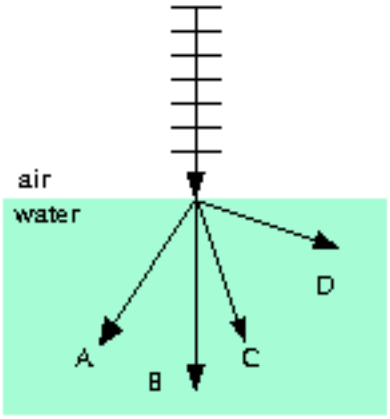
Exam IV Solution: Chapters 22—24

1. The law of reflection states that
   A) incoming light is reflected back along its original path.
   B) the angle of incidence is equal to the angle of reflection.
   C) the angles of incidence and reflection always add up to 90°.
   D) for curved mirrors, the angle of reflection is twice the angle of incidence.
   E) angle of incidence only equals angle of reflection for flat, perfectly smooth, plane mirrors.



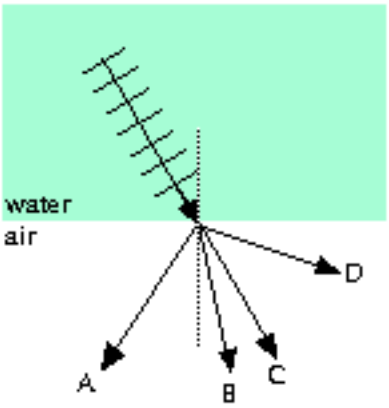
2. The parallel rays shown strike the surface and reflect as shown.
   A) Specular reflection.
   B) Spectacular reflection.
   C) Suffuse reflection.
   D) Diffuse reflection.
   E) Refuse reflection.

3. The principle of least time states that
   A) the shortest distance between two points is a straight line.
   B) the shortest path between two points is always the fastest path.
   C) it always takes less time for light to travel a path than anything else.
   D) a beam of light will always travel along the shortest path from one point to another.
   E) a beam of light will always follow the fastest path from one point to another.



4. An incoming beam of light strikes the surface of the water as shown on the right. Which ray shows the path of the transmitted beam? **B**
   E) None of these is correct!

5. When light passes from one medium to another,
   A) it continues to travel at 3×10^8 m/s regardless of the type of medium.
   B) it always slows down, and it always refracts regardless of the angle of incidence.
   C) it always speeds up, and it never refracts regardless of the angle of incidence.
   D) it bends only when it strikes the boundary between the media at a 90° angle to the surface.
   E) it may slow down or speed up, depending on the medium. The amount of refraction depends on the angle at which the light strikes the boundary.



6. An incoming beam of light strikes the boundary between the water and the air as shown on the right. Which ray shows the path of the transmitted beam? **D**
   E) None of these.

7. As a light wave passes from glass to air,
   A) its speed does not change and it does not bend.
   B) it slows down and bends away from the normal.
   C) it slows down and bends toward the normal.
   D) it speeds up and bends toward the normal.
   E) it speeds up and bends away from the normal.

8. You are watching your favorite goldfish in his tank. Because of the refraction of light, he appears
   A) larger and deeper than he actually is.
   B) smaller and deeper than he actually is.
   C) larger and shallower than he actually is.
   D) smaller and shallower than he actually is.
   E) no different than if he was out of the water.

9. The index of refraction for glass is 1.5 and the index for water is 1.3. Compare the speed of light through each of these media.
   A) The higher the index of refraction, the faster the speed of light through the medium.
   B) The higher the index of refraction, the slower the speed of light through the medium.

C) The speed is the same through either medium. It's the frequency of the light that changes: the greater the index, the greater the increase in frequency.
D) The speed remains constant. Both frequency and wavelength decrease as index of refraction increases.

10. A beam of light traveling through air will be bent more when it strikes which medium? Assume equal angles of incidence.
A) The glass will bend the light more. Higher index means more bending.
B) The water will bend the light more. Lower index of refraction means more bending.
C) The light will be bent by the same amount regardless of the index of the refracting medium.
D) The light will not be bent by either medium, because an index of refraction greater than 1 means that the medium is unable to transmit light.

11. Light traveling through air strikes the plastic surface of a transparent tabletop at an angle of 40° with respect to the normal. The index of refraction for lucite is 1.495. Find the angle of refraction.
A) θ=0° B) θ=16.1° **C) θ=25.5°** D) θ=41.0° E) θ=73.9°

12. Total internal reflection may be observed when a light ray strikes the boundary traveling
A) from a slower medium to a faster medium.
B) from a faster medium to a slower medium.
C) at an angle of exactly 45° with respect to the normal, moving from a faster to a slower medium.
D) at an angle of more than 45° with respect to the normal. The indices of refraction of the media do not matter.

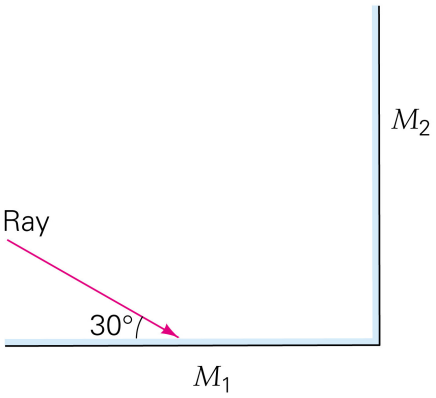
13. What is the critical angle for total internal reflection for glass with an index of refraction n=1.65 and air (n=1)?
A) θ=0° **B) θ=37°** C) θ=45° D) θ=53° E) θ=90°

14. You are driving I-40 across New Mexico. It's gorgeous! Suddenly your sister wakes up and yells, "Watch out! The road is wet! Don't skid!" What do you do?
A) Remind her of that time when you were little and she thought that if you ate Pop Rocks while drinking a Coke your head would explode. Then make fun of her hair from sleeping in the car.
B) Slow down and pull over. The road really is wet, and since you're in New Mexico on a sunny day, it's probably a trap. When you spin out on the wet road the aliens come and abduct you.
C) The road probably is wet, but there are no aliens. The water condenses on the highway because it is warmer than the surrounding desert. Just drive carefully, but you don't need to panic.
D) Nothing. Well, keep right on singing really loud along with the radio, but you don't need to worry about the road. It's a mirage caused by the refraction of light through the air.
E) Keep singing, but know that the mirage is not a result of refraction at all. It is a dispersion effect, as red light and blue light are reflected differently off the surface of the highway.

15. White light shines through a prism.
A) White light emerges, unbent.
B) The prism scatters the blue light, and only red light emerges.
C) The prism scatters the red light, and only blue light emerges.
D) Red light, having the longest wavelength, gets bent the most.
E) Blue light, having the shortest wavelength, gets bent the most.

16. You are vacationing in Hawaii, and after a late afternoon shower, you see a rainbow. No, wait! It's a *double* rainbow! Who doesn't love a rainbow?
A) The primary rainbow reads "ROYGBIV" from top to bottom. So does the secondary rainbow, just fainter.
B) The primary rainbow reads "ROYGBIV" from bottom to top. So does the secondary rainbow, just fainter.
C) The primary rainbow reads "ROYGBIV" from top to bottom. But the secondary rainbow reads "ROYGBIV" from bottom to top.
D) The primary rainbow reads "ROYGBIV" from bottom to top. But the secondary rainbow reads "ROYGBIV" from top to bottom.
E) The primary rainbow has a pot of gold guarded by a genial (slightly drunk) leprechaun. The secondary rainbow has a pot of haggis guarded by a surly (slightly drunk) Scotsman. Who knows how either one of them got to Hawaii.

17. At what angle with respect to the normal to mirror M_2 will the incident ray finally emerge?
A) 0° **B) 30°** C) 45° D) 60° E) 90°



18. How big must a mirror be to be used as a full-length mirror?
A) Any size will work. The farther away you get, the more of yourself you will see.
B) The mirror must be at least as tall as you are, or you will never see your complete image.
C) The mirror must be exactly half your height, at a distance exactly equal to your height. If you move any closer to the mirror, it needs to be bigger for you to see your complete image.
D) The ratio of mirror height to object distance must be exactly 1/2. This means that if you have a mirror 1m tall, you must stand 2m away from it to see your entire image. Your height does not matter.
E) The mirror must be at least half your height, and your distance from the mirror is not material.

19. When you use a second mirror to look at the back of your head, you are seeing
A) the real image of a real object.
B) the real image of a virtual object.
C) the virtual image of a real object.
D) the virtual image of a virtual object.

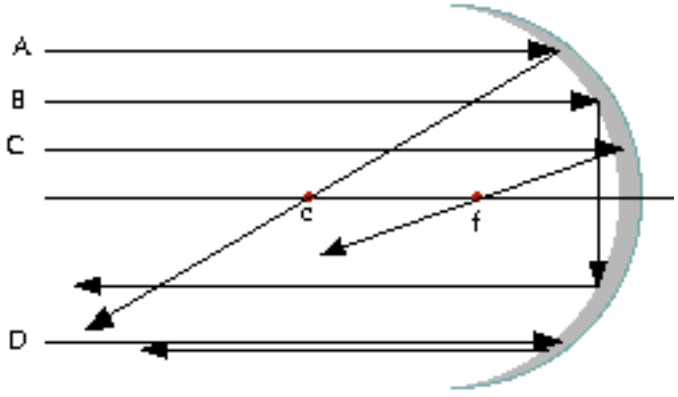
20. A person stands 2 m in front of a plane mirror and flexes his imaginary biceps. His reflection appears
A) 2 m behind the mirror.
B) 2 m in front of the mirror.
C) 1 m behind the mirror.
D) 1 m in front of the mirror.

21. Now he is holding a hairbrush and singing into it like it's a microphone (maybe we should leave before he starts combing over his bald spot). The brush is 20 cm tall. The image of the brush is
A) 2 cm tall. B) 10 cm tall. **C) 20 cm tall.** D) 40 cm tall.

22. His image in the mirror
A) is a little sad, but it's our own fault for snooping where we should have minded our own business.
B) is not inverted, since a plane mirror cannot create an image.
C) is inverted along the horizontal (x) left-right axis.
D) is inverted along the vertical (y) up-down axis.
E) is inverted along the horizontal (z) front-back axis.

23. Explain the difference between a concave mirror and a convex mirror.
A) Either mirror can form either real or virtual images. Concave mirrors curve outward, convex curve inward.
B) Concave mirrors can only form virtual images. Convex can only form real images. Both curve outward.
C) Concave mirrors can only form real images. Convex can only form virtual images. Both curve inward.
D) Convex mirrors curve outward and can form only virtual images. Concave mirrors are curved inward.
E) Convex mirrors cannot form either type of image. Concave mirrors can form either real or virtual images.

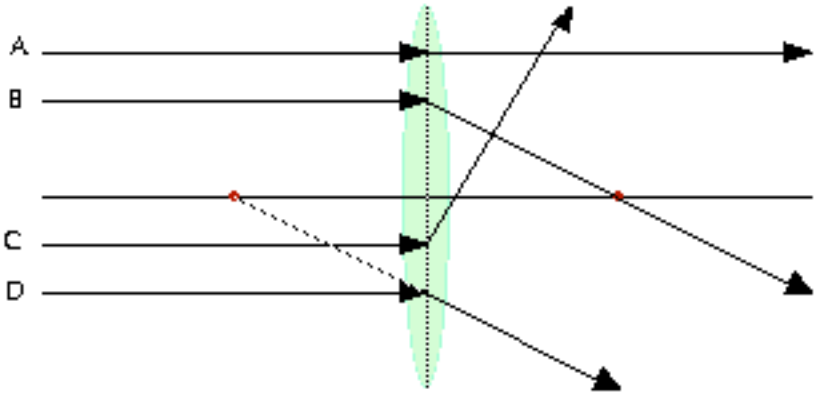
24. An incoming ray of light reflected off the concave mirror shown on the right will follow which path? **C**
E) None of these!



25. Explain the difference between a concave lens and a convex lens.
A) They are different shape: concave curves in, convex curves out. Either lens can be used to form real images.
B) A convex lens causes parallel light rays to be bent away from the negative focal point. A concave lens brings parallel light rays together at the positive focal point.
C) A convex lens corrects nearsightedness, and a concave lens is used to correct farsightedness.
D) Both lenses are curved outwards. A concave lens diverges light rays. A convex lens converges light rays. Because they both curve outwards, neither lens can be used to form a real image.
E) A concave lens is a diverging lens: it only forms virtual images. A convex lens is a converging lens: it can be used to form either real or virtual images.

26. Explain the difference between a real image and a virtual image.
    A) Either type of image can appear inverted or upright. The only way to tell the difference is to check the magnification: real images are the same size as the original object, virtual images are larger or smaller.
    B) A real image is always right side up, never inverted; this is why it cannot be distinguished from the original real object. A virtual image is always inverted, so it can easily be distinguished from the original object.
    C) Either type of image may appear magnified or minified. A real image will always be inverted with respect to the object. A virtual image will always appear upright.
    D) A real image is an image that can be displayed on a screen. Whether it is upright or inverted is not material. A virtual image is virtual because you can't see it; you can trace a ray diagram on paper to show where an image ought to form, but if you really looked for that image using an actual lens, you would not be able to locate it.
    E) There is no physical difference between real and virtual images; either may appear upright or inverted, either may appear magnified or minified. The convention is to call an image formed by a lens of any shape a real image, and an image formed by a mirror of any shape a virtual image.

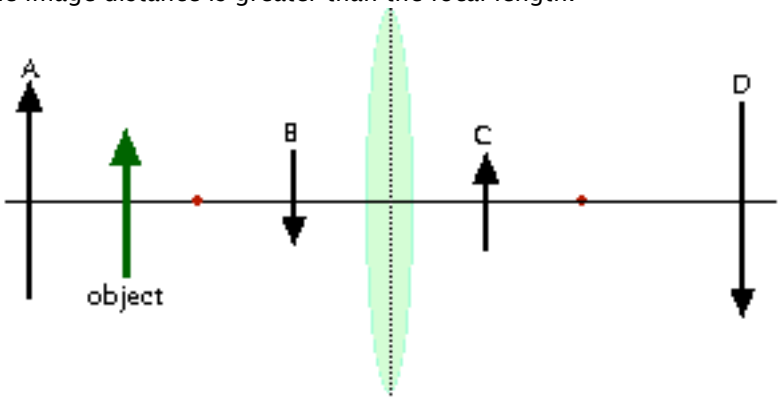
27. Which of the light rays is correctly drawn for the converging lens shown on the right? **B**
    E) None of these!



28. A converging lens
    A) can form either real or virtual images.
    B) can only be used to form images that are inverted.
    C) causes parallel light rays to be bent away from the positive focal point.
    D) is also called a negative lens because it is curved inward on both sides.

29. When a converging lens is used as a magnifying glass, the object is
    A) placed at a distance greater than the focal length in front of the lens.
    B) placed at a distance exactly equal to the focal length of the lens.
    C) is placed at a distance less than the focal length in front of the lens.
    D) distance does not matter, as long as the image distance is greater than the focal length.

30. Which of the images shown on the right will be formed when the object is placed as shown in front of the converging lens? **D**
    E) None of these!

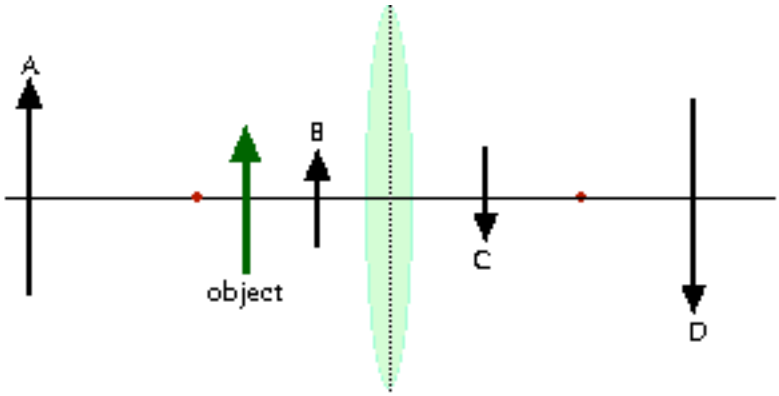


31. An object is placed at the focal point of a converging lens, $d_o = f$. What kind of image will be formed?
    A) None; the rays of light will all be parallel on both sides of the lens. No real or virtual image forms.
    B) A real image. Real rays of light will intersect on the side of the lens opposite the object.
    C) The real image is formed when real rays intersect on the same side of the lens as the object.
    D) Virtual. Real rays diverge. Virtual rays intersect on the opposite side of the lens as the object.
    E) A virtual image forms, but the virtual rays intersect on the same side of the lens as the object.

32. A real image
    A) appears where real light rays intersect.
    B) is always inverted and magnified.
    C) cannot be inverted, it is always upright.
    D) cannot be seen, so does not really exist.

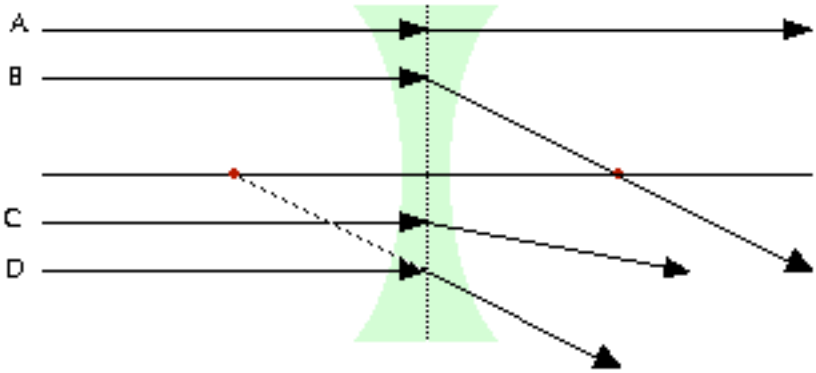
33. A virtual image
    A) appears where real light rays intersect.
    B) is always inverted and magnified.
    C) cannot be inverted, it is always upright.
    D) cannot be seen, so does not really exist.

34. Which of the images shown on the right will be formed when the object is placed as shown in front of the converging lens? **A**
    E) None of these!



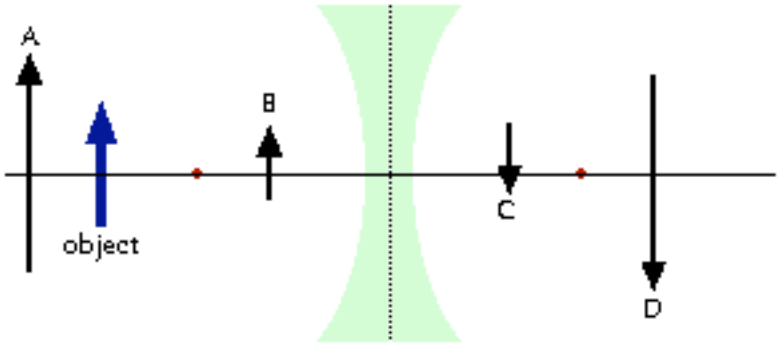
35. A diverging lens
    A) can form only virtual images.
    B) can only be used to form images that are inverted.
    C) causes parallel light rays to be bent toward the positive focal point.
    D) is also called a positive lens because it is curved outward on both sides.

36. Which of the light rays is correctly drawn for the diverging lens shown on the right? **D**
    E) None of these!



37. An object is placed at the focal point of a diverging lens, $d_o = f$. What kind of image will be formed?
    A) None; the rays of light will all be parallel on both sides of the lens. No real or virtual image forms.
    B) A real image. Real rays of light will intersect on the side of the lens opposite the object.
    C) The real image is formed when real rays intersect on the same side of the lens as the object.
    D) Virtual. Real rays diverge. Virtual rays intersect on the opposite side of the lens as the object.
    E) A virtual image forms, but the virtual rays intersect on the same side of the lens as the object.

38. Which of the images shown below will be formed when the object is placed as shown in front of the diverging lens? **B**
    E) None of these!



39. Spherical aberration
    A) is the tendency of lenses to make objects appear to be out of focus.
    B) is the result of using colored glass to make a lens.
    C) occurs when light passing through the edges of a lens is focused differently than light passing through the center of the lens.
    D) results because different colors of light have different speeds through the lens, so they will be bent by the lens slightly differently. Blue light will have a slightly shorter focus than red light.

40. Chromatic aberration
    A) is the tendency of lenses to make objects appear to be out of focus.
    B) is the result of using colored glass to make a lens.
    C) occurs when light passing through the edges of a lens is focused differently than light passing through the center of the lens.
    D) results because different colors of light have different speeds through the lens, so they will be bent by the lens slightly differently. Blue light will have a slightly shorter focus than red light.

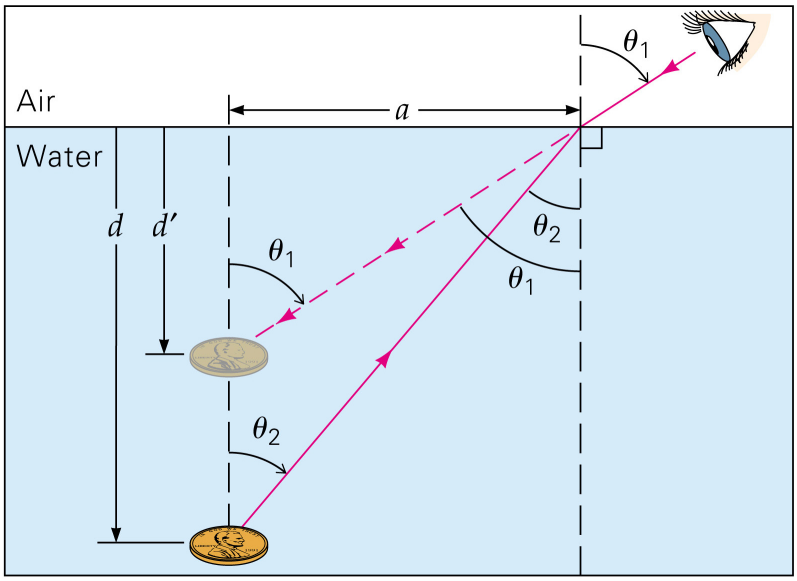
41. Young's double-slit experiment
    A) demonstrates convincingly that light is a particle. The pattern created on a screen shows two bright fringes that line up exactly with the position of each slit. There is a dark fringe on center, which you would expect since no particle passing through a slit could actually hit the center of the screen.
    B) demonstrates conclusively that light is a wave. The alternating pattern of bright and dark fringes on the screen show how two light waves interfere. The central bright maximum proves that the light can't be a particle.
    C) proves that light is a particle. When a bright light shines on a metal foil, the photons crash into the surface and knock electrons right off. Young observed that a wave could not do this, but he could not explain why. Einstein actually explained it, and won a Nobel Prize for his mathematical proof of Young's hypothesis.
    D) showed that light has a dual wave-particle nature. Newton first suggested this, but got distracted by trying to turn lead into gold before he could prove it. Young's experiment laid the groundwork for Maxwell, whose equations finally proved that electricity is a wave and magnetism is a particle.

42. The condition for constructive interference requires that the path length difference ΔL be equal to
    A) zero.
    B) ¼ the wavelength.
    C) ½ the wavelength.
    D) one whole wavelength.
    E) any odd multiple of ½ wavelengths.

43. Cryin' won't help you, prayin' won't do you no good...
    Cryin' won't help you, prayin' won't do you no good
    A) When the Levee Breaks
    B) Misty Mountain Hop
    C) Immigrant Song
    D) What Is and What Should Never Be
    E) Stairway to Heaven
    F) Houses of the Holy

44. Nothing personal, and please don't be offended. I'm sure you're doing just fine so far, it's just what's on random play.
    A) Pink Floyd (hint: for once, it's *not* Floyd)
    B) Led Zeppelin
    C) Mott the Hoople
    D) Alan Parsons Project
    E) Yes
    F) The Moody Blues

Problem 01



You have your head at the edge of the pool, and you are looking straight down at the last penny on the bottom. Your little brother was diving for pennies, but didn't get that one because it's at the deep end of the pool, where the penny is 3.5m below the surface of the water (n=1.33).

A) What is the relationship between the real and the apparent depth of the penny? Show your work!

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

$$\tan\theta_1 = \frac{a}{d'} \cong \sin\theta_1$$

$$\tan\theta_2 = \frac{a}{d} \cong \sin\theta_2$$

$$n_1\left(\frac{a}{d'}\right) = n_2\left(\frac{a}{d}\right)$$

$$d' = \frac{n_1 d}{n_2}$$

B) How deep do you perceive the penny to be?

$$d' = \frac{(1)(3.5\text{m})}{(1.33)} = 2.63\text{m}$$

Problem 02

A beam of light traveling through water (n=1.33) strikes the face of the high density polyethylene (HDPE) jug at a 45° angle. The angle of refraction is measured to be 37.6°.

A) Find the index of refraction for HDPE.

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

$$(1.33)\sin 45° = n_2 \sin 37.6°$$

$$n_2 = 1.54$$

B) What is the speed of light through the HDPE?

$$1.54 = \frac{3\times10^8 \frac{\text{m}}{\text{s}}}{v}$$

$$v = 1.95\times10^8 \frac{\text{m}}{\text{s}}$$

C) The original beam of light has a wavelength of 550nm in air. What is the wavelength in water? In the HDPE?

$$\lambda' = \frac{\lambda}{n}$$

$$\lambda' = \frac{(550\text{nm})}{(1.33)} = 414\text{nm in water}$$

$$\lambda' = \frac{(550\text{nm})}{(1.54)} = 357\text{nm in water}$$

A baby llama is called a cria! Who knew?

Problem 03

A section of a sphere is mirrored on both sides. An object placed in front of the concave mirror has a magnification M=+1.5.

A) Express the focal length in terms of the object distance.

$$M = -\frac{d_i}{d_o}$$

$$+1.5 = -\frac{d_i}{d_o}$$

$$d_i = -1.5d_o$$

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

$$\frac{1}{d_o} - \frac{1}{1.5d_o} = \frac{1}{f}$$

$$\frac{1}{d_o} - \frac{2}{3d_o} = \frac{1}{f}$$

$$\frac{3}{3d_o} - \frac{2}{3d_o} = \frac{1}{f}$$

$$\frac{1}{3d_o} = \frac{1}{f}$$

$$f = 3d_o$$

B) What is the magnification of the same object if it is placed at the same object distance in front of the convex side of the mirror? Show your work for partial credit.

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

$$\frac{1}{d_o} + \frac{1}{d_i} = -\frac{1}{3d_o}$$

$$\frac{1}{d_i} = -\frac{3}{3d_o} - \frac{1}{3d_o}$$

$$\frac{1}{d_i} = -\frac{4}{3d_o}$$

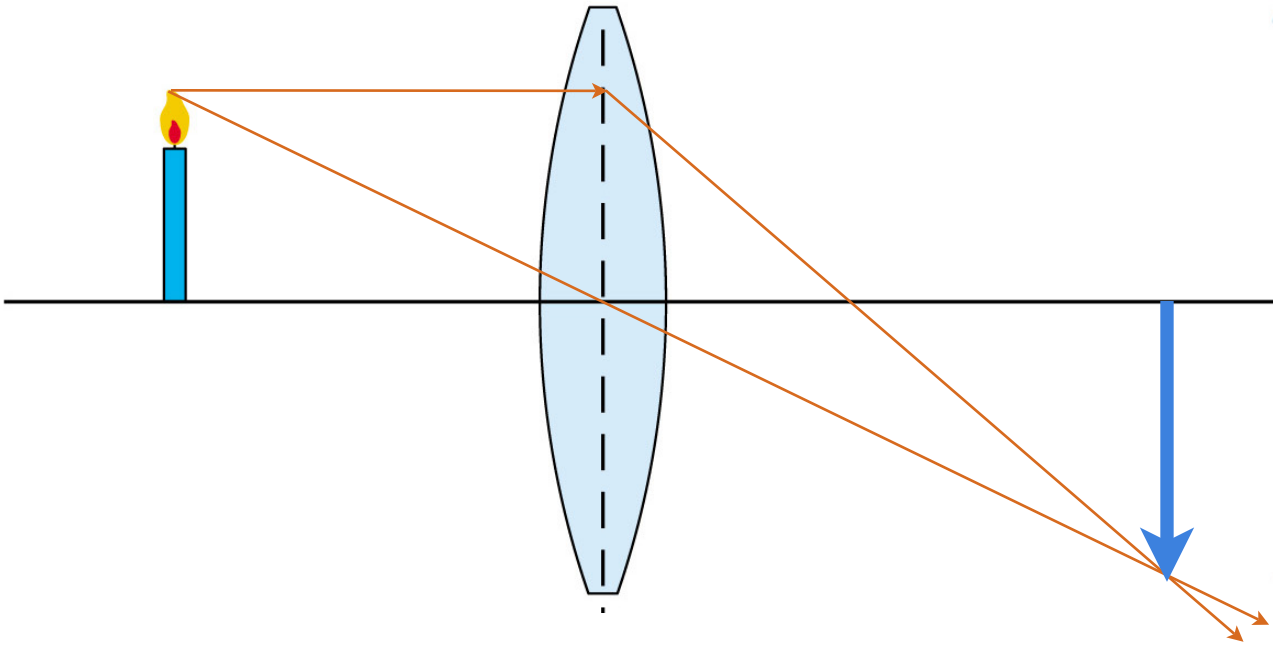
$$d_i = -\frac{3d_o}{4}$$

$$M = -\frac{d_i}{d_o}$$

$$M = -\frac{\left(-\frac{3d_o}{4}\right)}{d_o} = +\frac{3}{4} = +0.75$$

Problem 04

The 6 cm tall object shown is placed 12 cm in front of the converging lens. The image formed has a magnification M=-4/3.



A) Find the focal length of the lens and the object distance.

$$M = -\frac{d_i}{d_o} = \frac{h_i}{h_o}$$

$$-\frac{4}{3} = -\frac{d_i}{12}$$

$$d_i = 16\text{cm}$$

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

$$\frac{1}{12\text{cm}} + \frac{1}{16\text{cm}} = \frac{1}{f}$$

$$f = 6.86\text{cm}$$

B) Use the ruler to carefully (to scale!) show the position of the focal length, then construct an accurate ray diagram to locate the position of the image.

Problem 05

In a double-slit experiment using monochromatic light, the angular separation of the central maximum and the second order bright fringe is 0.160°. The second order fringe is found 2.25 mm from the center of the central maximum.

A) What is the distance from the slits to the screen?

$$\sin\theta \cong \frac{y}{L}$$

$$\sin(0.160°) = \frac{\left(2.25\times10^{-3}\,\mathrm{m}\right)}{L}$$

$$L = 0.81\,\mathrm{m}$$

B) Find the wavelength of the light used if the slit separation is 0.350mm.

$$y_n = \frac{n\lambda L}{d}$$

$$\left(2.25\times10^{-3}\,\mathrm{m}\right) = \frac{2\lambda(0.81\,\mathrm{m})}{\left(0.35\times10^{-3}\,\mathrm{m}\right)}$$

$$\lambda = 4.89\times10^{-7}\,\mathrm{m}$$