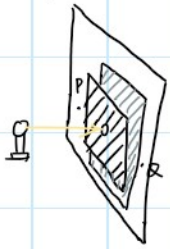
33.1 rays

Sunday, January 27, 2019 5:23 PM

- **Ray optics**: Not considering the electric & magnetic fields individually but think of the behavior of rays of light.
- **Rays**: Lines that represent the direction of propagation of light.

e.g. When add a second bulb on the left, what happens to



(a) the spot

(b) P, Q

(a) Does not affect

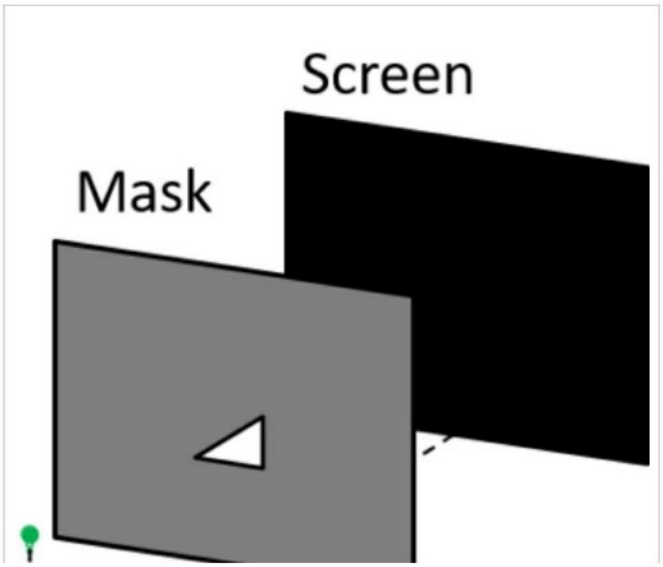
(b) P becomes brighter.

Q doesn't change.

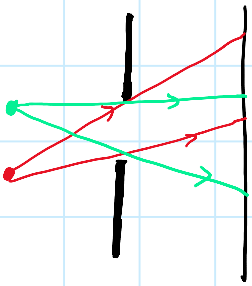
e.g.

many choice question

A small green light bulb is placed above a small red light bulb, and the bulbs are placed in front of a screen. A mask with a triangular hole is placed between the bulbs and the screen as shown. What is observed on the screen? Select all that apply.



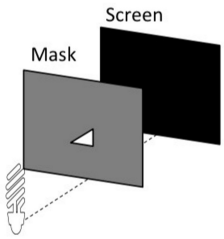
The red is above the green → shap is triangle.

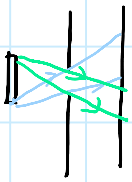


Light propagate by straight line.

e.g.

The small light bulbs are replaced with an extended light bulb. Which choice below would you observe on the screen?



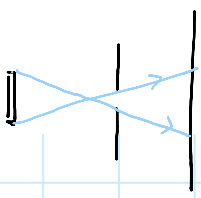


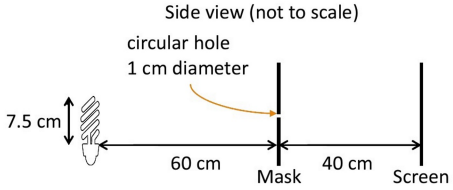
C

e.g ~~AAA~~

Now consider a bulb in front of a mask with a 1-cm diameter circular hole as shown. How would the height of the lit region on the screen change if the diameter of the hole were halved?

A. The height of the bright spot would be smaller than before, but more than half as high as before.
B. The height of the bright spot would be half as high as before.
C. The height of the bright spot would be the same size as before.





A

a point source of a light creates an approximately 1.67 cm circle on the screen. When d point halved, the d of circles halved.

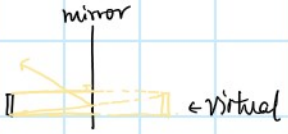
a point source of a light creates an approximately 1.0 cm circle
on the screen. When d point halved, the d of circles halved.
But there're some dots overlapped, so it won't be perfectly $\frac{1}{4}$.

33.2 Absorption, transmission, and reflection

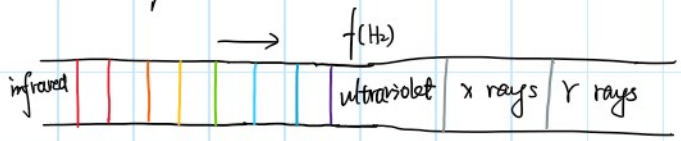
Sunday, January 27, 2019 10:38 PM

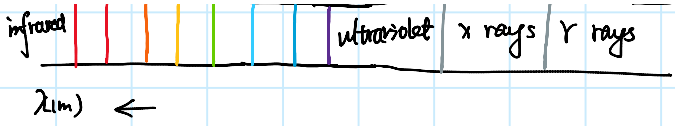
- **Transmitted light**: passes through a material.
  - Transparent
  - **Translucent**, in which light waves are transmitted diffusely.
    (Lights are redirected in random directions as pass through)
- **Absorbed light**: enters a material but never exits again.
  - **Opaque**: objects that absorb most of the light that strike them.
  - Energy carried by the wave is converted to other form.
- **Reflected light**: any light that is reflected from the surface of material.
  - Smooth surfaces reflect light specularly. ⟺ $\theta_i = \theta_r$ (diffuse reflection / specular reflection)
  - angle of incidence θ_i
    angle of reflection θ_r

  - Law of reflection $\theta_i = \theta_r$ at smooth surface.
    - For diffuse reflection, each ray obeys Law of reflection, but the normal lines don't parallel to each other.
  - Smooth: the height & separation of irregularities on the surface are small relative to the wavelength of the incident light.
- **Ray diagram** a diagram showing just a few selected rays.
- Image (optically formed duplicate of object)
  - **virtual image**: Rays do not actually travel through the image.
  - **real image**: Rays actually travel through the image.



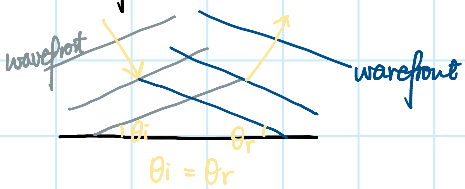
- Visible spectrum



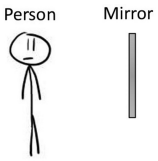


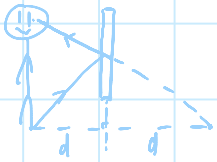
- When a light source produces all of the visible spectrum at roughly same intensities, the emitted light appears white.
- An object with color only transmit/reflect its own color light, and absorb all other light.

- Wavefront.



A person stands in front of a mirror as shown. Where do they perceive the mirror image of their feet? If they cannot see their feet, enter 0.



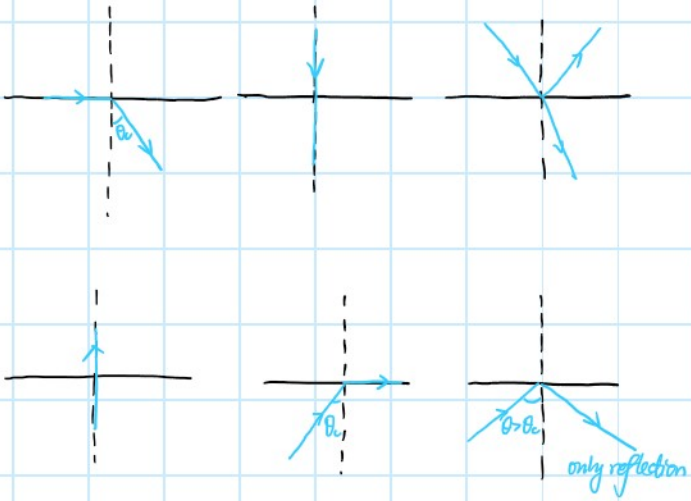


33.3 refraction & dispersion

Tuesday, January 29, 2019 11:09 AM

- $C_0 = 3 \times 10^8$ m/s in vacuum.
- **refraction**: bending of light as it moves from one material into another.
  - **angle of refraction** the angle between the refracted way & the normal way.
- When a light ray travels from one material into a second material where light travels more slowly, the ray bends toward the normal to the interface between the materials.
  - Generally $V_c \downarrow$ as $\rho \uparrow$
  - the amount of bending depends on { the angle of incidence; relative speeds in two media }

- **critical angle θ_c**: value for which the refracted ray emerges along the interface.

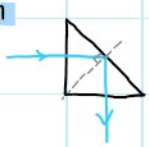


  - **total internal reflection** all light is reflected back into the higher-density medium when incident θ is larger than θ_c

- ~~total internal reflection~~ ~~light is reflected back into the~~

higher-density medium when incident θ is larger than θ_c.

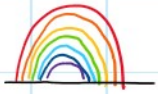
- Prism



undergoes total internal reflection

- Optical fibers

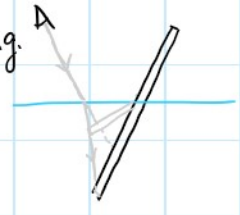
- **Dispersion** Angle of reflection also depends on f. since v_c depends slightly on f.
  - Causes rays of different colors to be dispersed.
  - high f bends more strongly.
    - high f light travels more slowly, $\therefore$ bends more strongly. (in most media)



- **Fermat's principle**

The path taken by a light ray between two locations is the path for which the time interval need to travel between those locations is a minimum.

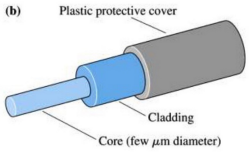
e.g.



the stick is appears more near to the surface.

An optical is used to send light long distances down the core. Note that the fiber does not need to be in a straight line. In an optical fiber, what can be said the speed of light in the core and the cladding?

A. The speed must be higher in the cladding.
B. The speed must be higher in the core.
C. The speeds must be the same.
D. The speed in the cladding could be higher or lower than that in the core.



It need perfect internal reflection. A

$\therefore \ell_{core} > \ell_{cladding}$

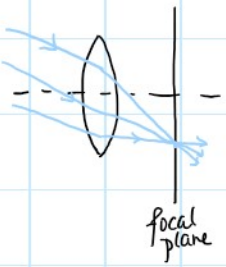
$\therefore v_{cladding} > v_{core}$

33.4 forming images

Tuesday, January 29, 2019 12:38 PM

- **Converging lens** a lens with convex surfaces
  - **focus / focal point** Rays parallel to the len axis converge through such a lens onto a single point.
  - **focal length** (f) the distance from the center of the lens to the focus

  - **focal plane** the parallel rays converge at a point on the focal plane



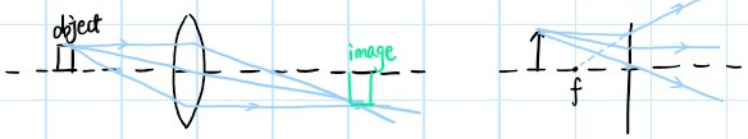
  - **paraxial** : Rays that run near the len axis, either parallel to it or at small angle.

- **Principal rays**: to determine where the rays emanating from a point on an object converge.

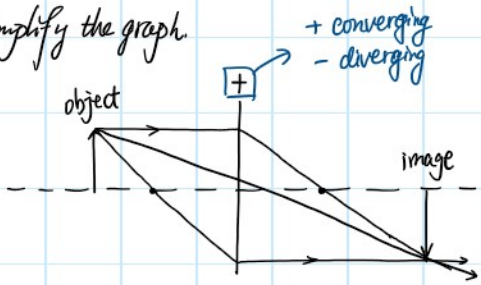
I. A ray that travels **parallel to the lens axis** before entering the lens.

II. A ray passes through **center** of lens.

III. A ray passes through the **focus** that is **on the same side** of the lens as the object.

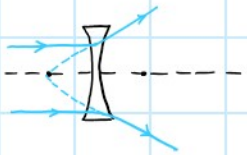


- Simplify the graph.



- No image forms if the image is placed at the focus.
- { real image — Can be projected on a screen; denoted by solid arrows.
  virtual image — Can't be projected on a screen.; denoted by dashed arrows.

- diverging lens (concave surface)



o Diverging lens has virtual focus

Because rays never actually through it,

Procedure: Principal rays for lenses

The propagations of principal rays for converging and diverging lenses are very similar. The description below holds for rays that travel from left to right.

Converging lens

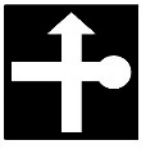
1. A ray that travels parallel to the lens axis before entering the lens goes through the right focus after exiting the lens.
2. A ray that passes through the center of the lens continues undeflected.
3. A ray that passes through the left focus travels parallel to the lens axis after exiting the lens. If the object is between the focus and the lens, this ray doesn't pass through the focus but lies on the line from the focus to the point where the ray originates.

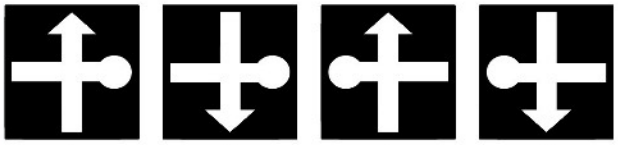
Diverging lens

1. A ray that travels parallel to the lens axis before entering the lens continues along the line from the left focus to the point where the ray enters the lens.
2. A ray that passes through the center of the lens continues undeflected.
3. A ray that travels toward the right focus travels parallel to the lens axis after exiting the lens.

- Regardless of the radii of curvature, the lens has two foci, one on either side of the lens at the same distance f from it.

A converging lens is used to project the object shown at right onto a screen. What does the image look like?





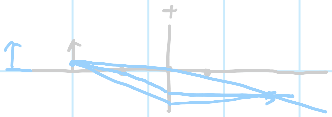
A. B. C. D.

Changing axis also make it inverted. D

Quiz: Covered lens

In the previous demo a piece of black tape is now placed over the top two thirds of the lens. Which of the follow is true?

A. Only the lower third of the object will show on the screen.
B. Only the upper third of the object will show on the screen.
C. The whole object will still show on the screen.



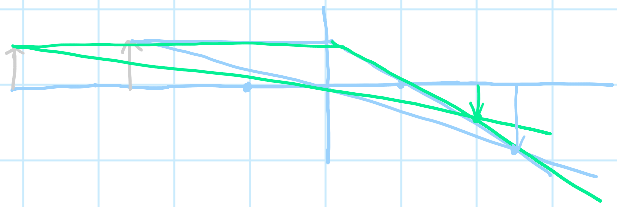
C

first draw the principle way, then can draw other rays -- since they all intersect on the same part of image.
The only difference is the brightness, since less rays arrive.

Quiz: Changing object location

In the previous demo the object was located about 1.5 focal lengths from the lens, and the image was located about 3 focal lengths from the screen. As you saw, the image was bigger than the object. What would happen to the image if we placed the object 3 focal lengths from the screen?

A. The image would be bigger than in the previous case.
B. The image would be smaller than in the previous case, but bigger than the object.
C. The image would be smaller than the object.



$\frac{1}{f} = \frac{1}{o} + \frac{1}{i}$ C

33.5 Snel's Law

Thursday, January 31, 2019 12:07 PM

- **Index of refraction** the speed of light in a medium is specified by index of refraction.

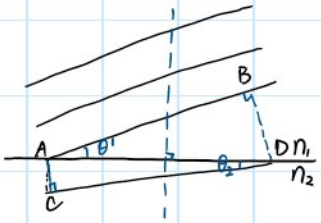
  $n \equiv \frac{c_0}{c}$, c_0, speed of light in vaccum.

  - $n_{vaccum} = 1$

    $n_{air} \cong 1$

  - If a light wave travels into another medium, f doesn't change since f is determined by source.

- **Snel's law** $n_1 \sin\theta_1 = n_2 \sin\theta_2$



$\sin\theta_1 = \frac{BD}{AD} = \frac{\lambda_1}{AD}$

$\sin\theta_2 = \frac{BC}{AD} = \frac{\lambda_2}{AD}$

$c \equiv \frac{c_0}{n} = \lambda f \quad \therefore \frac{\lambda_1}{\lambda_2} = \frac{n_2}{n_1}$

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

  - critical angle $\sin^{-1}\left(\frac{n_1}{n_2}\right)$

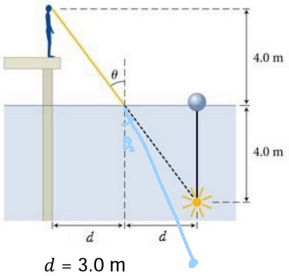
$\because \theta_1 = \frac{\pi}{2} \therefore \sin\theta_1 = 0$

$\sin\theta_c = \frac{n_1}{n_2}$

$\theta_c = \sin^{-1}\left(\frac{n_1}{n_2}\right)$

Quiz: Light in water

A researcher stands at the end of a lakeside pier, 4.0 m above the water surface and $2d$ = 6.0 m away from a buoy floating on the lake, as shown. A rope hangs from the bottom of the buoy down into the water, with a light attached to its end. When the researcher looks at the light from a position at which his line of sight intersects the water surface exactly halfway between the pier and the buoy, the light appears to be 4.0 m below the water surface.



d = 3.0 m

How far under the surface is the light? Enter answer in meters, but do not include the units in your answer.

Refractive index of water is 1.33

$n_{air} \cdot \sin\theta = n_{water} \cdot \sin\theta_2$, $\sin\theta = \frac{3}{5}$

$\frac{1 \cdot \frac{3}{5}}{1.33} = \sin\theta_2$

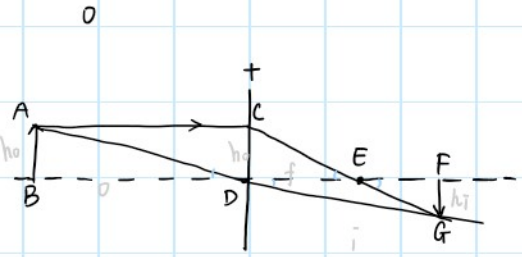
$\theta_2 = 26.82°$

$\frac{3m}{\tan\theta_2} = 5.934$ m

33.6 Thin lens & optical instruments

Thursday, January 31, 2019 12:23 PM

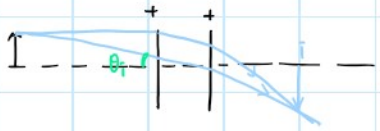
- lens equation $\frac{1}{f} = \frac{1}{o} + \frac{1}{i}$
  - f : focal length
    o : object distance
    i : image distance



- Magnification $M = \frac{h_i}{h_o} = -\frac{i}{o}$
- Sign Convension

Sign	Lens	Mirror
$f > 0$	converging lens	converging mirror
$f < 0$	diverging lens	diverging mirror
$o > 0$	object in front[b] of lens	object in front of mirror
$o < 0$[a]	object behind lens	object behind mirror
$i > 0$	image behind lens	image in front of mirror
$i < 0$	image in front of lens	image behind mirror
$h_i > 0$	image upright	image upright
$h_i < 0$	image inverted	image inverted
$\|M\| > 1$	image larger than object	image larger than object
$\|M\| < 1$	image smaller than object	image smaller than object

- Angular magnification $M_\theta \equiv \left|\frac{\theta_i}{\theta_o}\right|$ decides the image size relative to human eyes



- Small-angle approximation

  For small angles & object placed near to focus of external lens

  $\theta_i \approx \tan\theta_i \approx \frac{h_o}{f}$

  For small angles & object placed at eye's near point:

  $\theta_o \approx \tan\theta_o = \frac{h_o}{d_o}$

  $\therefore M_\theta \approx \frac{d_o}{f}$

- lens strength $d \equiv \frac{1m}{f}$, unit: diopters.
  - The strength of eyeglass lens

- The larger the focal length, the less effect the lens has on the path of the light.

numerical question

The human eye focuses incoming light rays, forming an image on the retina of he eye. We can approximate the human eye as a single thin lens 2.30 cm from the retina. What is the smallest distance an object can be from the lens such that an image is focused on the retina if the focal length of the lens is 2.10 cm?
Enter your answer in cm, but only include the number.
Your response has been hidden for privacy. Click **Show response** below to see it, or click **Change response** if you want to replace your current response with a new one.

$$\frac{1}{\frac{1}{2.1}-\frac{1}{2.3}} = 24.15 \text{ cm}$$

33.7 Spherical mirrors

Wednesday, February 6, 2019 4:54 PM

- Spherical mirrors have only a single focus.
- Radius of curvature (R) the length of the radius of the sphere on which the surface of the mirror lies.
  - $f = \frac{R}{2}$

OD ⊥ tangent line of the sphere

∴ the three angles equal.

AD = OD

$\therefore OD = \frac{R}{2} \cdot \frac{1}{\cos\theta}$, when $\theta \to 0$, $\cos\theta \to 1$

$\therefore OD \to \frac{R}{2}$ $\therefore f = \frac{R}{2}$

  - center: center of the sphere on which the mirror surface lies.
- $f > 0$ real focus

  $f < 0$ virtual focus

  $o > 0$ object in front of mirror

  $o < 0$ object behind mirror (only happens when obj is an image formed by another mirror/lens)

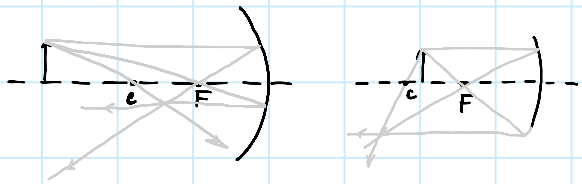
  Real image: locate at same side of the object, inverted.

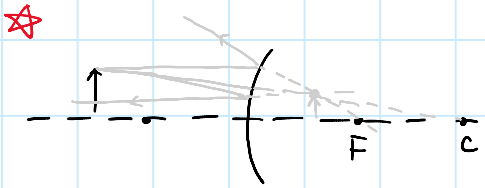
  Virtual image: locate at different side of the object, upright
- Diverging mirror always form virtual images when used alone.

  the image is much smaller than the object.
- { Diverging mirror: convex

  Converging mirror: concave.
- $M = \frac{h_i}{h_o} = -\frac{i}{o}$
- Principal rays for spherical mirror

- Principal rays for spherical mirror





Probs

Sunday, January 27, 2019 11:46 PM

33.5 In vacuum, a particular light wave has a wavelength of 400 nm. It then travels into a piece of glass, where its speed decreases to two-thirds of its vacuum speed. What is the distance between the wavefronts in the glass?

$n_1\lambda_1 = n_2\lambda_2$

$n_1 = 1, \lambda_1 = 400nm$

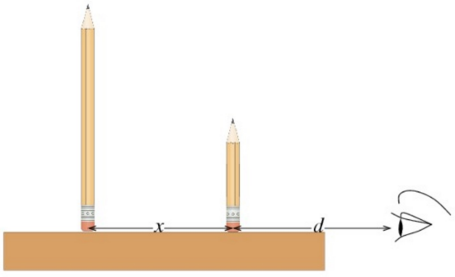
$n_2 = \frac{c_0}{c} = \frac{3}{2}$

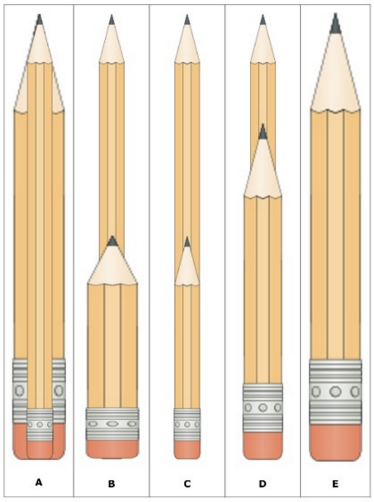
$\lambda_2 = \frac{2}{3} \cdot 400 = 267\ nm$

★★★

Angular size

Two new pencils are carefully balanced on a table top. One is shorter than the other. The shorter pencil is *exactly half* the length of the longer pencil. An observer looks at them from along the line joining the bases of the pencils, as indicated in the figure below. The distance x = 15cm.





If the observer's eye is at d = 15cm, which image shown above corresponds most closely to what would be seen?

- A
- B
- C
- D
- E

D

two pencils have the same angular size.

If the observer's eye is at d = 30cm, which image shown above corresponds most closely to what would be seen?

- A
- B
- C
- D
- E

D

If the observer's eye is at d = 200cm, which image shown above corresponds most closely to what would be seen?

- A
- B
- C
- D
- E

C.

★★★

Constants | Periodic Table

Constants | Periodic Table

A lens produces a real image of a real object.

Part A

Is the image inverted or upright?

▶ View Available Hint(s)

inverted

Real images are always inverted

Submit Previous Answers

✔ Correct

Part B

Is the lens diverging or converging?

converging

Diverging lens only forms virtual image.

Submit Previous Answers

✔ Correct

Part C

Is the image enlarged or reduced in size?

▶ View Available Hint(s)

cannot be determined

$f < f < 2f$ enlarged

$f < 2f$ smalled

Part D ✔

If two convex lenses identical in size and shape are manufactured from glass with two different indices of refraction, would the focal length of the lens with the greater index of refraction (lens 1) be larger or smaller than that of the other lens (lens 2)?

▶ View Available Hint(s)

smaller

Previous Answers

✔ Correct

f↑ less influence of lens on lights.

Part E ✔

If lens 1 from Part D were placed in exactly the same location as lens 2, would the image produced by lens 1 be larger or smaller than the image produced by lens 2?

▶ View Available Hint(s)

smaller

$\frac{1}{f} = \frac{1}{o} + \frac{1}{i}$

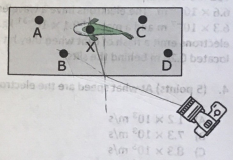
$\frac{1}{i} = \frac{1}{f} - \frac{1}{o} = \frac{o-f}{of}$

$i = \frac{of}{o-f} = \frac{o}{\frac{o}{f} - 1}$

o equals, $f\downarrow$ $\frac{o}{f}\uparrow$, $i\downarrow$

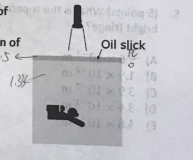
I) Lecture Multiple Choice (8 questions, 40 points total)

1. (5 points) You take a photo of a fish in a fish tank. The figure shows a top view of your camera and the tank. The fin of the fish is located at position X and is not in the water. Where does the body of the fish, which is in the water and below the fin, appear to be located in your photo.



A) Position A
B) Position B
C) Position C
D) Position D
E) Position X

2. (5 points) A diver is swimming underneath an oil slick with a thickness of 200 nm and an index of refraction of 1.50. A white light shines straight down towards the diver from above the oil slick. The index of refraction of water is 1.33. What is the longest wavelength of the light in water, λ_{water}, that is transmitted most easily to the diver?



A) 400 nm
B) 450 nm
C) 530 nm
D) 600 nm
E) 1200 nm

$\pi + \pi = \frac{4\pi nt}{\lambda}$

$1 \times 600 = 1.33\lambda_{water}$

$\lambda_{water} = 450$

Part G

If the observer sees an image that has $|M| < 1$ then the mirror could be ___

Select all that apply.

- [ ] Flat
- [x] Concave
- [x] Convex

Submit Previous Answers

✔ **Correct**

Part H

If the observer sees an image that has $|M| > 1$ then the mirror could be ___

Select all that apply.

- [ ] Flat
- [x] Concave
- [ ] Convex

Submit Previous Answers

✔ **Correct**

If the observer sees an image that moves to the *left* when the observer's eye moves to the *right* then the mirror could be ___

Select all that apply.

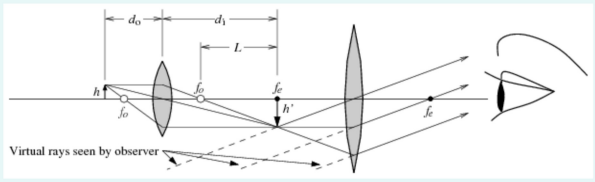
Imply that the image is inverted

- [ ] Flat
- [x] Concave
- [ ] Convex

Submit Previous Answers

✔ **Correct**

An experimenter sets up a microscope with a $f_o = 20.00\ \text{mm}$ objective lens. The object distance between the object and the center of the objective lens, $d_o = 22.00\ \text{mm}$.



Part A

What is the **image distance** between the objective lens and the image created by the objective, d_i?

$\frac{1}{i} = \frac{1}{f_o} - \frac{1}{o}$

220 mm

Part A

What is the **image distance** between the objective lens and the image created by the objective, d_i?

220 mm

$\frac{1}{i} = \frac{1}{f_o} - \frac{1}{o}$

$i = 220mm$

What is the **tube length**, L?

$L = i - f_o$

$= 200mm$

200 mm

What is the **lateral magnification** of the objective, M_o?

$M_o = -\frac{220mm}{22mm} = \frac{-i}{o}$

$= -10$

-10.0

If an eyepiece of focal length $f_e = 15.00\ \text{mm}$ is used, what is the magnifying power of this microscope?

-167

$M = \frac{25cm}{1.5cm} \cdot (-10)$

$= +67$

A camera with interchangeable lenses is used to photograph a distant object. The angular size of the object is 44 degrees.

Part A

What is the longest focal length lens that can be used on the camera in order for the image of the object to fit within the width of the film frame, 36 mm?

- 28 mm
- 35 mm
- 50 mm
- 90 mm
- 135 mm
- 150 mm
- 200 mm
- 300 mm

$\tan 22° = \frac{18}{f}$

$f = 44.6\ mm$