AP Physics Study Guide Chapters 22, 23, 24 Reflection, Refraction and Interference

Name______________________

Write each of the equations specified below, **include units for all quantities.**

Law of Reflection | Lens-Mirror Equation | Magnification Equation

index of refraction-light speed | Snell's Law

Chapter 22

Briefly explain why electromagnetic radiation (waves) are not mechanical waves. Include what they are comprised of.

List the names of six different types of electromagnetic radiation that are part of the electromagnetic spectrum.

1) 2) 3)

4) 5) 6)

All electromagnetic waves travel at what speed?_______________________ m/s

Chapter 23 Mirrors

Explain the difference between a real image and a virtual image for a mirror. Include where they appear in relation to the mirror.

The angles of incidence and reflection are both measured from ___________________ to the mirror.

Circle correct choices: Plane mirrors only form real/virtual images that are larger in size/the same size/ smaller in size compared to the object and are upright/inverted.

How far away does the image created by a plane mirror appear?

Write the relationship between the radius of curvature and the focal length for a spherical mirror.

A concave mirror forms real/virtual images when the object is outside the focal point and real/virtual images when the object is inside the focal point (circle correct choice).

Convex mirrors always form images with the same image characteristics. Circle the correct choices:

real virtual larger same size smaller upright inverted.

Indicate what the positive or negative value of the following quantities indicates

	Positive	Negative
focal length		
image distance		
image height		

Explain the refraction of light rays and what causes it.

Explain what the index of refraction of an optically transparent medium is and why it is always ≥ 1.0

Like reflection, the angles of incidence and refraction are both measured from ____________________.

Light rays going from a faster medium into a slower medium will refract ______________ the normal.

Light rays going from a slower medium into a faster medium will refract ______________ the normal.

For total internal reflection to occur a light ray must be travelling from a _______________ medium

into a _________________ medium and have an angle that is ≥ the __________________ angle.

Converging lenses form images with which image characteristics? Circle all that apply.

real virtual larger same size smaller upright inverted.

Diverging lenses always form images with the same image characteristics. Circle the correct choices:

real virtual larger same size smaller upright inverted.

Indicate what the positive or negative value of the following quantities indicates

	Positive	Negative
focal length		
image distance		
image height		

Explain what the process of dispersion is and what is created by it.

What is the wavelength range for the visible portion of the electromagnetic spectrum?

Dispersion, refraction, reflection, interference and diffraction are all examples of the ___________ nature of light.

Chapter 24

There are 3 factors that you need to account for in solving thin film interference problems.

1) Why is the wavelength of light changing as it travels from air into the film?

Write the formula used for calculating this change in wavelength.

2) Constructive or destructive interference, like with the 2-slit diffraction patterns, occurs when there is

a ____________ ______________ ___________________ between the rays entering the film and those

that have ____.

3) The rays transmitted into the film will be reflected off of the boundary between the film and the material it is on.   Explain the conditions for that ray to be inverted or not as a result of that reflection.

Therefore, taking all three of these conditions into account, write the relationships that define thin film interference on the lines below:

Constructive interference occurs when the path length difference between the incident ray and the

transmitted ray = ___________________________.

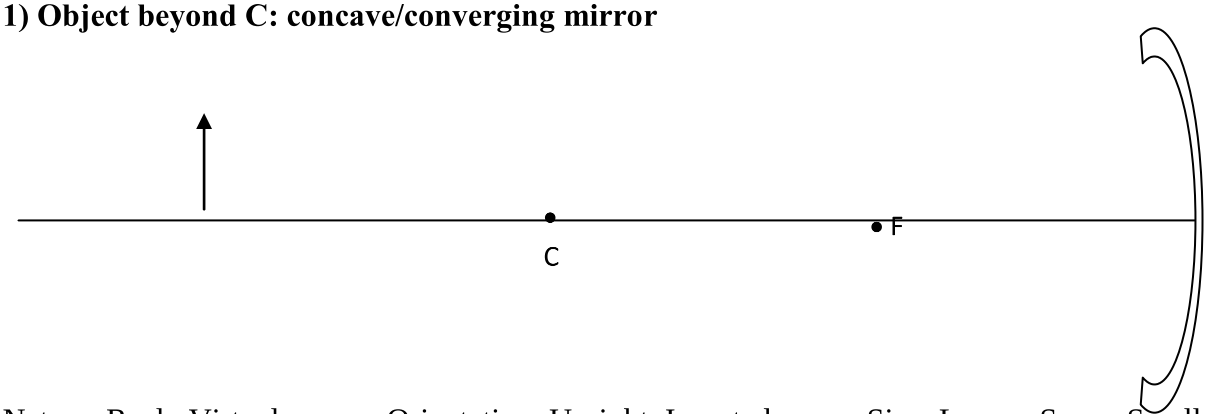
Destructive interference occurs when the path length difference between the incident ray and the

transmitted ray = ___________________________.

Once again the λ in these relationships is the wavelength of the light _______ _______ __________.

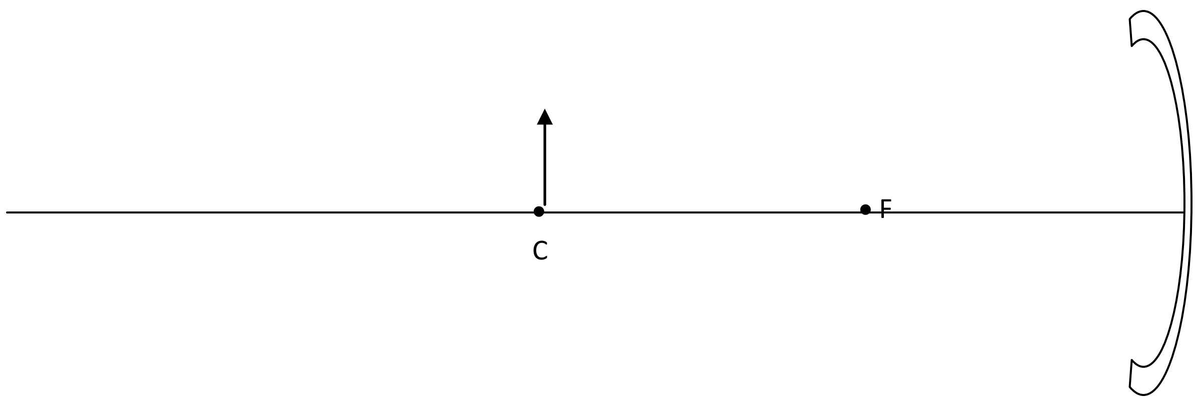
Draw ray tracing diagrams for each situation on the diagrams below. Use at least two of rays 1,2,3 – all three are not necessary. Show the image clearly on each diagram by drawing the arrow's image where it forms. Indicate image characteristics.

1) Object beyond C: concave/converging mirror



Nature: Real Virtual Orientation: Upright Inverted Size: Larger Same Smaller

2) Object at C: concave/converging mirror



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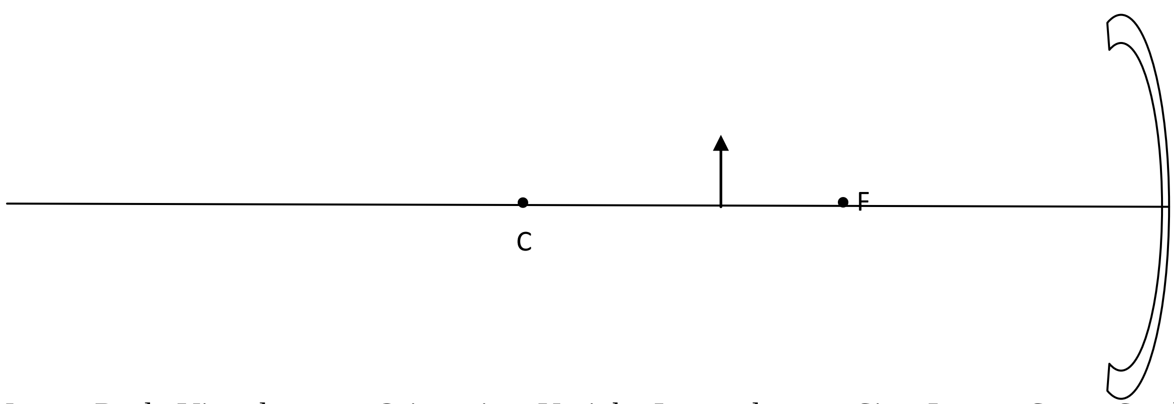
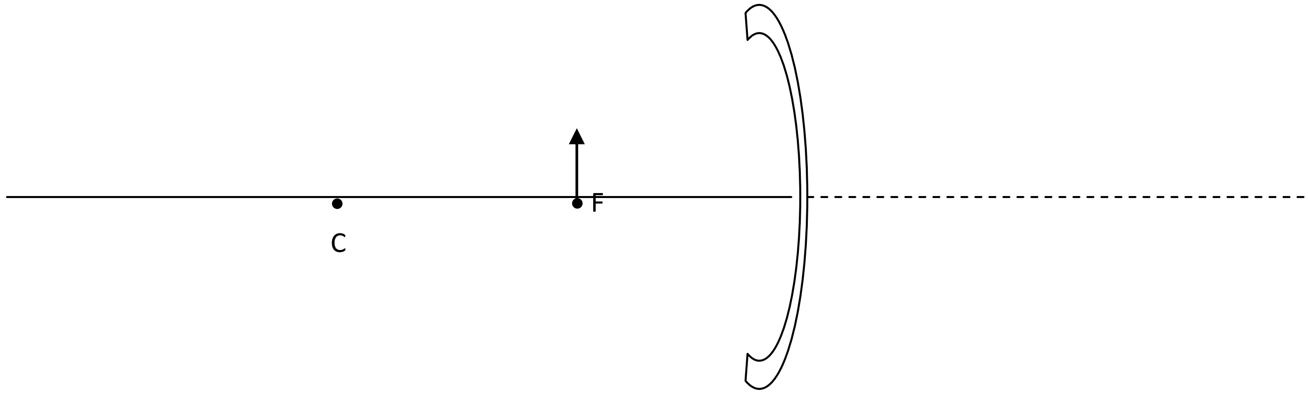
3) Object at F: concave/converging mirror



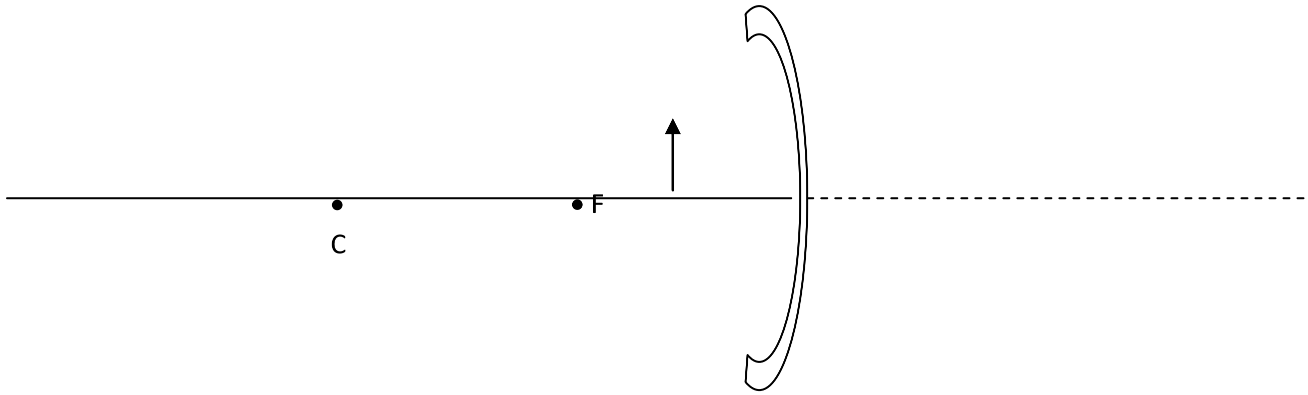
Nature: Real Virtual Orientation: Upright Inverted Size: Larger Same Smaller

4) Object at F: concave/converging mirror



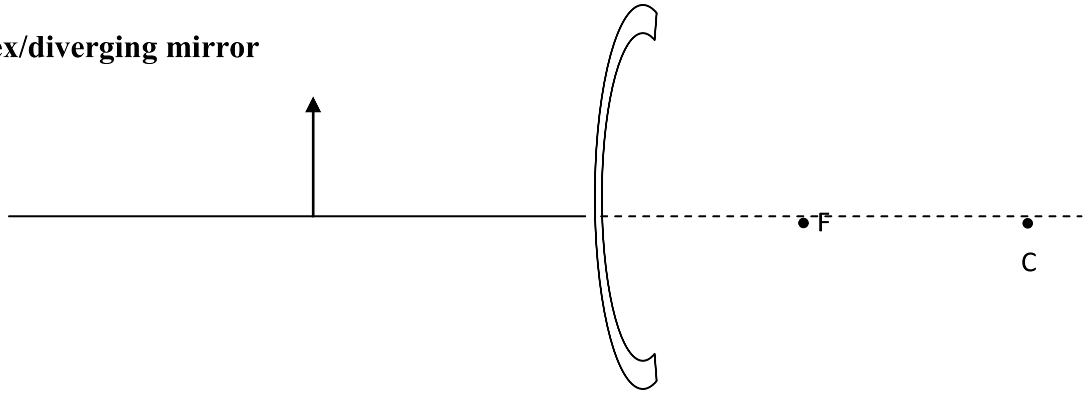
Nature: Real Virtual Orientation: Upright Inverted Size: Larger Same Smaller

5) Object between F and mirror: concave/converging mirror



Nature: Real Virtual Orientation: Upright Inverted Size: Larger Same Smaller

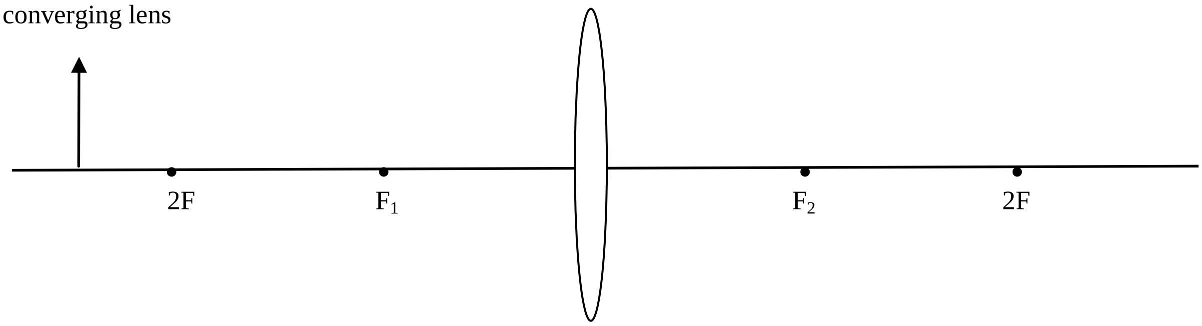
6) Convex/diverging mirror



Nature: Real Virtual Orientation: Upright Inverted Size: Larger Same Smaller

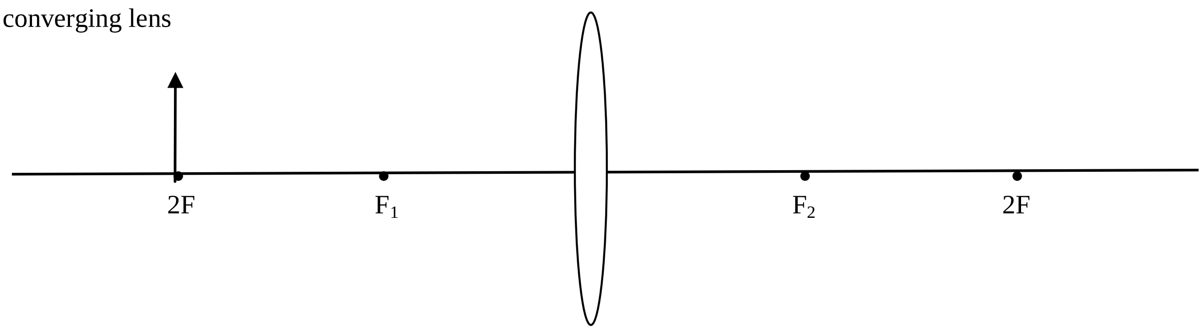
Draw ray tracing diagrams for all six lens/ object combinations below. Show at least 2 rays, both the incident and the refracted rays. Draw ray extensions clearly if the image is virtual. Draw the arrow's image where it forms and indicate image characteristics.

1) converging lens



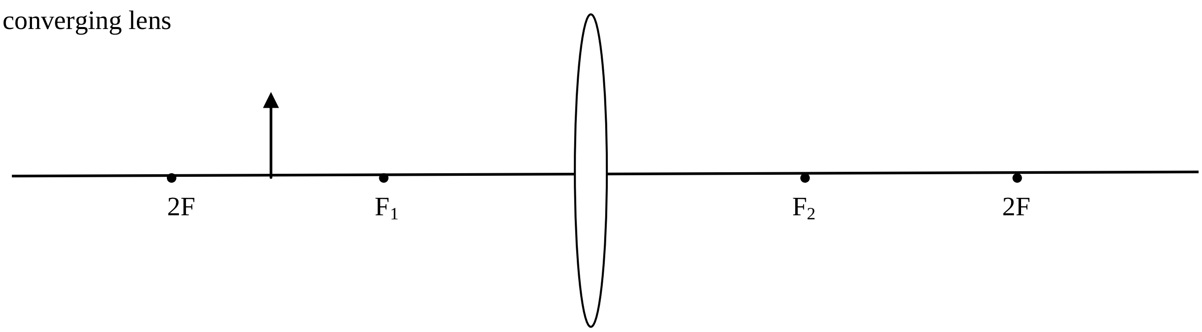
Nature: real virtual Orientation: upright inverted Size: larger same smaller

2) converging lens



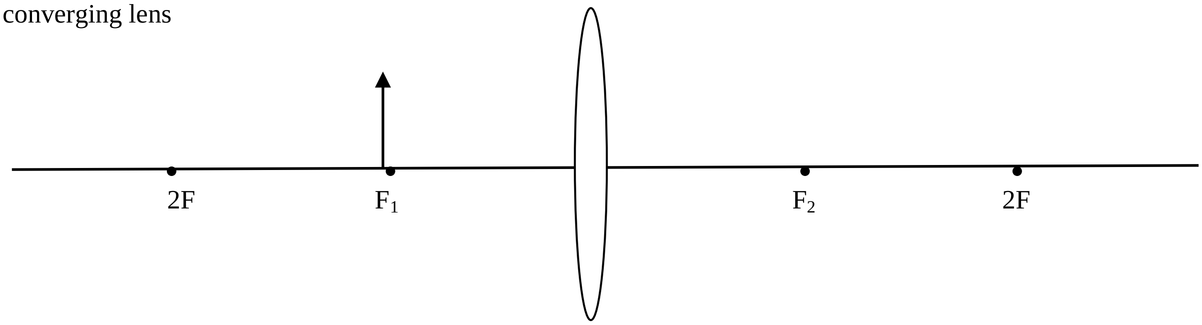
Nature: real virtual Orientation: upright inverted Size: larger same smaller

3) converging lens



Nature: real virtual Orientation: upright inverted Size: larger same smaller

4) converging lens

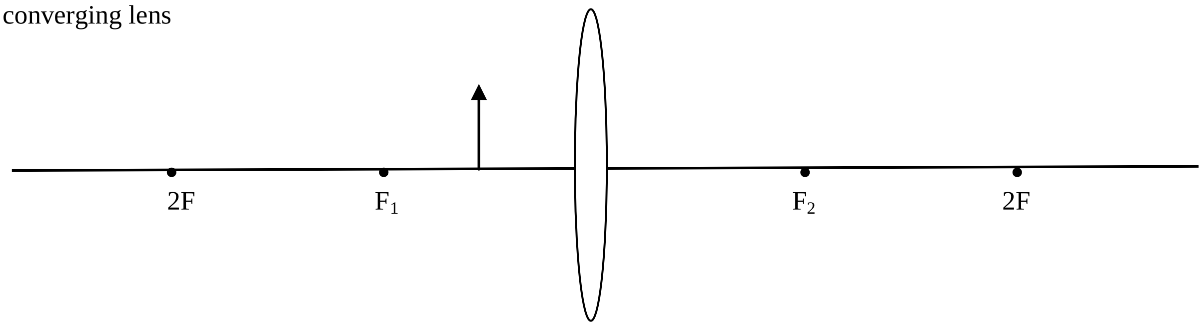


Nature: real virtual

Orientation: upright inverted

Size: larger same smaller

5) converging lens

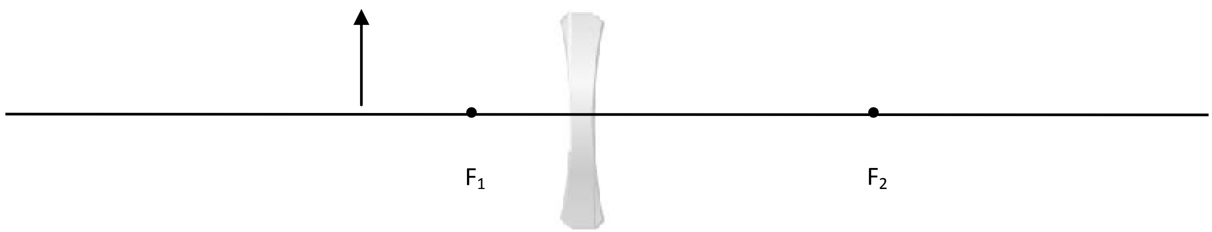


Nature: real virtual

Orientation: upright inverted

Size: larger same smaller

6)diverging lens

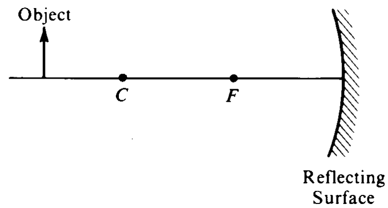


Nature: real virtual

Orientation: upright inverted

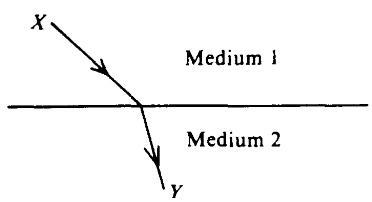
Size: larger same smaller

No process is required for these multiple choice questions. Put answers on lines provided.



1. An object is placed as shown in the figure above. The center of curvature C and the focal point F of the reflecting surface are marked. As compared with the object, the image formed by the reflecting surface is
   (A) upright and larger (B) upright and the same size (C) upright and smaller
   (D) inverted and larger (E) inverted and smaller. 1)_______

2. A postage stamp is placed 30 centimeters to the left of a converging lens of focal length 60 centimeters. Where is the image of the stamp located?
   (A) 60 cm to the left of the lens (B) 20 cm to the left of the lens
   (C) 20 cm to the right of the lens (D) 30 cm to the right of the lens 2)_______
   (E) 60 cm to the right of the lens



3. Light leaves a source at X and travels to Y along the path shown above. Which of the following statements is correct?
   (A) The index of refraction is the same for the two media.
   (B) Light travels faster in medium 2 than in medium 1.
   (C) Snell's law breaks down at the interface.
   (D) Light would arrive at Y in less time by taking a straight line path from X to Y than it does taking the path shown above.
   (E) Light leaving a source at Y and traveling to X would follow the same path shown above, but in reverse.

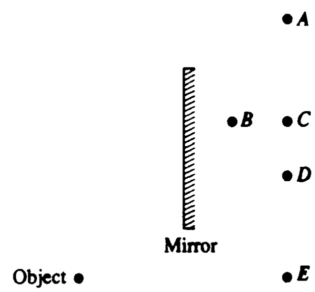
3)_______

Radio waves   Infrared radiation   Visible light   Ultraviolet radiation   Gamma radiation

4. For the five types of electromagnetic radiation listed above, which of the following correctly describes the way in which wavelength and frequency change as one goes from left to right?

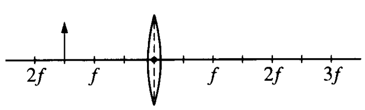
<u>Wavelength</u>	<u>Frequency</u>
(A) Decreases	Decreases
(B) Decreases	Increases
(C) Increases	Decreases
(D) Increases	Decreases
(E) Increases	Increases

4)_______



5. An object is placed near a plane mirror, as shown above. Which of the labeled points is the position of the image?
(A) A   (B) B   (C) C   (D) D   (E) E   5)________

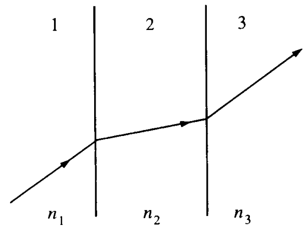
6. If the object distance for a converging thin lens is more than twice the focal length of the lens, the image is
(A) virtual and upright   (B) larger than the object   (C) located inside the focal point
(D) located at a distance between f and 2f from the lens
(E) located at a distance more than 2f from the lens   6)_______



7. An object is placed at a distance of 1.5f from a converging lens of focal length f, as shown above. What type of image is formed and what is its size relative to the object?

<u>Type</u>	<u>Size</u>
a. Virtual	Larger
b. Virtual	Same size
c. Virtual	Smaller
d. Real	Larger
e. Real	Smaller

7)_______



8. A light ray passes through substances 1, 2, and 3, as shown above. The indices of refraction for these three substances are n_1, n_2, and n_3, respectively. Ray segments in 1 and in 3 are parallel. From the directions of the ray, one can conclude that
   a. n_3 must be the same as n_1 b. n_2 must be less than n_1 8)________
   c. n_2 must be less than n_3 d. n_1 must be equal to 1.00
   e. all three indices must be the same

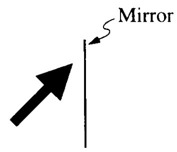
9. When one uses a magnifying glass to read fine print, one uses a
   (A) converging lens to produce a virtual image of the print 9)_______
   (B) converging lens to produce a real image of the print
   (C) mirror to produce a virtual image of the print
   (D) diverging lens to produce a real image of the print
   (E) diverging lens to produce a virtual image of the print

10. Which of the following CANNOT be accomplished by a single converging lens with spherical surfaces?

   (A) Converting a spherical wave front into a plane wave front
   (B) Converting a plane wave front into a spherical wave front 10)_______
   (C) Forming a virtual image of a real object
   (D) Forming a real upright image of a real upright object
   (E) Forming a real inverted image of a real upright object

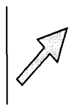
11. A concave mirror with a radius of curvature of 1.0 m is used to collect light from a distant star. The distance between the mirror and the image of the star is most nearly
   (A) 0.25 m (B) 0.50 m (C) 0.75 m (D) 1.0 m (E) 2.0 m

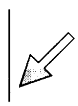
11)______

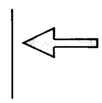


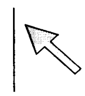
12. An object, slanted at an angle of 45°, is placed in front of a vertical plane mirror, as shown above. Which of the following shows the apparent position and orientation of the object's image.

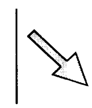
12)______

(A) 

(B) 

(C) 

(D) 

(E) 

28. Which of the following experimental observations provides the best support for the statement, "Light behaves like a wave" ?

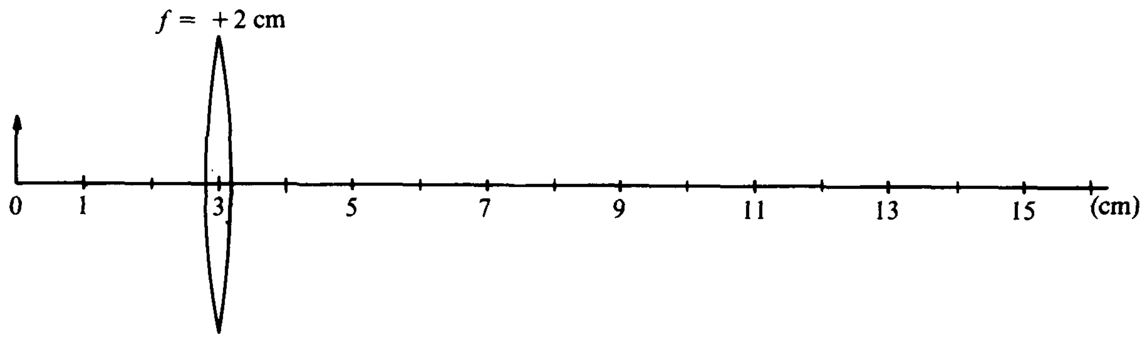
(A) Light can be reflected by a mirror.
(B) Light is scattered when passing through smoke.
(C) Monochromatic light forms bright and dark bands after passing through two narrow slits.
(D) White light can be broken into component colors by a prism.
(E) Light is bent by a gravitational field.

29. When a light wave passes from air into glass, quantities that remain constant include which of the following?

I. Frequency
II. Wavelength
III. Speed

(A) I only
(B) II only
(C) I and III only
(D) II and III only
(E) I, II, and III

28)______ 29)_______

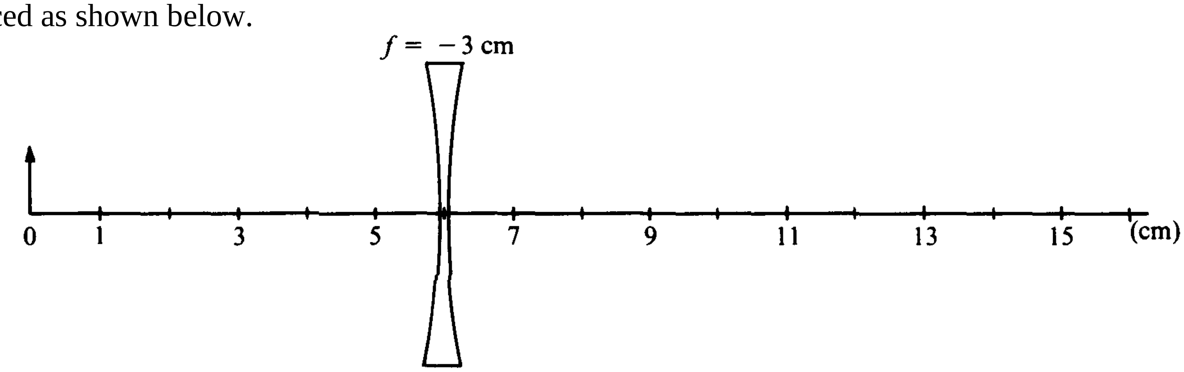


1) An object is placed 3 centimeters to the left of a convex (converging) lens of focal length f = 2 cm, as shown below.

a. Sketch a ray diagram on the figure above to construct the image. It may be helpful to use a straightedge such as the edge of the green insert in your construction.
b. Determine the ratio of image size to object size.

b)_____________

The converging lens is removed and a concave (diverging) lens of focal length f = -3 centimeters is placed as shown below.



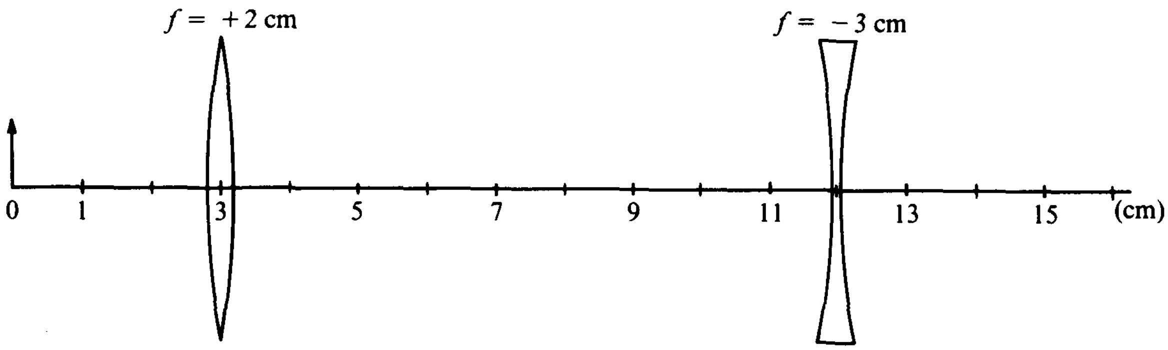
c. Sketch a ray diagram on the figure above to construct the image.
d. Calculate the distance of this image from the lens.

d)_____________

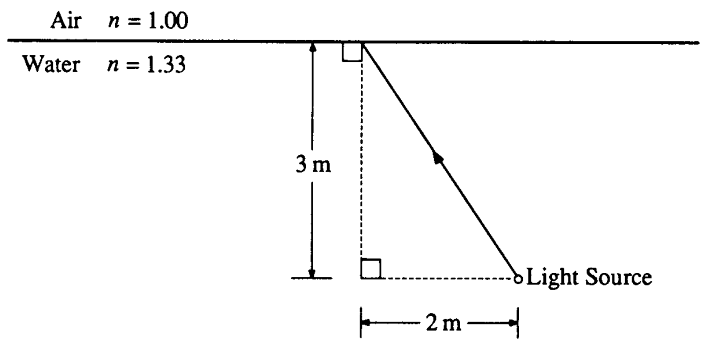
e. State whether the image is real or virtual.

e)________________

The two lenses and the object are then placed as shown below.



f. Construct a complete ray diagram to show the final position of the image produced by the two-lens system.



2) A beam of light from a light source on the bottom of a swimming pool 3.0 meters deep strikes the surface of the water 2.0 meters to the left of the light source, as shown above. The index of refraction of the water in the pool is 1.33.

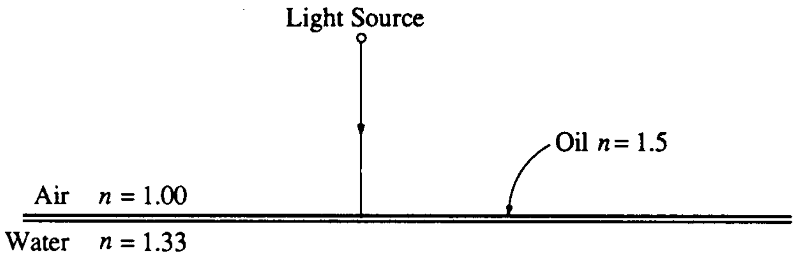
a. What angle does the reflected ray make with the normal to the surface?

a)____________

b. What angle does the emerging ray make with the normal to the surface?

b)____________

c. What is the minimum depth of water for which the light that strikes the surface of the water 2.0 meters to the left of the light source will be refracted into the air?



In one section of the pool, there is a thin film of oil on the surface of the water. The thickness of the film is 1.0 X 10^{-7} meter and the index of refraction of the oil is 1.5. The light source is now held in the air and illuminates the film at normal incidence, as shown above.

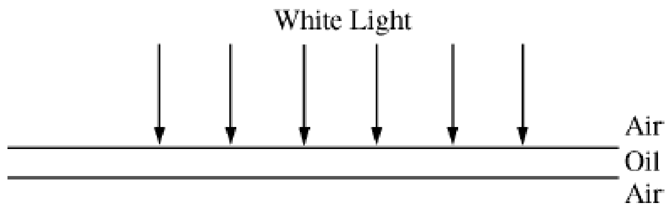
d. At which of the interfaces (air-oil and oil-water), if either, does the light undergo a 180° phase change upon reflection?

d)_____________

e. For what wavelengths in the visible spectrum will the intensity be a maximum in the reflected beam?

e)____________

3)



(10 points)

A wide beam of white light is incident normal to the surface of a uniform oil film. An observer looking down at the film sees green light that has maximum intensity at a wavelength of 5.2×10^{-7} m. The index of refraction of the oil is 1.7.

(a) Calculate the speed at which the light travels within the film.

a)_____________

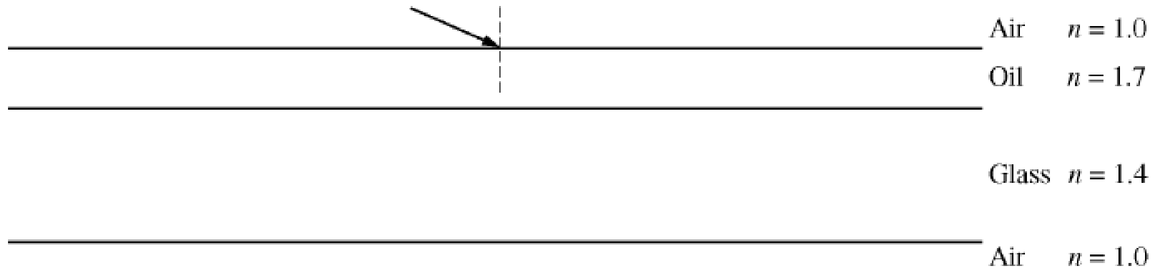
b) calculate the wavelength of the green light within the film

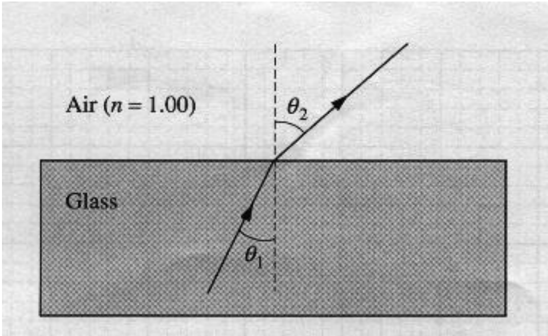
b)_____________

c) calculate the minimum possible thickness of the film

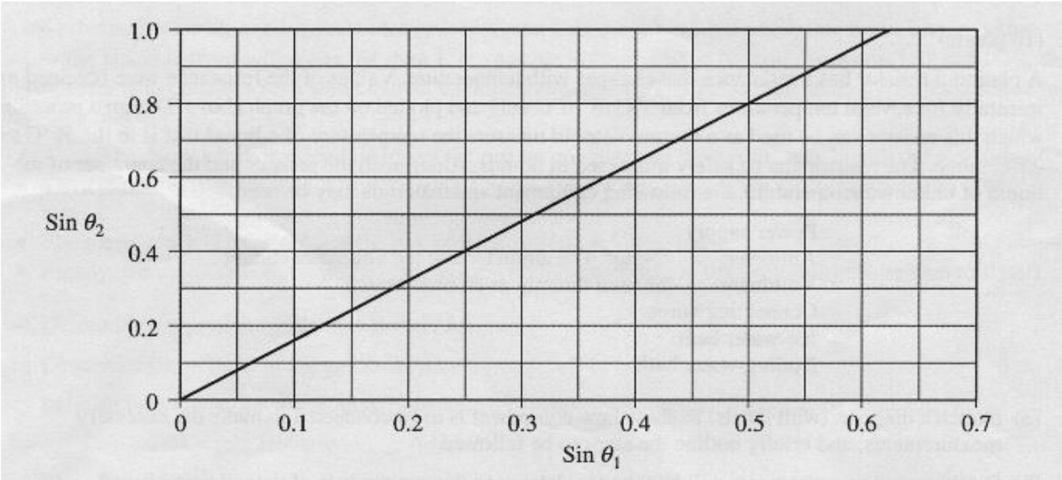
c)________________

(d) The oil film now rests on a thick slab of glass with index of refraction 1.4, as shown in the figure below. A light ray is incident on the film at the angle shown. On the figure, sketch the path of the refracted light ray that passes through the film and the glass slab and exits into the air. Clearly show any bending of the ray at each interface. You are NOT expected to calculate the sizes of any angles.





4) In an experiment a beam of red light of wavelength 675 nm in air passes from glass into air, as shown above. The incident and refracted angles are θ_1 and θ_2 respectively. In the experiment, angle θ_2 is measured for various angles of incidence θ_1 and the sines of the angles are used to obtain the line shown in the following graph.



(a) Assuming an index of refraction of 1.00 for air, use the graph to determine a value for the index of refraction of the glass for the red light. Explain how you obtained this value.

a)______________

(b) For this red light, determine the following.

i. The frequency in air i)__________

ii. The speed in glass ii)__________

iii. The wavelength in glass iii)__________

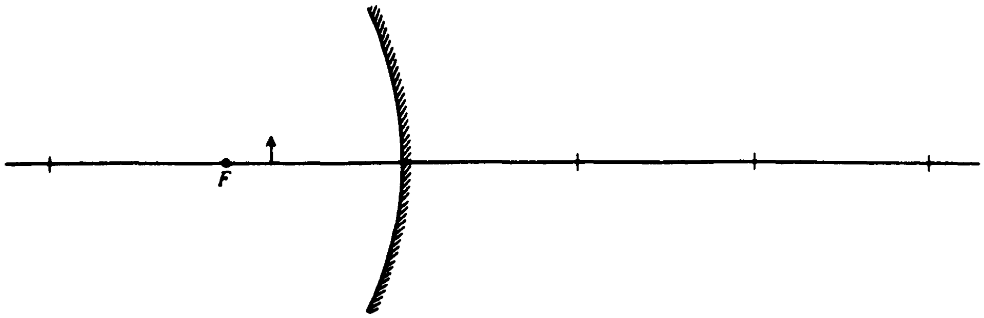
(c) The index of refraction of this glass is 1.66 for violet light, which has wavelength 425 nm in air.

i. Given the same incident angle θ_1, show on the ray diagram on the previous page how the refracted ray for the violet light would vary from the refracted ray already drawn for the red light.

ii. Sketch the graph of $\sin \theta_2$ *versus* $\sin \theta_1$ for the violet light on the figure on the previous page that shows the same graph already drawn for the red light.

(d) Determine the critical angle of incidence θ_c for the violet light in the glass in order for total internal reflection to occur.

d)____________



5) The concave mirror shown above has a focal length of 20 centimeters. An object 3 centimeter high is placed 15 centimeters in front of the mirror.

a. Using at least two principal rays, locate the image on the diagram above.

b. Is the image real or virtual? Justify your answer.

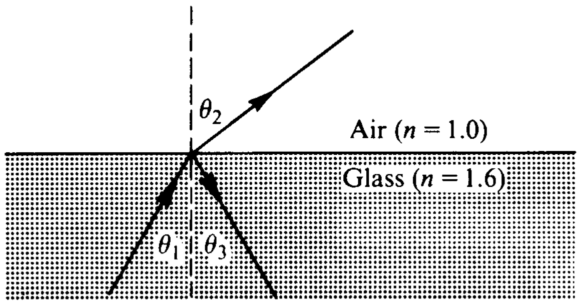
b)__________________

c) Calculate the distance of the image from the mirror.

c)__________________

d. Calculate the height of the image.

d)__________________



6) Light of frequency 6.0×10^{14} hertz strikes a glass/air boundary at an angle of incidence θ_1. The ray is partially reflected and partially refracted at the boundary, as shown above. The index of refraction of this glass is 1.6 for light of this frequency.

a. Determine the value of θ_3 if $\theta_1 = 30°$.

a)_____________

b. Determine the value of θ_2 if $\theta_1 = 30°$.

b)____________

c. Determine the speed of this light in the glass.

c)____________

d. Determine the wavelength of this light in the glass.

d)_____________

e. What is the largest value of θ_1 that will result in a refracted ray?

e)_____________

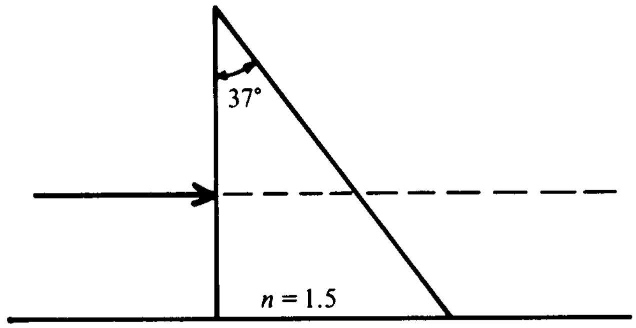


Figure I

7) The triangular prism shown in Figure I above has index of refraction 1.5 and angles of 37°, 53°, and 90°. The shortest side of the prism is set on a horizontal table. A beam of light, initially horizontal, is incident on the prism from the left.

a. On Figure I above, sketch the path of the beam as it passes through and emerges from the prism.

b. Determine the angle with respect to the horizontal (angle of deviation) of the beam as it emerges from the prism.

b)________________

c. The prism is replaced by a new prism of the same shape, which is set in the same position. The beam experiences total internal reflection at the right surface of this prism. What is the minimum possible index of refraction of this prism?

c)________________

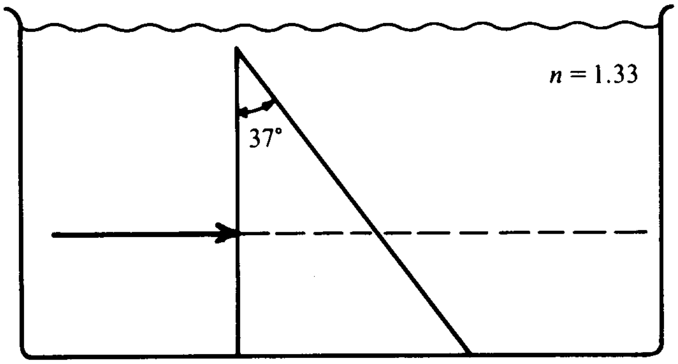


Figure II

The new prism having the index of refraction found in part (c) is then completely submerged in water (index of refraction = 1.33) as shown in Figure II above. A horizontal beam of light is again incident from the left.

d. On Figure II, sketch the path of the beam as it passes through and emerges from the prism.

e. Determine the angle with respect to the horizontal (angle of deviation) of the beam as it emerges from the prism.

e)_______________

Converging Lens Lab Experiment – Preliminary Exercises

Your goal is to accurately determine the focal length of a converging lens. You will need to be able to accomplish this three different ways:
1) by an experimental technique, measure the focal length of the lens using equipment provided in the lab. You should make only one measurement to do this.
2) by an algebraic method, measure four object and image distances and perform calculations to determine <u>one</u> value for the focal length of the lens.
3) by a graphical method use the same four object and image distance measurements to mathematically determine one value for the focal length.

a) In addition to the lens, which of the following equipment would you use to obtain the data?

______ electric light ________light holder ________ desk lamp ______plane mirror

______ thickness measuring device (calipers) ________ meterstick(s) ________ ruler ______lens holder

______ stopwatch ________ screen on a holder ________ diffraction grating

b) On the tabletop below, sketch the setup used to obtain the data, labeling the lens, the distances s_o and s_i, and the equipment checked in part a.

c) In detail, outline your procedure for accomplishing BOTH objectives 1 and 2 above – they are separate procedures. Be specific about the calculations you will perform with your data. Write legibly. Be clear and concise because you will be using this procedure in the lab to perform these measurements.

Objective 1

Objective 2

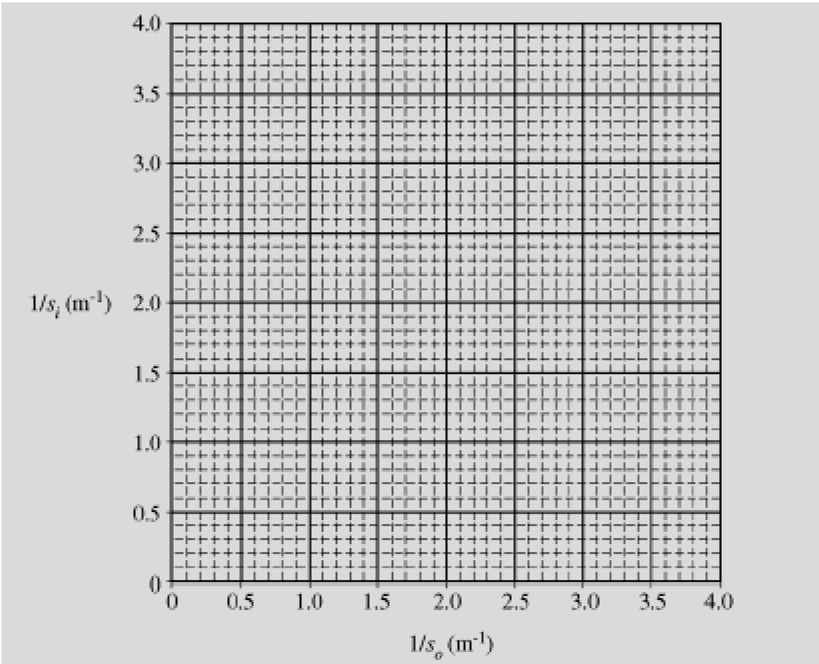
d) You will use the following set of data as practice for implementing the procedure you have developed.

Trial #	s_o (m)	s_i (m)	$1/s_o$ (m^{-1})	$1/s_i$ (m^{-1})
1	0.40	1.10	2.5	0.91
2	0.50	0.75	2.0	1.3
3	0.60	0.60	1.7	1.7
4	0.80	0.50	1.2	2.0
5	1.20	0.38	0.83	2.6

Perform the calculations you have outlined in part c above using the s_o and s_i data. Show your process below. You only need to do calculations for one trial for this workshop.

focal length algebraic method__________

e) For objective 3 you will need to create a linear graph using the data that you collected. For practice you will use the data in the table above. You will collect data in lab tomorrow and perform this experimentally at that time.
Create a linear graph of $1/s_i$ versus $1/s_o$ on the grid below and draw a best-fit line through the points.



f) Explain in detail how you will use your best-fit line to determine the focal length.

Perform the calculation that you have outlined above. Put the answer on the line provided

focal length graphical method____________