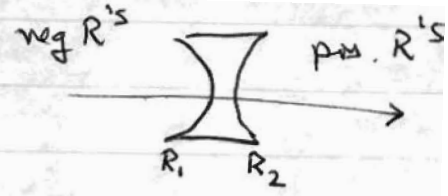
4/19/07

Lensmaker's Formula

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

glass



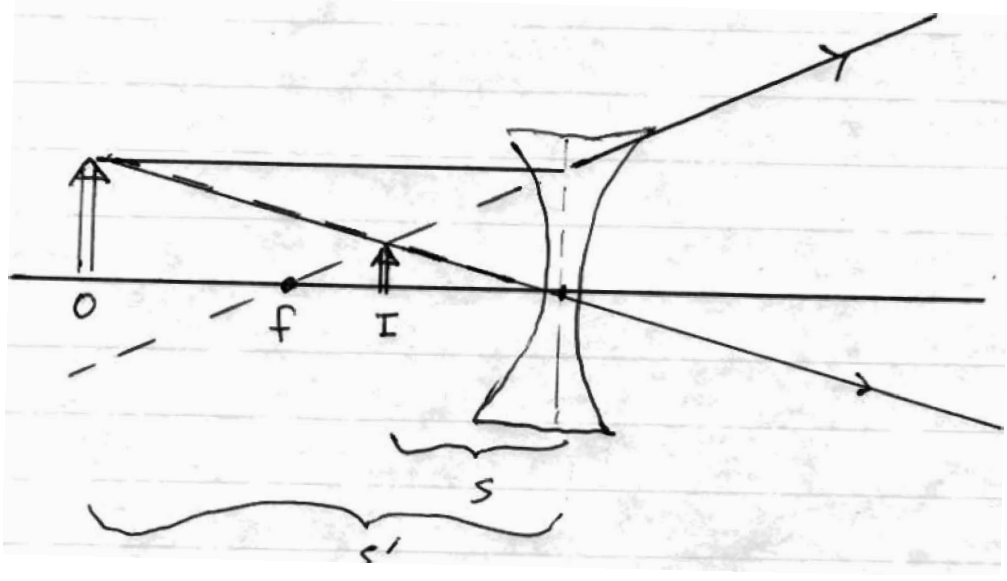
$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \quad ; \quad m = -\frac{s'}{s} = \frac{y'}{y}$$

Diverging Lens (Skinny in center, fat at edges)

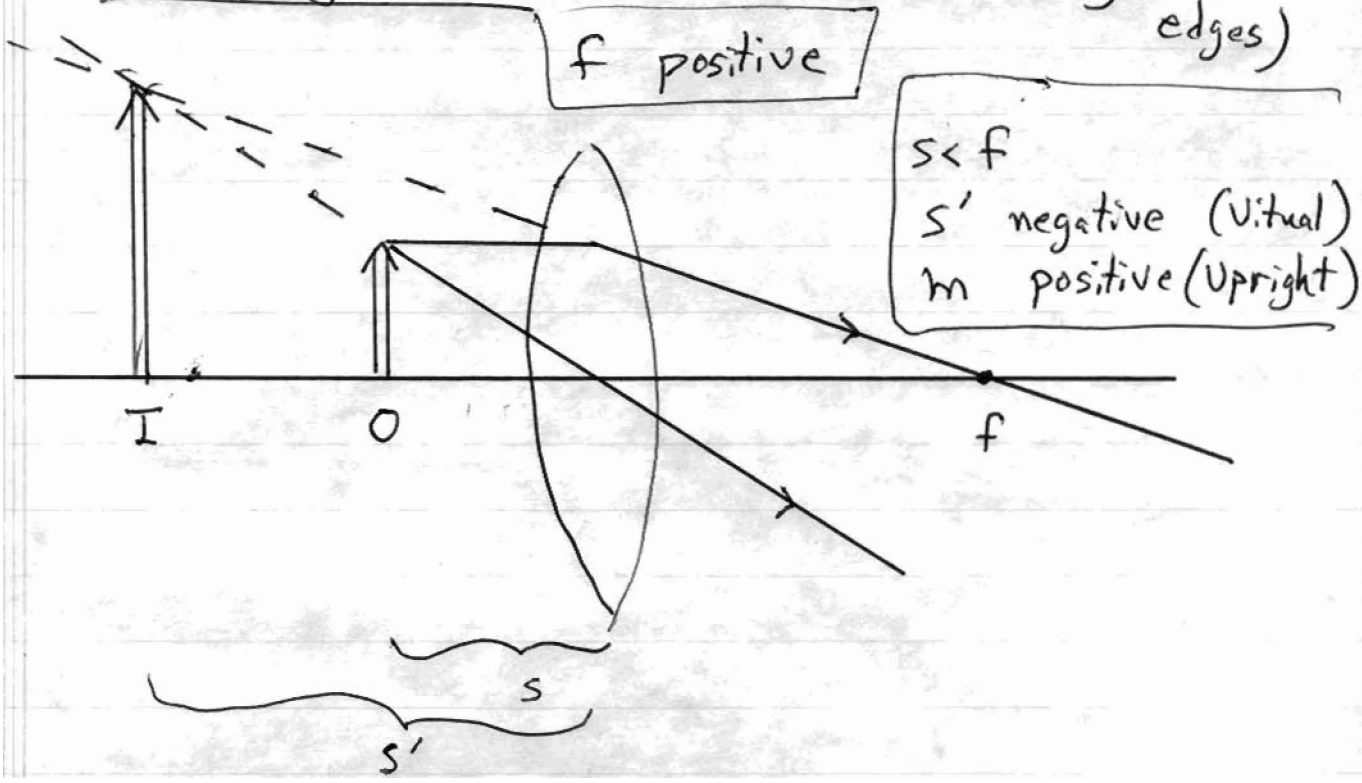
f negative

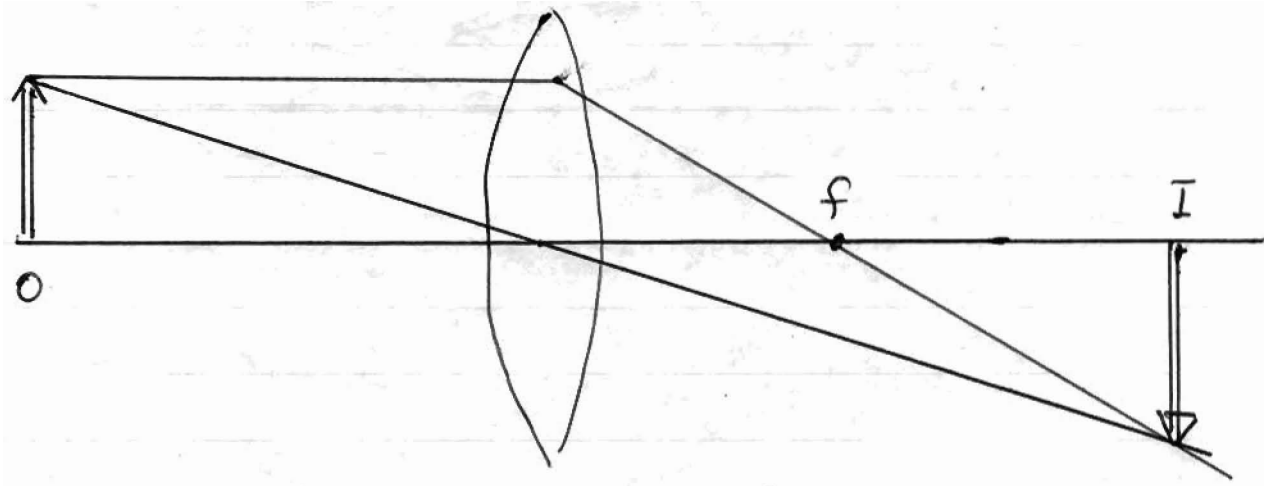
s′ negative (Vitual image)

m positive (Upright)



Converging Lens (fat in center, skinny around edges)





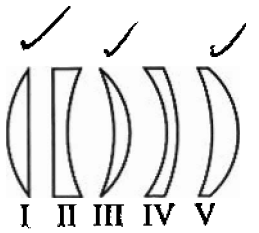
s > f

s' positive (real)

m negative (Inverted)

i.e. slide projector

Physics 24 Test-Level Problems for Recitation 27



D 1. Which of the glass lenses, when placed in air, will cause parallel rays of light to converge?

[A]I, II, and III [B] I, IV, and V
[C] II, III, and V [D[I, III, and V

2. You have a thin **diverging l** s whose focal points are 30.0 cm from the lens.

(a) You use the lens to form a virtual image of a light bulb. The distance between this image and the bulb is 60.0 cm. Calculate the distance from the light bulb to the lens.

$f = -30.0$ s' negative

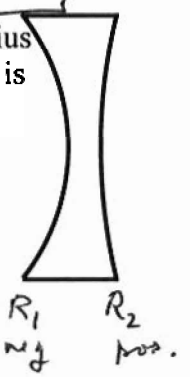
$$\frac{1}{s} + \frac{1}{-(s-60)} = \frac{1}{-30}$$

$$\frac{1}{s} - \frac{1}{s-60} = -\frac{1}{30} \qquad \frac{\cancel{s}-60-\cancel{s}}{s(s-60)} = -\frac{1}{30}$$

$$60(30) = s^2 - 60s \Rightarrow s^2 - 60s - 1800 = 0$$

$$s = \frac{60 \pm \sqrt{60^2 - 4(1800)}}{2} = \frac{60 \pm 103.9}{2} = \boxed{81.96\text{ cm}}$$

(b) Your lens in part a has a double-concave shape, as shown. One of the surfaces has a radius of curvature with an absolute value of 20.0 cm. If the lens has a refractive index of 1.5 and is surrounded by air, calculate the radius of curvature of the other surface.



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

$$-\frac{1}{30\text{ cm}} = 0.5\left(\frac{1}{-20} - \frac{1}{R_2}\right)$$

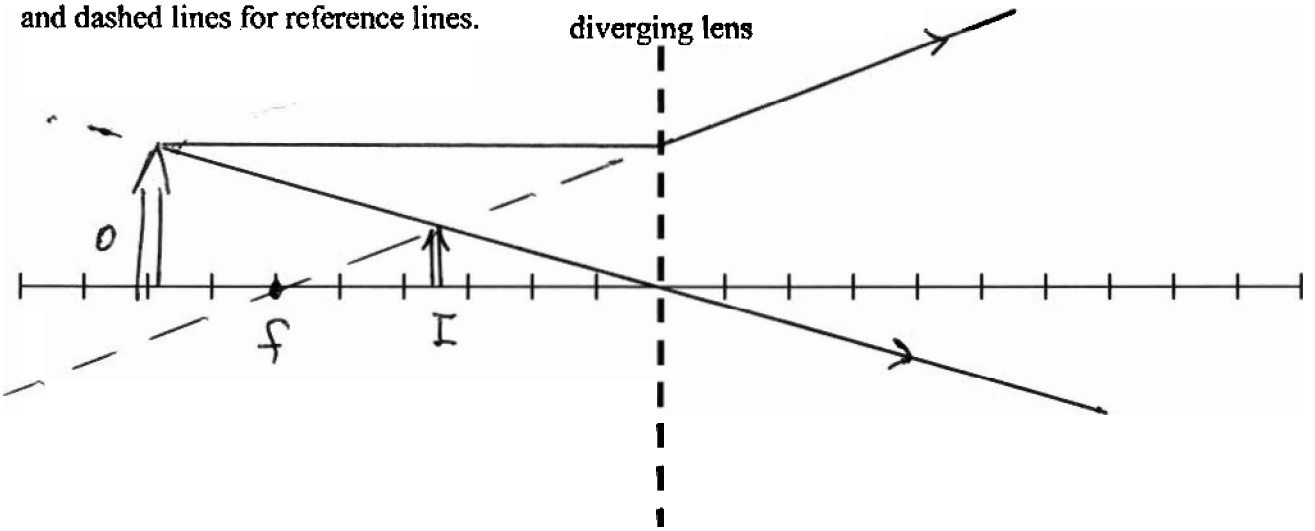
$$-\frac{1}{30} = -\frac{1}{40} - \frac{1}{2R_2}$$

$$\frac{1}{2R_2} = -\frac{1}{40} + \frac{1}{30}$$

$$2R_2 = 120.0$$

$$\boxed{R_2 = 60.0\text{ cm}}$$

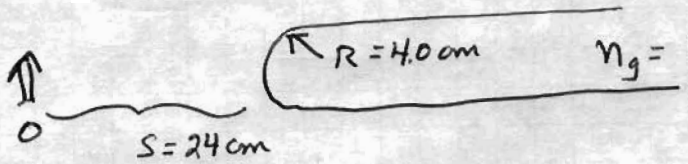
(c) Assume that the light bulb has been moved to 40.0 cm away from the lens. Draw a ray diagram for this new situation. (The spacing between the tick marks is 5.0 cm.) Use solid lines for actual light rays and dashed lines for reference lines.



34.20 The left end of a long glass rod 8.00 cm in diameter, with an index of refraction 1.60, is ground and polished to a convex hemispherical surface with a radius of 4.00 cm. An object in the form of an arrow 1.50 mm tall, at right angles to the axis of the rod, is located on the axis 24.0 cm to the left of the vertex of the convex surface. Find the position and height of the image of the arrow formed by paraxial rays incident on the convex surface. Is the image erect or inverted?

Refraction

$$\frac{n_a}{s} + \frac{n_b}{s'} = \frac{n_b - n_a}{R}$$



$$\frac{1.00}{24.0\text{ cm}} + \frac{1.60}{s'} = \frac{1.60 - 1.00}{4.0\text{ cm}} \Rightarrow \boxed{s' = 14.77\text{ cm}}$$

$$m = -\frac{n_a s'}{n_b s} = -\frac{(1.00)(14.77\text{ cm})}{(1.60)(24.0\text{ cm})} = -0.3846$$

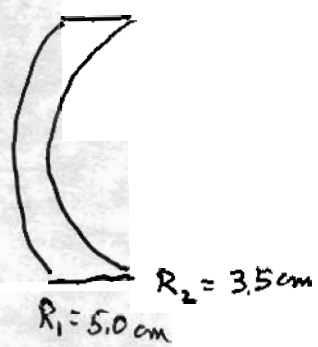
$$m = \frac{y'}{y} \Rightarrow -0.3846 = \frac{y'}{1.50\text{ mm}} \Rightarrow \boxed{y' = -0.577\text{ mm}}$$

34.27 A diverging meniscus lens (see Fig. 34.29b) with a refractive index of 1.48 has spherical surfaces whose radii are 5.00 cm and 3.50 cm. What is the position of the image if an object is placed 18.0 cm to the left of the lens?

$$\frac{1}{f} = (n - 1.00)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

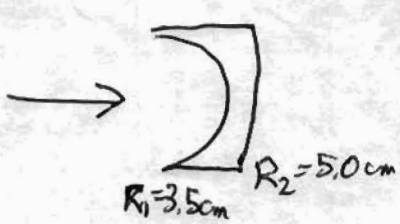
$$\frac{1}{f} = 0.48\left(\frac{1}{5.0\text{ cm}} - \frac{1}{3.5\text{ m}}\right)$$

$$\boxed{f = -24.3\text{ cm}}$$



$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \qquad \frac{1}{\ } + \frac{1}{s'} = \frac{1}{-24.3\text{ cm}} \Rightarrow \boxed{s' = -10.34\text{ cm}}$$

Flip lens



$$\frac{1}{f} = 0.48\left(\frac{1}{-3.5\text{ cm}} - \frac{1}{-5.0\text{ cm}}\right) = -24.3\text{ cm}$$

same as above !!

34.32 A converging lens with a focal length of 12.0 cm forms a virtual image 8.00 mm tall, 17.0 cm to the right of the lens. Determine the position and size of the object. Is the image erect or inverted? Are the object and image on the same side or opposite sides of the lens? Draw a principal-ray d this situation

$f = +12.0\text{ cm}$

$s' = -17.0\text{ cm}$

$$\frac{1}{s} + \frac{1}{-17.0\text{ cm}} = \frac{1}{12.0\text{ cm}}$$

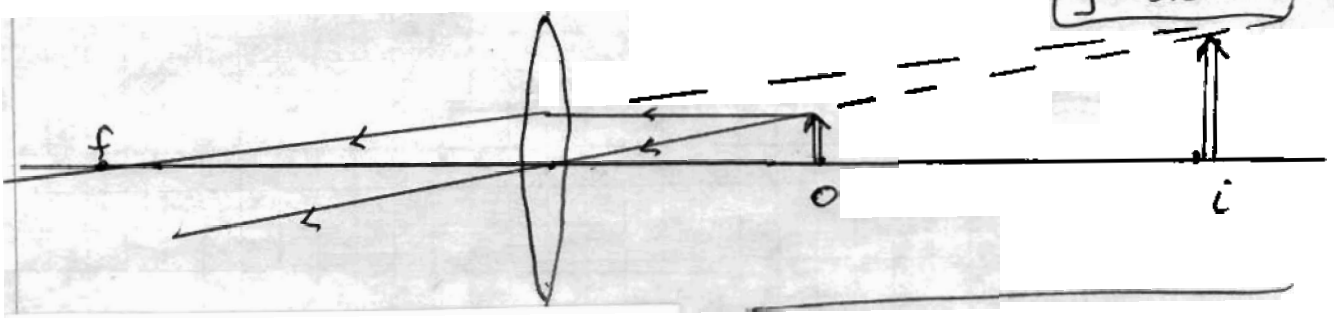
$$\boxed{s = 7.03\text{ cm}}$$

$$m = -\frac{s'}{s} = \frac{y'}{y} \qquad m = -\frac{-17.0\text{ cm}}{7.03\text{ cm}} = +2.42$$

upright

$$2.42 = \frac{8.00\text{ mm}}{y}$$

$$\boxed{y = 3.31\text{ mm}}$$



34.87 An object to the left of a lens is imaged by the lens on a screen 30.0 cm to the right of the lens. When the lens is moved 4.00 cm to the right, the screen must be moved 4.00 cm to the left to refocus the image. Determine the focal length of the lens.

$$\frac{1}{s} + \frac{1}{30} = \frac{1}{f}$$

$$\frac{1}{s+4} + \frac{1}{22} = \frac{1}{f}$$

$$\frac{30+s}{30s} = \frac{22+s+4}{22(s+4)}$$

$$22(s+4)(s+30) = 30s(26+s)$$

$$-8s^2 - 32s + 2{,}640 = 0 \qquad \div 8$$

$$s^2 + 4s - 330 = 0$$

$$s = \frac{-4 \pm \sqrt{16 + 4(330)}}{2} = -2 \pm 18.27 = 16.27\text{ cm}$$

$$\frac{1}{16.27\text{ cm}} + \frac{1}{30.0\text{ cm}} = \frac{1}{f} \Rightarrow \boxed{f = 10.55\text{ cm}}$$

Physics 24 **Special Homework Assignment #9**

A lens forms an image of an object. The object is 20.0 cm from the lens. The image is formed 15.0 cm from the lens on the ***same side*** as the object.

(a) What is the focal length of the lens? Based on the results of your calculation, is it a converging or diverging lens?

$s = 20.0\,cm$
$s' = -15.0\,cm$

$$\frac{1}{20} + \frac{1}{-15} = \frac{1}{f}$$

$f = -60\,cm$
$\therefore$ Diverging lens

(b) If the object is 8.0 mm tall, how tall is the image? Based on the results of your calculation, is it upright or inverted?

$$m = -\frac{s'}{s} = \frac{y'}{y} \qquad -\frac{-15.0}{20.0} = \frac{y'}{8.0\,mm} \qquad \therefore$$

$y' = +6.00\,mm$
upright

(c) Verify your calculations by making a complete a ray diagram showing the formation of the image using the figure provided. Adjacent marks on the principal axis are separated by 10.0 cm.