This print-out should have 19 questions. Multiple-choice questions may continue on the next column or page – find all choices before answering.

Vertical Flat Mirror
001 10.0 points

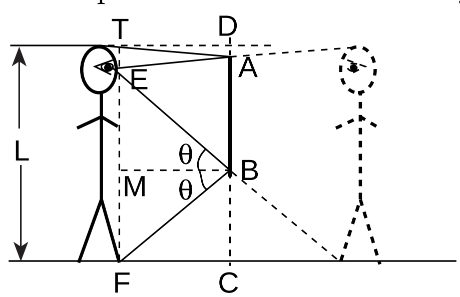
Hint: A ray diagram would be helpful.

Determine the minimum height of a vertical flat mirror in which a person 77 in. in height can see his or her full image.

Correct answer: 38.5 in..

Explanation:

In the figure, the mirror is labeled AB. A ray from the woman's foot F strikes the bottom of the mirror at B, with an angle equal to θ and proceeds to the woman's eye.



The two right triangles EBM and FBM are identical, since they share the common side MB and angle θ. Therefore

$$EM = MF = \frac{1}{2}EF$$

which is also the distance BC. Similarly, a ray from the top of the woman's head T strikes the top of the mirror at A and proceeds to her eye. The same line of reasoning as above leads to the conclusion that

$$DA = \frac{1}{2}TE$$

Thus the length AB of the mirror is $\frac{1}{2}(TE + EF)$, which is one half the woman's height. Note that the mirror's bottom edge must be exactly $\frac{1}{2}EF$ from the floor for a full-height image to be possible. Note also that the conclusions reached here are valid regardless of how far she stands from the mirror.

Christmas Tree Ornament 02
002 (part 1 of 2) 10.0 points

An object is 14 cm from the surface of a reflective spherical Christmas-tree ornament 5.78 cm in diameter.

What is the position of the image?

Correct answer: −1.30981 cm.

Explanation:

$\frac{1}{p}+\frac{1}{q}=\frac{1}{f}=\frac{2}{R}$	$m=\frac{h'}{h}=-\frac{q}{p}$	
Convex Mirror	$0 > f$	
$\infty > p > 0$	$f < q < 0$	$0 < m < 1$

$$\text{Let: } D = 5.78 \text{ cm} \quad \text{and}$$
$$p = 14 \text{ cm}.$$

p is positive since it is in front of the mirror and R is negative since it is behind the mirror. A spherical Christmas-tree ornament is a convex mirror, so

$$\frac{1}{p}+\frac{1}{q}=-\frac{2}{|R|}.$$

We are given the object distance, p, and can find the radius of curvature from the diameter, $|R| = \frac{|D|}{2}$. Inserting these values into the mirror equation and solving for q, we find

$$q = -\frac{1}{\frac{4}{D}+\frac{1}{p}}$$
$$= -\frac{1}{\frac{4}{(5.78 \text{ cm})}+\frac{1}{(14 \text{ cm})}}$$
$$= \boxed{-1.30981 \text{ cm}}.$$

003 (part 2 of 2) 10.0 points

What is the magnification of the image?

Correct answer: 0.0935578.

Explanation:

The magnification is given by

$$M = -\frac{q}{p} = -\frac{-1.30981 \text{ cm}}{14 \text{ cm}} = \boxed{0.0935578}.$$

Object Moving Closer 02

004 (part 1 of 4) 10.0 points

The goal of this problem is to describe the image of an object as it moves from far away towards a convex mirror of radius R.

For a convex mirror, the focal length is

1. $f = R$ and is positive.

2. $f = 2R$ and is positive.

3. $f = R/2$ and is negative. **correct**

4. $f = R$ and is negative.

5. $f = 2R$ and is negative.

6. $f = R/2$ and is positive.

Explanation:

The focal length is $f = \dfrac{R}{2}$. For a convex mirror, $R < 0$, so f is also negative.

005 (part 2 of 4) 10.0 points

The distance s' of the image to the mirror is a function of the distance s of the object to the mirror and the focal length f of the mirror. What is this function?

1. $s' = f\left(\dfrac{f-s}{s}\right)$

2. $s' = f\left(\dfrac{s-f}{s}\right)$

3. $s' = f\left(\dfrac{s}{s+f}\right)$

4. None of these.

5. $s' = f\left(\dfrac{s+f}{s}\right)$

6. $s' = f\left(\dfrac{s}{s-f}\right)$ **correct**

7. $s' = f\left(\dfrac{s}{f-s}\right)$

Explanation:

The formula for a convex mirror is the same as for a concave mirror,

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

Rearranging, we get

$$\frac{1}{s'} = \frac{s-f}{fs}.$$

Thus,

$$s' = f\left(\frac{s}{s-f}\right)$$

006 (part 3 of 4) 10.0 points

What is the formula for m, the magnification, and how does it relate to the orientation of the image?

1. $m = s'/s$, if $m < 0$ the image is inverted

2. $m = -s'/s$, if $m < 0$ the image is inverted **correct**

3. $m = s'/s$, if $m > 0$ the image is inverted

4. $m = -s'/s$, if $m > 0$ the image is inverted

Explanation:

$m = -\dfrac{s'}{s}$, just as in the concave mirror case. If $m < 0$, the image is inverted.

007 (part 4 of 4) 10.0 points

When $s > 0$, what is s', and what is the image like?

1. $s' < 0$, image is bigger than object, and erect

2. $s' > 0$, image is smaller than object, and inverted

3. $s' > 0$, image is bigger than object, and inverted

4. $s' < 0$, image is bigger than object, and inverted

5. $s' > 0$, image is smaller than object, and erect

6. $s' < 0$, image is smaller than object, and inverted

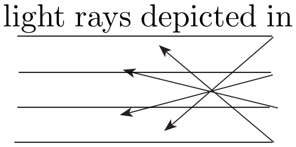
7. $s' > 0$, image is bigger than object, and erect

8. $s' < 0$, image is smaller than object, and erect
correct

Explanation:
From the graph, when $s > 0$, $s' < 0$. For all values of $s > 0$, $|s'| < s$, so the image is smaller than the object. As $m = -\dfrac{s'}{s} > 0$, the image is erect.

Ray Diagrams
008 10.0 points

Consider the light rays depicted in the figure.



What type of reflecting or refracting surface is depicted?

1. converging lens

2. Unable to determine.

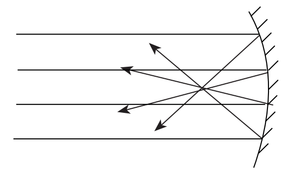
3. plane mirror

4. diverging mirror

5. converging mirror **correct**

6. diverging lens

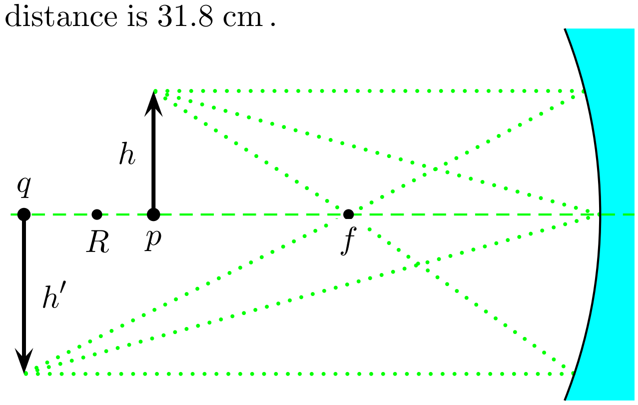
Explanation:



The parallel light rays reflect and pass through a single point, which must be the focal point of a converging (concave) mirror.

Spherical Mirror B 01
009 10.0 points

A concave spherical mirror forms a real image 1.29 times the size of the object. The object distance is 31.8 cm .



Scale: 10 cm =

Find the magnitude of the radius of curvature of the mirror.

Correct answer: 35.8271 cm.

Explanation:

$\dfrac{1}{p}+\dfrac{1}{q}=\dfrac{1}{f}=\dfrac{2}{R}$		$M=\dfrac{h'}{h}=-\dfrac{q}{p}$
Concave Mirror		$f>0$
$\infty > p > f$	$f < q < \infty$	$0 > M > -\infty$

Note: The radius of curvature for a concave mirror is positive.

$$M = -\frac{q}{p} = -1.29 \,. \qquad (1)$$

Solving for q, we have

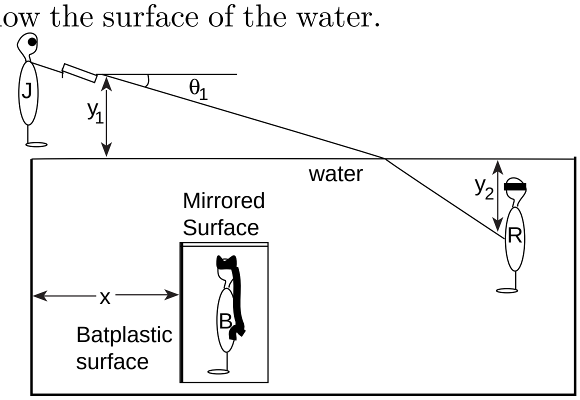
$$\begin{aligned} q &= -M\,p \qquad (2)\\ &= -(-1.29)\,(31.8\text{ cm})\\ &= 41.022\text{ cm}\,. \end{aligned}$$

Substituting these values into the mirror equation

$$\begin{aligned} R &= 2\,f\\ &= \frac{2}{\frac{1}{p}+\frac{1}{q}} \qquad (3)\\ &= \frac{2}{\frac{1}{(31.8\text{ cm})}+\frac{1}{(41.022\text{ cm})}}\\ &= \boxed{35.8271\text{ cm}}\,. \end{aligned}$$

Batman and Robin a
010 10.0 points

Batman and Robin are attempting to escape that dastardly villain, the Joker, by hiding in a large pool of water (refractive index $n_{water} = 1.333$). The Joker stands gloating at the edge of the pool. (His makeup is water-soluble.) He holds a powerful laser weapon $y_1 = 1.39$ m above the surface of the water and fires at an angle of $\theta_1 = 27.7^\circ$ to the horizontal. He hits the Boy Wonder squarely on the letter "R", which is located $y_2 = 3.28$ m below the surface of the water.



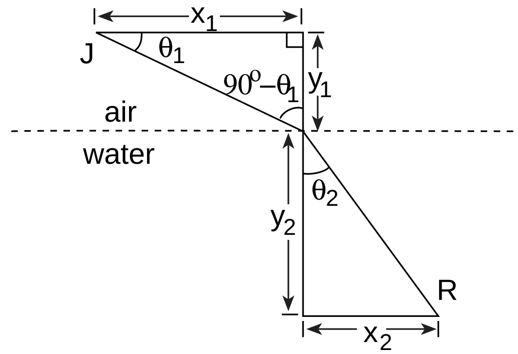
How far (horizontal distance) is Robin from the edge of the pool? (Fear not, Batfans. The "R" is made of laser-reflective material.)

Correct answer: 5.56192 m.

Explanation:

Basic Concepts: Snell's law, Total internal reflection.

Solution: Let x_1 be the horizontal distance from the laser to where the laser beam strikes the water and x_2 the horizontal distance from that point to Robin (see the following figure).



Then we have

$$\begin{aligned} x_1 &= \frac{y_1}{\tan\theta_1}\\ &= \frac{(1.39\text{ m})}{\tan(27.7^\circ)}\\ &= 2.64756\text{ m}\,. \end{aligned}$$

From Snell's law,

$$n_{air}\,\sin(90^\circ-\theta_1) = n_{water}\,\sin\theta_2.$$

So

$$\begin{aligned} \sin\theta_2 &= \frac{\sin(90^\circ-27.7^\circ)}{(1.333)}\\ &= 0.664211\\ \theta_2 &= \arcsin(0.664211)\\ &= 41.6219^\circ\,. \end{aligned}$$

Hence,

$$\begin{aligned} x_2 &= y_2\,\tan\theta_2\\ &= (3.28\text{ m})\,\tan 41.6219^\circ\\ &= 2.91436\text{ m}\,. \end{aligned}$$

Therefore, the distance of Robin from the edge of the pool is

$$\begin{aligned} x_1+x_2 &= 2.64756\text{ m}+2.91436\text{ m}\\ &= 5.56192\text{ m}\,. \end{aligned}$$

Focal Length of a Thin Lens
011 (part 1 of 2) 10.0 points

An object located 32.8 cm in front of a lens forms an image on a screen 11 cm behind the lens.

Find the focal length of the lens.

Correct answer: 8.23744 cm.

Explanation:

$$\text{Let :} \quad p = 32.8 \text{ cm} \quad \text{and} \quad q = 11 \text{ cm}\,.$$

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{q+p}{p\,q}$$
$$f = \frac{p\,q}{p+q} = \frac{(32.8 \text{ cm})\,(11 \text{ cm})}{32.8 \text{ cm} + 11 \text{ cm}} = \boxed{8.23744 \text{ cm}}\,.$$

012 (part 2 of 2) 10.0 points

What is the magnification of the object?

Correct answer: −0.335366.

Explanation:

Magnification is

$$M = -\frac{q}{p} = -\frac{11 \text{ cm}}{32.8 \text{ cm}} = \boxed{-0.335366}\,.$$

Virtual Image and Lenses
013 (part 1 of 2) 10.0 points

The light rays from an upright object when passing through a lens from left to right lead to a virtual image. The absolute value of the magnification of this image is greater than one.

Select the correct statement.

1. The lens can only be a divergent lens.

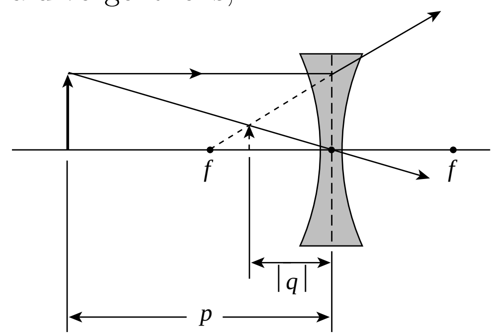
2. The lens can either be a convergent or a divergent lens.

3. The lens can only be a convergent lens. **correct**

Explanation:

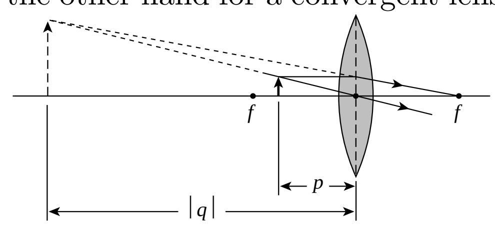
Two situations lead to virtual images.

For a divergent lens,



for any $p > 0$, the image is always located on the same side of the lens (virtual) with the image closer to the lens than the object ($|q| < p$), with the size of the image always reduced.

On the other hand for a convergent lens,



when an object is placed within the focal point ($0 < p < f$), the corresponding image is located on the same side of the lens (virtual) and outside of the focal point ($|q| > f$), leading to a larger image.

014 (part 2 of 2) 10.0 points

What is the nature of this virtual image?

1. Upright and located to the left of the lens **correct**

2. Upright and located to the right of the lens

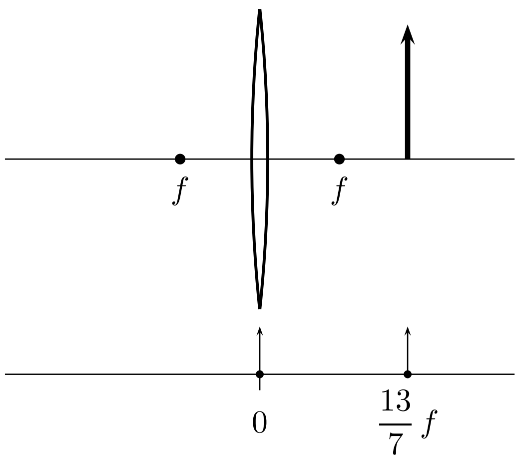
3. Inverted and located to the left of the lens

4. Inverted and located to the right of the lens

Explanation:

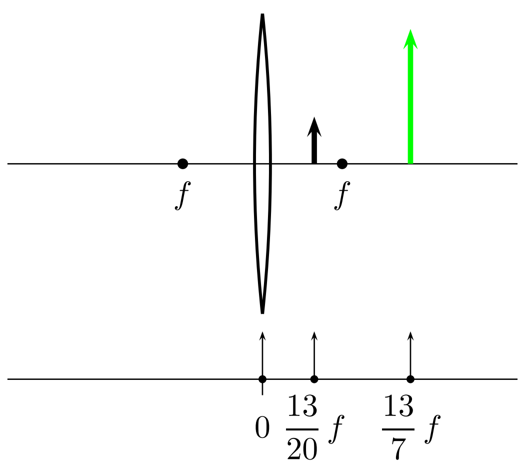
Lens Convergent Diagram
015 10.0 points

A virtual object is located to the right of a convergent lens. The object's distance and image's distance from the lens and the lens' focal length are shown in the figures.



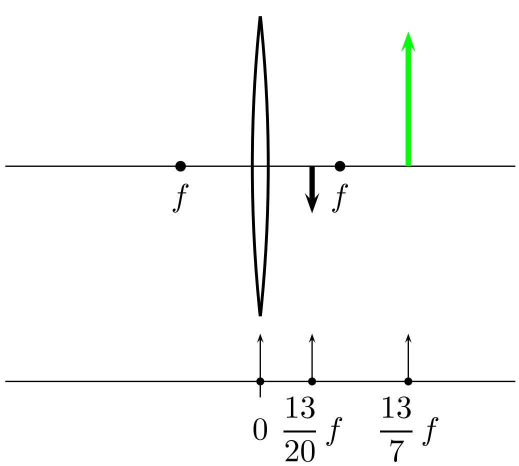
Which diagram correctly shows the image? The convergent lens in this problem is a part of a lens system so the object in this problem may be either real or virtual. Construct a ray diagram.

1.

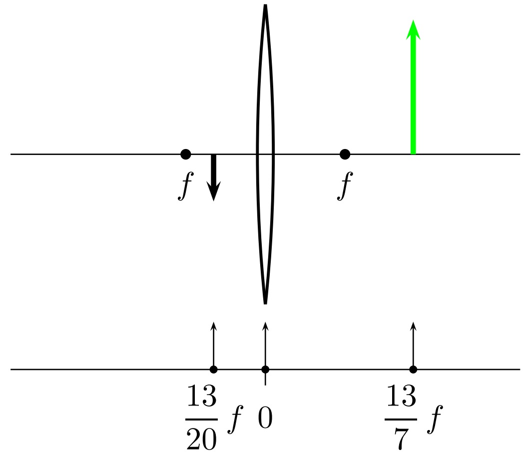


correct

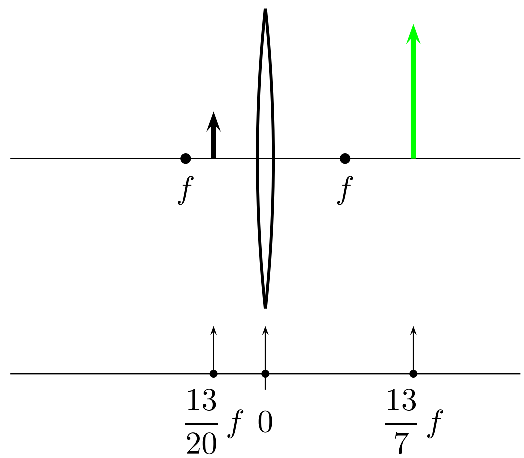
2.



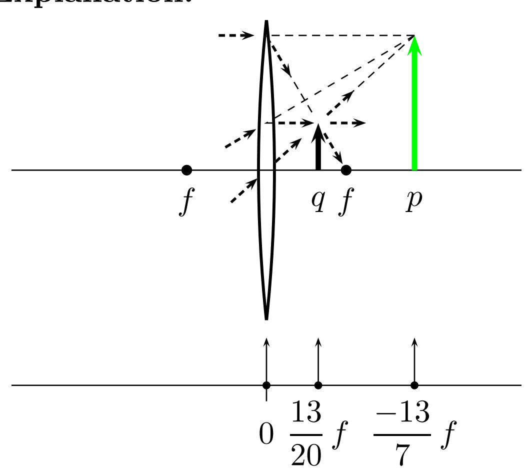
3.



4.



Explanation:



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

$$\frac{1}{q} = -\frac{1}{p} + \frac{1}{f} = -\frac{-7}{13\,f} + \frac{1}{f}$$

$$= \frac{-(-7) + 13}{13\,f} = \frac{20}{13\,f}$$

$$q = \frac{13}{20}\,f\,.$$

The magnification of this lens is

$$m = -\frac{q_1}{p_1} = -\frac{\dfrac{13}{20}\,f}{\dfrac{13}{-7}\,f} = -\frac{-7}{20} = \frac{7}{20}\,.$$

Concave Mirror Image 02

016 (part 1 of 4) 10.0 points

A certain concave spherical mirror has a focal length of 12 cm.

Find the location of the image for an object distance of 23.5 cm.

Correct answer: 24.5217 cm.

Explanation:

$\frac{1}{p}+\frac{1}{q}=\frac{1}{f}=\frac{2}{R}$		$m=\frac{h'}{h}=-\frac{q}{p}$
Concave Mirror		$f>0$
$\infty > p > f$	$f < q < \infty$	$0 > m > -\infty$
$f > p > 0$	$-\infty < q < 0$	$\infty > m > 1$

$$\text{Let}: \quad p_1 = 23.5\text{ cm} \quad \text{and} \quad f = 12\text{ cm}\,.$$

$$\frac{1}{q_1} = \frac{1}{f} - \frac{1}{p_1}$$

$$q_1 = \frac{p_1\, f}{p_1 - f} = \frac{(23.5\text{ cm})\,(12\text{ cm})}{23.5\text{ cm} - 12\text{ cm}} = \boxed{24.5217\text{ cm}}\,.$$

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017 (part 2 of 4) 10.0 points

What is the magnification for an object distance of 23.5 cm?

Correct answer: −1.04348.

Explanation:

The magnification is given by

$$M_1 = -\frac{q_1}{p_1} = -\frac{24.5217\text{ cm}}{23.5\text{ cm}} = \boxed{-1.04348}\,.$$

This value of M_1 means that the image is smaller than the object. The negative sign means that the image is inverted. Finally, because $q_1 = 24.5217$ cm is positive, the image is located on the front side of the mirror and is real.

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018 (part 3 of 4) 10.0 points

Find the location of the image for an object distance of 5.64 cm.

Correct answer: −10.6415 cm.

Explanation:

$$\text{Let}: \quad p_2 = 5.64\text{ cm}\,.$$

Equation (1) implies

$$q_2 = \frac{p_2\, f}{p_2 - f} = \frac{(5.64\text{ cm})\,(12\text{ cm})}{5.64\text{ cm} - 12\text{ cm}} = \boxed{-10.6415\text{ cm}}\,,$$

that is, in this case the image is virtual because it is located behind the mirror.

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019 (part 4 of 4) 10.0 points

Calculate the magnification for an object distance of 5.64 cm.

Correct answer: 1.88679.

Explanation:

The formula for the magnification yields

$$M_2 = -\frac{q_2}{p_2} = -\frac{-10.6415\text{ cm}}{5.64\text{ cm}} = \boxed{1.88679}\,.$$

From this, we see that the image is 1.88679 times as large as the object and the positive sign for M_2 indicates that the image is upright. The negative value of q_2 means that the image is behind the mirror and is virtual.