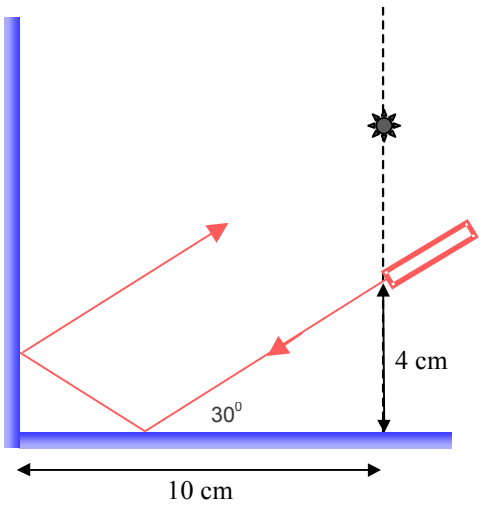
Week 8 Solutions

1. Flat mirror combination

A laser beam located 4 cm above a horizontal surface shoots a beam of light at a flat mirror with a 30^0 angle with respect to the horizontal. The reflected beam then strikes a second flat mirror that is at a right angle with respect to the first. The final reflected beam hits the star somewhat above the laser and in the same plane as the laser.



a) What is the angle of incidence of the initial beam on the horizontal flat mirror according to our common convention?

Angles of incidence, reflection, and refraction are measured from the normal to the surface. Here, we have $\theta_{inc} = 90° - 30° = 60°$.

b) What is the angle of incidence of the reflected beam as it strikes the second flat mirror?

The mirrors are perpendicular to each other, so we have a 30-60-90 right triangle in the corner. As in part a), the angle of incidence is 90° - 60° = 30°.

c) The final beam hits the starred spot. How high is the star above the horizontal surface?

Use some trigonometry: tan(30°) = 0.577, so:

i) The light hits the bottom mirror $\frac{4\ \text{cm}}{\tan\left(30^\circ\right)} = 6.928\ \text{cm}$ to the left of the laser.

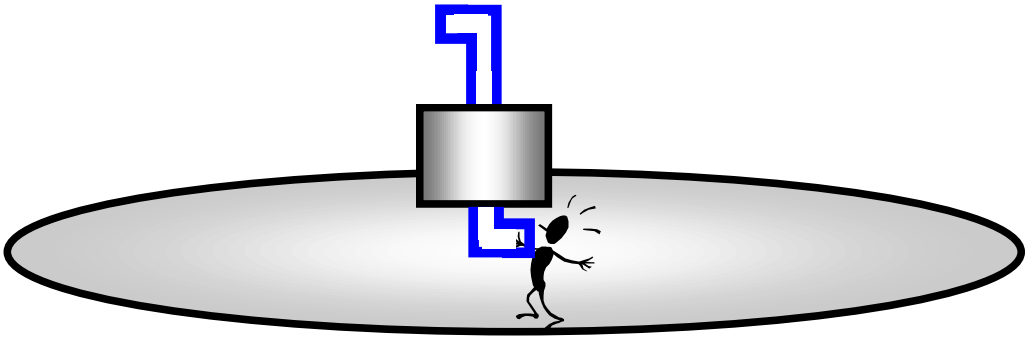
ii) After the bounce, the light travels (10-6.928) left, then 10 cm right (total left-right travel = 13.072 cm), rising 13.072 * 0.577 = 7.543 cm before hitting the star.

Week 8 Solutions

2: The Periscope

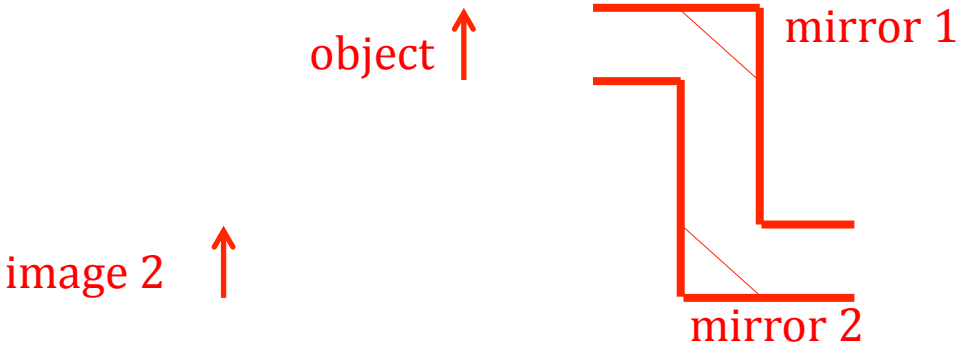
Our little friend is using a submarine's periscope to peek outside the sub. Use this page to make a large sketch of the periscope with internal mirrors and rays to indicate how this device works. Using flat mirrors is the simple way to go!

CHALLENGE: Will the final image (the image that our little friend sees) be upright or inverted? Will it look magnified? Justify your answer to your TA with a drawing.



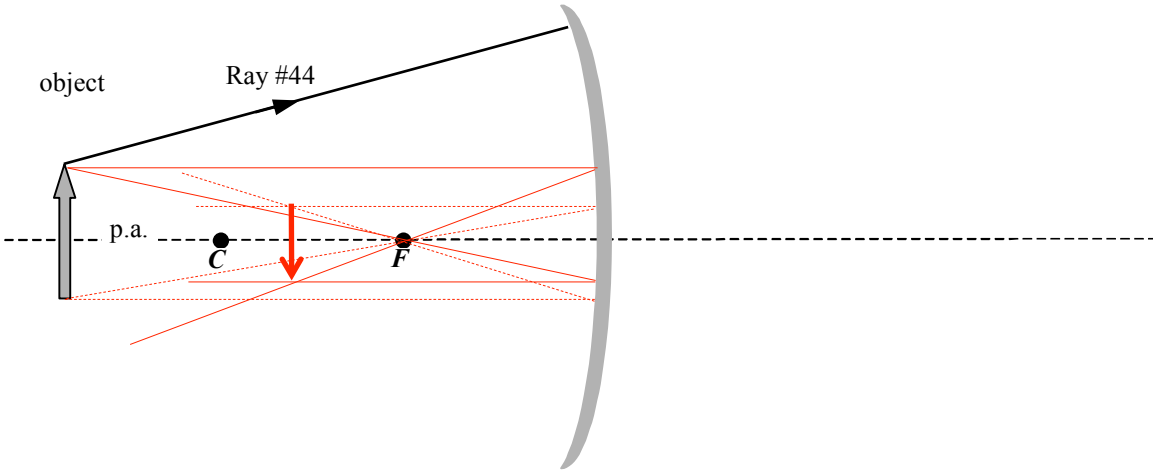
The simplest periscope just uses two flat mirrors, oriented at 45°:
I'll let you verify the locations of the images.
You see image 2, which is upright and the same size as the object. Flat mirrors don't magnify.

Real submarine periscopes are more complicated.
They use telescope optics to magnify the image and increase the field of view.



Week 8 Solutions

3. Concave mirror with object well outside focal length



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a) Use ray tracing to find the location of the image. Make sure you image the entire object. Notice it spans the principal axis. (Ignore the ray labeled #44 for now.) See the diagram above. Solid lines are rays from the arrowhead. Dashed lines are from the tail.

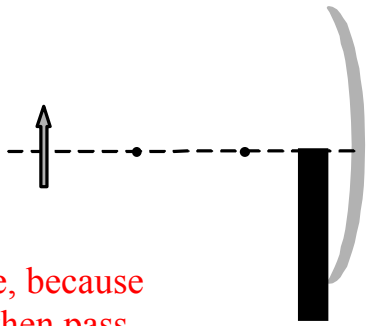
b) Describe the characteristics of this image by circling the right choices:

REAL	VIRTUAL	
UPRIGHT	INVERTED	
ENLARGED	REDUCED	SAME SIZE

c) Complete "Ray #44" in the diagram. Where does it go after reflecting off the mirror?

I won't draw it on the diagram above, because it would become very messy. All rays that come from the object's arrowhead pass through the image's arrowhead, so that's where Ray #44 goes.

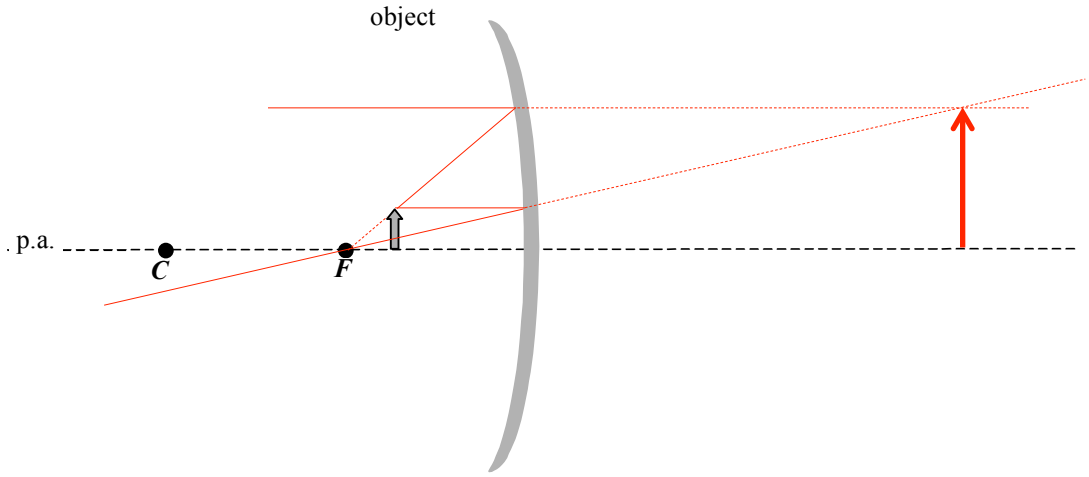
d) Suppose somebody covers the bottom half of the mirror as shown in the mini-picture below. Will the image still form? Discuss this a bit and then draw some lines to support your conclusions. First prize for the group with the best explanation!



Every small piece of the mirror produces an image, because wherever rays from the object hit the mirror they then pass through the image. When part of the mirror is covered, fewer rays participate, and the image is not as bright.

Week 8 Solutions

4. Concave mirror with object "inside" focal length



a) Use ray tracing to find the location of the image. Hint: you might think about extending your rays "behind" the mirror.

Use the same method as in problem 3. If the rays don't cross in front of the mirror, you need to extend them behind the mirror to find the location of the virtual image.

b) Describe the characteristics of this image by circling the right choice:

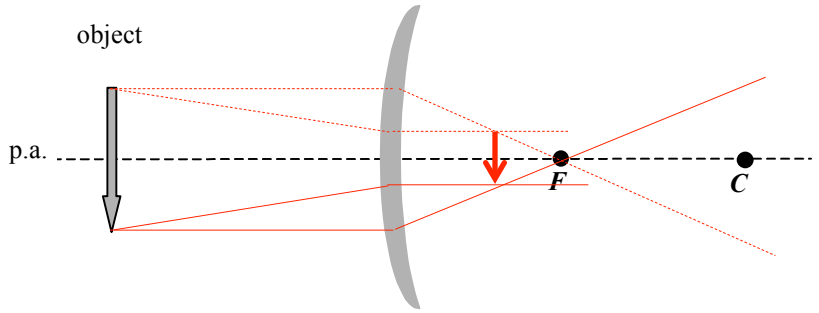
REAL	VIRTUAL	
UPRIGHT	INVERTED	
ENLARGED	REDUCED	SAME SIZE

c) Describe an everyday situation where you might find a mirror of this type in use, that is, with the object inside the focal length of a concave mirror.

Shaving mirrors and mirrors used for applying cosmetics are usualy concave with long focal lengths so that one obtains a magnified, upright image.

Week 8 Solutions

5. Convex mirror



a) Use ray tracing to find the location of the image. Make sure you image the entire object. Notice it spans the principal axis.

See the figure above.

b) Describe the characteristics of this image by circling the right choice:

REAL	VIRTUAL	
UPRIGHT	INVERTED	
ENLARGED	REDUCED	SAME SIZE

c) Describe an everyday situation where you might find a mirror of this type in use, that is, with a convex mirror. Hint: pretty common.

The external rear-view mirrors on cars and trucks are convex, because they give a big field of view. The reduction of image size is the reason they have the warning, " WARNING: Objects in the mirror are closer than they appear."