PH 222 Activity 9

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These problems are borrowed/adapted from Chapter 34 of *Physics for Scientists and Engineers*, as well as its associated *Student Workbook*.

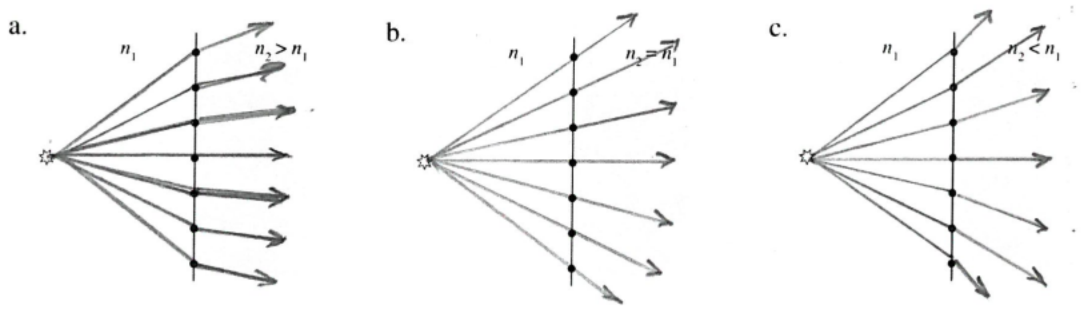
Activity 1

Are the following most reasonably described by the wave model of light, the ray model of light, either, or neither?

Situation	Model
human eye	ray
optical telescope	ray
antireflection coatings on the telescope lenses	wave
light passing through a 1-cm-diameter hole	ray
light passing through a 0.1-mm-diameter hole	wave
interferometer	wave
white light dispersed into a rainbow by a prism	ray
white light dispersed into a rainbow by a diffraction grating	wave

Activity 2

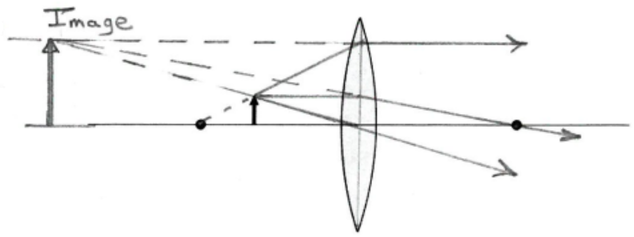
Draw seven rays from the object that refract after passing through the seven dots on the boundary.



Activity 3

An object is near a lens whose focal points are shown.

(a) Use ray tracing to locate the image of this object.



(b) Is the image upright or inverted?

Upright

(c) Is the image height larger or smaller than the object height?

Larger

(d) Is this a real or a virtual image? Explain how you can tell.

Virtual. The rays do not converge on the image point. Instead, the rays appear to diverge from the image point.

(e) Say you are given that the object is a distance $\frac{2f}{3}$ from the lens (where f is the focal length). How far back is the image, and how does its height compare to that of the object?

In other words, $s = \frac{2f}{3}$. By the thin lens equation,

$$\begin{aligned} \frac{1}{s} + \frac{1}{s'} &= \frac{1}{f} \\ \frac{3}{2f} + \frac{1}{s'} &= \frac{1}{f} \\ \frac{1}{s'} &= -\frac{1}{2f} \\ s' &= -2f. \end{aligned}$$

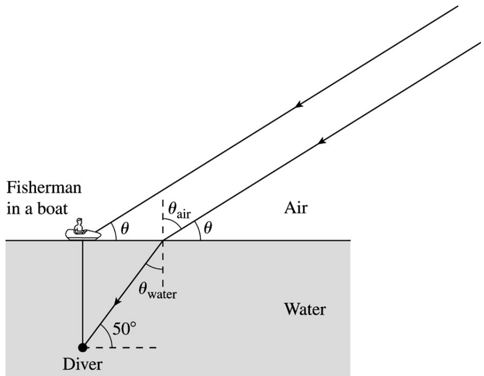
The negative sign suggests a virtual image, which is a distance $2f$ from the lens on the same side as the object. The magnification is

$$m = -\frac{s'}{s} = \frac{2f}{2f/3} = 3,$$

and the height ratio $h'/h = |m| = 3$, so the image is 3 times as tall as the object.

Activity 4

An underwater diver sees the sun 50° above horizontal. How high is the sun above the horizon to a fisherman in a boat above the diver?



The angle the diver sees the sun at is part of a right triangle, with the angle the incoming ray makes with the vertical (θ_{water}) being the other non-right angle. As such, $\theta_{water} = 40°$.

We can relate θ_{water} to θ_{air} by Snell's law:

$$n_{air} \sin\theta_{air} = n_{water} \sin\theta_{water} \implies \sin\theta_{air} = \frac{n_{water}}{n_{air}} \sin\theta_{water} = \frac{1.33}{1.0} \sin(40°) \implies \theta_{air} \approx 58.7°.$$

The angle above the horizon is complementary to this angle, so $\theta = 90° - \theta_{air} = 31.3° \approx 31°$. Since the sun is far away from both the fisherman and the diver, its rays are parallel, so the fisherman will see the sun at the same angle above the horizon.