Week 9

Physics 1409/1430 – Physics 2

Hello and Welcome to the weekly resources for PHY 1409/1430 – Physics 2!

This week is Week 9 of classes, and typically in this week of the semester, your professors are covering these topics below. If you do not see the topics your particular section of class is learning this week, please take a look at other weekly resources listed on our website for additional topics throughout the semester.

We also invite you to take a look at the group tutoring chart on our website to see if this course has a group tutoring session offered this semester.

If you have any questions about these study guides, group tutoring sessions, private 30-minute tutoring appointments, the Baylor Tutoring YouTube channel or any tutoring services we offer, please visit our website www.baylor.edu/tutoring or call our drop in center during open business hours, M-Th 9am-8pm on class days, at 254-710-4135.

Important Information

Important Conventions

Keywords: Law of reflection, Concave Mirror, Convex Mirror, Mirror Equation

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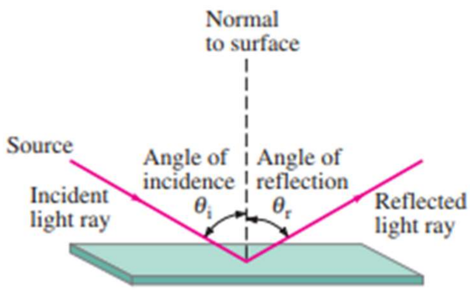
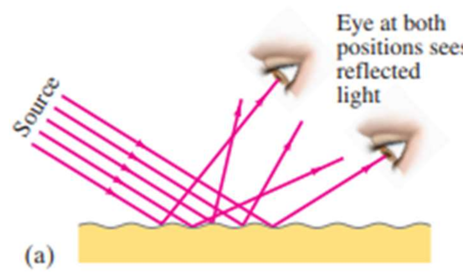
Law of Reflection

Light has a dual nature. It is an electromagnetic wave, but it also works as a ray. This perspective is what is called the ray model of light. For the duration of this chapter, we will consider light as rays, straight lines persisting infinitely. These rays reflect and refract (I will elaborate on this term later in the doc). First, let us consider reflection.

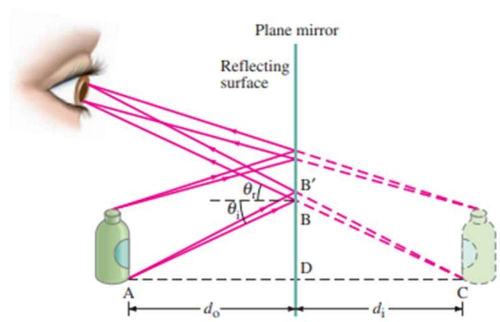
We all use mirrors in our homes. They are in pretty much every building. What we typically use are plane mirrors. These are smooth surfaces, and they show the best example of the law of reflection.

In the ray model of light, light reflects off all surfaces. It is what allows us to see things. These light rays hit the surface and reflect off the surface. The ray that hit the surface is called the incident ray. The ray that reflects off is the reflected ray. The path for the rays is predictable. The point at which the light rays hit the surface, we project and imaginary perpendicular line to the surface. This is called the normal to the surface. The angle that the incident ray makes with the normal (angle of incidence) is ALWAYS equal to angle the reflected ray makes with the normal (angle of reflection). This is the law of reflection. It also determines how we perceive things. The angle between the rays as shown in the figure below.





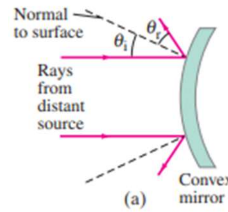
Not only does it affect how we see surfaces but also how we see images, how we see ourselves in the mirror. There are infinite rays of light always bouncing off and intersection of these lines for the images we see. The images we see seem to be behind the mirror even though the object is behind us. What we see is called a virtual image. The image forms from a projection of the rays. The distance of the image from the mirror depends on the type of mirror. Let's first get some terms straight.



Object Distance (d_o): the distance of the object from the mirror (also lenses!).

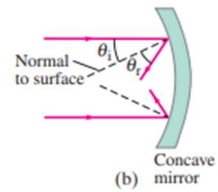
Image Distance (d_i): the distance of the image from the mirror (also lenses!).

What we are used to is seeing plane mirrors. But mirrors come in lots of different forms. Most ubiquitous is spherical mirrors. Mirrors for cars are a notable example for this. Due to the curvature, the image that is formed is very different from reality.

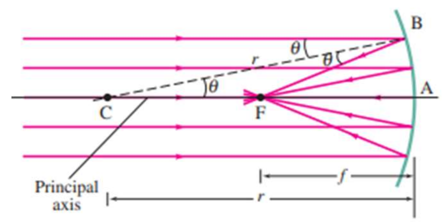


There two kinds of spherical mirrors:

1) Convex Mirror: this is a diverging lens. The light rays that hit the surface diverge as shown in the image.
2) Concave Mirror: this a converging lens. The light rays that hit the surface converge toward a focal point (also called focus. Highly important)



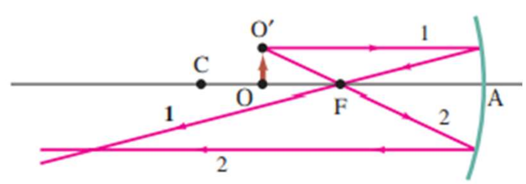
When looking at lenses, we try to project an imaginary line going through the center of the lens. This is called the principal axis. On this axis lies the focus. The light rays that strike the surface are focused on this point. The distance of the focus from the mirror is called the focal length. The focal length is as follows: r stands for the radius of the curvature of the mirror.



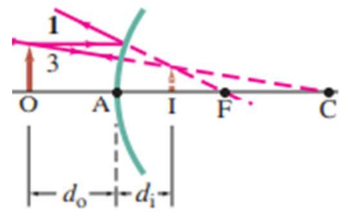
$$f = \frac{r}{2}$$

What is essential to understand in this chapter is how to draw ray diagrams and the rules they follow for forming images.

What is essential is drawing these rays correctly based on their position. Above we have a concave mirror. The light rays should therefore curve toward the center. What you want to find is the point where the rays intersect. Draw one ray parallel to the principal axis. This ray should reflect and go through the focus. This drawing will look different based on what side of the focus the object is on. The second should pass through the focus and converge like ray 2. This is purely a visualization tool but it is essential to learn before looking at lenses. The drawing for convex mirrors is different.



For convex mirrors, the focus is on the other side of the mirror. The light rays hit the surface and projections of them go through the focus on the other side. The intersection is where the image forms.



Based on these principles, the points where these image forms and the height of the image can be predicted. First, the ratio of the object distance and image distance is always equal to the ratio of the height of the image and height of the object. This ratio is called the magnification of the image, describing what the image looks like compared to the object.

$$m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

The focal length, image distance and object distance also relate to one another. After some derivation, we get the mirror equation.

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

Another important component is sign convention. The skills I mention in this document are important to master because they get a bit more complicated once we start looking at lenses.

The sign conventions are as follows:

1) The image height is positive if the image is upright and inverted if it is negative.
2) The image distance, object distance and focal length are positive it they are in front of the mirror (left side of it for diagrams above) and negative if they are behind the mirror (right side of the mirror for diagrams above).

Example

An external car mirror is convex with a radius of curvature 16 m. Determine the location of the image and its magnification for an object 10 m from the mirror,

Solution

$1/d_o + 1/d_i = 1/f$

$1/d_i = 1/(r/2) – 1/d_o$

$1/d_i = 1/(-16/2) – 1/10 = -1/8 – 1/10 = -18/80$ the focus for the convex mirror is behind it

d_i = -4.4 cm

$m = -d_i / d_o = 4.4/10 = 0.44$

All images are from Physics: Principles with Applications (7th Edition) by Douglas C. Giancoli

CHECK YOUR LEARNING

1. A person whose eyes are 1.5 m above the floor stands 3 m in front of a vertical plane mirror whose bottom edge is 10 cm above the ground. What is the horizontal distance x to the base of the wall supporting the mirror of the nearest point on the floor that can be seen reflected in the mirror?
2. A dentist wants a short mirror that, when 4 cm from the tooth, will produce 6x upright image. What kind of mirror must be used and what must be the radius of curvature?
3. A mirror at an amusement park shows an upright image of any person who stands 1 m in front of it. If the image is 2 times the persons height, what is the radius of curvature of the mirror?

THINGS YOU MAY STRUGGLE WITH

1. Getting used to seeing the ray diagrams and visualizing the path of light based on the type of mirror. Be sure to know generally how the ray diagrams are drawn for the various types of mirrors. Remember the difference between the types of mirrors. Plane mirrors are level surfaces. They reflect light based on the law of reflection. The curved mirrors either cause light to converge (concave) or diverge (convex).
2. Be sure to remember the name for the curvature of the mirrors not by the type of effect they have but by the direction in which the curvature goes. If it curves toward the object side, the mirror is concave. If it curves away from the object, the mirror is convex. Identifying them by the direction of curvature will be less confusing to keep names straight when we get to lenses.
3. The most important thing you must keep straight are the sign conventions for the types of mirrors and their object distance, image distance and focus signs. Problems primarily concern using the mirror equation that is stated above, but the thing that will be paramount will be the signs for each value. Make sure to practice this concept with questions so that you can get the sign conventions down.
4. All the skills taught here will be useful when we consider lenses so be sure to learn to draw ray diagrams, learn how we define the sign conventions and using the mirror equation.

Thanks for checking out these weekly resources! Don't forget to check out our website for group tutoring times, video tutorials and lots of other resource: www.baylor.edu/tutoring ! Answers to check you learning questions are below!

Answers: 1. 0.214m 2. 9.6 cm 3. 4m

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