Week 10

Physics 1409/1430 – Physics 2

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

This week is Week 10 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.

Keywords: Refraction, Snell's Law, Thin Lens Equation, Lens maker's Equation

Important Information

Important Conventions

Refraction:

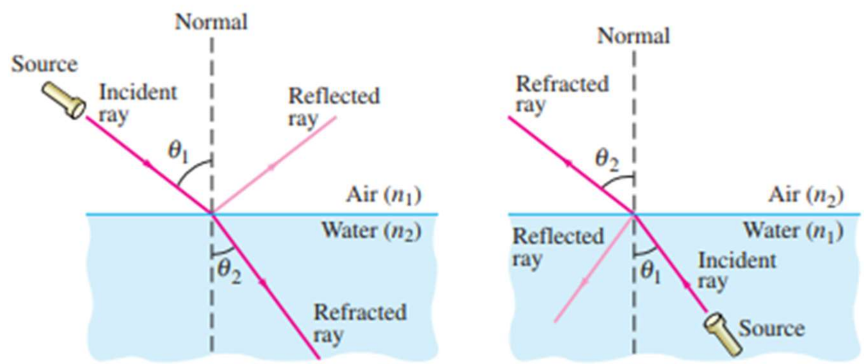
When light hits a reflective surface, it bounces off, which is reflection. When light passes through materials, it refracts. Refraction is the change of direction of the light rays when it passes through a material. For the direction of refraction, the influence comes from the index of refraction of a material (n). Index of refraction for a material is the ratio of the speed of light in a vacuum to the speed of light in the material itself.

$$n = \frac{c}{v}$$

The index cannot be smaller than 1 since the maximum possible speed is in a vacuum. This index of refraction determines how much light bends as it passes through the surface. The relation of the index of refraction to the source of light determine how light bends.

The diagrams have components similar to components of reflection diagrams. There is an incident ray and a refracted ray that passes through the surface. The point at which the incident ray hits the surface is where the normal for the surface is considered.

When the n of the first medium is smaller than the second medium, the refracted ray bends towards the normal. When the n of the first medium is bigger than that of the second medium, the refracted ray bends away from the normal.



(a) $n_2 > n_1$: Ray bends toward ⊥ (b) $n_1 > n_2$: Ray bends away from ⊥

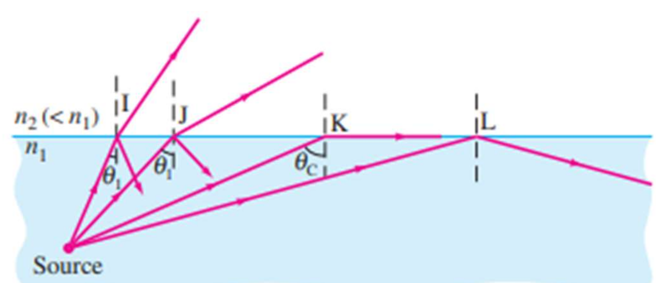
When light passes into a medium with a higher n, the speed of light decreases, which is why it bends toward the normal. When light passes into a medium with a lower n, the speed of light increases, which is why it bends away from the normal.

The angles that the incident ray and the refracted ray make with the normal are determined by Snell's Law, which is essentially the following formula.

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

Total Internal Reflection:

Not all the light that hits a refractive surface passes through the material, some of it is reflected. If light hits a refractive surface at the right angle, it is all reflected. This angle called the critical angle. Now, if the source of light is in the material, the

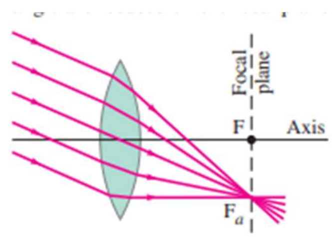


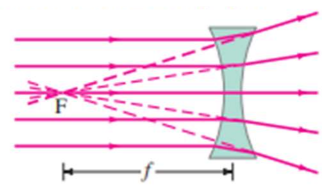
light is continuously reflected in the material. This is effect is called total internal reflection. The critical angle can be calculated using the following formula.

$$\sin\theta_C = \frac{n_2}{n_1}$$

This effect is the basis of fiber optic cables. Information can be transmitted at the speed of light, and it is a method that is widely used in large buildings and communication across continents.

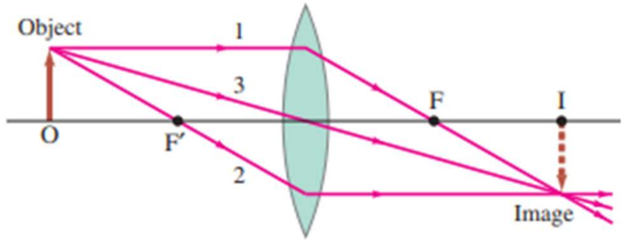
Thin Lenses:





The same way that reflection in spherical mirrors affects the image that is formed, there are spherical lenses that affect image formation. Much like for mirrors, there are converging lenses and diverging lenses. The converging lenses are called convex lenses. The diverging lenses are called concave lenses. The best way to determine how to name each is based on the shape of the curvature.

We use ray diagrams to see image formation for lenses as well. But there is a change in conventions. For lenses, there are two focus points on both side of the lens, the same distance from the lens. Use the following diagram as reference to how to draw ray diagrams.



As the rays actually pass through the lens, the images formed are real images. If the images are formed on the same side of the lens, they are virtual images. For determining the image formation, we use the thin lens equation. This equation is the same as the one we used for mirrors but the conventions you use will differ.

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

Sign Conventions:

1. The focal length is positive for convex lenses and negative for concave lenses.
2. The object distance is positive if the source of light and the object are on the same side otherwise it is negative
3. The image distance is positive if the image is on the opposite side of the lens as the source of light and negative otherwise.
4. The height of the image is positive if it is upright and negative if inverted.

Magnification of a lens is the ratio of the image height to object height.

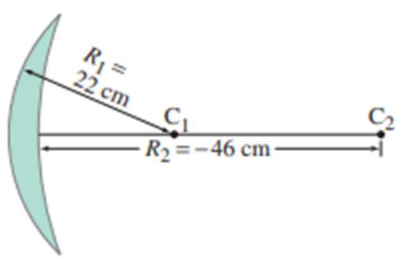
$$m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

<u>Lens maker's Equation:</u>

For spherical lenses, both sides do not have to be the same. For such spherical lenses, we use the lens maker's equation.

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

The R1 and R2 represent the two surfaces and their sign is determined by the kind of surface.



The converging surface (convex) is positive; the diverging surface (concave) is negative.

CHECK YOUR LEARNING

1. A light beam coming from an underwater spotlight exits the water at an angle of 30°. At what angle incidence did it hit the air water interface from below the surface?
2. What is the power of a 25 cm focal length lens? What is the focal length of a -5 D lens? Are they converging or diverging?
3. How far from 1.2 cm focal length lens must an object be placed if its image is to be magnified 3X and be real? What if the image is to be virtual and magnified 3X?

THINGS YOU MAY STRUGGLE WITH

1. Getting familiar with ray diagrams and visualizing the path of light based on the type of lenses. Be sure to know generally how the ray diagrams are drawn for the various types of lenses. Remember the difference between the types of lenses. Convex lenses are converging, and concave lenses are diverging.
2. Be sure to remember the name for the curvature of the mirror/lens not by the type of effect they have but the direction in which the curvature goes. If it curves toward the object side, its concave. If it curves away from the object, the mirror is convex. This way it will be less confusing to keep names straight.
3. The most important thing you must keep straight are the sign conventions for the types of mirrors/lenses and their object distance, image distance and focus signs. Problems primarily concern using the mirror/lens equation that is stated above (mirror eq is the same) but the thing that will be paramount will be the signs for each value. Make sure to practice this with questions so that you can get the sign conventions down.
4. Approach problems involving multiple lenses by splitting up the problem into multiple subproblems per lens. Then use ray diagrams to track the image formed as light passes through each lens.

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. 22.1° 2.(a) 4D , converging (b) -20 cm, diverging 3. -0.8 cm, -1.6 cm

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