Physics 152

Lecture 11

Wednesday, February 7, 2007

• Law of Refraction
• Total Internal Reflection
• Dispersion
• Mirrors

http://www.volnet.com/ladder/

Announcements

Help sessions
• W 9 - 10 pm in NSC 118
• MasteringPhysics
• WU #7 due Monday
• Hwk #2 due next Wednesday
• WU #8 due next week Friday
• Mock test posted online

Announcements

Hint: Be able to do the homework (MasteringPhysics and workbook) and you’ll do fine on the exam!

You may bring one 3”X5” index card (handwritten on both sides), a pencil or pen, and a scientific calculator with you.

I will put any constants and mathematical formulas that you might need on a single page attached to the back of the exam.

Exam #1

Thursday, Feb. 15, 2007
5:00 pm – 6:15 pm
Ch. 14, 20 - 23

Ch. 22: Wave Optics

Law of Refraction (a.k.a. Snell’s Law)

\[
\frac{\sin \theta_2}{\sin \theta_1} = \frac{v_2}{v_1}
\]

Where \( v \) is the speed of light in the medium in which the light ray travels.

Ch. 22: Wave Optics

5:00 pm – 6:15 pm
Ch. 14, 20 - 23

Exam #1

• One graphing problem.
• One essay, proof or discussion question.
• Two problems with multiple parts.
• One section of multiple choice.
6 questions roughly evenly divided between waves and optics.
The speed of light is always given by

\[ c = f \lambda \]

The frequency with which waves leave one medium must equal the frequency with which they enter another (otherwise we'd have waves piling up at a boundary, and we never observe that to occur).

Characteristics of the material which relates how the speed of light in that material changes compared to the speed of light in vacuum...

\[ n = \frac{\text{speed of light in vacuum}}{\text{speed of light in medium}} = \frac{c}{v} \]

So it must be that the wavelength of the light waves changes as light goes from one medium to the next...

\[ n_1 \lambda_1 = n_2 \lambda_2 \]

We can now reformulate Snell's law using the index of refraction:

\[ n_1 \sin \theta_1 = n_2 \sin \theta_2 \]
So let’s say we’re under water in a swimming pool looking up toward the surface.

If we up look at an angle of 70° to the normal of the surface, what do we see? (I.e., compute the angle of refraction.)

Worksheet Problem #3

The sine of an angle is always a number between -1 and 1. It cannot be 1.25! What’s going on here?

For light rays traveling into a material with a smaller index of refraction, there exists a critical angle greater than which the light rays cannot enter the second medium. These light rays are totally reflected by the boundary back into the original medium. The law of reflection applies in this case.

Critical angle for total internal reflection

Notice that this expression only makes sense when \( n_1 > n_2 \) (i.e. when the light ray moves from a medium with larger index of refraction to one of smaller index of refraction).

With the exception of vacuum, all materials bend different wavelengths of light different amounts.

That is, the index of refraction of the material is dependent on wavelength (frequency).

In general, the index of refraction decreases with increasing wavelength. This implies that red light (long wavelength) will be bent the least and blue light (short wavelength) will be bent the most.

Now I understand how a prism works!!!

The prism refracts different wavelengths different amounts.

The colors of the rainbow appear

Ah, white light (which is composed of all colors) enters the prism
Let’s start by studying what happens when light strikes a plane mirror (a 2D surface).

Let’s look at our plane mirror problem again, this time from a top view perspective...

Virtual Images

When we use this term, we’re referring to an image which forms at a location at which no light from the object is received.

So in the case of our plane mirror, although the object appears to be located behind the mirror, if we look behind the mirror, we’ll see nothing there!

Hence, the image is called a virtual image.

It is useful to define a quantity which tells us how the size of the image is related to the size of the object. We call it Magnification!

\[ M = \frac{h'}{h} \]

For a plane mirror, \( h' = h \), so \( M = 1 \).
While the most common mirrors we use are generally plane mirrors, not all mirrors are flat.

Another large class of mirrors are known as **Spherical Mirrors**.

**Convex:**

"It must be the other one!"

**Concave:**

"It's like a cave on the side from which light approaches."

Remembering which is which can be confusing!

Whether we're dealing with concave or convex mirrors, we define their *center of curvature* to be the point which would be the center of the sphere if the sphere was complete.

In 2D, it's the place where you'd stick the compass point to draw the circle.

We next define the *principle axis* to be the line passing through the center of curvature along a radius through the center of the mirror.

Let's call the distance from the center of curvature to the mirror *R*.
The radius passes through the center of curvature and is perpendicular to the surface of the mirror. The radius is the normal.

**Law of Reflection** \( \theta_i = \theta_r \)

All rays parallel to the principle axis that strike the surface of the concave mirror are reflected through the same point: the focus of the mirror.

Objects at infinity will have images at the focus.

We define the distance between the surface of the mirror and the focus along the principle axis as the focal length \( f \).

For spherical mirrors, \( f \) and \( R \) are related by geometry:

\[
f = \frac{R}{2}
\]

How do we locate images for objects closer than infinity?

### Rules of the Game (Concave)

1) A ray parallel to the principle axis of the mirror will be reflected through the focal point.

2) A ray passing through the center of curvature (C) will be reflected back through C.
3) A ray passing through the focal point will be reflected back parallel to the principle axis.

Now that we know how to find where the image will be located, let’s try to figure out how tall the image will be (i.e. let’s determine the magnification of the concave mirror).

The image formed by the concave mirror is inverted, but real (that is, if I put my eye at the location of the image, I see the image).

Now use geometry to determine magnification…

A 2nd pair of similar triangles produces the mirror equation

With a little algebra, you get...
Quick Guide to Sign Conventions

- $p > 0$ if the object is in front of the mirror (real)
- $p < 0$ if the object is behind the mirror (virtual)
- $q > 0$ if the image is in front of the mirror (real)
- $q < 0$ if the image is behind the mirror (virtual)

A man's face is 30.0 cm in front of a concave shaving mirror. His image is upright and 1.50 times larger than his actual face. What is the focal length of the mirror?

Worksheet Problem #5

1. 12.0 cm
2. 20.0 cm
3. 70.0 cm
4. 90.0 cm
5. 120.0 cm