Physics 152

Lecture 14

Wednesday, February 14, 2007

• Thin lenses
• Optical instruments

http://www.voltnet.com/ladder/

Help sessions
• W 9 - 10 pm in NSC 148
• MasteringPhysics
  • Hwk #2 due Thursday
  • WU #8 due Friday
  • Mock test posted online

Announcements

Announcements

Exam #1

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

• 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.

Ch. 23: Geometric Optics

Worksheet Problem #1

Concept Quiz!

Lens & Overhead

Ch. 23: Geometric Optics

The Human Eye
The human eye is really just another, relatively simple optical system. The eye takes advantage of refraction to focus light from objects in our field of view onto the retina.

Normal Eye

Incoming light rays pass through the cornea and pupil of the eye, where they then intersect the lens, which focuses light onto the retina.

The normal eye is able to comfortably focus objects at distances from the far point (infinity) to as close as the near point (about 25 cm).

As you are no doubt aware, two common defects plague human vision:

- Hyperopia (or farsightedness)
- Myopia (or nearsightedness)

Each of these problems causes blurred vision and is the result of an inability of the eye to properly focus light on the retina.

Hyperopia

For the farsighted person, the lens of the eye focuses the light at a point beyond the back of the retina.

Objects at a great distance from the observer appear fairly clear, but objects close to the observer are blurred.

Myopia

For the nearsighted person, the lens of the eye focuses the light at a point in front of the retina.

Objects close to the observer appear fairly clear, but objects far from the observer are blurred.

We can correct these optical defects quite simply by prescribing corrective lenses to be placed in front of the eye.

What type of lens will we want to put in front of an eye suffering from hyperopia?

1) Converging
2) Diverging

Hyperopia

Helps out the eye with hyperopia by starting to bring the light to a focus before it encounters the lens of the eye.
Helps out the eye with myopia by separating the incoming light before it encounters the abnormally strong focusing lens of the eye.

Optometrists and ophthalmologists usually prescribe lenses by describing the power of the corrective lens.

\[ P = \frac{1}{f} \]

\[ = 1 \text{ diopter} \]

A person has far points at 8.00 cm from the right eye and 10.0 cm from the left eye. Write a prescription for the powers of the corrective lenses. What types of lenses are they (converging/diverging)?

Worksheet Problem #2

The angular magnification of an object is simply the ratio of the angle subtended by the object at your eye when magnified to that angle when unmagnified and placed at the near point.

A diagram will help here...

Our simple magnifier has a focal length less than 25 cm and will produce an image with an angular magnification given by:

\[ m = \frac{\theta}{\theta_0} \]

This ratio achieves its maximum value in the geometry of the last slide (where the image appears at the near point).

In that case, the object should be placed at

\[ p = \frac{25f}{25 + f} \]

where \( p \) and \( f \) are both measured in cm.
When the object is placed at the distance $p$ in front of the simple magnifier, the maximum angular magnification occurs.

$$m = 1 + \frac{25}{f}$$

The simple magnifier is a useful device. Not only do we find it in magnifying glasses, but they also serve as the eyepieces for microscopes and telescopes!

Let's look at how a telescope works a little more closely.

There are two principle types of optical telescopes: **reflecting** and **refracting**.

**Reflecting** telescopes use a mirror to bring distant light to a focus. A lens (the eyepiece) is then used to magnify the image formed by the primary mirror.

**Refracting** telescopes use a lens to bring distant light to a focus and a second lens (the eyepiece) to magnify the image formed by the first lens.

A stamp collector uses a lens with 5.0-cm focal length as a simple magnifier. The virtual image of the stamp is produced at the near point (25 cm) from his eye. How far from the lens should the stamp be placed? What is the angular magnification of the stamp?

Worksheet Problem #3

Let's look in more detail at a **refracting** telescope (though everything we derive here will also be applicable to the reflecting telescope as well).

In general, the objects at which we peer through telescopes are a LONG distance from us. So, let’s assume an object distance of infinity.

$$m = \theta / \theta_o$$

$$m = \frac{\theta}{\theta_o} = \frac{h' / f_e}{-h' / f_o} = -f_o / f_e$$
A telescope has an objective focal length of 100 cm and an eyepiece focal length of 1.0 cm. How long should the telescope barrel be? What is the angular magnification of this telescope?

Worksheet Problem #4

Chapter 25

Electric Charges and Forces

We’re now going to start down the path of examining forces with origins not visible to us. We call the quality of matter responsible for the first these forces “charge,” a substance never directly observed in the history of the human race!

Attraction in Nature

Amber (lektron in Greek) attracts straw/feathers when rubbed (observed by Thales of Mileus ~ 600 B.C.).

Iron ore from the country of Magnesia seemed to have a natural affinity for metals.

When released, all objects seem to fall toward the ground.

Electrostatic and Magnetic Forces

William Gilbert (1540 - 1603, English physician)
- clarifies the difference between the attraction of amber and that of magnetic iron ore;
- shows that many materials besides amber exhibit electrical attraction
- showed that the behavior of a compass needle results from the magnetic field of the Earth!

Stephen Gray (early 1700’s) shows that the electrostatic attractive and repulsive forces can be transferred through contact alone. Metals didn’t need to be rubbed.

Two Kinds of Charge

Charles Du Fay (1698 - 1739) first postulated the existence of two distinct kinds of electricity: vitreous (the glass rod) and resinous (the silk). But thought they existed together in most matter and when separated through friction, resulted in an electrical force.

Benjamin Franklin (1706 - 1790) hypothesized a one-fluid model of electricity: charge is transferred from one body to another (e.g. through rubbing); but the total charge on the two bodies combined remains the same.

Conservation of Charge.

Franklin decided to call the materials which he believed had an excess charge: “positive” a deficiency of charge: “negative”

Hence:
The glass rod (vitreous) was positive when rubbed with silk.
The amber (resinous) was negative when rubbed with wool.
Unfortunately, as we would later learn: electrons (negative charge carriers) are generally more mobile than protons (positive charge carriers) that generally remain fixed in the nucleus of atoms.

Parenthetical Remark:

So materials with excess electrons appear negatively charged. Nevertheless, Franklin’s convention has stuck with us... quite literally!

Charge is Quantized

Robert Millikan (1868 - 1953) in a very clever experiment showed that electrical charge came in quantized units. In other words, charge of 0, +/- 1e, +/- 2e, +/- 3e,... +/- ne (where n is an integer) could be observed, but never a charge of 1.5e.

An electron carries a charge of -1e. A proton carries a charge of +1e.

Electrons and protons carry charge. They are responsible for the electrical forces we encounter. Atoms are made up of electrons and protons. Matter is composed of atoms.

So why doesn’t every object we encounter exert an electric force on every other object around it?

Electrically Neutral...

Most objects in nature are electrically neutral (i.e. they contain an equal number of protons and electrons).

\[ N_e = N_p \]

Therefore most objects exert no electrical force on the objects around them.

Atoms in which \( N_e < N_p \) or \( N_e > N_p \) are called ions.

Insulators and Conductors

Objects on which electrons move freely are known as conductors. Most metals are good conductors. Electrical wires are made of good conductors (e.g., copper, gold).

Objects on which charges do not move freely are known as insulators. Glass, amber, rubber, silk and cloth are all examples of good insulators.
If rubber is such a bad conductor, why is it so easy to put a charge on rubber by rubbing it with wool?

If metals are good conductors, why is it hard to charge them by rubbing them with wool?

The charges remain near the end of the rubber rod—right where we rubbed them on!

Rub charges on here

They move down the conductor toward our hand.
Eventually ending up in the ground.

A good conductor distributes the charge uniformly over its surface.

Rubber glove insulates copper rod from us and therefore the ground.

Notice that the Earth’s surface (ground) acts as a vast source and sink for electrical charge. Touching a conductor to ground will neutralize the charge on the conductor.

If the conductor is positively charged, electrons flow from the ground to the conductor.
If the conductor is negatively charged, electrons flow off the conductor into the Earth.

So when we talk about an object being grounded, we literally mean that it is connected via a conductor to the Earth’s surface.

All electrical outlets now have a ground prong. And most electrical devices use a 3-prong plug that requires the ground connection.
Well….just in case the device malfunctions, it’s nice to be able to siphon off the excess electrical charges to ground rather than allowing them to accumulate in the device.

If they build up in the device, they will eventually find their way to ground. If a person comes in contact with the device, the resulting flow of charges through the body can be deadly.

The ground prong provides a nice safety feature.

Charging by Induction

We can take advantage of the Earth’s ability to accept and provide charges to place a net charge on a conductor….

Here’s how you do it!

Induction Step 1

COPPER

Rubber

Bring negatively charged rubber ball close to a copper rod. The copper rod is initially neutral.

Negative charges on the copper run away from the rubber ball and into the ground.

Induction Step 2

COPPER

Rubber

The copper rod is now positively charged. The electrons originally on it were forced away into the ground by the negative charges on the rubber ball.

Induction Step 3

COPPER

Rubber

Finally, remove the rubber ball...

Put a rubber glove on your hand to insolate the copper rod from ground.

Induction Step 4

COPPER

The excess positive charge is trapped on the copper rod with no path to ground. It redistributes itself uniformly over the copper rod. We have taken an initially neutral copper rod and induced a positive charge on it!