Reflection and Mirrors

Cool Things Light Does

So, What is Light?

It moves at about 300,000,000 m/sec!

Different Wavelengths Lead To: EMS

Radio Waves

- Astronomy
  - Communication – AM, Shortwave, TV, FM
    - VLA  
    - VLBA
    - James Webb (IR)
  - Hubble (visible)
  - Chandra (x-ray)
# Frequency Allocation Chart

- The chart  
- Demonstration of it  
- How to apply for it

## Microwave

- Radar (Airport, Police, Weather Stations)  
- Cooking  
- Cell Phones

## Infrared

- TV remotes/remote keyboard  
- Heating/Drying  
- Night Vision

## Visible Light

- Photography  
- Photosynthesis

## Ultraviolet

- Sterilize Food and Surfaces  
- Run Solar Cells  
- Set Dental Fillings
SteriPen® Journey Water Purifier
Uses ultraviolet light to purify water – a great choice for hiking or traveling
$99.95

Veil Nebula in different spectra
- **Multiple wavelengths together**
- **IR**
- **UV**
- Visible?
- **Xray?**
- **Background**

Lab 1: Don’t Shatter My Image
- The angle of incidence equals the angle of reflection.
- A plane mirror results in a virtual image (located behind the mirror).
- The distance from the object to the mirror is equal to the distance from the mirror to the image – distance is “conserved” in an image

Lab 2 (and 1B): Images—The Law of Reflection
- The reflected rays can be extended behind the mirror to locate the position of the virtual image.
- These are the paths your brain assumes the rays must have followed.

**Xray**
- Bones Pictures

**Gamma Radiation**
- Medical Imaging
- Cancer Treatment
- (A form of nuclear radiation)
• Ray model of light – assume light travels in straight line paths called rays.
• We use this to demonstrate how we see things. If I see a dog, I assume the light is traveling directly to my eye from the dog.
• This is, of course, an idealization. The light we “see” is only a fraction of the total light reflected/emitted from the dog – we see a very narrow beam; small bundle of photons.

• Light can be reflected, absorbed, or transmitted by matter. Very shiny mirrors can reflect almost 95% of the incident light.
• Angle of incidence vs. angle of reflection.

• Note that the rays from her feet hit the mirror and reflect at B thus hitting her eye. You don’t actually ever see any of you coming from the mirror below point B. Really, to see your whole body, you would only need a mirror half as tall as you.
• Is this a real image or a virtual image?

• Rays look like they are coming from behind the glass, rays “always” travel in straight line paths
  • Use geometry and the law of reflection to show that the image will appear the same size, the same distance from the mirror, etc
    – Image distance: $s_i$ on blue sheet, $d_i$ in the textbook
    – Object distance: $s_0$ on blue sheet, $d_0$ in the textbook

Real Images vs. Virtual Images

When you think of a reflection, like looking into a mirror – that is a virtual image. The rays do not actually pass through the image itself, therefore the image would not appear on a paper or a screen if the screen were placed at the location of the image.

A real image is one where the rays actually do pass through the image. If you place a screen at that position, you can get the image. I bet you have all seen a real image in the last month – where?

• Worksheet 1A: Light Sources
  – You need a ruler and protractor
Shadows and Eclipses

- Ray—a thin beam of light.
- Sharp shadows can be produced by:
  - Small light source nearby
  - Larger source farther away
- Umbra—a total shadow
- Penumbra—a partial shadow
  - Appears where light from one source is blocked, but other light fills in
  - Or, where light from a broad source is only partially blocked
- Eclipses
  - During a solar eclipse, the sun’s rays taper to provide an umbra and a surrounding penumbra
  - During a lunar eclipse, the earth casts a shadow (umbra) on the moon.

Shadows

Solar Eclipse

Lunar Eclipse
• Worksheet 1B: Shadows and Illumination
  – You need a ruler or a protractor

Three types of mirrors
• Plane – flat
• Concave – bumps inward
• Convex – bumps outward

Anish Kapoor’s 23-ton mirror

Rockefeller Center
2006

Convex Side

Concave Side
Plane Mirror Images

The "Who Tall Are You" mirror

Light from an object in front a mirror spreads out in all directions.

Only two of these rays are needed to figure out what the mirror does with the light – any two rays will do.

One ray heading upward and one downward work well.

Draw the normals and measure the angles of incidence.

Draw the reflected rays such that the angle of incidence = the angle of reflection.
Because the reflected rays are diverging (moving apart) you trace them backwards to their imagined origin.

These reflected rays arrive at your eye exactly as light rays from a real object would. Your brain doesn't know the difference between where light really comes from and where it appears to come from.

Describing Images - SALT

- **Size** - compared to the object
  - Same Size
  - Reduced (Smaller)
  - Enlarged (Bigger)
- **Attitude**
  - Upright
  - Inverted
- **Location**
  - In front of or behind the mirror
- **Type of Image**
  - Real – light rays actually go there
  - Virtual – light rays never actually go there

How would you describe this image?

- Upright
- Same Size
- Virtual

This image is...

- It is located as far behind the mirror as the object is in front of the mirror.
- This is the only type of image formed by a plane mirror.
Curved Mirrors
Convex and Concave

Pass Out Small Concave Mirrors

Features of a spherical mirror

Collect Small Mirrors

Where will this image form?

All rays follow the Law of Reflection, but some are easier to predict than others.
“Special” Rays

Easy to Predict Concave Mirrors

One ray travels in toward the mirror from the tip of the arrow on a line parallel to the principle axis.

This ray is reflected from the mirror on a path that goes through the focal point.

Another ray travels in toward the mirror from the tip of the arrow on a path through the focal point.

This ray is reflected from the mirror on a path parallel to the principle axis.

But where is the image and what does it look like?
The image is located where the reflected rays cross.

The image is inverted, reduced, and real.

Concave Mirrors form many kinds of images

Describe each image.

Describe this image.

Spherical Aberration

- Results from the fact that not all rays pass through the same focal point
- Fuzziness can be reduced by:
  - Small Aperture
  - Parabolic Mirrors
- Spherical Mirrors are easier to make
“Special”
Easy to Predict
Rays
Convex Mirrors

Features of Convex Mirrors

One ray travels in toward the mirror from the tip of the arrow on a line parallel to the principle axis.

This ray is reflected from the mirror on a path that “includes” the focal point.

Another ray travels in toward the mirror from the tip of the arrow on a path that “includes” the focal point.

This ray is reflected from the mirror on a path parallel to the principle axis.
Since the rays “diverge”, they are extended backwards until they meet.

But where is the image and what does it look like?

The image is located where the reflected rays “seem to” cross.

Describe this image.

This is the only type of image formed by a convex mirror.
- Upright
- Virtual
- Reduced

Mirror Worksheet

Part a only (Diagrams)
Use a straight edge!
Draw the entire arrow as an image!
Draw the reflected portion of the ray!
Mirror Formulae

a.k.a. Mirror Formulas

Formulas apply to both concave and convex mirrors.

\[
\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}
\]

\[
\frac{h_i}{h_o} = \frac{-d_i}{d_o} = M
\]

- \(f\) is the focal length of the mirror
- \(M\) is the magnification
- \(d_i\) is the image distance
- \(d_o\) is the object distance
- \(h_o\) is the height of the object
- \(h_i\) is the height of the image.

Formula Conventions

- \(f\) is positive for concave mirrors and negative for convex mirrors
- \(d_o\) is always positive
- \(d_i\) is always positive for real images and negative for virtual images
- \(h_o\) is always positive
- \(h_i\) is positive for upright images and negative for inverted images
- \(M\) is greater than 1 for enlarged images, 1 for same size images, and less than 1 for reduced images

Example Problem (Convex Mirror)

- \(f = -3\) cm (convex mirror)
- \(h_o = 3\) cm
- \(d_o = 7\) cm

Solution for image distance

\[
\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}
\]

\[
\frac{1}{-3} = \frac{1}{7} + \frac{1}{d_i}
\]

\(d_i = -2.1\)

Negative means "virtual" image (behind mirror)
Seems correct

Solution for image height

\[
\frac{h_i}{h_o} = \frac{-d_i}{d_o}
\]

\[
\frac{h_i}{3} = \frac{(-2.1)}{7}
\]

\(h_i = 0.9\)

Positive means upright
Seems correct
Example Problem (Concave Mirror)

- \( f = +3 \text{ cm} \) (concave mirror)
- \( h_o = 1.7 \text{ cm} \)
- \( d_o = 8 \text{ cm} \)

Solution for image distance

\[
\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}
\]

\[
\frac{1}{3} = \frac{1}{8} + \frac{1}{d_i}
\]

\[
d_i = 4.8
\]

Positive means “real” image (in front of mirror)

Seems correct

Solution for image height

\[
\frac{h_i}{h_o} = \frac{-d_i}{d_o}
\]

\[
\frac{h_i}{1.7} = \frac{-(4.8)}{8}
\]

\[
h_i = -1.02
\]

Negative means inverted

Seems correct

Mirror Worksheet

Parts b, c and d (Calculations)
Round all answers to 2 decimal places.

Reflection of Sound

Marshalltown – Acoustical Clouds
**Davies Symphony Hall**
San Francisco

**PV Band “Band Shell”**

**Acoustic Anechoic Chamber**
/ ánikóik / adj. free from echo.

**Acoustical Engineering**
- The experienced Harley-Davidson community demands a certain distinctive and unmistakable sound.
- You know it’s a Harley as soon as you hear it, before you even see it.
- Our product is identified just as much by how it sounds as how it looks.

**Senior NVH Engineer**
- John Deere senior engineer Loren DeVries places small microphones around the cab of a John Deere 4400 compact utility tractor in the company’s noise and vibration laboratory. Mr. DeVries is measuring the sound field around the tractor cab for input into a computer model.

**Controlling Reflected Sound**
The PV Band Room
Reflectance

Reflectance – The portion of the incident light that is reflected.

Reflectance – The % of light reflected from a surface.
- TiO$_2$ – about 95%
- Coal Dust – about 5%

The Earth’s Reflectance
- Polar ice reflects light from the sun. As this ice begins to melt, less sunlight gets reflected into space.
- It is instead absorbed into the oceans and land, raising the overall temperature, and fueling further melting.
- This results in a positive feedback loop called ice albedo feedback, which causes the loss of the sea ice to be self compounding.
- The more it disappears, the more likely it is to continue to disappear.

Reducing Reflectance
- Auto dimming mirrors are based on the science of electrochromics, which is the process of reversibly darkening materials by applying electricity.

Diffuse and Specular Reflection
- Each ray still follows the Law of Reflection
Water fills in the cracks, making the surface more smooth. It changes from a diffuse reflector to a specular reflector.

How Smooth?

$\frac{1}{6} \lambda$