

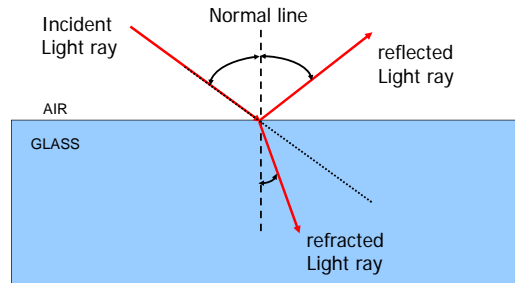
L 30 Light and Optics - 2

- Measurements of the speed of light (c)
- Index of refraction $n_{\text{medium}} = c/v$
 - the bending of light – refraction
 - total internal reflection
- Color (wavelength and frequency, $c = \lambda f$)
- Dispersion
 - rainbows
- Atmospheric scattering
 - blue sky and red sunsets
- Law of reflection
 - mirrors
 - Image formation

1

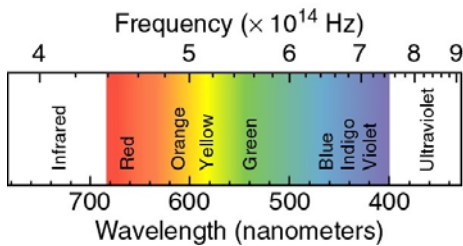
Reflection and refraction at a surface

Index of refraction $n = c/v > 1$



2

VISIBLE LIGHT



COLOR → WAVELENGTH or FREQUENCY
 Wavelength \times Frequency = c = speed of light
 e.g., $6 \times 10^{14} \text{ Hz} \times 500 \times 10^{-9} \text{ m} = 3 \times 10^8 \text{ m/s}$

3

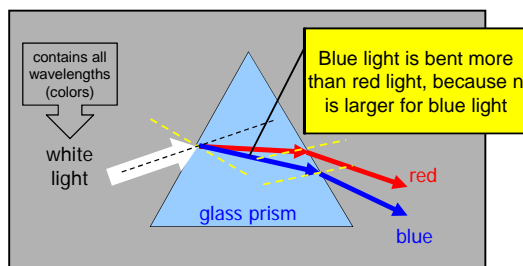
The index of refraction (n) depends of the color (wavelength) of the light

color	Wavelength (nm)	n
red	660	1.520
orange	610	1.522
yellow	580	1.523
green	550	1.526
blue	470	1.531
violet	410	1.538

1 nanometer (nm) = $1 \times 10^{-9} \text{ m}$

4

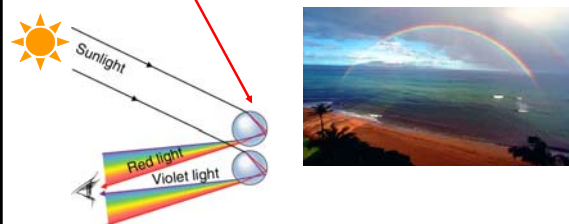
Different colors are refracted (bent) by different amounts, this phenomenon is called *dispersion*



5

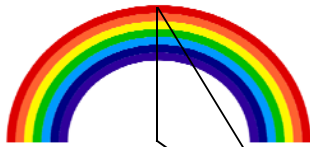
The rainbow

- Rainbows are caused by **dispersion of sunlight** from water droplets which act as tiny prisms



6

Why is it a rain BOW ?



The rain drops must be at just the correct angle (42°) between your eyes and the sun to see the rainbow. This angle is maintained along the arc of a circle.



7

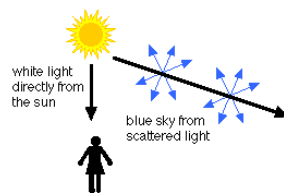
Atmospheric scattering

- Why is the **sky blue** and **sunsets red**?
- It is due to the way that sunlight is **scattered** by the atmosphere (N_2 and O_2)
- **Scattering** → atoms *absorb* light energy and *re-emit* it, but not at the same wavelength
- Sunlight contains a full range of wavelengths in the visible region

8

Atmospheric scattering: blue sky

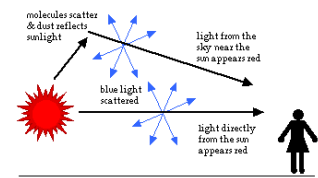
- Short wavelengths are scattered more than long wavelengths
- Blue light (short) is scattered 10 times more than red light
- The light that we see in the sky when not looking directly at the sun is scattered blue light



9

Atmospheric scattering: red sunset

- At sunset, the sun is low on the horizon
- When looking at the sun it appears red because much of the blue light is scattered out leaving only the red



10

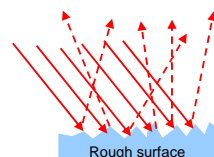
Why are clouds white?

- Clouds consist of *water droplets* and very *small ice crystals*
- **The water droplets and ice scatter the sunlight**
- Scattering by water and ice (particles) is very different from scattering by molecules
- The atoms are smaller than the wavelength of light, but the ice and water particles are larger
- Scattering by particles does not favor any particular wavelength so the white light from the sun is scattered equally → clouds are white!

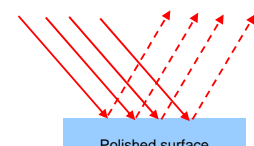
11

Mirrors → reflection

- Light does not pass through metal (e.g. Aluminum)
- Light is reflected at the surface
- Two types of reflection: **diffuse** and **specular**



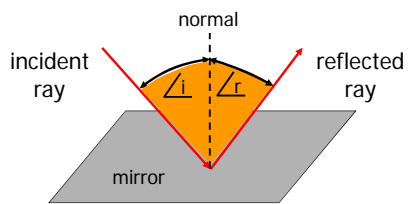
Diffuse reflection:
Fuzzy or no image



Specular reflection:
Sharp image

12

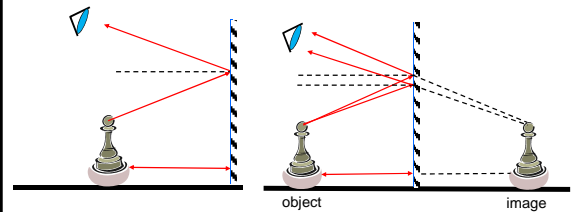
The law of reflection



- The incident ray, reflected ray and normal all lie in the same plane, and
- The angle of reflection = angle of incidence
 $\angle_r = \angle_i$

13

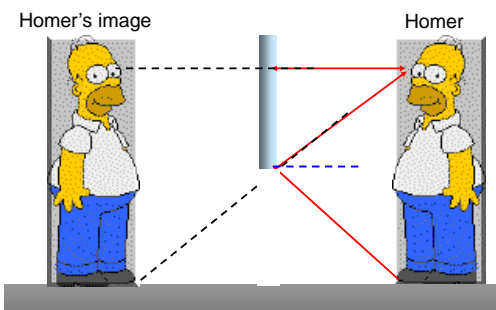
image formation by plane mirrors



- The reflected rays are **diverging** when they leave the object so they will not come to a focus point; our eyes perceive the reflected rays as coming from a point **behind** the mirror → this is called a **virtual image**
- A virtual image can be seen with our eyes but cannot be projected onto a screen (our eyes focus the diverging rays onto the retina)
- The image is the same distance behind the mirror as the object is in front of the mirror, and the image is the same height as the object

14

You only need a mirror half as tall as you are to see your whole self



15

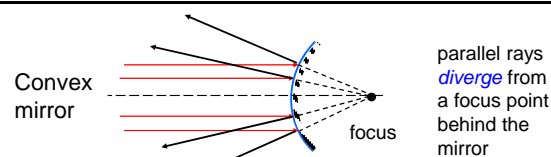
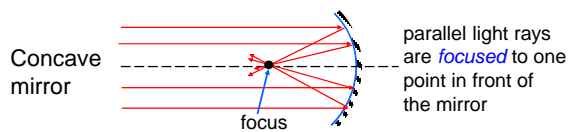
The image of your right hand is your left hand



AMBULANCE is printed backward so that you can read it correctly in your real-view mirror

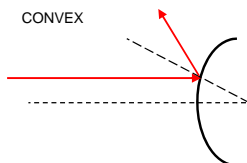
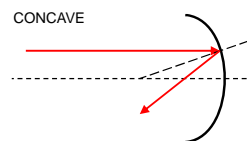
16

Spherical or curved mirrors



17

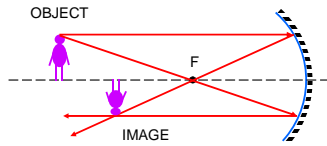
Reflection from a curved surface



- Reflection at a curved surface is governed by the law of reflection – **angle of reflection equals angle of incidence**.
- The direction of the normal changes from one point to another on a curved surface.

18

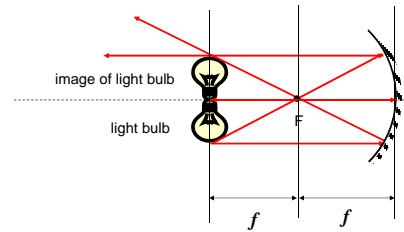
Real image formed by a concave mirror



When the object is at a distance greater than the focal point, the reflected light rays meet at a point in front of the mirror, so the image is **REAL**; it is **INVERTED** and **DIMINISHED** in size.

19

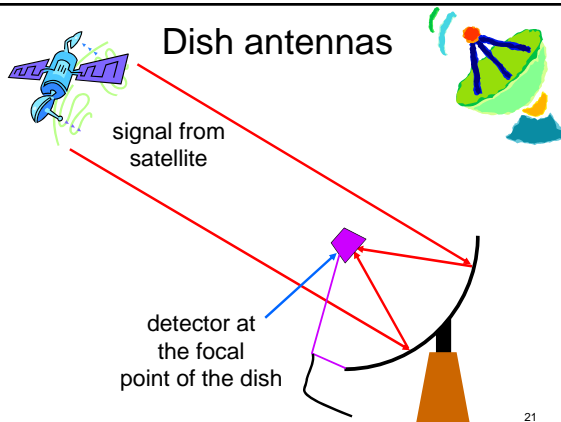
Where is the light bulb?



A concave mirror will form a *real* image of an object placed at twice its focal length at a distance of twice the focal length. It will be inverted and the same size as the object.

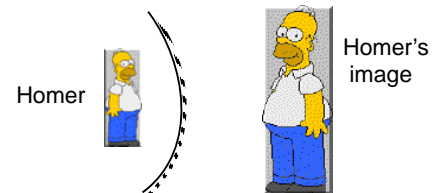
20

Dish antennas



21

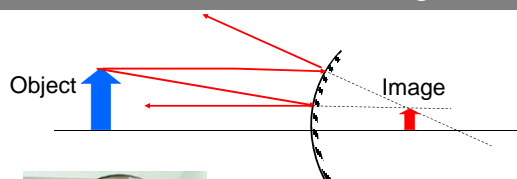
Magnifying mirrors



when something placed within the focus of a concave mirror, an enlarged, upright image is formed. this principle is used in a shaving or makeup mirror

22

Convex mirrors: wide angle view



A convex lens provides a **wide angle view**. Since it sees more, the images are reduced in size. Passenger side mirrors are often of this type with the warning: "**Objects appear farther than they actually are.**" Because they appear smaller, they appear to be farther away.

23