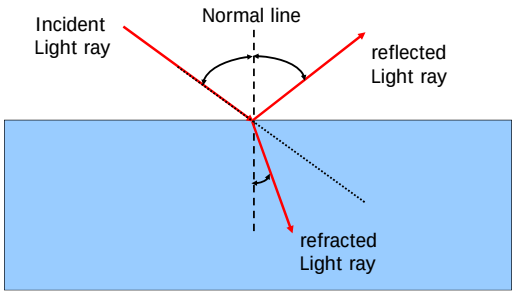
L 30 Light and Optics - 2

- Measurements of the speed of light (c)
- Index of refraction $v_{medium} = c/n$
  - 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



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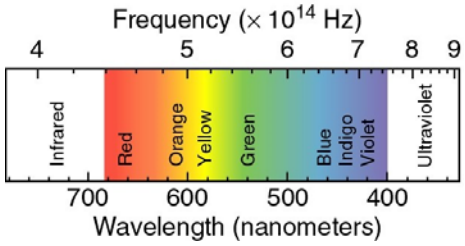
VISIBLE LIGHT



Color ➔ WAVELENGTH OR FREQUENCY

Wavelength × Frequency = c (speed of light)
= 3 x 10^8 m/s

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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 × 10^{-9} m

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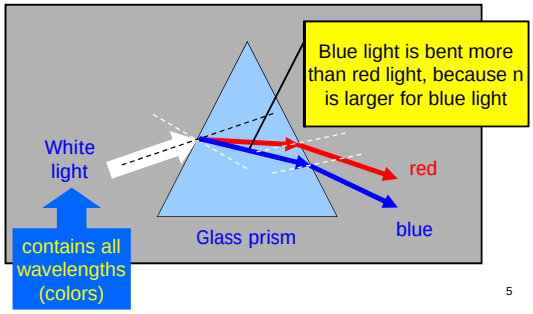
Different colors are refracted (bent) by different amounts, we call this *dispersion*



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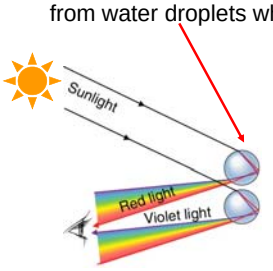
The rainbow

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



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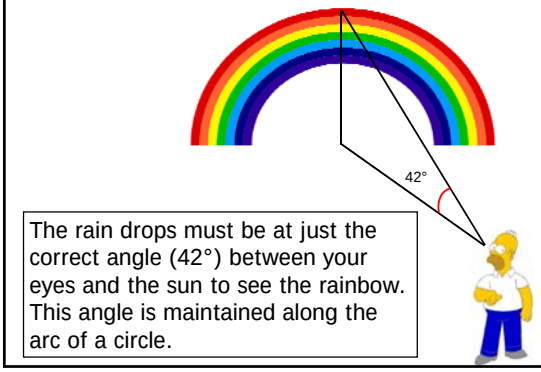
Why is it a rain BOW ?



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.

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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

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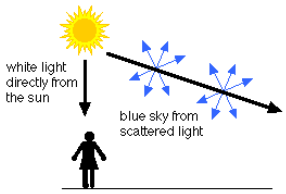
Atmospheric scattering: blue sky

- 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



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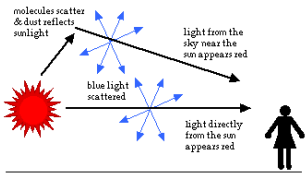
Atmospheric scattering: red sunset

- 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



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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!

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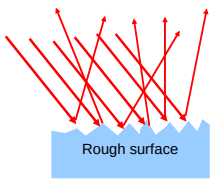
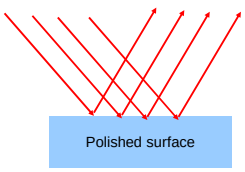
Mirrors → reflection

- Light does not pass thru metals – it is reflected at the surface
- Two types of reflection: diffuse and specular



Diffuse reflection: Fuzzy or no image



Specular reflection: Sharp image

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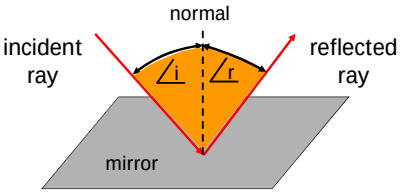
The law of reflection



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

$\angle r = \angle i$

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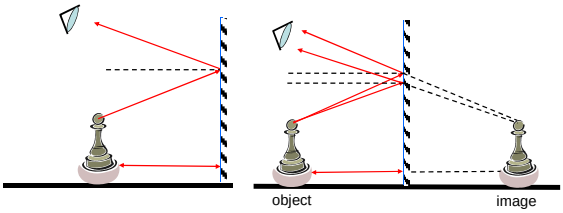
image formation by plane mirrors



• 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

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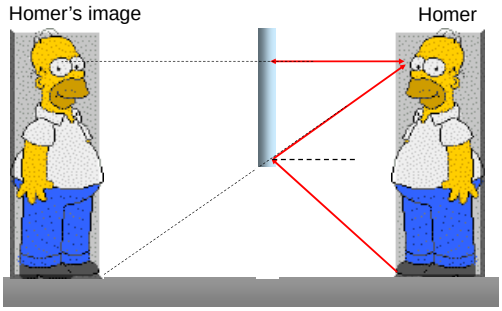
You only need a mirror half as tall as you are to see your whole self



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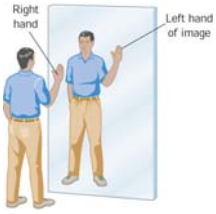
The image of your right hand is your left hand



AMBULANCE is painted backward so that you see it correctly in your real-view mirror

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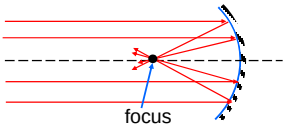
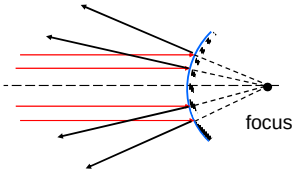
Spherical or curved mirrors

Concave mirror



parallel light rays are *focused* to one point in front of the mirror

Convex mirror



parallel rays *diverge* from a focus point behind the mirror

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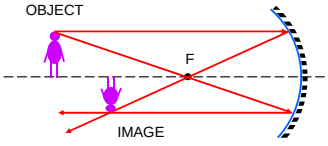
Real image formed by a concave mirror



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.

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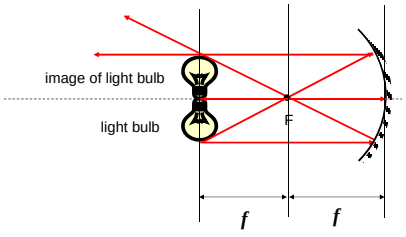
Where is the light bulb?



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.

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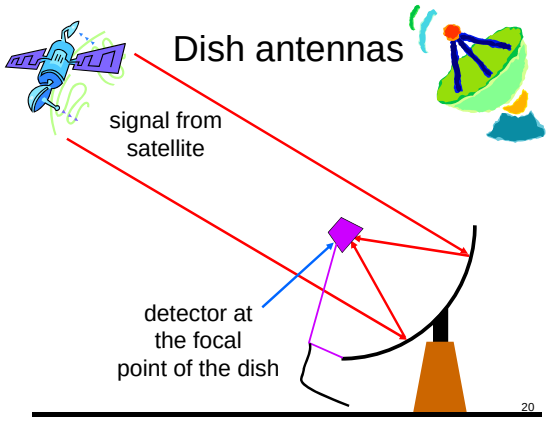
Dish antennas



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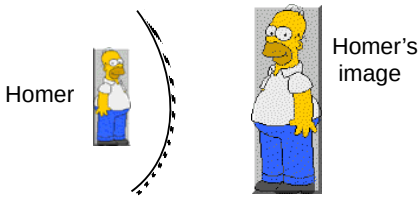
Magnifying mirrors



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

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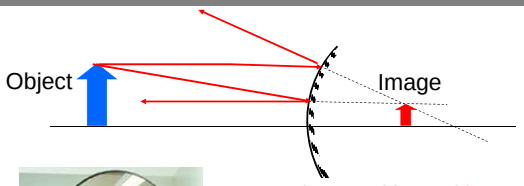
Convex mirrors: wide angle view



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.