Ways the Direction of Light Can Change

- **Reflection** **light path** ***bends back from a reflective surface*** **(e.g. mirror, surface of pond, table, chair, pen, etc......)**

- **Refraction** ***light path bends at interface*** **between two transparent media of** ***different indices of refraction*** **(densities).**

- **Scattering*** **light path changed by interaction with small particles (e.g. molecules, dust , etc..) about same size as light wavelength.**

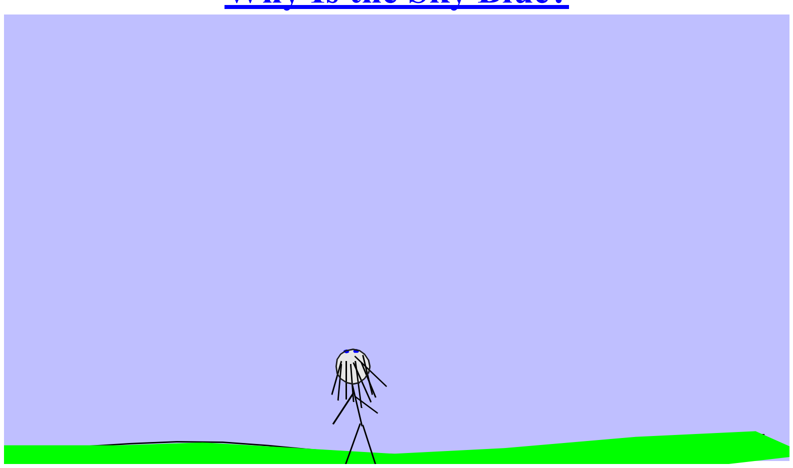
- **Dispersion*** **light paths are refracted by different amounts**

- **Diffraction*** **light waves interfere constructively and destructively**

Effect** ***stronger **for** **blue light** **than** **red light.**

Scattering of Light

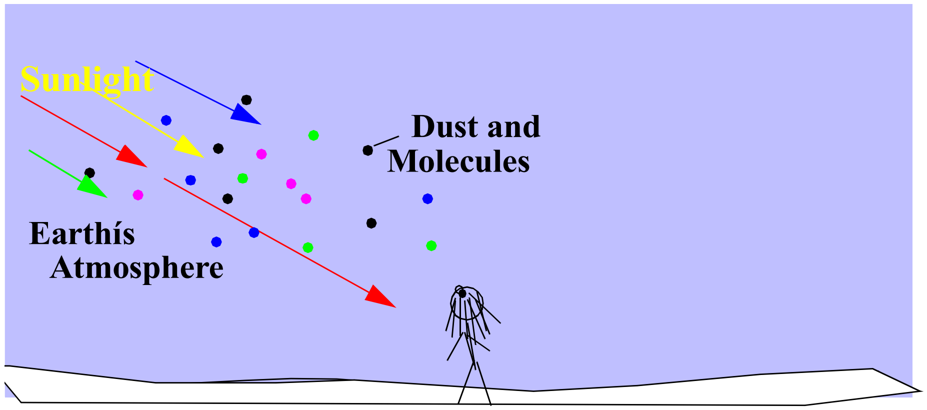
Why Is the Sky Blue?



Why does the whole sky appear blue in color?

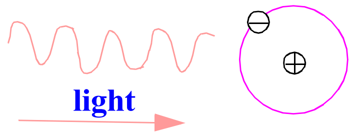
What color is the Sun? Why?

WHY IS THE SKY BLUE?

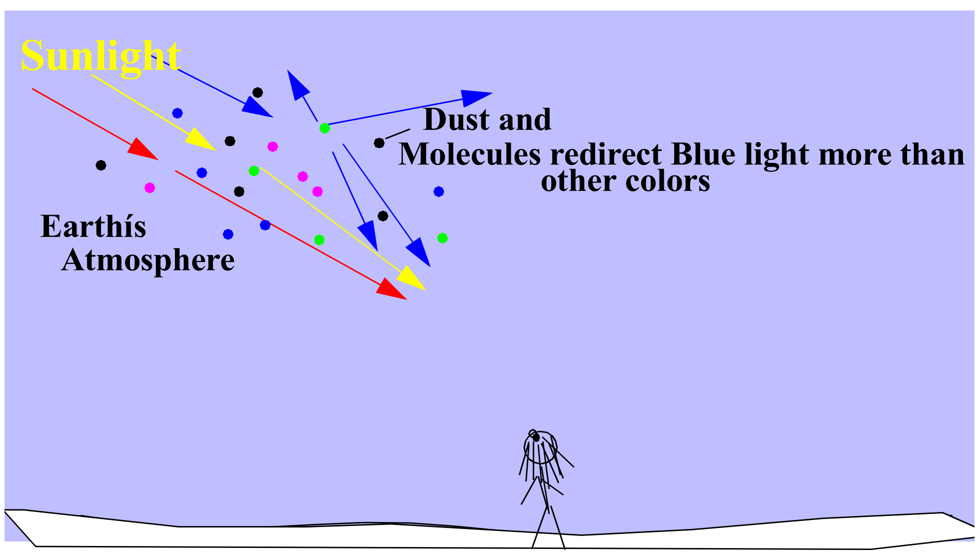


Light Scattering: Blue light is scattered (re-directed) in all different directions by dust and large molecules in the Earthís atmosphere *more than* other colors.

Atoms interact with light



Why Is the Sky Blue?

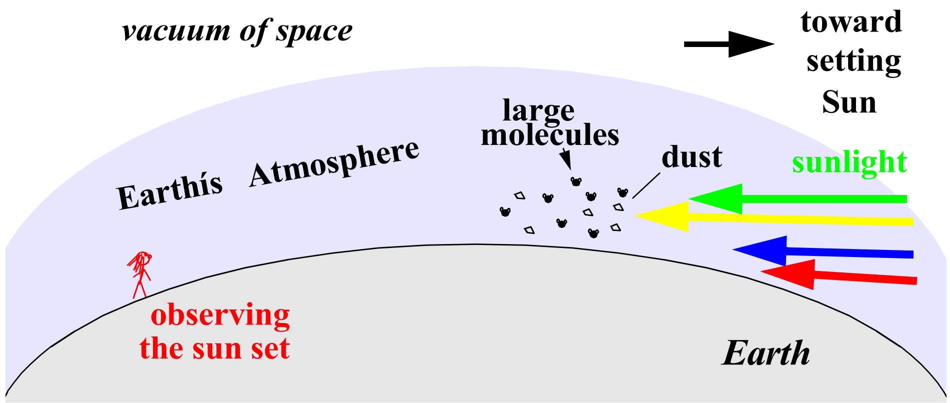


Blue light is scattered (re-directed) in all different directions by dust and large molecules in the Earthís atmosphere *more than* other colors.

Why does the whole sky appear blue in color?

What color is the Sun? Why?

Why Does the Setting Sun Look Red?



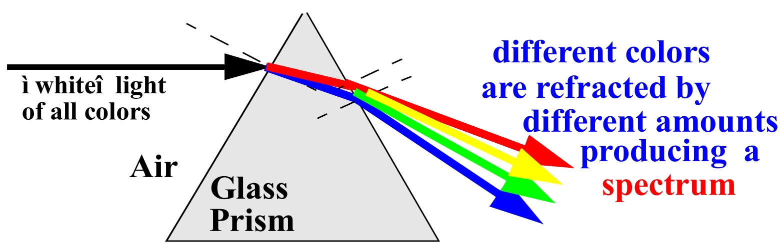
The Sun emits all colors of light. When the Sun sets, you see the Sun appear very low on the horizon. You must look at the setting sun through a long path through the Earthís atmosphere.

ï What do the molecules and dust in the atmosphere do to the different colors light coming from the sun?

ï How does ì scatteringî of the sunlight make the setting sun appear red?

Dispersion of Light

How Are Different Colors Refracted?



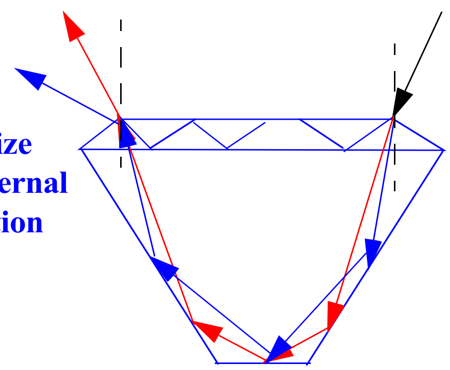
Dispersion: Light of different wavelengths (colors) refract (their light paths bend) by different amounts when light passes from one transparent medium (like air) into another transparent medium (like glass which has a different density, and a different ì index of refractionî).

The shorter the wavelength (higher the frequency) the more light is refracted.

Diamonds

What Causes Diamonds to Sparkle?

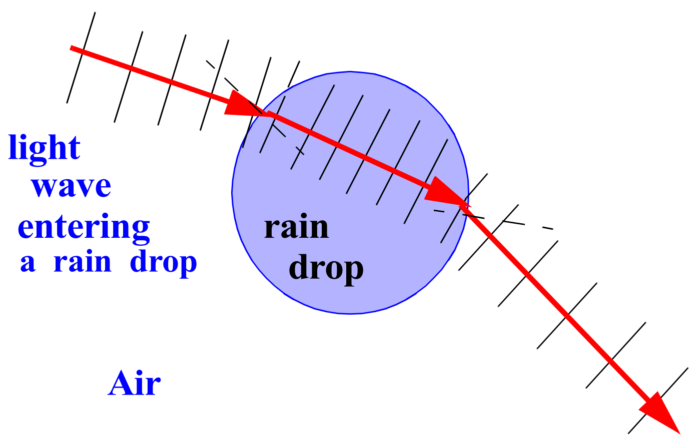
- Small critical angle for total internal reflection
- Cut so that virtually all light is reflected back out through the front surface
- Large index of refraction causes large dispersion and large separation of colors



n = 2.4 index of refraction
large, so dispersion or separation of colors very large

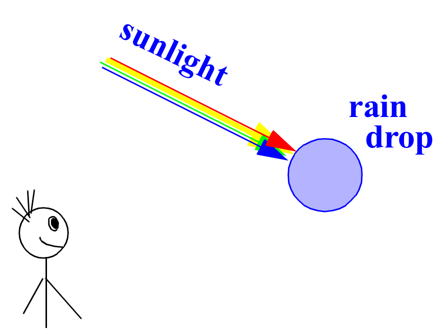
Rainbows

How Does a Rainbow Form?

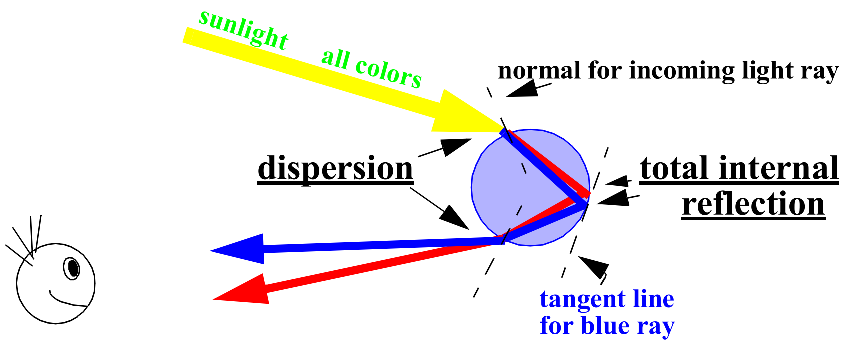


Light slows down at the air-water interface, and speeds up at the water-air interface.

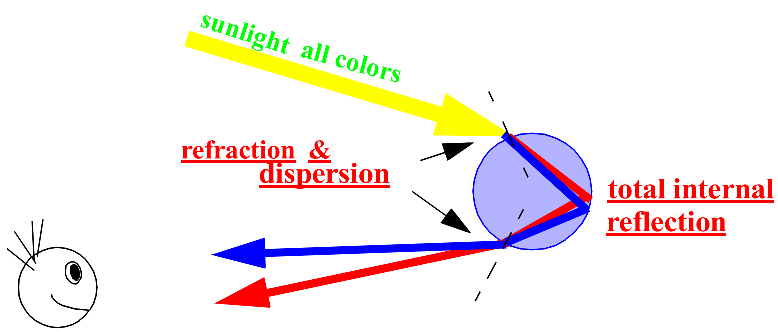
What are all of the things that can happen to these light rays?



Rainbow Formation

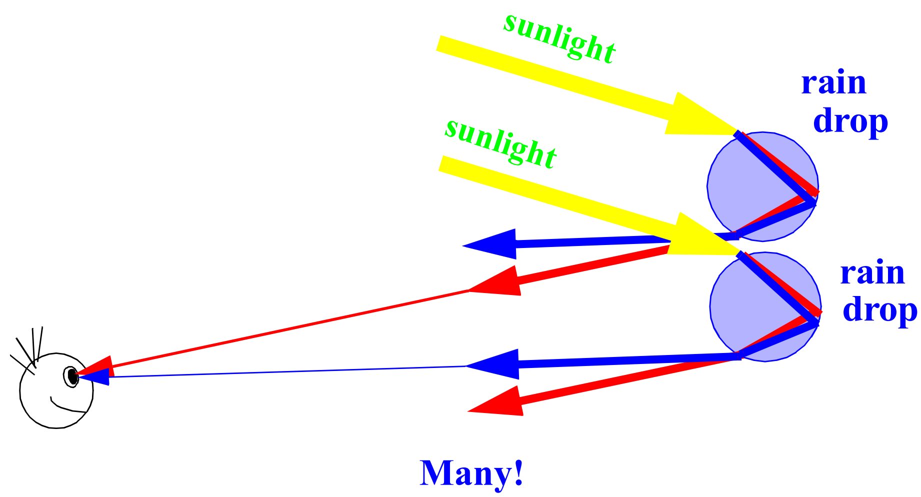


What Causes a Rainbow?

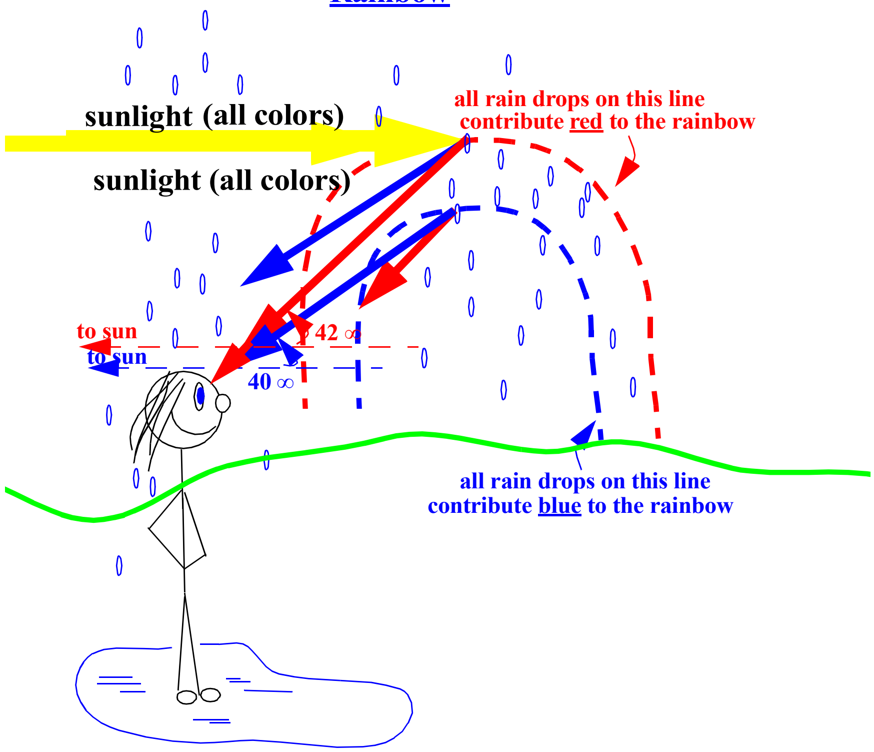


Two refractions + one total internal reflection

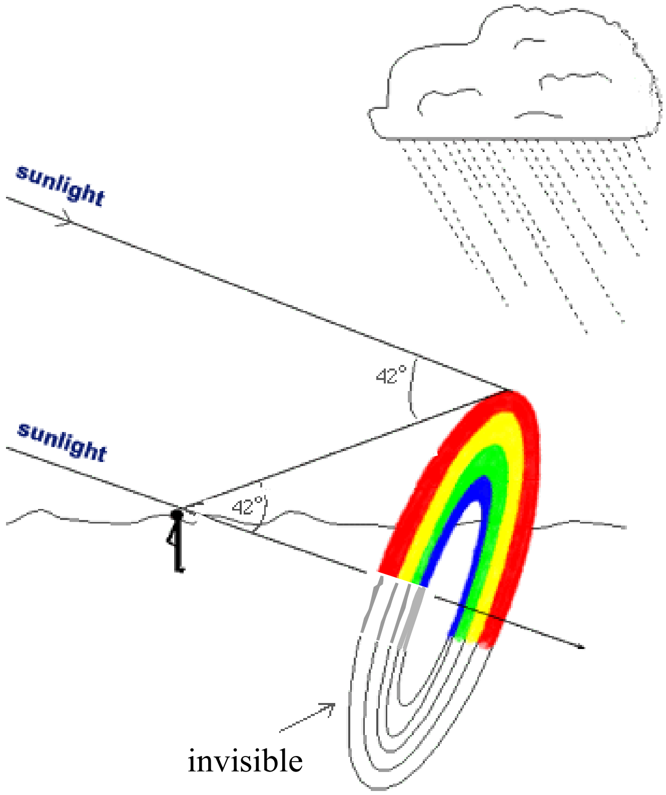
Why Are Many Raindrops Needed to See a Rainbow?



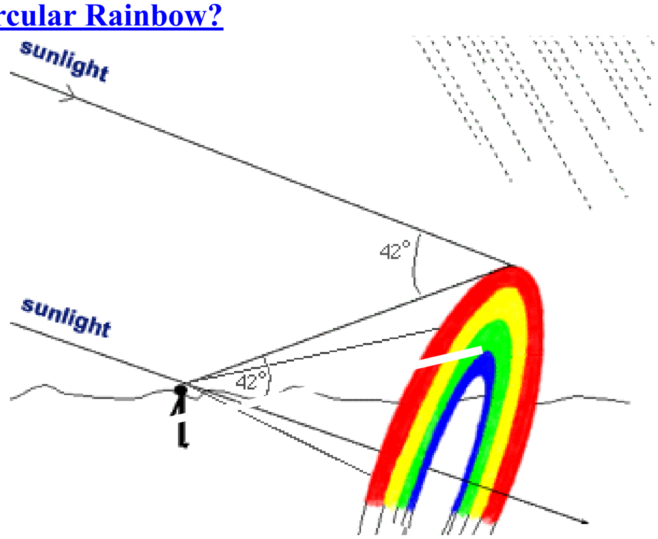
Rainbow



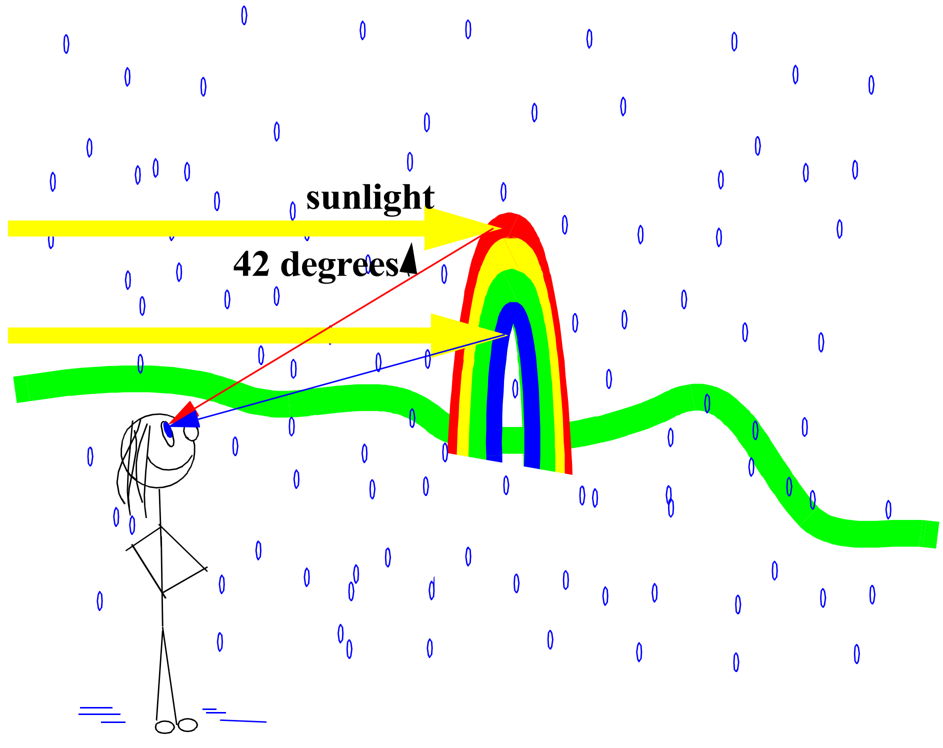
Why Do We See only Half a Rainbow?



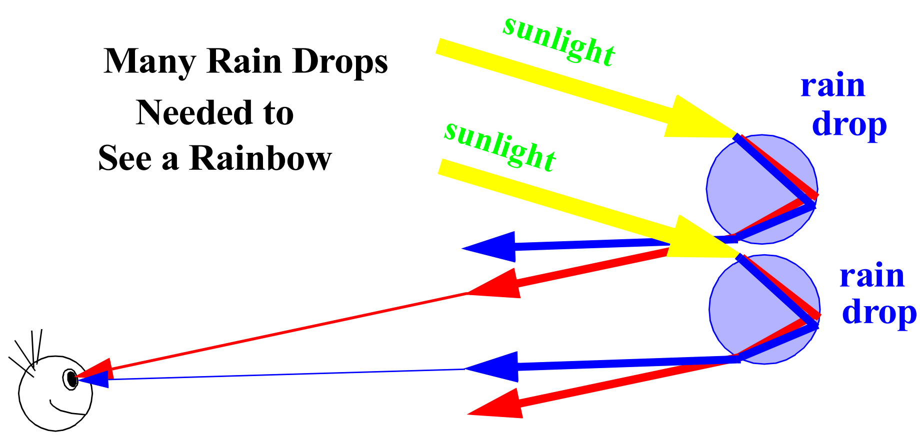
Why Do We See a Circular Rainbow?



In the right conditions, every one sees a ì personalî rainbow.



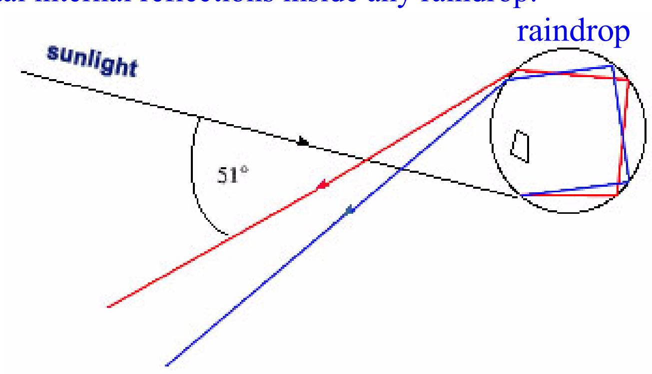
WHY ARE MANY RAINDROPS NEEDED TO SEE A RAINBOW?



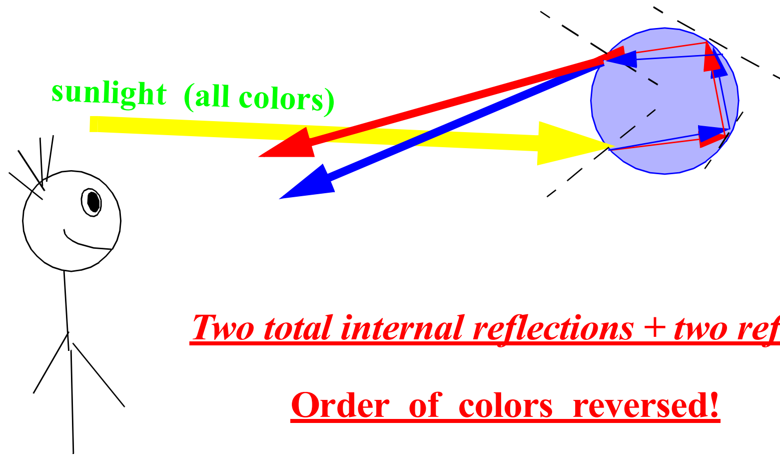
Double Rainbow

What Causes a the Secondary Rainbow?

Sunlight can have 2 total internal reflections inside any raindrop:



Double Rainbow

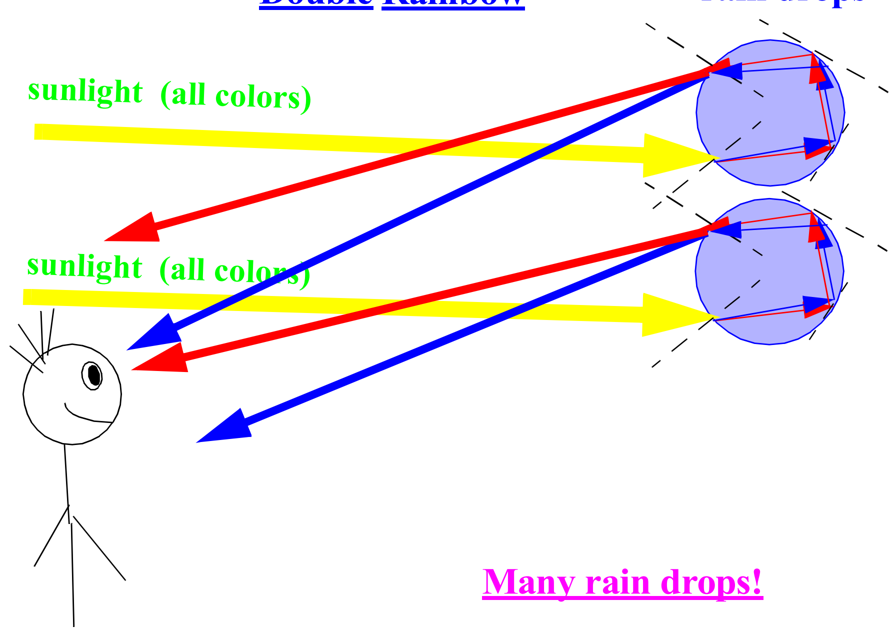


Two total internal reflections + two refractions

Order of colors reversed!

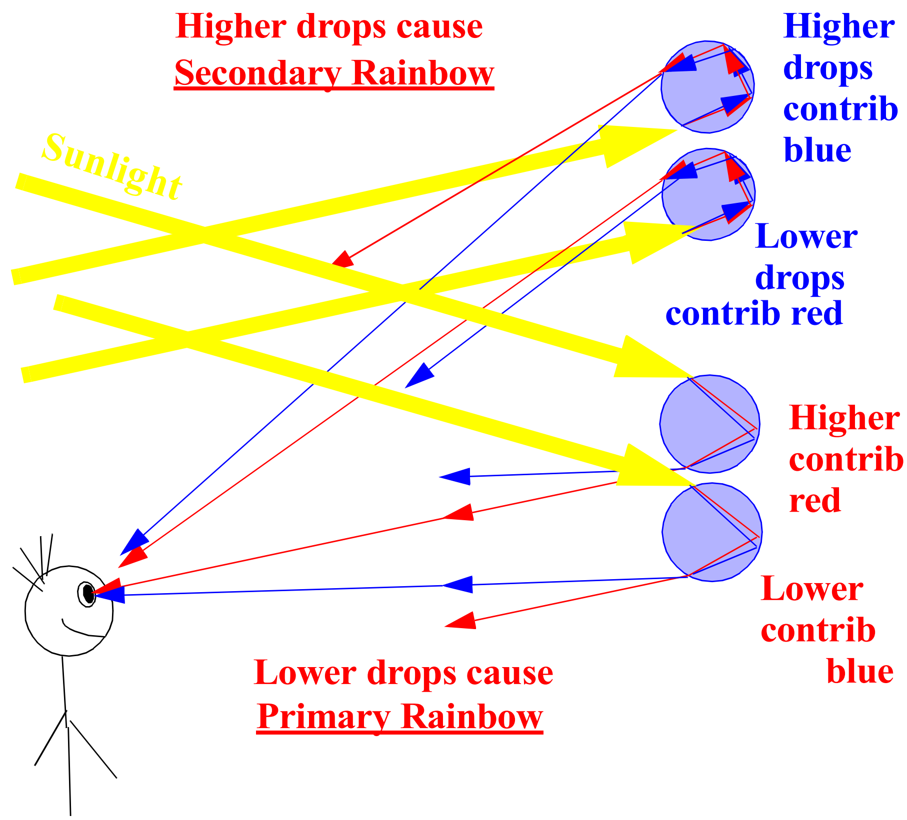
How many rain drops does it take to see all the colors in a double rainbow?

Double Rainbow

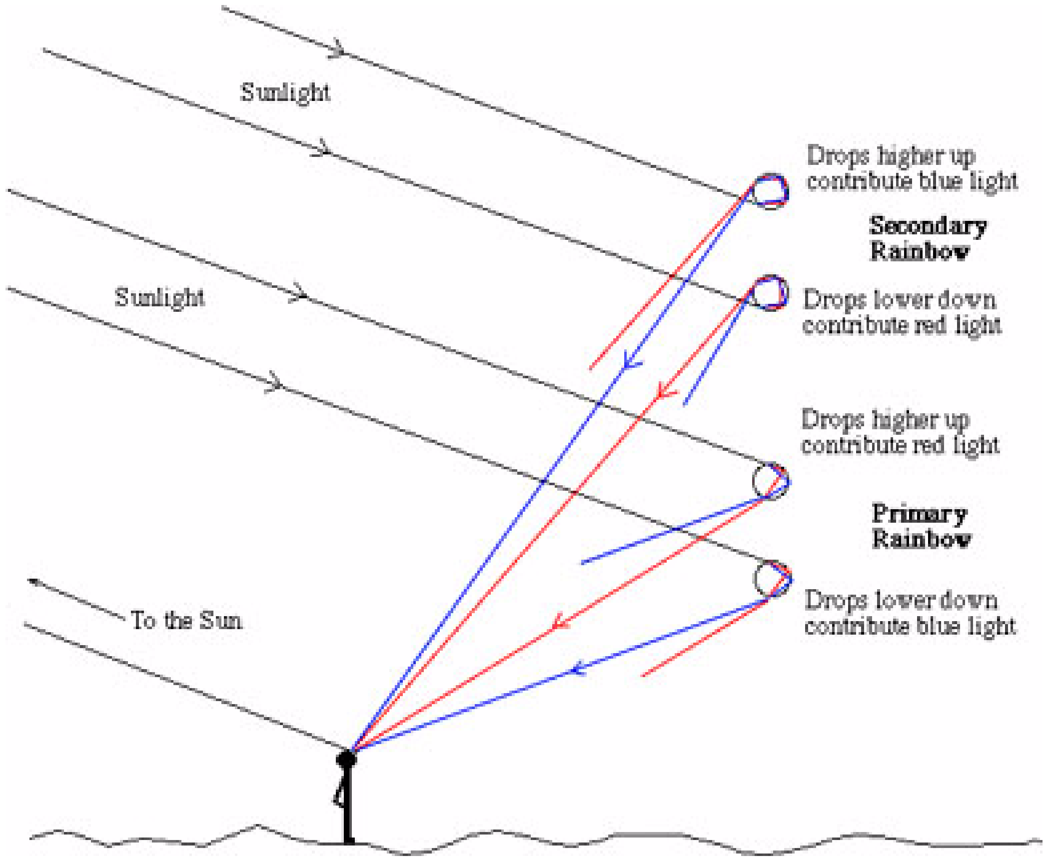


Many rain drops!

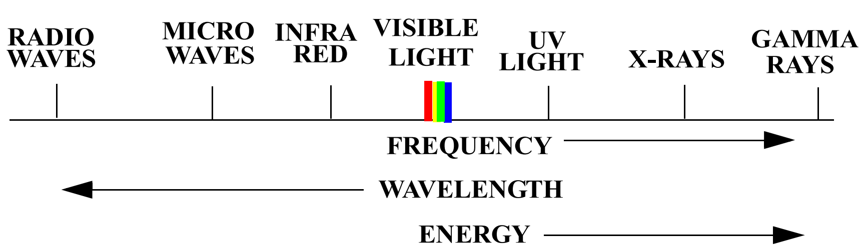
Why is the Secondary higher than Primary Rainbow?



Secondary Rainbow: Why is the Color Order Reversed?



Electromagnetic Spectrum



<u>**Energy of an Electromagnetic Wave**</u>

$$E = const \times frequency$$

$$E = hf$$

$$frequency = \frac{c}{wavelength}$$

$$E = \frac{hc}{wavelength} = \frac{hc}{\lambda}$$

where E = energy carried by an electromagnetic wave in units of *Joules*

f = frequency of an electromagnetic wave in units of *Hertz* (cycles/sec)

λ = wavelength of an electromagnetic wave in units of *meters*

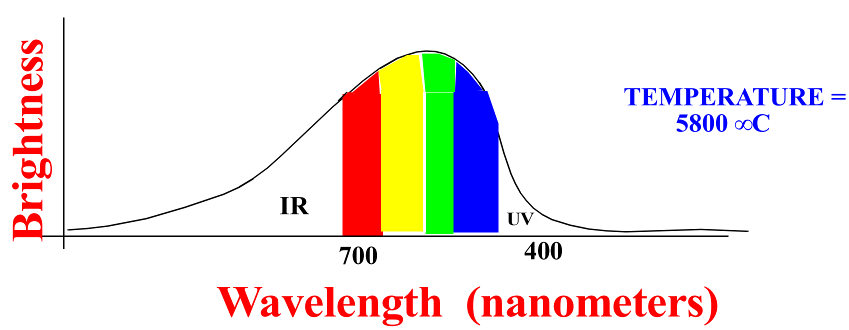
c = speed of an electromagnetic wave = 300,000 km/s in a vacuum.

h = Planckís constant = 6.6×10^{ñ34} Joule second

Our eyes are sensitive only to the:

<u>**Visible Light Part of the Electromagnetic Spectrum**</u>

<u>**Sunlight**</u>



Particle Model for Light

E = hf = energy of one *photon* of light

h = Planckís constant = 6.6×10^{-34} J s

f = frequency of light (Hz)

E is in units of Joules per photon

λ = wavelength of light (nm)

$$\lambda = \frac{c}{f}$$

$$E = \frac{hc}{\lambda} = \text{energy of one photon}$$

How many photons does a 100 Watt light bulb emit each second?

(Remember: 100 Watts = 100 Joule/sec)

Energy(light bulb) = 100 Joules/s

E(one photon) = hf Joules/photons

$$\text{No. photons} = \frac{E_{LB}}{E_{photon}} = \frac{100}{(hf)}$$

$$= \frac{100\,W}{6.6x10^{ñ34}\,Jsx10^{15}\,Hz}$$

$= 1.5 \times 10^{20}$ photon/sec

So <u>100 Watt light bulb</u> emits 150,000,000,000,000,000,000 photons each sec!!

or 150 million trillion photons every sec..