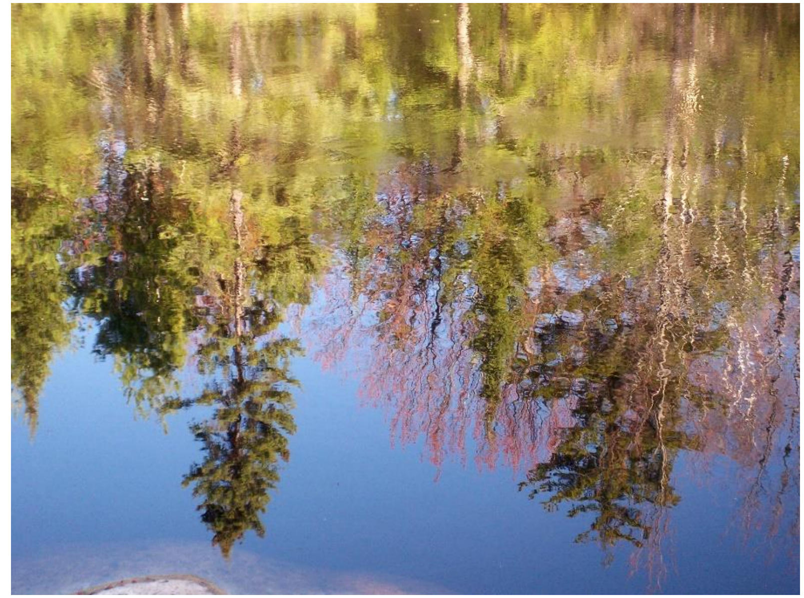
Unit 3: Reflection, Refraction and Dispersion of Light

1. Reflection of Light. Images in Plane Mirrors.
2. Refraction of Light. Snell's Law.
3. Total Internal Reflection.
4. Dispersion of Light.

Reading: Ch.2 of the textbook and material posted on Blackboard.

What is the difference between these reflections?



Non-polished surfaces diffusely reflect (scatter) light in all directions.

Photos: Maia Nenkova

1. Reflection of Light on Boundaries.

*Specular Reflection: **i = r***

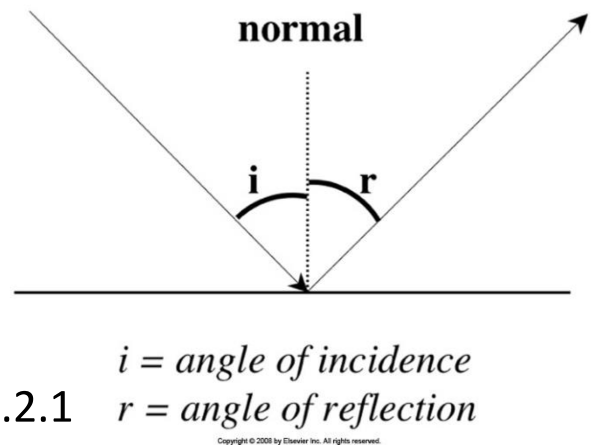


Fig.2.1

Terminology:

- Incident ray of light
- Reflected ray of light
- Angle of incidence (i) and angle of reflection (r) are measured in respect to the normal.

The law of specular (mirror) reflection:
the angle of incidence is equal to the angle of reflection,

$$i = r$$

Plane Mirrors

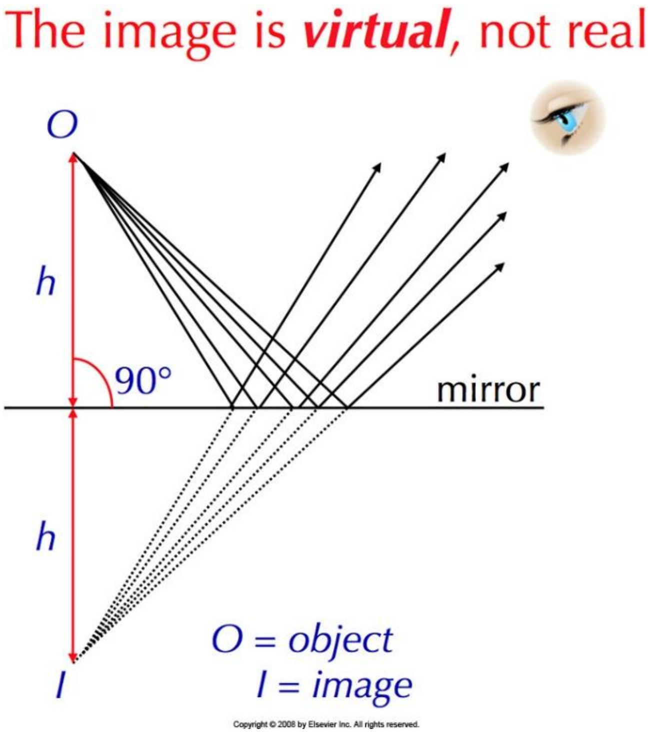


Fig.2.2

The diverging reflected rays of object O behave as if originating from the image I.

- The image I is virtual, at a point behind the plane of the mirror.
- The image I is at the same distance behind the mirror as the object is from the mirror.
- No real light rays originate from the image.

How a plane mirror forms an image:
http://www.physicsclassroom.com/mmedia/optics/ifpm.cfm

The reflectivity curves determine the reflected colour:

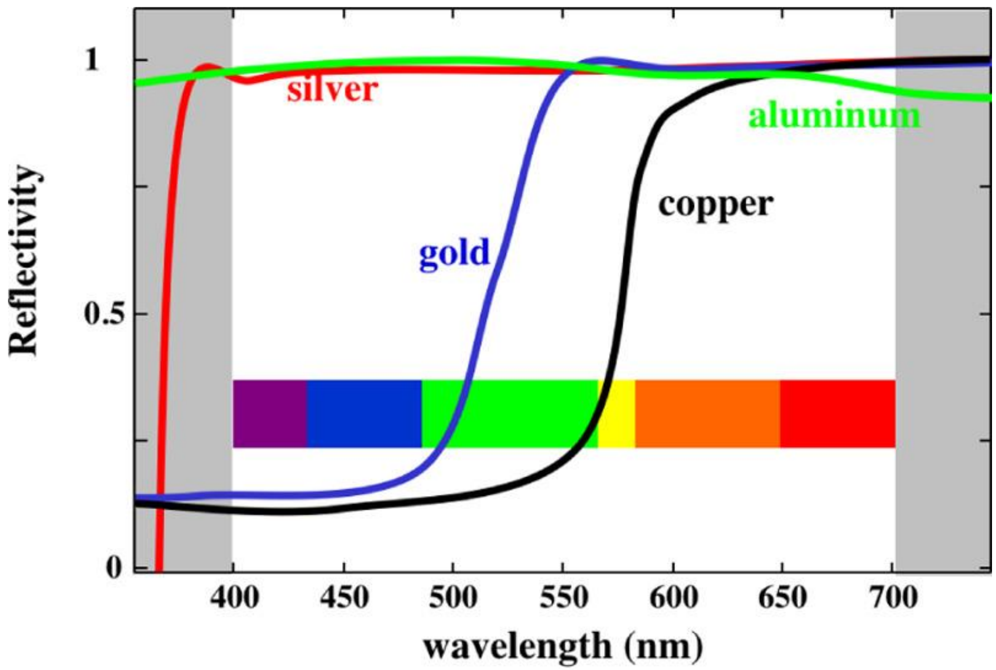


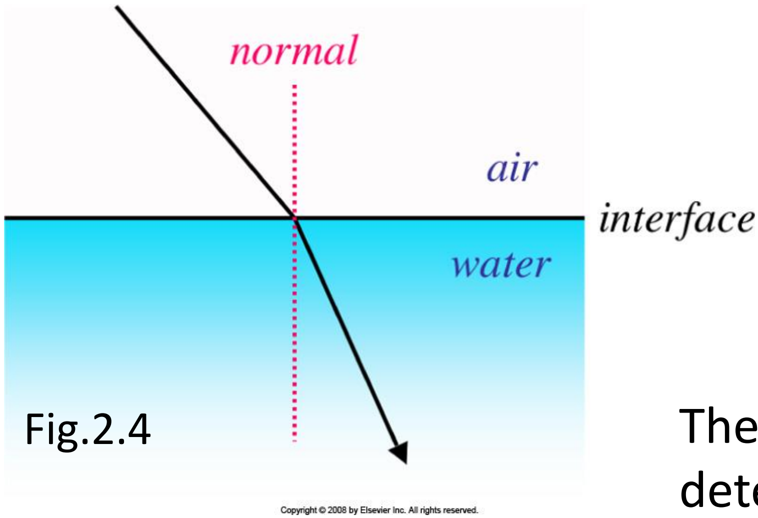
Fig.2.3

Gold absorbs blue – appears yellow;

Copper absorbs blue and green – looks orange-red;

Silver and Aluminum have flat reflectivity curves across the visible spectrum – they appear gray; they are the best materials for mirrors.

2. Refraction of Light.



Observation: when light travels from a less dense to a denser medium in bends toward the normal, and it slows down.

The speed of light in vacuum is c = 3×10^8 m/s.

The index of refraction of a medium determines the speed of light in it:

$$v = \frac{c}{n}$$

The index of refraction depends on the density of the medium.

Material	n
Vacuum	*1.00000*
Air at 0°C	*1.00029*
Water at 20°C	*1.33*
Plexiglass	*1.50*
Glass (crown)	*1.52*
Cubic zirconia	*2.16*
Diamond	*2.42*

Snell's Law: $n_a \sin\theta_a = n_m \sin\theta_m$

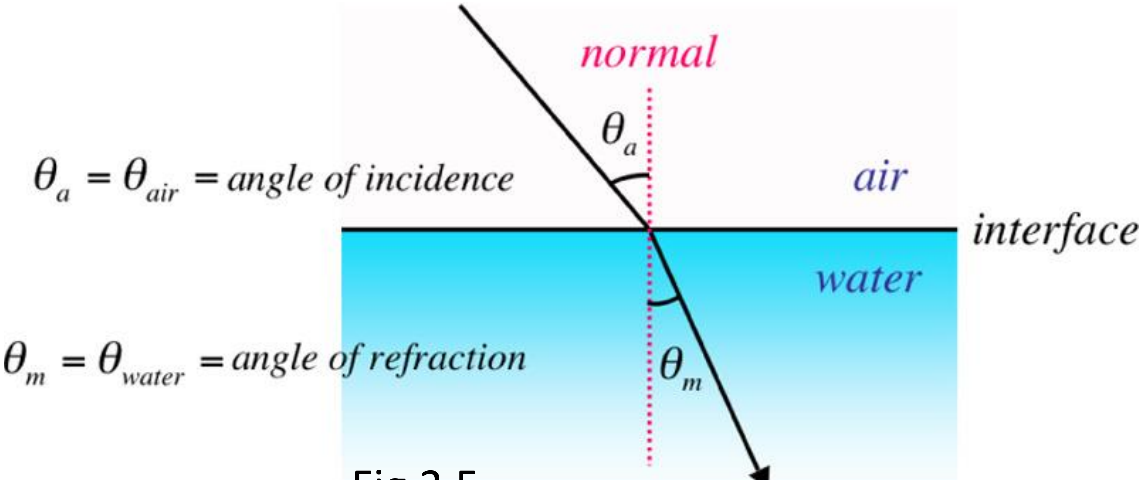


Fig.2.5

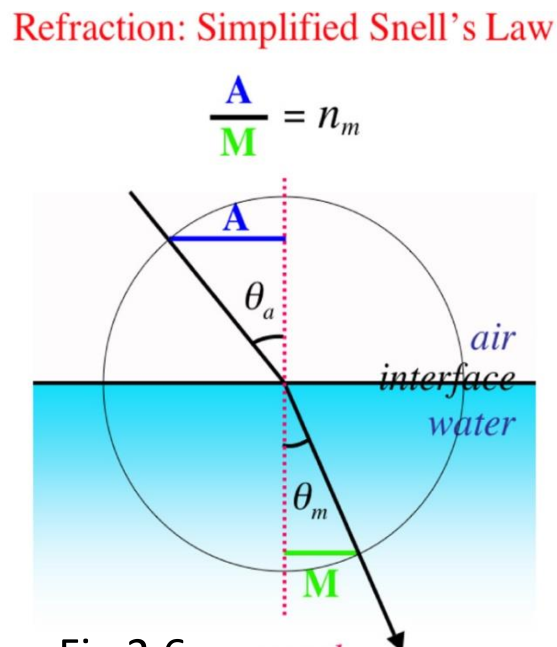


Fig.2.6

Rays are reversible – they can be traced backward
(from water to air in the figures).

3. Total Internal Reflection.

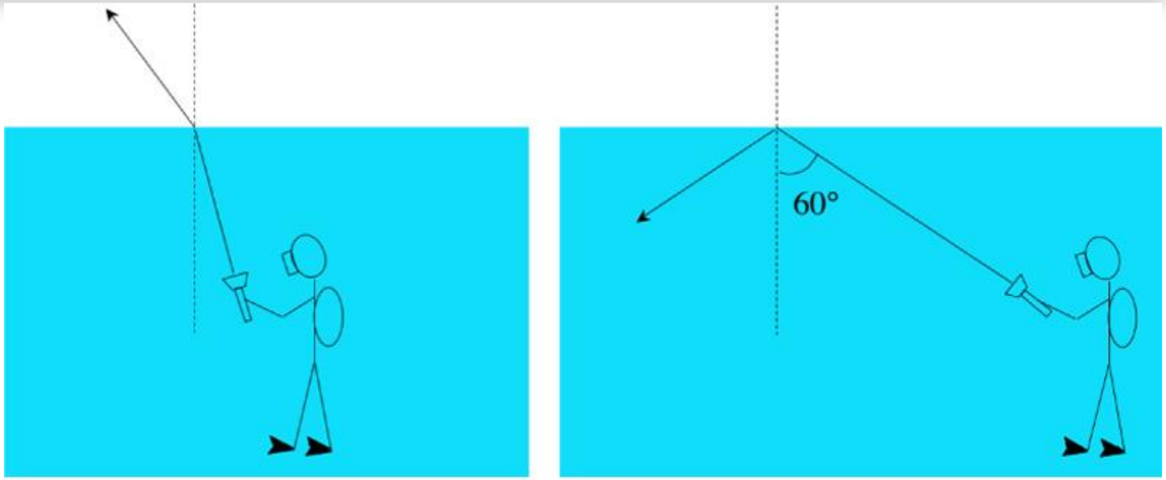


Fig.2.7

Observed when

- the incident ray travels from a denser to less dense medium, and
- the angle of incidence is greater than the critical angle

To find the critical angle substitute $n_a = 1$ and $\sin 90^{o} = 1$ in Snell's law.

$$\sin\theta_c = \frac{1}{n_m}$$

Example: reflection and refraction in diamonds.

- Find the critical angle of total internal reflection in diamonds.

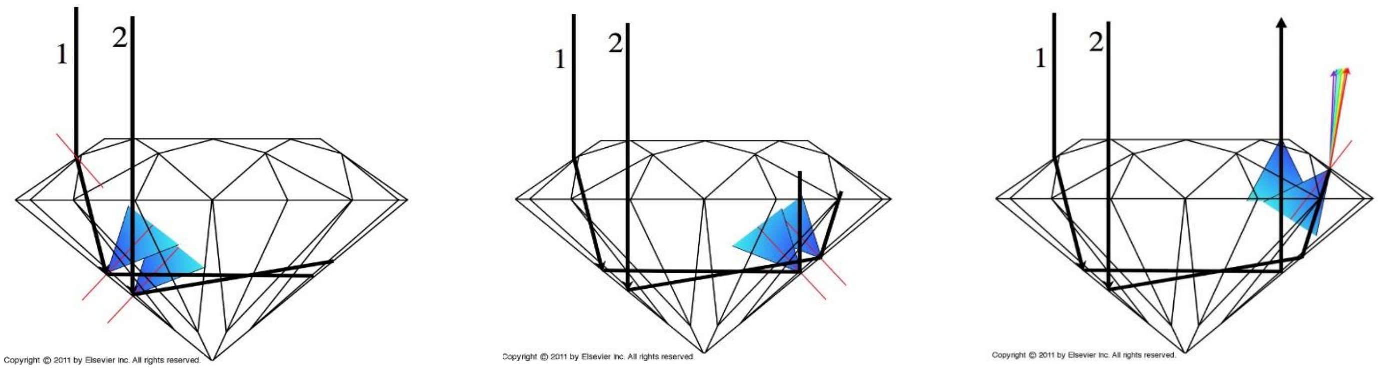
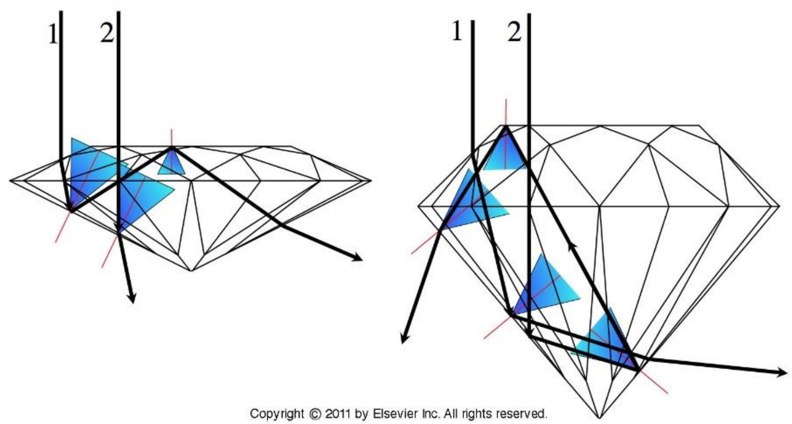


Fig.2.12-2.14 Rays 1 and 2 will undergo total internal reflection if they reach the inner surface at angles greater than the critical angle.

Fig.2.15 If the diamond is cut too shallow, or too deep, some light will be lost in refraction to air and there will be less sparkle.



Optical illusions as result of refraction from denser to less dense medium

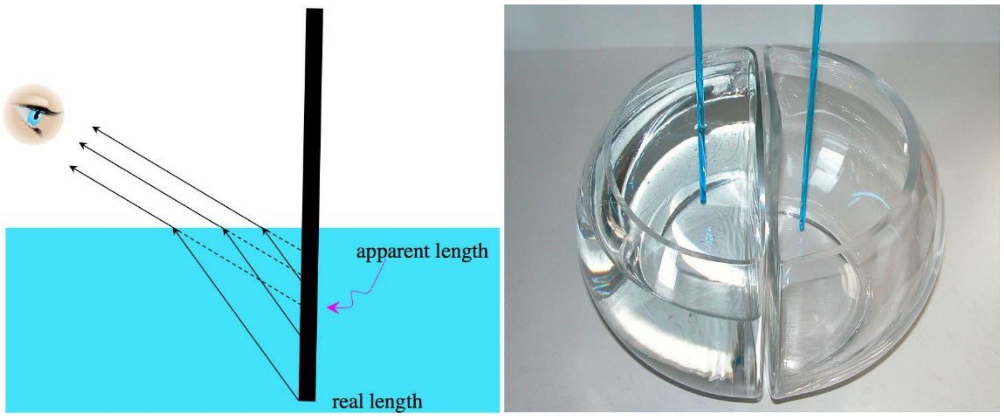
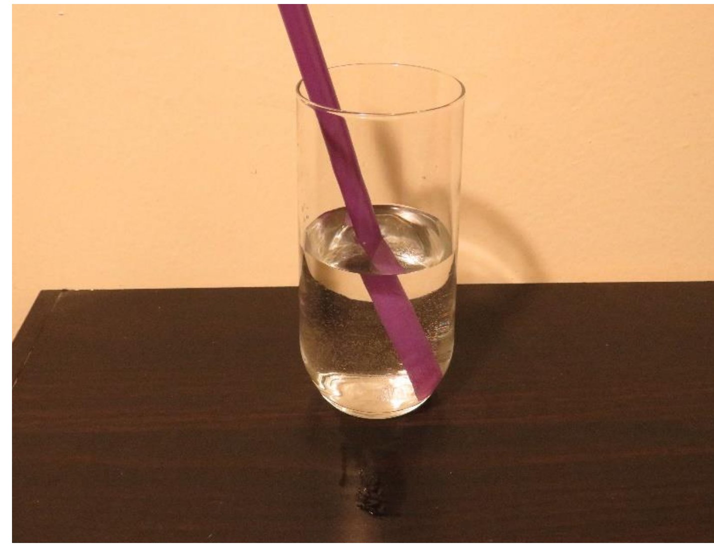


Fig.2.8



A vertical stick under water appears to be shorter, due to refraction. If the stick is not vertical, it will appear bent at the air-water interface.

How deep is the fish?

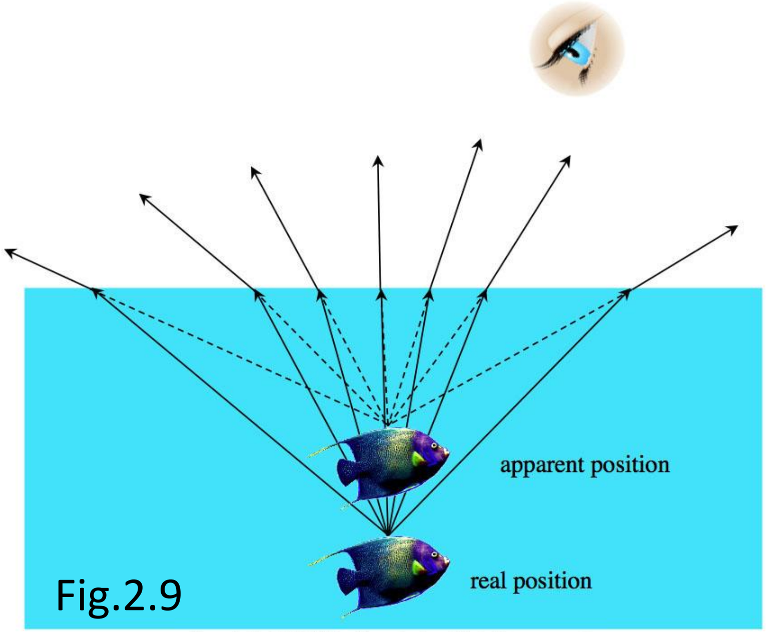


Fig.2.9

If you look from above the fish appears closer to the surface, but its size is not changed.

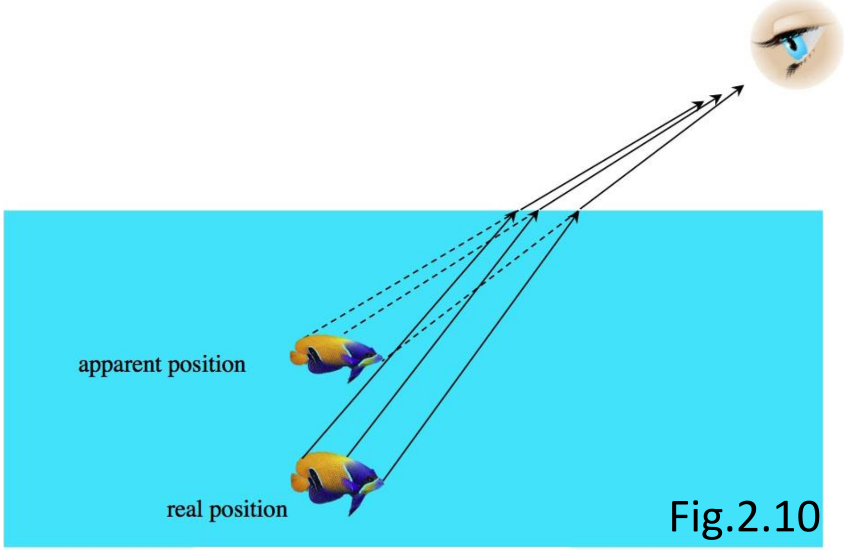


Fig.2.10

If you look at an angle the fish appears closer to the surface, and vertically compressed.

4. Dispersion of Light.

The index of refraction depends slightly on wavelength, which causes dispersion of natural light.

Example: typical glass has n_{violet} = 1.53, but n_{red} = 1.51 (Violet has λ = 400 nm; red has λ = 700 nm).

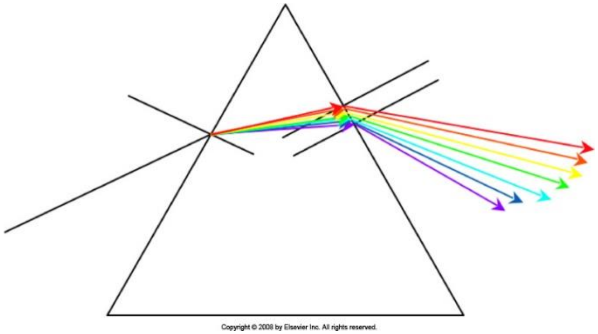
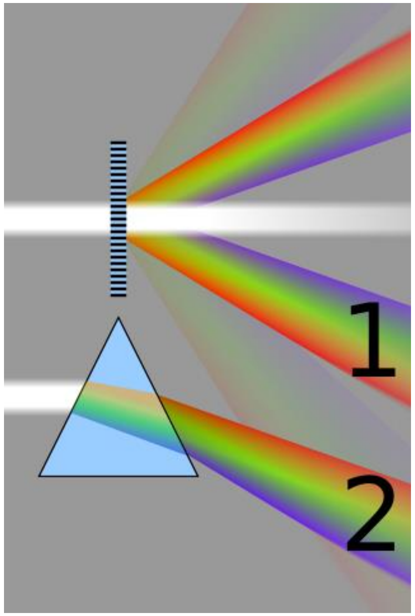


Fig.6.1

In dispersion violet deflects more than red, which is the opposite of the case of diffraction.

Can you explain this?



Under the rainbow …

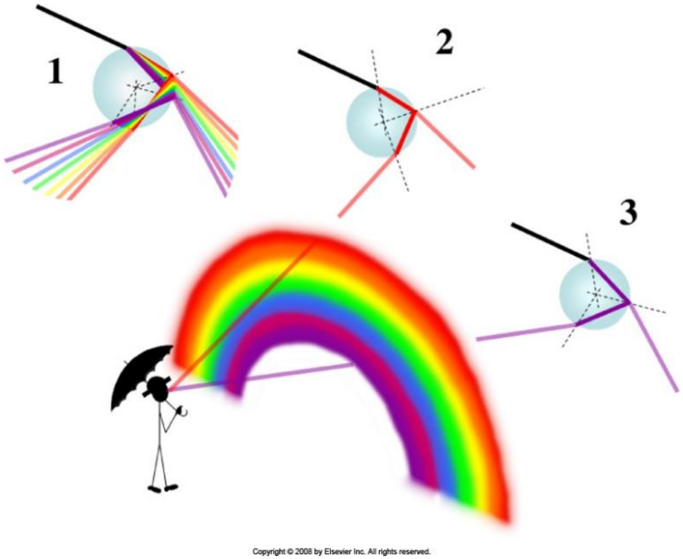


Fig.2.19

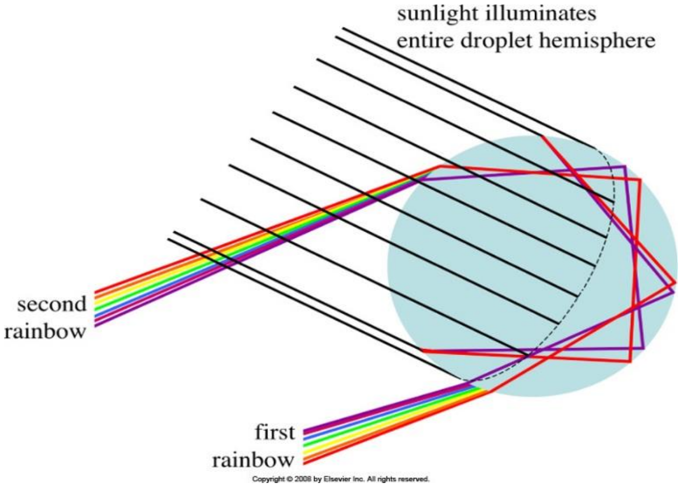


Fig.2.21