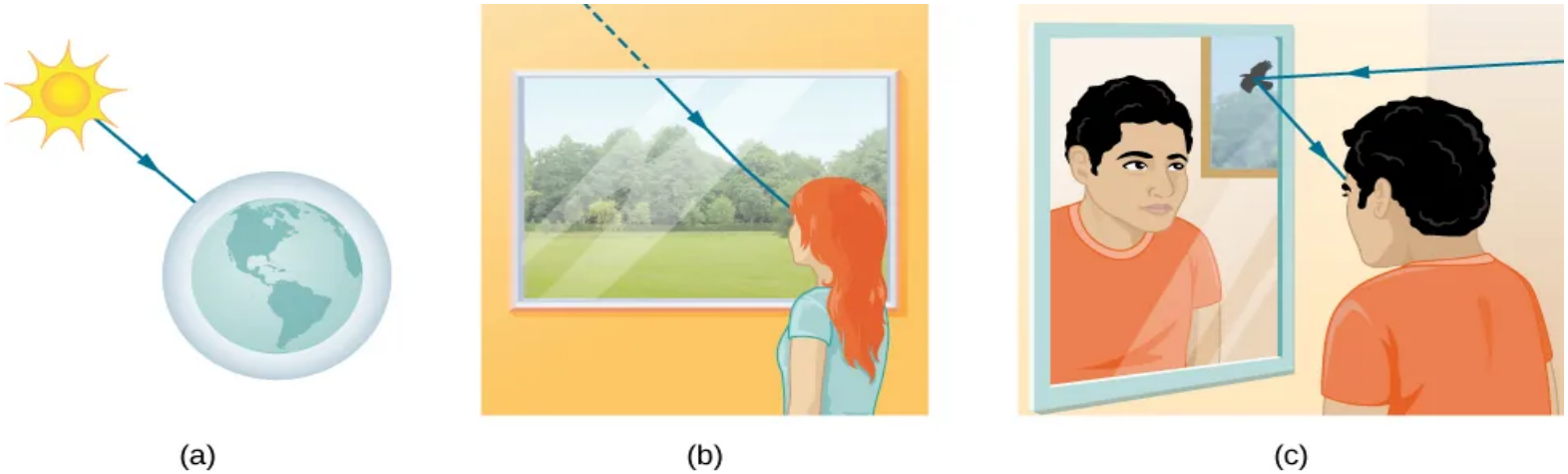
# Ray Model of Light

3 ways light can travel from a source to another location



(a) (b) (c)

a directly from source through vaccum . Sun to Earth

b light can travel through various media like Air, glass, water to the observer

c light can also arrive after being reflected such as mirrors

## Ray of Light

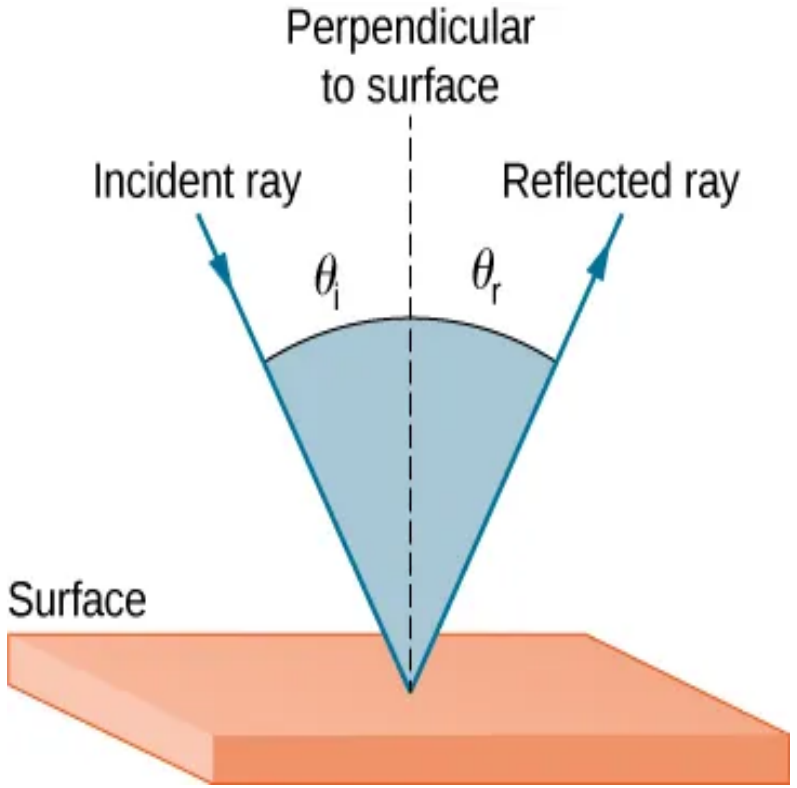
We model path of light as a straight line called ray

- Light behaves both as a particle and a wave
- When light interacts with an object several times larger than its wavelength($\approx 10^{-6}$), it travels in a straight line and acts like a ray.
- Light may change direction when it
  - reflection : encounters objects (such as a mirror)
  - refraction: passing from one material to another (such as in passing from air to glass)

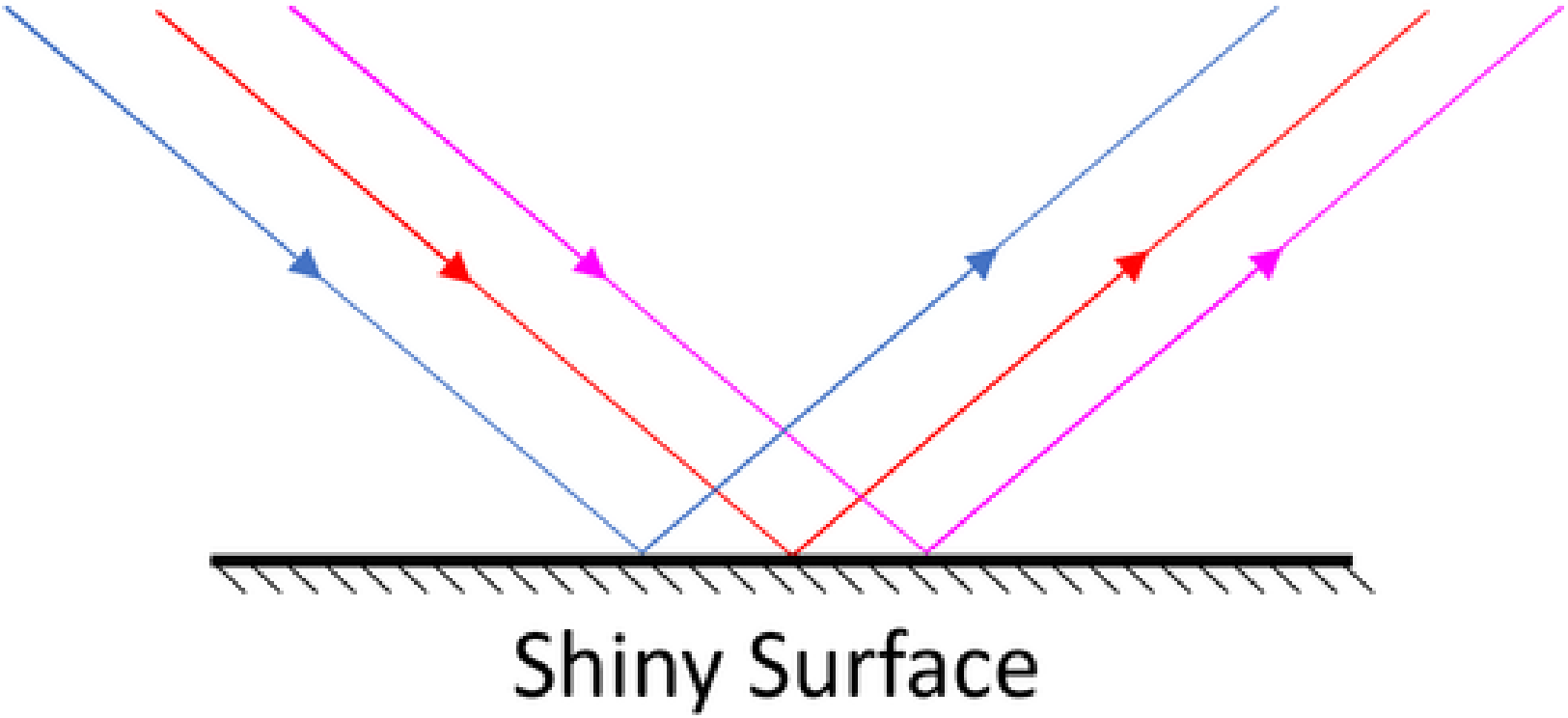
## Law of Reflection

the law states that agle of reflection is equal to angle of incidence

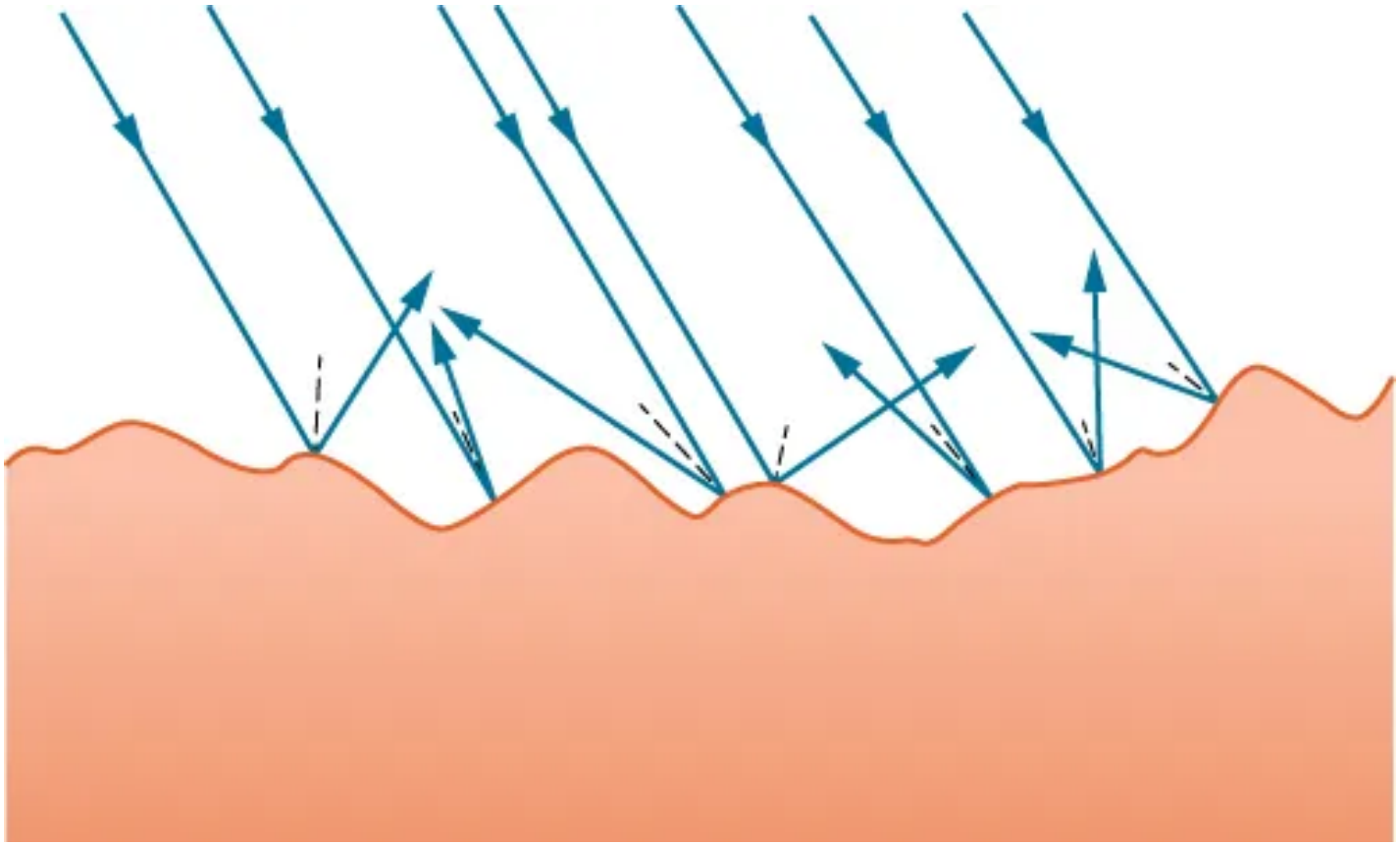
$$\theta_r = \theta_i$$

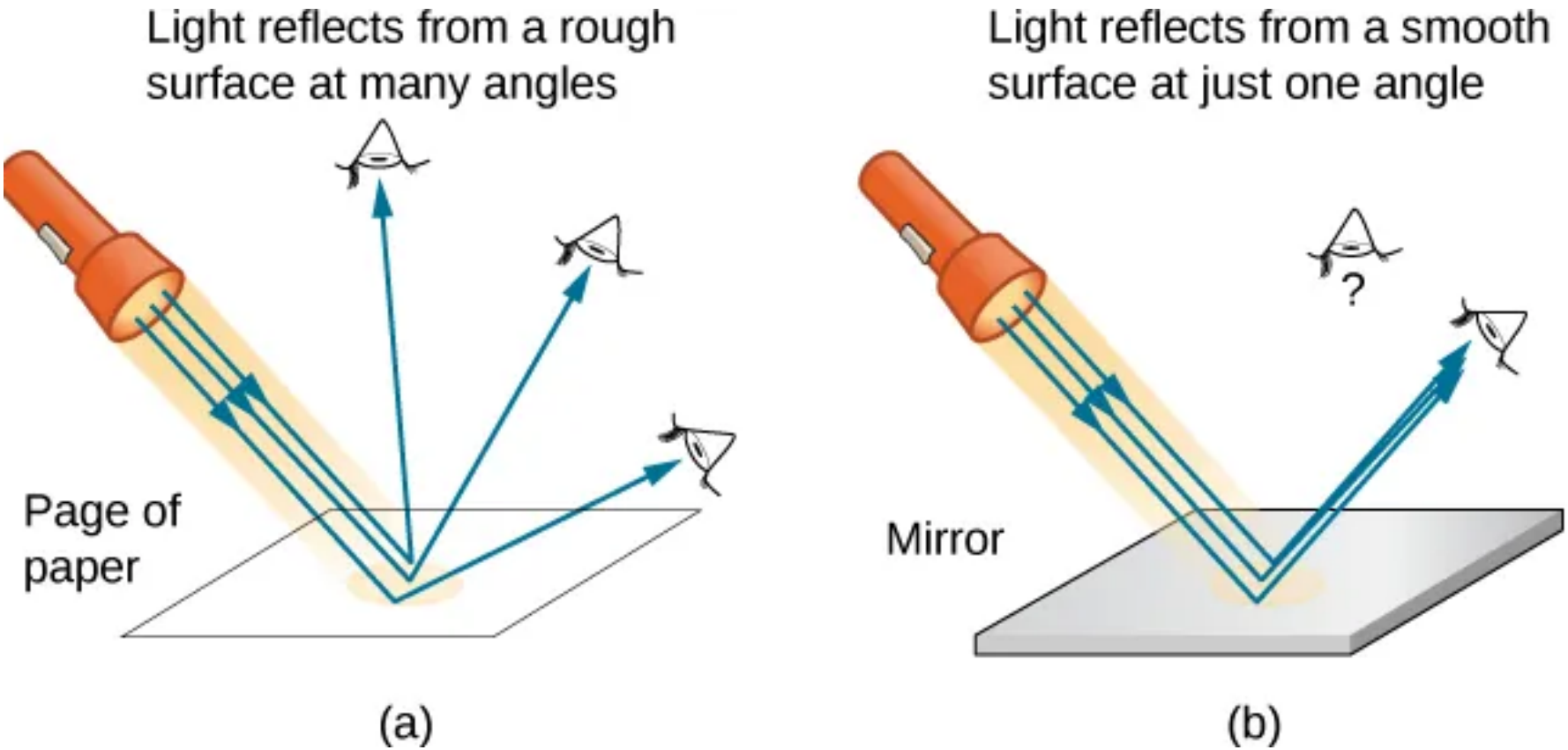


# Specular Reflection

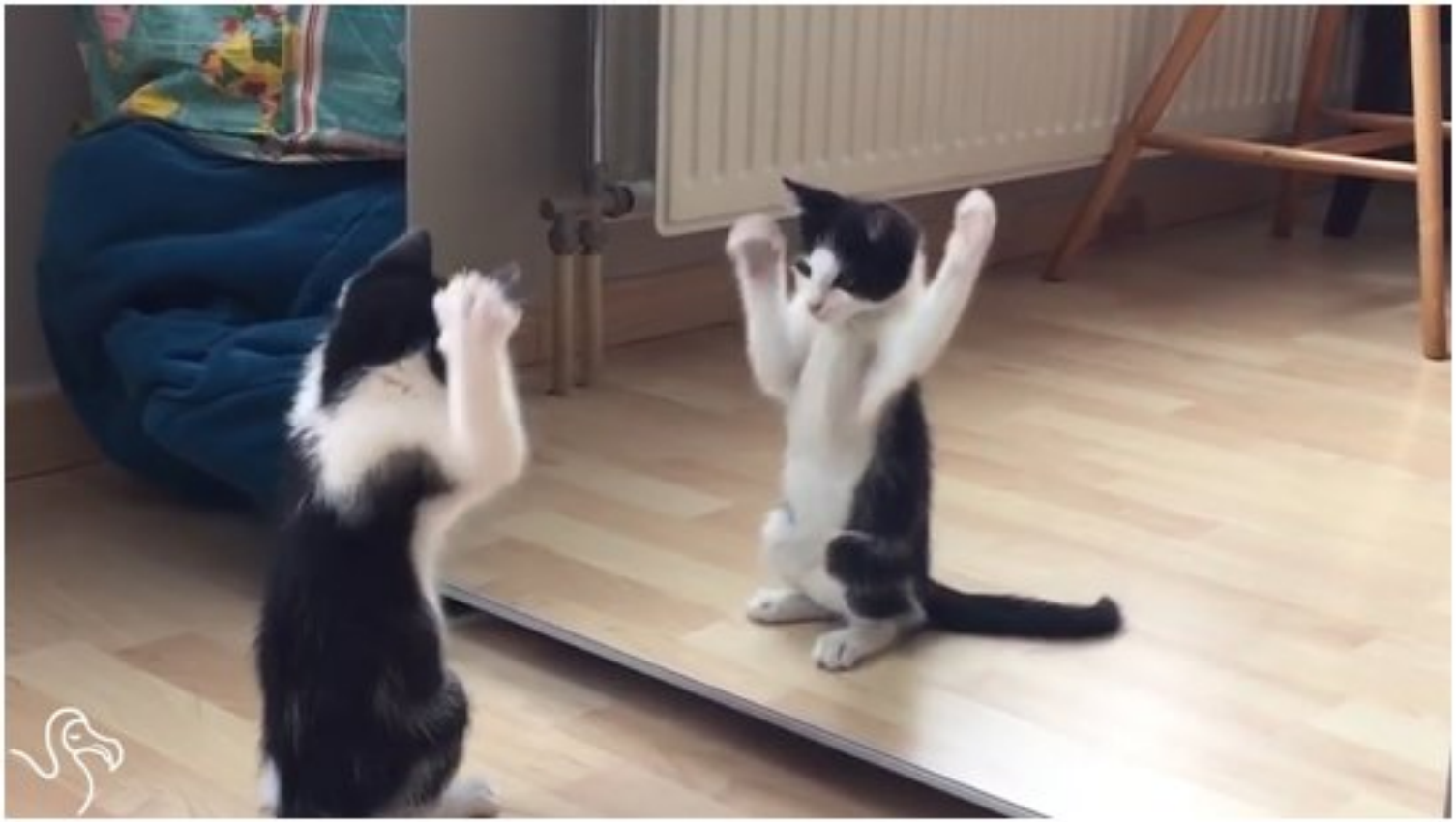


# Diffused Reflection




Light reflects from a rough surface at many angles
Page of paper
(a)
Light reflects from a smooth surface at just one angle
?
Mirror
(b)

# Reflections: Mirror



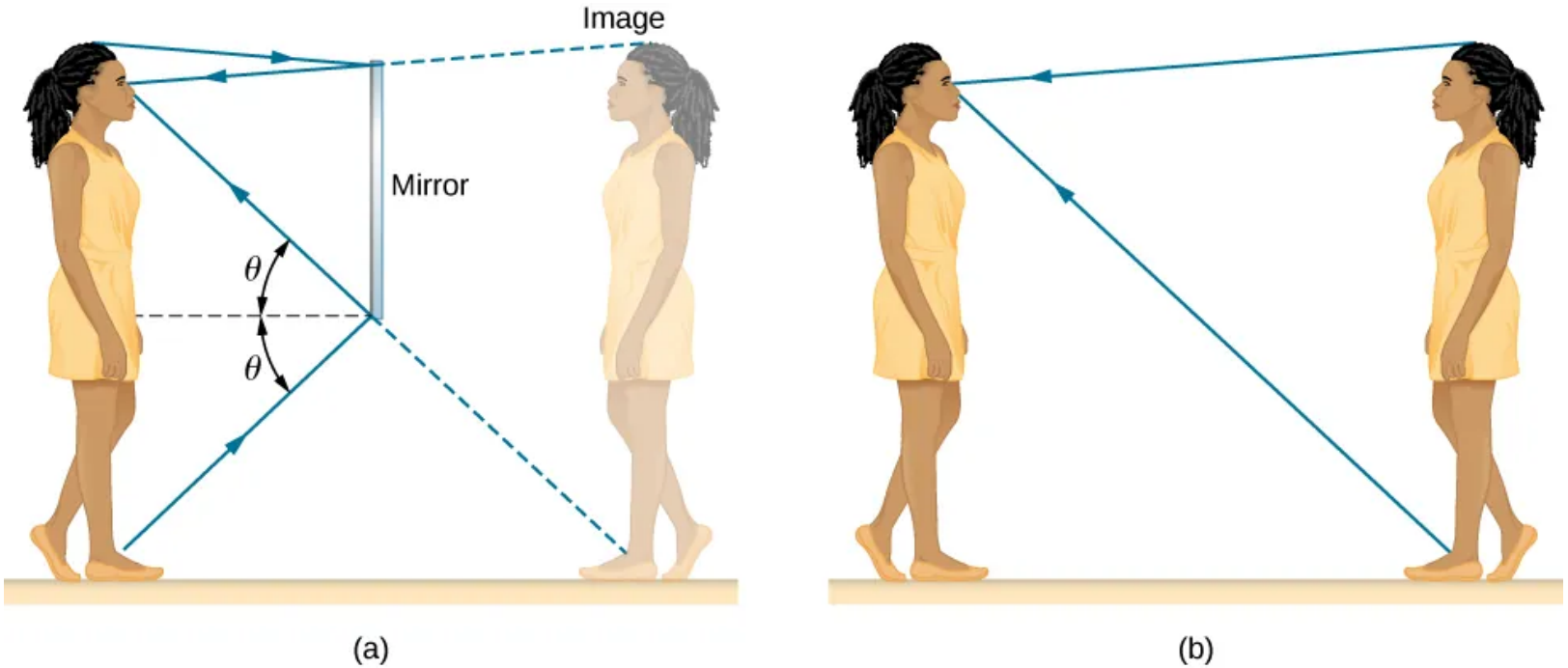


Image
Mirror
θ
θ
(a)
(b)

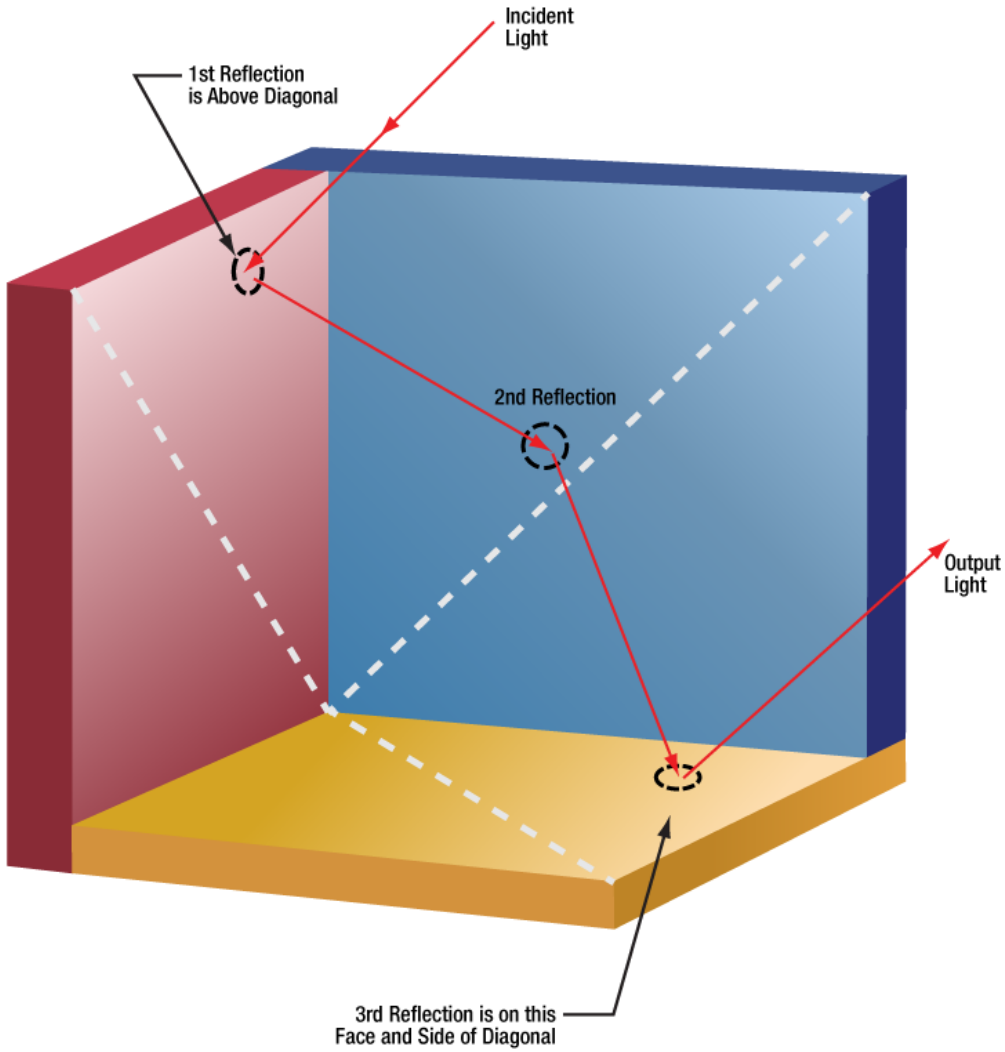
# Reflections: Retroreflector

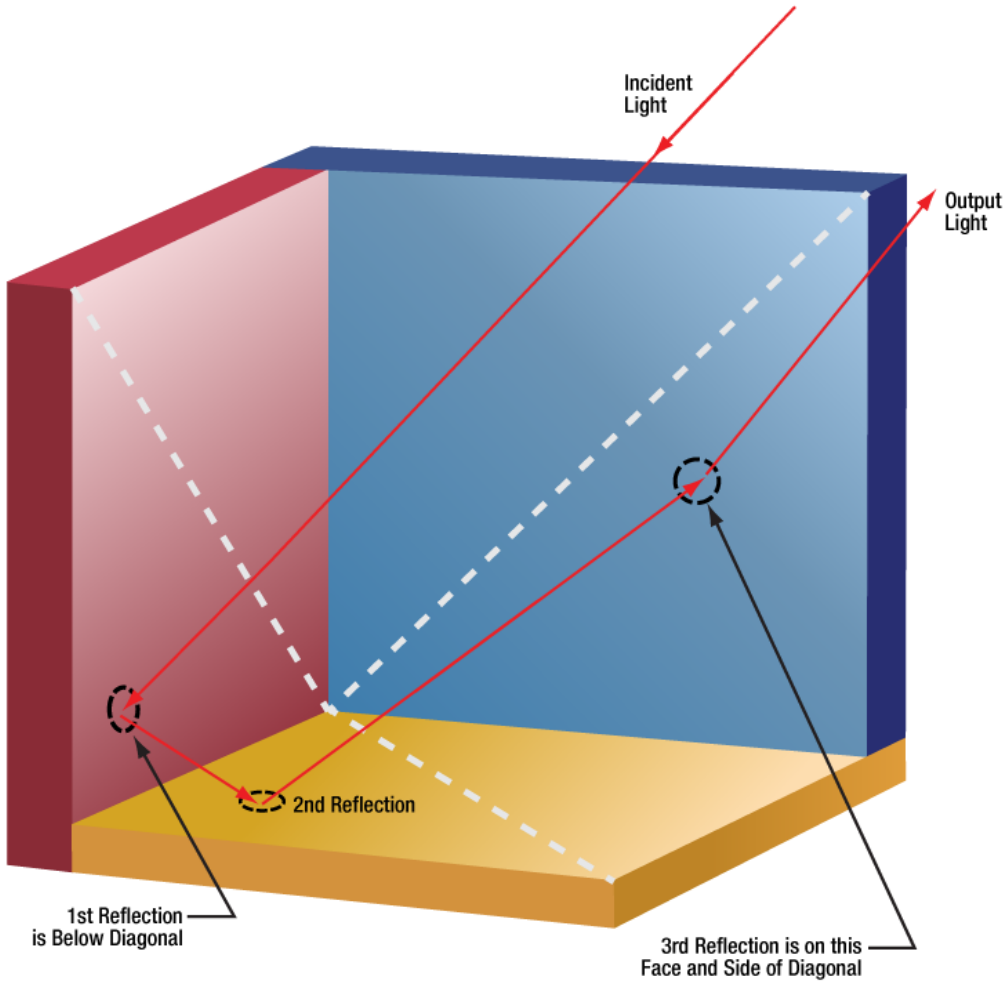
## Defenition

A **retroreflector** is a device or surface that reflects radiation (usually light) back to its source with minimum scattering

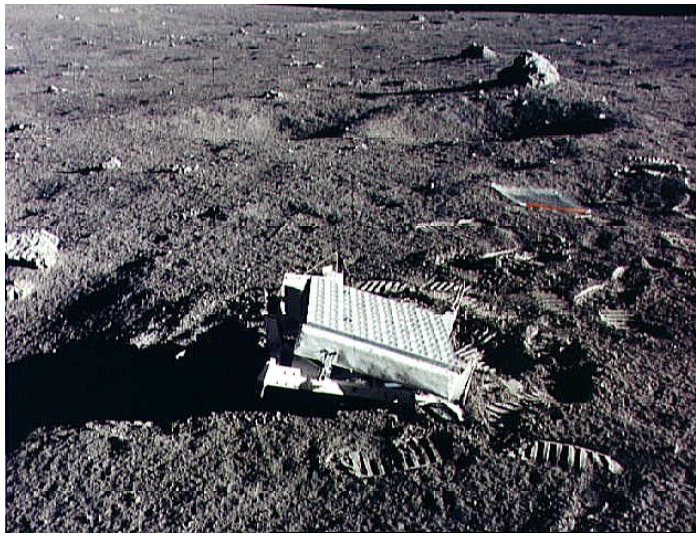
What is the difference from a **planar mirror** ?
This works in wide range of angle of incidence while mirror needs to be perpendicular to the wave front

# Retroreflector: Corner Cube Reflector

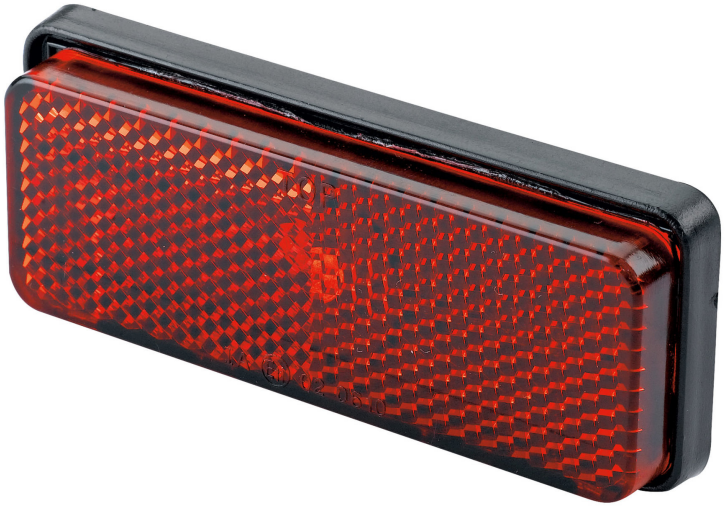



Incident
Light
Output
Light
2nd Reflection
1st Reflection
is Below Diagonal
3rd Reflection is on this
Face and Side of Diagonal

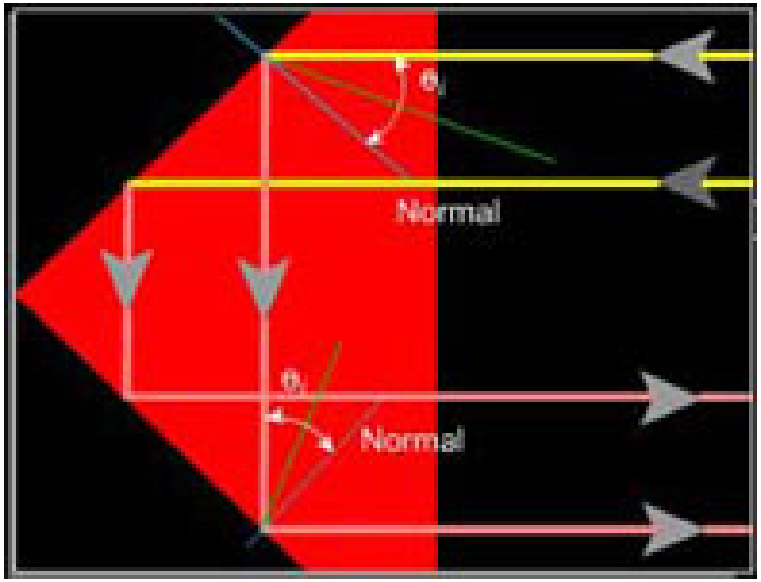
# Retroreflector : Uses



- Astronauts placed a corner reflector on the Moon to measure its gradually increasing orbital distance. Laser signals from Earth can be bounced from that corner reflector to measure the gradually increasing distance to the Moon of a few centimeters per year.



(a) cycle reflectors




(b) working principle

- Retroreflection ensures high visibility if the driver and the light source are located together in case of cycle reflectors

# Retroreflector : Radar

- Small boats made of fiberglass or wood do not strongly reflect radio waves emitted by radar systems. To make these boats visible to radar (to avoid collisions, for example), radar reflectors are attached to boats, usually in high places

# The actual location of Mug ?

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Both are not the actual location !!!

# Why two mugs ?

## Refraction

The changing of a light ray's direction (loosely called bending) when it passes through substances of different refractive indices is called **refraction**

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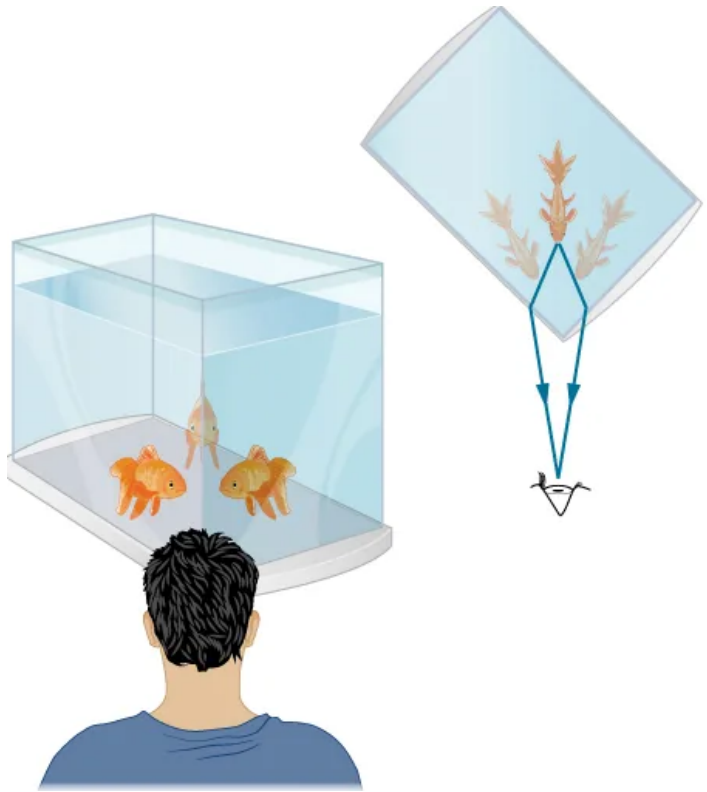
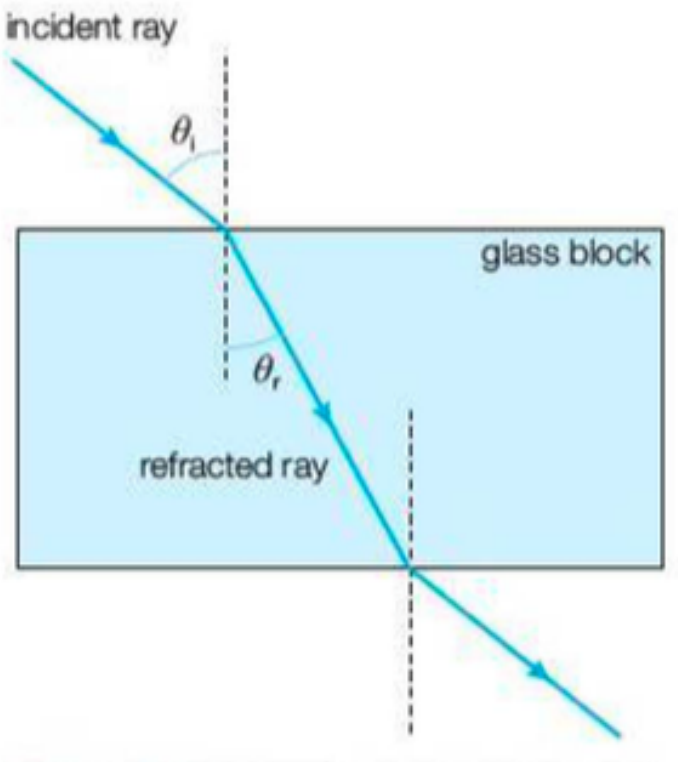
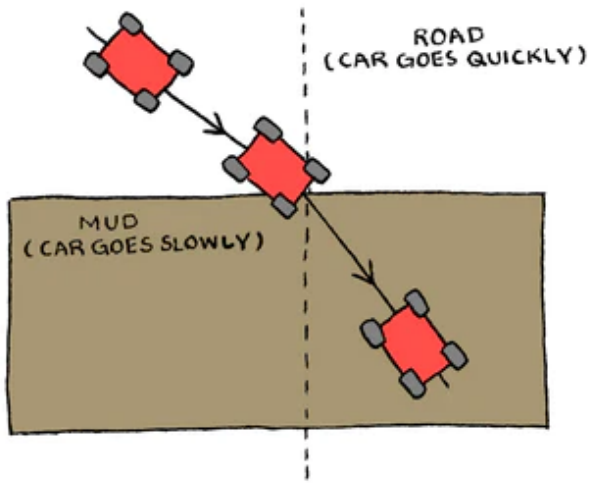


# Velocity of Light

$$v = c/\eta$$



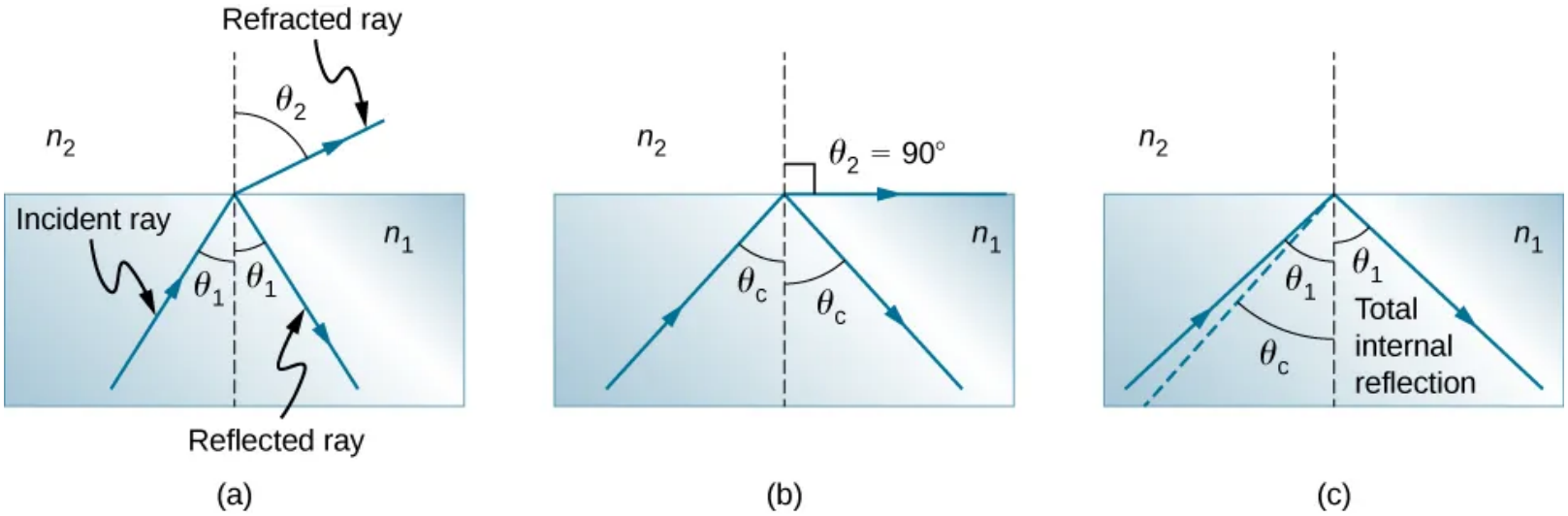

(a) Refraction through a glass block




(b) Direction of Bending

## Snell's Law

$$\eta_1 \sin\theta_1 = \eta_2 \sin\theta_2$$




a. $\eta_1 > \eta_2 \implies \theta_2 < \theta_1$

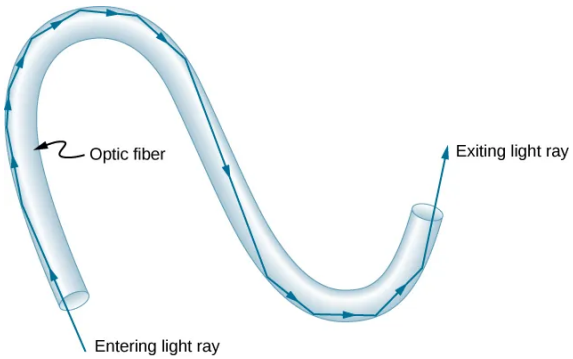
b. $\theta_1 \uparrow \implies \theta_2 \uparrow$. At $\theta_1 = \theta_c, \theta_2 = 90°$

c. At $\theta_1 > \theta_c$, all of the light is reflected back in to medium = **total internal reflection**

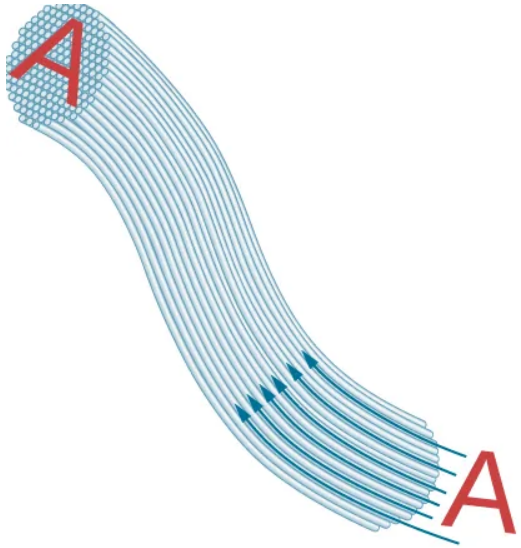
$$\theta_c = \sin^{-1}\left(\frac{\eta_1}{\eta_2}\right) \text{ for } \eta_1 > \eta_2$$

# What is happening here?

# Fiber Optical Cables and Endoscopes




(a) Total internal reflection in fiber optic cable




(b) Bundle of Fiber optic cables


(c) Endoscospic Camera