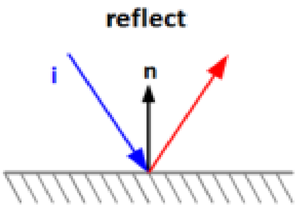
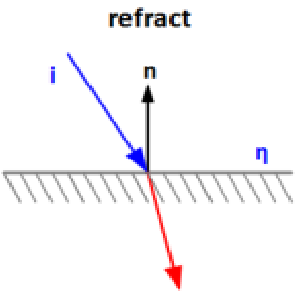
L 17-Reflection and Refraction& Fibre Optics

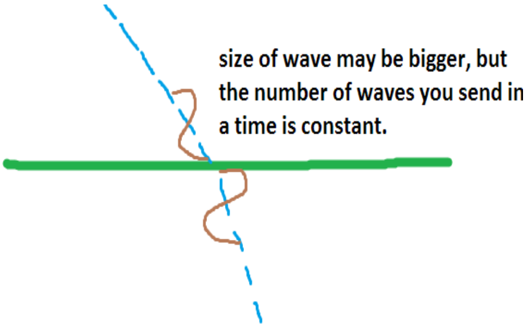
Reflection and Refraction

Reflection is bouncing of light rays off a barrier or interface.

Refraction is the bending of light rays when passing through a surface between one transparent material and another.







- The incident angle and the reflected angle are equal.
- The refracted angle may be larger or smaller than the incident angle
- The refractive quality of lenses is frequently used to manipulate light in order to change the apparent size of images. Magnifying glasses, spectacles, contact lenses, microscopes and refracting telescopes are all examples of this manipulation.

Snell's Law

Refraction is described by Snell's Law:

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

Where θ_1 is the angle between the ray and the surface normal in the first medium, θ_2 is the angle between the ray and the surface normal in the second medium, and n_1 and n_2 are the indices of refraction, $n = 1$ in a vacuum and $n > 1$ in a transparent substance.

All angles are to be measured from the normal to the surface.

Total internal reflection

As light travels from a slow medium to a faster medium, such as from water into air, it is refracted away from the normal. As the incident angle increases, the refracted angle increases.

At a large enough incident angle ("critical angle"), the refracted angle is 90° and the refracted ray travels along the interface between the two media.

$$n_1 \sin ø_c = n_2 \sin 90^o$$

$$\sin ø_c = n_2/n_1$$

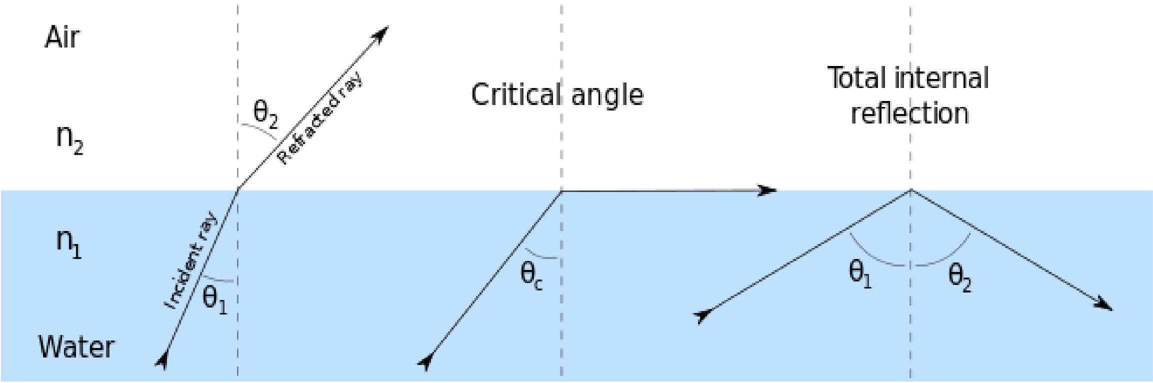
At angles larger than $ø_c$ no light travels out of the slower medium; it is all reflected internally.

Total internal reflection, in physics, complete reflection of a ray of light within a medium such as water or glass from the surrounding surfaces back into the medium.

The phenomenon occurs if the angle of incidence is greater than a certain limiting angle, called the **critical angle**.

In general, total internal reflection takes place at the boundary between two transparent media when a ray of light in a medium of higher index of refraction approaches the other medium at an angle of incidence greater than the critical angle. For a water-air surface the critical angle is 48.5°.

Because indices of refraction depend on wavelength, the critical angle (and hence the angle of total internal reflection) will vary slightly with wavelength and, therefore, with color. At all angles less than the critical angle, both refraction and reflection occur in varying proportions.



Total internal reflection (TIR) is the phenomenon that involves the reflection of the entire incident light off the boundary.

TIR only takes place when both of the following two conditions are met:

1. **The light is in the denser medium and approaching the less dense medium.**
2. **The angle of incidence is greater than the so-called critical angle.**

- **Total internal reflection will not take place unless the incident light is traveling within the more optically dense medium towards the less optically dense medium.**
- **TIR will happen for light traveling from water towards air, but it will not happen for light traveling from air towards water.**
- **TIR would happen for light traveling from water towards air, but it will not happen for light traveling from water (n=1.333) towards crown glass (n=1.52).**
- **TIR occurs because the angle of refraction reaches a 90-degree angle before the angle of incidence reaches a 90-degree angle.**
- **The only way for the angle of refraction to be greater than the angle of incidence is for light to bend away from the normal.**
- **Since light only bends away from the normal when passing from a denser medium into a less dense medium, then this would be a necessary condition for total internal reflection.**

FIBRE OPTICS

- **The principle of fiber optic action is based through the process of Total Internal Reflection**
- **Fiber optics, which is the science of light transmission through very fine glass or plastic fibers, continues to be used in more and more applications due to its inherent advantages over copper conductors.**
- **Optical fiber made of pure glass with a diameter of 125 microns equivalent to 0.125 mm consisting of the external reflective layer and internal transmission cylinder,**
- **They have the capacity of carrying digital information in the form of optical signals over long distances.**

An optical fiber is made of 3 concentric layers:

1. **Core: This central section made of silica or doped silica, is the light transmitting region of the fiber.**

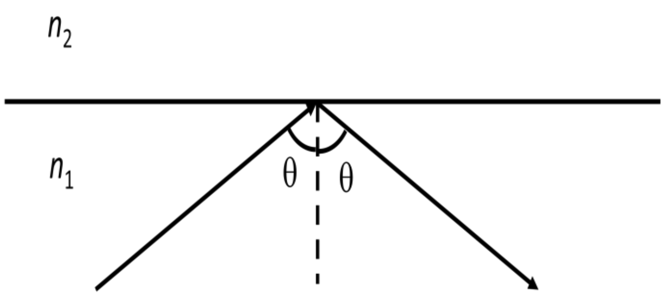
2. **Cladding:** This is the first layer around the core. It is also made of silica, but not the same composition as the core. This creates an optical waveguide which confines the light in the core by **total internal reflection** at the core-cladding interface.
3. **Coating:** The coating is the first non-optical layer around the cladding. The coating typically consists of one or more layers of polymer that protect the silica structure against physical or environmental damage.
4. **Buffer:** The buffer is an important feature of the fiber. It is 900 microns and helps protect the fiber from breaking during installation and termination and is located outside of the coating.

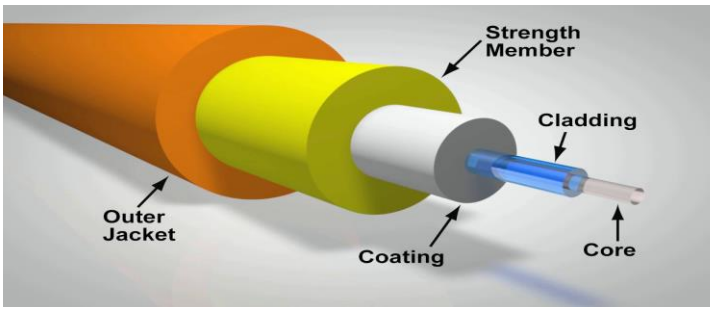
The light is "guided" down the core of the fiber by the optical "cladding" which has a lower refractive index that traps light in the core through "total internal reflection."

Fibre Optics Basics:

Light travelling in a medium of refractive index n_1 will experience total internal refraction at a boundary with a material of index n_2 if $n_1 > n_2$ and $\Theta > \Theta_c$ where:

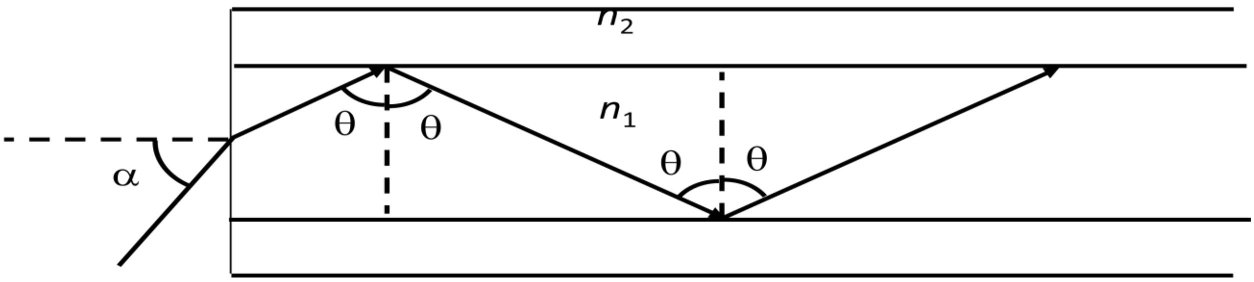
$$\sin \Theta_c = n_2 / n_1$$





Total internal reflection keeps light rays bouncing down the inside of a fiber-optic cable.

- Acceptance Angle
  - **In order to propagate down a fibre, a ray must be incident at the core-cladding interface at an angle > Θ_c**
  - **This places a limit on the range of angles which can enter the fibre: $\alpha < \Theta_c$**



Type of optical fiber

- **Single-mode fiber is used for long-distance transmission,**
- **Multimode fiber is used for shorter distances.**

Fiber optics has several advantages over traditional metal communications lines:

- **Fiber optic cables have a much greater bandwidth than metal cables. This means that they can carry more data.**
- **Fiber optic cables are less susceptible than metal cables to interference.**
- **Fiber optic cables are much thinner and lighter than metal wires.**
- **Data can be transmitted digitally (the natural form for computer data) rather than analogically**

The main disadvantage of fiber optics is that the cables are expensive to install. In addition, they are more fragile than wire and are difficult to splice.

Applications of fiber optics in medicine

Fiber optics display a variety of characteristics that make them useful in the medical field.

- **They are insensitive to electromagnetic disturbances and**
- **Are commonly small in size. Additionally,**
- **Their ability to withstand high temperatures, strong electromagnetic fields like MRIs, and ionizing radiation make fiber optics the perfect medical tool.**
- **Optical fibers are nontoxic, chemically inert, and intrinsically safe and thus, are an ideal material to use in and near the human body.**

Endoscopy

Endoscope: is a tube with built-in light sources, an instrument used to examine the interior of a hollow organ or cavity of the body.

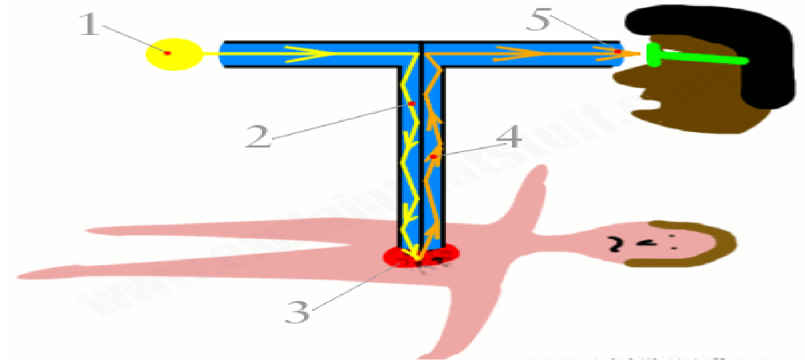
Is the insertion of a long, thin tube directly into the body to:

- **Observe an internal organ or tissue in detail.**
- **It can also be used to carry out other tasks including imaging and minor surgery.**

Endoscopes are minimally invasive and can be inserted into the natural openings of the body such as the mouth or anus.

How do endoscopes work?

1. **One of the two main endoscope cables carries light from a bright lamp in the operating room into the body, illuminating the cavity where the endoscope has been inserted.**
2. **The light bounces along the walls of the cable into the patient's body cavity.**
3. **The diseased or injured part of the patient's body is illuminated by the light shining in.**
4. **Light reflected off the body part travels back up a separate fiber-optic cable, bouncing off the glass walls as it goes.**
5. **The light shines into the physician's eyepiece so he or she can see what's happening inside the patient's body. Sometimes the fiber-optic cable is directed into a video camera (which displays what's happening on a television monitor) or a CCD (which can capture images like a digital camera or feed them into a computer for various kinds of image enhancement)**



- **Doctors use endoscopes to investigate symptoms such as nausea and abdominal pain, confirm diagnoses by performing biopsies, or give medical treatment.**

Type of endoscope

A number of instruments are used for viewing internal body cavities. Unlike most other medical imaging devices, endoscopes are inserted directly into the organ.

Because modern endoscopy has relatively few risks, delivers detailed images and is quick to carry out, it has proven incredibly useful in many areas of medicine.

- **Endoscopes is used to examine the internal organs like the throat or esophagus.**
- **The cystoscope (bladder),**
- **Nephroscope (kidney),**
- **Bronchoscope (bronchus),**
- **Arthroscope (joints) and**
- **Colonoscope (colon),**
- **Proctoscopes (rectum)**
- **Laparoscope (abdomen or pelvis).**

They can be used to examine visually and diagnose, or assist in surgery such as an arthroscopy.

Fiber optic biomedical sensors

Fiber optic biomedical sensors are another huge application of fiber optic technology. These sensors can be intrinsic or extrinsic and are able to measure a variety of physiological characteristics:

- **Body temperature,**
- **Blood temperature,**
- **Muscle displacement,**
- **Heart rate**

Optical coherence tomography (OCT),

A type of biomedical sensor, is a medical imaging technique that utilizes imaging sensors to capture micron-scale, two and 3-D images from within an optical scattering media, like biological tissue.