MODULE 02

FOR B2 CERTIFICATION

PHYSICS

Aviation Maintenance Technician Certification Series

COMPLIANT WITH EASA PART 66/147

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REVISION LOG

VERSION	EFFECTIVE DATE	DESCRIPTION OF CHANGE
001	2018 12	Module Creation and Release

PHYSICS

SUB-MODULE 01

MATTER

SUB-MODULE 02

MECHANICS

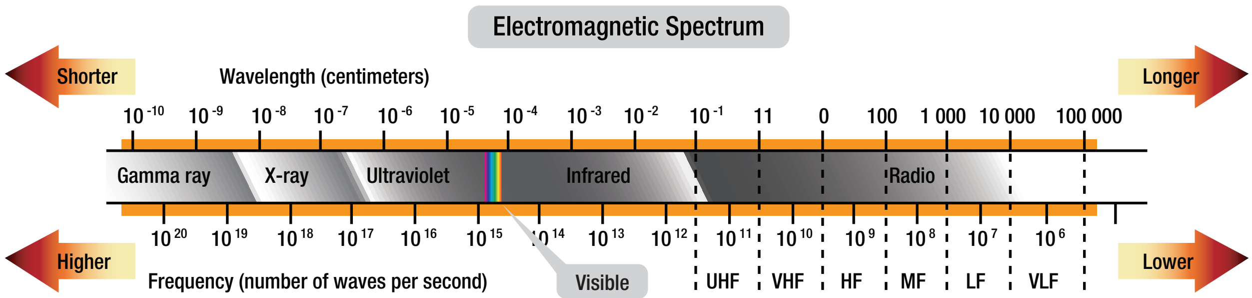

Figure 4-1. Radio waves are just some of the electromagnetic waves found in space.

THE NATURE OF LIGHT

Light is a form of electromagnetic radiation. It is part of the wide spectrum of electromagnetic radiation that surrounds us at all times. Visible light is a relatively small part of the spectrum. (***Figure 4-1***)

SPEED OF LIGHT

Light is a type of wave. As in the case of all wave motion, the wave moves with a definite speed. The speed of light (c) is exactly 299 792 458 meters per second which is 186 282.4 miles per second. It should be noted that this is the speed of light in a vacuum. The passage of light through matter reduces this speed. Materials have a refractive index (n) which is the speed of light (c) in a vacuum divided by the speed of light through the material (v). The refractive index of air is 1.000 29. The refractive index of water is 1.33 and approximately 1.6 for glass. This means that light travels slower through water than air and slower through glass than water.

The wavelength of visible light is usually measured in a unit called the Angstrom (A): 1A = 10^{-10}m. Various colors of visible light have characteristic wavelengths. They also have characteristic frequencies since the frequency of light × wavelength = speed of light. With symbols this is written $f\lambda = c$. ***Figure 4-1*** lists various colors of light and their respective wavelengths.

Wavelengths of visible light.

- Violet = 4 500 A
- Blue = 4 800 A
- Green = 5 200 A
- Yellow = 5 800 A
- Orange = 6 000 A
- Red = 6 400 A

REFLECTION

Reflection is a change in direction of a lightwave when it strikes a different media than that in which it was traveling so that the wave returns back into the original media. Mirror-like reflection is called specular reflection. This can occur when the reflective surface is a material that suppresses the propagation of the light wave or in a material that allows the passage of light such as water or glass. Specular reflection is shown in ***Figure 4-2***.

A perpendicular line drawn from the point where the light strikes the mirror is called the normal. The light striking the mirror forms an angle of incidence (Øi) with the normal. The light reflected from the mirror also forms an angle with the normal called the angle of reflection (Ør). It is a law of reflection that the angle of incidence is equal to the angle of reflection. Two further laws of reflection are: the incidence ray, the reflective ray and the normal at the point of incidence lie in the same plane, and the reflected ray and the incidence ray are on opposite sides of the normal.

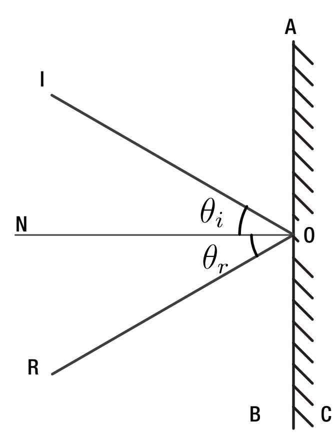

Figure 4-2. Specular reflection.

Reflection can occur off of a plane surface such as a typical flat mirror or piece of glass. It can also occur off of a curved surface. When reflection occurs off of a flat surface, it is said to form a mirror image. When occurring off of a curved surface the image may be magnified or demagnified.

Most curved mirrors are spherical. They can be convex (bulging outward toward the light source) or concave (bulging inward away from the light source). A convex mirror reflects light outward and demagnifies the image. It also provides a wider field of view. Convex mirrors are commonly used as passenger-side rear-view mirrors on automobiles. A concave mirrors focuses light when it reflects. The image it reflects depends on the distance away from the surface. Generally, a concave mirror is used so that it magnifies the image. It can be found in telescopes and in make-up mirrors to gain a close look at one's face. (***Figure 4-3***)

REFRACTION

Refraction is the phenomenon observed when light changes direction due to it passing through a medium in which it travels at an altered speed. When light enters a slower medium at an angle, its frequency remains the same. This is established at the source of the light. But as soon as part of the incoming light ray reaches a slower medium, its wavelength is shortened and the light bends towards the normal line. The amount of bend depends of the speed of light through the medium. The slower the speed, the more light will bend.

As previously mentioned, materials have a refractive index which compares the speed of light through a vacuum to the speed of light through the material. The higher the refractive index, the slower the speed of light through the material.

Using information about how light will pass through a medium enables the production of optic lenses. Snell's Law provides a mathematical equation for determining the angle that light will refract when passing from one medium through another:

$$\frac{n_1}{n_2} = \frac{\sin\emptyset_2}{\sin\emptyset_1}$$

In this equation; n_1 is the index of refraction of the first medium and n_2 is the index of refraction of the second medium through with the light will pass and bend. The angles are measured from the normal.

LENSES

Because light can be directed at different angles using various mediums, lenses are developed to focus light so that it is beneficial. Eye glasses are made so that the incoming light will be corrected so that it focuses the image of the object being looked at directly on the retina of the eye.

A lens can be defined as any device that transmits and refracts light. Note that some lenses are constructed to focus electromagnetic waves that are not visible light such as microwaves. A lens can be simple, causing a single refraction of light, or compound, consisting of more than one simple lens. Compound lenses are used to refine the focus and eliminate aberrations. An aberration

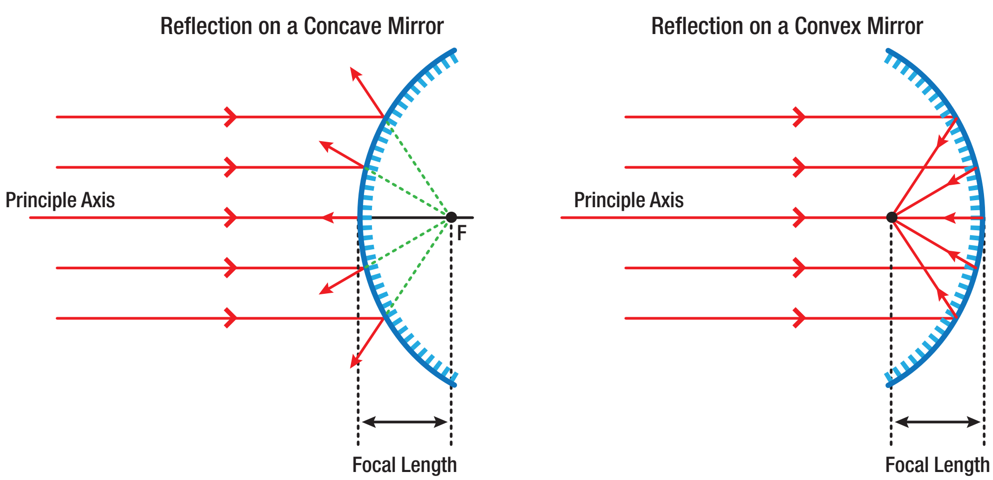

Figure 4-3. Reflection patterns of light on a concave and convex mirrored surface.

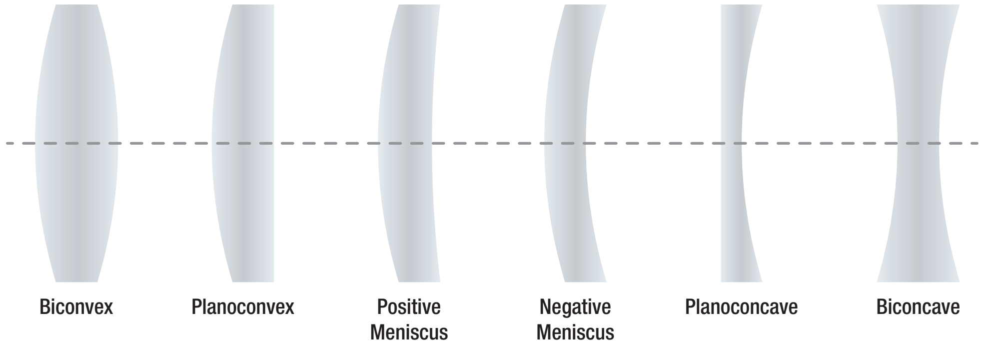

Figure 4-4. A sample of different shaped lenses.

in optics is the failure of rays to converge at a single focus point because of the limitations or defects in the lens. In addition to the material a lens is made from, the shape of a lens also factors in to the direction and focus of light passing through it. (***Figure 4-4***)

Similar to mirrors, lenses are often ground spherically. A lens that bulges outward from the lens is convex, a lens that curves into the lens is concave. Variations exist. Advanced optic manufacturing technology now allows the creation of aspheric lenses (non-spherical).

FIBER OPTICS

Fiber optics is the branch of optical technology concerned with the transmission of light through fibers. Electrical data is converted to optical signals and sent through optical fibers at the speed of light. The transmission of data through optical fibers offers wide bandwidth, light weight, and freedom from electromagnetic influence. (***Figure 4-5***)

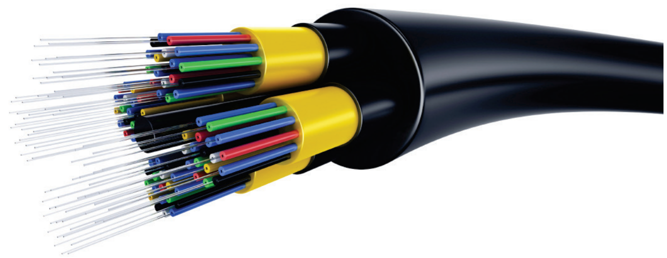

Figure 4-5. Fiber optic cable bundle.

CABLE CONSTRUCTION

A fiber's cladding is usually coated with a tough buffer layer which may be further surrounded by a glass jacket layer. These layers add strength to the fiber but do not contribute to its optical properties. Fiber bundles sometimes put light-absorbing material between the fibers to prevent light that leaks out of one fiber from entering another. (***Figure 4-6***)

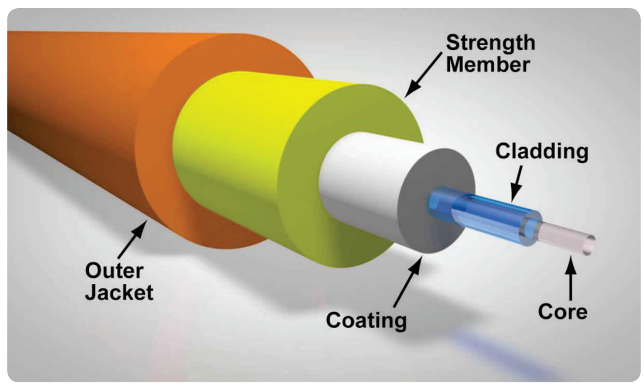

Figure 4-6. Construction of a fiber optic cable.

Fiber cable can be very flexible, but optical loss increases greatly if the fiber is bent to a radius smaller than around 30 mm, creating problems if the cable is bent around corners or wound around a spool. Some fiber optic cables are reinforced with glass yarns to increase strength and also to protect the cable core against rodents and insects.

FIBER MODES

Single-mode (or mono-mode) fiber has a core diameter less than about ten times the wavelength of the propagating light and can process only a single signal at a time. Most single-mode fiber is designed for use in the near infrared portion of the light spectrum.

Fiber with a core diameter greater than 10 micrometers is called multi-mode fiber. In multi-mode fiber, multiple rays of light are guided along the fiber core by the internal reflection of the cladding surrounding the fiber. Each light pulse carries its own piece of data and is transmitted through the cable at different angles so as not to interfere with other pulses traveling through the same cable. Rays that reflect from the cladding at angles greater than the critical angle are completely reflected. Rays that meet the boundary at a lower angle are refracted into the cladding, and do not convey light or information along the fiber. (***Figures 4-7 and 4-8***)

Attenuation in fiber optics, also known as transmission loss, is the reduction in intensity of the light beam as it travels through the fiber medium. Attenuation is caused by both scattering and absorption within the fiber and is an important factor limiting the transmission of a signal across large distances. Much research has gone into limiting attenuation. It has been said that if ocean water was as clear as single-mode fiber, one could see all the way to the bottom of the Marianas Trench in the Pacific Ocean, a depth of 36 000 feet.

TERMINATION AND SPLICING

Optical fibers are connected to terminal equipment by optical fiber connectors. (***Figure 4-9***) Standard connectors provide a physical contact where the mating surfaces touch each other at an angled surface to achieve the lowest possible attenuation and reduced reflections.

A fiber-optic connector is basically a rigid cylindrical barrel surrounded by a sleeve that holds the barrel in its mating socket. A typical connector is installed by preparing the fiber end and inserting it into the rear of the connector body. Quick-set adhesive is usually used to hold the fiber securely, and a strain relief is secured to the rear. Once the adhesive sets, the fiber's end is polished to a mirror finish. Various polish methods are used, depending on the type of fiber and the application. For single-mode fiber, fiber ends are polished with a slight curvature that makes the mated connectors touch only at their cores. This is called a physical contact (PC) polish. Such connections have higher loss than PC connections, but greatly reduce back reflection, because light that reflects from the angled surface leaks out of the fiber core.

Optical fibers may be connected to each other by connectors or by splicing; that is, joining two fibers together to form a continuous waveguide. The generally accepted splicing method is known as arc fusion splicing, which melts the fiber ends together with an electric arc. For quicker fastening jobs, a mechanical splice can also be used.

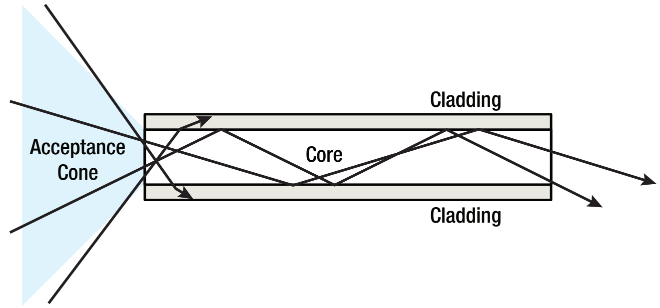

Figure 4-7. Propagation of light through a multimode optical fiber.

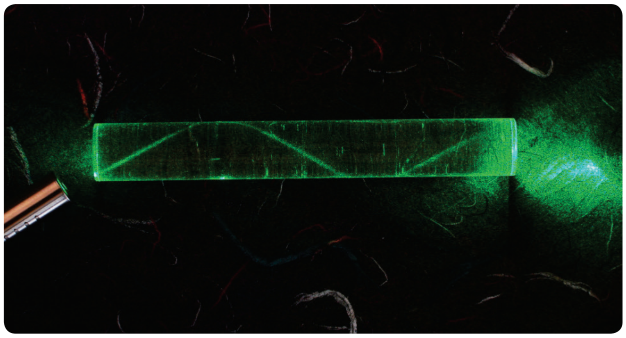

Figure 4-8. A laser bouncing through an acrylic rod illustrating the reflection of light in a multimode optical fiber.

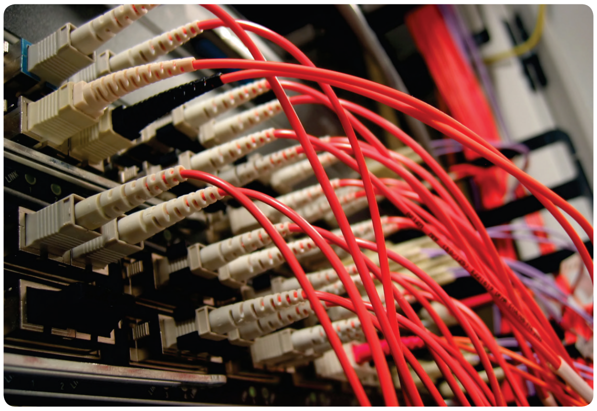

Figure 4-9. Fiber optic cable connections into a data panel.

In fusion splicing, the two cable ends are fastened inside a splice enclosure and the fiber ends are stripped of their protective coating and outer jacket. The ends are cleaved with a precision cutter and are placed in the splicer. The splice area is inspected via a magnified view screen to check the cleaves before and after the splice. The splicer then emits a small spark at the gap to burn off dust and moisture. Then the splicer generates a larger spark that fuses the ends together permanently. The optical loss due to the splice is measured by directing light through the cladding on one side and measuring light leaking from the cladding on the other. A splice loss of optical clarity under 0.1 dB is typical.