

**EVALUATING
ACADEMIC READINESS
FOR APPRENTICESHIP TRAINING**
Revised for
ACCESS TO APPRENTICESHIP

**SCIENCE SKILLS
LIGHT**

**AN ACADEMIC SKILLS MANUAL
for
The Construction Trades: Mechanical Systems**

This trade group includes the following trades:
Electrician (Construction, Maintenance & Industrial),
Network Cabling Specialist, Plumber,
Refrigeration & Air Conditioning Mechanic,
Sprinkler & Fire Protection, and Steamfitter

*Workplace Support Services Branch
Ontario Ministry of Training, Colleges and Universities*

Revised 2011

In preparing these Academic Skill Manuals we have used passages, diagrams and questions similar to those an apprentice might find in a text, guide or trade manual. This trade related material is not intended to instruct you in your trade.

**It is used only to
demonstrate how understanding an academic skill will help
you find and use the information you need.**

SCIENCE SKILLS

LIGHT

*An academic skill required for the study of the
Construction Trades: Mechanical Systems*

INTRODUCTION

In some of your trades, you might be required to install fibre optics cable. A fibre optic cable transmits telecommunication signals as a beam of light. A knowledge of the basic properties of light can help you understand how a beam of light travels along a glass cable, transmitting information.

This skills manual looks at the following properties of light:

- ◆ Electromagnetic waves
- ◆ Definition of light
- ◆ Reflection and Refraction
- ◆ Fibre optics

ELECTROMAGNETIC WAVES

Light is a special type of energy that we can see. Our visual sense is involved in the definition of what light is. But light energy also has a scientific definition.

Light is an Electromagnetic Wave

Light rays are part of a large group of rays and waves called *electromagnetic waves*. All electromagnetic waves move at the same, very fast, speed. Since the speed of an electromagnetic wave was first measured in light rays, the speed is defined as the *speed of light*.

All electromagnetic waves carry energy that can be transmitted to matter. We cannot detect the energy of an electromagnetic wave until it interacts with matter and changes into a form that we can sense, such as heat or light. The *photon* is the basic unit of energy carried by the waves.

Types of Electromagnetic Waves

Electromagnetic waves are grouped into several categories based on the *wavelength* of the different types of waves. Waves consist of successive troughs and peaks. The distance from the peak of one wave to the peak of the next is called a wave length. A wavelength is measured in micrometers. (A micrometer or micron is equal to .001 millimeter.).

Waves are also described by their **frequency**. Frequency is defined as the number of waves or cycles per unit of time. For example, frequency can be described as the number of waves generated per cycle. If a wave has a longer wavelength, a smaller number of these waves are generated per second compared to a wave with a shorter wavelength. We say that wavelength is inversely proportional to frequency. When wavelength becomes larger, the frequency becomes smaller and vice versa.

The different regions in the electromagnetic spectrum are defined by the wavelength (and therefore the frequency) of the radiation. Electromagnetic radiation is grouped into radio waves, microwaves, infrared radiation, visible light, ultraviolet rays, x-rays and gamma rays. These regions are shown in Figure 1.

The region on the right, with the longest wavelengths (10^8), shows radio waves. Slightly shorter wavelengths are called microwaves. Then there are infrared waves, which we feel as heat, visible light, ultraviolet rays, X-rays and finally, on the left, gamma rays, which have the shortest wavelengths (10^{-6}).

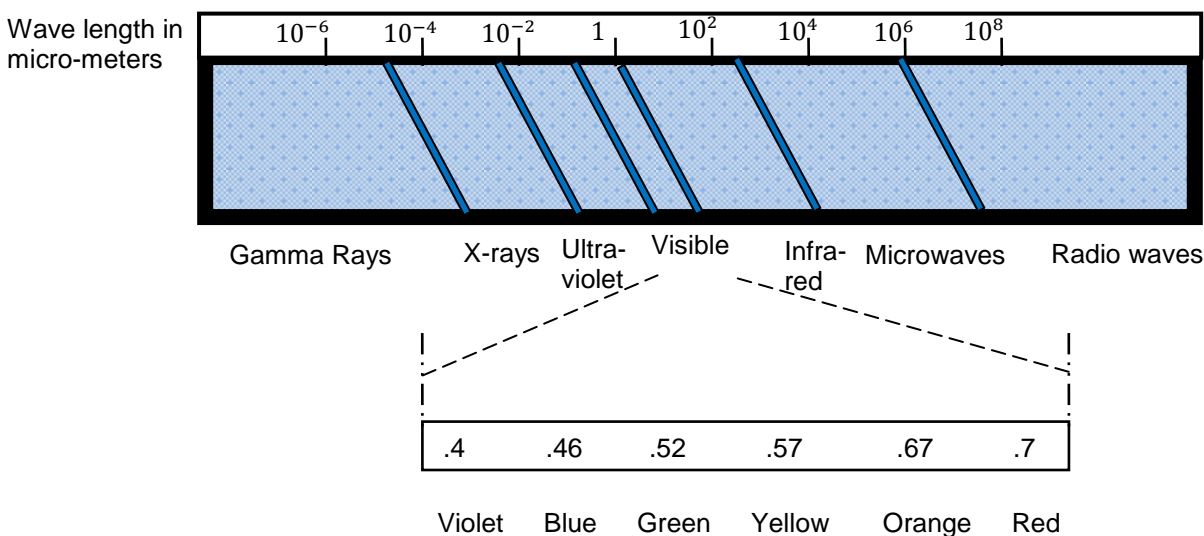


FIGURE 1: The Electromagnetic Spectrum Showing Details of Visible Light

Look at the illustration again. Notice that visible light waves are a very small part of the whole electromagnetic spectrum. They are the only part of the spectrum that we can actually see. Our other senses can detect the longer infrared waves as heat on our skin. If we are out in shorter ultraviolet waves for too long our skin will burn. To observe the other waves, we need to use technological devices such as radio receivers.

An electromagnetic wave consists of both a magnetic field and an electric field, which are at right angles to each other. See Figure 2 below. Energy transmitted by an electromagnetic wave travels perpendicularly through these fields.

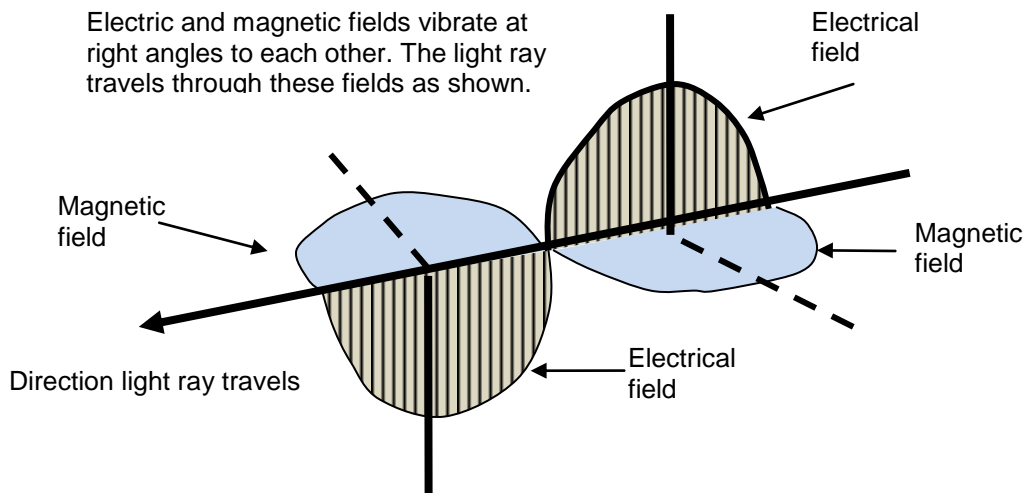


Figure 2: An Electromagnetic Wave

DEFINITION OF LIGHT

Light can be defined as the part of the electromagnetic spectrum that our eyes can see. Light waves are only a small part of the whole electromagnetic spectrum. Visible light occupies the middle of the spectrum. The wavelengths of light rays vary between .4 and .75 micrometers. You can see this in Figure 1.

Light energy can travel from the sun through space without needing any matter to transmit it. It travels in wave motion through electric and magnetic fields as small energy packets called photons.

When a photon of light hits a molecule of an object, some of its energy is transmitted to that object. When a photon of light hits the retina in our eyes, it transmits energy to the nerves located on the retina. These nerves are called optic nerves. Light causes the optic nerves to react. The signal striking the optic nerve fibres goes to the brain, where an image of what we are seeing is formed.

We perceive the different wavelengths of light as different colours. The longer wavelengths, around .75, are seen as red. The shorter lengths are seen as violet. The full spectrum of colours we see are red, orange, yellow, green, blue, indigo and violet (the colours we see in rainbows). The combination of all colours is seen as white while the absence of colour is perceived as black.

Sources of Light

Most of the light on earth comes from the sun. Early sources of artificial light came from fires and candles. In more recent times, metal filaments in light bulbs that glow when heated provide us with light. Fluorescent tubes produce light when ultraviolet radiation inside the tube causes phosphors coated on the glass to emit light rays.

When the filament of a light bulb becomes hotter, its molecules gain enough energy to glow. The bulb becomes luminous. *An object which emits light is said to be **luminous***. When light from a luminous source reaches the surface of another object, that object is said to be ***illuminated***.

When light shines on a surface, some is reflected by the surface, some is absorbed and some is transmitted.

- When we see an object, what actually stimulates our optic nerves is the light that is reflected from the surface of the object.
- Some of the light hitting the surface of the object is also absorbed by the object, increasing the energy of the object.
- Light can travel right through some materials like air, glass and water. These materials *transmit* light.

Different materials reflect, absorb or transmit light in different amounts.

REFLECTION AND REFRACTION

Reflection of light

Electromagnetic waves travel in straight lines unless something gets in their way. For example, when light hits the surface of an object, some of the light is *reflected* (bounced off) at an angle. The rest of the light is transmitted (passes through) or is absorbed.

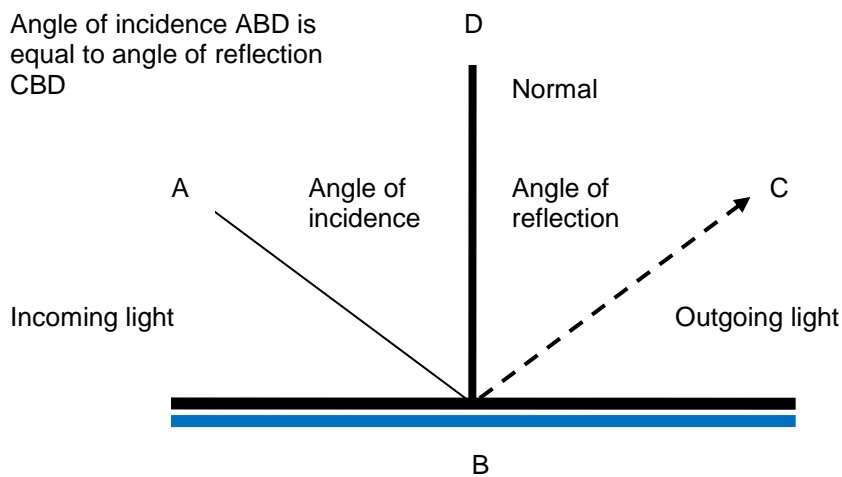


Figure 3 Reflection of Light

When light hits a flat surface at an angle, it reflects off at the same angle. To measure these angles, a line called a normal is drawn perpendicular to the surface. The angle between the incoming ray and the normal, called the angle of incidence, is equal to the angle of the outgoing ray and the normal, called the angle of reflection. See Figure 3.

Unless we look directly at a luminous source, we see the light rays that are reflected from an object. The photons of light in the reflected rays transmit their energy to our eyes. The energy stimulates optic nerves located there that go to our brain. Our brain then uses a complex process to analyze what it sees.

Transmission of Light

Some surfaces are constructed so that light is not reflected from them. When light is transmitted through these objects, it travels through them instead of being reflected. The material making up these objects is called *translucent*. Since light travels in a straight line, it will continue traveling through translucent material in a straight line, if it is the same density as the original medium, usually air.

Refraction of Light

Water has a higher density than air, so light rays slow down when passing from air to water. This causes the ray of light to change direction, or bend where it enters the water. This *bending of light rays when they pass from one medium to another is called refraction*. This is the reason that a pencil in a glass of water appears bent.

Light consists of different wavelengths that we see as colours. A ray of light consisting of a single colour is called *monochromatic* light. A ray of white light contains wavelengths of all the colours, so it is called *polychromatic* light.

Light of a longer wavelength is slowed down less than light of a shorter wavelength when it is transmitted from one medium into another, such as from air to a glass prism. Thus red light, which has a longer wavelength, will refract or bend less than violet light when it travels from air to water or glass.

Dispersion of Light

When a ray of white light passes through glass that is shaped into a prism, the different wavelengths of colours are slowed down at different rates and so they bend at different angles. This causes the colours to separate from each other. The light is refracted into bands of colours.

The process in which polychromatic light bends into separate colours is called *dispersion*. In a prism, white light is dispersed or bent into separate colours, allowing us to see the colour spectrum. Colours are refracted in the following order, starting from the least refracted to the most refracted:

- Red
- Orange
- Yellow
- Green
- Blue
- Indigo
- Violet .

A prism disperses white light into separate bands of colour

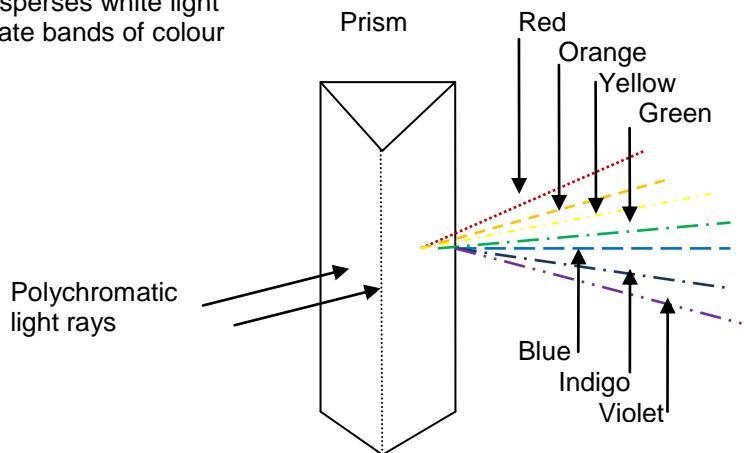


Figure 4: Dispersion of Light

Absorption of Light

At twilight, we see in varying shades of grey. Reflected light from objects hits the back of our eye where the information is sent to the brain. Our brain interprets these messages in a way we call sight or vision. Part of the brain interprets information about the shape, size and distance of objects. This is the information available in low light conditions.

When the full spectrum of light hits an object, some is reflected but most wavelengths are absorbed. Usually all but one wavelength is absorbed. The one wavelength that isn't absorbed is reflected. This is the wavelength that hits the retina in our eye after being reflected in full light.

Our retina is sensitive to the wavelength of light it receives. If it receives a short wavelength, the brain interprets that information as the colour violet.

When we see in colour, we are actually seeing the wavelengths that haven't been absorbed. A leaf absorbs all colours except green. That is the only colour that is reflected to our eye. So we see the leaf as green. If an object absorbs all colours, we see that object as black. If an object reflects all colours, we see that object as white.

FIBRE OPTICS

When light strikes the boundary between a medium with a very high index of refraction and another with a very low index, the light is totally reflected and none is refracted. The light remains inside the medium it is traveling in. This is called *total internal reflection*.

A fibre optic cable is usually made of a narrow coating of very pure glass around a fibre core. The light rays bounce off the glass coating and travel along the core. Light can travel long distances over these cables. The light continues to bounce off the glass even when the cable bends.

Fibre optics cable uses light pulses produced by a laser. A laser creates a narrow beam of light that travels along the cable in brief pulses. In light produced by a laser, all the light rays have exactly the same wavelength. This light can be visible light or longer wavelength infrared light.

To send information over the Internet using an ordinary telephone line, a modem is used to convert the on-off digital signals from a computer into a low-frequency sound signal. The telephone line carries the sound signal. The sound signals are converted back into bits of information in the receiving modem.

High speed fibre optics cables can transfer information at a much greater speed and capacity than telephone lines. The bits of digital information from the computer are sent as on-off flashes of laser light along the fibre optic cable. At the other end, the flashes of light are converted into on-off digital signals in the receiving computer.

A fibre optic cable can carry many separate digital pieces of information by multiplexing. The bits from each message are put into small packets. Packets from different messages can be mixed together and sent at one time. At the receiving end, the messages are separated and reassembled. To increase capacity even more, several multiplexed signals can be sent at different frequencies over the same cable. In this way, a single cable carries a very large number of messages at one time.

CONCLUSION

Light is a form of energy that moves as an electromagnetic wave. It is the visible part of the electromagnetic spectrum. When light is reflected off an object and strikes our eyes, the light energy excites the nerve fibres that carry the signal to the brain. Our brain organizes the signals into a perceived image.

Light is used to transfer information in a fibre optic cable. Light moves along a glass core at high speeds, carrying messages that have been converted from digital on-off signals to pulses of light. At the receiving end, the pulses of light are converted back into digital signals that then display the message.

Answer the following questions about light by placing the correct word in the blank space. The answers are on the last page.

1. Light travels in small energy packets called _____ .
2. All the different types of electromagnetic waves move at the same speed. This is called the speed of _____ .
3. The electromagnetic waves with the longest wavelengths are _____ waves.
4. Light is the part of the _____ spectrum that we can see.
5. We feel infrared waves as _____ on our skin.
6. When light is _____ , it travels through objects such as glass instead of being reflected.
7. The bending of light rays when they travel from one medium to another is called _____ .
8. When light hits an object, some of the wavelengths are reflected but most are _____ by the object.
9. When we see something, our optic nerves are stimulated by light reflected from the object. Visual signals are sent to the _____ , which organizes the received signals into an image.
10. When we see a coloured object, we see the _____ wavelength of light, the part that isn't absorbed by the object.
11. The process where polychromatic light is bent into separate colours is called _____ .
12. Light of a longer wavelength such as red light is refracted or bent _____ than light of a shorter wavelength such as violet light when traveling through a prism
13. If an object reflects all colour wavelengths back, we see the colour _____ .
14. If an object absorbs all colour wavelengths, we see the colour _____ .
15. When light strikes a medium with a very high index of refraction, all the light is reflected and none is refracted. This is called _____ internal reflection.
16. In a fibre optic cable, the _____ rays bounce off the glass coating and travel along the fibre core.

17. The light in a fibre optic cable is produced by a _____ .
18. The bits of digital information from a computer are sent as on-off _____ of light along a fibre optics cable.
19. Multiplexing involves sending many separate pieces of _____ that are mixed together and sent at one time.

ANSWERS

1. photons
2. light
3. radio
4. electromagnetic
5. heat
6. transmitted
7. refraction
8. absorbed
9. brain
10. reflected
11. dispersion
12. less
13. white
14. black
15. total
16. light
17. laser
18. flashes
19. information