CHAPTER 3 – THE ELECTROMAGNETIC SPECTRUM

3-1 The Nature of Electromagnetic Waves

1. What do all mechanical waves such as sound waves have in common?
   All mechanical waves such as sound waves transfer energy from one place to another, and they
   require a medium through which to travel.

2. Which type of waves transfers energy without a medium?
   Electromagnetic waves can transfer energy without a medium.

3. What are electromagnetic waves?
   Electromagnetic waves are transverse waves that have some electrical properties and some magnetic
   properties.

4. What does an electromagnetic wave consist of?
   An electromagnetic wave consists of changing electric and magnetic fields.

5. How do electromagnetic waves travel?
   Electromagnetic waves travel as vibrations in electric and magnetic fields.

6. What is an electric field?
   An electric field is a region in which charged particles can be pushed or pulled.

7. When does an electric field occur?
   Wherever there is an electric charge, there is an electric field associated with it.

8. What is a moving electric charge a part of?
   A moving electric charge is part of an electric current.

9. What surrounds and electric current?
   An electric current is surrounded by a magnetic field.

10. What is a magnetic field?
    A magnetic field is a region in which magnetic forces are present.

11. What causes an electromagnetic field to change?
    When the electric field changes, so does the magnetic field and vice versa. When one field vibrates
    so does the other. The two fields constantly cause each other to change resulting in an
    electromagnetic wave.

12. What is electromagnetic radiation?
    Electromagnetic radiation is energy that is transferred by electromagnetic waves.

13. Would light from the sun reach Earth if light was a mechanical wave? Why or why not?
    Light from the sun and stars could not travel through space to the Earth if light was a mechanical
    wave. Outer space is a vacuum so there is no medium for a mechanical wave to travel through.
    Electromagnetic radiation does not need a medium.
14. At what speed do electromagnetic waves travel?
   All electromagnetic waves travel at the same speed - about 300,000,000 meters per second or 300,000 kilometers per second in a vacuum.

15. How long does it take light from the sun to reach Earth?
   Light from the sun travels the 150 million kilometers to Earth in about 8 minutes.

16. How does a medium affect the speed at which electromagnetic waves travel?
   Electromagnetic waves travel at slower speeds when traveling through a medium, but they still travel a million times faster than sound can travel in air.

17. How do the properties of electromagnetic radiation fit the wave model?
   In general, the wave model can explain many of the properties of electromagnetic radiation. Light has many of the properties of waves, but light can also act as though it is a stream of particles.

18. How is polarized light different from ordinary light?
   An ordinary beam of light has waves that vibrate in all directions. Polarized light has waves that only vibrate in one direction.

19. Explain polarization.
   A polarizing filter only allows waves that are vibrating in one direction (vertically or horizontally) to pass through it. The other waves are blocked.

20. What is the photoelectric effect?
   The photoelectric effect is the movement of electrons in a substance when light is shined on the substance.

21. What is a photon?
   A photon is a tiny particle or packet of light energy.

22. Is light a wave or is it a set of particles?
   Light is a wave and a set of particles.

3-2 - Waves of the Electromagnetic Spectrum

1. Which wave characteristic(s) is/are the same for all electromagnetic waves and which is/are different?
   All electromagnetic waves travel at the same speed, but they have different wavelengths and different frequencies.

2. How are frequency and wavelength of electromagnetic waves related?
   As the wavelength of an electromagnetic wave decreases, the frequency of the wave increases. Waves with the longest wavelengths have the lowest frequencies. Waves with the shortest wavelengths have the highest frequencies.

3. How are frequency of a wave and wave energy related?
   The amount of energy carried by an electromagnetic wave increases with frequency. Waves with a high frequency have a high amount of energy.
4. What is the electromagnetic spectrum?
The electromagnetic spectrum is the name for the range of electromagnetic waves when they are placed in order of increasing frequency.

5. Which types of waves make up the electromagnetic spectrum?
The electromagnetic spectrum is made up of radio waves, infrared rays, visible light, ultraviolet rays, X-rays, and gamma rays.

6. What are radio waves?
Radio waves are the electromagnetic waves with the longest wavelengths and lowest frequencies.

7. What is the function of a radio receiver?
A radio receiver converts radio waves into sound waves that people can hear.

8. What are microwaves?
The radio waves with the shortest wavelengths and the highest frequencies are microwaves.

9. How does a microwave oven heat food?
Inside a microwave oven, water molecules in food absorb energy from the microwaves, causing the food to get hot.

10. Besides being used to heat food, what are some other uses for microwaves?
Microwaves are used to transmit cellular telephone calls. They are also used in radar and in medicine to produce pictures of tissues inside the human body.

11. What is radar and what do the letters in the word radar stand for?
Radar is a system that uses short-wavelength microwaves to locate objects by detecting reflected radio waves. Radar stands for radio detection and ranging.

12. What is magnetic resonance imaging?
Magnetic resonance imaging (MRI) is a process that uses radio waves to form pictures of the inside of the human body.

13. What are infrared rays?
Infrared rays are electromagnetic waves with higher frequencies and shorter wavelengths than radio waves.

14. Why are infrared rays called heat rays?
Infrared waves are called heat rays because you can feel the longest infrared rays as warmth.

15. What is an infrared camera?
An infrared camera is a camera that takes pictures by using infrared rays instead of light.

16. What are thermograms?
Thermograms are pictures taken with an infrared camera.

17. What is visible light?
Visible light is electromagnetic waves that are visible to the human eye. Visible light has shorter wavelengths and higher frequencies than infrared waves.
18. What color are the longest waves of visible light?
   The longest waves of visible light are red.

19. What are the colors in the visible spectrum in order of increasing frequencies?
   The colors in the visible spectrum are red, orange, yellow, green, blue, indigo, and violet.

20. What are ultraviolet rays?
   Ultraviolet rays (UV) are electromagnetic waves with frequencies higher than visible light, but lower than X-rays.

21. What are UV lamps used for?
   UV lamps are often used to kill bacteria on hospital equipment and in food processing plants.

22. What are X-rays?
   X-rays are electromagnetic waves with very short wavelengths. They have higher frequencies than ultraviolet waves, but shorter than gamma rays.

23. What are X-rays used for?
   X-rays are used to make images of bones inside the human body. They are also used to take pictures of objects used in industry and engineering.

24. What are gamma rays?
   Gamma rays are electromagnetic waves with the shortest wavelengths and highest frequencies. They are the most penetrating of all electromagnetic waves.

25. What produces gamma rays?
   Some radioactive substances and certain nuclear reactions produce gamma rays.

26. What are gamma rays used for?
   Gamma rays are used in medicine in radiation therapy to kill cancer cells and can also be used to examine the body’s internal structures.

SECTION 3-3 - PRODUCING VISIBLE LIGHT

1. What is an illuminated object?
   An illuminated object is an object that can be seen because it reflects light.

2. What is a luminous object?
   A luminous object is an object that gives off its own light. Examples are the sun and light bulbs.

3. What are five common types of lighting?
   Common types of lighting include incandescent, fluorescent, neon, sodium vapor, and tungsten-halogen light bulbs.

4. What is a spectroscope?
   A spectroscope is an instrument that is used to view the different colors of light produced by different sources.

5. What are incandescent lights?
   Incandescent lights are lights that glow when a filament inside them gets hot.
6. What is a filament?
   A filament is a thin wire tungsten coil found inside an incandescent light bulb.

7. How does an incandescent bulb produce light?
   When an electric current passes through the filament in the bulb, it heats up. When the filament gets hot enough, it gives off red light. As it continues to heat up, it gives off other colors of the spectrum.

8. Which colors of the electromagnetic spectrum are given off by an incandescent light bulb?
   Incandescent lights give off red, orange, yellow, green, blue, and violet light.

9. What is white light?
   All of the colors of the spectrum combined together produce white light.

10. What percent of the energy of an incandescent light bulb is given out as light? What happens to the remaining energy?
    Less than 10% of the energy is given out as light. The remaining energy is given off as infrared rays which cause the bulb to get very hot.

11. What are fluorescent lights?
    Fluorescent lights are long, narrow light tubes that contain a gas.

12. How does a fluorescent bulb produce light?
    When an electric current passes through the tube, it causes the gas in the bulb to emit ultraviolet waves. Light is emitted when the ultraviolet waves hit a powder that coats the inside of the tube.

13. Why are fluorescent bulbs more economical than incandescent bulbs?
    Fluorescent light bulbs give off most of their energy as light so they use less electricity than incandescent bulbs for the same amount of light. They also last longer.

14. What is a neon light?
    A neon light is a sealed glass tube filled with neon.

15. How does a neon light produce light?
    When an electric current passes through the tube, particles of the gas absorb energy. The energy is released in the form of light.

16. What color light does neon give out? How are other colors produced?
    Neon gives out red light. Different gases produce different colors of light. For example, argon gas and mercury vapor - greenish blue light, helium - pale pink light, and krypton - a pale violet light.

17. What is a sodium vapor light?
    A sodium vapor light contains a small amount of solid sodium as well as neon and argon gas.

18. How does a sodium vapor light work?
    When the sodium vapor light is heated, the neon and argon glow. The glow heats the sodium, causing it to change to sodium gas.

19. What color light does a sodium vapor light produce?
    The sodium gas gives off a yellow light.

20. What are sodium vapor lights commonly used for street lighting?
They are very economical because they require little electricity to give off a large amount of light.

21. What are tungsten-halogen lights?
   Tungsten-halogen lights have tungsten filaments, and they contain a halogen gas.

22. How does a tungsten-halogen light produce light?
   They work partly like incandescent bulbs. When electricity passes through the filament, the filament
   gets hot and glows. The halogen makes the filament give off a bright white light.

23. What are tungsten-halogen lights used for?
   They are used in overhead projectors and also in floor lamps.

24. Why are tungsten-halogen lights so popular?
   They provide bright light from small bulbs, but use very little electricity for the amount of light they
   give off.

25. What is bioluminescence?
   Bioluminescence is light produced as a result of a chemical reaction among proteins and oxygen in
   some organisms.

26. What do organisms use bioluminescence for?
   Organisms deep in the ocean use bioluminescence as a source of light, to search for food, and to
   attract mates.

Section 3-4 - Wireless Communication

1. How are radio and television programs transmitted?
   Radio and television programs are carried or transmitted by radio waves.

2. How are radio transmissions produced?
   Radio transmissions are produced when charged particles move back and forth in transmission
   antennas. The transmissions are sent out in all directions. Radio waves carry information from the
   antenna of broadcasting station to the receiving antenna of your radio or television.

3. What is a kilohertz and a megahertz? What do they measure?
   A kilohertz is 1,000 hertz. A megahertz is 1,000,000 hertz or 1,000 kilohertz. The frequencies of
   radio and television signals are measured in kilohertz (kHz) and megahertz (MHz).

4. What are the two main radio frequency bands?
   Two common radio bands are AM and FM.

5. What do the terms AM and FM mean?
   AM stands for amplitude modulation. FM stands for frequency modulation.

6. What remains constant in an AM wave and in a FM wave?
   In an AM wave, the amplitude of the wave changes, and the frequency of the wave remains constant.
   AM frequencies range from 535 kHz to 1,605 kHz.
   In a FM wave, the frequency of the wave changes, and the amplitude of the wave remains constant.
   FM frequencies range from 88 MHz to 108 MHz.
7. Explain how AM and FM broadcasts transmit information.

**AM Broadcasts:** The information that will become sound is coded as changes or modulations in the amplitude of the wave. At the broadcasting station, music and speech are converted from sound into electronic signals. The electronic signals for AM broadcasts are then converted into a pattern of changes in the amplitude of a radio wave.

**FM Broadcasts:** FM signals travel as changes, or modulations, in the frequency of the wave.

8. Why are AM radio stations able to broadcast over long distances?

AM waves have relatively long wavelengths and are easily reflected by Earth’s ionosphere. When reflected by the ionosphere, the waves bounce back to Earth’s surface which allows them to travel over long distances, especially at night when the absorption of radio waves by the ionosphere is reduced.

9. What is the ionosphere?

The ionosphere is an electrically charged layer high in Earth’s atmosphere.

10. How does the ionosphere affect AM and FM waves?

AM radio waves are reflected by the ionosphere. Because FM waves have higher frequencies and more energy, they penetrate the atmosphere and pass through the ionosphere instead of being reflected back to Earth.

11. How are television broadcasts produced?

Television broadcasts are similar to radio broadcasts, except that the electromagnetic waves carry picture signals as well as sound. In cable television, the signals are sent through cables.

12. What are the two main bands of television wave frequencies?

The two main bands of television wave frequencies are VHF and UHF.

13. What do the terms UHF and VHF mean?

VHF stands for Very High Frequency. Channels range from frequencies of 54 MHz to 216 MHz and correspond to channels 2 through 13 on your TV set.

UHF stands for Ultra High Frequency. Channels range from frequencies of 470 MHz to 806 MHz and correspond to Channels 14 through 69.

14. How do cellular telephones transmit signals?

Cellular telephones transmit and receive signals using high-frequency radio waves, or microwaves.

15. How do cellular telephones work?

The cellular telephone system works over regions divided up into many small areas called cells. Each cell has its own transmitter and receiver. Cellular telephone signals are strong enough to reach a few nearby cells. They cannot travel great distances so the signals are relayed between cells. In this way, a cellular phone can be used to communicate over long distances.

16. How do cordless telephones work?

A cordless telephone is just like an ordinary phone except that there is no cord between the handset and the base. The base of the phone is connected to the telephone system, and the information is transmitted from the handset to the base by radio waves.
17. How does a pager work?
   When you leave a message for a pager, the information is first sent to a receiving station. There it is
coded and sent as electromagnetic waves to the correct pager. The receiving pager then beeps or
vibrates letting the owner know there is a message.

18. How does a communication satellite work?
   Communication satellites work like the receivers and transmitters of a cellular phone system. The
radio waves are sent from Earth up to the satellite, which then relays the waves to other receivers on
Earth.

19. How does a satellite telephone system work?
   Radio waves from one phone are sent up through the atmosphere, received by a communications
satellite, and transmitted back to Earth to the receiving phone. The system makes calling available
anywhere in the world, but it may be more expensive than the cellular telephone system.

20. How do television satellites work?
   Television networks use communications satellites to send their signals to local stations across the
country. The television signals are changed into radio waves using frequency modulation.

21. What does the term GPS mean?
   The term GPS stands for the Global Positioning System.

22. What is a GPS used for and how does it work?
   The GPS is used for navigation. It uses a group of two dozen communications satellites that work
together. The GPS satellites broadcast radio signals to Earth. The signals can give you your exact
location on Earth’s surface or in the air. Anyone on Earth with a GPS receiver can receive these
signals.