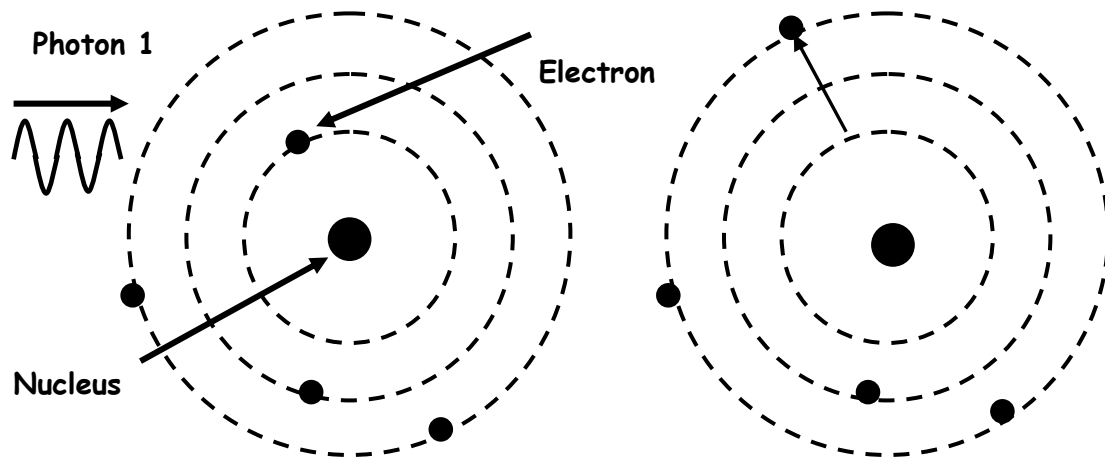


## Period 3 Solutions: Electromagnetic Waves - Radiant Energy II

### 3.1 Applications of the Quantum Model of Radiant Energy

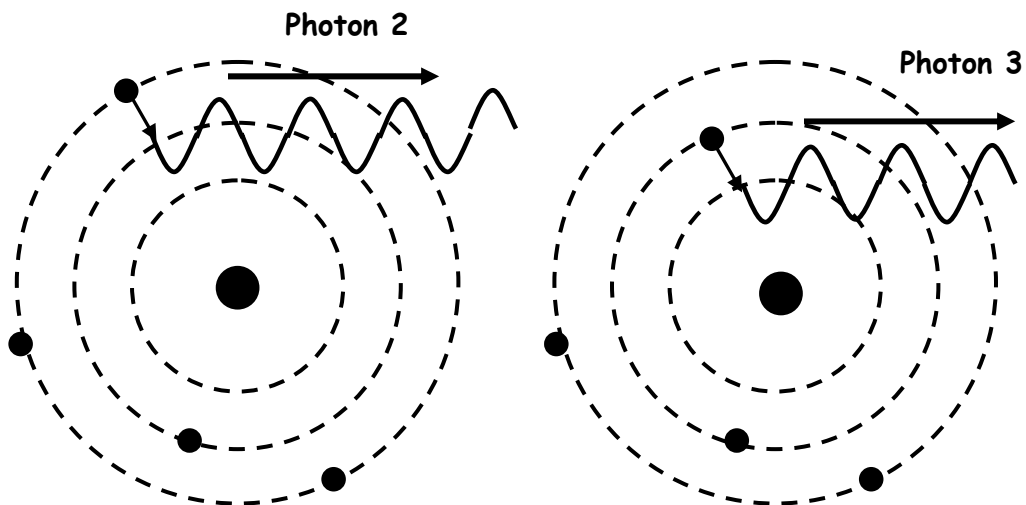
#### 1) Photon Absorption and Emission

The diagrams below illustrate an atomic nucleus and energy levels of the atom's electrons (not drawn to scale). Diagram #1 shows a photon incident on an electron in an atom. In diagram #2, an electron in the atom has absorbed a photon and has moved to a higher energy level. Diagram #3 shows the atom emitting a photon of light and dropping to a lower energy level. Diagram #4 shows the same atom some time later, after the electron has emitted a second photon and dropped to an even lower energy level. Answer the questions below based on these diagrams.



**Time 1:** An ultraviolet light photon is absorbed by an electron.

**Time 2:** The electron moves up two energy levels.



**Time 3:** The electron drops down one energy level and emits one photon of visible light.

**Time 4:** The electron drops down one more energy level and emits a second photon.

- a) Does the absorbed photon #1 or the emitted photon #2 have more energy?  
**Photon #1** How do you know?

**The absorption of photon #1 causes the electron to move up two energy levels. The emission of photon #2 causes the electron to drop down only one energy level.**

- b) Which photon has a larger frequency, the absorbed or either of the emitted photons? How do you know?

**The absorbed photon (photon #1) has a higher frequency. Photons with greater energy have a higher frequency.**

- c) Which photon has a longer wavelength – the absorbed or the emitted photon? How do you know?

**The emitted photon has a longer wavelength. Photons with less energy and lower frequency have longer wavelengths.**

- d) If the absorbed photon #1 is a photon of blue visible light, what color of light could emitted photon #2 be?

**The emitted photon could be any form of electromagnetic radiation with less energy than the photon of blue light that was absorbed. The emitted photon could be green, yellow, orange, or red light, depending on the amount of energy released when the electron changes energy levels.**

- e) Compare the energy of photon #1 to the energies of photons #2 and #3.

**The law of conservation of energy tells us that the sum of the energies of the emitted photons #2 and #3 must equal the energy of the absorbed photon #1.**

## 2) Ultraviolet Light and Fluorescence

Your instructor will demonstrate the results of shining several types of radiant energy on fluorescent materials.

- a) What happens when an atom fluoresces?

**Photons in the ultraviolet are absorbed by the atom. Photons of visible light are then emitted by the atom as it cascades down to its ground state.**

- b) Which light source works the best? **ultraviolet**

- c) Will a glow coil provide suitable light for the materials to fluoresce? **No**

Why or why not?

**The energy per photon of infrared radiation is not enough to raise an electron in an atom to an energy level such that the atom can emit photons of visible light.**

- d) "Write" on the Write and See boards using light from the red pen and then light from the blue pen. Does the red pen leave an impression on the board? **No** Does the blue pen? **Yes**
- e) Explain the different effects when red and blue photons strike the fluorescent board. (Hint: How can the visible light given off by fluorescing materials be explained in terms of the energy of photons?)

**A photon of blue light has a shorter wavelength and more energy than a photon of red light. The energy per photon of red light is not enough to raise an electron in the atoms of the fluorescent material on the board to an energy level such that the atom can emit photons of visible light (fluoresce).**

### 3) Visible Light Spectra from Gases

- a) Observe the tube of glowing mercury vapor through a diffraction grating. Describe what you see.

**Bright lines of indigo, violet, blue, and possibly green.**

- b) What do you see when you view the glass tube with neon vapor?

**Bright lines of red, orange, and yellow.**

- c) Why do you see bright emission lines when viewing gases?

**Electrical energy raises electrons in the gas atoms to a higher energy level. When the electrons fall back down to lower energy levels, they emit photons of light. The neon and mercury gases emit photons of only a few distinct frequencies that produce bright lines when viewed through the diffraction gratings. The colors seen depend on the energy of the emitted photons.**

### 4) Visible Light Spectra from Solids

- a) Your instructor will again demonstrate the glowing solid light bulb filament you observed in Period 1. Observe the bulb through a diffraction grating and describe what you see.

**A continuous spectrum of colors that are arranged in order of increasing photon energy: red, orange, yellow, green, blue, indigo, violet.**

- b) How does the spectrum of a glowing solid compare to the spectrum of a glowing gas?

**In glowing gases, electrical energy raises electrons to a higher energy level. When the electrons fall back down to lower energy levels, they emit photons of light. The frequencies (or wavelengths or colors) emitted depend upon atoms of which the chemical element are emitting the photons. When viewed through a diffraction grating, the result is photon emission lines characteristic of that particular element.**

**When molecules are compressed into solids, the vibrations of the atoms are more complex. Photons of all visible light frequencies (colors) are emitted. Through a diffraction grating, the light from the bulb filament shows a continuous spectrum of emission lines.**

- c) What happens when the white light from the filament bulb shines through a prism?

**The prism acts much like a diffraction grating. White light is separated into a continuous spectrum rainbow of colors by a prism or a diffraction grating. However, while blue light is bent the most by a prism, red light is bent the most by a diffraction grating.**

- d) Your instructor will reduce the power to the bulb filament. Reducing the bulb brightness results from lowering the temperature of the filament. Describe what you see when viewing the dimmed bulb through a diffraction grating.

**You still see a continuous spectrum, however the red portion of the spectrum is now brighter than the blue portion.**

- e) When the power to this bulb is reduced until no visible light is seen, does the filament still emit photons? If so, what type of photons?

**While the filament is still warm, it emits photons of infrared frequencies. These photons can be detected with an infrared camera.**

## 5) Polarized Radiant Energy

Your instructor will discuss polarization of light.

- a) Look at the classroom ceiling lights through a polarizing filter. What happens to the light from the ceiling bulbs when it passes through the filter?

**The ceiling bulbs produce electromagnetic waves of radiation that vibrate in all directions. As the light passes through the filter, all of the electromagnetic waves are absorbed except those that vibrate in one direction. These waves have been polarized.**

- b) Look at the ceiling lights through two polarizing filters. What happens when you rotate one of the filters?

**If two filters are oriented in the same direction, the polarized light from the first filter passes through the second filter unchanged. If the second filter is rotated by 90 degrees, the polarized light from the first filter is blocked by the second filter.**

- c) Light reflected from a horizontal surface, such as a mirror, becomes polarized.

Look at the OHIO sign and the reflection of the sign. Now view the sign and its reflection through a polarizing filter. Describe what happens when you rotate the polarizing filter. Why does rotating the filter have this effect?

**The image of the OHIO sign in the mirror disappears as the polarizing filter is rotated because the light reflected from the mirror is polarized by the reflection process. When the polarized light from the mirror passes through a polarizing filter aligned in the same direction, light can pass through. When the filter is rotated 90°, the polarized light is blocked.**

### 3.2 Information Transferred with Radiant Energy

#### 6) Requirements for information transfer

- a) Your instructor will discuss information transfer. What are the requirements for the transfer of information?

**There must be a sender and a receiver of the information. The transfer involves the modulation (changing in a deliberate manner) of some type of energy. This modulation of the energy is known as the signal.**

- b) Any energy source that combines with the signal in any way is known as noise. Watch the demonstration of noise in a signal with a slide projector. List two changes that improve the signal-to-noise ratio.

**The signal can be increased by increasing the current to the projector. The noise can be reduced by dimming the room lights.**

- c) If the average energy of the noise is doubled, what must happen to the average energy in the signal if the signal-to-noise ratio is to remain unchanged?

**The energy of the signal must also double.**

- d) Your instructor will discuss what is meant by encoding information for transfer.

List at least 3 schemes for encoding information.

**Information must be coded in some language understood by both the sender and the receiver. Examples include spoken and written English, sign language, Morse code, any computer language, and AM and FM radio signals created by a radio transmitter and "decoded" by a radio receiver.**

#### 7) Digital transfer of information

- a) What is a pixel? Look for pixels in the pictures on your table.

**A pixel is a small dot that is part of any overall image on television or computer screens, newspaper photographs, faxes, etc. A photograph has a resolution at the molecular level, so its image is almost continuous.**

- b) Using Morse code and telegraph keys, have a contest between two groups at your table. Try to send and successfully receive your mother's first name. Is Morse code an analog or a digital signal? Why?

**A digital signal is produced by sequentially stopping and starting the energy being transferred. The simplest digital signal is one in which the energy transfer is sequentially turned off or on for a fixed amount of time in each case. Morse code is a digital signal consisting of two kinds of "on" signal – a long "on" signal and a short "on" signal.**

## 8) Transferring information with electromagnetic radiation

Your instructor will discuss how electromagnetic signals are transferred.

- a) What is a carrier wave?

**A carrier wave is used to send signals in an electromagnetic wave. Information is sent by modulating (changing) the carrier wave in some manner.**

- b) List 3 common mediums through which an electromagnetic signal can be transmitted.

**Air or free space, fiber optic cable, or coaxial cable**

- c) How does a fiber optic cable transmit information? How is it possible for a signal to be transmitted through a bent cable?

**Fiber optic cables send optical carrier waves (light) along a transparent, flexible plastic fiber. The core of each optical fiber has a large index of refraction. The core is wrapped in transparent material that has a lower index of refraction. When the light tries to leave the optical fiber, it is reflected. This process is called total internal reflection.**

- d) How do coaxial cables transmit information?

**A television coaxial cable consists of an insulated central wire surrounded by a conducting tube. The electromagnetic radiation from the broadcasting station can move through the cable in the space between the conducting tube and the inner wire, even though the cable may have many turns and twists to the television receiver. Since the cable can handle frequencies to 1,000 MHz, it can carry many carrier waves. Each channel corresponds to a different carrier wave frequency.**

## 3.3 How Are Signals Broadcast? - Commonly Used Carrier Waves

### 9) Microwave transmissions

- a) Microwave transmissions are usually sent between a source and a single receiver. Use a microwave transmitter to send microwaves to the microwave receiver.

Try to shield the signal using a sheet of aluminum, a glass plate, and a metal grid. Try to reflect the microwave signal using the same materials. Record your results below.

	Shields waves?	Reflects waves?
Aluminum sheet	___yes___	___yes___
Glass plate	___partially___	___partially___
Grid held horizontally	___no___	___no___
Grid held vertically	___yes___	___yes___

- b) Why do different orientations of the metal grid give different results?

**The microwaves from the transmitter are horizontally polarized. The waves can pass through the space between the horizontal metal bars, but are absorbed by the vertical metal bars.**

- c) Group Discussion Question: Why does a microwave oven have a glass door with metal gratings?

## 10) Visible light transmissions

- a) Connect a solar cell to the white amplifier/loudspeaker. What happens when an LED flashlight connected to a radio shines on the solar cell? What type of radiant energy transfers information?

**A modulated (changing) current from the radio transfers information by modulating the amplitude of the beam of visible light from the LED flashlight. The energy from the LED flashlight produces a changing electric current in the solar cell. This changing current produces sound waves in the amplifier's loudspeaker.**

- b) Your instructor will show you how to use a laser beam to send a modulated signal to a solar cell.

- 1) How is energy transferred from the radio to the laser beam?

**A modulated (changing) current from the radio transfers information by vibrating the cone of a loud speaker. A beam splitter (small rectangle) attached to the speaker cone modulates the amplitude of the beam of laser light.**

- 2) How does the modulated laser beam produce sound in the second loudspeaker?

**The modulated laser beam strikes a solar cell and produces a changing electric current in the solar cell. This changing current produces sound waves in the second loudspeaker cone.**

- 3) What is this type of modulation called?

**Amplitude modulation (AM)**

## 11) Radio wave transmissions

Your instructor will discuss broadcasting.

- a) How is it possible that every radio station transmits its signal at a distinct frequency while sending a signal made up of a variety of frequencies (musical pitches)?

**Carrier waves of very high frequency (kilohertz or megahertz) are encoded with information much lower frequency. Musical pitches and other audible sound waves of much lower frequency (less than 20 kilohertz) are converted via microphones into electrical signals. These signals are encoded on carrier waves by radio transmitters and are broadcast through the air. Radio receivers can be tuned to pick up only a certain frequency at a time, thereby receiving the carrier wave of a**

**specific radio station. The signal on the carrier wave can be decoded by the radio receiver to produce the variety of frequencies present in the original sound wave.**

- b) A radio station transmits radio waves with a wavelength of 3.3 meters.  
What is the frequency of the station?

$$f = \frac{S}{L} = \frac{3 \times 10^8 \text{ m/s}}{3.3 \text{ m}} = 0.909 \times 10^8 \text{ Hz} = 90.9 \times 10^6 \text{ Hz} = 90.9 \text{ MHz}$$

- c) Information can be encoded on a carrier wave by modulating the wave's amplitude.  
What other feature of a wave could be modulated?

**The wave frequency can be modulated.**

- d) Which type of modulation is less likely to be affected by noise in a radio broadcast?

**Frequency modulation is less affected by noise from electromagnetic radiation.**