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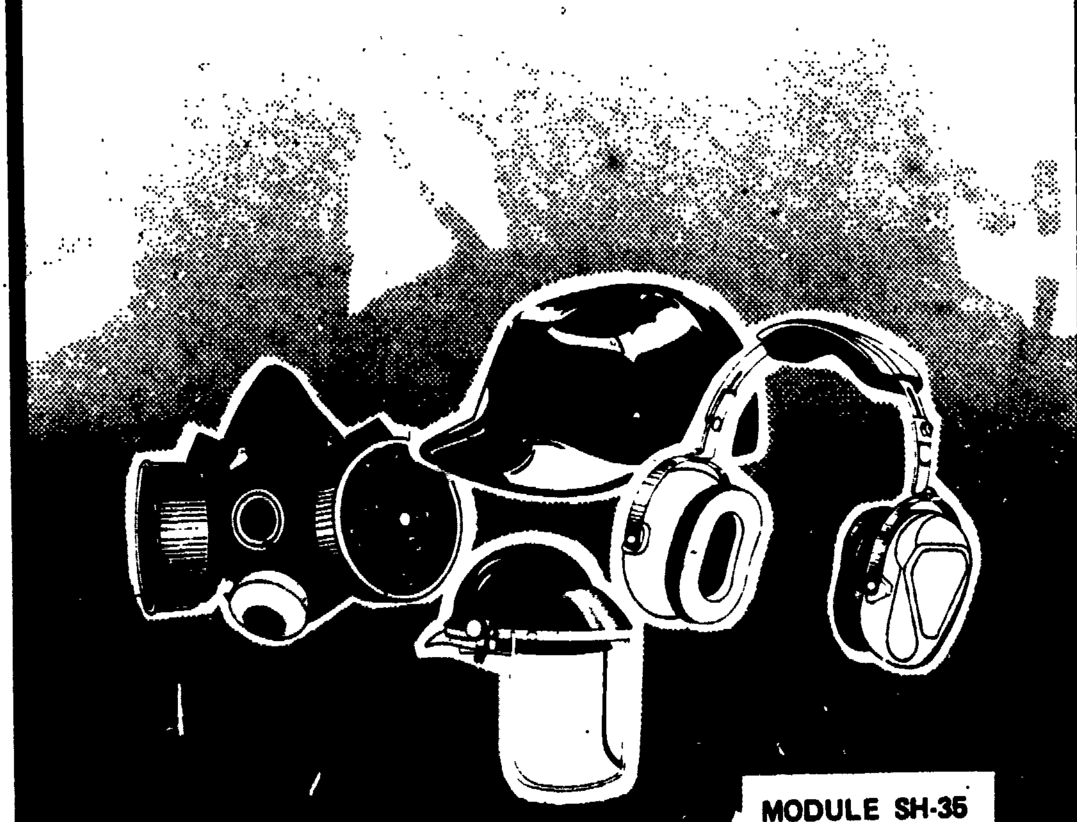
ABSTRACT

This student module on ionizing and nonionizing radiation protection is one of 50 modules concerned with job safety and health. This module describes various types of ionizing and nonionizing radiation, and the situations in the workplace where potential hazards from radiation may exist. Following the introduction, 13 objectives (each keyed to a page in the text) the student is expected to accomplish are listed (e.g., Identify the main source of ultraviolet radiation). Then each objective is taught in detail, sometimes accompanied by illustrations. Learning activities are included. A list of references and answers to learning activities complete the module. (CT)

SAFETY AND HEALTH

IONIZING AND NONIONIZING RADIATION PROTECTION



MODULE SH-35

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INTRODUCTION

Radiation is energy, released from a source in the form of particles or electromagnetic waves. Radiant energy is present almost everywhere, and our bodies are constantly absorbing some forms of radiation. Fortunately, most energy sources of radiation are sufficiently weak, or we are far enough away from them, that the radiation levels entering our bodies are usually low and relatively harmless.

Radiation is emitted from the sun, light bulbs, hot objects, high-voltage devices, X-ray machines, lasers, nuclear materials, and countless other energy sources in our environment. Some forms of radiation are potentially more hazardous than others. Some workplaces are also more likely to present radiation hazards.

Two reasons that radiation hazards require particular caution are 1) because many forms of dangerous radiation are invisible and can't be seen, and 2) because the other sensory elements (such as pain, etc.) may not detect damagingly high levels of radiation until it is too late.

This module will describe various types of ionizing and nonionizing radiation, the situations in the workplace where potential hazards from radiation may exist, hazardous exposure levels of each type, and guidelines for avoiding radiation hazards.

OBJECTIVES

Upon completion of this module, the student should be able to:

1. Define ionizing and nonionizing radiation. (Page 3)
2. Describe the effects that ionizing radiation can have on humans and the levels of ionizing radiation that are considered hazardous. (Page 4)
3. Identify the source of OSHA regulations concerning ionizing and nonionizing radiation. (Page 7)
4. List the five types of ionizing radioactivity. (Page 8)
5. Identify which types of ionizing radiation are the most penetrating. (Page 10)
6. Discuss external and internal hazards of ionizing radioactivity. (Page 12)

7. Discuss protection measures for ionizing radiation. (Page 15)
8. Discuss proper warning, measuring, and protective devices used in safe radioactivity practices. (Page 17)
9. Describe the primary sources of ionizing radiation in industry and where to go if a worker has a radiation question or problem. (Page 21)
10. List and identify the types of nonionizing radiation. (Page 22)
11. Identify the main source of ultraviolet radiation. (Page 26)
12. Identify the greatest threat to an exposed worker by laser radiation. (Page 29)
13. Recognize and define the classes of lasers as defined for safe operation. (Page 32)

OBJECTIVE 1: Define ionizing and nonionizing radiation.

Radiation is the process by which energy moves away from a source in a straight line. Energy may be radiated in the workplace in many forms, such as visible light, ultraviolet light, infrared, X-rays, gamma rays, and nuclear (or particle) radiation. Overexposure to radiation can have a variety of damaging effects, ranging from superficial skin burns to cancer and to death.

Radiation is frequently classified into two groups: ionizing and nonionizing. Ionizing radiation transfers enough radiation to the body upon absorption to cause chemical changes, or ionization of the atoms and molecules in the tissue or organs. Examples of ionizing radiation include X-rays, alpha rays (protons), beta rays (electrons), and gamma rays. Acute exposure to ionizing radiation is rare but can occur from being very near to radiation sources such as very high voltage (such as cathode-ray tubes), X-ray machines, and nuclear materials and spills in places like hospitals and nuclear reactors (power plants). The dangers in ionizing radiation are that it is invisible, it usually does not inflict pain when it is being absorbed (so it is absorbed unnoticed), and it can accumulate in the body from one exposure to another. The biological and chemical changes in the body caused from ionizing radiation are usually irreversible.

Exposures to nonionizing radiation are much more common and usually less hazardous. Forms of nonionizing radiation include all those relatively low-energy, electromagnetic radiations such as microwaves, infrared, light (including lasers), and ultraviolet. Overexposure to nonionizing radiation usually results in some sort of a "burn," either at the surface of the skin or internally. The eye and the skin are parts of the body that are particularly vulnerable to nonionizing radiation. One of the most hazardous sources of nonionizing radiation is the laser.

ACTIVITY 1:*

1. Describe the difference between ionizing and nonionizing radiation.

   ____

   ____

2. List three occupational activities where ionizing radiation may be present.

   a. ____
   b. ____
   c. ____

3. List three occupational activities where nonionizing radiation may be present.

   a. ____
   b. ____
   c. ____

> **OBJECTIVE 2:** Describe the effects that ionizing radiation can have on humans and the levels of ionizing radiation that are considered hazardous.

When considering health and safety, the total amount of radiation and the rate of exposure are important. The term "dosage" is most frequently used to describe the total amount of radiant energy received, or deposited, in tissue.

The dosage received from a source of radiation can be expressed in rads, rems, or millirems. For human tissue, the rad (radiation-absorbed dosage) and the rem (radiation equivalent in man) are roughly equal for exposure to gamma and X-radiation and represent the amount of radiation that deposits 100 ergs of energy in one gram of material. The rem is the dose measured in rads for all different types of radiation including the ionizing radiation from particles like alpha, beta, and neutrons multiplied by quality and distribution factors that produces bio-effects. A millirem is one-thousandth of a rem. To

*Answers to Activities appear on page 34.

give some idea of the size of things being discussed, a person receives about 20 millirems of radiation from a dental X-ray, and about 150 millirems of radiation from a chest X-ray. Table 1 gives the average annual radiation dose received by the general population.

TABLE 1. AVERAGE ANNUAL RADIATION DOSE EQUIVALENTS RECEIVED BY THE GENERAL POPULATION.

Dose (rems)	Effects
0.100 - 1.140	Natural background radiation
0.020 - 0.150	Diagnostic X-rays (typical)
0.003 - 0.005	Therapeutic X-rays
0.0002	Medical radioisotopes
0.0015	Fallout (from atmoshperic testing, 1954-62)
0.00085	Radioactive pollutants from nuclear power plants (1970)
0.002	Smoking one pack of cigarettes per day
0.170	Maximum annual limit proposed (by the International Commission on Radiological Protection, 1970) from all sources exclusive of medical and background

Another unit of radiation that needs to be mentioned and defined is the Curie (C). While the rem is a measure of the effect of radiation on whatever absorbs it, the Curie describes the radiant activity of the source of radiation in terms of counted particles/unit time. The Curie is simply a measurement of radioactivity in a sample of material. Essentially, the Curie is a measure of the number of particles that are radioactive and released from a given sample, and does not measure either the length of time that the sample will remain radioactive or the kinds of particles or energy of the particles that are being emitted.

Once again, exposure to radiation can have two major biological effects on humans: (1) genetic damage to reproductive cells, producing mutations that can be passed on to future generations in the form of fetal and infant deaths, and physical and mental deformities; and (2) somatic damage to tissues other than reproductive cells, which can cause various forms of luekemia, cancer of the nervous system, bone, thyroid, or lung cancer, miscarriages, cataracts, shortening of life span, and damage to unborn children.

Some of the effects from exposure to different doses of radiation are given in Table 2.

TABLE 2. EFFECTS OF RADIATION ON HUMANS FROM WHOLE-BODY, SHORT-TERM EXPOSURES.

Dose (rems)	Effects
0-25	No detectable clinical effects.
25-100	Slight, short-term reduction in number of some blood cells, disabling sickness not common.
100-200	Nausea and fatigue, vomiting if dose is greater than 125 rems, longer-term reduction in number of some blood cells.
200-300	Nausea and vomiting first day of exposure, up to a 2-week latent period followed by appetite loss, general malaise, sore throat, pallor, diarrhea, and moderate emaciation. Recovery in about 3 months unless complicated by infection or injury.
300-600	Nausea, vomiting, and diarrhea in first few hours. Up to a one-week latent period followed by loss of appetite, fever and general malaise in the second week, followed by hemorrhage, inflammation of mouth and throat, diarrhea, and emaciation. Some deaths in two to six weeks. Eventual death for 50% if exposure is above 450 rems; others recover in about six months.
600 or more	Nausea, vomiting, and diarrhea in first few hours. Rapid emaciation and death as early as second week. Eventual death approaching 100% of people exposed.

ACTIVITY 2:

1. Define the following terms related to radiation activity and dosage:

   a. Rad ______________________________

   ____

   b. Rem ______________________________

   ____

   c. Curie ______________________________

2. List the two major biological effects that radiation can have on humans.

   a. ______________________________

   b. ______________________________

OBJECTIVE 3: Identify the source of OSHA regulations concerning ionizing and nonionizing radiation.

Man has always been exposed to the natural radioactivity in his environment. It is in the soil, in the water we drink, and even in our bodies. This natural background level of radioactivity is quite low. The present-day problem of radioactivity has arisen, however, because of all the radioactive materials mined, developed, and used in modern life since the nuclear age began. Since the 1940s, radioactive substances have been used in weapons, for energy production, and in medicine.

In recent years, the industrial use of radioactive materials has increased, also. More and more employees are becoming subject to frequent doses of radiation. The basic aim of a radiation protection program in an industrial facility is to control exposures of its employees and all other individuals, including members of the general population who may come into contact with radiation or radioactive materials.

The type and energy of emitted radioactive particles are among the factors that were considered in establishing maximum permissible concentrations for the various radioactive substances. These safe limits are published in the Code of Federal Regulations, which controls management of radioactive materials. The publication known as 29 Code of Federal Regulations, Part 1910 (29 CFR 1910) contains the occupational safety and health standards for general industry that were promulgated by the Occupational Safety and Health Administration (OSHA) under the United States Department of Labor.

Within this publication, subpart G, Sections 1910.96 and 1910.97, deal with the regulations involved in the two major divisions of radiation — ionizing radiation and nonionizing radiation. Section 1910.96 has regulations and standards applicable to ionizing radiation types and sources. Section 1910.97 covers nonionizing radiation forms. According to the definition of the 29 CFR 1910, ionizing radiation includes alpha rays, beta rays, gamma rays, X-rays, high-speed electrons, high-speed protons, and other atomic particles; but does not include visible and ultraviolet radiation, infrared radiation, microwaves, or laser, which in this paper are classified as nonionizing radiation. The

OSHA standards have few requirements regarding nonionizing radiations. Section 1910.133, "Eye and face protection," states: "Suitable eye protectors shall be provided where machines or operations present the hazard of...injurious radiation..." Section 1910.96, "Ionizing radiation," indicates that the word "radiation" does not include radio waves, visible light, or infrared or ultraviolet light. Section 1910.97, "Nonionizing radiation," restricts that term to the radio-frequency region, including microwaves.

ACTIVITY 3:

What are the sources for the Occupational Safety and Health Administration's regulations concerning (1) ionizing and (2) nonionizing radiation?

1. ______________________________

2. ______________________________

OBJECTIVE 4: List the five types of ionizing radioactivity.

Ionizing radiation has always been a part of man's natural environment, and since the discovery of X-rays, nuclear fuels, and nuclear weapons, it has become a significant part of the industrial environment of many workers. Alpha, beta, and neutron particles, and X-rays and gamma rays are ionizing radiation. Each of these emits energy that can injure the exposed worker. This energy, when absorbed by living tissue, produces damage by a process called ionization.

To understand a little about ionization, it is necessary to remember that the body is made up of various chemical compounds that are in turn made up of atoms. Each atom has a nucleus with its own outer system of electrons.

When ionization occurs, some of the electrons surrounding the atoms are forcibly ejected away from the nucleus. The greater the exposure to ionizing radiation, the more electrons are displaced, and the more physical damage is sustained by the cells containing the atoms that have lost electrons. This

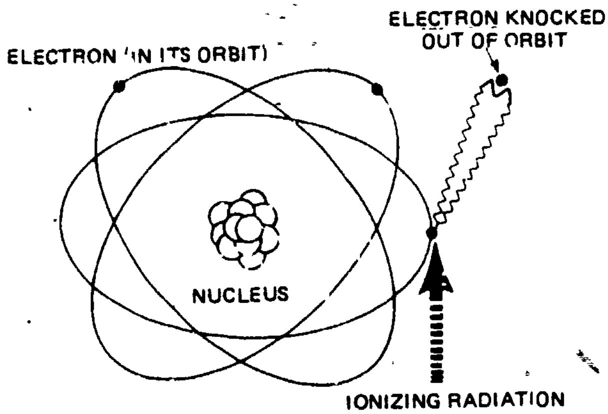

Figure 1. Electron excited out of orbit by ionizing radiation.

may lead to functional changes in the tissues of the body. Figure 1 illustrates the process of ionization.

Electromagnetic (EM) radiation, which includes light from the sun, consists primarily of nonionizing radiation because most types of EM radiation (radio frequency, microwaves, infrared light, and ultraviolet radiation) are not sufficiently energetic to cause ionization when they are absorbed in materials; their main effect is to heat or burn. X-rays and gamma rays are exceptions; they are forms of EM radiation that are sufficiently energetic to cause ionization, and thus are classified as ionizing radiation. The sun contains a significant amount of gamma radiation but we do not normally receive it in our bodies because the gamma rays are filtered out by the atmosphere before they reach the surface of the earth.

The five kinds of radioactivity that are classified as ionizing are (1) alpha α, (2) beta β, (3) X-ray, (4) gamma γ, and (5) neutron. The first four are the most important since neutron sources usually are not used in ordinary industrial operations.

ACTIVITY 4:

List the five types of ionizing radioactivity.

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________

OBJECTIVE 5: Identify which types of ionizing radiation are the most penetrating.

Of the five types of radiation mentioned, alpha particles are the least penetrating of a material, such as human tissue. They will not penetrate anything but the thinnest of substances. For example, paper, cellophane, and thick skin will stop alpha particles. They contain a high level of energy, however, and will ionize to a great extent in the surface tissues with which the particles interact.

Beta radiation has considerably more penetrating power than the alpha radiation. As an example, beta radiation will penetrate several sheets of paper and up to 1/25 of an inch of aluminum before its intensity is reduced significantly. However, beta rays are less ionizing than alpha.

Most of us are somewhat familiar with X-rays and their penetrating ability in medical practices. A substance, such as lead, is required to act as a barrier or shield against the penetrating power of x-rays. This type of a shield is much greater in mass than what is needed for shielding beta radiation.

For all practical purposes, gamma rays have the same penetrating power as X-rays and require the same kinds of heavy shielding materials. Actually, gamma rays and X-rays are electromagnetic radiations (as in the nonionizing radiation types) with similar properties. The primary difference is that gamma rays are produced by nuclear processes, while X-rays may result from the displacement and temporary alteration of the electronic structure of the atoms or from the slowing down of certain high-speed electrons. Examples of gamma emitters in industry are cobalt-60, cesium-137, and iridium-192.

Figure 2 illustrates the penetrating power of alpha, beta, and gamma radiation.

X-rays are produced intentionally for a number of purposes. These include:

- Medical diagnosis of fractured bones, presence of foreign bodies, constricted or blocked passages, and other internal conditions.
- Treatment of cancers that can be reached by external source of ionizing radiation.

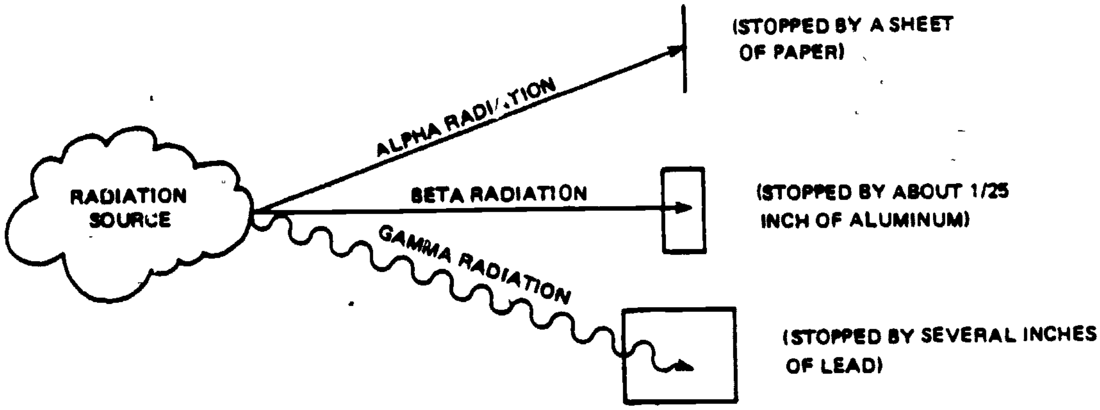

Figure 2. The penetrating power of alpha, beta, and gamma radiation.

- Nondestructive examinations of welds, other fastenings, and internal structures for the existence of cracks, etc.; determining conditions in the interior of sealed containers; and the presence of foreign materials.
- Examination of packages and baggage for illegal articles, such as in the inspections of "carry-on" parcels in airports prior to boarding a commercial airliner.

Neutrons are very penetrating and have characteristics that make it necessary to employ shielding materials containing a high concentration of hydrogen atoms rather than the use of high-density materials.

ACTIVITY 5:

(Circle the correct answer.)

Which of the following types of ionizing radiation is the <u>least</u> penetrating?

1. Gamma rays.
2. Beta rays.
3. X-rays.
4. Neutron rays.

OBJECTIVE 6: Discuss external and internal hazards of ionizing radioactivity.

Radioactive materials that emit X-rays, gamma rays, or neutrons can be "external hazards." This means that such materials can be located some distance from the body and emit radiation that will produce ionization (and thus damage the tissues) as it passes through the body. The external types require control of exposure time, working at a safe distance, use of barriers, or a combination of all three for adequate protection.

As long as radioactive material that emits only low-energy alpha particles remains outside of the body, it will not cause injury. Internally, it is a hazard because its ionizing ability through very short distances in soft tissue makes it very dangerous to health. Once inside the body — in the lungs, stomach, or an open wound — the alpha particles have easy access to vital cells because there is no thick layer of skin to serve as a barrier. Alpha-emitting radioactive materials that concentrate in specific parts of the body are very hazardous. Examples are Ra^{226} and Ra^{224}. In terms of actual tissue damage produced by ionization, the effects of external and internal types are the same. The difference lies in the protective measures that must be taken against each kind of hazard.

Table 3 is a list of frequently-used isotopes showing the half-life ($T_{\frac{1}{2}}$)* and type of emitter.

Alpha emitters and other radioactive materials can enter the body by four means:

1. Breathing.
2. Swallowing.
3. Skin breaks.
4. Skin absorption.

*The half-life of radioactive materials is defined as that period of time required for one-half of the material's potential radiation to be released. The half-life of various materials vary from a fraction of a second to more than one million years.

TABLE 3. FREQUENTLY-USED ISOTOPES.

Isotope	Half-Life	Emitter Type
Sr^{85} (strontium)	$T_{1/2}$ = 65 days	γ
Sr^{96} (strontium)	$T_{1/2}$ = 28 years	β
I^{129} (iodine)	$T_{1/2}$ = 1.56×10^{7} years	β, γ
I^{131} (iodine)	$T_{1/2}$ = 8.08 days	β, γ
I^{128} (iodine)	$T_{1/2}$ ≈ 25 minutes	β, γ
Ra^{226} (radium)	$T_{1/2}$ = 1622 years	α, γ
Ra^{224} (radium)	$T_{1/2}$ = 3.64 days	α, γ
Ra^{225} (radium)	$T_{1/2}$ = 14.8 days	β, γ

Figure 3 shows the two ways that radiation may adversely affect humans.

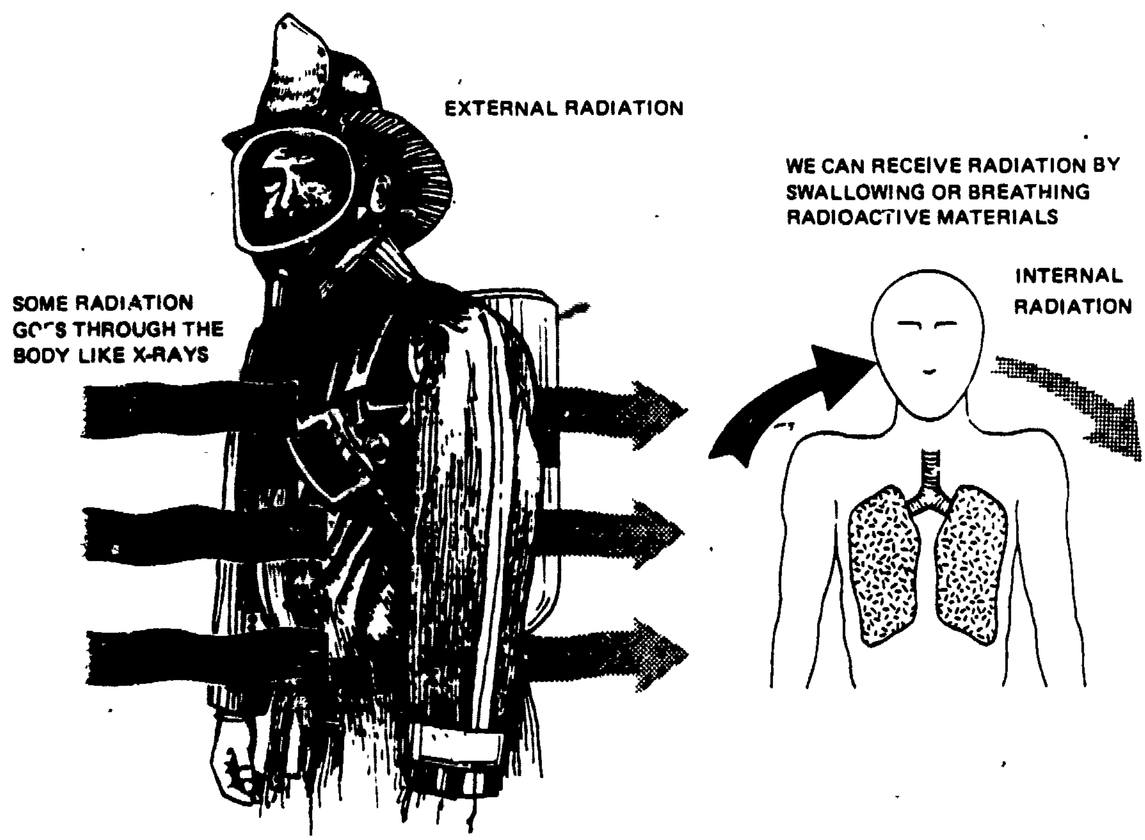

Figure 3. Radiation effects on humans.

Sensitivities of various tissues and organs of the body are shown in Table 4.

TABLE 4. EFFECTS OF IONIZING RADIATION ON BODY TISSUES AND ORGANS.

Tissue or Organ Affected	Effect
Blood	White cells (leucocytes) are the most sensitive to radiation, which will reduce their number and leave the body open to infection. In severe cases, the number of platelets will drop after one week so that the blood's clotting capability is reduced. Weeks later, the number of red cells will decrease to the point that anemia results.
Bone marrow	Damage to the blood can be overcome if there is replacement of the injured blood cells by new ones from the bone marrow. However, radiation damage can injure the bone marrow so that cell replacement cannot take place. Damage to the body will be permanent in such cases.
Digestive system	The various portions of the digestive system vary in sensitivity and types of damage. The small intestine is probably the most sensitive. When walls of the digestive tract are damaged, the dead cells are released into the passages, obstructing their normal processes so that nausea and vomiting occur. Breaking away of surface cells on the lining may lead to ulcers and inability to absorb food. Infection may occur with bloody diarrhea.
Eyes	The eyes are among the parts of the body sensitive to radiation, and the lens cells are the easiest damaged by ionizing radiation. The lenses gradually become opaque with "cataracts" since the cells are not replaced as are blood cells. Other parts of the eye, such as the retina, are less sensitive, but will be affected by high exposures as would any other body cell.
Hair	Radiation can lead to loss of hair. This effect is generally temporary after exposure stops; however, the new hair may be of a new color or have other characteristics different from the original.
Lymphatic system	The lymph nodes (which filter out foreign matter from the lymph) are affected by a heavy dose of radiation.
Nervous system	Damage to the brain may occur if blood vessels and the blood supply to it are damaged. The spinal cord and nerves are highly resistant to low doses of radiation.

Tissue or Organ Affected	Effects
Other organs	Other major organs, such as the kidneys, circulatory system, respiratory system, and liver are generally highly resistant to ionizing radiation and will be injured only by very high dosages, such as those that result from the presence of an internal source.
Reproductive organs	Immediate effects would be the same as those on other cells. To produce sterility in a person would require almost a fatal dose. Genetic effects produced by radiation damage to reproductive cells can only be surmised, and would not be known for several generations after exposure.
Skin	Skin is easily damaged. The dead layer prevents lower-level damage by the alpha particles, and attenuates the effects of beta particles.

The effects that occur during a substantial single exposure are said to be "acute" and can produce both immediate and delayed effects on the body. Small, but repeated, radiation exposures are said to be "chronic" and generally have delayed effects. Acute exposures usually result from mishaps. Chronic exposures are due principally to constantly recurring and unrecognized conditions.

ACTIVITY 6:

A person can receive internal radiation by four means. What are they?

1. ______________________
2. ______________________
3. ______________________
4. ______________________

OBJECTIVE 7: Discuss protection measures for ionizing radiation.

Because alpha emitters are an internal hazard, one must take precautions against breathing or ingesting them, or contaminating open cuts with them. If there is a chance that alpha particles can become airborne, the radioactive material must be handled in a closed ventilation and exhaust system.

Radioactive materials must not be allowed to contaminate food or be handled carelessly so that they can be transferred to the mouth. No edible material of any kind, cosmetics, or cigarettes should be brought into an area where there might be the possibility of radioactive contamination. Hands should be washed and outer protective clothing discarded after leaving the hazardous area and before eating, smoking, etc. Also, good filter-type respirators can be used, but they are not recommended unless there is no other protective device available.

Time, distance, and shielding are important tools in handling radioactive materials safely. Time, as a way of protection, is almost self-explanatory. Because a radiation dose is absorbed at a certain level per unit of time, the shorter the time of exposure, the smaller the radiation dose received. Work procedures involving the use of radioactive materials should be reviewed carefully to keep exposure time to an absolute minimum.

The use of distance is also a very valuable tool. In simple terms, the farther one is away from a radiation source, the less harm is likely to occur. This is why radioactive sources are often handled with tongs and in enclosed environments.

Shielding is commonly used to protect against radiation from radioactive sources. The more material placed between a source and a person, the less radiation the person will receive (except for neutrons). If the mass is concentrated (i.e., density is increased), as in lead, the barrier thickness required for the same degree of protection will be less than it would be for a less dense material such as concrete.

In addition to the above, keep the following important points in mind:

1. Access to areas in which equipment or materials producing ionizing radiations are present should be restricted to personnel directly dealing with the operation, maintenance, or other required activity.

2. Protective clothing and equipment should be worn in an area containing radioactive material to prevent contamination of other areas by tracking or picking up contamination. The clothing to be used depends on the types and levels of radioactivity that might be present. Approved radioactive coats should be worn even where trace amounts only will be found. Coveralls, hoods, masks, gloves, shoe coverings, and other equipment will depend on the risk and level of possible contamination.

3. Any person who believes that he has been subjected to ionizing radiation that may be present should report to a medical facility for examination promptly.

4. No matter how well designed and maintained safety devices and control equipment are, they are not better than the people using them — BE CAREFUL! Use shielding, time, and distance to control dose delivery.

ACTIVITY 7:

(Circle the correct answer.)

Which of the following are important tools in safely handling radioactive materials?

1. Shielding from source.
2. Time of exposure.
3. Distance from radiation.
4. All of the above.

OBJECTIVE 8: Discuss proper warning, measuring, and protective devices used in safe radioactivity practices.

Many types of meters are used to measure various kinds of radiation. Because radiation is odorless, tasteless, and not visible, it is necessary to have detection instruments to measure radiation levels wherever a harmful or potentially harmful amount of radioactivity may be present. The most common types of instruments are Geiger counters, Geiger-Mueller counters, film badges, and dosimeters. However, these instruments measure gamma, X-ray, and beta radiation only. If there is reason to believe that alpha radiation is present, it is necessary to use a special alpha meter. Aside from direct radiation exposure, there is a very limited possibility that, in certain specific areas, neutron radiation could occur, and additional instruments measure the potential for this kind of exposure.

Basically, counters are used to record radiation levels for general use in making decisions, locating radioactive materials, etc. Film badges and dosimeters record the exposures received by individuals. Figure 4 shows a Geiger counter and a personnel dosimeter.

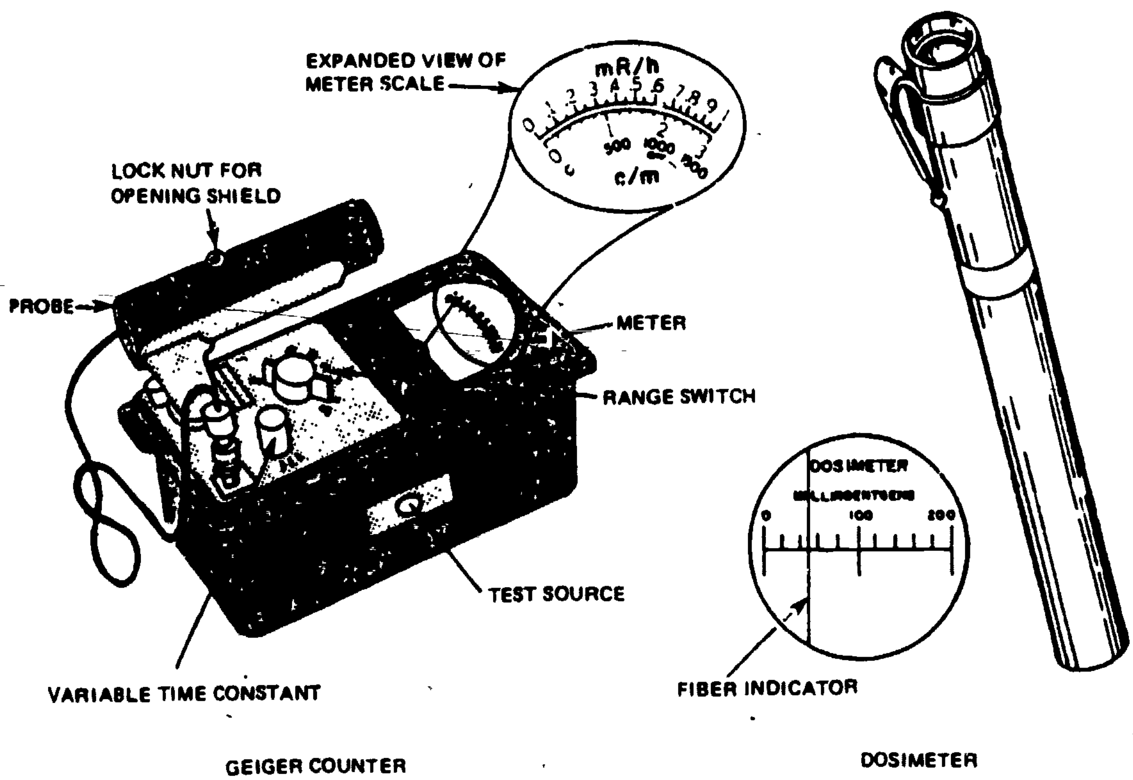

Figure 4. Radiation detection instruments.

Dosimeters come in several forms; the usual type for most safety personnel is the pocket model. This device looks l ke a ballpoint pen. The dosimete· requires periodic charging with a battery to operate accurately.

Film badges (Figure 5) are used to record the amount of radiation received from beta, X-ray, or gamma radiation, while special badges are available for neutron radiation. Film badges are worn by an individual for a period of time and, if they are worn correctly, will provide an estimate of an accumulated dose of radiation to the whole body or to just a part of the body, such as an arm or foot. Alpha radiation cannot be measured with film badges because the alpha particles will not penetrate the paper that must be used over the film emulsion to exclude light.

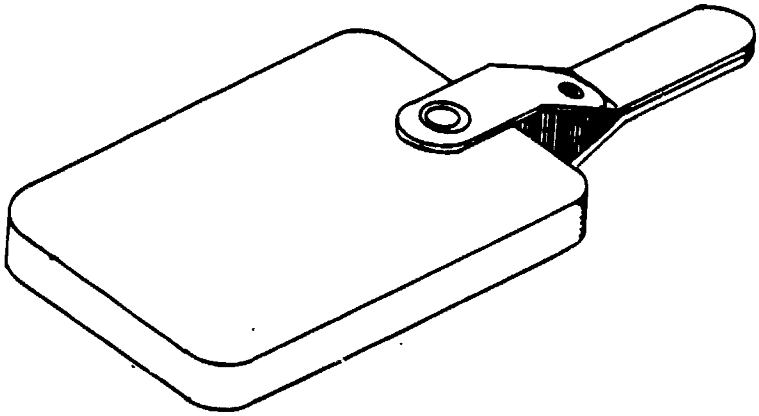

Figure 5. View of a typical film badge worn by individuals in radiation areas.

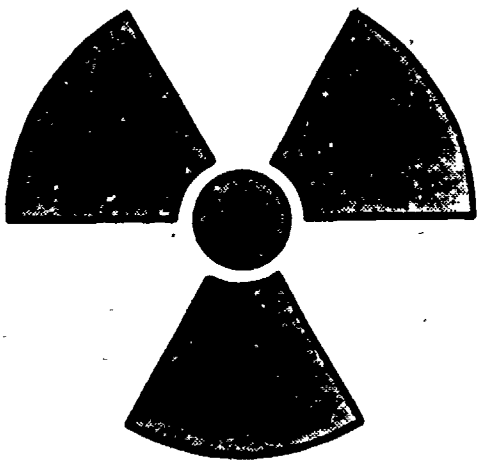

Figure 6. The radiation caution symbol.

Finally, every package of radioactive materials and every area of potential hazard must be labeled and noted. Every label, tag, or sign used to indicate a potential radioactive hazard will employ the radiation caution symbol (see Figure 6) and will have a yellow or white background and red or magenta lettering. There are regulations from the Nuclear Regulatory Commission and the Department of Transportation that govern the size, design, content, and placement of each label, tag, or sign. Each label, tag, or sign is meant for a specific circumstance or use, which is also covered by the regulations mentioned above. It is recommended that these regulations be consulted prior to the use of any of the radioactive warning indicators. Figure 7 shows several examples of warning labels, tags, and signs commonly used in industry and government.

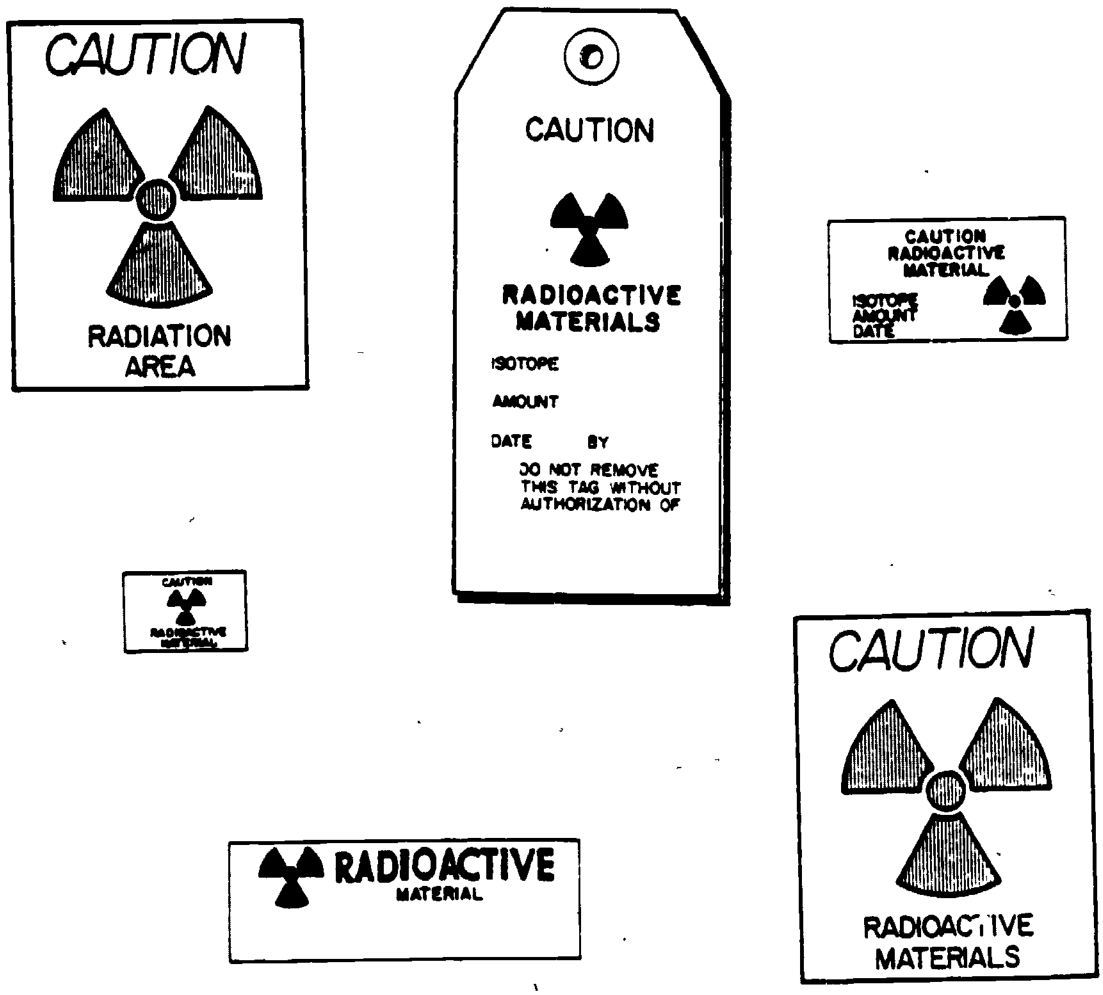

Figure 7. Examples of radioactive warning signs, tags, and labels.

ACTIVITY 8:

(Circle the correct answer.)

The type of radiation measuring device that measures the dosage of radiation received by individuals, and that is usually in the snape of a pen, is termed a:

1. Geiger-Mueller counter.
2. Geiger counter.
3. Film badge.
4. Dosimeter.

OBJECTIVE 9: Describe the primary sources of ionizing radiation in industry and where to go if a worker has a radiation question or problem.

With the widespread use of radioactive isotopes in industry and the increasing use of X-ray sources, ionizing radiation exposures may occur in a wide variety of occupations. Table 5 shows the diversity of occupations potentially exposed to ionizing radiations.

TABLE 5. POTENTIAL IONIZING RADIATION HAZARD OCCUPATIONS.

Aircraft Workers	Nuclear Power Plant Workers
Biologists	Nurses
Dentists	Petroleum Refinery Workers
Drug Makers	Physicists
Electron Microscopists	Plastic Technicians
Embalmers	Prospectors
Food Preservers	Radar Operators
High-Voltage Workers	Radiologists
Industrial Radiographers	Research Workers
Luminous Dial Painters	Tile Glazers
Machinists	Uranium Millworkers
	X-Ray Personnel

Most organziations that deal with ionizing radiation on a regular basis have a designated radiation control officer or a radiation protection professional, known as a Health Physicist.

Lastly, a listing of the state radiation control offices is provided at the end of this module. These authorities should be contacted and consulted when questions arise beyond the knowledge or scope of the employee and there is no radiation safety specialist within the organization.

ACTIVITY 9:

1. List two occupations related to your present or future field of work that may have ionizing radiation hazards.

   a. ______________________

   b. ______________________

2. Write the mailing address of the office nearest to you where you may inquire about potential radiation hazards.

____

____

OBJECTIVE 10: List and identify the types of nonionizing radiation.

Nonionizing radiation affects the human body primarily by overheating or burning the skin, eyes, tissue, bone, or internal organs. Nonionizing radiation includes all those parts of the electromagnetic spectrum where the photons are not energetic enough when absorbed to cause a material to ionize. The electromagnetic (EM) spectrum, shown in Figure 8, is energy transmitted in the form of electromagnetic waves. The sources of electromagnetic radiation include electric antennas (including electrical power cables), hot (incandescent) objects, electric arcs, lighting and heat lamps, cathode ray (television) tubes, lasers, X-ray machines, and the sun.

The chart in Figure 8 shows the various components of the EM spectrum, classified according to the wavelength, or frequency, of the emitted radiation and subdivided into ranges. Although no range of radiation is sharply

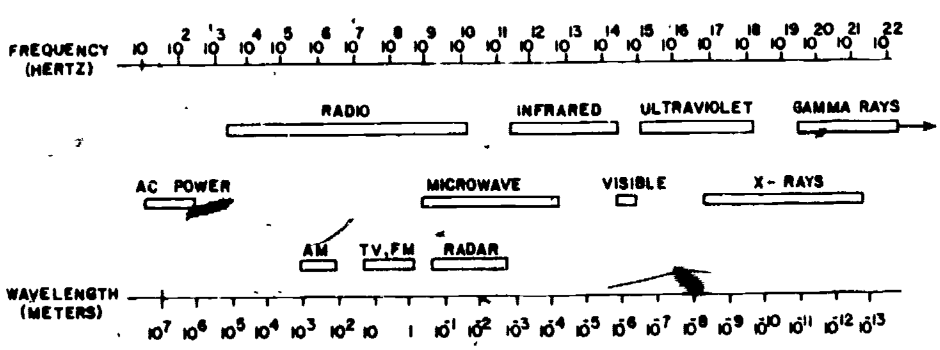

Figure 8. Electromagnetic spectrum showing different frequency and wavelengths.

separated from another and, in fact, the ranges overlap, it is necessary to separate these ranges into groups because of the physical and biological effects associated with each type of radiation.

This objective addresses only that portion of the EM spectrum that can be described as nonionizing radiation, that is, the portion of the EM spectrum shown in Figure 8 from the long wave ultraviolet (UV) range to the left on the chart will be discussed. There are four basic groups in this remainder of the EM spectrum; they are: (1) low frequency, (2) microwaves, (3) infrared (IR), and the (4) visible and long wave UV radiation ranges. One source of nonionizing radiation, the laser, that has outputs in the UV, visible, and IR ranges, is of particular concern and will be discussed at length.

LOW FREQUENCY

The longer wavelengths — including power frequencies, broadcast radio, and shortwave radio — can produce general heating of the body. The health hazard from these radiation sources is very small, however, since it is unlikely that they would be found in intensities great enough to cause significant effect.

MICROWAVES

Microwaves have wavelengths of 3 m (meters) to 3 mm (millimeters) (100 to 100,000 megahertz [MHz]) and are found in radar, communications, and other industrial applications.

Various estimates have been made of the number of workers potentially exposed to microwave (also sometimes known as radio-frequency [RF]) radiation in industry, including one estimate of approximately 21 million workers. Effects from exposure to this type of radiation include adverse changes in the central nervous system, blood, and genetic and reproductive systems. Research has also shown symptoms of overexposure such as headache, increased fatigue, partial loss of memory, irritability, and sleepiness, among others, although some are in dispute.

Usually, a rise in body temperature, as well as localized damage, can result from an exposure of sufficient intensity and time. (Generally, the longer wavelengths will produce a greater temperature rise in deeper tissues of the body than shorter-wavelength radiation types.) In addition, flammable gases and vapors may ignite when they are inside metallic objects located in a microwave beam.

Power intensities for microwave are given in units of watts per square centimeter (W/cm^2). As a safety precaution, areas having a power intensity of over 0.01 watt per square centimeter should be avoided. In such areas, dummy loads should be used to absorb the energy output while equipment is being operated or tested. If a dummy load cannot be used, adjacent populated areas should be protected by adequate shielding.

The presence of microwave radiation poses a special problem to cardiac patients with electronic heart devices, commonly called "pacemakers." Microwaves can cause pacemakers to malfunction to the extent that a patient equipped with such a device may pass out or have a cardiac arrest (die). Although appliances such as microwave ovens have undergone significant improvements in recent years to shield the microwaves, it is still advisable to post warning signs of "CAUTION – MICROWAVE DEVICES OPERATING IN THIS AREA."

Because of the size of this potentially exposed group at work and the continuing expansion of microwave use in industry, microwave radiation precautions and safety are a must. Table 6 lists occupations with activities and/or products in which microwave radiation is usually present and may be a potential hazard.

TABLE 6. POTENTIAL MICROWAVE HAZARD OCCUPATIONS.

Microwave/Radio-Frequency Radiation
Automotive Workers
Food Product Workers
Furniture and Wood Workers
Glass Fiber Workers
Paper Product Workers
Plastic Heat-Sealing Workers
RF/Microwave Application Workers
Rubber Products Workers
Textile Workers

INFRARED

Infrared radiation does not penetrate below the superficial layer of the skin, so its only effect is to heat the skin and the tissues immediately below it. Except for thermal burns, the health hazard could be considered negligible. (The skin provides its own warning mechanism by having a pain threshhold below that of the burn threshold.)

However, there is no adequate warning mechanism such as pain to protect against damage to the eyes. Excessive exposure of the eyes to infrared radiation, especially from furnaces and similar hot bodies has been said for many years, to produce "glass blower's cataract" or "heat cataract." This condition is an opacity of the rear surface of the lens of the eye. It was first reported among the hand blowers of glass in England in the early 1900s.

Proper eye protection is a necessity for workers in an intense infrared radiation environment.

A wide range of infrared radiation wavelengths representing large variations in temperature is encountered in many industries from direct (example: lamps) and indirect (example: heat) sources. Occupations potentially associated with infrared radiation exposures include the following found in Table 7.

TABLE 7. POTENTIAL INFRARED HAZARD OCCUPATIONS.

Infrared Radiation	
Bakers	Glass Furnace Workers
Blacksmiths	Heat Treaters
Braziers	Iron Workers
Chemists	Laser Operators
Cloth Inspectors	Motion Picture Machine Operators
Cooks	Skimmers, Glass
Electricians	Solderers
Firemen	Steel Mill Workers
Foundry Worker	Stokers
Furnace Workers	Welders
Glass Blowers	

ACTIVITY 10:

1. List eight types of electromagnetic radiation and identify which are classified as nonionizing.
   a. ______
   b. ______
   c. ______
   d. ______
   e. ______
   f. ______
   g. ______
   h. ______

2. Identify two sources of each type of the EM radiation listed below:
   a. Low frequency ______ ______
   b. Microwaves ______ ______
   c. Infrared ______ ______

3. The most common effect on the body that low-frequency, microwave, and infrared radiations all share is:
   a. Cause death.
   b. Hormone changes.
   c. Heating of the skin.
   d. Cardiac arrest.

OBJECTIVE 11: Identify the main source of ultraviolet radiation.

Ultraviolet (UV) radiation is an invisible radiant energy that is produced by natural and artificial sources; UV is frequently present along with visible light sources. It aids in the production of visible light from fluoresent lamps, lasers, instrument panel dial glow, and it produces special effects that appear in some visual presentations. UV is also used in chemical synthesis and analysis, product inspection, crime detection, medical diagnosis and treatment, photocopying, photoelectric scanning, and electrostatic processes. The sun is the major source of ultraviolet radiation. Many artificial sources are found in industry, such as germicidal lamps, carbon arcs, welding and cutting torches, furnaces, and laboratory test and analysis equipment.

Ultraviolet radiation can be injurious to the skin and particularly to the eyes. Most people have experienced skin damage known as sunburn caused by ultraviolet radiation that is part of the sun's light. The severity of sunburn depends on the length of exposure and the intensity of the radiation, as well as on the individual's sensitivity. Continued exposure to ultraviolet radiation speeds skin aging and can even cause skin cancer. Skin cancer is most common among people who must work outdoors in the sun, such as farmers, seamen, and power-line workers.

Exposure of the eyes to ultraviolet radiation is particularly dangerous because the radiation cannot be seen or, at first, felt. Therefore, persons being exposed are not always aware that their eyes are being affected. The invisible radiation may later produce discomfort due to its absorption by the outer layer of the eye. Conjunctivitis, the resulting condition (often called "ground glass eyeball" or "welder's flash"), usually occurs four to eight hours after exposure. It is extremely painful and, although the pain is usually temporary, permanent damage is done to the eyes.

Ultraviolet radiation is so readily absorbed by the human skin and eye that the exposure often is severe and becomes so painful that the worker quickly learns to protect himself thereafter. Prolonged exposure of the unprotected skin and eyes should always be avoided and persons with fair skin, especially, should avoid even occasional exposure. Barrier creams and lotions give some protection for brief exposures; however, protective clothing, gloves, and face shields are advised for all exposures, whether brief, intermittent, or prolonged. Enclosures or shields that are nontransparent to the radiation also can be used to control the exposure.

Approved goggles, properly fitted with the correct lenses, are absolutely essential for all welding, cutting, and open-arc operations. Side and back screens should be used for these operations to protect nearby workers. Remember that bright shiny surfaces can reflect harmful ultraviolet light from an open arc and these should be masked or removed from the work areas.

Ventilation is needed, not to protect the worker's skin or eyes from radiation, but to remove toxic gases that may be ted by the interaction of ultraviolet radiation with air and atmospheric contaminants. This interaction can produce hazardous concentrations of ozone, oxides of nitrogen, and other toxic gases. These toxic gases can be produced by the interaction of solvent vapors and ultraviolet radiation (or by contact of the gases with arcs or hot metal surfaces). For these reasons, it is essential that workplaces where ultraviolet radiation is present be well ventilated. Where ventilation is being designed, it should be kept in mind that photochemical reactions can take place at some distance from both the ultraviolet sources and the work operations where the solvent fumes originate.

In general, workers should be aware of possible ultraviolet radiation in their work area and should follow the general rules and guidelines issued by management to protect them on the job.

Occupations associated with potential UV radiation exposure include the following ones listed in Table 8. Obviously, there are many more.

TABLE 8. POTENTIAL ULTRAVIOLET RADIATION HAZARD OCCUPATIONS.

Ultraviolet Radiation	
Agricultural Workers	Optometrists
Beauty Salon Workers	Paint and Color Testers
Brick Masons	Physiological Optics Workers
Cattlemen	Pipeline Workers
Chemists	Plastic Curers
Construction Workers	Policemen
Dentists	Printers
Farmers	Road Workers
Fishermen	Seamen
Gardeners	Maintenance Workers
Graphic Illustrators	Meat Curers
Laboratory Workers	Nurses
Lifeguards	Oilfield Workers

Ultraviolet Radiation	
Ski Instructors	Tissue Culture Workers
Sportsmen	Tobacco Irradiators
Surveyors	Welders
Textile Inspectors	Wood Curers

ACTIVITY 11:

Name two sources of ultraviolet radiation.

1. ______________________________
2. ______________________________

OBJECTIVE 12: Describe the greatest threat to an exposed worker by laser radiation.

The word "laser" is an acronym for "Light Amplification by Stimulated Emission of Radiation." Lasers are highly directional light sources with some unique characteristics that have made them very useful in many industrial, laboratory, and construction applications including welding, drilling holes in metals and baby bottle nipples, cutting diamonds, aligning wings on airplanes, repairing damaged retinas, performing surgery, and taking three-dimensional pictures. Some lasers have their output wavelength in the UV; some in the visible, and some in the IR.

Light from conventional sources, such as the sun or a light bulb, radiates in all directions. This light is termed incoherent. On the other hand, light produced by a laser contains all the same wavelength traveling in only one direction and is termed coherent. The intensity of the energy in a laser beam can be far greater than that received from the incoherent light of the sun or a welding arc and, therefore, can be extremely damaging, especially to the eye. These light-emitting atoms are "pumped" full of energy and stimulated to fall to a lower energy level, giving off light waves in the process that are directed to produce the coherent laser "beam."

The human body is vulnerable to the outputs of certain lasers; these lasers can cause damage to the eyes and skin under certain circumstances.

Research relating to the injury thresholds to the eye and skin has been conducted in order to understand the biological hazards of laser radiation. It is now accepted that the human eye is almost always more vulnerable to injury than human skin. In the far-ultraviolet and far-infrared regions of the optical spectrum, the cornea (the clear, outer front surface of the eye's optics) absorbs the laser energy and may be damaged. The cornea, unlike the skin, does not have an external layer of dead cells to protect it from the environment. In the near-ultraviolet and near-infrared region at certain wavelengths the lens of the eye may be vulnerable to injury. Of greatest concern, however, is laser exposure in the retinal hazard region of the optical spectrum — approximately 400 nm (violet light region), to 1400 nm (near-infrared). Within this range, laser rays are brought into focus in a very tiny spot on the retina. This is illustrated in Figure 9.

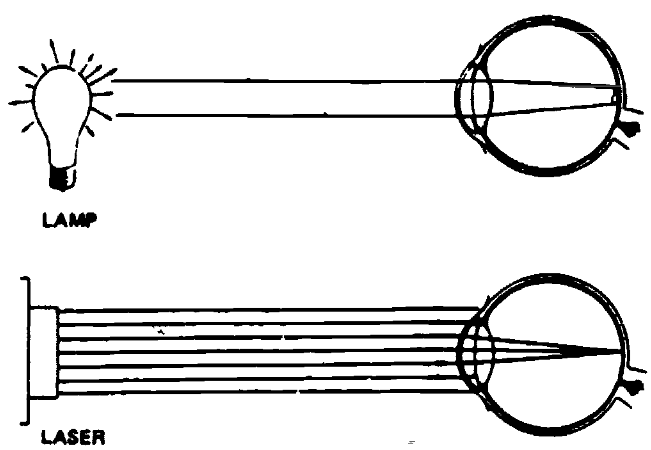

Figure 9. A laser source creates a far smaller and more concentrated retinal image than a lamp bulb.

If the eye is not focused at a distance or if the laser light has been reflected off rough surfaces that diffuse the light, this worst-case hazard does not exist. Much higher levels of laser radiation would be necessary to cause injury. Likewise, since this ocular focusing effect does not apply to the skin, the skin is far less vulnerable to injury from these wavelengths. The light entering the eye from a laser in the retinal hazard region is concentrated by a factor of 100,000 times when it strikes the retina.

Besides damage to the eye and skin, a laser also presents several other hazards. Most lasers require the use of high voltages and should be treated with caution so as to prevent serious electrical shock and burns. Flammable solvents and materials may be associated with a particular laser operation and are capable of being ignited by a laser beam. Lasers may also lead to potential explosion through their heat-producing capacity.

ACTIVITY 12:

(Circle the correct answer.)

Which of the following area of the body has the greatest potential for damage by laser radiation?

1. Skin.
2. Eyes.
3. Ears.

OBJECTIVE 13: Recognize and define the classes of lasers as defined for sa operation.

All laser products and systems can be grouped into at least four primary categories to indicate potential risk. The following delineation of lasers into safety categories has been adopted by the Bureau of Radiological Health, U.S. Department of Health and Human Sources, the American National Standards Institute (ANSI Z 136.1 Standard) and the American Conference of Governmental Industrial Hygienists.

- Class I — Class I, or "exempt lasers," are those that cannot emit a hazardous level of laser radiation under normal operating conditions. There may be a more hazardous laser embedded in the enclosure of the Class I product, but no harmful laser radiation can escape the enclosure.
- Class II — Class II, or "low-power" laser devices, are those visible lasers that do not have enough power to injure a person accidentally, but that may produce retinal injury when viewed directly for more than one-fourth second.
- Class IIIa — Class IIIa includes only visible lasers that cannot induce injury when viewed within the beam with the unaided eye, but may cause retinal damage if the energy is collected and focused into the eye (as with binoculars).

- Class IIIb — Class IIIb consists of lasers that can produce accidental injury if viewed directly. Viewing of a mirror-like reflection should also be considered hazardous.
- Class IV — Class IV includes lasers that not only produce a hazardous direct or reflected beam but also a hazardous diffuse reflection and a significant skin hazard. A Class IV laser system can also be described as any that exceeds the output limits of a Class III device. Very stringent controls are required for this class of lasers.

Like any other hazardous operation, lasers can be operated safely through the use of suitable facilities, equipment, and trained personnel. Class II lasers require no special safety measures. However, as in the case of a movie projector, a person should not stare directly into the projected beam.[1] Safety training is desirable for those working with Class III systems. Eyewear may be necessary if intrabeam viewing cannot be precluded. Operation within a marked, controlled area is also recommended. Finally, for Class IV lasers or laser systems, eye protection is almost always required; facility interlocks and further safeguards are used. In all cases, particular attention must be given to the safety of unsuspecting visitors or spectators in laser areas.

There are general guidelines for working safely with lasers. These are:

1. Never look directly into any laser beam or its reflection.
2. Avoid looking at reflections in the laser mirrors, shiny spherical objects such as doorknobs, screw heads, windowpanes, watch crystals, rings, tools, jewelry, mirrors, or shiny surfaces of laboratory equipment.
3. Never allow any part of the body to intercept a high-powered laser beam or its reflection.
4. Laser operations should not be conducted in areas where flammable liquids or combustible vapors are present.
5. Atmospheric contamination can result from materials bombarded and vaporized by the incident beam. Toxic materials from such vapors could include lead, ozone, carbon monoxide, cadmium, mercury, etc.
6. Persons exposed to laser beams should be furnished with protective goggles of an optical density suitable for the particular laser wavelength and power density of the beam. It should also be remembered that laser goggles may deteriorate with age or exposure to the laser beam.
7. Lasers should be used only in well-defined areas in which access can be controlled. The area should be posted with appropriate signs to alert persons passing by the area that a potential hazard exists.

8. The laser system should be activated only by or under the direct supervision of a person knowledgeable of the hazards involved with the use of lasers. When not in use, the laser system should be made inaccessible to unauthorized personnel.

9. Personnel working with lasers should have eye examinations periodically and whenever they may have been exposed to laser radiation.

ACTIVITY 13:

1. Name the class of lasers that almost always requires eye-protectors and may also have a significant skin hazard. ______________________

2. List five guidelines for working safely with lasers and tell why they are important.

   a. ______________________________
   ____

   b. ______________________________
   ____

   c. ______________________________
   ____

   d. ______________________________
   ____

   e. ______________________________
   ____

REFERENCES

Accident Prevention Manual for Industrial Operations. National Safety Council, 1975.

American Conference of Governmental Industrial Hygienists. Guide for Control of Laser Hazards. Cincinnati, OH: 1976.

American National Standards Institute. Safe Use of Lasers, Standard Z 136.1, ANSI. New York, NY: 1976 (under revision).

Federal Performance Standards for Light Emitting Products. Rockville, MD: U.S. Department of Health Education and Welfare, Bureau of Radiological Health, Food and Drug Administration.

Isman, Warren E. and Carson, Gene P. Hazardous Materials. Riverside, NJ: Mcmillan Company, 1980.

Laser Institute of America. Guide for the Selection of Laser Eye Protection. 1st ed. Cincinnati, OH 1978.

Laser Institute of America. Laser Safety Guide. 4th ed. Cincinnati, OH: 1974.

Laser Institute of America. "Information Bulletin 03." Waco, TX: 1979.

Robertson, J. Craig. A Guide to Radiation Protection. New York: John Wiley and Sons, Inc., 1976.

Sax, N. Irving. Dangerous Properties of Industrial Materials. 5th ed. Cincinnati, OH: Van Nostrand Reinhold Co., 1975.

Technical Education Research Center – Southwest. Nuclear Technology Courses – Course 1 Radiation Physics, Course 2 Radiation Protection I, and Course II Radiation Detection and Measurement. Waco, TX: TERC-SW, 1977.

ANSWERS TO ACTIVITIES

ACTIVITY 1

1. Ionizing radiation transfers enough radiation to the body to cause chemical changes. Nonionizing radiation causes a burn.
2. The answers would include these among others:
   a. Hospitals.
   b. Dentist offices.
   c. Nuclear reactors.
3. The answers would include these among others:
   a. Lifeguards.
   b. Cooks using microwave ovens.
   c. Heat from a boiler.

ACTIVITY 2

1. a. Rad — Radiation-absorbed dosage.
   b. Rem — Radiation equivalent in man.
   c. Curie — Radiant activity of the source of radiation in term of counted particles/unit time.
2. a. Genetic damage.
   b. Somatic damage.

ACTIVITY 3

1. 29 CFR 1910, Subpart G, Section 1910.96.
2. 29 CFR 1910, Subpart G, Section 1910.97.

ACTIVITY 4

1. Alpha.
2. Beta.
3. X-ray.
4. Gamma.
5. Neutron.

ACTIVITY 5

2. Beta rays.

ACTIVITY 6

1. Breathing.
2. Swallowing.
3. Skin breaks.
4. Skin absorption.

ACTIVITY 7

4. All of the above.

ACTIVITY 8

4. Dosimeter.

ACTIVITY 9

1. a. Use Table 4 for some examples.
   b. Use the Appendix.

ACTIVITY 10

1. a. Electric power.
   b. Radar.
   c. Infrared.
   d. Visible.
   e. X-rays nonionizing.
   f. Ultraviolet nonionizing.
   g. Gamma rays nonionizing.
   h. Cosmic nonionizing.
2. a. Broadcast radio Short wave radio.
   b. Radar Communications.
   c. Furnace or heat emitting devices High intensity lights.
3. c. Heating of the skin.

ACTIVITY 11

The answers would include these among others:

1. Sun.
2. Germicidal lamps, carbon arcs, welding and cutting torches, furnaces, and laboratory test and analysis equipment.

ACTIVITY 12

2. Eyes.

ACTIVITY 13

1. Class IV.
2. Any five of the nine guidelines listed on pages 32 and 33.

For information on State and local requirements for radiation matters, contact the appropriate office indicated below:

Alabama

Div. of Rad. Hlth.
State Dept. of Public Hlth.
State Office Bldg.
Montgomery, AL 36104
205-832-5990

Alaska

Rad. Hlth. Program
Dept. of Hlth. & Soc. Studies
Pouch H-06F
Juneau, AK 99811
907-465-3120

Arizona

Arizona Atomic Energy Comm.
2929 W. Indian School Rd.
Phoenix, AZ 85017
602-255-4845

Arkansas

Div. of Env. Hlth. Serv.
Dept. of Health
4815 W. Markham St.
Little Rock, AR 72201
501-661-2301

California

Radiological Hlth. Sect.
State Dept. of Hlth. Serv.
714 P Street
Sacramento, CA 95814
916-322-2073

Colorado

Rad. & Haz. Waste Control
Dept. of Health
4210 East 11th Ave.
Denver, CO 80220
303-320-8333 ext. 6246

Connecticut

Radiation Control
Dept. of Env. Protection
State Office Building
Hartford, CT 06115
203-566-5668

Delaware

Office of Radiation Safety
Dept. of Hlth. & Social Serv.
Jesse S. Cooper Memorial Bldg.
Capitol Square
Dover, DE 19901
302-994-2506 ext. 42

District of Columbia

Bur. of Occup. & Inst. Hyg.
415 12th Street, NW, Suite 314
Washington, DC 20004
202-724-4358

Florida

Radiological Hlth. Program
Dept. of Hlth. & Rehab. Serv.
1317 Winewood Blvd.
Tallahassee, FL 32301
904-487-1004

Georgia

Radiologial Hlth. Unit
State Office Bldg.
47 Trinity Ave.
Atlanta, GA 30334
404-894-5795

Guam

Bur. of Env. Hlth.
Dept. of Pub. Hlth. & Soc. Serv.
P.O. Box 2816
Agana, GU 96910
734-9057

Hawaii

Noise & Radiation Branch
Dept. of Health
P.O. Box 3378
Honolulu, HI 96801
808-548-3075

Idaho

Radiation Control Section
Idaho Dept. of Hlth. & Wel.
State House
Boise, ID 83720
208-334-3335

Illinois

Div. of Radiation Protection
Dept. of Public Hlth.
535 W. Jefferson St.
Springfield, IL 62761
217-782-2[illegible]2

Indiana

Radiological Hlth. Section
Indiana State Board of Hlth.
1330 W. Michigan St.
Indianapolis, IN 46206
317-633-0150

Iowa

Rad. Hlth. & Work Dis. Sec.
Iowa Dept. of Hlth.
Lucas State Office Bldg.
Des Moines, IA 50319
515-281-4928

Kansas

Bureau of Radiation Control
Dept. of Hlth. & Env.
Forbes Field, Bldg. 321
Topeka, KS 66620
913-862-9360 ext. 284

Kentucky

Radiation Control Branch
275 E. Main St.
Frankfort, KY 40621
502-564-3700

Louisiana

Nuclear Energy Commission
Office of Env. Affairs
P.O. Box 14690
Baton Rouge, LA 70804
504-925-4518

Maine

Radiological Hlth. Program
157 Capitol St.
Augusta, ME 04330
207-289-3826

Maryland

Div. of Radiation Control
Dept. of Hlth. & Mental Hyg.
201 W. Preston St.
Baltimore, MD 21201
301-383-2744

Massachusetts

Radiation Control Program
Mass. Dept. of Pub. Hlth.
600 Washington St., Rm. 770
Boston, MA 02111
617-727-6214

Michigan

Div. of Radiological Hlth.
3500 N. Logan St.
P.O. Box 30035
Lansing, MI 48909
517-37[illegible]

Minnesota

Section of Rad. Control
Minnesota Dept. of Hlth.
717 Delaware St., SE
Minneapolis, MN 55440
612-296-5323

Mississippi

Div. of Radiological Hlth.
State Board of Hlth.
P.O. Box 1700
Jackson, MS [illegible]205
601-354-6657

Missouri

Bur. of Radiological Hlth.
Div. of Hlth.
1511 Christy Lane — P.O. Box 570
Jefferson City, MO 65101
314-751-2713 ext. 332

Montana

Occup. Hlth. Bureau
Dept. of Hlth. & Env. Sci.
Cogswell Bldg.
Helena, MT 59601
406-449-3671

Nebraska

Div. of Radiological Hlth.
301 Centennial Mall, So.
P.O. Box 95007
Lincoln, NB 68509
402-471-2168

Nevada

Radiological Hlth. Section
505 E. King St. - Hlth. Div.
Carson City, NV 89710
702-885-4750

New Hampshire

Bureau of Env. Hlth.
Hlth. & Welfare Bldg.
Hazen Drive
Concord, NH 03301
603-271-4588

New Jersey

Bur. of Rad. Protection
Div. of Env. Quality
380 Scotch Rd.
Trenton, NJ 08628
609-292-5586

New Mexico

Env. Improvement Div.
Dept. of Hlth. & Env.
P.O. Box 968
Santa Fe, NM 87503
505-827-5271

New York

Bur. of Radiological Hlth.
Empire State Plaza
Tower Bldg.
Albany, NY 12237
518-474-2846

Bur. of Radiation Control
NY City Dept. of Hlth.
377 Broadway
New York, NY 10013
212-566-7750

North Carolina

Rad. Protection Sect.
Div. of Facility Serv.
P.O. Box 122()
Raleigh, NC 27605
919-733-4283

North Dakota

Div. of v. Engr.
ND Dept. of Hlth.
1200 Missouri Ave.
Bismarck, ND 58501
701-224-2348

Ohio

Rad. Hlth. Program
Dept. of Hlth.
246 No. High St. - P.O. Box 118
Columbus, OH 43216
614-466-1380

Oklahoma

Occup. & Rad. Hlth. Serv.
N.E. 10th & Stonewall Sts.
P.O. Box 53551
Oklahoma City, OK 73152
405-271-5221

Oregon

Radiation Control Section
State Hlth. Division
P.O. Box 231
Portland, OR 97207
503-229-5797

Pennsylvania

Bur. of Rad. Protection
Dept. of Env. Resources
P.O. Box 2063
Harrisburg, PA 17120
717-787-2480

Puerto Rico

Rad. Hlth. Division
Dept. of Hlth.
Box 10427 Caparra Hghts. Sta.
Rio Piedras, PR 00922
809-767-3563

Rhode Island

Div. of Occup Hlth. & Rad. Con.
Dept. of Hlth.
Cannon Bldg.
Davis Street
Providence, RI 02908
401-277-2438

South Carolina

Bur. of Radiological Hlth.
SC Dept. of Hlth. & Env. Con.
2600 Bull St.
Columbia, SC 29200
803-758-5548

South Dakota

Sanitation & Safety Program
State Dept. of Hlth.
Joe Foss Office Bldg.
Pierre, SD 57501
605-773-3918

Tennessee

Div. of Radiological Hlth.
Dept. of Public Hlth.
344 Cordell Hull Bldg.
Nashville, TN 37219
615-741-7812

Texas

Div. of Occup. Hlth. & Rad. Con.
Texas Dept. of Hlth.
1100 West 49th St.
Austin, TX 78756
512-458-7341

Utah

Bur. of Rad. & Occup. Hlth.
State Dept. of Hlth.
Box 2500
Salt Lake City, UT 84103
801-533-6734

Vermont

Div. of Occup. & Rad. Hlth.
Dept. of Health
10 Baldwin St.
Montpelier, VT 05602
802-828-2886

Virginia

Bur. of Rad. Hlth.
Dept. of Health
109 Governor St.
Richmond, VA 23219
804-786-5932

Virgin Islands

Natural Res. Mgmt.
Div. of Natural Res.
P.O. Box 4340
Charlotte Amalie
St. Thomas, VI 00801
809-774-6420

Washington

Rad. Control Section
Dept. of Soc. & Hlth. Serv.
MS LD-11, Airdustrial Park
Olympia, WA 98504
206-753-3468

West Virginia

Rad. Hlth. Section
Industrial Hygiene Div.
151 11th Ave.
South Charleston, WV 25303
304-348-3526

Wisconsin

Rad. Protection Section
Division of Hlth.
P.O. Box 309
Madison, WI 53701
608-266-1791

Wyoming

Rad. Hlth. Serv.
Div. of Hlth. & Med. Serv.
Hathaway Bldg., 4th Fl.
Cheyenne, WY 82001
307-777-7956