LASER RADIATION SAFETY

University of Houston – Clear Lake

Laser Radiation Safety

TABLE OF CONTENTS

LASER RADIATION SAFETY

COURSE OBJECTIVES

Upon completion of this course, you will be able to:

- Identify lasers and reflective light.
- Define the classification of lasers.
- Describe biological effects of laser radiation.
- Define laser radiation safety requirements and precautions.
- Identify and recall safety rules for working with lasers.

COURSE INTRODUCTION

In 1960, Theodore H. Maiman developed the first laser. Since then, our society has become dependent on them in many ways. Lasers are used in compact discs, bar-code scanners at the check-out counter, and in long distance phone lines to carry out calls. UHCL also uses lasers to perform daily tasks.

This course is designed to familiarize the employee with lasers and their dangers along with necessary precautions.

LESSON ONE

LASER AND REFLECTIVE LIGHT

LESSON OBJECTIVES

Upon completion of this lesson, you will:

- Understand laser light
- Understand reflective light and its forms

LESSON INTRODUCTION

Laser radiation equipment is used on a daily basis at UHCL to help workers perform useful tasks. Many types of lasers are available today, ranging in size from devices that can rest on a fingertip to those that fill large buildings. All these lasers have certain basic characteristic properties in common. In this lesson, some of the properties of a laser and its reflective qualities will be discussed.

Laser

Laser stands for **light amplification** by **stimulated emission** of **radiation**. Lasers are classified with microwaves as nonionizing radiation which causes harm to people from thermal effects. Lasers generate a nonionizing radiation in the form of light wavelengths which are collimated through a tube.

NOTE: **Collimated** means straightening and paralleling the light patterns to consolidate the size of the beam.

Laser wavelengths are either visible or non-visible light. Light that cannot be seen is as dangerous as light that can. Each employee should take appropriate precautions when working with laser equipment whether the light is visible or non-visible.

Lasers are more effective at many tasks than any other light source because of irradiance. **Irradiance**, or brightness, means the amount of optical power that is projected into a specific area.

Along with high irradiance, lasers have coherent light. **Coherent light** means the light waves are lined up or parallel. With the light waves aligned, the intensity of the light is more powerful and can be sustained longer than conventional light. In comparison, a conventional source such as a light bulb has incoherent light. This means the wavelengths are different and can easily scatter. The light from most conventional sources spreads out very fast over a distance area. This causes the conventional source to lessen its irradiance quickly. Laser light is usually collimated and delivers most of its output as a narrow beam which loses little power with distance. That is, a laser can deliver more power to a small area of skin (or eye) than any other known light source. However, then direct laser beam itself is not the only source of harm, **the reflective light from the beam can cause equally severe damage.**

Reflective Light

Reflective light is the light produced from a secondary source. Such as a person capturing sunlight on a mirror redirecting the light onto another source. When the mirror redirects the light that is considered reflective light.

There are two general types of reflections: specular and diffuse.

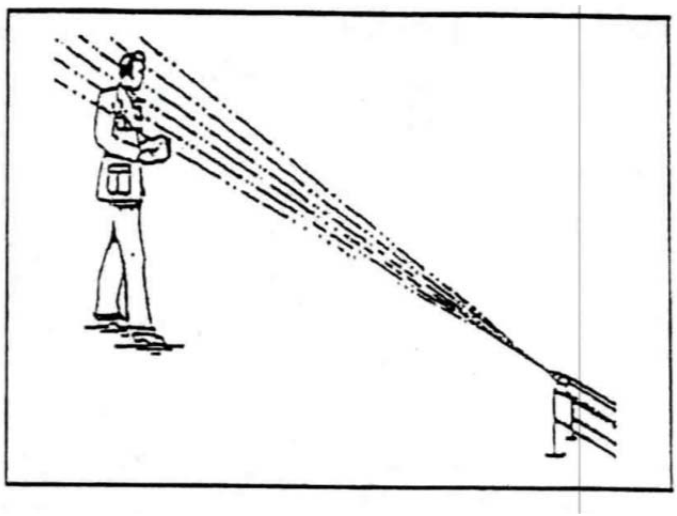
The type of reflection depends upon the kind of surface the laser beam encounters. Surfaces are either rough or smooth. Reflections from rough surfaces are called diffuse reflections. Reflections from smooth surfaces are called specular reflections.

Surfaces which cause specular reflections are called **mirror-like**. Surfaces causing diffuse reflections, we can call **scatters**. But what looks rough to visible light and scatters it, may be mirror-like to the longer wavelength such as infrared which will reflect it specularly.

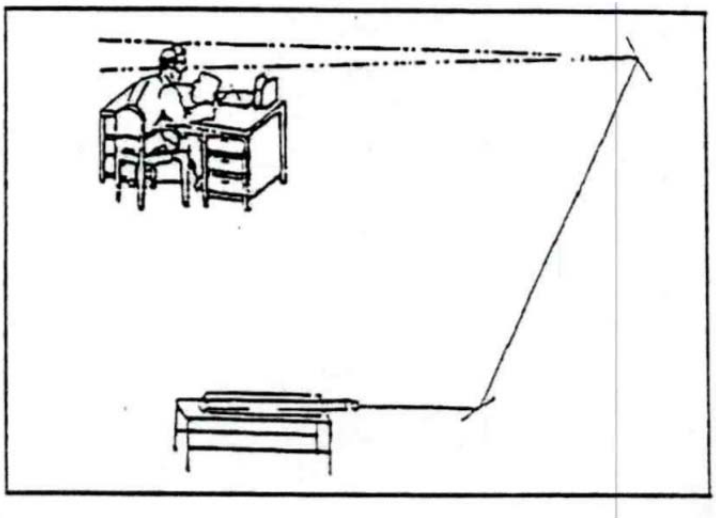
The specular reflection can cause more damage than the diffuse reflection. The diffuse reflection spot has its light scattered in all directions. Its retinal irradiance is much reduced from that of the original source. Compared to the specular reflection spot which keeps its light beam condensed, specular retinal irradiance is only slightly reduced from the original source.

Health physicists caution against looking at either Class 3b or Class 4 laser reflections. **ANSI (American National Standard Institute)** explains that Class 4 lasers are the lasers with enough power to have their diffuse reflection cause harm. However, Class 3b also possesses a warning: **"Hazardous diffuse reflections are possible from a focused or small diameter beam of a Class 3b laser".**

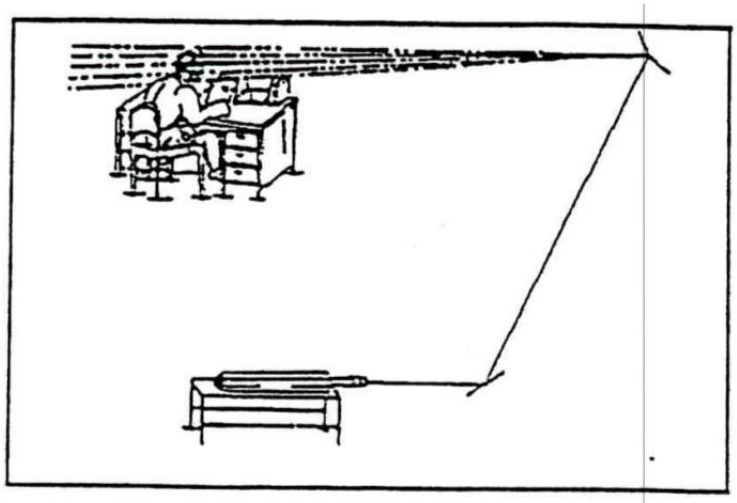
A certain class of reflections is given a special name: **Fresnel reflections.** These reflections are actually a subclass of specular reflections, and as such are much more dangerous as direct mirror reflections. These reflections from the curved surfaces of shiny object: bottles, cans, furniture, lenses, etc. There is a documented case of an eye injury from a coke bottle inadvertently placed in a laser beam.



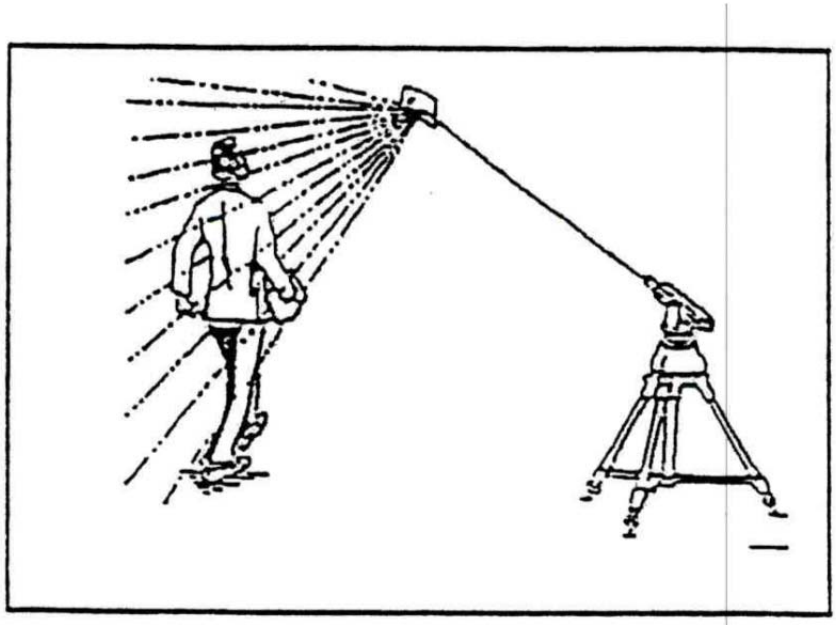
A direct interbeam viewing is most hazardous.
Figure 1.



Specular reflections are most hazardous
when the reflecting surface is flat or concaved.
Figure 2.



Curve-surface specular reflections are less hazardous than flat surface specular reflections.
Figure 3.



Diffuse reflection is less hazardous than specular.
Figure 4.

LESSON ONE

CONCLUSION

Understanding the laser's light properties and its reflective qualities are important in protecting an employee from potential harm.

Lesson Two will introduce the various classes of lasers which have been established.

Name:_____ Affiliation:_____Date:_____

Lesson One
Laser and Reflective Light

Learning Activity

Directions: Using the manual as a reference, complete the following sentences:

1. Laser stands for _____ _____ by _____ _____ of _____.

2. Lasers are more effective at many tasks than any other light source because of _____.

3. _____ _____ is the light produced from a secondary source.

4. Laser wavelengths are either _____ or _____.

5. The specular reflection can cause _____ than the diffuse reflection.

LESSON TWO

LASER CLASSIFICATION

LESSON OBJECTIVES

Upon completion of this lesson, you will:

- Identify the 5 classes of lasers.
- Define each class of lasers.
- Identify safety precautions specific to the particular class.

LESSON INTRODUCTION

Each laser is placed into a particular class. This class determines specific safety regulations and precautions. Understanding and being able to identify the class of the laser being used will enable an employee to take proper steps to ensure the work place is safe.

LASER CLASSIFICATION

The laser standard ANSI Z-136.1 established five general classes of lasers. The power generated by the laser beam and its wavelengths determines the classification of the laser. The hazard each class presents correlates roughly with the beam power. These classifications are defined in the ANSI standard.

Classes of Lasers

The class of laser determines the training requirements and safety protection needs. The classes are:

- Class 1 - Beam Power: Microwatt
- Class 1a – Beam Power: Up to 4.0 milliwatt (not intended for viewing)
- Class 2 - Beam Power: Up to 1.0 milliwatt (visible only)
- Class 3a - Beam Power: 1.0 to 5.0 milliwatts
- Class 3b - Beam Power: Up to .5 watts
- Class 4 - Beam Power: Above .5 watts

Class 1 - Microwatt

Any laser system that cannot normally produce a hazard is identified as Class 1. Lasers designated as Class 1 are exempt from all radiation control measures and surveillance. Laser printers are an example of Class 1 lasers. Laser printers pose no physical harm as long as they are locked.

Class 1a – Up to 4.0 milliwatt Beam Power (not intended for viewing)

Class 1a is based upon a 1000-second exposure and applies only to lasers that are "not intended for viewing" such as a supermarket laser scanner. The beam from a Class 1a laser is defined such that the beam does not exceed the Class 1 limit for a duration of 1000 seconds.

Class 2 - Up to 1.0 Millwatt Beam Power

Any low power visible laser which does not normally present a hazard because of the involuntary human aversion response is categorized as Class 2. The "aversion response" or "Blink reaction" will protect a human eye from damage. However, if the eye stares at the beam without blinking, it may cause harm. This class of lasers is used at UHCL for tangent determination and other alignment tools. These lasers are labeled often times with a sign warning: "Do Not Stare Directly into the Beam." However, no eye protection (i.e., goggles) is necessary when working with Class 2 Laser.

Class 3a - 1.0 to 5.0 Milliwatt Beam Power

Class 3a lasers can be visible or nonvisible and may not produce a hazard if viewed for only momentary periods with the unaided eyes. However, this class of laser can cause mild eye damage if started at or if viewed with collecting optics. These lasers are labeled with caution or warning signs. Eye protection may be needed depending upon job requirements.

Class 3b - Up to 0.5 Watt Beam Power

Lasers that have an output radiant power equal to or less than 0.5 watt are listed as Class 3b. These lasers are capable of inflicting serious eye damage if eye protection is not worn. Reflective beams from these lasers can also cause serious eye damage. This class of laser requires special safety precautions. Danger signs are required at any entrance to the laser radiation area. Also, in some cases, there are flashing red lights above the entrances or exits. This is an OSHA requirement warning any non-suspecting person of the danger.

Class 4 - Above 0.5 Watts Beam Power

Lasers are classified as Class 4 that have an output exceeding 0.5 watts. This laser is capable of inflicting permanent eye and skin damage. Eye protection, along with skin protection, should be worn at all times. Like Class 3b, not only direct beam, but also reflective beam can cause serious damage. Fire hazard is also a consideration in this class. The laser beam possesses enough thermal energy to produce a fire if reflected onto a flammable material. It is important to eliminate any burnable material in the work area. Specific safety requirements must be adhered to for Class 4 lasers. There must be danger signs placed around the area. Flashing red lights and an interlocking system at the entrances/exits are required.

Signs

With all classes except 1, danger or caution signs are required to notify personnel of potential laser hazards. These signs will be placed on the laser equipment or displayed on each entrance or exit of the laser facility. Each sign will identify the class of laser such as Class 2, 3a, 3b, or 4. The sign will also provide warning information such as: "Do No Stare Directly into Beam."

LESSON TWO

CONCLUSION

Except for Class 1 or Class 1a, each class of lasers must be identified with at least a caution sign. These signs will identify the class and type of laser. This will warn all personnel of a potential for harm. Understanding the class of the laser being used and taking the specific precaution can ensure the employee a safe work area while producing a quality UHCL product.

Lesson Three will review the parts of the eye and the way in which the eyes work. Lesson Three also discusses the harm a laser can cause to the eyes and skin.

Name:_____ Affiliation:_____Date:_____

Lesson Two
Laser Classification

Learning Activity

Directions: Use your manual as the reference, complete the following sentences:

1. Class _____ is any laser or laser system that cannot normally produce a hazard.

2. The aversion response or "_____ _____" will protect a human eye from damage.

3. Class 2 lasers are labeled often times with a sign warning "Do Not Stare Directly Into The _____."

4. A class 4 laser is capable of inflicting _____ eye and skin damage.

5. With all classes except 1 or 1a, _____ or _____ signs are required to notify personnel of potential laser hazards.

LESSON THREE

BIOLOGICAL EFFECTS OF LASER RADIATION

LESSON OBJECTIVES

Upon completion of this lesson, you will:

- Know the parts of the eye.
- Identify the way the eye works.
- Identify the vulnerable parts of the eye.
- Describe damage caused by skin exposure.

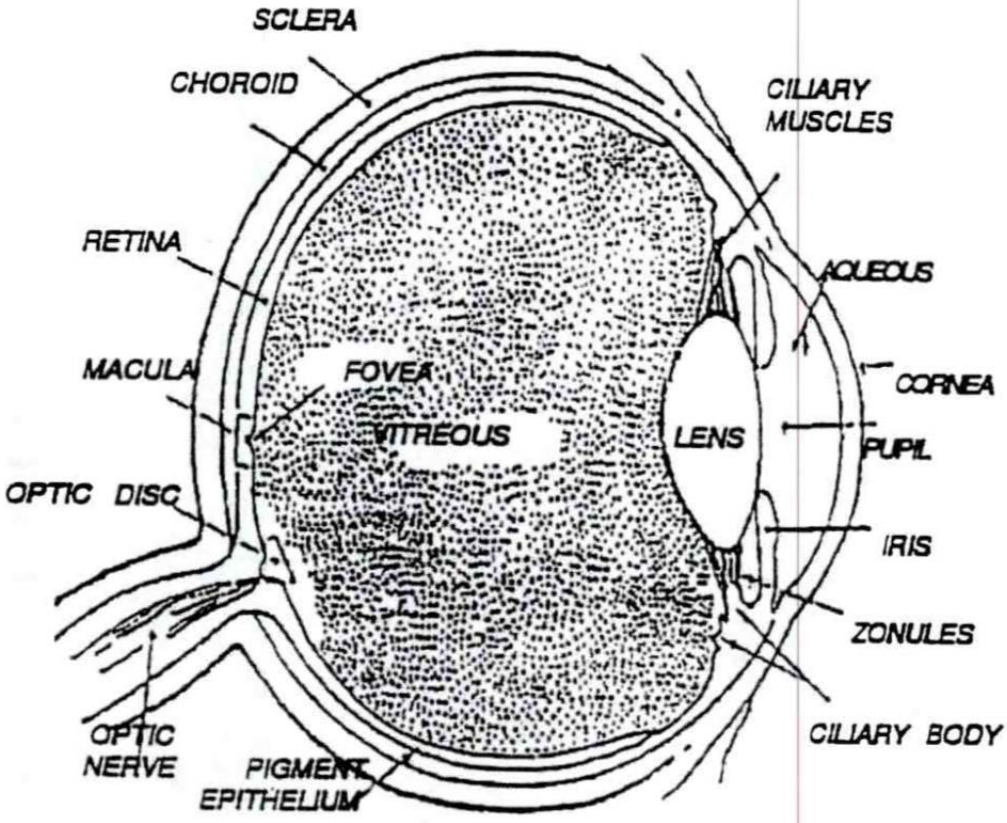
LESSON INTRODUCTION

Both the eyes and skin can be affected by exposure to laser radiation. However, the eye compared to the skin can be affected more severely and sometimes permanently. Because of that, a larger portion of this lesson concentrates solely on the eye.

BIOLOGICAL EFFECTS OF LASER RADIATION

The Eye

The areas of the body which can be affected by the use of lasers are the eyes and the skin. Even though the skin can be affected, the eyes can be permanently damaged in a very short exposure time. The eyes are more vulnerable to visible and infrared lasers because of the eye anatomy. There are several important parts of the eye:



EYE ANATOMY

Cornea

The transparent coating of the eyeball which covers the iris and pupil and admits light to the interior.

Pupil

The circular black portion of the eye which expands and contracts to regulate light into the eye.

Lens

A transparent biconvex spherical shape in the eye that focuses light rays upon the retina.

Retina

The sensory membrane that lines the eye and receives the images formed by the lens. It is the immediate instrument of vision and is connected to the brain by the optic nerve.

Fovea

A small section of the retina which provides acute vision.

Optic Nerves

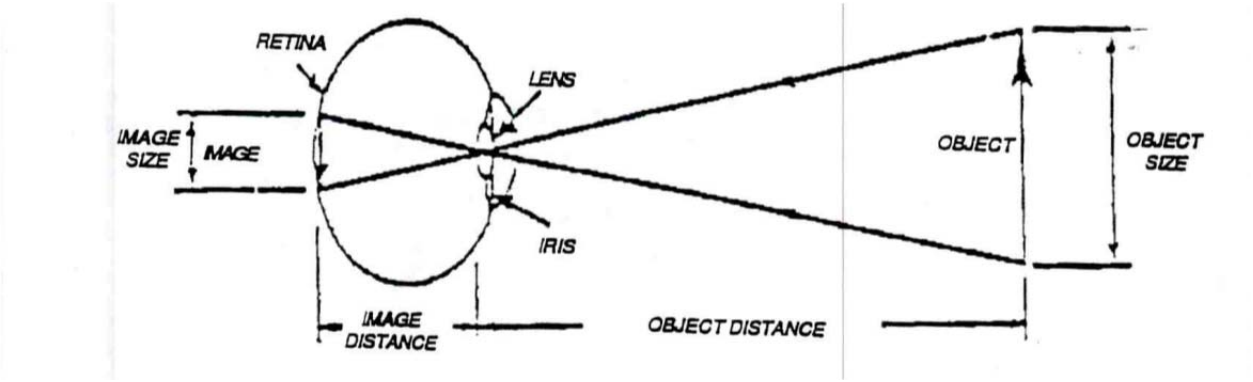
The two nerves (one nerve bundle from each eye) connecting the retina to the cranial nerves which connects visual stimuli to the brain. If the optic nerve is totally damaged, sight is lost permanently.

How the Eye Works

Each part of the eye has a different role to play. If any one part of the eye is damaged, it causes overall sight problems. For example, if the fovea is damaged, direct viewing sight will be impaired. Only side vision will remain because the foveal damage is irreparable. Another example is damage to the optic nerve. Since the optic nerve cannot be repaired, any damage done to the nerve is permanent.

For a person to view an object, the image must first:

- Pass through the cornea—then
- to the pupil which expands and contracts needed light---then
- to the lens which focuses on the object---then
- the image is turned upside down---and
- viewed by the retina which sends a message to the optic nerve---then
- the optic nerve sends the image to the brain---and
- there is sight.



The Vulnerability of the Eye

The eye is more vulnerable to visible and near infrared lasers because these radiations penetrate the eye and focus onto the retina. An unconventional light source such as a light bulb, black light, or even the sun, depending on the wavelength can either be absorbed mainly by the cornea or lens. These conventional light source rays are often diffused by the time the rays reach the eyes. However, laser power does not diffuse and can easily damage the eye. The brightness of the laser beam on the retina is a billion times greater than the light bulb. The laser beam is a very concentrated light source. What makes the laser a beneficial tool for business and medicine is that it has a single collimated beam which loses little power with distance. This is the same reason the laser can be very dangerous.

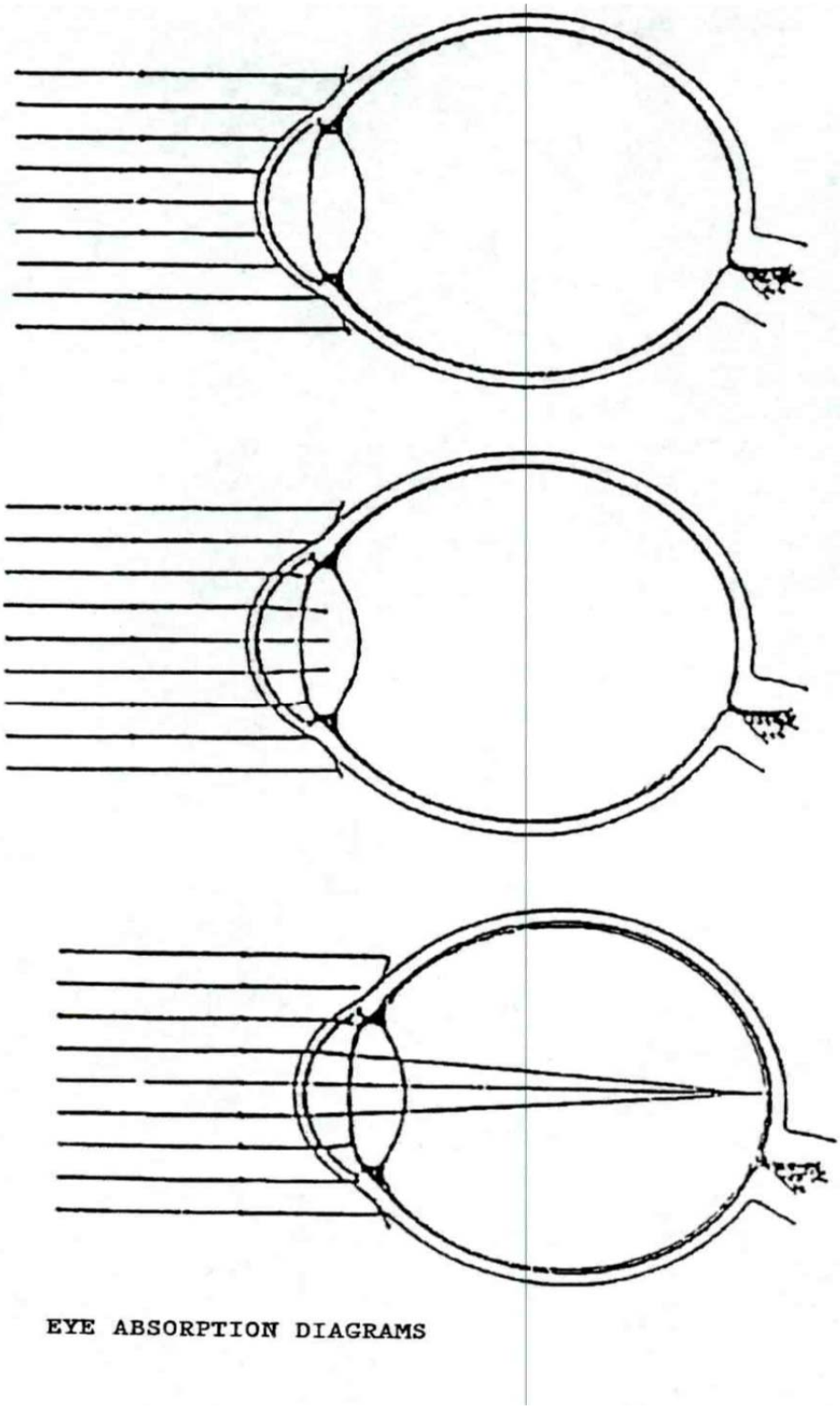
Skin

As stated earlier, the eye is not the only part of the body that can be affected by laser radiation. The skin can also be damaged. A Class 4 laser will cause damage to the skin as well as the eye. Radiation at these levels are absorbed into the skin and the cornea. Damage for both the cornea and the skin are equally probable, though it is undoubtedly more serious to damage a cornea than the skin. A skin burn can usually heal itself, but the only fix for a damaged cornea is corneal transplants.

Far infrared
(3000 nm – 1 mm)
& middle UV
(200 – 315 nm)

Near UV
(320 – 390 nm)
& middle infrared
(1400)

Visible &
near infrared
(400 – 1400 nm)



EYE ABSORPTION DIAGRAMS

LESSON THREE

CONCLUSION

It is always easier to protect than to correct. Understanding how the body works is the first step to understanding how to protect it. In this lesson, the eye has been discussed in detail. Protecting the eyes and body is the number one concern at UHCL for laser safety.

Lesson Four discusses laser radiation safety requirements and precautions.

Name:_____ Affiliation:_____Date:_____

Lesson Three
Biological Effects of Laser Radiation

Learning Activity

Directions: Using your manual as a reference, complete the following sentences:

1. The _____ is the sensory membrane that lines the eye and receives the images formed by the lens.

2. The _____ _____ are the nerves connecting the retina to the cranial nerves which connect visual stimuli to the brain.

3. Since the optic nerve cannot be repaired, any _____ done to the nerve is permanent.

4. The brightness of the laser beam on the _____ is a billion times greater than on the light bulb.

5. A Class _____ laser will cause damage to the skin as well as the eye.

LESSON FOUR

LASER RADIATION SAFETY REQUIREMENTS AND PRECAUTIONS

LESSON OBJECTIVES

Upon completion of this lesson, you will:

- Define Radiation Safety Committee.
- Describe eye protection needed for laser work.
- Describe what to do if an employee is exposed.

LESSON INTRODUCTION

UHCL and OSHA have adopted ANSI established standards to regulate the use of lasers. These documents put emphasis proper safety standards. This lesson will be an introduction to these procedures. It is important to understand and obey these rules.

LASER RADIATION SAFETY REQUIREMENTS AND PRECAUTIONS

UHCL and **OSHA (Occupational Safety and Health Administration)** abide by ANSI Z-136.1 **"American National Standard for the Safe Use of Lasers."** Both of these documents outline the safety requirement needed while working around or with laser equipment.

Radiation Safety Committee

UHCL has an organization responsible for administering radiation safety. It is the Radiation Safety Committee (RSC). Laser radiation is controlled under the guidance of this committee.

A Maximum Permissible Exposure (MPE) is the level of laser radiation to which a person may be exposed without hazardous effects or adverse biological changes in the eye and skin. If the laser is a Class 3b or 4, before the laser can be operated the manufacturer must establish a Nominal Hazard Zone (NHZ). The NHZ is the space around the laser which has radiation exceeding the MPE. Beyond the boundary of the NHZ, exposure levels are below MPE.

Appropriate flashing red lights shall be activated at entrances to Class 4 laser radiation areas to warn of laser radiation activities inside. Signs shall be posted warning of a laser radiation area to protect unsuspecting personnel. No personnel shall be allowed to enter a laser radiation area without previous approval from the Area Supervisor.

Safety Equipment

Eyes

Eye protection is required when working with Class 3b and 4 lasers. There is not a universal eye protection for lasers. Since lasers have different wavelengths such as ultraviolet or infrared and different intensities of light, it is important to use the proper specific protection. First, identify the wavelength and the class of laser and then insure the eye protection is adequate for that wavelength and intensity. Other physical and chemical hazards to the eyes shall also be considered and adequate face shields, goggle, etc., are required.

Skin

For Class 4 Lasers, gloves and protective clothing may be required to eliminate any exposure to the laser or reflective beam by the skin.

Exposure

All incidents involving the possibility of personnel being injured in a laser radiation area (i.e., exposure) shall immediately be reported verbally to your supervisor.

Other Protection

The only fatal laser radiation accidents have occurred through electrocution. This is caused by direct electrical contact. Mainly service personnel have reported fatal accidents. It is important to remember that most laser systems employ high voltage power. When servicing the equipment, never work alone. CPR training is advised for anyone working with the electrical system of lasers.

LESSON FOUR

CONCLUSION

The safety precautions only work if they are practiced daily. Staying current with requirements is essential for each employee. Making the work place a safe place can only be accomplished by working together.

Lesson Five reviews set rules for working with lasers.

Name:_____ Affiliation:_____Date:_____

Lesson Four
Laser Radiation Safety Requirements and Precautions

Learning Activity

Directions: Using your manual as a reference, complete the following sentences:

1. UHCL has an organization responsible for administering Radiation Safety. It is the _____ _____ _____.

2. The _____ _____ _____. is the level of laser radiation to which a person may be exposed without hazardous effects or adverse biological changes in the eyes and skin.

3. _____ _____ is required when working with Class 3b and 4 lasers.

4. There is not a _____ eye protection for lasers.

5. All incidents involving the possibility of personnel being injured in a laser radiation area shall be immediately reported verbally to your _____.

6. The only fatal laser radiation accidents have occurred through _____.

LESSON FIVE

SAFETY RULES FOR WORKING WITH LASERS

LESSSON OBJECTIVES

Upon completion of this lesson, you will:

- Define and list safety rules for working with lasers.

LESSON INTRODUCTION

In this lesson, a list of rules is designed for working with lasers. This information has been stated in previous lessons. However, the importance of the rules out-weighs the problem of redundancy. Safety can never be overstated.

SAFETY RULES FOR WORKING WITH LASERS

- Avoid looking directly into any laser beam or at its reflection.
- When possible, arrange set-up so that laser beams are not at normal standing or sitting heights.
- Remove all unnecessary specular (shiny) reflecting surfaces from the laser beam area.
- Operate lasers only in well-defined areas in which access can be controlled, and post the area with ANSI approved “laser warning signs” to alert anyone passing by or coming into the areas of the potential hazard.
- Only specifically trained persons knowledgeable in the hazards involved should be allowed to operate laser systems.
- Never leave a portable operating laser unattended. When not in use, the laser system should be rendered inaccessible.
- Be aware that the most lethal part of the laser system is the high power voltage it employs. While servicing the equipment, several people have been electrocuted.
- Never place the beam directly on persons, vehicles, equipment, etc.
- Use appropriate protective clothing.

LESSON FIVE

CONCLUSION

It is important to follow the rules. The rules are outlined to protect not only the employee, but also the product. Working together is needed to provide a safe working area and a quality product.

Name:_____ Affiliation:_____Date:_____

LESSON FIVE
SAFETY RULES FOR WORKING WITH LASERS

Learning Activity

Directions: Using your manual as a reference, complete the following sentences:

1. Avoid looking directly into any _____ _____ or at its reflection.

2. Remove all unnecessary _____reflecting surfaces from the laser beam area.

3. Only specifically _____ persons knowledgeable in the hazards involved should be allowed to operate laser systems.

4. Never leave a portable operating laser _____.

COURSE CONCLUSION

Since the invention of the laser in the 1960's society has continually found new uses for it. Along with the laser's development, safety protection has been a constant concern. The objective of this course was to familiarize the employee with the laser and identify the biological effect that the laser may have on the body. With each employee working together, UHCL can develop a safe and quality working environment for many years to come.