BLS™
THE BOARD OF LASER SAFETY

Certified Laser Safety Officer (CLSO)

EXAM REFERENCE GUIDE

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INCLUDES:

- Test Taking Tips
- Practice Questions
- Detailed Breakdown of Exam Areas of Practice

BLS CLSO Review Board

The BLS Certified Laser Safety Officer (CLSO) Review Board is established to effect knowledgeable revisions of the CLSO exam content and eligibility requirements. This exam study guide was developed by the following CLSO Review Board Members:

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The Board of Laser Safety would like to convey a special thanks to the listed review board members, without whom this guide would not have been possible.

Board of Laser Safety®
Certified Laser Safety Officer® Program

Examination Reference Guide

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Certified Laser Safety Officer® Program

Examination Reference Guide

1. General Information

In achieving certification, the Certified Laser Safety Officer (CLSO) recognizes and assumes the responsibilities incumbent upon the practice of laser safety. As a requirement of being certified, such persons act professionally, safely and in accordance with the Code of Professional Conduct. Each certificant has a professional and ethical obligation to practice only in those areas of laser safety in which he or she is competent. The CLSO has a commitment to remain professionally active in the field of laser safety by maintaining certification. As the industry and technology changes, so must the knowledge of the CLSO.

This guide is intended to help candidates prepare for the CLSO examination by giving them an overview of the exam areas of practice as well as sample test questions. However, use of the guide by itself will not be adequate preparation for the exam.

The references given in this guide are intended to provide candidates with reference material related to the general topics covered in the exam. This does not mean to imply that study of these references, only, will ensure successful performance on the examination. This listing is by no means complete; candidates may need to consult additional reports, journals and textbooks for information not provided in the references below.

At the same time, not all of these references are necessary to successfully complete the examination. They are provided as a guide to the type of material that should be studied.

Information regarding requirements for certification, exam dates and locations, and applications and fees are available from:

Board of Laser Safety
13501 Ingenuity Drive, Suite 128
Orlando, FL 32826
407.985.3810 or 800.345.2737

FAX: 407.380.5588
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Caution - The information in this guide about the exam and other matters are believed to be correct at the time of publishing; however, the candidate is advised to review the current copy of the CLSO Policies and Procedures Manual.

1.1 Board of Laser Safety Code of Professional Conduct

This code provides principles of professional conduct for Laser Safety Officers certified by the BLS. As a requirement of being certified, such persons act professionally, safely and in accordance with this code.

CLSOs shall:

1. Practice the profession using their knowledge and skill for the enhancement of safety and health of people whose lives and well-being may depend on their professional judgment.
2. Strive to increase or improve their self-development, competence, professional knowledge and skills in the area of laser safety.
3. Perform services and assignments only in the areas of their competence.
4. Act in the best interests of public health and safety.
5. Avoid conflicts of interest.
6. Be honest and impartial and act responsibly to uphold the integrity of the profession while serving the public, employees, employers and clients with fidelity.
7. Counsel the public, employees, employers and clients regarding potential health and safety risks to avoid unsafe practices and injury.
8. Obey all federal and state laws applicable to the profession.

1.2 Examination Information

Exam dates, locations, and delivery method are administrative decisions and at the discretion of the BLS staff. There will be a minimum of two (2) paper and pencil exam dates per year, in the spring and fall. Other exam dates throughout the year may be added at the discretion of the BLS staff.

The exam consists of 100 multiple-choice questions. Test takers will be given 3 hours to complete it. Each question has a possibility of five (5) answers. Some answers require calculations.

This reference guide will provide at least two (2) practice questions for each Area of Practice in order for exam candidates to familiarize themselves with the format of the test.

Other than the practice questions contained in this manual, BLS does not review, approve nor endorse any practice exam materials.

There are nine (9) areas of practice on the subject matter of laser safety. To assist you in understanding the subject matter, the areas of practice and what percentage they represent on the exam are provided here.

Area of Practice I – Lasers & Optics Fundamentals – 11%

Area of Practice II – Laser/Optical Radiation Bioeffects – 11%

Area of Practice III – Non-beam Hazards Associated with Lasers – 8%

Area of Practice IV – Laser Control Measures – 17%

Area of Practice V – Regulations and Standards – 14%

Area of Practice VI – Hazard Evaluation & Classification – 15%

Area of Practice VII – Maximum Permissible Exposures (MPE) – 11%

Area of Practice VIII – Laser Safety Program Administration – 10%

Area of Practice IX – Laser Measurements – 3%

2. Study Techniques & Test Taking Tips

2.1 Study Techniques

Each exam candidate should study in the way that is most effective for himself or herself. Below are suggestions to aid studying efforts:

- Identify which areas you know well and which areas warrant further study.
- Set a timeline to study each section.
- Complete practice questions to familiarize yourself with the exam format
- Use varying study techniques that engage different styles of learning. Flashcards with images, highlighting text, audio recording notes and listening to them, and asking someone to quiz you are examples of methods that work well for visual, auditory, and verbal learning styles.
- Although experience is an important factor in understanding the material on the exam, the exam is based on content published in the Z136.1-2014, as well as other standards and regulations; therefore, it is important to answer the question based on what is found in the relevant standards and regulations.

2.2 Test Taking tips

Here are a few strategies to consider prior to beginning the examination:

- Carefully read the question and each answer before selecting the most correct answer.
- Allow yourself time to answer all questions.
- Answer the questions you are sure of first, then go back and answer the remaining ones.
- Answer all questions, even if you are unsure of the answer. An educated guess is better than no guess at all.
- If you are unsure of an answer, your first instinct is usually the correct one.
- Read questions carefully to ensure comprehension.
- Read all answer choices before selecting an answer.
- Eliminate answers you know are not right.
- Prepare for the exam using the calculator you will use during the exam. Candidates may use simple scientific, non-programmable calculators. Calculators on mobile phones are prohibited.
- Don’t forget to breathe!

3. Areas Of Practice

3.1 Area of Practice I: Lasers & Optics Fundamentals

Exam Score Weight: 11%

Description: The practice of laser safety requires a basic knowledge of how lasers work, a technical and quantitative understanding of relevant laser radiation parameters, and how the laser beam and associated hazards are modified by various common optical elements.

Task 1 – Radiometric Terms and Units

Radiometric terms characterize the distribution of electromagnetic radiation power and energy in space. The biological effects of optical radiation, including laser radiation, depend on the amount of radiation power and energy absorbed by the target tissue. Therefore, a sound knowledge of radiometric terminology is essential for the quantitative evaluation of laser beam hazards.

Task 2 – Properties of Laser Radiation

An understanding of the unique characteristics of laser radiation provides a necessary basis for discerning the physical and biological effects of laser beam exposure, and how these effects differ from those of other optical radiation sources.

Task 3 – Laser Output

The key characteristics of a laser beam determine the potential physical and biological effects of exposure to that beam at any distance from the laser. Therefore, an understanding of the laser output parameters is essential for defining and quantifying the hazards associated with the laser beam.

Task 4 – Laser Types & Wavelengths

Specific lasers types have associated characteristics that impact output and hazard parameters. Wavelength indicates where on the electromagnetic spectrum a monochromatic laser's output lies, and hence the physical and biological properties of laser radiation having that wavelength. A familiarity with both of these subjects is necessary in the recognition and evaluation of laser-related hazards.

Task 5 – Electromagnetic Radiation (EMR)

Laser radiation and non-laser radiation associated with laser operation are comprised of EMR. An understanding of EMR properties and interaction with matter is fundamental to evaluating and controlling the related hazards

Task 6 – Laser Components
Every laser is comprised of three critical components and potentially several other auxiliary parts necessary for sustained operation. Each element of the laser system can engender its own hazards, so an awareness and understanding of each part's role and associated hazards is necessary for a comprehensive hazard evaluation.

Task 7 – Geometrical Optics
A laser beam is shaped and its propagation determined by the optics through which the beam passes. Laser beam hazards cannot be properly evaluated without an understanding of geometric optics.

Task 8 – How Lasers Work
Laser system designs employ various approaches to producing beam. As with Task 6, each element of the laser system can engender its own hazards, so an awareness and understanding of each part's role and associated hazards is necessary for a comprehensive hazard evaluation.

Task 9 – Laser Applications
The three elements of laser hazard evaluation (capability of injuring personnel or interfering with task performance, environment of use including access to beam path, and personnel who may be exposed) specified in section 3.1 of the ANSI Z136.1-2014 Standard are determined in large part by the laser application. Therefore, a familiarity with various laser applications informs the associated hazard evaluation and control measures.

Terms to Know: Attenuation, average power, beam diameter, beam divergence, beam waist, coherence, collimated beam, diffuse reflection, duty cycle, electromagnetic radiation, energy, frequency, geometric optics, hertz, illuminance, joule (J), LASER, lasing medium, meter (m), power, Q-switch, radian (rad), radiant flux, radiometry, refraction, resonator cavity, specular reflection, watt (W) wavelength, velocity

Practice Question 1:

Which of the following most accurately describes electromagnetic radiation?

A. is composed of negatively charged electrons travelling at the speed of light
B. has no mass, no electric charge, and travels at the speed of light
C. can have a positive or negative electric charge, no mass, and travels at the speed of light
D. is composed of photons, alpha particles, beta particles, or other sub-atomic particles
E. has the same mass as an electron, no electric charge, and travels at the speed of light

Practice Question 2:

Which of the following statements most correctly explains the monochromatic nature of conventional lasers?

A. The pulse repetition frequency is adjusted to produce the emitted wavelength.
B. The emitted wavelength is determined entirely by the length of the resonant cavity.
C. The emitted wavelength depends on the temperature of the lasing media according to Wein's law.
D. Narrow band pass spectral filters block wavelengths higher and lower than the emitted wavelengths.
E. The emitted wavelength is characteristic of an energy level transition within the electron structure of the elements or molecules in the lasing media.

3.2 Area of Practice II: Laser/Optical Radiation Bioeffects

Exam Score Weight: 11%

Description: Lasers can cause damage to both the eye and the skin. The wavelength of the laser, irradiance or radiant exposure, and duration of exposure determines the bioeffect. A knowledge of the biological effects of exposure to laser radiation provides the LSO with critical insight into how to prevent those deleterious effects.

Task 1 – Effects on the Eye
An LSO should be familiar with the structure and function of the eye, so that they know what parts will be affected by the different wavelengths and what subsequent damage can be done. The difference between photochemical and thermal effects must also be understood and appreciated. The retina, lens, cornea are the main structures that can be damaged by laser radiation.

a. Structure and Function of the Human Eye
b. Optical Gain of the Eye
c. Photochemical and Thermal Effects
d. Retinal Effects
e. Corneal Effects
f. Lens Effects

Task 2 – Effects on the Skin
The LSO should understand the different components of the skin and how each of them will be affected by laser radiation. The LSO should also know the difference between thermal and photochemical effects.

a. Structure of the Skin
b. Thermal Effects
c. Photochemical Effects

Terms to Know: Absorption, amsler grid, aversion response, C_A, C_B, C_C, C_E, C_P, chromophore, cornea, epithelium, erythema, illuminance, integrated radiance, lesion, photochemical effect, radiance, radiant flux, retinal hazard region, T_1, T_2, thermal effect, T_{max}, t_{min}.

Practice Question 3:

Correction factor C_C increases the MPE value to correct for:

A. Absorption of near infrared light in the cornea
B. Pre-retinal absorption at the blue end of the visible spectrum
C. Reduced thermal hazards at the blue end of the visible spectrum
D. The angle subtended by an extended source when it exceeds 1.5mrad
E. Pre-retinal absorption of near infrared light between 1150 and 1400 nm

Practice Question 4:

Photochemical injuries to the eye can be caused by which laser?

A. Argon (488 nm)
B. HeNe (633 nm)
C. Ti-Sapphire (800 nm)
D. InGaAs (980 nm)
E. Carbon dioxide (10600 nm)

3.3 Area of Practice III: Non-beam Hazards Associated with Lasers

Exam Score Weight: 8%

Description: Non-beam hazards (NBH) are those hazards arising from the presence of laser systems excluding exposure of human tissue to direct or scattered laser radiation. Worker exposure to these NBH can occur during the installation, set up, operation, maintenance, service, and repair of a laser system. Some NBH can be life threatening.

Candidates should familiarize themselves with the concept of occupational exposure limits, such as those published by the Occupational Safety and Health Administration and the American Conference of Governmental Industrial Hygienists. Candidates need a basic understanding of how to identify, assess and apply a hierarchy of controls to mitigate these NBH.

Task 1 – Irradiance Dependence of Specific NBH
Laser generated air contaminants (LGAC), fire, plasma radiation, and ionizing radiation are some of the hazards that occur due to the interaction of laser beams with target material. Operational factors such as target material composition, exposure duration, and pulse characteristics will affect the NBH produced. The candidate should have an understanding of these relationships.

Task 2 - Physical Hazards
Physical hazards associated with laser operations include fire and explosions, heat, noise, and electricity. The candidate should be familiar with fundamental fire protection, electrical safety and explosion mitigation measures.

Task 2. Laser-Target Interaction Radiation and Collateral Radiation
Laser target interaction radiation (LTIR) is non-laser radiation emitted by a material as a result of being exposed to a laser beam, including for example plasma radiation generated during certain laser material processing operations. Collateral radiation is any electromagnetic radiation emitted by a laser or laser system, for example from flashlamp radiation leakage or X-rays from high voltage vacuum tubes.

Task 4. Chemical and Biological Hazards

Chemical hazards may include solvents for cleaning, laser dyes, lasing medium, compressed gases, or fumes, aerosols and particulates generated when the beam interacts with a material. Resultant NBH produced when a beam interacts with a material will depend on multiple factors such as material composition, irradiance levels, exposure duration and pulse characteristics.

Pathogenic/infectious contaminants may become aerosolized when a laser beam interacts with tissue or other biological material.

Task 5. Human Factors and Ergonomics

Factors such as workstation layout, accessibility, illumination, and repetitive motion should be considered when designing, installing and operating laser systems.

Terms to Know: Aerosol, arc flash, collateral radiation, cryogen, dBA, dust, electrocution, ELF, fume, laser target interaction, LGAC, nonionizing radiation, permissible exposure limit, plasma, ppm, RF, SDS (safety datasheet), and threshold limit value.

Practice Question 5:

CW laser beams producing a minimum irradiance of what level or more may be considered an ignition hazard?

A. 0.25 W/cm^2
B. 0.5 W/cm^2
C. 0.5 mW/cm^2
D. 0.25 mW/cm^2
E. 0.1 W/cm^2

Practice Question 6:

A component of some laser systems that is associated with the generation of x-ray radiation is high-voltage vacuum tubes with a voltage greater than:

A. 15 mV
B. 5 kV
C. 10 V
D. 15 kV
E. 10 mV

3.4 Area of Practice IV: Laser Control Measures

Topic: Control Measures
Exam Score Weight: 17%

Description: Measures to control access to hazardous laser radiation are essential to the LSO's toolbox. Control measures include engineering and administrative controls, laser eye protection, and skin protection.

Task 1 – Engineering Controls
Engineering controls include protective housing, interlocks, key control, beam enclosures, entryway controls, area warning devices, emergency stops, protective barriers and curtains, emission-warning indicators, and others. In general, the higher the class laser, the more engineering (and other) controls are required.

Task 2 – Administrative and Procedural Controls
Administrative controls include standard operating procedures, training, alignment procedures, spectator control, authorized personnel, and others. While administrative controls are not as effective as engineering control measures, they play a vital role in laser safety.

Task 3 – Signs and Labels
Warning signs and equipment labels are essential for maintaining a safe workplace. They are crucial in communicating the relative hazard of the laser, as well as other essential information, such as wavelength, laser class and power, PPE requirements, and other information.

Task 4 – Personal Protective Equipment (eyes and skin)
Enclosing the laser equipment and beam path is the preferred method of control; however, when other control measures are not practical, the LSO must prescribe Laser Eye Protection and possibly skin protection to the laser user.

Terms to Know: Alignment procedure, collecting optics, entryway control, interlock, laser controlled area (LCA), laser eye protection, open beam path, optical density, wavelength

Practice Question 7:
A filter with an optical density of 2.0 will transmit what percent of the laser energy through the filter?

A. 1
B. 1.2
C. 2
D. 22
E. 220

Practice Question 8:
What control measure is most applicable for a Class 3B laser?

A. Skin protection
B. Preventing intrabeam viewing
C. Preventing the viewing of diffuse beam reflections
D. Preventing the viewing of off-axis scattered radiation
E. Preventing hazards from secondary plasma emission produced by interactions of target materials

3.5 Area of Practice V: Regulations and Standards

Exam Score Weight: 14%

Description: Organizations that use lasers have a legal obligation to comply with all applicable laws and regulations, as well as a due diligence burden to adhere to the relevant industry consensus standards. One of the primary duties of the LSO is to assess their site's regulatory status and alert the responsible management of any noncompliance, and to assess the extent to which the pertinent standards have been followed. Fulfilling this responsibility requires that the LSO have a working familiarity with all applicable regulatory requirements and standards.

Task 1 – ANSI Z136.1 Safe Use of Lasers standard

An LSO should have a working knowledge of Z136.1 and an understanding of the vertical standards, including the industry to which the standard applies. For example, ANSI Z136.3 *Safe Use of Lasers in Health Care* is used within the medical industry; ANSI Z136.4 *Recommended Practice for Laser Safety Measurements for Hazard Evaluations* provides guidance for making optical measurements associated with laser safety requirements, ANSI Z136.5 *Safe Use of Lasers in Educational Institutions* is used in educational institutions, etc.

Task 2 – 1040.10 - 21 CFR Subchapter J – Federal Laser Product Performance Standard (FLPPS)

Although the FLPPS applies only to manufacturers of laser products, the LSO must understand the sorts of activities that constitute manufacture in this context, since many facilities may engage in such activities without actually selling any laser systems. The LSO must also understand the obligations of any entity that introduces a laser into commerce.

Task 3 – OSHA Regulations

The LSO needs to be aware of the Occupational Safety and Health Administration (OSHA) regulatory requirements pertaining to lasers, including

a. Construction Industry Standard (29 CFR 1926)
    - Non-ionizing Radiation (29 CFR 1926.54)
b. General Industry Standard
    - Personal Protective Equipment (29 CFR 1910.132)
    - Eye and Face Protection (29 CFR 1910.133)
    - Respiratory Protection (29 CFR 1919.134)
    - Lock out/Tag out (29 CFR 1910.147)
    -

Task 4 – IEC 60825-1 Safety of Laser Products

The laser industry is very much an international business, and the LSO is very likely to encounter lasers manufactured in conformance with the International Electrotechnical Commission (IEC) Standards or various individual nation's derivatives of those standards. Examples include the IEC 60825 and 60601 series of standards. LSOs need to understand how lasers complying with such standards fit into the FLPPS and related regulations, as well as the corresponding ANSI Z136 guidance. Consulting the FDA/CDRH's Laser Notice 50 and Laser Notice 56 would be a good starting point.

Task 5 – FAA Laser Regulations

The Federal Aviation Administration has understandable concerns about the use of lasers with navigable airspace. The LSO needs to understand the consequent regulatory requirements pertaining to laser use (e.g. outdoor laser light shows) near operating aircraft. The FAA's Order 7004.2 would be a good place to start.

Task 6 – State and Local Regulations

Individual states and some large municipalities have their own laser safety regulations, which can vary widely from location to location (e.g. some states require strict conformance with ANSI Z136 standards and require registration of each Class 3B and 4 laser, while other states may have little or no regulatory requirements for laser use). The LSO must be aware of this jurisdictional aspect of the laser regulatory environment, and of the need to access and comply with the applicable local laser-related statutes for their sites that use lasers.

Terms to Know: ANSI, CFR, FAA, FDA/CDRH, FLPPS, ICNIRP, IEC, NIST, OSHA, Shall, Should, Standard, Regulation

Practice Question 9:

In the ANSI Z136 Standard series, the word "shall":

A. Is to be understood as mandatory
B. Is to be understood as advisory
C. Is only applicable to Class 3b and 4 lasers
D. Is only applicable to Class 4 lasers
E. Is only used in the ANSI Z136.1 standard and not the vertical standards

Practice Question 10:

A laser manufactured for use in the U.S. must comply with what standard

A. ANSI Z136.1 for Safe Use of Lasers
B. ANSI Z136.9 Safe Use of Laser in Manufacturing Environments
C. IEC 60825-1 Safety of Laser Products
D. 21 CFR 1040.10 Federal Laser Product Performance Standards
E. 29 CFR 1926.54 Non-ionizing Radiation

3.6 Area of Practice VI: Hazard Evaluation & Classification

Exam Score Weight: 15%

Description: Evaluating laser hazards and properly determining the laser or laser system hazard class is one of the most important functions of the LSO since the evaluation of both potential intrabeam and non-beam hazards from possession, use, storage, and disposal of a laser or laser system is critical in implementing effective administrative and/or engineering control measures to sustain a safe working environment. While conducting laser hazard evaluation for installation, testing, operation, maintenance, and service of a laser or laser system, considerations should include, but are not limited to, characteristics of the laser, operation parameters, working conditions, and user qualification of the laser or laser system.

Task 1 – Determining Laser Hazard Class

Since the laser class is based on the laser's capability of injuring personnel, all laser or laser systems shall be classified based on their accessible radiation during operation. Classification shall be defined according to the maximum output power or radiant energy available for the intended use. Parameters required to determine the laser hazard class (or accessible emission limit) are wavelength(s), type of a laser or laser system (i.e., continuous-wave or pulsed), limiting aperture, exposure duration, pulse repetition frequency, emergent beam radiant exposure, etc. Typically, information for maximum output power or radiant energy of most commercial laser products is provided by the manufacturer and thus no measurements are needed to be performed by knowledgeable individuals for laser classification..

Task 2 – Laser Hazard Classification

In general, the higher the laser classification, the greater the severity of damage the laser or laser system can cause to personnel or property. Specifically, lasers are classified into several classes which include Class 1, Class 1 M, Class 2, class 2M, Class 3R, Class 3B, and Class 4.

Task 3 – Environment in Which the Laser is Used

Once a laser or laser system has been properly classified, the environment in which it is used needs to be considered including whether the laser is used indoors or outdoors and the possibility of exposing personnel to a primary or reflected beam path. The following aspects should be taken into account while conducting the hazard evaluation:

a. Nominal Hazard Zone – the area in which exposure to the laser beam is greater than the Maximum Permissible Exposure (MPE) and where control measures are necessary

b. Indoor Applications - usually indoor hazard evaluations consider whether the laser beam is enclosed or operated in a room enclosure used to control beam exposure and personnel entering the area.

c. Outdoor Applications – use of the laser or laser system outdoors requires consideration for all laser optics used and potential hazards to personnel audiences and aircrafts flying in the vicinity of the outdoor laser system setup.

Task 4 – Determining Exposure Conditions

In addition to approved laser operators, individuals who may be exposed to laser radiation or non-beam hazards include other workers, maintenance and service personnel, and visitors in the vicinity of a laser or laser system. Further control measures may be required to provide adequate protection.

Terms to Know: Accessible emission limit (AEL), aperture, continuous wave, control measure, controlled area, exposure duration, irradiance, maximum permissible exposure (MPE), nominal hazard zone (NHZ), non-beam hazards, Nominal Ocular Hazard Distance (NOHD), pulsed laser, pulse repetition frequency (PRF), radiant energy, radiant exposure, radiant power, reflectance, repetitive pulse laser, viewing angle

Practice Question 11:

The upper limit of the power output for a Class 3B laser is __________.

A. 1 mW
B. 5 mW
C. 50 mW
D. 100 mW
E. 500 mW

Practice Question 12:
Which class of laser presents the greatest potential danger to life and health?

A. Class 1
B. Class 2
C. Class 3R
D. Class 3B
E. Class 4

**Note, an equation sheet will not be provided during the exam. Candidates do not need to memorize equations; however, candidates should know how to calculate basic MPEs, output power and irradiance, among other things. Candidates may bring a non-programmable scientific calculator to the exam.*

3.7 Area of Practice VII: Maximum Permissible Exposure (MPE)

Exam Score Weight: 11%

Description: The MPE refers to the level of exposure to a laser beam that can be considered to be theoretically safe and not harmful to tissues of the eye and/or skin. The LSO must understand that MPE calculations are essential to evaluate the potential laser hazards to the eye or skin in order to provide the proper PPE to the laser user whenever the engineering and administrative controls cannot provide adequate protection from laser hazards. The MPE is also used in determining the Nominal Hazard Zone (NHZ).

Task 1 – Parameters Needed to Determine MPE

To determine the MPE, parameters which need to be considered are wavelength, exposure duration, types of a laser or laser system (i.e., continuous-wave or pulsed), limiting aperture, multiple-pulse correction factor, pulse duration, and pulse repetition frequency.

Task 2 – Extended and Small Source Viewing

According to ANSI Z136.1, laser sources within the retinal hazard region are considered either point or extended . Correction factors used to calculate MPEs may depend on which viewing condition applies.

Task 3 – Ocular MPE

MPEs for ocular exposure are expressed relative to the limiting aperture area. For certain spectral regions, wavelength correction factors may be included in determining the MPEs. For the ultraviolet spectral region, both thermal and photochemical hazards must be evaluated.

a. Visible & Infrared Exposures: In the wavelength range from 400 nm to 600 nm, a wavelength correction factor based on reduced photochemical hazards is included. In the wavelength range from 700 nm to 1400 nm, a wavelength correction factor based on either reduced absorption properties of melanin pigment granules found in the retinal pigment epithelium or pre-retinal absorption of radiant energy is included.

b. Ultraviolet Exposures: In the wavelength range from 180 nm to 400 nm, both thermal and photochemical effects must be considered.

c. Repetitively Pulsed Exposures: The laser exposure from any single pulse in a pulse train should not exceed the MPE for a single pulse of that pulse duration, nor should the average power from any group of pulses delivered during the total exposure duration exceed the applicable MPE. Under some laser output conditions, a repetitive pulse correction factor may also apply.

Task 4 – Skin MPE (Z136.1-2014 8.4)
MPEs for skin exposure are for worst-case conditions. A wavelength correction factor is required for an emitted laser in the near-infrared spectral region. For the ultraviolet spectral region, both thermal and photochemical hazards must be evaluated.

a. Visible & Infrared Exposures: In the wavelength range from 700 nm to 1400 nm, a wavelength correction factor based on reduced absorption properties of melanin pigment granules found in the skin is included.

b. Ultraviolet Exposures: In the wavelength range from 180 nm to 400 nm, both thermal and photochemical effects must be considered.

c. Repeated Exposures: For repetitive-pulse lasers or laser systems, the laser exposure to the skin should not exceed the MPE based on a single-pulse exposure and the average irradiance of the pulse train should not exceed the MPE applicable for the total pulse train duration. The multiple-pulse correction factor does not apply to skin exposure.

Terms to Know: Absorption, apparent visual angle, alpha min (α_{min}), alpha max (α_{max}), correction factors, aperture, continuous wave, cornea, diffuse reflection, exposure duration, extended source, infrared, intrabeam viewing, irradiance, maximum permissible exposure (MPE), photochemical effect, point source, pulse duration, pulsed laser, pulse repetition frequency (PRF), repetitive pulse laser, retina, thermal effect, ultraviolet radiation, visible radiation, wavelength.

Practice Question 13:

Which of the following correction factors increases the MPE for ocular exposure due to pre-retinal absorption of radiant energy in the spectral region between 1150 nanometers and 1400 nanometers?

A. C_A
B. C_B
C. C_C
D. C_E
E. C_P

Practice Question 14:

What is the MPE for a 0.25 s exposure to a classroom laser pointer that operates at a wavelength of 670 nm?

A. 0.64 $\mu W \cdot cm^{-2}$
B. 1 $mW \cdot cm^{-2}$
C. 2.5 $mW \cdot cm^{-2}$
D. 5 $mW \cdot cm^{-2}$
E. 2.5 $W \cdot cm^{-2}$

3.8 Area of Practice VII: Laser Safety Program Administration

Exam Score Weight: 11%

Description: The candidate should be familiar with the key elements of a successful laser safety program as described in the ANSI standard.

Task 1 – Standard Operating Procedures (SOP)

An SOP is a formal written description of the safety and administrative procedures to be followed in performing a specific task. The LSO needs to understand when an SOP is required and what elements should be covered in it. Some of these are:

a. Requirements by laser class
b. Control measures
c. Responsibilities
d. Alignment

Task 2 – Training for Employees

The LSO shall ensure that adequate safety education and training are provided to laser personnel. Laser training should be commensurate to the classification of laser being used. Some important elements to training are:

a. Bioeffects
b. Laser classification
c. Control Measures
d. Fundamentals of laser operation
e. Specular and diffuse reflections

Task 3 – Laser Audits

The LSO shall periodically audit or survey by inspection for the presence and functionality of the laser safety features and control measures required by laser classification. Some key elements to laser audit are:

a. Laser Controlled Area
b. Warning signs and labels
c. Laser classification
d. Engineering/administrative controls
e. Standard Operating Procedures
f. Key control
g. Collecting optics
h. Audible/ visible warning device
i. Entryway controls
j. Training
k. Non-beam hazards

Task 4 – Accident Investigation & Documentation

The LSO should be familiar with the causes of laser accident and understanding the mechanisms of injury associated with different types of lasers. The LSO should also develop a plan to respond to notifications of incident of actual or suspected exposures to harmful laser radiation. Some important elements are:

a. Medical assistance
b. Incident investigation
c. Documentation
d. Laser characteristics
e. Exposure situation

Task 5 – Duties and Responsibilities of an LSO

The LSO is designated by the employer with the authority and responsibility to effect knowledge, evaluation, and control of laser hazards, and to monitor and enforce the control of such hazards. Some duties and responsibilities include:

a. Laser classification
b. Hazard evaluations
c. Control measures
d. Laser Controlled Area
e. Training
f. SOPs
g. Signage
h. Incident Investigation

Task 6 – Medical Surveillance

Pre-assignment, Periodic, Termination, and Post suspected injury examinations are part of a Medical Surveillance Program. It is important for the LSO to understand when each are required. Important elements are:

a. Symptoms
b. Wavelength
c. Emission characteristics
d. Exposure situation
e. Visual Acuity
f. Macular function
g. Skin examination

Terms to Know: Amsler grid, authorized personnel, control measures, employer, hazard evaluation, laser supervisor, operator, safety program, records, scotoma, service personnel, SOP, training

Practice Question 15:

Which of the following statements best describes the ANSI Z136.1 Standard's position regarding laser safety committees?

A. Laser safety committees must never be established.
B. Laser safety committees may be created as needed.
C. Every facility utilizing lasers must have a laser safety committee.
D. Laser safety committees are required if a facility has more than ten lasers.
E. Every facility with Class 3B or 4 lasers must have a laser safety committee.

Practice Question 16:

According to the ANSI Z136.1 Standard, who is most responsible for ensuring that a laser is not operated unless there is adequate control of laser hazards to employees, visitors, and the general public?

A. The laser supervisor
B. The laser safety officer
C. Local law enforcement
D. The laser safety committee
E. Employees working with lasers

3.9 Area of Practice IX: Laser Measurements

Exam Score Weight: 3%

Description: As noted in ANSI Z136.1, the LSO would normally rely on the manufacturer's information for most commercial laser products, and would not need to perform measurements. However LSOs need to understand when laser measurements are appropriate, and the various requirements for such measurements to ensure their adequacy should the need arise.

Task 1 – Point Source
Should measurements of laser output become necessary, the LSO should know the significance of the point source designation and when it applies.

Task 2 – Extended Source
Should measurements of laser output become necessary, the LSO should know the significance of the extended source designation and when it applies.

Task 3 – Instruments Used for Measurements
While an LSO need not necessarily be familiar with the particulars of specific instrumentation, they should understand the parameters to be measured, and the constraints on measurement.

Terms to Know: Angular Subtense, Extended Source, Field of View, Limiting Aperture, Measurement Aperture, Point Source, Power, Radiant Energy, Uncertainty

Practice Question 17:

When is it necessary to measure the area of the beam that gives the maximum reading?

A. The beam is not homogeneous.
B. The beam diameter is less than the limiting aperture.
C. The beam diameter is less than the measurement aperture.
D. The beam diameter exceeds the measurement aperture**.**
E. The entire beam enters the effective measurement aperture.

Practice Question 18:

Which aperture must be used to distinguish between Class 3B and Class 4 lasers?

A. The laser beam diameter
B. The 9 mm maximum pupil opening
C. The measurement instrument field of view
D. The limiting aperture listed in ANSI Z136.1
E. The measurement aperture listed in ANSI Z136.1

3.10 References

[1] Board of Laser Safety® Certified Laser Safety Officer® Policies & Procedures Manual [https://www.lasersafety.org/wp-content/uploads/2016/09/CLSO-Policies-Procedures-Manual.pdf] p. 9

[2]See e.g.

- D. H. Sliney. Radiometric Quantities and Units Used in Photobiology and Photochemistry: Recommendations of the Commission Internationale de l'Eclairage (International Commission on Illumination). Photochemistry and Photobiology, 2007, 83: 425–432. http://photobiology.info/PDF/Sliney2007.pdf
- H. Moseley and D. H. Sliney. Radiometric Units and Quantities. Physics in Medicine & Biology 42(5), 1997 http://iopscience.iop.org/article/10.1088/0031-9155/42/5/002/meta

3.11 Practice Question Answers

Question Number	Correct Answer
1.	B
2.	E
3.	E
4.	A
5.	B
6.	D
7.	A
8.	B
9.	A
10.	D
11.	E
12.	E
13.	C
14.	C
15.	B
16.	A
17.	D
18.	E

4. Additional Resources

4.1 Recommended Study Materials

1. ANSI Z136.1-2014, *Safe Use of Lasers* (Laser Institute of America, Orlando, FL, 2014).

2. *Safety with Lasers and Other Optical Sources*, edited by D. Sliney and M. Wolbarsht (Plenum, New York, 1980). 294-296; 317; 347-379; 392-406

3. Laser Institute of America, *Laser Safety Guide*, 1st ed. (Laser Institute of America, Orlando, FL, 2015)

4. R. Henderson and K. Schulmeister, *Laser Safety*. (Abingdon, UK, 2003)

5. American Conference of Governmental Industrial Hygienists. ACGIH® TLVs® and BEIs® [published annually] (Cincinnati, OH; ACGIH).

6. DiNardi, SR, Ed. The Occupational Environment – Its Evaluation and Control, 2nd ed. (American Industrial Hygiene Association, 2003)

7. International Commission on Non-Ionizing Radiation Safety (ICNIRP). https://www.icnirp.org/

8. National Institue for Occupational Safety and Health. NIOSH Pocket Guide to Chemical Hazards; https://www.cdc.gov/niosh/npg/default.html

9. National Fire Protection Association. NFPA 115 Standard for Laser Fire Protection (Quincy, MA: NFPA)

10. Castelluccio D. Implementing AORN Recommended Practices in Laser Safety. AORN Journal 95(5):612-24, 2012.

4.2 Internet Resources

1. Food and Drug Administration: 21 CFR 1040.10.
   http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/cfrsearch.cfm

2. Indiana University-Purdue University Indianapolis: Online Laser Safety Training (guest registration required)
   https://protect.iu.edu/environmental-health/laboratory-safety/laser-safety.html

3. Occupational Safety and Health Administration: Safety and Health Topics, Laser Hazards
   http://www.osha.gov/SLTC/laserhazards/

4. Princeton University: Laser Safety Training Guide
   https://ehs.princeton.edu/sites/ehs/files/media_files/Laser%20Training%20Guide%202007%2013-08.pdf

5. Sam's Laser FAQ: Laser Safety
   http://www.repairfaq.org/sam/lasersaf.htm#saftoc

6. Sam's Laser FAQ: What is a Laser and How Does It Work?
   http://www.repairfaq.org/sam/laserfaq.htm#faqwil

7. The Physics Classroom: Anatomy of the Eye
   http://www.physicsclassroom.com/Class/refrn/U14L6a.html

8. The Physics Classroom: Specular vs. Diffuse Reflection
   http://www.physicsclassroom.com/Class/refln/U13L1d.html

9. University of California, Berkeley: Laser Safety Training Supplement
   https://www.ehs.berkeley.edu/sites/default/files/lines-of-services/laser-safety/74lasersafety.pdf

10. University of North Carolina: Laser Safety Training
    http://ehs.unc.edu/training/self-study/laser-safety-training/

11. Laser Effects on the Human Eye Fact Sheet: OSHA and LIA Alliance
    https://de356l4tocdyu.cloudfront.net/pdf/OSHAEyeFactSheet.pdf

12. Occupational Safety and Health Administration: Safety and Health Topics, Laser Hazards
    http://www.osha.gov/SLTC/laserhazards/

13. UCSD Laser Safety Program
    https://blink.ucsd.edu/safety/radiation/lasers/effects.html

APPENDIX A. Selected Maximum Permissible Exposures (MPEs)

$1.8t^{0.75} \times 10^{-3}$ J/cm^2	Visible region including 0.25 sec (from 5×10^{-6} to 10 sec exposure)
$C_B \times 10^{-4}$ W/cm^2	Visible region (400 to 500 nm) including 600 sec (from 100 to 30,000 sec exposure)
$C_A \times 10^{-3}$ W/cm^2	IR (700 to 1050 nm) including 10 sec (from 10 to 30,000 sec exposure)
$5.0\ C_C \times 10^{-3}$ W/cm^2	IR (1050 to 1400 nm) including 10 sec (from 10 to 30,000 sec exposure)

APPENDIX B. Correction Factors from Table 6a, 6b, 6c of ANSI Z136.1-2014

$C_A = 10^{0.002(\lambda-700)}$	Reduced absorption by melanin (700 to 1050 nm)
$C_B = 10^{0.02(\lambda-450)}$	Blue light correction factor (450 to 600 nm)
$C_C = 10^{0.018(\lambda-1150)}$	Preretinal absorption (1150 to 1200 nm)
$C_E = \alpha/\alpha_{min}$	Extended source, 400 to 1400 nm, for $\alpha_{min} \leq \alpha < \alpha_{max}$
$C_E = \alpha^2/(\alpha_{max}\,\alpha_{min})$	Extended source, 400 to 1400 nm, for $\alpha_{max} \leq \alpha$

APPENDIX C. Nominal Hazard Zone (NHZ)

$r_{NHZ} = (1/\varphi)[(4\Phi/\pi MPE) - a^2]^{1/2}$	Direct viewing of laser beam
$r_{NHZ} = f_o/b_o\ (4\Phi/\pi MPE)^{1/2}$	Lens on laser (focused beam)
$r_{NHZ} = 1.7/NA\ (\Phi/\pi MPE)^{1/2}$	Fiber optics, multimode fiber
$r_{NHZ} = \omega_o/\lambda\ (\pi\Phi/2MPE)^{1/2}$	Fiber optics, singlemode fiber
$r_{NHZ} = (\rho\Phi\cos\theta/\pi MPE)^{1/2}$	Diffuse reflection

APPENDIX D. Optical Density

$D_\lambda = \log_{10}(1/\tau)$	Optical density
$D_\lambda = \log_{10}(I_o/I)$	OD for incident and transmitted intensity
$D_\lambda = \log_{10}(E_o/MPE_E)$	OD for MPE in terms of irradiance
$D_\lambda = \log_{10}(H_o/MPE_H)$	OD for MPE in terms of radiant exposure

APPENDIX E. Barrier Separation Distance

$D_s = (1/\varphi)[(4\Phi/\pi TL) - a^2]^{1/2}$	Direct intrabeam exposure
$D_s = f_o/b_o\ (4\Phi/\pi TL)^{1/2}$	Lens on laser (focused beam)
$D_s = (\rho\Phi\cos\theta/\pi TL)^{1/2}$	Diffuse reflection

APPENDIX F. Miscellaneous Equations

$Q = \Phi t$	Radiant energy and radiant power conversion
$H = 4Q/\pi D_L^2$	Radiant exposure for a circular beam
$E = 4\Phi/\pi D_L^2$	Irradiance for a circular beam
$H = Et$	Radiant exposure and irradiance conversion
$\Phi_{peak} = Q_p/t$	Peak power from pulse energy pulse length
$\Phi_{avg} = Q_pF$	Average power from pulse energy and PRF
$n = Ft$	Number of pulses from PRF and exposure duration
$D_L = \sqrt{(a^2 + \varphi^2 r^2)}$	Laser beam spot size
$d = f\varphi$	Focused image diameter
$\alpha = D_L \cos\theta/r$	Viewing angle for a given spot size at distance r
$r_{max} = D_{exit}\cos\theta/\alpha_{min}$	Maximum distance for extended-source viewing
$\varphi = s/r$	Plane angle definition in radians
$\Omega = A/R^2$	Solid angle definition in steradians
$G = D_o^2 / D_e^2$	Optical gain – ratio of corneal irradiance through magnifying optics to that received by unaided eye
$I_2 = I_1 \times \text{magnification}^2$	Increase in intensity with magnification

NOTE: The laser equation sheet is not intended to be comprehensive but includes equations that may be used often by practicing laser safety officers. Descriptions are intentionally concise; see ANSI Z136.1 for more complete descriptions. Also, some quantities may be scaled with a different multiple or submultiple prefix (e.g., micro- vs. milli-) than shown.

APPENDIX G. Quantities and Units

Symbol	Quantity	Unit	Symbol
A	area	square centimeter	cm^2
a	emergent beam diameter	millimeter	mm
b_o	beam diameter on lens	centimeter	cm
D_e	diameter of exit pupil	centimeter	cm
D_{exit}	exit port diameter of laser	centimeter	cm
D_L	beam spot size	centimeter	cm
D_λ	optical density	dimensionless	---
D_o	diameter of objective	centimeter	cm
D_S	barrier separation distance	centimeter	cm
d	diameter of focused spot	centimeter	cm
E	irradiance	watts per square centimeter	W/cm^2
E_o	incident irradiance	watts per square centimeter	W/cm^2
F	pulse repetition frequency	hertz	Hz (s^{-1})
f,f_o	focal length	length	cm
G	gain	dimensionless	---
H	radiant exposure	joules per square centimeter	J/cm^2
H_o	incident radiant exposure	joules per square centimeter	J/cm^2
I_o	incident intensity	watts or watts / square centimeter	W or W/cm^2
I	transmitted intensity	watts or watts / square centimeter	W or W/cm^2
MPE_E	MPE as irradiance	watts per square centimeter	W/cm^2
MPE_H	MPE as radiant exposure	joules per square centimeter	J/cm^2
n	number of pulses	pulses	---
NA	numerical aperture	dimensionless	---
r_{NHZ}	nominal hazard zone	distance	cm
r	distance - radius	length	---
Q	radiant energy	joules	J
Q_p	pulse energy	joules	J
s	arc length	centimeter	cm
TL	barrier threshold limit	watts per square centimeter	W/cm^2
T	pulse duration	seconds or sec	
t	exposure duration	second	s or sec
α	viewing angle	milliradian	mrad
λ	wavelength	micrometer	µm
φ	beam divergence	milliradian	mrad
Φ	radiant power	watts	W
Φ_{avg}	average beam power	watt	W
Φ_{peak}	peak beam power	watt	W
θ	viewing angle (normal & eye)	radian	rad
ρ	reflectivity	dimensionless	---
τ	transmittance	dimensionless	---
Ω	solid angle	steradian	sr
ω_o	mode field diameter	micrometer	µm

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