Certified Laser Safety Officer

Exam Reference Guide
## Table of Contents

- General Information ........................................................................................................1
- Examination Information ...............................................................................................2
- Other Hard Copy Materials ............................................................................................3
- Web Pages and Free Online Tutorials .............................................................................3
- Laser Safety Equation Sheets.........................................................................................5
  - Selected Maximum Permissible Exposures (MPEs) ..................................................5
  - Correction Factors from Table 6 of ANSI Z136.1 ..................................................5
  - Nominal Hazard Zone (NHZ) ....................................................................................6
  - Optical Density .........................................................................................................6
  - Barrier Separation Distance .....................................................................................6
  - Miscellaneous Equations .........................................................................................7
- Quantities and Units: Laser Safety Equation Sheet ...................................................8
General Information
In achieving certification, the Certified Laser Safety Officer (CLSO) recognizes and assumes the responsibilities due to 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 references for each section of the exam. 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 text books 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
Email: bls@lasersafety.org
Webpage: http://www.lasersafety.org

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.
**Examination Information**
This examination is multiple-choice, consisting of 100 questions. Each question has a possibility of five (5) answers. Some answers require calculations. Here are a few issues to consider prior to beginning the examination:

1. Allow yourself time to answer all questions.
2. Answer the questions you are sure of first, then go back and answer the remaining ones.
3. Answer all questions, even if you are unsure of the answer. An educated guess is better than no guess at all.
4. If you are unsure of an answer, your first instinct is usually the correct one.

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%

In general, the following reference materials should be obtained or reviewed, as they contain information included in most, or all, of the areas of practice:

Other Hard Copy Materials


Web Pages and Free Online Tutorials

   http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/cfrsearch.cfm

2. Indiana University-Purdue University Indianapolis: Online Laser Safety Training  
   (guest registration required)  
   http://www.ehs.iupui.edu/lasersafetypro/safety_home.asp

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

   http://web.princeton.edu/sites/ehs/laserguide/index.htm

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
   http://socrates.berkeley.edu/~phylabs/adv/LaserSafeTrainSup04.pdf

    http://ehs.unc.edu/training/self_study/laser/

11. U.S. Army CHPPM: *Lasers and Their Effects on the Human Eye*
Laser Safety Equation Sheets

Selected Maximum Permissible Exposures (MPEs)

\[ 1.8 t^{0.75} \times 10^{-3} \text{ J/cm}^2 \]
Visible region including 0.25 sec (from \( 18 \times 10^{-6} \) to 10 sec exposure)

\[ C_B \times 10^{-4} \text{ W/cm}^2 \]
Visible region (0.400 to 0.500 µm) including 600 sec (from 100 to \( 3 \times 10^4 \) sec exposure)

\[ C_A \times 10^{-3} \text{ W/cm}^2 \]
IR (0.700 to 1.050 µm) including 10 sec (from 10 to \( 3 \times 10^4 \) sec exposure)

\[ 5.0 C_C \times 10^{-3} \text{ W/cm}^2 \]
IR (1.050 to 1.400 µm) including 10 sec (from 10 to \( 3 \times 10^4 \) sec exposure)

Correction Factors from Table 6 of ANSI Z136.1

\[ C_A = 10^{2(\lambda-0.700)} \]
Reduced absorption by melanin (0.700 to 1.050 µm)

\[ C_B = 10^{20(\lambda-0.450)} \]
Blue light correction factor (0.450 to 0.600 µm)

\[ C_C = 10^{18(\lambda-1.150)} \]
Preretinal absorption (1.150 to 1.200 µm)

\[ C_E = \alpha/\alpha_{\text{min}} \]
Extended source, 0.400 to 1.400 µm, for \( \alpha_{\text{min}} \leq \alpha \leq \alpha_{\text{max}} \)

\[ C_E = \alpha^2/(\alpha_{\text{max}} \alpha_{\text{min}}) \]
Extended source, 0.400 to 1.400 µm, for \( \alpha > \alpha_{\text{max}} \)

\[ C_P = n^{-0.25} \]
Repetitive pulse correction factor (0.180 to 1000 µm)

\[ T_1 = 10 \times 10^{20(\lambda-0.450)} \]
Replace thermal by photochemical MPE, 0.450 to 500 µm

\[ T_2 = 10 \times 10^{(\alpha \cdot -1.5)/98.5} \]
Time related to eye movement, 0.400 to 1.400 µm
Nominal Hazard Zone (NHZ)

\[ r_{NHZ} = \left(\frac{1}{\phi}\right)[(4\Phi/\pi MPE) - a^2]^{1/2} \]  
Direct viewing of laser beam

\[ r_{NHZ} = \frac{f_o}{b_o} \left(\frac{4\Phi}{\pi MPE}\right)^{1/2} \]  
Lens on laser (focused beam)

\[ r_{NHZ} = 1.7/NA \left(\frac{\Phi}{\pi MPE}\right)^{1/2} \]  
Fiber optics, multimode fiber

\[ r_{NHZ} = \frac{\omega_o}{\lambda} \left(\frac{\pi \Phi}{2 MPE}\right)^{1/2} \]  
Fiber optics, singlemode fiber

\[ r_{NHZ} = \left(\frac{\rho\Phi\cos\theta}{\pi MPE}\right)^{1/2} \]  
Diffuse reflection

Optical Density

\[ D_{\lambda} = \log_{10} \left(\frac{1}{\tau}\right) \]  
Optical density

\[ D_{\lambda} = \log_{10} \left(\frac{I_o}{I}\right) \]  
OD for incident and transmitted intensity

\[ D_{\lambda} = \log_{10} \left(\frac{E_o}{MPE_E}\right) \]  
OD for MPE in terms of irradiance

\[ D_{\lambda} = \log_{10} \left(\frac{H_o}{MPE_H}\right) \]  
OD for MPE in terms of radiant exposure

Barrier Separation Distance

\[ D_s = \left(\frac{1}{\phi}\right)[(4\Phi/\pi TL) - a^2]^{1/2} \]  
Direct intrabeam exposure

\[ D_s = \frac{f_o}{b_o} \left(\frac{4\Phi}{\pi TL}\right)^{1/2} \]  
Lens on laser (focused beam)

\[ D_s = \left(\frac{\rho\Phi\cos\theta}{\pi TL}\right)^{1/2} \]  
Diffuse reflection
Miscellaneous Equations

\[ Q = \Phi t \]  
Radiant energy and radiant power conversion

\[ H = \frac{4Q}{\pi D_L^2} \]  
Radiant exposure for a circular beam

\[ E = \frac{4\Phi}{\pi D_L^2} \]  
Irradiance for a circular beam

\[ H = Et \]  
Radiant exposure and irradiance conversion

\[ \Phi_{\text{peak}} = \frac{Q_p}{t} \]  
Peak power from pulse energy pulse length

\[ \Phi_{\text{avg}} = \frac{Q_p F}{t} \]  
Average power from pulse energy and PRF

\[ n = Ft \]  
Number of pulses from PRF and exposure duration

\[ D_L = \sqrt{a^2 + \phi^2 r^2} \]  
Laser beam spot size

\[ d = f\phi \]  
Focused image diameter

\[ \alpha = \frac{D_L \cos \theta}{r} \]  
Viewing angle for a given spot size at distance \( r \)

\[ r_{\text{max}} = \frac{D_{\text{exit}} \cos \theta}{\alpha_{\text{min}}} \]  
Maximum distance for extended-source viewing

\[ \phi = \frac{s}{r} \]  
Plane angle definition in radians

\[ \Omega = \frac{A}{R^2} \]  
Solid angle definition in steradians

\[ G = \frac{D_0^2}{D_e^2} \]  
Optical gain

\[ I_2 = I_1 \times \text{magnification}^2 \]  
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.
# Quantities and Units: Laser Equation Sheet

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Quantity</th>
<th>Unit</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>area</td>
<td>square centimeter</td>
<td>cm²</td>
</tr>
<tr>
<td>a</td>
<td>emergent beam diameter</td>
<td>millimeter</td>
<td>mm</td>
</tr>
<tr>
<td>b₁</td>
<td>beam diameter on lens</td>
<td>centimeter</td>
<td>cm</td>
</tr>
<tr>
<td>Dₑ</td>
<td>diameter of exit pupil</td>
<td>centimeter</td>
<td>cm</td>
</tr>
<tr>
<td>Dₑₑₑₑ</td>
<td>exit port diameter of laser</td>
<td>centimeter</td>
<td>cm</td>
</tr>
<tr>
<td>Dₑₑₑₑ</td>
<td>beam spot size</td>
<td>centimeter</td>
<td>cm</td>
</tr>
<tr>
<td>Dₑₑₑₑ</td>
<td>optical density</td>
<td>dimensionless</td>
<td>---</td>
</tr>
<tr>
<td>Dₒ</td>
<td>diameter of objective</td>
<td>centimeter</td>
<td>cm</td>
</tr>
<tr>
<td>Dₑₑₑₑ</td>
<td>barrier separation distance</td>
<td>centimeter</td>
<td>cm</td>
</tr>
<tr>
<td>d</td>
<td>diameter of focused spot</td>
<td>centimeter</td>
<td>cm</td>
</tr>
<tr>
<td>E</td>
<td>irradiance</td>
<td>watts per square centimeter</td>
<td>W/cm²</td>
</tr>
<tr>
<td>Eₒ</td>
<td>incident irradiance</td>
<td>watts per square centimeter</td>
<td>W/cm²</td>
</tr>
<tr>
<td>F</td>
<td>pulse repetition frequency</td>
<td>hertz</td>
<td>Hz (s⁻¹)</td>
</tr>
<tr>
<td>fₑₑₑₑ</td>
<td>focal length</td>
<td>length</td>
<td>cm</td>
</tr>
<tr>
<td>G</td>
<td>gain</td>
<td>dimensionless</td>
<td>---</td>
</tr>
<tr>
<td>H</td>
<td>radiant exposure</td>
<td>joules per square centimeter</td>
<td>J/cm²</td>
</tr>
<tr>
<td>Hₒ</td>
<td>incident radiant exposure</td>
<td>joules per square centimeter</td>
<td>J/cm²</td>
</tr>
<tr>
<td>Iₒ</td>
<td>incident intensity</td>
<td>watts or watts / square centimeter</td>
<td>W or W/cm²</td>
</tr>
<tr>
<td>Iₑₑₑₑ</td>
<td>transmitted intensity</td>
<td>watts or watts / square centimeter</td>
<td>W or W/cm²</td>
</tr>
<tr>
<td>MPEₑₑ</td>
<td>MPE as irradiance</td>
<td>watts per square centimeter</td>
<td>W/cm²</td>
</tr>
<tr>
<td>MPEₑₑₑₑ</td>
<td>MPE as radiant exposure</td>
<td>joules per square centimeter</td>
<td>J/cm²</td>
</tr>
<tr>
<td>n</td>
<td>number of pulses</td>
<td>pulses</td>
<td>---</td>
</tr>
<tr>
<td>NA</td>
<td>numerical aperture</td>
<td>dimensionless</td>
<td>---</td>
</tr>
<tr>
<td>rₑₑₑₑ</td>
<td>nominal hazard zone</td>
<td>distance</td>
<td>cm</td>
</tr>
<tr>
<td>r</td>
<td>distance - radius</td>
<td>length</td>
<td>---</td>
</tr>
<tr>
<td>Q</td>
<td>radiant energy</td>
<td>joules</td>
<td>J</td>
</tr>
<tr>
<td>Qₑₑₑₑ</td>
<td>pulse energy</td>
<td>joules</td>
<td>J</td>
</tr>
<tr>
<td>s</td>
<td>arc length</td>
<td>centimeter</td>
<td>cm</td>
</tr>
<tr>
<td>TL</td>
<td>barrier threshold limit</td>
<td>watts per square centimeter</td>
<td>W/cm²</td>
</tr>
<tr>
<td>T</td>
<td>pulse duration</td>
<td>second</td>
<td>s or sec</td>
</tr>
<tr>
<td>t</td>
<td>exposure duration</td>
<td>second</td>
<td>s or sec</td>
</tr>
<tr>
<td>a</td>
<td>viewing angle</td>
<td>milliradian</td>
<td>mrad</td>
</tr>
<tr>
<td>λ</td>
<td>wavelength</td>
<td>micrometer</td>
<td>µm</td>
</tr>
<tr>
<td>φ</td>
<td>beam divergence</td>
<td>milliradian</td>
<td>mrad</td>
</tr>
<tr>
<td>Φ</td>
<td>radiant power</td>
<td>watts</td>
<td>W</td>
</tr>
<tr>
<td>Φₑₑₑₑ</td>
<td>average beam power</td>
<td>watt</td>
<td>W</td>
</tr>
<tr>
<td>Φₑₑₑₑₑ</td>
<td>peak beam power</td>
<td>watt</td>
<td>W</td>
</tr>
<tr>
<td>θₑₑₑₑ</td>
<td>viewing angle (normal &amp; eye)</td>
<td>radian</td>
<td>rad</td>
</tr>
<tr>
<td>ρ</td>
<td>reflectivity</td>
<td>dimensionless</td>
<td>---</td>
</tr>
<tr>
<td>τ</td>
<td>transmittance</td>
<td>dimensionless</td>
<td>---</td>
</tr>
<tr>
<td>Ω</td>
<td>solid angle</td>
<td>steradian</td>
<td>sr</td>
</tr>
<tr>
<td>ωₒ</td>
<td>mode field diameter</td>
<td>micrometer</td>
<td>µm</td>
</tr>
</tbody>
</table>
The mission of the BLS is to provide a means for improvement in the practice of laser safety by providing opportunities for the education, assessment, and recognition of laser safety professionals.