Certified Laser Safety Officer

Exam Reference Guide

Board of Laser Safety

Board of Laser Safety®
Certified Laser Safety Officer® Program

Examination Reference Guide

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Certified Laser Safety Officer® Program

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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:

1. *ANSI Z136.1 (2014), American National Standard for Safe Use of Lasers*, Laser Institute of America, Orlando, FL.
2. *Safety with Lasers and Other Optical Sources*, Sliney, D. and Wolbarsht, M., Plenum, New York, NY, 1980.

Other Hard Copy Materials

1. *CLSO's Best Practices in Laser Safety*, Laser Institute of America, Orlando, FL, 2008.
2. *Laser Radiation*, Hitchcock, R.T. and R.J. Rockwell, Jr., American Industrial Hygiene Association, Fairfax, VA, 1999.
3. *Laser Safety*, Henderson, R. and Schulmeister, K., Institute of Physics Publishing, Bristol, UK and Philadelphia, PA, 2004.
4. *Laser Safety Guide*, Marshall, W. and Sliney, D. (editors), Laser Institute of America, Orlando, FL, 2007.
5. *Laser Safety Management*, Barat, K., CRC Press, New York, NY, 2005.
6. *Laser Safety: Tools and Training*, Barat, K., CRC Press, New York, NY, 2008.
7. *LIA Guide for the Selection of Laser Eye Protection*, Sliney, D. (editor), Laser Institute of America, Orlando, FL, 2007.
8. Marshall, W.J., "Understanding laser hazard evaluation," *J Laser Appl*. 7:99-105 (1995).

Web Pages and Free Online Tutorials

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

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

11. U.S. Army CHPPM: *Lasers and Their Effects on the Human Eye*
https://de356l4tocdyu.cloudfront.net/pdf/OSHAEyeFactSheet.pdf

Laser Safety Equation Sheets (Z136.1 – *2007*)*

Selected Maximum Permissible Exposures (MPEs)

$1.8t^{0.75} \times 10^{-3}$ J/cm^2	Visible region including 0.25 sec (from 18×10^{-6} to 10 sec exposure)
$C_B \times 10^{-4}$ W/cm^2	Visible region (0.400 to 0.500 µm) including 600 sec (from 100 to 3×10^4 sec exposure)
$C_A \times 10^{-3}$ W/cm^2	IR (0.700 to 1.050 µm) including 10 sec (from 10 to 3×10^4 sec exposure)
$5.0\ C_C \times 10^{-3}$ W/cm^2	IR (1.050 to 1.400 µm) including 10 sec (from 10 to 3×10^4 sec exposure)

Correction Factors from Table 6 of ANSI Z136.1 (*2007*)

$C_A = 10^{2(\lambda-0.700)}$	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)
$C_E = \alpha/\alpha_{min}$	Extended source, 0.400 to 1.400 µm, for $\alpha_{min} \leq \alpha \leq \alpha_{max}$
$C_E = \alpha^2/(\alpha_{max}\,\alpha_{min})$	Extended source, 0.400 to 1.400 µm, for $\alpha > \alpha_{max}$
$C_P = n^{-0.25}$	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
$T_2 = 10 \times 10^{(\alpha-1.5)/98.5}$	Time related to eye movement, 0.400 to 1.400 µm

** 3/7/2018 Edit: The current exam is based on the Z136.1 (2014).*

Nominal Hazard Zone (NHZ)

$r_{NHZ} = (1/\phi)[(4\Phi/\pi MPE) - a^2]^{1/2}$	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

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

Barrier Separation Distance

$D_s = (1/\phi)[(4\Phi/\pi TL) - a^2]^{1/2}$	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

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
$D_L = \sqrt{(a^2 + \phi^2 r^2)}$	Laser beam spot size
$d = f\phi$	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
$\phi = s/r$	Plane angle definition in radians
$\Omega = A/R^2$	Solid angle definition in steradians
$G = D_o^2 / D_e^2$	Optical gain
$I_2 = I_1 \times \text{magnification}^2$	Increase in intensity with magnification

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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

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	second	s 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

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.

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