



Certified Laser Safety Officer

Exam Reference Guide



Board of Laser Safety[®]
Certified Laser Safety Officer[®] Program

Examination Reference Guide
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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 you prepare for the CLSO examination by giving you 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 the candidate 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, and the candidate 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
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407.380.1553 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 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 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%

Suggested Study References

In addition to studying for this exam, each candidate is encouraged to take the online practice test available through CASTLE Worldwide, a testing agency contracted by the BLS. The practice test will assist candidates preparing for the exam by providing valuable information concerning the exam's format, style, and level of difficulty. The practice test is comprised of 35 questions representing all areas of the exam. Once the candidate submits their answers for scoring, they immediately receive a detailed score report indicating areas of strength and weakness, thus letting them know where to concentrate their studies. The practice test can be taken at www.castleworldwide.com. There is a \$50 fee collected by CASTLE to take the practice test.

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 (2007), 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 Safety Guide*, Marshall, W. and Sliney, D. (editors), Laser Institute of America, Orlando, FL, 2007.
3. *LIA Guide for the Selection of Laser Eye Protection*, Sliney, D. (editor), Laser Institute of America, Orlando, FL, 2007.
4. *Laser Safety Management*, Barat, K., CRC Press, New York, NY, 2005.
5. *Laser Safety: Tools and Training*, Barat, K., CRC Press, New York, NY, 2008.
6. *Laser Safety*, Henderson, R. and Schulmeister, K., Institute of Physics Publishing, Bristol, UK and Philadelphia, PA, 2004.
7. *Laser Radiation*, Hitchcock, R.T. and R.J. Rockwell, Jr., American Industrial Hygiene Association, Fairfax, VA, 1999.
8. Marshall, W.J., "Understanding laser hazard evaluation," *J Laser Appl.* 7:99-105 (1995).

Web Pages and Free Online Tutorials

1. The Physics Classroom: *Specular vs. Diffuse Reflection*
<http://www.physicsclassroom.com/Class/refln/U13L1d.html>
2. The Physics Classroom: *Anatomy of the Eye*
<http://www.physicsclassroom.com/Class/refrn/U14L6a.html>
3. Princeton University: *Laser Safety Training Guide*
<http://web.princeton.edu/sites/ehs/laserguide/index.htm>
4. University of North Carolina: *Laser Safety Training*
http://ehs.unc.edu/training/self_study/laser/
5. Indiana University-Purdue University Indianapolis: *Online Laser Safety Training* (guest registration required)
http://www.ehs.iupui.edu/lasersafetypro/safety_home.asp

6. University of California, Berkeley: *Lase Safety Training Supplement*
<http://socrates.berkeley.edu/~phylabs/adv/LaserSafeTrainSup04.pdf>
7. Sam's Laser FAQ: *What is a Laser and How Does It Work?*
<http://www.repairfaq.org/sam/laserfaq.htm#faqwil>
8. Sam's Laser FAQ: *Laser Safety*
<http://www.repairfaq.org/sam/lasersaf.htm#saftoc>
9. U.S. Army CHPPM: *Lasers and Their Effects on the Human Eye*
<http://chppm-www.apgea.army.mil/laser/Publications/Fact%20Sheets/250130498.pdf>
10. Occupational Safety and Health Administration: Safety and Health Topics,
Laser Hazards
<http://www.osha.gov/SLTC/laserhazards/>
11. Food and Drug Administration: 21 CFR 1040.10.
<http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/cfrsearch.cfm>

Laser Safety Equation Sheets

Selected Maximum Permissible Exposures (MPEs)

$1.8t^{0.75} \times 10^{-3} \text{ J/cm}^2$	Visible region including 0.25 sec (from 18×10^{-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 3×10^4 sec exposure)
$C_A \times 10^{-3} \text{ W/cm}^2$	IR (0.700 to 1.050 μm) including 10 sec (from 10 to 3×10^4 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 3×10^4 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)
$C_E = \alpha/\alpha_{\min}$	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

Nominal Hazard Zone (NHZ)

$r_{\text{NHZ}} = (1/\phi)[(4\Phi/\pi\text{MPE}) - a^2]^{1/2}$	Direct viewing of laser beam
$r_{\text{NHZ}} = f_o/b_o (4\Phi/\pi\text{MPE})^{1/2}$	Lens on laser (focused beam)
$r_{\text{NHZ}} = 1.7/\text{NA} (\Phi/\pi\text{MPE})^{1/2}$	Fiber optics, multimode fiber
$r_{\text{NHZ}} = \omega_o/\lambda (\pi\Phi/2\text{MPE})^{1/2}$	Fiber optics, singlemode fiber
$r_{\text{NHZ}} = (\rho\Phi\cos\theta/\pi\text{MPE})^{1/2}$	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
$D_\lambda = \log_{10} (E_o/\text{MPE}_E)$	OD for MPE in terms of irradiance
$D_\lambda = \log_{10} (H_o/\text{MPE}_H)$	OD for MPE in terms of radiant exposure

Barrier Separation Distance

$D_s = (1/\phi)[(4\Phi/\pi\text{TL}) - a^2]^{1/2}$	Direct intrabeam exposure
$D_s = f_o/b_o (4\Phi/\pi\text{TL})^{1/2}$	Lens on laser (focused beam)
$D_s = (\rho\Phi\cos\theta/\pi\text{TL})^{1/2}$	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
$\Phi_{\text{peak}} = Q_p/t$	Peak power from pulse energy pulse length
$\Phi_{\text{avg}} = Q_p F$	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
$r_{\text{max}} = D_{\text{exit}} \cos\theta/\alpha_{\text{min}}$	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

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



Board of Laser Safety

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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