

**QUESTION 7**

You are a military health physicist with an additional duty as laser safety officer at a large military installation. The following are questions on the basics of nonionizing radiation protection.

**GIVEN:**

HeNe laser wavelength: 633 nm

Ruby laser wavelength: 694.3 nm

**Maximum Permissible Exposure for Direct Ocular Exposure Intra-beam Viewing  
from a Laser Beam\***

Wavelength $\lambda$ ( $\mu\text{m}$ )	Exposure Time $t$ (s)	MPE
0.400 to 0.700	$10^{-9}$ to $1.8 \times 10^{-5}$	$5 \times 10^{-7} \text{ J cm}^{-2}$
0.400 to 0.700	$1.8 \times 10^{-5}$ to 10	$1.8 t^{3/4} \times 10^{-3} \text{ J cm}^{-2}$
0.400 to 0.550	10 to $10^4$	$1 \times 10^{-2} \text{ J cm}^{-2}$
0.550 to 0.700	10 to $T_1$	$1.8 t^{3/4} \times 10^{-3} \text{ J cm}^{-2}$
0.550 to 0.700	$T_1$ to $10^4$	$10 C_B \times 10^{-3} \text{ J cm}^{-2}$
0.400 to 0.700	$10^4$ to $3 \times 10^4$	$C_B \times 10^{-6} \text{ W cm}^{-2}$

\*  $C_B = 1$  for  $\lambda = 0.400$  to  $0.550 \mu\text{m}$ ;  $C_B = 10^{15(\lambda - 0.550)}$  for  $\lambda = 0.550$  to  $0.700 \mu\text{m}$ ;  
 $T_1 = 10 \times 10^{20(\lambda - 0.550)}$  second for  $\lambda = 0.550$  to  $0.700 \mu\text{m}$  [From ANSI Z136.1 (1993)]

**STATE ALL ASSUMPTIONS****POINTS**

- 20** A. Match the following radiometric quantities to their appropriate units and **define the term**.
- |                      |                                       |
|----------------------|---------------------------------------|
| 1. Radiant exposure  | a. $\text{W cm}^{-2}$                 |
| 2. Radiant power     | b. $\text{W sr}^{-1}$                 |
| 3. Radiant energy    | c. J                                  |
| 4. Radiant intensity | d. $\text{W sr}^{-1} \text{ cm}^{-2}$ |
| 5. Radiance          | e. $\text{J cm}^{-2}$                 |
|                      | f. W                                  |
|                      | g. $\text{J sr}^{-1} \text{ cm}^{-2}$ |
- 12** B. Briefly describe the **three** basic components of all lasers. **Number your responses. Only the first three responses will be graded.**
- 30** C. A ruby laser has the following characteristics:
- pulse energy: 20 J
  - pulse rate: 2  $\text{min}^{-1}$
  - pulse duration: 10  $\mu\text{s}$
  - beam
  - divergence: 15 mrad
  - aperture

diameter: 2 mm

What is the required optical density for protective goggles to reduce the radiant exposure to the maximum permissible exposure at one meter from the laser?

- 38** D. A 50-mW HeNe continuous emission laser is used to give a light show at an outdoor concert. The laser has an aperture diameter of 3 mm and a beam divergence of 0.3 mrad. Calculate the following:
1. The emergence irradiance.
  2. The hazardous intra-beam viewing distance (that is, the distance to the point where the MPE is not exceeded assuming continuous viewing). Neglect atmospheric attenuation.