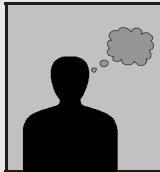


# GATE

## **MADE EASY** **WORKBOOK** 2027



**Detailed Explanations of  
Try Yourself Questions**

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### **Instrumentation Engineering** Optical Instrumentation



# 1

## Basic Optics



### Detailed Explanation of Try Yourself Questions

**T1. Sol.**

$$\mu_g = \frac{4}{3}$$

We know,  $n_1 \sin \theta_i = n_2 \sin \theta_r$

$$1 \times \sin 30^\circ = \frac{4}{3} \times \sin \theta$$

$$\theta_r = \sin^{-1} \frac{0.5}{1.33}$$

$$\theta_r = 20.08^\circ$$

**T2. Sol.**

The maximum number of lines required are

$$\frac{\text{Mean } (\lambda_1, \lambda_2)}{\lambda_1 - \lambda_2} = \frac{589.6 + 589}{2(589.6 - 589)}$$

$$= \frac{589.3}{0.6} = 982.16 \approx 982$$

■■■■

# 2

## Fiber Optics



### Detailed Explanation of Try Yourself Questions

**T1. Sol.**

$$\begin{aligned} \text{NA} &= \sqrt{n_1^2 - n_2^2} \\ &= \sqrt{(1.5)^2 - (1.45)^2} = 0.384 \end{aligned}$$

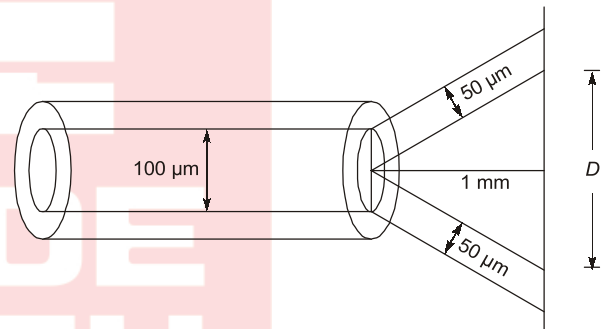
**T2. Sol.**

$$\begin{aligned} P &= 2 \text{ mW} \\ \text{Attenuation} &= 10 \times \frac{10}{1000} = 0.1 \text{ dB} \\ R &= 0.55 \text{ A/w} \\ \text{Detector current} &= 0.55 \times \frac{2}{10^3} \text{ Amp.} \\ &= 1.1 \text{ mA} \end{aligned}$$

**T3. Sol.**

$$\begin{aligned} \Delta t &= \frac{n_1 L}{C} \left[ \frac{n_1}{n_2} - 1 \right] \\ &= \frac{1.46 \times 1000}{3 \times 10^8} \left[ \frac{1.46}{1.45} - 1 \right] \\ &= 33.56 \text{ ns.} \end{aligned}$$

**T4. Sol.**



$$\begin{aligned} \therefore \text{Spot diameter} &= 2r\theta_a \\ \text{here } \theta_a &= \sin^{-1} \text{Na} \\ &= \sin^{-1} \sqrt{1.5^2 - 1.485^2} \\ &= 12.216^\circ \\ &= 0.213 \text{ rad} \end{aligned}$$

$$\begin{aligned} D &= 2 \times 1000 \times 0.213 = 427 \mu\text{m} \\ \text{Total length of photo-detector array} \\ &427 + 50 + 50 \mu\text{m} = 527 \mu\text{m} \\ \text{Diameter of one photodetector} &= 5 \mu\text{m} \\ \text{So, total number of photo detector in array} \end{aligned}$$

$$= \frac{527}{5} \approx 106$$

**T5. Sol.**

$$\theta_c = \sin^{-1} \left[ \frac{1}{\mu} \right] = \sin^{-1} \left[ \frac{1}{1.45} \right] = 46.33^\circ$$





**Detailed Explanation**  
*of*  
**Try Yourself Questions**

**T1. Sol.**

$$\begin{aligned} \therefore \Delta\theta &= \frac{1.22\lambda}{d} = \frac{1.22 \times 729 \times 10^{-9}}{6 \times 10^{-3}} \\ &= 1.48 \times 10^{-4} \text{ rad} \\ \text{Areal spread} &= \pi (r\theta)^2 \\ &= 3.14 \times 54.76 \times 10^8 \\ &= 1.72 \times 10^{10} \end{aligned}$$

**T2. Sol.**

$$\begin{aligned} \therefore \Delta\theta &= \frac{1.22\lambda}{d} \\ \frac{\Delta\theta_1}{\Delta\theta_2} &= \frac{\lambda_1}{\lambda_2} \times \frac{d_2}{d_1} \\ \frac{\Delta\theta}{\Delta\theta_2} &= \frac{\lambda}{2\lambda} \times \frac{d}{2d} \\ \Delta\theta_2 &= 4\Delta\theta \\ &= 4 \text{ Times} \end{aligned}$$

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# 4

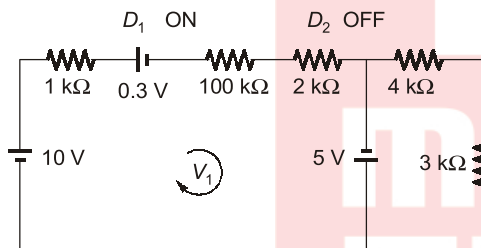
## Light Emitting Diode (LED) Photodiode, Photo-Resistor



### Detailed Explanation of Try Yourself Questions

**T1. Sol.**

$D_1$  and  $D_2$  are in forward bias

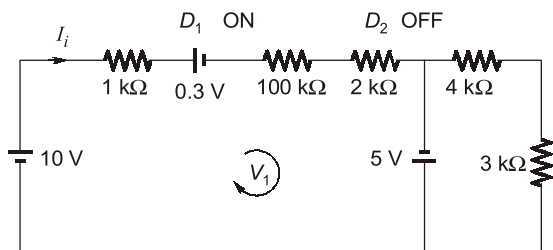


$$V_{2K} = ? \quad V_{3K} = ?$$

$$i_2 = \frac{-5V}{4k\Omega + 3k\Omega} = \frac{-5}{7k\Omega}$$

$$= -0.7214 \text{ mA}$$

$$V_{3k\Omega} = i_2 \times 3k\Omega = -2.14 \text{ V}$$



From circuit

$$I_i = \frac{10 - 0.3 + 5}{103k\Omega} = 0.142 \text{ mA}$$

$$\text{So, } V_{2k\Omega} = I_i \times 2k\Omega = 0.142 \times 2 = 0.28 \text{ V}$$

**T2. Sol.**

$$0.75 = \frac{I_p/q}{P/h\nu} \Rightarrow \frac{I_p}{q} \times \frac{h\nu}{P}$$

$$I_p = \frac{0.75 \times 65 \times 10^{-6} \times 1200 \times 10^{-9}}{6.625 \times 10^{-34} \times 3 \times 10^8}$$

$$I = 47.1 \mu\text{A}$$

**T3. Sol.**

$$I = \text{Sensitivity} \times \text{Intensity} \times \text{Area}$$

$$I = 0.55 \times 10 \times 10^{-3} \times 10^{-2}$$

and output voltage

$$V_o = -IR_L$$

$$= -5.5 \times 10^{-5} \times 100 \times 10^3 = -5.5 \text{ V}$$

**T4. Sol.**

$$\therefore R = \frac{I_p}{P_i}$$

$$I_p = P_i \cdot R$$

$$= I \times A \times R$$

$$= \frac{10^{-3} \text{ W}}{10^{-4}} \times 10 \times 10^{-6} \times 0.5 \frac{\text{A}}{\text{W}}$$

$$= 0.5 \times 10^{-4} \text{ A}$$

$$V_L = IR$$

$$= 0.5 \times 10^{-4} \times 100k\Omega = 5 \text{ V}$$



# 5

## Interference



### Detailed Explanation of Try Yourself Questions

**T1. Sol.**

$$\begin{aligned} \therefore n\lambda &= t(\mu - 1) \\ 5 \times 589 \times 10^{-9} &= 5 \times 10^{-6} (\mu - 1) \\ \mu &= 1.589 \end{aligned}$$

$$x_n = \frac{D}{d} n\lambda$$

$$x_{10} = \frac{40}{2} \times 10 \times 589 \times 10^{-9}$$

$$= 117.8 \mu\text{m}$$

**T2. Sol.**

$$\lambda = 589 \text{ nm}$$

$$d = 2 \text{ mm}$$

$$D = 4 \text{ cm} = 40 \text{ mm}$$

$$D \gg d$$

Location  $n$  of  $n^{\text{th}}$  bright fringe from the central position  $x_n$  is

Fringe width ( $\beta$ )

$$= \frac{D}{d} \lambda = \frac{40}{2} \times 589 \times 10^{-9}$$

$$= 11.78 \mu\text{m}$$

