# GATE

## MADE EASY Workbook 2025

**Detailed Explanations of**
**Try Yourself *Questions***

# Instrumentation Engineering

## Optical Instrumentation



MADE EASY PUBLICATIONS

# 1 Basic Optics

## Detailed Explanation of Try Yourself Questions

**T1. Sol.**

$$\mu g = \frac{4}{3}$$

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

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

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

$$\theta_r = 20.08°$$

**T2. Sol.**

The maximum number of lines required are

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

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

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# 2 Fiber Optics

## Detailed Explanation of Try Yourself Questions

**T1. Sol.**

$$NA = \sqrt{n_1^2 - n_2^2}$$

$$= \sqrt{(1.5)^2 - (1.45)^2} = 0.384$$

**T2. Sol.**

$$P = 2\ \text{mW}$$

$$\text{Attenuation} = 10 \times \frac{10}{1000} = 0.1\,\text{dB}$$

$$R = 0.55\ \text{A/w}$$

$$\text{Detector current} = 0.55 \times \frac{2}{10^3}\ \text{Amp.}$$

$$= 1.1\ \text{mA}$$

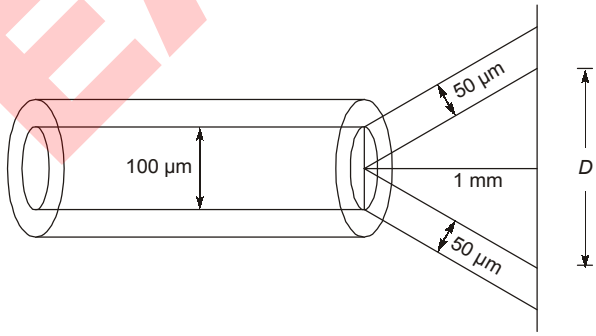
**T3. Sol.**

$$\Delta t = \frac{n_1 L}{C}\left[\frac{n_1}{n_2} - 1\right]$$

$$= \frac{1.46 \times 1000}{3 \times 108}\left[\frac{1.46}{1.45} - 1\right]$$

$$= 33.56\ \text{ns.}$$

**T4. Sol.**




$\because$ Spot diameter $= 2r\theta_a$

here $\theta_a = \sin^{-1} Na$

$= \sin^{-1}\sqrt{1.5^2 - 1.485^2}$

$= 12.216°$

$= 0.213$ rad

$D = 2 \times 1000 \times 0.213 = 427\ \mu m$

Total length of photo-detector array

$427 + 50 + 50\ \mu m = 527\ \mu m$

Diameter of one photodetector $= 5\ \mu m$

So, total number of photo detector in array

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

**T5. Sol.**

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

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# 3 Lasers

## Detailed Explanation of Try Yourself Questions

**T1. Sol.**

$$\therefore \quad \Delta\theta = \frac{1.22\lambda}{d} = \frac{1.22 \times 729 \times 10^{-9}}{6 \times 10^{-3}}$$

$$= 1.48 \times 10^{-4} \text{ rad}$$

$$\text{Areal spread} = \pi (r\theta)^2$$

$$= 3.14 \times 54.76 \times 10^{8}$$

$$= 1.72 \times 10^{10}$$

**T2. Sol.**

$$\therefore \quad \Delta\theta = \frac{1.22\,\lambda}{d}$$

$$\frac{\Delta\theta_1}{\Delta\theta_2} = \frac{\lambda_1}{\lambda_2} \times \frac{d_2}{d_1}$$

$$\frac{\Delta\theta}{\Delta\theta_2} = \frac{\lambda}{2\lambda} \times \frac{d}{2d}$$

$$\Delta\theta_2 = 4\,\Delta\theta$$

$$= 4 \text{ Times}$$

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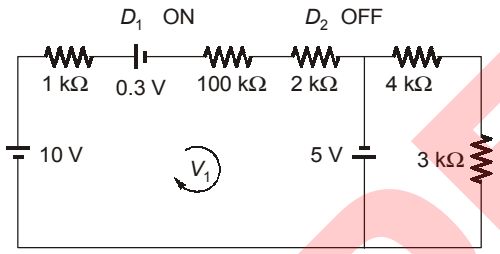
# 4 Light Emitting Diode (LED) Photodiode, Photo-Resistor

## Detailed Explanation of Try Yourself Questions

**T1. Sol.**

$D_1$ and $D_2$ are in forward bias

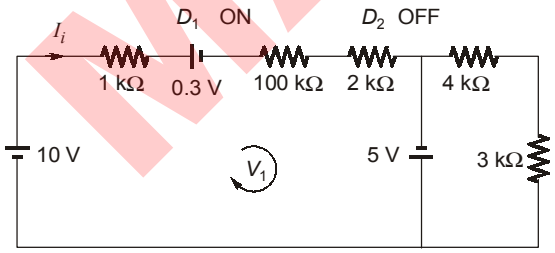



$V_{2K} = ?$ $V_{3K} = ?$

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

$= -0.7214$ mA

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




From circuit

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

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

**T2. Sol.**

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

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

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

**T3. Sol.**

$I =$ Sensitivity $\times$ Intensity $\times$ Area

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

and output voltage

$V_o = -IR_L$

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

**T4. Sol.**

$$\therefore \quad R = \frac{I_p}{Pi}$$

$I_p = P_i \cdot R$

$= I \times A \times R$

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

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

$V_L = IR$

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

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# 5 Interference

## Detailed Explanation of Try Yourself Questions

**T1. Sol.**

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

**T2. Sol.**

$\lambda = 589$ nM
$d = 2$ mm
$D = 4$ cm $= 40$ mm
$D >> d$

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

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

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

$$= 117.8\ \mu m$$

Fringe width ($\beta$)

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

$$= 11.78\ \mu m$$

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