29 Years
Previous Solved Papers

GATE 2021

Instrumentation Engineering

- Fully solved with explanations
- Topicwise presentation
- Analysis of previous papers
- Thoroughly revised & updated

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GATE - 2021 : Instrumentation Engineering Topicwise Previous GATE Solved Papers (1992-2020)

First Edition	:	2011
Second Edition	:	2012
Third Edition	:	2013
Fourth Edition	:	2014
Fifth Edition	:	2015
Sixth Edition	:	2016
Seventh Edition	:	2017
Eighth Edition	:	2018
Ninth Edition	:	2019
Tenth Edition	**:**	**2020**

Preface

Over the period of time the GATE examination has become more challenging due to increasing number of candidates. Though every candidate has ability to succeed but competitive environment, in-depth knowledge, quality guidance and good source of study is required to achieve high level goals.

B. Singh (Ex. IES)

The new edition of **GATE 2021 Solved Papers : Instrumentation Engineering** has been fully revised, updated and edited. The whole book has been divided into topicwise sections.

At the beginning of each subject, analysis of previous papers are given to improve the understanding of subject.

I have true desire to serve student community by way of providing good source of study and quality guidance. I hope this book will be proved an important tool to succeed in GATE examination. Any suggestions from the readers for the improvement of this book are most welcome.

B. Singh (Ex. IES)
Chairman and Managing Director
MADE EASY Group

Contents

Unit . IX

Optical Instrumentation

Contents

UNIT IX

Optical Instrumentation

Syllabus :

Optical sources and detectors: LED, laser, photo-diode, light dependent resistor and their characteristics; interferometer: applications in metrology; basics of fiber optic sensing.

Analysis of Previous GATE Papers

Exam Year	1 Mark Ques.	2 Marks Ques.	Total Marks
1992	1	3	**7**
1993	2	1	**4**
1994	–	1	**2**
1995	–	3	**6**
1996	1	5	**11**
1997	1	2	**5**
1998	–	2	**4**
1999	–	10	**20**
2000	–	6	**12**
2001	4	–	**4**
2002	5	3	**11**
2003	3	7	**17**
2004	3	8	**19**
2005	2	5	**12**
2006	4	4	**12**

Exam Year	1 Mark Ques.	2 Marks Ques.	Total Marks
2007	4	8	**20**
2008	3	5	**13**
2009	1	5	**11**
2010	2	2	**6**
2011	2	2	**6**
2012	3	1	**5**
2013	1	1	**3**
2014	2	3	**8**
2015	2	4	**10**
2016	–	2	**4**
2017	–	1	**2**
2018	1	2	**5**
2019	2	3	**8**
2020	–	2	**4**

1 Basics of Fibre Optics (Optical)

1.1 In an optical fibre with the core and cladding having refractive index n_1 and n_2 respectively, ($n_1 > n_2$), the numerical aperture is .... when the light enters the fibre in air.

[1992 : 1 Mark]

1.2 An optical fibre is characterized by
(a) total internal reflection
(b) a core material of refractive index lower than that of cladding
(c) scattering loss
(d) diffraction [1993 : 1 Mark]

1.3 A ray of light enters a glass optical fibre (refractive index 1.45) surrounded by air. Calculate the angle of incidence greater than which causes total internal reflection. [1993 : 1 Mark]

1.4 A step index optical fiber, whose refractive indices of the core and cladding are 1.44 and 1.40 respectively, is surrounded by air. Its numerical aperture is
(a) 0.12 (b) 0.75
(c) 0.06 (d) 0.34 [1996 : 1 Mark]

1.5 An optical fibre has a refractive index of 1.641 for the core and 1.422 for the cladding. The critical angle above which a ray will be totally internally reflected is
(a) 37° (b) 41°
(c) 45° (d) 60° [1999 : 2 Marks]

1.6 The refractive indices of the core and cladding of an optical fibre are 1.46 and 1.455 respectively. The diameter of the core is 4 μm. When operated at a wavelength of 1.31 μm, the fibre functions as a
(a) single-mode fibre with a numerical aperture of 0.1
(b) multimode fibre with a numerical aperture of 0.15
(c) single-mode fibre with a numerical aperture of 0.12
(d) ten-mode fibre with a numerical aperture of 0.12 [2003 : 2 Marks]

1.7 The refractive index of the core of an optical fibre is n_1 and that of the cladding is n_2. If $(n_1 - n_2) = \Delta n$, then the fibre can be made single mode with numerical aperture unchanged by
(a) reducing core diameter and increasing Δn
(b) reducing both core diameter and Δn
(c) reducing core diameter alone
(d) reducing Δn alone [2004 : 1 Mark]

1.8 A step index fibre has a core refractive index of 1.46 and a cladding refractive index of 1.45. The pulse dispersion in ns/km due to the effect of numerical aperture alone is
(a) 33.3 (b) 31.5
(c) 29.5 (d) 25.2

[2004 : 2 Marks]

1.9 The maximum solid angle of acceptance of light coupled into a step index fibre having core and cladding refractive indices of 1.48 and 1.45 respectively, is
(a) 0.28 steradians (b) 0.30 steradians
(c) 0.32 steradians (d) 0.34 steradians

[2005 : 2 Marks]

Statement for Linked Answer Questions (1.10 to 1.11):

In a step-index optical fiber, the refractive indices of the core and the cladding are equal to 1.501 and 1.499, respectively, at the wavelength of 850 nm. The fiber is surrounded by air.

1.10 The numerical aperture of the optical fibre is
(a) 0.077 (b) 0.501
(c) 1.499 (d) 1.501

[2006 : 2 Marks]

1.11 An LED emitting light around wavelength of 850 nm is butt-coupled to the optical fiber. If the LED is assumed to be a Lambertial source, then efficiency of coupling LED light to the fiber is
(a) 7.70% (b) 1.02%
(c) 0.60% (d) 0.57%

[2006 : 2 Marks]

Statement for Linked Answer Questions (1.12 to 1.13):

The numerical aperture of a step index fiber in (refractive index = 1), is 0.39. The diameter of the core is 200 μm.

1.12 The angle of acceptance when the fiber is used in water (refractive index = 1.33) is closest to
(a) 15° (b) 16°
(c) 17° (d) 18°

[2007 : 2 Marks]

Answers Basics of Fibre Optics (Optical)

1.1	Sol.	1.2	(a)	1.3	(43.6)	1.4	(d)	1.5	(d)	1.6	(c)	1.7	(c)
1.8	(a)	1.9	(a)	1.10	(a)	1.11	(c)	1.12	(c)	1.13	(b)	1.14	(b)
1.15	(b)	1.16	(c)	1.17	(106)	1.18	(0.75)	1.19	(30)	1.20	(c)	1.21	(28)

Explanations Basics of Fibre Optics (Optical)

1.1 Sol.

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

where,
$n_1 \Rightarrow$ R.I of core
$n_2 \Rightarrow$ R.I of cladding

1.2 (a)

An optical fibre uses total interval reflection of light for transfer of data via light.

1.3 (43.6)

If the angle of incidence is greater than the critical angle then it leads to Total internal reflection of light.

$$\text{Critical angle } (\theta_c) = \sin^{-1}\left(\frac{1}{\mu}\right)$$

$$= \sin^{-1}\left(\frac{1}{1.45}\right) = 43.6°$$

1.4 (d)

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

$$= \sqrt{(1.44)^2 - (1.40)^2} = \sqrt{0.1136}$$

$$= 0.337 \approx 0.34$$

1.5 (d)

$$n_1 \sin\theta_c = n_2 \sin 90°$$

$$\therefore \sin\theta_c = \left(\frac{n_2}{n_1}\right) = \frac{1.422}{1.641} = 0.866$$

$$\therefore \theta_c = \sin^{-1}(0.866) \approx 60°$$

1.6 (c)

If fibre core diameter is exceedingly small (2 - 10 μm) i.e if fibre core diameter is close to wavelength of propagated light wave then it is single mode transmission.

Now, numerical aperture,

$$\text{N.A.} = \sqrt{n_1^2 - n_2^2}$$

$$= \sqrt{(1.46)^2 - (1.455)^2} = 0.12$$

1.7 (c)

A multimode fiber optic cable can be made single made by either varying the Numerical Aperture (NA) or by reducing the diameter of core, and if we vary Δn NA will very as $NA = n\sqrt{2\Delta}$

Here, since NA is made fixed the fiber can then be made single mode fiber by reducing the core diameter alone, hence option (c) is correct.

1.8 (a)

$$\Delta = \frac{n_1 - n_2}{n_1} = \frac{1.46 - 1.45}{1.46} = \frac{0.01}{1.46} = 6.89 \times 10^{-3}$$

$$\Delta T = \frac{n_1 L}{C}\Delta \quad \text{(for step index fibers)}$$

$$= \frac{1.46 \times 1000}{3 \times 10^8} \times 6.89 \times 10^{-3}$$

$$= 3.33 \times 10^{-8} = 33.3 \text{ n-sec.}$$

1.9 (a)

$$\text{Solid angle} = \pi(\sin\theta_a)^2$$

$$\because \quad \sin\theta_A = \sqrt{n_1^2 - n_2^2} = \sqrt{1.48^2 - 1.45^2}$$

$$= \sqrt{0.0879} = 0.296$$

Solid angle = 0.28 steradins

1.10 (a)

$$\text{N.A.} = \sqrt{n_1^2 - n_2^2} = \sqrt{(1.501)^2 - (1.499)^2} = 0.077$$

1.11 (c)

$$\text{Coupling Efficiency} = (\text{NA})^2 = \left(\sqrt{n_1^2 - n_2^2}\right)^2$$

Substituting values,

Coupling Efficiency = $(1.501^2 - 1.499^2) = 0.006$

$\Rightarrow$ Coupling efficiency = 0.006 × 100% = 0.60%

1.12 (c)

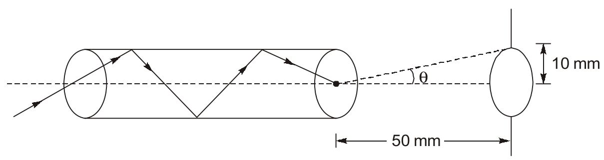
$$A.A = \sin^{-1}\left(\frac{N.A.}{\mu_w}\right) \quad (\mu_w = \text{R.I. of water})$$

$$= \sin^{-1}\left(\frac{0.39}{1.33}\right) \simeq 17°$$

1.13 (b)

The amount of light that can be gathered is depicted by the numerical aperture (N.A.) of the fiber, and N.A. is independent of the surrounding medium so the answer is 1.0.

1.14 (b)



Clearly, $\theta = \tan^{-1}\left(\frac{10}{50}\right) = 11.45°$

$$\text{N.A.} = \sin\theta = \sin(11.45°) = 0.19 \simeq 0.2$$

1.15 (b)

$\Delta = 0.01$; $n_1 = 1.5$

$$\text{N.A.} = n_1\sqrt{2\Delta}$$

$$= 1.5\sqrt{2\times 0.01} = 1.5\sqrt{0.02} = 0.212$$

$$\sin\theta_a = \text{N.A.}$$

$$\theta_a = \sin^{-1}(\text{N.A.}) = \sin^{-1}(0.212)$$

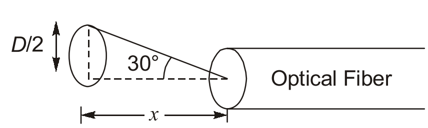
$$\simeq 12.1°$$

1.16 (c)

$$\text{N.A.} = \sin\theta_a = 0.5$$

$\therefore$ $\theta_0 = \sin^{-1} 0.5 = 30°$

$$D = 5 \text{ mm}$$



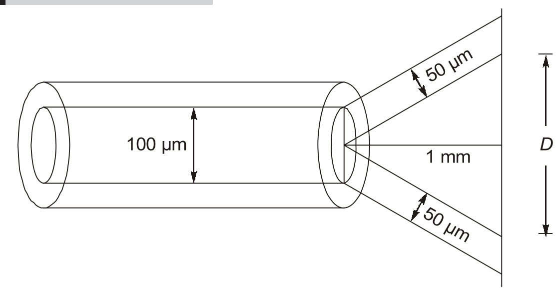
We have to find this distance 'X', as it is the focal of the lens

$$\tan 30° = \frac{D/2}{x}$$

$$\frac{1}{\sqrt{3}} = \frac{5}{2x}$$

$$x = \frac{5\sqrt{3}}{2} = 4.33 \text{ mm}$$

1.17 106 (105 to 107)



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

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

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

$$= 12.216° = 0.213 \text{ rad}$$

$$D = 2\times 1000\times 0.213 = 427 \ \mu\text{m}$$

Total length of photo-detector array

427 + 50 + 50 μm = 527 μm

Diameter of one photodetector = 5 μm

So, total number of photo detector in array

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

1.18 (0.75)

$$v \propto \frac{1}{\mu}$$

but $v \propto \frac{1}{t}$

$\therefore$ $t \propto \mu$

$\therefore$ $\frac{t_1}{t_2} = \frac{1.5}{2} = 0.75$

1.19 30 (29 to 31)

From the given figure

$$\text{N.A.} = n_o \sin\theta_A = \sqrt{n_1^2 - n_2^2}$$

where, $n_0 \rightarrow$ Refractive index of air [$n_0 = 1$]

$n_1 \rightarrow$ Refractive index of core [$n_1 = 1.5$]

$n_2 \rightarrow$ Refractive index of cladding [$n_2 = 1.4142$]

$\theta_A \rightarrow$ Maximum acceptance angle

$$\theta_A = \sin^{-1}\left[\sqrt{n_1^2 - n_2^2}\right]$$

$$\theta_A = \sin^{-1}\left[\sqrt{(1.5)^2 - (1.4142)^2}\right]$$

$$\theta_A = 30°$$

2 Interferometer, Applications in Metrology (Optical)

2.1 In a wave propagation, a path difference of x_0 corresponds to a phase difference of

(a) λx_0 (b) πx_0

(c) $\left(\frac{2\pi}{\lambda}\right)x_0$ (d) $\frac{x_0}{\lambda}$

[1995 : 2 Marks]

2.2 Match the instrument to the characteristic

List-I

(a) Interferometer

(b) Monochromator

List-II

(i) Wavelength dispersion Magnifying power

(ii) Flatness measurement

[1997 : 2 Marks]

2.3 For a change in elevation level of 1.5 μm between an optical flat and a surface, a light wave of wavelength 0.5 μm produces fringes. The number of fringes is

(a) 3 (b) 6

(c) 9 (d) 12

[1998 : 2 Marks]

2.4 An interference filter has been made with a dielectric of magnesium fluoride (refractive index μ = 1.38) for a nominal wavelength of 455 nm. The required thickness of the dielectric for first order interference is

(a) 8.2 nm (b) 16.5 nm

(c) 82 nm (d) 165 nm

[2000 : 2 Marks]

2.5 An optical flat is tested against a standard reference flat in a Newton's interferoscope if the optical flat is as good as the reference, the fringes observed are a set of

(a) concentric rings

(b) elliptical rings

(c) hyperbolic fringes

(d) straight and parallel fringes

[2001 : 1 Mark]

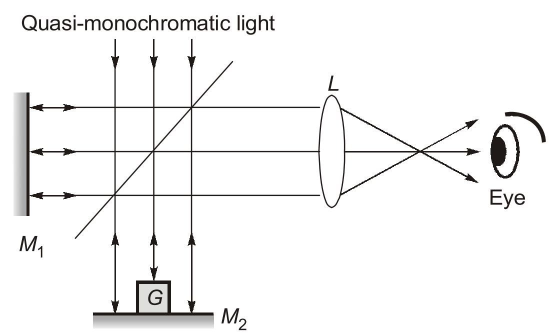
2.6 Two narrow straight slits, 0.25 mm apart are illuminated by an unknown monochromatic source of light. If the fifth bright fringe is 12 mm away from the central fringe when the screen is at a distance of 0.8 m from the slits. Then the wave length of the unknown source is

(a) 540 nm (b) 600 nm

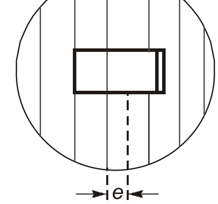
(c) 700 nm (d) 750 nm

[2002 : 2 Marks]

2.7 Koster's modification of Michelson interferometer is used to determine the thickness of a gauge *G*. The gauge *G* is placed on the mirror M_2 as shown in figure (a). The field-of-view observed through the lens *L* is shown in figure (b). The fractional-fringe shift e, as shown in figure (b), is measured to be 0.15 when the wavelength of light used is 0.63 μm. A quick check with a micrometer shows that the gauge length is approximately 100 μm. Then an accurate estimate of gauge length, in μm, is



(a)



(b)

(a) 99.902 (b) 100.804

(c) 100.000 (d) 101.706

[2003 : 2 Marks]

2.8 In a Michelson's interferometer illuminated by a coherent and quasi-monochromatic light source, a very small frequency shift is introduced in the light returning from one of the arms. The effect on the observed fringe pattern is

(a) a decrease in contrast
(b) an increase in contrast
(c) appearance of two sets of the same pattern
(d) uniform movement across the observation plane

[2004 : 2 Marks]

2.9 A tissue with a refractive index 1.33 is introduced in one of the light paths of a Michelson interferometer operating with a monochromatic coherent light source of wavelength 589 nm. After the introduction of a tissue sample of thickness Δt, the fringe pattern is observed to shift by 50 fringes. If thickness is $2\ \Delta t$, the fringe pattern will shift by

(a) 25 fringes (b) 50 fringes
(c) 100 fringes (d) 200 fringes

[2008 : 2 Marks]

Statement for Linked Answer Questions (2.10 to 2.11):
A Michelson interferometer illuminated with a source of central wavelength λ_0 and spectral width Δl is adjusted for equal path difference for the beams returning from the two mirrors. When one of the mirrors is moved by a distance of 0.1 mm from this position, 300 fringes move past the field of view. When the mirror is moved further, the fringes completely disappear when the mirror is approximately 4 cm from the initial position.

2.10 The central wavelength of the source is

(a) 540 nm (b) 632.8 nm
(c) 667 nm (d) 720 nm

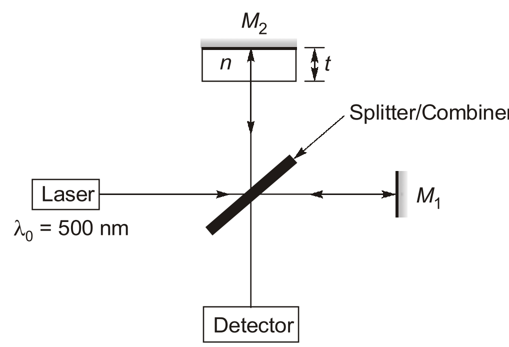
[2009 : 2 Marks]

2.11 The spectral width of the source $\Delta\lambda$ is approximately

(a) 0.0056 nm (b) 0.0100 nm
(c) 0.0500 nm (d) 0.1000 nm

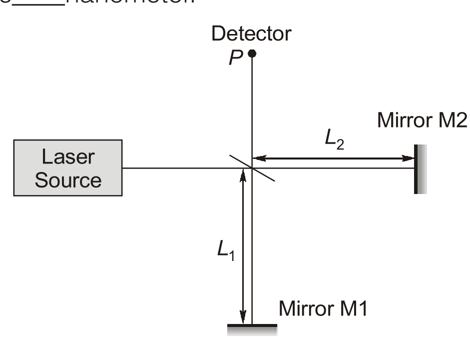
[2009 : 2 Marks]

2.12 A Michelson Interferometer using a laser source of wavelength λ_0 = 500 nm with both the mirrors (M_1 and M_2) fixed and positioned equidistant from the splitter/combiner is shown in the figure. When a dielectric plate of refractive index n = 1.5, of thickness t, is placed in front of the mirror M_2, a dark fringe is observed on the detector. When the dielectric plate is removed without changing the position of the mirrors M_1 & M_2, a bright fringe is observed on the detector. The minimum thickness t (in nm} of the dielectric is __________ .



[2018 : 2 Marks]

2.13 Consider a Michelson interferometer as shown in the figure below. When the wavelength of the laser light source is switched from 400 nanometer to 500 nanometer, it is observed that the intensity measured at the output port P goes from a minimum to a maximum. This observation is possible when the smallest path difference between the two arms of the interferometer is____nanometer.



[2019 : 2 Mark]

■■■

Answers **Interferometer, Applications in Metrology (Optical)**

2.1	(c)	2.2	(a)-(ii), (b)-(i)	2.3	(b)	2.4	(d)	2.5	(a)	2.6	(d)
2.7	(a)	2.8	(c) 2.9 (c)	2.10	(c)	2.11	(a)	2.12	(250)	2.13	(500 or 1000)

Explanations Interferometer, Applications in Metrology (Optical)

2.1 (c)

$$\frac{\text{Phase difference}}{2\pi}\lambda = \text{Path difference}$$

i.e. $$\frac{\phi_0}{2\pi}\lambda = x_0$$

$$\Rightarrow \quad \phi_0 = \frac{2\pi}{\lambda}x_0$$

2.3 (b)

$$2(\Delta x) = n\lambda$$

$$\therefore \quad 2 \times (1.5 \times 10^{-6}) = n \times 0.5 \times 10^{-6}$$

$$\therefore \quad n = \frac{2\times1.5\times10^{-6}}{0.5\times10^{-6}} = 6 \text{ fringes}$$

2.4 (d)

$$n\lambda = 2\mu t$$

for first order interference, $n = 1$

$$\therefore \quad \lambda = 2\mu t$$

$$t = \frac{\lambda}{2\mu} = \frac{455\times10^{-9}}{2\times1.38} = 164.8\times10^{-9} \approx 165 \text{ nm}$$

2.6 (d)

$d = 0.25$ mm ; $X_5 = 12$ mm ; $D = 0.8$ m

$$X_5 = 5\left(\frac{\lambda D}{d}\right)$$

$$\lambda = \frac{X_5\times d}{5D} = \frac{12\times10^{-3}\times0.25\times10^{-3}}{5\times0.8}$$

$$= 0.75 \times 10^{-6} = 750 \times 10^{-9} \text{ m} = 750 \text{ nm}$$

2.7 (a)

Given fractional fringe shift, $e = 0.15$

and λ of light used = 0.63 μm

$\Rightarrow$ Error in length of gauge = $e \cdot \lambda = 0.0945$ μm

So, Actual length = $100 - 0.0945 \simeq 99.9055$

$\simeq 99.902$ μm

2.9 (c)

$$n\lambda = 2\Delta x = 2t(\mu - 1) \quad [\therefore n \propto t]$$

as Δt is replaced to $2(\Delta t)$.

$\therefore$ n will also gets doubled.

$$n' = 2n = 2 \times 50 = 100 \text{ fringes}$$

2.10 (c)

$$n\lambda = 2(\mu x)$$

$$\lambda = \frac{2(\Delta x)}{n} = \frac{2\times0.1\times10^{-3}}{300} = 0.66666 \times 10^{-6}$$

$$= 666.66 \text{ nm} \approx 667 \text{ nm}$$

2.11 (a)

The spectral width of the source ($\Delta\lambda$) is approximately

$$\Delta\lambda = \frac{(\lambda_{av})^2}{2x} = \frac{(667\times10^{-a})^2}{2\times4\times10^{-2}} = 0.0056 \text{ nm}$$

2.12 250 (249 to 251)

From the given explanation, we can understand that, "when a tissue of thickness 't' of refractive index 'N', is placed then a dark fringe is observed"

So,

$$\text{Path difference} = \frac{\lambda_0}{2}$$

$$\text{Path difference} = 2(N-1)t$$

$$2(N-1)t = \frac{\lambda_0}{2}$$

$$2(1.5-1)t = \frac{500 \text{ nm}}{2}$$

$$t = 250 \text{ nm}$$

2.13 (500 or 1000)

As per the question the optical path difference in both the cases (400 nm or 500 nm) should be same but for 400 nm wavelength we should get distructive interference whereas for 500 nm wavelength we should get constructive interference.

$\therefore$ For constructive interference optical path difference $(2x) = n\lambda_c$

For distructive interference optical path difference

$$(2x) = \frac{(2m+1)\lambda_D}{2}$$

As per question,

$$h\lambda_c = \frac{(2m+1)\lambda_D}{2}$$

$$n(500) = \frac{(2m+1)400}{2}$$

$\therefore$ For $n = 2$ or $m = 2$ condition satisfied

$\therefore$ Optical path difference

$$2x = n\lambda = 2(500 \text{ nm}) = 1000 \text{ nm}$$

■■■

3 LED, Lasers & Photodiode (Optical)

3.1 A laser beam (λ = 632.8 nm) having a divergence of 1 milli-radian is directed towards the moon at a distance of approximately 4×10^5 km. The beam would have spread to a diameter of

(a) 400 km (b) 200 km
(c) 100 km (d) 4 km

[1996 : 2 Marks]

3.2 Two crossed length of the He-Ne laser beam is 120 cm. Its coherence time in seconds is

(a) 4×10^{-1} (b) 4×10^{-3}
(c) 4×10^{-5} (d) 4×10^{-9}

[1997 : 1 Mark]

3.3 A frequency stabilized He-Ne laser with a wavelength of 6328 Å has a bandwidth of 1 MHz. Its coherence length is

(a) 0.3 m (b) 3 m
(c) 30 m (d) 300 m

[1999 : 2 Marks]

3.4 In a He-Ne laser operating at a wavelength of 632.8 nm. the actual laser transition takes place between the energy levels of

(a) Helium (b) Neon
(c) Helium and Neon (d) None of these

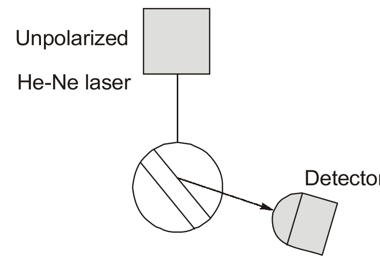
[2002 : 1 Mark]

3.5 A He-Ne laser beam having a wavelength of 632.8 mm is expanded to a diameter of 1 meter and then pointed towards the moon. If the distance of the moon from earth is 3.8×10^5 km, the diameter of the central maxima on the surface of the moon is.

(a) 1 m (b) 100 m
(c) 587 m (d) 720 m

[2002 : 2 Marks]

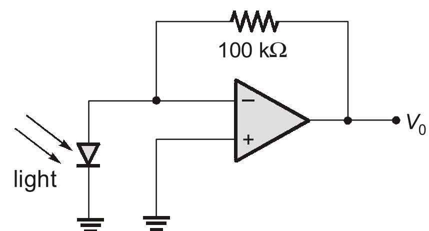
3.6 An unpolarized He-Ne laser beam of wavelength 632.8 nm is reflected from the flat surface of a dielectric. A detector analyzes the reflected beam. It is found that when the angle between the incident and the reflected beams is 115°-34′ the light is completely plane polarized. The refractive index of the dielectric at this wavelength is



(a) 1.521 (b) 1.587
(c) 1.621 (d) 1.571

[2002 : 2 Marks]

3.7 A photo-detector circuit is given in figure. The photo-diode has an active area the photo-diode has an active area of 10^{-2} cm^2 and sensitivity of 0.55 A/W. When light of intensity 10 mW/cm^2 falls on the photo-diode, the output V_0 is



(a) 10.1 V (b) 5.5 V
(c) –5.5 V (d) –10.1 V

[2003 : 2 Marks]

3.8 A PIN photodetector has a junction capacitance of 16 pF, active area of 10 mm^2 and a responsivity of 0.5 A/W. It is illuminated by a light of intensity 1 mW/cm^2. A voltage output is obtained by connecting a 100 kΩ load resistor R_L in series with the detector. The steady state voltage across R_L will be

(a) 0.5 V (b) 1.5 V
(c) 5.0 V (d) 7.0 V

[2004 : 2 Marks]

3.9 A He-Ne laser of cavity length 500 mm has an oscillating bandwidth of 1500 MHz. The maximum number of longitudinal oscillating modes that is accommodated within the bandwidth is

(a) 4 (b) 5
(c) 30 (d) 40

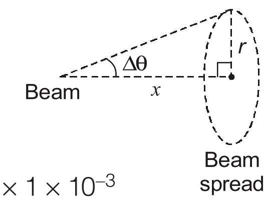
[2004 : 2 Marks]

Explanations LED, Lasers & Photodiode (Optical)

3.1 (*)

From figure,

Radius, $r = x\tan\Delta\theta$



For small θ, $\tan q \simeq \theta$

$\Rightarrow \quad r = x\Delta\theta$

$\Rightarrow \quad r = 4\times10^5\times1\times10^{-3}$

$= 400$ km

So diameter, $d = 2\times400 = 800$ km

3.1 (*)

$\Delta\theta = 1$ millradian

$= 1\times10^{-3}$

$r = 4\times10^5$ km

Spread diameter $(D) = 2r(\Delta\theta)$

$= 2\times4\times10^5\times1\times10^{-3}$

$= 8\times10^2 = 800$ km

3.2 (d)

$$t = \frac{L}{c} = \frac{120\times10^{-2}}{3\times10^8} = 4\times10^{-9}$$

3.3 (d)

Given bandwidth, $B = 1\times10^6\ \text{sec}^{-1}$

$$\Rightarrow \text{Coherence length} = \frac{\text{Speed of light (m/sec)}}{\text{Bandwidth (sec}^{-1})}$$

$$= \frac{3\times10^8}{1\times10^6} = 300\ \text{m}$$

3.4 (b)

In He-Ne laser, He molecule gives energy to Ne molecule which leads laser transition of Ne.

3.5 (c)

$\lambda = 632.8$ mm ; $d = 1$ m

angle of divergence, $\Delta\theta$,

$$\Delta\theta = \frac{1.22\lambda}{d} = \frac{1.22\times632.8\times10^{-9}}{1}$$

$= 772\times10^{-9}$ m

Diameter of central maxima $(D) = 2r(\Delta\theta)$

$= 2\times3.8\times10^5\times772\times10^{-9}$

$= 5867.2\times10^{-4} = 0.5867$ km

$= 586.7\ \text{m} \approx 587$ m

3.6 (b)

$2i = 115° - 34' = 115.566°$

$$\therefore \quad i = \frac{115.566}{2} = 57.783°$$

Refractive index $(\mu) = \tan i$

(By Brewster's law)

$= \tan(57.783°) = 1.587$

3.7 (c)

I = Sensitivity × Intensity × Area

$I = 0.55\times10\times10^{-3}\times10^{-2}$

$= 5.5\times10^{-5}$ Amp

and o/p voltage,

$V_0 = -IR_L = -5.5\times10^{-5}\times100\times10^3$

$V_0 = -5.5$ V

3.8 (c)

Light beam sensed by the photodiode of area 10 mm^2 when illuminated by a surge of 1 mW/cm^2.

$$1\times10^{-3} = \frac{\text{Power}}{10\ \text{mm}^2} = \frac{\text{Power}}{10\times10^{-2}\ \text{cm}^2}$$

$\therefore$ Power $= 10\times10^{-3}\times10^{-2} = 10^{-4}$ watts

Responsivity = 0.5 A/watts

$\therefore$ amount of current flow corresponding to 10^{-4} watts is

$$0.5 = \frac{\text{Current}}{10^{-4}}$$

Current $= 0.5\times10^{-4}$ A

$\therefore$ Voltage induced across R_L

$= R_L\times0.5\times10^{-4}$ V

$= 100\times10^3\times0.5\times10^{-4}\ \text{V} = 5$ V

3.9 (b)

$$\Delta\nu = \frac{c}{2L} = \frac{3\times10^8}{2\times500\times10^{-3}}$$

$$\text{Number of modes} = \frac{\text{B.W}}{\Delta\nu} = \frac{1500\times10^6}{3\times10^8}$$

= 5 modes

3.10 (b)

$$\Delta\nu = \frac{C}{2L} = \frac{3\times10^8}{2\times0.4}$$

$= 3.75\times10^8\ \text{Hz} = 375$ MHz

3.11 (b)

The limiting divergence of the laser light is relatively small.

Since the divergence is small so the spread is less hence the spot diameter is less.