OPTICAL INSTRUMENTATION
(AEIE 4126)

Time Allotted : 2½ hrs   **Full Marks : 60**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and
<u>any 4 (four)</u> from Group B to E, taking <u>one</u> from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A

1. Answer any twelve: **12 × 1 = 12**

Choose the correct alternative for the following

(i) Fiber optic sensors use the following as a prime means of measurement
(a) Electric field   (b) Magnetic field
(c) Optical field   (d) Gravitational field.

(ii) Light is guided within the core of a step index fiber by
(a) refraction at the core–air interface
(b) total internal reflection at the core cladding interface
(c) total internal reflection at the outer surface of the cladding
(d) change in speed of light within the core.

(iii) Nonradiative radiation is due to
(a) Photon emission   (b) Absorption
(c) Phonon emission   (d) All of these.

(iv) Total internal reflection will happen due to
(a) refractive index of the core is less than cladding
(b) refractive index of the core is greater than cladding
(c) refractive index of the core is equal to cladding
(d) all of these.

(v) Two optical fiber with numerical aperture 0.17 and 0.20 are to be spliced. What will be the loss at the joint in the forward direction?
(a) Zero dB   (b) 1.41 dB
(c) 1.82 dB   (d) 2.50 dB.

(vi) The Light wavelength that Si can absorb is 1.12 µm. What is the approximate band gap of Si?
(a) 1.1 eV   (b) 1.4 eV
(c) 1.74 eV   (d) 2.3 eV.

(vii) A 2*2 directional coupler has an input power level of 10 μw. The power available at output ports 1 & 2 are 45 μw & 45 μw, respectively. What is the coupling ratio?

(a) 45%   (b) 50%   (c) 90 %   (d) 100%.

(viii) Unoccupied or vacant probability of occupation is expressed as

(a) 1-f (E)   (b) 1+f (E)
(c) f (E)   (d) none of these.

(ix) Which of the following detectors give amplified output?

(a) p-n photodiode   (b) p-i-n photodiode
(c) Avalanche photodiode   (d) Photo voltaic detector.

(x) Lowest signal loss and highest bandwidth are characteristic of which of the following type of fibers?

(a) Air core   (b) Multimode
(c) Single mode   (d) Plastic core.

Fill in the blanks with the correct word

(xi) What is the cut-off wavelength of a step index single mode fiber with core diameter of 8.2 μm and NA = 0.12, _____.

(xii) Write the refractive index of a graded index fiber in terms of profile parameter _____.

(xiii) The relation between NA and relative refractive index _____.

(xiv) A step index fiber has a core with a refractive index of 1.5 and a cladding refractive index of 1.46. Its numerical aperture is _____.

(xv) The densities of electron and holes are the same in _____.

Group - B

2. (a) What do you mean by indirect and direct band gap materials? *[(CO2)(Remember/LOCQ)]*

   (b) Prove that the internal efficiency of a LED be expressed as $\eta_{int} = r_r / [r_r + r_{nr}]$.
                                                  [(CO3)(Analyze/IOCQ)]

   (c) The radiative and non-radiative recombination lifetimes of the minority carriers in the active region of a double heterojunction LED are 50 nS and 90 nS respectively. Determine the total carrier recombination lifetime and the power internally generated within the device when the peak emission wavelength is 0.87 μm at a drive current of 40 mA.   *[(CO3)(Evaluate/HOCQ)]*

(2 + 2) + 4 + 4 = 12

3. (a) What do you meant by quantum efficiency and responsivity of a photo detector? Calculate the wavelength at which quantum efficiency and responsivity are equal.   *[(CO4)(Remember/LOCQ)]*

   (b) How the quantum efficiency of such diode can be improved?   *[(CO4)(Apply/IOCQ)]*

   (c) A photo diode has quantum efficiency of 50% at 0.90 μm. Calculate responsivity and received optical power if mean photo current is 10 μA.   *[(CO4)(Evaluate/HOCQ)]*

(2 + 2 + 1) + 3 + (2 + 2) = 12

Group - C

4. (a) What is meant by optical and electrical confinement in a laser?
[(CO3)(Understand/LOCQ)]

   (b) What is the importance of mole fraction in the fabrication direct band gap semiconductor? How a direct band gap semiconductor is converted into indirect band gap semiconductor?
[(CO2)(Remember/LOCQ)]

   (c) Derive the expression of concentration of electron in conduction band with the basic concept of k space analysis.
[(CO2)(Apply/IOCQ)]

   (2 + 2)+ (2 + 2) + 4 = 12

5. (a) Why refractive index of the core is more than cladding in the optical fiber? What is the acceptance angle?
[(CO1)(Remember/LOCQ)]

   (b) Explain multipath time dispersion and material dispersion. How can these be minimized?
[(CO1)(Analyse/IOCQ)]

   (c) An optical fiber has a NA of 0.20 and a cladding refractive index of 1.59. Determine the acceptance angle for fiber in water, which has a refractive index of 1.33.
[(CO1)(Evaluate/HOCQ)]

   (2 + 2) + (2 + 2 + 2) + 2 = 12

Group - D

6. (a) What are the various types of optical fiber? What are factors to be encountered during the fabrication of optical fiber?
[(CO1)(Understand/LOCQ)]

   (b) Derive an expression of multipath dispersion for the meridional ray propagation through the optical fiber.
[(CO1)(Remember/LOCQ)]

   (c) A multipath step index fiber is operating at a wavelength of 0.85 μm with a core diameter of 80 μm and a relative refractive index difference is of 1.5%. If the refractive index of core is 1.48. (i) Determine normalized frequency of the fiber (ii) the number of guided modes
[(CO1)(Evaluate/HOCQ)]

   (2 + 2) + 4 + (2 + 2) = 12

7. (a) What are the causes of intrinsic and extrinsic losses in optical fiber?
[(CO1)(Remember/LOCQ)]

   (b) Derive the total loses in case of intrinsic type losses in dB.
[(CO1)(Remember/LOCQ)]

   (c) The speed of light in vaccum and that in core of SI fiber is $3*10^8$ and $2*10^8$ m/s respectively. When the fiber is placed in air, the critical angle at the core cladding interface is 75 °. Calculate (i) NA of fiber. (ii) Multipath dispersion per unit length.
[(CO1)(Evaluate/HOCQ)]

   4 + 4 + 4 = 12

Group - E

8. (a) What is electro-optic effect? What do you mean by Pockel effect and Kerr effect?
[(CO6)(Remember/LOCQ)]

   (b) Draw the arrangement of a Pockel electro-optic based amplitude modulator system.
[(CO6)(Remember/LOCQ)]

(c)   Calculate the change in refractive index due to the longitudinal electro optic effect for a 5 cm long crystal of lithium niobate for an applied voltage of 10 kV. If the wavelength of light being propagating through the crystal is 850 nm. Calculate V_π for the crystal.

[(CO6)(Evaluate/HOCQ)]

(2 + 2 + 2) + 2 + (2 + 2) = 12

9. (a)   How are fiber-optic sensors classified?   *[(CO6)(Remember/LOCQ)]*
    (b)   Briefly describe Mach-Zehnder interferomatric sensor.   *[(CO6)(Remember/LOCQ)]*
    (c)   In case of a fiber-optic based system, show that the below relation in the sensing arm due to change in strain is given approximately by, $\frac{\Delta\emptyset}{\Phi} = [\frac{\Delta L}{L} + \frac{\Delta n}{n}]$

[(CO6)(Apply/IOCQ)]

2 + 4 + 6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	53.13	23.95	22.91

Course Outcome (CO):

After the completion of the course, the students will be able to:
1. Learn the techniques of communications using optical fiber.
2. Learn the difference between direct and indirect band gap semiconductors.
3. Characterize structures and performance of LEDs and lasers.
4. Learn the structures and performance of photo detectors (like photo diode, PIN diode, APD etc).
5. Explain the techniques of measurement of distance, length, velocity, acceleration, current, voltage using laser. Formulate the structure of generalized measurement system.
6. Acquire the knowledge of different types of Optical Fiber sensors and their applications.

LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question.