



MADE EASY
Leading Institute for ESE, GATE & PSUs

ESE 2026 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electronics & Telecommunication Engineering

Test-6 : Electromagnetics + Basic Electrical Engineering [All topics]

Computer Organization and Architecture-1 + Materials Science-1 [Part Syllabus]

Electronic Devices & Circuits-2 + Advanced Communications-2 [Part Syllabus]

Name :

Roll No :

Test Centres	Student's Signature
Delhi <input checked="" type="checkbox"/> Bhopal <input type="checkbox"/> Pune <input type="checkbox"/> Hyderabad <input type="checkbox"/> Jaipur <input type="checkbox"/>	

Instructions for Candidates

- Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
- There are Eight questions divided in TWO sections.
- Candidate has to attempt FIVE questions in all in English only.
- Question no. 1 and 5 are compulsory and out of the remaining THREE are to be attempted choosing at least ONE question from each section.
- Use only black/blue pen.
- The space limit for every part of the question is specified in this Question Cum Answer Booklet. Candidate should write the answer in the space provided.
- Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
- There are few rough work sheets at the end of this booklet. Strike off these pages after completion of the examination.

FOR OFFICE USE

Question No.	Marks Obtained
Section-A	
Q.1	12
Q.2	48
Q.3	
Q.4	
Section-B	
Q.5	19
Q.6	
Q.7	31
Q.8	30
Total Marks Obtained	140

Signature of Evaluator

Cross Checked by

*• Your accuracy is good -
• Attempt more number of*

No keep it up - -

IMPORTANT INSTRUCTIONS

CANDIDATES SHOULD READ THE UNDERMENTIONED INSTRUCTIONS CAREFULLY. VIOLATION OF ANY OF THE INSTRUCTIONS MAY LEAD TO PENALTY.

DONT'S

1. Do not write your name or registration number anywhere inside this Question-cum-Answer Booklet (QCAB).
2. Do not write anything other than the actual answers to the questions anywhere inside your QCAB.
3. Do not tear off any leaves from your QCAB, if you find any page missing do not fail to notify the supervisor/invigilator.
4. Do not leave behind your QCAB on your table unattended, it should be handed over to the invigilator after conclusion of the exam.

DO'S

1. Read the Instructions on the cover page and strictly follow them.
2. Write your registration number and other particulars, in the space provided on the cover of QCAB.
3. Write legibly and neatly.
4. For rough notes or calculation, the last two blank pages of this booklet should be used. The rough notes should be crossed through afterwards.
5. If you wish to cancel any work, draw your pen through it or write "Cancelled" across it, otherwise it may be evaluated.
6. Handover your QCAB personally to the invigilator before leaving the examination hall.

Section A : Electromagnetics + Basic Electrical Engineering

Q.1 (a) An L-band pulse radar with a common transmitting and receiving antenna having a directive gain of 2500 operates at 1300 MHz and transmits 150 kW. If the object is 100 km from the radar and its scattering cross section is 6 m^2 , find:

- The magnitude of the incident electric field intensity at the object.
- The magnitude of scattered electric field intensity at the radar.
- The amount of power captured by the object.
- The power absorbed by the antenna from the scattered wave.

[12 marks]

Given, Gain = 2500, $f = 1300 \text{ MHz}$
 $P_t = 150 \text{ kW}$, $d = 100 \text{ km} = 10^5 \text{ m}$

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{1300 \times 10^6} = 0.23 \text{ m.}$$

$$P_{\text{in density}} = \frac{P_t \cdot G}{4\pi r^2} = \frac{150 \times 10^3 \times 2500}{4\pi \times (10^5)^2}$$

$$= 2.9 \times 10^{-3} \frac{\text{W}}{\text{m}^2}$$

$$P_{\text{in}} = \frac{E_{\text{in}}^2}{2\eta}$$

$$E_{\text{in}} = \sqrt{P_{\text{in}} \cdot 2\eta}$$

$$E_{\text{in}} = \sqrt{2 \times 2.9 \times 10^{-3} \times 120\pi}$$

$$E_{\text{in}} = 1.5 \text{ V/m.}$$

$$\eta = 120\pi$$

(iv)

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{1300 \times 10^6} = 0.23 \text{ m.}$$

$$A_e = \frac{G \lambda^2}{4\pi} = \frac{2500 \times (0.23)^2}{4\pi}$$

$$A_e = 10.6 \text{ m}^2$$

 $P_{\text{ant}} =$ 

Q.1 (b) What are the methods of starting of synchronous motors?

[12 marks]

Q.1 (c) A rectangular waveguide with $a = 2b = 2.4$ cm is filled with teflon ($\epsilon_r = 2.11$, loss tangent of 3×10^{-4}). Assume that the walls of the waveguide are coated with gold ($\sigma_c = 4.1 \times 10^7$ S/m) and that a TE_{10} wave at 5 GHz propagates down the waveguide. Find :

- (i) Dielectric attenuation coefficient, α_d .
 (ii) Conductor attenuation coefficient, α_c .

[12 marks]

Given,
$$c = \frac{c}{\sqrt{\epsilon_r}} v$$

$$v = \frac{3 \times 10^8}{\sqrt{2.11}} = 2.06 \times 10^8 \text{ m/s.}$$

$$f_{c \text{ TE}_{10}} = \frac{v}{2a} = \frac{2.06 \times 10^8 \text{ m/s}}{2 \times 2.4 \text{ cm.}}$$

$$f_{c \text{ TE}_{10}} = \frac{2.06 \times 10^8}{2 \times 0.024}$$

$$f_{c \text{ TE}_{10}} = 4.302 \text{ GHz}$$

For good conductor,
$$\alpha_c = \sqrt{\frac{\omega \mu \sigma}{2}}$$

- Q.1 (d) The short-circuited tests on two single-phase transformer gave the following results:
200 kVA : 3% rated voltage ; rated current at 0.25 power factor lagging
500 kVA : 4% rated voltage ; rated current at 0.3 power factor lagging
These two transformers are connected in parallel. How do they share a load of 560 kW at 0.8 power factor lagging?

[12 marks]

- Q.1 (e) The interface $x + y = 8$ between two media carries no current. If medium 1 ($x + y \geq 8$) is non-magnetic with magnetic field intensity $\vec{H}_1 = -3\hat{a}_x + 2\hat{a}_y - \hat{a}_z$ A/m. Find :
- (i) The magnetic energy density in medium 1.
 - (ii) Magnetization, \vec{M}_2 and Magnetic Flux density, \vec{B}_2 in medium 2 ($x + y \leq 8$) with $\mu_2 = 5\mu_0$.
 - (iii) The angles \vec{H}_1 and \vec{H}_2 make with the normal to the interface.

[12 marks]

- Q.2 (a) A 150 kVA, 2500/250 V, single-phase two winding transformer is to be used as an auto transformer for stepping up the voltage from 2500 V to 2750 V. At rated load, the two winding transformer has 2.5% loss, 3% voltage regulation and 4% impedance. For the auto transformer, determine the following:
- Voltage and current rating.
 - kVA rating.
 - Efficiency.
 - Percentage impedance.
 - Regulation.
 - Short circuit current on each side.

[20 marks]

Given, V_1/V_2 ratio = $\frac{2500}{250}$, Rating = 150 kVA.

$$I_{\text{secondary}} = \frac{150 \text{ kVA}}{250 \text{ V}} = 600 \text{ A}$$

$$I_{\text{primary}} = \frac{150 \text{ kVA}}{2500 \text{ V}} = 60 \text{ A}$$

$$I_L = I_{\text{primary}} + I_{\text{secondary}} = 660 \text{ A}$$

Voltage Rating = $\frac{2750V}{250V} \rightarrow$ Primary
Secondary.

(ii) KVA rating = KVA $_{2\text{-winding}}$ $\left(\frac{K}{K-1}\right)$

$$K = \frac{V_H}{V_L} = \frac{2750}{250} = 150 \text{ KVA} \times \left(\frac{1.1}{1.1-1}\right)$$

$$K = 1.1 \Rightarrow 150 \text{ KVA} \times \frac{1.1}{0.1}$$

KVA rating \Rightarrow 1650 KVA

A

(iii) Loss = 2.5%. \therefore 2.5% of 150 KVA = 3.75 kW

$$\eta = \frac{\text{KVA}}{\text{KVA} + \text{Losses}} \quad \eta = \frac{150}{150 + 3.75} \times 100\% = 97.56\%$$

(iv) % $Z_{\text{auto}} = \% Z_{2w} \left(1 - \frac{1}{K}\right) = 0.4 \left(1 - \frac{1}{1.1}\right)$
 $= 0.364\%$

(v) Regulation $_{(\text{auto})} = \text{Regulation}_{(2w)} \left(1 - \frac{1}{K}\right)$
 $= 3\% \left(1 - \frac{1}{1.1}\right)$
 $= 0.273\%$

A

$$(vi) \quad \text{LV side } (I_{sc}) = \frac{I_{\text{rated}, L}}{Z_{\text{auto}}} = \frac{680}{0.00364} = 181,318 \text{ A}$$

$$\text{HV side } (I_{sc}) = \frac{I_{\text{rated}, H}}{Z_{\text{auto}}} = \frac{600}{0.00364} = 164,835 \text{ A}$$

- Q.2 (b) (i) A 50Ω lossless line has $V_L = 20e^{j20^\circ} \text{ V}$ and $Z_L = 50e^{j25^\circ} \Omega$. Find the current at $\lambda/8$ distance from the load.
- (ii) A uniform plane wave in air with $\vec{E} = 8 \cos(\omega t - 4x - 3z) \hat{a}_y \text{ V/m}$ is incident on a dielectric slab ($z \geq 0$) with $\mu_r = 1$, $\epsilon_r = 0.2$, $\sigma = 0$. Determine the reflected E field and H field.

[10 + 10 marks]

(i) Given $Z_0 = 50 \Omega$

$$V_L = 20 e^{j20^\circ} \text{ V}$$

$$Z_L = 50 e^{j25^\circ} \Omega$$

$$L = \lambda/8$$

$$I_L = \frac{V_L}{Z_L} = \frac{20 e^{j20^\circ}}{50 e^{j25^\circ}} = 0.4 e^{-j5^\circ} \text{ A}$$

$$\beta = \frac{2\pi}{\lambda} = \frac{2\pi}{\lambda/8}$$

$$\beta L = \frac{2\pi}{\lambda} \times \frac{\lambda}{8} = \frac{\pi}{4} = 45^\circ$$

$$\frac{V_L}{Z_0} = 0.4 e^{j20^\circ}$$

$$I(\lambda) = I_L \cos(\beta L) + j \frac{V_L}{Z_0} (\sin \beta L)$$

$$I\left(\frac{\lambda}{8}\right) = \frac{1}{\sqrt{2}} \left[0.4 (\cos 5^\circ - j \sin 5^\circ) \right] + j (0.4) \frac{1}{\sqrt{2}} (\cos 20^\circ + j \sin 20^\circ)$$

$$I\left(\frac{\lambda}{8}\right) \approx 0.2828 (0.654 + j0.852)$$

$$= 0.304 e^{j52.5^\circ} \text{ A}$$

(ii)

Given $\vec{E}_i = 8 \cos(\omega t - 4x - 3z) \hat{a}_y$

$$\mu_r = 1$$

$$\epsilon_r = 0.2$$

$$\sigma = 0$$

$$\vec{k} = 4\hat{a}_x + 3\hat{a}_z$$

$$|\vec{k}| = 5, \quad \theta_i = \frac{3}{5}$$

Incident
angle.

$$\theta_i = 53.13^\circ$$

10

$$\eta_1 = 120\pi, \quad \eta_2 = 120\pi \sqrt{\frac{1}{0.2}} = 843 \Omega$$

$$\Gamma = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1} = \frac{843 - 377}{843 + 377}$$

$$\rho =$$

$$\Gamma = \frac{\eta_2 \cos \theta_i - \eta_1 \cos \theta_t}{\eta_2 \cos \theta_i + \eta_1 \cos \theta_t}$$

2

Q.2 (c) A 4-pole compound generator has armature, series-field and shunt-field resistance of 1Ω , 0.5Ω and 100Ω respectively. This generator delivers 4 kW at a terminal voltage of 200 V . Allowing 1 V per brush for contact drop, calculate for both short-shunt and long-shunt connections:

- (i) the generated emf, and
 (ii) the flux per pole if the armature has 200 lap-connected conductors and is driven at 750 rpm .

[20 marks]

Given $P = 4$, $R_a = 1 \Omega$, $P = 4 \text{ kW}$
 $R_{sc} = 0.5 \Omega$, $V = 200 \text{ V}$
 $R_{sh} = 100 \Omega$

$$I_L = \frac{P}{V} = \frac{4 \text{ kW}}{200} = 20 \text{ A}$$

$$I_{sh} = \frac{V}{R_{sh}} = \frac{200}{100} = 2 \text{ A}$$

$$I_a = I_L + I_{sh} = 22 \text{ A}$$

$$E_g = V + I_a (R_a + R_{sc}) + 2V_b$$

$$= 200 + 22 (1 + 0.5) + 2$$

$$E_g = 235 \text{ V}$$

①

②

For lap-connected $A = P = 4$

$$Z = 200$$

$$N = 750 \text{ rpm}$$

$$E_g = \frac{P \phi N (Z)}{60 (A)}$$

$$\therefore \phi = \frac{60 E_g A}{N P Z}$$

$$\phi = \frac{60 E_g}{N Z} = \frac{60 \times 235}{750 \times 200}$$

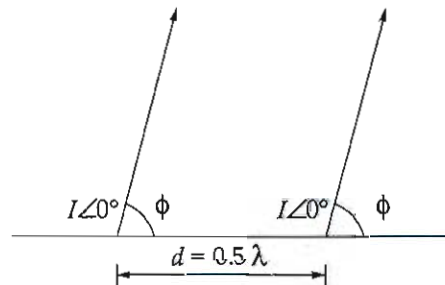
$$\phi = 0.094 \text{ Wb.} \quad **$$

OR

$$\phi = 94 \text{ mWb.} \quad **$$

20

- Q.3 (a) (i) Consider an array of two non-directional radiators with spacing $d = 0.5 \lambda$. Determine the directions of maximum radiation when the radiators are excited as shown in figure.



- (ii) The following S -parameters are obtained for a microwave transistor operating at 2.5 GHz: $S_{11} = 0.85 \angle -30^\circ$, $S_{12} = 0.07 \angle 56^\circ$, $S_{21} = 1.68 \angle 120^\circ$, $S_{22} = 0.85 \angle -40^\circ$. Determine the input reflection coefficient when $Z_L = Z_0 = 75 \Omega$.

[10 + 10 marks]

Q.3 (b)

A 4-pole long shunt compound d.c. generator has 1200 armature conductors and running at a speed of 500 r.p.m. The diameter of the pole shoe circle is 0.35 m and the ratio of pole arc to pole pitch is 0.7 while the length of the shoe is 0.2 m.

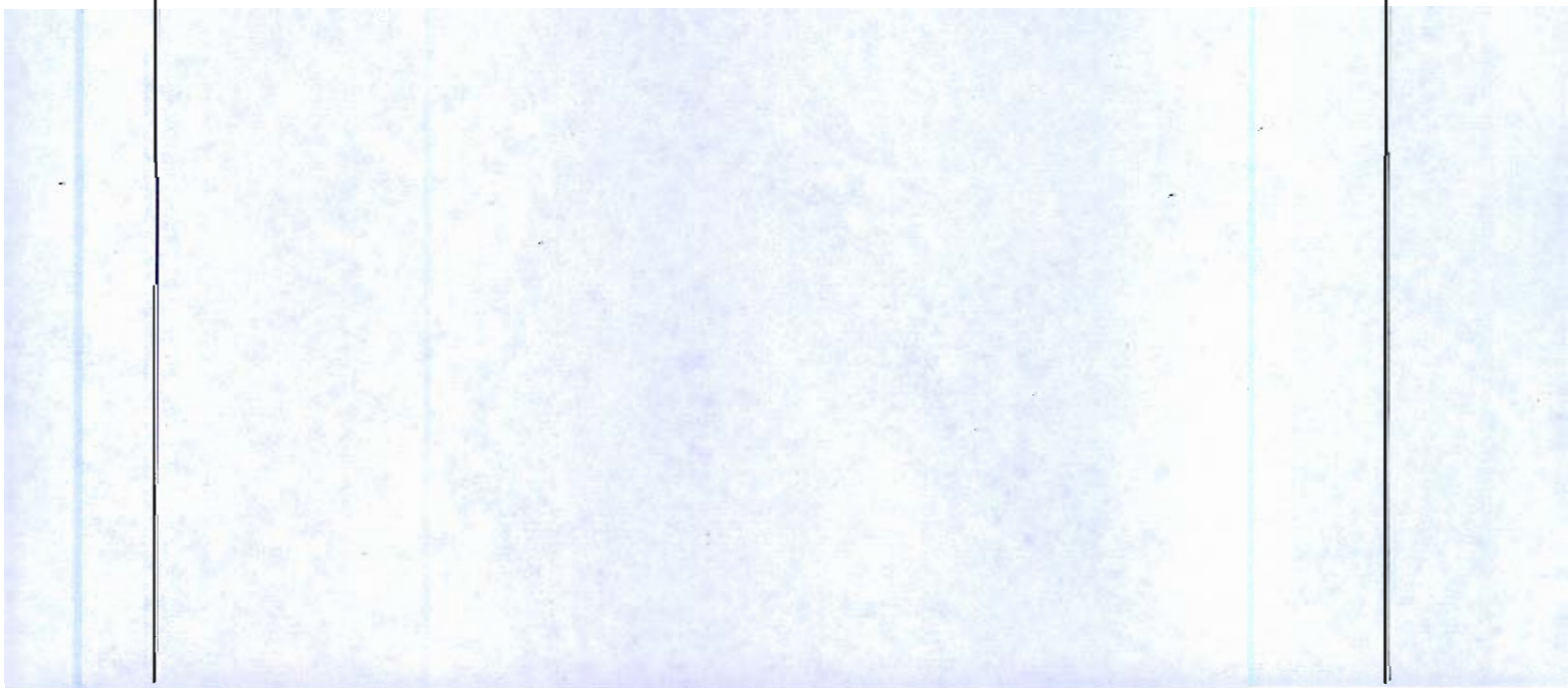
Assume the shunt field, series field and armature resistance are $100\ \Omega$, $0.1\ \Omega$ and $0.1\ \Omega$ respectively. If the flux density in the air gap is 0.75 T, load current is 100 A and voltage drop per brush is 1 V, then calculate load voltage when

- (i) armature winding is lap connected.
- (ii) armature winding is wave connected.

[20 marks]

- Q.3 (c) A plane wave with $\vec{E} = 30 e^{-\alpha z} \sin(\omega t - z) \hat{a}_x$ V/m is propagating through a lossy dielectric medium having an intrinsic impedance of $300 \angle 30^\circ \Omega$ and $\mu_r = 1$. Establish the phasor and instantaneous field expressions for \vec{H} , and find the loss tangent, propagation constant, wave polarization and the dielectric constant of the medium at 15 MHz. Also determine the skin depth and the depth at which the amplitude of the field is 1% of the value at $z = 0$.

[20 marks]



- Q.4 (a)
- (i) When a transmission line of finite length is terminated with a load equal to its characteristic impedance, it appears as an "infinite line" to the sending end source. Justify this by applying voltage and current equations.
 - (ii) An air filled parallel plane waveguide carries the TM_2 mode. The separation between the plates of the waveguide is 20 cm. If the phase velocity of the mode is $1.5c$, find the frequency and guided wavelength of mode.

[10 + 10 marks]

Q.4 (b) A series motor, with an unsaturated magnetic circuit and 0.5Ω total resistance, when running at a certain speed takes 60 A at 500 V. If the load torque varies as the fan load varies with the speed, calculate the resistance required to reduce the speed by 25%.

[20 marks]

Q.4 (c) A 460 V, 25 hp, 60 Hz, 4-pole, Y-connected wound rotor induction motor has the following impedances per phase referred to stator side:

$$R_1 = 0.641 \, \Omega, R_2 = 0.332 \, \Omega;$$

$$X_1 = 1.106 \, \Omega, X_2 = 0.464 \, \Omega, \text{ and } X_m = 26.3 \, \Omega$$

- (i) What is maximum torque of this motor? At what slip and speed does it occur?
- (ii) What is the starting torque of this motor?
- (iii) When the rotor resistance is doubled, what is the speed at which the maximum torque now occurs? What is the new starting torque of the motor?

[20 marks]

**Section B : Computer Organization and Architecture-1 + Materials Science-1
+ Electronic Devices & Circuits-2 + Advanced Communications-2**

Q.5 (a) A hypothetical 32-bit CPU utilizes a fixed length instruction format that supports four distinct fields: an opcode, a Register Address, a Memory Address, and an Immediate constant field. The following specifications are provided:

- The opcode size is 7 bits.
- The register file contains 32 registers.
- The system supports a 4 kB RAM (assume byte-addressable).
- Each instruction is one word (32 bits) long.

Determine the number of bits available for the immediate constant field and calculate the largest unsigned constant that can be represented within this instruction.

[12 marks]

- Q.5 (b) (i) Iron has a density of 7.87 g/cm^3 and the mass of an iron atom is $9.27 \times 10^{-26} \text{ kg}$. If the atoms are spherical and tightly packed (Ignore the spaces between the spheres),
1. What is the volume of an iron atom?
 2. What is the distance between the centers of adjacent atoms?
- (ii) Silver has FCC structure and its atomic radius is 1.44 \AA . Find the spacing between the (220), (200) and (111) planes.

[6 + 6 marks]

(i) Given $\rho = 7.87 \text{ g/cm}^3$

(Mass) ~~Atom~~ = $9.27 \times 10^{-26} \text{ kg}$

$$\text{Volume} = \frac{\text{Mass}}{\text{Density}} = \frac{9.27 \times 10^{-26} \text{ (kg)}}{7.87 \times 10^3 \frac{\text{kg}}{\text{m}^3}}$$

①

$$\text{Volume} = 1.18 \times 10^{-29} \text{ m}^3$$

②

distance b/w centres of adjacent atoms (d) = $2r$

Now, $V = \frac{4}{3} \pi r^3$

$$r = \sqrt[3]{\frac{3V}{4\pi}} = \sqrt[3]{\frac{3 \times 1.18 \times 10^{-29}}{4 \times \pi}}$$

$$r = 1.41 \times 10^{-10} \text{ m}$$

$$r = 1.41 \text{ \AA}$$

$$d = 2r$$

$$d = 2 \times 1.41 = 2.82 \text{ \AA}$$

(ii) For silver (FCC), $a = 2\sqrt{2}r$

$$r = 1.44 \text{ \AA}$$

$$\therefore a = 2\sqrt{2} \times 1.44 \text{ \AA}$$

$$a = 4.07 \text{ \AA}$$

Now,

$$d_{hkl} = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$$

~~of hkl~~

$$\Rightarrow d_{220} = \frac{a}{\sqrt{4+4+0}} = \frac{a}{\sqrt{8}} = \frac{4.07 \text{ \AA}}{\sqrt{8}} = 1.43 \text{ \AA}$$

$$\Rightarrow d_{200} = \frac{a}{\sqrt{4+0+0}} = \frac{a}{\sqrt{4}} = \frac{a}{2} = \frac{4.07 \text{ \AA}}{2} = 2.035 \text{ \AA}$$

$$\Rightarrow d_{111} = \frac{a}{\sqrt{1+1+1}} = \frac{a}{\sqrt{3}} = \frac{4.07 \text{ \AA}}{\sqrt{3}} = 2.34 \text{ \AA}$$

- Q.5 (c) At 300 K, an ideal Si p-n junction solar cell has a short-circuit current of 2 A and an open-circuit voltage of 0.5 V. How does the maximum output power of the solar cell change if the temperature raises to 400 K?

[12 marks]

Given, $I_{sc} = 2 \text{ A}$
 $V_{oc} = 0.5 \text{ V}$ } (At 300 K)

New $V_{oc} = -0.0023 \times (400 - 300)$

New $V_{oc} = -0.23 \text{ V}$

[V drop by $2.3 \text{ mV}/^\circ\text{C}$ or $2.3 \text{ mV}/\text{K}$ (Temperature change)]

$\frac{P_{max}}{V_{oc} I_{sc}} = \text{Fill Factor}$

$P_{max} = (\text{Fill factor}) V_{oc} I_{sc}$

Q.5 (d) Two step index fibers exhibit the following parameters:

- (i) A multimode fiber with a core refractive index of 1.5, a relative refractive index difference of 3% and an operating wavelength of 0.82 μm.
- (ii) An 8 μm core diameter single-mode fiber with a core refractive index same as in part (i), a relative refractive index difference of 0.3% and an operating wavelength of 1.55 μm.

Estimate the critical radius of curvature at which large bending losses occur in both cases.

[12 marks]

1

Given, $n_1 = 1.5$, $\Delta = 3\% = 0.03$
 $\lambda = 0.82 \mu m$

For Multi-mode, $R_c = \frac{3n_1^2 \lambda}{4\pi(NA)^3}$

$$R_c = \frac{3 \times 1.5^2 \times 0.82 \times 10^{-6}}{4\pi (0.36)^3}$$

$R_c \approx 8.88 m$

$NA = \sqrt{\Delta \cdot n_1}$
 $NA = 0.36$

Don't write here

(ii) For single-mode,

$$R_c \approx \frac{3n_1^2 \lambda}{4\pi (n_1^2 - n_2^2)^{3/2}} \quad **$$

$$\Delta = 0.3\%$$

$$\Delta = 0.003$$

$$\lambda = 1.55 \mu\text{m}$$

$$\Delta = \frac{n_1 - n_2}{n_1} = \frac{1.5 - n_2}{1.5} = 0.03$$

$$n_2 = 1.4955$$

$$(n_1^2 - n_2^2) \approx 2n_1^2 \Delta$$

$$R_c = \frac{3 \times 1.5^2 \times 1.55 \times 10^{-6}}{4\pi (2 \times 1.5^2 \times 0.003)^{3/2}}$$

$$R_c \approx 533.6 \text{ m}$$

$$R_c = 0.53 \text{ mm}$$

- Q.5 (e) (i) Explain how to check conflict serializability and view serializability of the following schedule:

$S : r_1(X) ; r_3(Y) ; r_3(X) ; r_2(Y) ; r_2(Z) ; w_3(Y) ; w_2(Z) ; r_1(Z) ; w_1(X) ; w_1(Z)$

- (ii) The transmitting and receiving antennas with respective heights of 49 m and 25 m are installed to establish communication at 100 MHz with a transmitted power of 100 Watts. Determine the LOS distance and the received electrical field signal strength at receiver.

[6 + 6 marks]

- Q.6 (a) Consider the following hypothetical format used to represent the floating-point data, to be stored in the memory.

Format:

S (Sign)	BE (Bias Exponent)	M (Mantissa)
1 bit	7 bit	12 bit

Data: $(-14.75) \times 2^{12}$ is to be stored in the memory.

Calculate the hexadecimal equivalent when the data is stored in the Main Memory

- Without normalisation.
- With normalisation; and also denormalise the obtained result and bring back to its original form $(-14.75) \times 2^{12}$.

[8 + 12 marks]

Q.6 (b) Consider an MOS capacitor fabricated on P-type Si substrate with a doping of $5 \times 10^{16} \text{ cm}^{-3}$, oxide thickness of 10 nm and N^+ poly-gate.

(i) Find C_{ox} (Oxide capacitance), V_{fb} (Flatband voltage) and V_t (Threshold voltage) of the MOS capacitor.

(ii) Find the accumulation charge (C/cm^2) at $V_g = V_{fb} - 1 \text{ V}$.

(iii) Find the depletion and inversion charge at $V_g = 2 \text{ V}$.

(Assume, $\chi = 4.05 \text{ eV}$, $E_g = 1.12 \text{ eV}$, $n_i = 10^{10} \text{ cm}^{-3}$, $\epsilon_{ox} = 3.45 \times 10^{-13} \text{ F/cm}$, $\epsilon_s = 1.04 \times 10^{-12} \text{ F/cm}$, $q = 1.6 \times 10^{-19} \text{ C}$, $V_T = 0.026 \text{ V}$)

[12 + 4 + 4 marks]

- Q.6 (c) A digital satellite communication link, with uplink frequency of 30 GHz transmits data at 1 Mbps. The downlink provides $\frac{E_b}{N_0}$ of 30 dB. The net uplink losses work out to 211.5 dB. Determine the antenna diameter for the transmitting earth station to get overall $\frac{E_b}{N_0}$ of 17 dB, in optimal configuration assuming following parameters.
- (i) Transponder amplifier output of 200 mW.
 - (ii) Antenna efficiency of 60%.
 - (iii) Satellite receive antenna gain of 45 dB.
 - (iv) Satellite receive noise power density of -169 dBm/Hz.

[20 marks]

- Q.7 (a) (i) In general, ceramic materials used for engineering applications can be divided into two groups: Traditional ceramics and Engineering ceramics. Briefly explain them.
- (ii) What are the two methods for preparing ceramic raw materials? What types of ingredients are added to them?

[10 + 10 marks]

⇒ Ceramics are inorganic compounds. They are compounds b/w metals and non-metals.

They are divided into two groups.

Traditional Ceramics

⇒ They are primarily based on natural minerals.

i.e., Clay,
Silica (Quartz),
Feldspar.

⇒ They are naturally occurring and used for centuries.

Ex. Porcelain, Sanitary ware.

Engineering Ceramics

They are primarily based on raw-materials.

like Carbides, Nitrides,
Oxides.

• They have various electrical and mechanical and thermal properties.

Ex. Al_2O_3 , ZrO_2 , SiC ,
 Si_3N_4 etc.

(ii)

Two Methods to prepare them →

① Chemical Synthesis → This involves various
Methods like

① Sol-gel process.

② CVD (Chemical Vapour
deposition)

② Grinding → (Used for natural occurring
minerals.)

Q.7(b)

A multimode parabolic graded index fibre has an acceptance angle of 8° .

- (i) Estimate relative refractive index between core axis (n_1) and cladding (n_2) when sum of refractive index (RI) of core and cladding is 3.046.
- (ii) Also calculate solid acceptance angle, RI of cladding and number of modes if the diameter of core is $40 \mu\text{m}$ and wavelength is $1.2 \mu\text{m}$.

[10 + 10 marks]

Given, $\theta_a = 8^\circ$, $n_1 + n_2 = 3.046$ — (1)

$$NA = \sin(\theta_a)$$

$$NA = \sin(8^\circ) = 0.139$$

$$NA = \sqrt{n_1^2 - n_2^2} = 0.139$$

Squaring both sides,

$$n_1^2 - n_2^2 = (0.139)^2$$

$$(n_1 + n_2)(n_1 - n_2) = (0.139)^2$$

$$(3.046)(n_1 - n_2) = 0.0193$$

$$n_1 - n_2 = 0.00636$$
 — (2)

Solving (1) and (2) we get,

$$n_1 \cong 1.526$$

$$n_2 \cong 1.520$$

Now, $\Delta = \frac{n_1 - n_2}{n_1}$ ← Relative refractive index

$$\Delta = \frac{1.526 - 1.520}{1.526}$$

$$\Delta = 0.004167$$

(OR)

$$\Delta = 0.4167 \%$$

(ii)

$$V = \frac{2\pi a}{\lambda} (NA)$$

$$n_2 = 1.520$$

**

Solved previously.

$$V = \frac{2\pi \times 20}{1.2} \times 0.139$$

$$V = 14.58$$

End

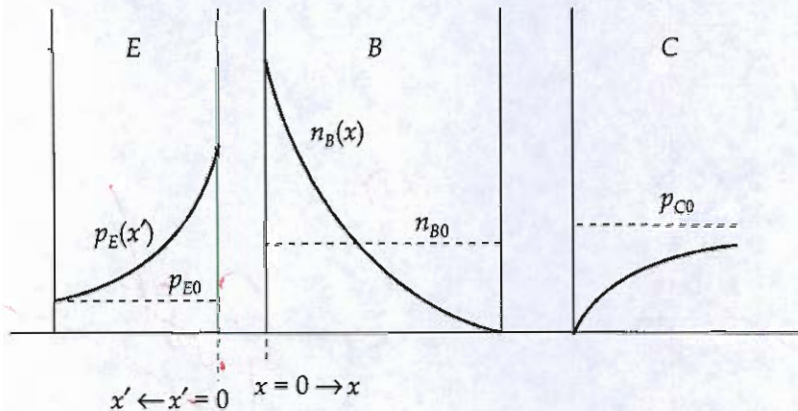
$$\text{No. of Modes } (M_g) = \left(\frac{\alpha}{\alpha + 2} \right) \frac{V^2}{2}$$

$$\alpha = 2 \text{ (parabolic)}$$

$$\text{No. of Modes } (M_g) = \frac{V^2}{4} = \frac{(14.58)^2}{4}$$

$$(M_g) \cong 53 \text{ modes.}$$

- Q.7 (c) A uniformly doped silicon *npn* bipolar transistor is to be biased in forward active mode with the *B-C* junction reverse biased by 3 V. The metallurgical base width is $1.1 \mu\text{m}$. The doping concentrations in different regions are $N_E = 10^{17} \text{ cm}^{-3}$, $N_B = 10^{16} \text{ cm}^{-3}$ and $N_C = 10^{15} \text{ cm}^{-3}$. Assume that $n_i = 1.5 \times 10^{10} \text{ cm}^{-3}$ at $T = 300 \text{ K}$.
- For $T = 300 \text{ K}$, calculate *B-E* voltage (V_{BE}) at which the minority carrier electron concentration at $x = 0$ is 10 percent of majority carrier hole concentration in the base.
 - Determine the minority carrier hole concentration at $x' = 0$ (in the emitter) for this bias.
 - Determine the neutral base width for this bias.



[20 marks]

- Q.8 (a) (i) Consider a hypothetical CPU that supports instructions with two register operands, one memory operand, and 7-bit immediate field. The instruction set size is 120. A specific program contains 200 such instructions. If the system supports 64 registers and has a 2 kB memory space (byte-addressable), calculate the total storage space required to store this program in Bytes.
- (ii) Explain maximum usable frequency in ionospheric propagation. Derive a relationship between MUF and critical frequency.

[10 + 10 marks]

(ii) By Snell's law,

$$\mu = \frac{\sin \theta_i}{\sin \theta_r}, \text{ Refractive index } \rightarrow \mu$$

For reflection to occur at peak of path,
 $\theta_r = 90^\circ$

$$\therefore \mu = \sin \theta_i$$

Relation b/w frequency and N
 (e-density)

$$\mu = \sqrt{1 - \frac{81N}{f^2}}$$

At f_c , all wave are reflected back,
 ($\theta_i = 0$)

$$\text{so } f_c = \sqrt{81N_{\max}}$$

Put, $\mu = \sin \theta_i$ for MUF (f_{\max})

$$\sin^2 \theta_i = 1 - \frac{f_c^2}{f_{\text{MUF}}^2} = 1 - \sin^2 \theta_i = \cos^2 \theta_i$$

$$f_{\text{MUF}} = f_c \sec \theta_i$$

**

- Q.8 (b) (i) The spacing between the principle planes in a crystal of NaCl is 2.82 \AA . It is found that the first order Bragg's reflection occurs at 10° .
1. What is the wavelength of X-rays?
 2. At what angle, the second order reflection occurs?
 3. What is the highest order of reflection seen?
- (ii) Consider a MOSFET whose gate width changes as a function of distance along the channel as:
 $W(x) = W_0 + x$
 where $x = 0$ at the source and $x = L$ at the drain. Except for its gate width, assume that this MOSFET is like the typical MOSFET.
1. Find an expression for drain current, I_D for this device. Ignore the bulk charge effect.
 2. Derive an expression for $I_{D\text{sat}}$ for this device.

[10 + 10 marks]

(i) Given $d = 2.82 \text{ \AA}$, $\theta = 10^\circ$

Using Bragg's Reflection ,

$$n\lambda = 2d \sin \theta$$

$$1 \times \lambda = 2 \times 2.82 \sin 10^\circ$$

$$\lambda = 0.979 \text{ \AA}$$

(ii) $n = 2$ for 2nd order ,

$$2 \times \lambda = 2d \sin \theta_2$$

$$\sin \theta_2 = \frac{\lambda}{d} = \frac{0.979 \text{ \AA}}{2.82 \text{ \AA}}$$

$$\theta_2 = 20.31^\circ$$

(iii)

For n_{\max} , $\sin\theta \approx 1$

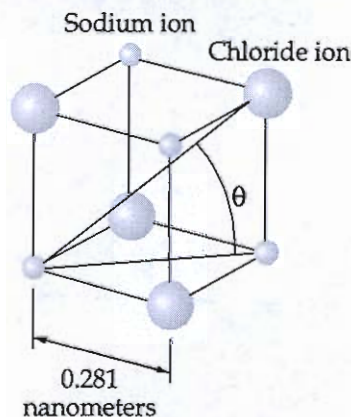
$$\therefore n_{\max} = \frac{2d}{\lambda}$$

$$n_{\max} = \frac{2 \times 2.82}{0.979}$$

$$n_{\max} \approx 5.76$$

Highest Integer taken ($\therefore n = \underline{\underline{5}}$)

- Q.8 (c) (i) The drawing shows sodium and chloride ions positioned at the corners of a cube that is part of the crystal structure of sodium chloride (common table salt). The edge of the cube is 0.281 nm (1 nm = 1 nanometer = 10^{-9} m) in length.
- Find the distance (in nanometers) between the sodium ion located at one corner of the cube and the chlorine ion located on the diagonal at the opposite corner.
 - What is the value of the angle θ in the drawing?



- (ii) Given the following properties of chromium: Density = 7.19 g/cm^3 , atomic number = 24, atomic weight = 52 g/mol , melting point = 1907°C , boiling point = 2672°C , number of vacancies = $2.574 \times 10^{22} \text{ atoms/m}^3$. Calculate the activation energy for vacancy formation in chromium at 670°C .

[10 + 10 marks]

(i) Given (edge length) $a = 0.281 \text{ nm}$.

①

Distance b/w them is calculated as, (Body diagonal)

$$d = \sqrt{a^2 + a^2 + a^2}$$

$$d = \sqrt{3a^2} = \sqrt{3} a$$

$$d = 0.4867 \text{ nm}$$

②

$$\tan\theta = \frac{a}{a\sqrt{2}} = \frac{1}{\sqrt{2}}$$

$$\theta \approx 35.26^\circ$$

10

(ii) Number of atoms $(N) = \frac{\rho \cdot N_A}{A}$

Given $\rho = 7.19 \text{ g/cm}^3 = 7.19 \times 10^6 \text{ g/m}^3$

$N_A = 6.023 \times 10^{23}$

$A = 52 \text{ gmol}^{-1}$

$\therefore N = \frac{7.19 \times 10^6 \times 6.023 \times 10^{23}}{52}$

$N = 8.326 \times 10^{28} \frac{\text{atoms}}{\text{m}^3}$

Now,

$T = (670 + 273.15) \text{ K}$
 $= 943.15 \text{ K}$

$$Q_v = -KT \ln \left(\frac{N_v}{N} \right)$$

$Q_v = - \left(\begin{matrix} 8.6 \times 10^{-5} \\ \text{(K)} \end{matrix} \times \begin{matrix} 943.15 \\ \text{(T)} \end{matrix} \right) \ln \left(\frac{2.574 \times 10^{22}}{8.326 \times 10^{28}} \right)$

$Q_v = 1.218 \text{ eV/atom}$ **

Space for Rough Work

Space for Rough Work

Space for Rough Work
