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ESE 2026 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electronics & Telecommunication Engineering

Test-7 : Advanced Electronics + Electronic Measurements and Instrumentation [All topics]

Electromagnetics-1 + Basic Electrical Engineering-1 [Part Syllabus]

Computer Organization and Architecture-2 + Materials Science-2 [Part Syllabus]

Name : ....

Roll No :

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Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. There are Eight questions divided in TWO sections.
3. Candidate has to attempt FIVE questions in all in English only.
4. 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.
5. Use only black/blue pen.
6. 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.
7. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
8. 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	50
Q.2	45
Q.3	
Q.4	
Section-B	
Q.5	17
Q.6	56
Q.7	58
Q.8	
Total Marks Obtained	226

Signature of Evaluator ....   Cross Checked by ....

• Good Keep it Up

• Try to highlight the answer (numerical) using black colour pen

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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.

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Section A : Advanced Electronics + Electronic Measurements & Instrumentation

Q.1 (a) A 4-dial decade box has following resistance values,
decade '*a*' of 10 × 1000 Ω ± 0.1%
decade '*b*' of 10 × 100 Ω ± 0.1%
decade '*c*' of 10 × 10 Ω ± 0.5%
decade '*d*' of 10 × 1 Ω ± 1.0%
The dial is set at 4639 Ω.
Find the percentage limiting error and the range of resistance value.

[12 marks]

Q1(a) Given : The dial is set at 4639 Ω

statement : 4639 can be written as

∘ 4000 + 600 + 30 + 9.

calculating G.A.E Errors for the given values :-

$$GAE_a = \frac{0.1}{100} \times 4000 = 4.$$

$$GAE_b = \frac{0.1}{100} \times 600 = 0.6$$

$$GAE_c = \frac{0.5}{100} \times 30 = 0.15$$

$$GAE_d = \frac{1}{100} \times 9 = 0.09.$$

(6)

• Since above are absolute errors, hence they can be added.

overall Absolute error = 4.84 Ω. —— (1)

Hence limiting error can be calculated as follows :

$$\frac{x}{100} \times 4639 = 4.84 \quad \text{(from ①)}$$

$$\boxed{\therefore \% \text{ L.E} = 10.43\%}$$

Range of the Resistance values would be :

$$\text{Range} = 4639 \pm 4.84\,\Omega$$

$$R_{max} = 4639 + 4.84 = 4643.84\,\Omega$$

$$R_{min} = 4639 - 4.84 = 4634.16\,\Omega$$

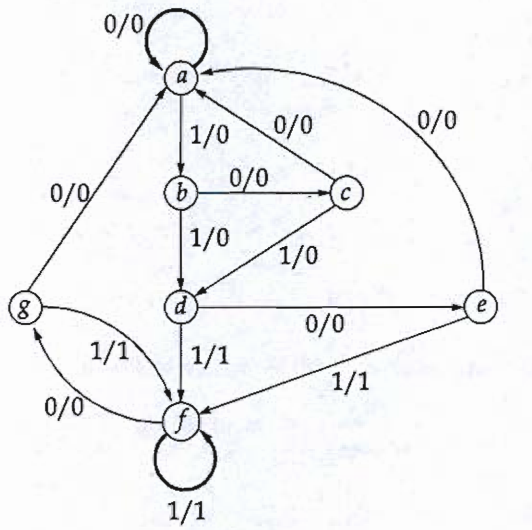
$$\therefore \boxed{\text{Range} = 4634.16 - 4643.84\,\Omega}$$

Ans

12

V. Good.

Q.1 (b) Obtain a reduced state table and reduced state diagram for the sequential machine whose state diagram is shown in figure.



[12 marks]

q1 (b) making a state table from the given above diagram.

PS	i/p	NS	o/p
a	0	a	0
a	1	b	0
b	0	c	0
b	1	d	0
c	0	a	0
c	1	d	0
d	0	e	0
d	1	f	1
e	0	a	0
e	1	f	1
f	0	g	0
f	1	f	1
g	0	a	0
g	1	f	1

(e) & (g) are similar

since (e) and (g) are alike, reduced state table:

(g) can be neglected:

PS	i/p	NS	o/p
a	0	a	0
a	1	b	0
b	0	c	0
b	1	d	0
c	0	a	0
c	1	d	0
d	0	e	0
d	1	~~f~~ d	1
e	0	a	0
e	1	~~f~~ d	1
f	0	e	0
f	1	f	1

(d) & (f) are similar

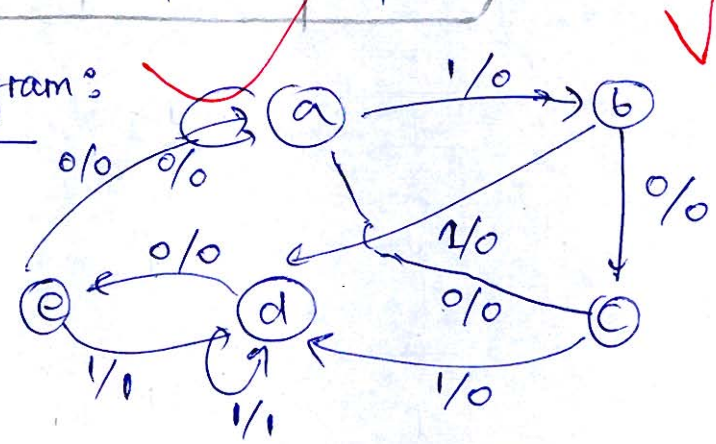
final state table:

PS	i/p	NS	o/p
a	0	a	0
a	1	b	0
b	0	c	0
b	1	d	0
c	0	a	0
c	1	d	0
d	0	e	0
d	1	d	1
e	0	a	0
e	1	d	1

12

V. Good

state diagram:



Q.1 (c) In a dynamometer type wattmeter, the flux density in the fixed coil is 1.1 mWb/m^2. The moving coil of 2.5 cm diameter has 500 turns of copper wire. If the voltage applied across the moving coil is 100 V, its total resistance is 2000 Ω and the wattmeter is measuring the power flowing in a load having a power factor 0.7, estimate the torque when the axes of the fixed and moving coils are at (i) 45° and (ii) 90°.

[12 marks]

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Q.1 (d) Explain the process of diffusion and also, state Fick's Laws of diffusion.

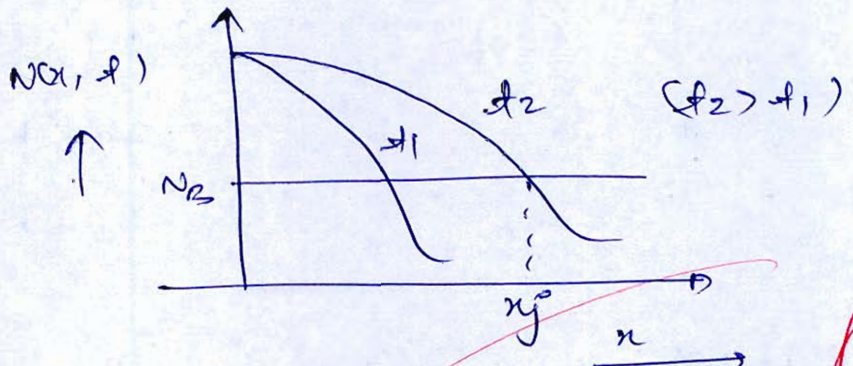
[12 marks]

Q1 (d)

- Diffusion is a process under which carriers are transported from higher concentration to lower concentration under certain temperature conditions.
- For fabrication purposes, diffusion takes place in 2 stages.
  1. Pre-deposition
  2. drive-in.
- Both are high temperature processes

① Pre deposition phase: In this phase, the carriers follow (erfc) profile,

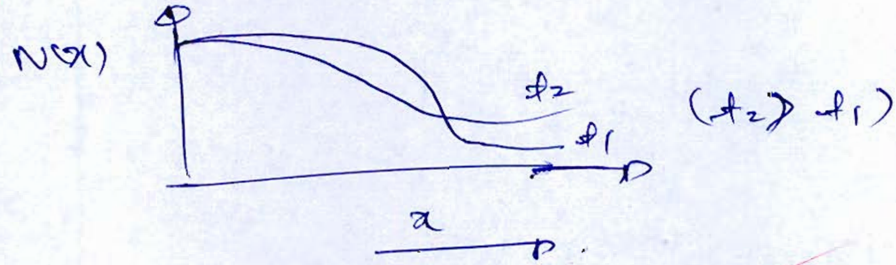
$$N(x,t) = N_0 \, \text{erfc}\left(\frac{x}{2\sqrt{Dt}}\right).$$



② drive-in phase

- Source is turned off.
- Profile follows distribution :-

$$N(x) = \frac{Q}{\sqrt{\pi D t}} e^{-x^2/4Dt}.$$



Fick's laws for diffusion:

These are helpful in understanding the physics behind diffusion process.

① $\frac{\partial N}{\partial x} = \frac{\partial N}{\partial t}$. ② $N(x,t) = D\frac{\partial^2 N}{\partial x^2}$

Q.1 (e) A thermistor has a resistance of 3980 Ω at the ice point (0° C) and 794 Ω at 50°C. The resistance temperature relationship is given by $R_T = aR_0e^{b/T}$. Calculate the constants a and b. (Assume, $R_0 = 1\ \Omega$)

[12 marks]

Q1 (e)

given relationship : $R_T = aR_0e^{b/T}$.

$R_0 = 1\ \Omega$.

Resistance	Temp (°c)	Temp (°k)
3980 Ω	0°c	273 K
794 Ω	50°c	323 K

substituting values,

$3980 = a(1)e^{b/273}$ — ①

$794 = a(1)e^{b/323}$ — ②

÷ ① & ②,

$\frac{3980}{794} = e^{b/273} \cdot e^{-b/323}$

$= e^{b\left[\frac{1}{273} - \frac{1}{323}\right]}$

$1.6119 = b \times 5.67 \times 10^{-4}$

∴ $b = 2842.71$ — ③

on solving,

$a = 0.1195$ — ④

conclusion :

hence ③ & ④ are the respective answers.

12

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Q.2 (a) Phosphorous is diffused into uniformly doped *P*-type Si with original doping concentration of the sample being $10^{17}/cm^3$ at 1100 °C. Given that the solid solubility of phosphorous in Si at 1100 °C is $10^{22}/cm^3$ and the diffusion coefficient at this temperature is 10^{-14} cm^2/sec.

(i) Calculate the total number of phosphorous atoms per unit area of Si surface after pre-deposition time of 1 hour. Also calculate the junction depth.

(ii) If after this, drive in is carried out for 2 hours at the same temperature, what will be the final junction depth and surface concentration?
[Assume erfc(3.12) = 10^{-5}]

[20 marks]

Q 2 (a) Diffusion takes place in 2 stages
(i) Pre-deposition
(ii) Driver in.

Given: $N_0 = 10^{22}/cm^3$, $T = 1100°c$
$D = 10^{-14}\ cm^2/sec$.

Statement: for a pre-deposition process,

$$N(x,t) = N_0\, erfc\left(\frac{x}{2\sqrt{Dt}}\right) \quad \text{——— (1)}$$

using (1) to find, dose (Q)

$$\text{Dose } (Q) = \int_{-\infty}^{\infty} N(x,t)\,.dx\,.$$

$$Q = N_0 \int_{-\infty}^{\infty} erfc\left(\frac{x}{2\sqrt{Dt}}\right).dx, \quad \text{let } v = \frac{x}{2\sqrt{Dt}}$$

$$Q = 2N_0\sqrt{Dt}\int_{-\infty}^{\infty} erfc(v).dv \cdot \left[\because \int_{-\infty}^{\infty} erfc(x).dx = \frac{1}{\sqrt{\pi}}\right]$$

$$\therefore \boxed{Q = 2N_0\sqrt{\frac{Dt}{\pi}}} \text{ (atoms/cm}^2\text{)} \quad \text{——— (2)}$$

substituting values in equation (2),

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$$Q = 2 \times 10^{22} \times \sqrt{\frac{10^{-14} \times 3600}{\pi}}$$

on solving, $Q = 6.77 \times 10^{16}$ atoms /cm3

Hence, the above value is the total phosphorous atoms per unit area of Si surface after pre-depos^n of 1hr.

calculation of junction depth: (x_j)

at $x = x_j$, $N(x,t) = N_B$ (back ground doping)

$$N_B = N_0 \, erfc\left(\frac{x_j}{2\sqrt{Dt}}\right) \quad \text{———} \quad (3)$$

on solving (3),

$$\frac{x_j}{2\sqrt{Dt}} = erfc^{-1}\left[\frac{N_B}{N_0}\right] \; ; \; \frac{x_j}{2\sqrt{Dt}} = erfc^{-1}\left[10^{-5}\right]$$

from given $erfc(3.12) = 10^{-5}$.

$$\therefore \frac{x_j}{2\sqrt{Dt}} = 3.12 \; ; \; x_j = 2\sqrt{Dt} \times 3.12 .$$

on solving, $x_j = 3.744 \times 10^{-5}$ cm.

$x_j = 0.3744\ \mu m$

Q2 (a) (ii) under drive-in conditions,

$$N(x) = N_s \, e^{-x^2/4Dt} .$$

where, $N_s = \frac{Q}{\sqrt{\pi Dt}}$; N_s: Surface concentration.

$$N_S = \frac{6.77 \times 10^{16}}{\sqrt{\pi \times 10^{-14} \times 2 \times 3600}}$$

$x_j^2 = 3.08 \times 10^{-9}$

$x_j^o = 5.55 \times 10^{-5}$ cm

$x_j^o = 0.55$ um.

$N_S = 4.50 \times 10^{21}$ atoms/cm^3

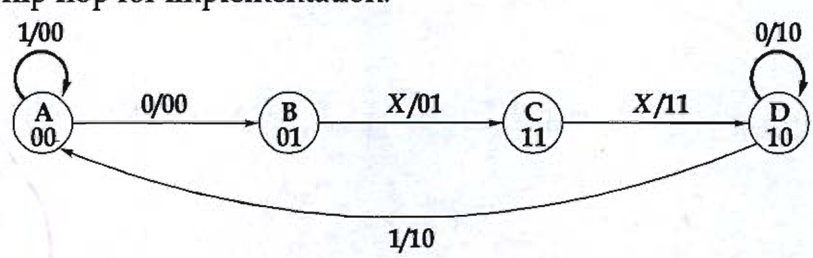
final junction depth:

$$10^{17} = 4.50 \times 10^{21} e^{-x_j^2/4Dt}$$

on solving,

$$-10.7147 = -\frac{x_j^{o2}}{4Dt}$$

Q.2 (b) Design a circuit that will function as prescribed by the state diagram shown in figure. Use S-R flip flop for implementation.



[20 marks]

Q2 (b)

making a state table from the above given state diagram,

statement: for an SR flip flop, the relationship between present and next state is

Q	Q^+	S	R
0	0	0	X
0	1	1	0
1	0	0	1
1	1	X	0

State Table :

PS	i/p	NS	o/p
0 0	0	0 1	0 0
0 0	1	0 0	0 0
0 1	0	1 1	0 1
0 1	1	1 1	0 1
1 0	0	1 0	1 0
1 0	1	0 0	1 0
1 1	0	1 0	1 1
1 1	1	1 0	1 1

using SR flip flops : By the help of Excitation table,

PS	i/p	NS	o/p				
$Q_1 Q_0$	X	$Q_1^+ Q_0^+$	Z	S_1	R_1	S_0	R_0
0 0	0	0 1	0 0	0	X	1	0
0 0	1	0 0	0 0	0	X	0	X
0 1	0	1 1	0 1	1	0	X	0
0 1	1	1 1	0 1	1	0	X	0
1 0	0	1 0	1 0	X	0	0	X
1 0	1	0 0	1 0	0	1	0	X
1 1	0	1 0	1 1	X	0	0	1
1 1	1	1 0	1 1	X	0	0	1

10

Drawing respective K-maps,

for S_1

Q_1 \ Q_0X	00	01	11	10
0	(0)	(1)	1 (3)	1 (2)
1	X (4)	(5)	X (7)	X (6)

$S_1 = Q_0$

for R_1:

Q_1 \ Q_0X	00	01	11	10
0	X (0)	X (1)	(3)	(2)
1	(4)	1 (5)	(7)	(6)

$R_1 = \overline{Q_0} X$

for S_0

Q_1 \ Q_0X	00	01	11	10
0	1 (0)	(1)	X (3)	X (2)
1	(4)	(5)	(7)	(6)

$S_0 = \overline{Q_1}\,\overline{X}$

for R_0:

Q_1 \ Q_0X	00	01	11	10
0	(0)	X (1)	(3)	(2)
1	X (4)	X (5)	1 (7)	1 (6)

$R_0 = Q_1$

Z_A

Q_1 \ Q_0X	00	01	11	10
0	(0)	(1)	(3)	(2)
1	1 (4)	1 (5)	1 (7)	1 (6)

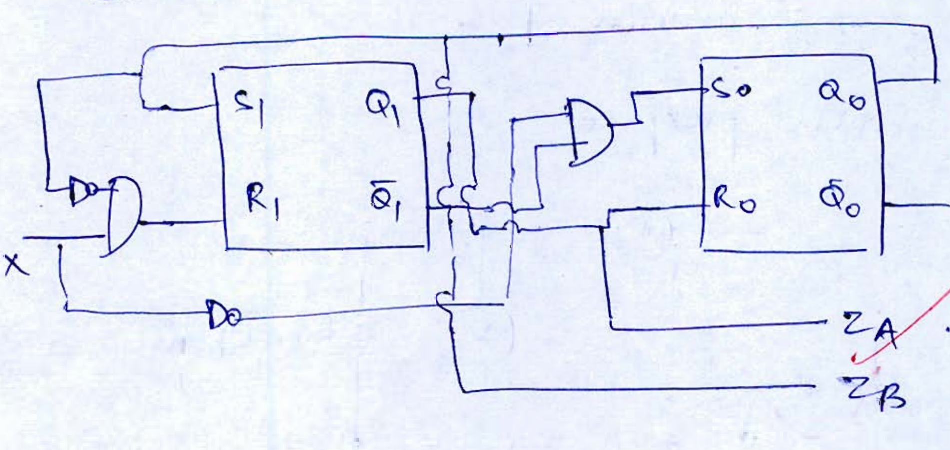
$Z_A = Q_1$

Z_B

Q_1 \ Q_0X	00	01	11	10
0	(0)	(1)	1 (3)	1 (2)
1	(4)	(5)	1 (7)	1 (6)

$Z_B = Q_0$.

Designing circuit :-



[SR flip flop implementation].

Q.2 (c) A voltmeter having a sensitivity of 1000 Ω/V reads 100 V on its 150 V scale when connected across an unknown resistor in series with a milliammeter.

(i) When the milliammeter reads 5 mA, calculate:

1. Apparent resistance of the unknown resistor.
2. Actual resistance of the unknown resistor.
3. %error in the measurement.

(ii) When the milliammeter reads 800 mA and the voltmeter reads 40 V on its 150 V scale. Calculate:

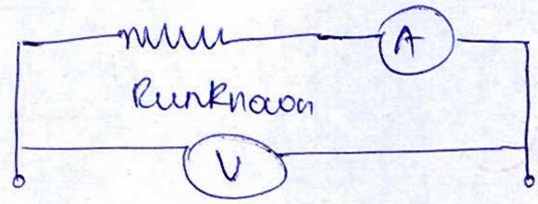
1. Apparent resistance of the unknown resistor.
2. Actual resistance of the unknown resistor.
3. % error in the measurement.

(iii) Define the cause of errors. And also conclude the methods to minimize that cause.

[6 + 6 + 8 marks]

Q2 (c) Given: voltmeter, sensitivity = 1000Ω/V.

from the above description, the circuit can be drawn as,

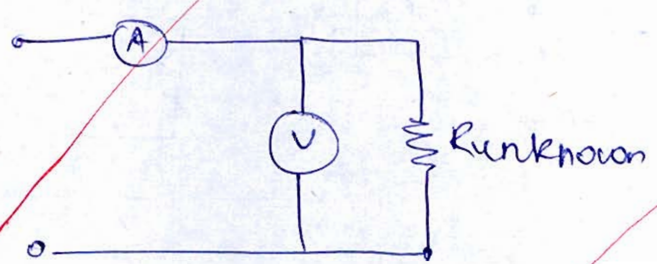


[connection given]

for simplification purposes:-

Case ①

100V, 5mA



we know,

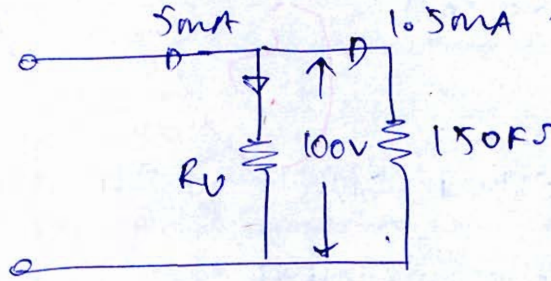
$$\text{Sensitivity} = \frac{1}{I_{fs}} = \frac{R_s + R_m}{V}$$

① Apparent resistance $\boxed{R_{Apparent} = \frac{100}{5} = 20\,k\Omega}$.

② Actual resistance,

$\{R_m = 150\,k\Omega\}$ $\left(0.8\,10^3 = \frac{R_m}{150}\right)$ (FS value)

∴



$I_{unknown} = 3.5mA$

∴ $\boxed{R_{actual} = 28.57\,k\Omega}$.

③ % Error = $\frac{MV - TV}{TV} \times 100 = \frac{20 - 28.57}{28.57}$

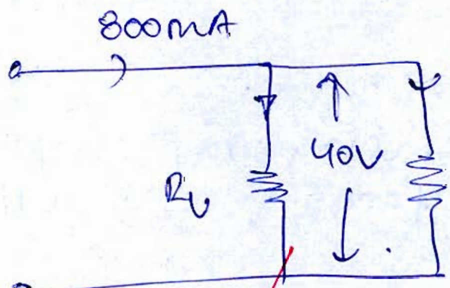
$\boxed{\%\ Error = -30.01\%}$.

Case ②

① Apparent resistance ⇒ $R_{apparent} = \frac{40}{800}$

$\boxed{R_{apparent} = 50\,\Omega}$

② actual resistance,



$I_m = \frac{40}{150} = 0.266mA$

$I_V = 799.733mA$.

$V = I \times R$

$R = \frac{40}{799.73}$, $R_{actual} = 50.01\,\Omega$

$\% \text{ Error} = \frac{50 - 50.01}{50.01} = -0.033\%$

Q2 (c) (iii) Errors are undesired effects which change the value of the reading.

It's types include the following and causes:-

GROSS	SYSTEMATIC	RANDOM
Random in nature	• because of human mistakes	• not in control at all.

Systematic errors:

Instrumental Errors	Environmental Errors	Observational error
because of improper use of instrument	Eg's include ~~parallax~~ stray MF effect's.	Eg's include parallax effect

• Errors can be compensated by identifying the causes and taking equivalent measures to overcome the effects.

Q.3 (a) The law of deflection of a moving-iron ammeter is given by $I = 4\theta^n$ ampere, where θ is the deflection in radian and n is a constant. The self-inductance when the meter current is zero is 10 mH. The spring constant is 0.16 N-m/rad.

(i) Determine an expression for self-inductance of the meter as a function of θ and n.

(ii) With $n = 0.75$, calculate the meter current and the deflection that corresponds to a self-inductance of 60 mH.

[20 marks]

Q.3 (b) (i) Explain the process for the production of semiconductor grade (electronic grade) silicon.

(ii) Explain the Czochralski method of the single crystal growth in silicon wafer preparation.

[20 marks]

Q.3 (c) **(i)** Define the following Errors in Frequency Meter:

1. The ±1 count error
2. The Time base error
3. Trigger Error
4. Frequency Measurement Error

(ii) A frequency meter measuring the ratio of two frequencies displays 1133 when the pulses of the unknown frequency (f_2) are counted over 100 cycles of the known frequency (f_1). If f_1 = 33 kHz, determine f_2.

[12 + 8 marks]

Q.4 (a) Discuss the *PN* junction diode fabrication process.

[20 marks]

Q.4 (b) In a low voltage Schering bridge designed for the measurement of permittivity, the branch *AB* consists of the two electrodes between which the specimen under test may be inserted and a resistance R_1 in parallel, arm *BC* is a non-reactive resistor R_3 in parallel with a standard capacitor C_3, arm *CD* is a non-reactive resistor R_4 in parallel with standard capacitor C_4; Arm *DA* is a standard air capacitor of capacitance C_2. Without the specimen between the electrodes, balance is obtained with the following values; $C_3 = C_4 = 120$ pF, $C_2 = 150$ pF, $R_3 = R_4 = 5000\ \Omega$. With the specimen inserted these values become $C_3 = 200$ pF, $C_4 = 1000$ pF, $C_2 = 900$ pF and $R_3 = R_4 = 5000\ \Omega$. In each test, $\omega = 5000$ rad/sec. Find the relative permittivity of the specimen.

[20 marks]

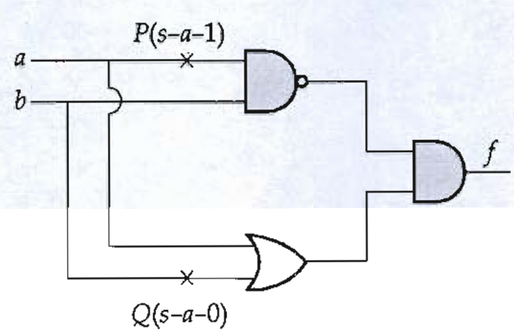
Q.4 (c) Consider the logic circuit shown in the figure below. Two specific faults are identified in the circuit:

Fault *P*: Line *a* at the input of the NAND gate is stuck at 1 (s-a-1).

Fault *Q*: Line *b* at the input of the OR gate is stuck-at-0 (s-a-0)

(i) Determine the test vectors (a, b) required to detect fault *P* and fault *Q* individually.

(ii) Analyze whether these two faults are indistinguishable. Provide a mathematical justification by comparing the faulty output function $f_P(a, b)$ and $f_Q(a, b)$.



[20 marks]

Section B : Electromagnetics-1 + Basic Electrical Engineering-1
Computer Organization and Architecture-2 + Materials Science-2

Q.5 (a) A parallel plate capacitor is made of circular discs of radius 0.1 m. The medium inside is air. The spacing between the two plates is 0.05 m. A voltage of $50 \cos 10^4 t$ volts is applied between the two plates. Find the rms value of the displacement current flowing through the capacitor using Maxwell's equations.

Also show that the rms value of the total capacitor current calculated from voltage equation is same as the displacement current.

Assume permittivity of free space $\varepsilon_0 = \frac{1}{36\pi} \times 10^{-9}$ F/m.

[12 marks]

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Q.5 (b) The total core loss of a transformer is found to be 2800 W at 400 V, 50 Hz. When the transformer is supplied at 200 V and 25 Hz, the core loss is 1000 W. Calculate hysteresis and eddy current loss at 400 V and 50 Hz. Also calculate hysteresis and eddy current losses at 800 V, 25 Hz (Assume Steinmetz exponent ≅ 2)

[12 marks]

Q5 (b) Total core loss = 2800 at 400V, 50Hz.

when 200V, 25Hz, Total core loss = 1000 W.

we know, Total core losses = Hysteresis losses ∝ (Af) + Eddy Current losses (Bf²).

∴ $2800 = A(50) + B(50)^2$ — (1)

$1000 = A(25) + B(25)^2$ — (2)

6

on solving,

$A = 24, \quad B = 0.64.$

at 400 V, 50 Hz,

$P_H = 24(50) = 1200$ watts

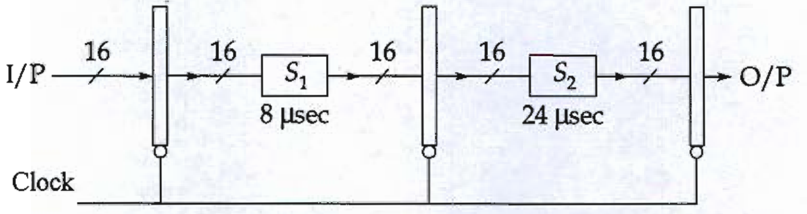
$P_{eddy} = 0.64(50)^2 = 1600$ watts.

at 800 V, 25 Hz,

$P_H = 24(25) = 600$ watts

$P_{eddy} = 0.64(25)^2 = 400$ watts.

Q.5 (c) The figure shown below indicates a two-stage pipeline with stage delays indicated below the stages. Latch delays are to be ignored.

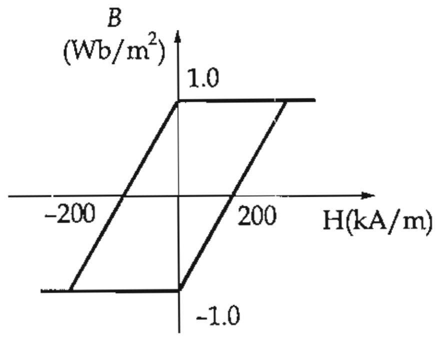


(i) Calculate throughput and latency of the pipeline shown above.

(ii) The pipeline stage 2 is now split in three equal sub-stages. Find out the new throughput and latency for the complete pipeline.

[12 marks]

Q.5 (d) The B-H curve for a hard ferromagnetic material is a parallelogram as shown in figure below:



(i) What is the total hysteresis loss per cycle?

(ii) What is the $(BH)_{max}$ product?

[6 + 6 marks]

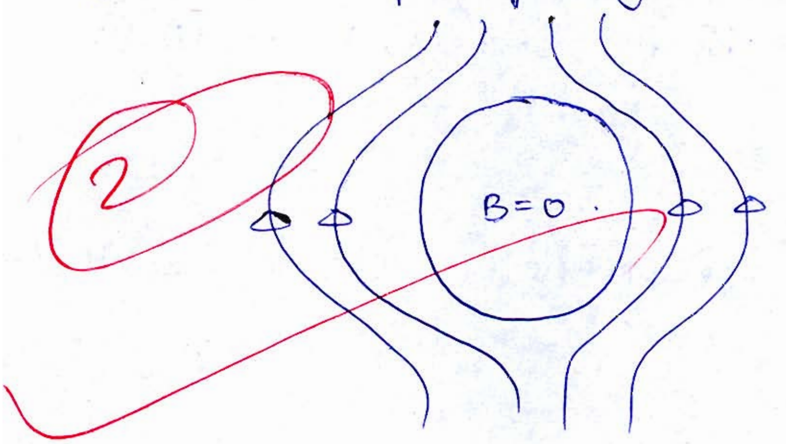
Q.5 (e) Explain the following phenomena with respect to superconductors:
(i) Meissner effect **(ii)** Silsbee rule **(iii)** Frequency effect

[4 + 4 + 4 marks]

Q5 (e) (i)

Meissner effect :

It is a condition in which magnetic flux lines are completely rejected by a material.



(meissner effect)

Silsbee Rule :

we know, $B = \mu_0 \mu_r H$.

$B = \mu_0 [1 + \chi_m] H$.

$B = \mu_0 H + \mu_0 \chi_m H$.

Do not write in this margin

where, $\chi_m = \mu_r - 1$.

also, $\frac{M}{H} = \chi_m$

under this rule, $\chi_m = -1$.

Hence $\boxed{\mu_r = 0}$.

Hence for a superconducting material, relative permeability is zero.

9

frequency effects :

- As frequency increases, entropy increases, Hence superconductivity decreases, vanishes at higher frequencies.
- for DC & low frequencies, superconductivity exists.

Q.6 (a) A computer uses a Byte addressable main memory of size 4 MB with a 4-Way Set Associative cache memory. The block in each cache contains 64 bytes and the tag field contains 10 bits. Calculate:

(i) The physical address split

(ii) Number of main memory blocks

(iii) Cache size

(iv) Tag directory size

(v) Number of comparators needed.

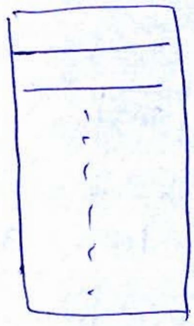
[20 marks]

Q6 (a) Given:

lines 

(CM)

- 4 way set Associative cache memory
- Block size = 64B.
- TAG = 10 bits.

 blocks

(MM)

- Byte addressable
- size = 4MB.

Statement: for a set Associative cache memory field is described as

TAG	SO	B.O

ATQ,

(i) Physical address split:

Since given main memory is of 4MB.

Hence P.A. split: $2^2 . 2^{20}$ B

$= 2^{22}$.

$\therefore$ (22) bits are needed to be used in P.A. split.

20

(ii) Number of main memory blocks

$$\# \text{blocks} = \frac{\text{main memory size}}{\text{block size}} = \frac{4MB}{64B} = \frac{2^{22}}{2^6}.$$

$\#$ blocks $= 2^{16}$ blocks.

(iii) Cache size : given TAG = 10 bits.

TAG	SO	BO
10	x	6

(total = 22)

SO = 22 − (10+6)

SO = 6 bits

Hence S.O = 6 bits.

$\#$ lines in c.m $= \dfrac{\text{cm size}}{\text{block size}}$ & $\text{SO} = \dfrac{\#\text{ lines in cm}}{\text{P-way}}$.

$\therefore \#$ lines in cm $= 2^6 \times 2^2 = 2^8$.

Hence cm size $= 2^8 \times 64$ B

$= 2^8 \times 2^6$ B $= 2^4$ KB

cm size = 16 KB

(iv) TAG directory size : $\#$ lines in cm $\times$ TAG bits

$= 2^8 \times 10 = 2560$ bits.

Q.6 (b) **(i)** What are the differences between Carbon Dots and Quantum Dots?

(ii) Write a short note on Top-Down Technique and Bottom-Up Technique used for synthesis of nano materials.

[10 + 10 marks]

Q6 (b) (i)

Carbon dots

- when carbon is synthesized under extremly small ranges, carbon dots are obtained.
- carbon has differented properties based upon the hybridization and arrangement of atoms.
- Under such small ranges, they can be used for bio medical and other such related purposes.

Quantam dots

- when a particle is in the quantum range, based on the spin of the particle, it's effects are modulated to the desired needs.
- Quantum dots vary from carbon dots based off the spatial arrangement of atoms and use cases.

Q6(b) (ii) Nano material is a type of material which has atleast one dimension in the nano range. It's type include:

1. 0 dimensional nanomaterials
2. 1 dimensional nanomaterials
3. 2 dimensional nanomaterials.

• They can be synthesized using 2 processes.

1. Bottom up
2. Top down.

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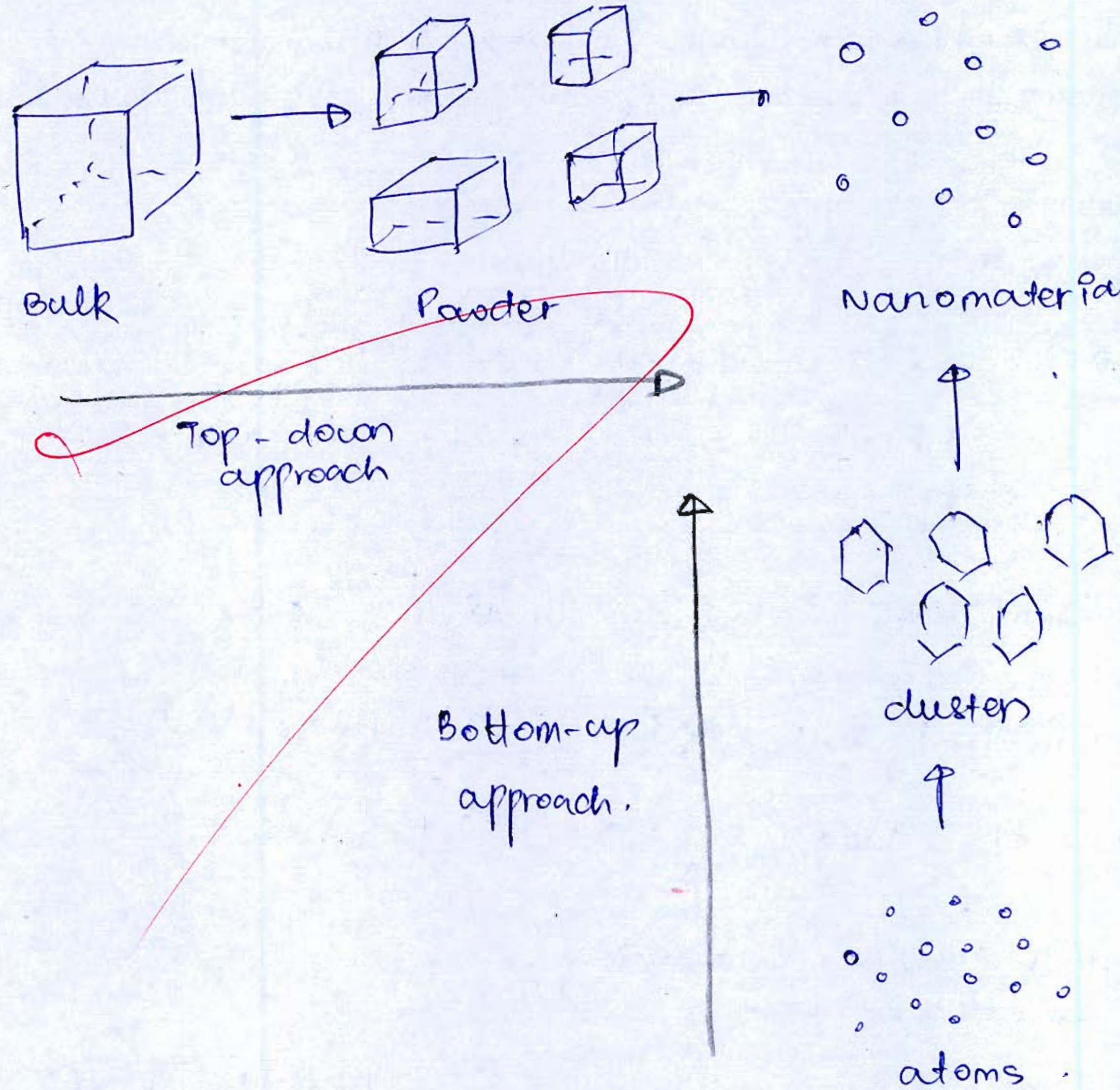
Bottom - up Approach: we start off at the atomic level and go-up to the nano range (eg) sol-gel technique.

Advantages: 1. defects are minimized.
2. Controlled process.

disadvantages: 1. difficult to implement over Top-down.

Top-down Approach: we start off at the bulk range and go down to Nano level.



{ Diagramatic Description of the two processes }

Top - down examples:

1. Ball milling.
2. Lithographic processes.

Advantages : 1. Production is higher.

disadvantages : 1. defects formed are more.

Q.6 (c) A particular lossless material has $\mu_r = 4$ and $\varepsilon_r = 9$. A 10 MHz uniform plane wave is propagating in the $\hat{a}_y$ direction with $E_{x_0} = 400$ V/m and $E_{y_0} = E_{z_0} = 0$ at $P(0.6, 0.6, 0.6)$ and $t = 60$ ns.

Determine:

(i) β, λ, v_p and η (ii) $E(t)$ (iii) $H(t)$

[20 marks]

Q6 (c)

Given: • lossless material • $f = 10$ MHz

• $\mu_r = 4$. • $E_{x0} = 400$ V/m.

• $\varepsilon_r = 9$.

Statement: ① for a lossless medium, $\sigma = 0$, $\alpha = 0$.

② Generalized expression of electric field is

$E(x,t) = E_0 e^{-\alpha z} \cos(\omega t - \beta z)$ ——— ①

(i) β, λ, v_p and η calculations:

$\gamma = \sqrt{j\omega\mu(\sigma + j\omega\epsilon)}$; $\sigma = 0$; $\gamma = j\omega\sqrt{\mu\epsilon}$; $\gamma = j\beta$.

$\therefore \beta = \omega\sqrt{\mu\epsilon}$; $\beta = \frac{2\pi \times 10^7 \times \sqrt{36}}{3 \times 10^8}$; $\boxed{\beta = 1.25 \text{ rad/m}}$

• $\lambda = \frac{2\pi}{\beta}$; $\lambda = 5$ m. ; $\boxed{\lambda = 5\text{m}}$

• $v_p = \frac{\omega}{\beta} = \frac{c}{\sqrt{\mu_r \varepsilon_r}}$; $v_p = \frac{3 \times 10^8}{6} = \boxed{0.5 \times 10^8 \text{ m/s}}$

• $\eta = \sqrt{\frac{j\omega\mu}{\sigma + j\omega\epsilon}}$; $\eta = 120\pi\sqrt{\frac{\mu_r}{\varepsilon_r}}$ => $\boxed{\eta = 251.33\,\Omega}$

η [η !?]

(ii) from equation ①, According to given condition,

$$E(y,t) = E_{0} \cos(\omega t - \beta y)\, \hat{a_n}$$

substituting values,

$$E(y,t) = 400 \cos(2\pi \times 10^{7} t - 1.28 y)\, \hat{a_n} \text{ V/m}$$

(iii) calculation of H(t).

$$H = \frac{\vec{a_k} \times \vec{E}}{\eta} \quad \text{——— ②}$$

using ②,

$$H(y,t) = \frac{-400}{\eta} \cos(2\pi \times 10^{7} t - 1.28 y)\, \hat{a_z}$$

$$\boxed{H(y,t) = -1.59 \cos(2\pi \times 10^{7} t - 1.28 y)\, \hat{a_z} \text{ A/m}}$$

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Q.7 (a) A 3-phase induction motor has a starting torque of 100% and a maximum torque of 200% of the full-load torque. Determine:

(i) slip at which maximum torque occurs;

(ii) full-load slip;

(iii) rotor current at starting in per unit of full-load rotor current.

[20 marks]

Q7 (a) Given: 3φ induction motor.

Conditions: $T_{st} = 100\% \, T_{Fl}$

$T_{max} = 200\% \, T_{Fl}$.

rewriting conditions: $T_{st} = T_{Fl}$ ——— (1)

$T_{max} = 2T_{Fl}$ ——— (2)

Statement: for an induction motor,

$$\frac{T}{T_{max}} = \frac{2}{\frac{S}{S_{Tmax}} + \frac{S_{Tmax}}{S}}.$$

at starting, $S_{ST} = 1$.

10

$$\frac{T_{st}}{T_{max}} = \frac{2}{\frac{1}{S_{Tmax}} + \frac{S_{Tmax}}{1}}.$$

∴ (1) & (2), ∴ $\frac{T_{st}}{T_{max}} = \frac{1}{2}$.

$$\frac{1}{2} = \frac{2}{\frac{S_{Tmax}^2 + 1}{S_{Tmax}}}$$

rearranging, $S_{Tmax}^2 + 1 = 4S_{Tmax}$

on solving, $S_{Tmax} = 0.267 \ (✓) \ , \ 3.73 \ (✗)$

$$\therefore \boxed{S_{Tmax} = 0.267}$$

(ii) full load slip:

$$\frac{1}{2} = \frac{T_{Fl}}{T_{max}} = \frac{2}{\frac{S_{Fl}}{0.267} + \frac{0.267}{S_{Fl}}}$$

$$\frac{S_{Fl}^2 + (0.267)^2}{(0.267)(S_{Fl})} = 4$$

$$S_{Fl}^2 + 0.0712 = 1.068\, S_{Fl}$$

on solving $S_{Fl} = 0.996 \ (✗) \ , \ 0.07144 \ (✓)$

$$\therefore \boxed{S_{Fl} = 0.07144}$$

(iii) we know the relationship between Torque and current:

$$T \propto \frac{I_2^2}{S}$$

$$T_{st} \propto \frac{I_{st}^2}{1} \quad \text{— (1)}$$

$$T_{Fl} \propto \frac{I_{Fl}^2}{S_{Fl}} \quad \text{— (2)}$$

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Dividing ③ & ④.

$$\frac{T_{st}}{T_{fl}} = \left(\frac{I_{st}}{I_{fl}}\right)^2 \times S_{fl}.$$

$$\sqrt{\frac{1}{S_{fl}}} = \frac{I_{st}}{I_{fl}}.$$

So $\boxed{\frac{I_{st}}{I_{fl}} = 3.741 \text{ A/p.u}}$.

Q.7 (b) The magnetic field intensity of a linearly polarized uniform plane wave propagating in the $+Y$-direction in sea water ($\epsilon_r = 80$, $\mu_r = 1$, $\sigma = 4$ S/m) at $y = 0$ is

$$\vec{H} = 0.1 \sin\left(10^{10}\pi t - \frac{\pi}{3}\right)\hat{a}_x \text{ A/m.}$$

At $y = 0$, determine the following :

(i) The attenuation constant, intrinsic impedance, the wavelength and skin depth.

(ii) The location at which the amplitude of $\vec{H}$ is 0.01 A/m.

(iii) The expression for $E(y, t)$ and $H(y, t)$ at $y = 0.5$ m as functions of t.

[20 marks]

Q7 (b)

Given : • $\epsilon_r = 80$ • $\sigma = 4$ S/m.
• $\mu_r = 1$

$\vec{H} = 0.1 \sin\left(10^{10}\pi t - \frac{\pi}{3}\right) a_x$ A/m (@ $y = 0$).

20

Statements : ① : Analyzing medium characteristics.

loss tangent $= \frac{\sigma}{\omega\epsilon} = \frac{4}{10^{10}\pi \times 80 \times 8.854 \times 10^{-12}}$

$$\frac{\sigma}{\omega\epsilon} = 0.179.$$

since, loss tangent is in the range of

$1 < \frac{\sigma}{\omega\epsilon} < 100$; it is an imperfect dielectric medium.

Propagation constant (γ)

$\gamma = \sqrt{j\omega\mu(\sigma + j\omega\epsilon)} = \sqrt{j10^{10}\pi \times 4\pi \times 10^{-7}(4 + j10^{10}\pi \times 80 \times 8.854\times10^{-12})}$

$\gamma = \sqrt{j39478.4176(4 + j22.58)}$

$\gamma = \sqrt{j157913.67 - 891422.66}$

$\gamma = \sqrt{905301.65 \angle 169.95}$

$\gamma = 951.47 \angle 84.975$, $\boxed{\gamma = 83.33 + 947.81}$

on comparison,

$\boxed{\alpha = 83.33 \text{ Np/m}}$ & $\boxed{\beta = 947.81 \text{ rad/m}}$

Intrinsic Impedance (η)

$\eta = \sqrt{\frac{j\omega\mu}{\sigma + j\omega\epsilon}}$ on solving, $\eta = \sqrt{1746.12 \angle 10.19^\circ}$

$\boxed{\eta = 41.78 \angle 5.095^\circ \ \Omega}$

wave length (λ)

$\lambda = \frac{2\pi}{\beta} = \frac{2\pi}{947.81}$; $\boxed{\lambda = 6.62\times10^{-3} \text{ m}}$

skin depth, $\delta = \frac{1}{\alpha}$

$$\delta = \frac{1}{83.33} = 0.012\ m.$$

(ii) location where $\vec{H}$ is 0.01 A/m.

$H(z) = H_{io}\, e^{-\alpha z}$.

$0.01 = 0.1\, e^{-83.33 \times z}$.

$\frac{-2.3025}{-83.33} = z$.

$$z = 0.0276\ m$$

(iii) standard HCH equation.

$\vec{H}(y,t) = 0.01 \sin\left(10^{10}\pi t - \frac{\pi}{3} - \beta y\right).\ \hat{a}_n$ A/m.

$\vec{H}(y,t) = 0.1 \sin\left(10^{10}\pi t - \frac{\pi}{3} - 947.81 y\right) \hat{a}_n$ A/m.

at $y = 0.5$:

$$\vec{H}(t) = 0.1 \sin\left(10^{10}\pi t - \frac{\pi}{3} - 473.905\right) \hat{a}_n \text{ A/m}.$$

we know

$\vec{E} = (\vec{H} \times a_k)\eta$.

$$\vec{E}(t) = 4.178\, e^{j5.095^\circ} \sin\left(10^{10}\pi t - \frac{\pi}{3} - 473.905\right) \hat{a}_z \text{ V/m}.$$

Q.7 (c) **(i)** A solenoid is 0.25 m long having 1000 turns and has 2.5 A current flowing through it in a vacuum chamber. When placed in pure oxygen environment, the magnetic induction exhibits an increase of 1.04×10^{-8} Wb/m^2. Find the magnetic susceptibility of oxygen.

(ii) Write a short note on optical properties of semiconducting nanoparticles.

[10 + 10 marks]

Q7 (c) (i)

Given: $l = 0.25m$.

$N = 1000$.

$I = 2.5$

statements: (1) $\oint H.dl = I$. (Ampere circuital law)

(2) $B = \mu_0 H$. (pure vacuum environment).

from (1), $H \times l = I$

$$H = \frac{NI}{l} = \frac{1000 \times 2.5}{0.25} = 10^4 \text{ A/m}.$$

when in pure ~~oxy~~ vacuum,

$\vec{B} = \mu_0 \vec{H}$.

$\vec{B_0} = 4\pi \times 10^{-7} \times 10^4$

$\boxed{\vec{B_0} = 4\pi \times 10^{-3} \text{ Wb/m}^2}$.

Good

10

when placed in pure oxygen environment.

$\vec{B} = \mu_0 \mu_r \vec{H}$.

$\vec{B} = \mu_0 (1 + \chi_m) \vec{H}$

$\{ \because \chi_m = \mu_r - 1 \}$

$\vec{B} = \mu_0 H + \mu_0 \chi_m \vec{H}$.

$\vec{B}' = \vec{B_0} + \mu_0 \chi_m H$.

Given, $\vec{B}' - \vec{B}_0' = 1.04 \times 10^{-8}$ wb/m^2

$$1.04 \times 10^{-8} = 4\pi \times 10^{-7} \times \chi_m \times 10^4 .$$

on Solving, $\boxed{\chi_m = 8.276 \times 10^{-7}}$

Q7 (c) (ii)

optical properties of semi-conducting Nano particles :

- Nano particles are materials which have atleast one dimension in nano range.
- Under semiconducting application they can be used as an excellent source to make detector circuits.
- Since surface area to volume ratio is very high for nano particles, the optical detecting capabilities provide an edge over tradational materiale
- The losses are also very less when such Materials are impelemented.

0

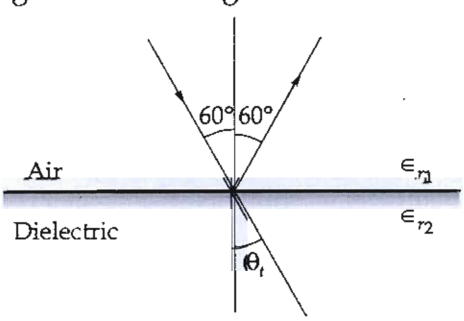
Q.8 (a) (i) In spherical co-ordinates, let $\hat{a}_\theta, \hat{a}_\phi$ denotes unit vectors along the θ, ϕ directions.

$$\vec{E} = \frac{100}{r}\sin\theta\cos(\omega t - \beta r)\hat{a}_\theta \text{ V/m}$$

and $$\vec{H} = \frac{0.265}{r}\sin\theta\cos(\omega t - \beta r)\hat{a}_\phi \text{ A/m}$$

represents the electric and magnetic field components of the EM wave at large distance r from a dipole antenna in a free space. Find the average power (W) crossing the hemispherical shell located at $r = 1$ km $\left(0 \le \theta \le \frac{\pi}{2}\right)$.

(ii) A right circularly polarized (RCP) plane wave is incident from air onto a dielectric interface at an angle of 60° to the normal. It is observed that the reflected wave is linearly polarized. Calculate the value of the relative dielectric constant (ϵ_{r2}) and the corresponding **Brewster's angle** for this interface.



[10 + 10 marks]

Q.8 (b) The efficiency at unity pf of a 6600/384 V, 200 kVA single phase transformer is 98% at full load and at half load. The pf at no load is 0.2 lagging and the full load regulation at a lagging pf of 0.8 is 4%. Draw the equivalent circuit referred to LV side mentioning all values.

[20 marks]

Q.8 (c) (i) Find the candidate keys for the relation $R(X, Y, Z, W, P)$ if all FDs of the set $F = \{Y \rightarrow Z, Z \rightarrow Y, Z \rightarrow W, Y \rightarrow P\}$ hold for all instances of R.

(ii) Relation $R(A, B, C, D, E, F)$ satisfies following FDs:
$AB \rightarrow C, C \rightarrow A, BC \rightarrow D, ACD \rightarrow B, BE \rightarrow C, CE \rightarrow FA,$
$CF \rightarrow BD, D \rightarrow EF.$
Determine the closure of LHS of all FD's.

[10 + 10 marks]

OOOO

Space for Rough Work

Space for Rough Work

$Q^{+} = S + \bar{R}Q$.

Q	Q^{f}	S	R
0	0	0	X
0	1	1	0
1	0	0	1
1	1	X	0

Space for Rough Work

$\oint \vec{H} \cdot d\vec{l} = I$

$H \cdot l = I$ $\quad$ $H \times$

$\left\{ H = \frac{NI}{l} \right\}$ $\quad$ $L = \frac{N\phi}{I}$

$\left\{ H = \frac{1000 \times 2.5}{0.25} \right\}$

$\vec{H} = 10^4$ A/m

$\vec{B} = \mu_0 \vec{H}$ (vacuum)

$\vec{B} = \mu_0 \mu_r \vec{H}$ (pure oxygen)

$\chi_m = \mu_r - 1$

$\mu_r = 1 + \chi_m$

$\vec{B} = \mu_0 [1 + \chi_m] H$

$\boxed{\vec{B} = \mu_0 H + \mu_0 \chi_m H}$

overall.

Space for Rough Work