



**MADE EASY**

Leading Institute for ESE, GATE & PSUs

# 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 :

### Test Centres

Delhi

Bhopal

Jaipur

Pune

Hyderabad

### Student's Signature

### 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	26
Q.2	
Q.3	
Q.4	
Section-B	
Q.5	
Q.6	
Q.7	
Q.8	
<b>Total Marks Obtained</b>	152

Signature of Evaluator

Cross Checked by

*you are doing good -- keep it up.*

*Lenze CoA ; EMI.*

## 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 : Advanced Electronics + Electronic Measurements & Instrumentation**

Q.1 (a) A 4-dial decade box has following resistance values,

decade 'a' of  $10 \times 1000 \Omega \pm 0.1\%$

decade 'b' of  $10 \times 100 \Omega \pm 0.1\%$

decade 'c' of  $10 \times 10 \Omega \pm 0.5\%$

decade 'd' of  $10 \times 1 \Omega \pm 1.0\%$

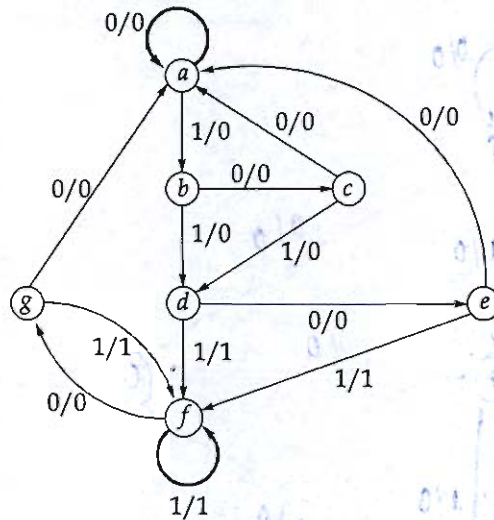
The dial is set at 4639  $\Omega$ .

Find the percentage limiting error and the range of resistance value.

[12 marks]



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

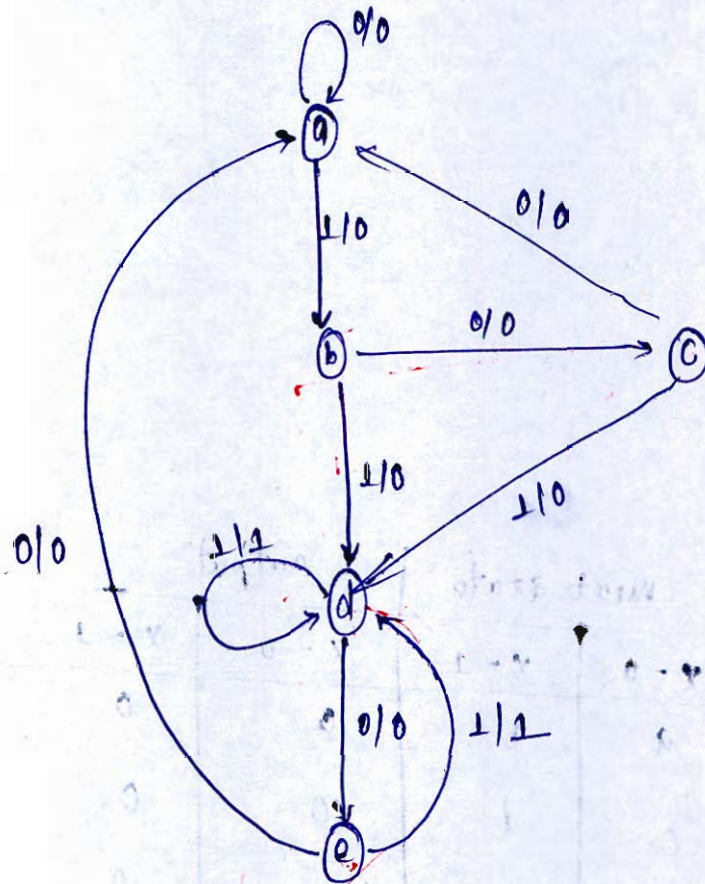


[12 marks]

Present state	Next state		output	
	x = 0	x = 1	x = 0	x = 1
a	a	b	0	0
b	c	d	0	0
c	a	d	0	1
d	e	<del>f</del> d	0	1
e	a	<del>f</del> d	0	1
<del>f</del>	<del>g</del> e	f	0	1
<del>g</del>	a	f	0	1

∴  $e = g$  then cancel  $g$  and replace by  $e$   
 Now  $d = f$  then cancel  $f$

Reduced state diagram



✓

12

- Q.1 (c) In a dynamometer type wattmeter, the flux density in the fixed coil is  $1.1 \text{ mWb/m}^2$ . The moving coil of  $2.5 \text{ cm}$  diameter has  $500$  turns of copper wire. If the voltage applied across the moving coil is  $100 \text{ V}$ , its total resistance is  $2000 \Omega$  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)  $45^\circ$  and (ii)  $90^\circ$ .

[12 marks]

Resistance  $R = 2000 \Omega$   
 $V = 100 \text{ V}$   
 Cos  $\phi = 0.7$

$$B = 1.1 \text{ mWb/m}^2$$

$$N = 500$$

$$2r = 2.5 \text{ cm} \Rightarrow r = 1.25 \times 10^{-2} \text{ m}$$

We know Torque,

$$T = BAIN \sin \theta$$

$$A = \pi r^2 = \pi \times (1.25 \times 10^{-2})^2$$

Power,  $P = VI \cos \phi = \frac{V^2}{R}$

$$I = \frac{V}{R \cos \phi} = \frac{100}{2000 \times 0.7}$$

$$I = 71.43 \times 10^{-3} \text{ A}$$

①

$$\theta = 45^\circ$$

$$T = 1.1 \times 10^{-3} \times \pi \times (1.25 \times 10^{-2})^2 \times 71.43 \times 10^{-3} \times 500 \times \sin 45^\circ$$

$$T = 1.963 \times 10^{-5} \text{ N-m}$$

②

$$\theta = 90^\circ$$

$$T = 1.1 \times 10^{-3} \times \pi \times (1.25 \times 10^{-2})^2 \times 71.43 \times 10^{-3} \times 500 \times \sin 90^\circ$$

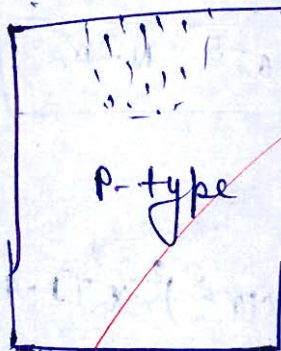
$$T = 1.928 \times 10^{-5} \text{ N-m}$$

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

[12 marks]

Process of Diffusion: Diffusion is a natural process where ion or molecule travels from high concentration to low concentration.

→ Bigger Molecules.



Incomplete



Q.1 (e)

A thermistor has a resistance of  $3980 \Omega$  at the ice point ( $0^\circ \text{C}$ ) and  $794 \Omega$  at  $50^\circ \text{C}$ . The resistance temperature relationship is given by  $R_T = aR_0 e^{b/T}$ . Calculate the constants  $a$  and  $b$ . (Assume,  $R_0 = 1 \Omega$ )

[12 marks]

$$R_T = a R_0 e^{b/T}$$

$$R_T = a e^{b/T} \quad (\because R_0 = 1 \Omega)$$

at ICE point  $T = 0^\circ \text{C}$     (i)  $R_T = 3980$   
 $T = 273 + 0 = 273 \text{ K}$

$$3980 = a e^{b/273} \quad \text{--- (1)}$$

at  $T = 50^\circ \text{C}$ ,    (ii)  $R_T = 794 \Omega$   
 $T = 50 + 273 = 323 \text{ K}$

$$794 = a \cdot e^{b/323} \quad \text{--- (2)}$$

Eq (1)  $\div$  (2)

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

$$b \left( \frac{1}{273} - \frac{1}{323} \right) = \ln \left( \frac{3980}{794} \right)$$

By solving  $b = 2042.009$

From Eq (1) Put the value of  $b$

$$3980 = a e^{\frac{2042.009}{273}}$$

$$a = 0.1195$$

(12)

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

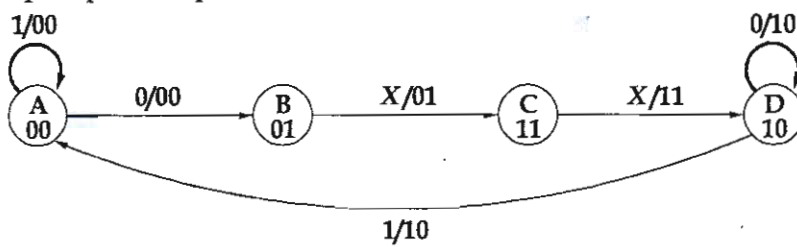
- (i) Calculate the total number of phosphorous atoms per unit area of Si surface after pre-deposition time of 1 hour. Also calculate the junction depth.
- (ii) If after this, drive in is carried out for 2 hours at the same temperature, what will be the final junction depth and surface concentration?

[Assume  $\text{erfc}(3.12) = 10^{-5}$ ]

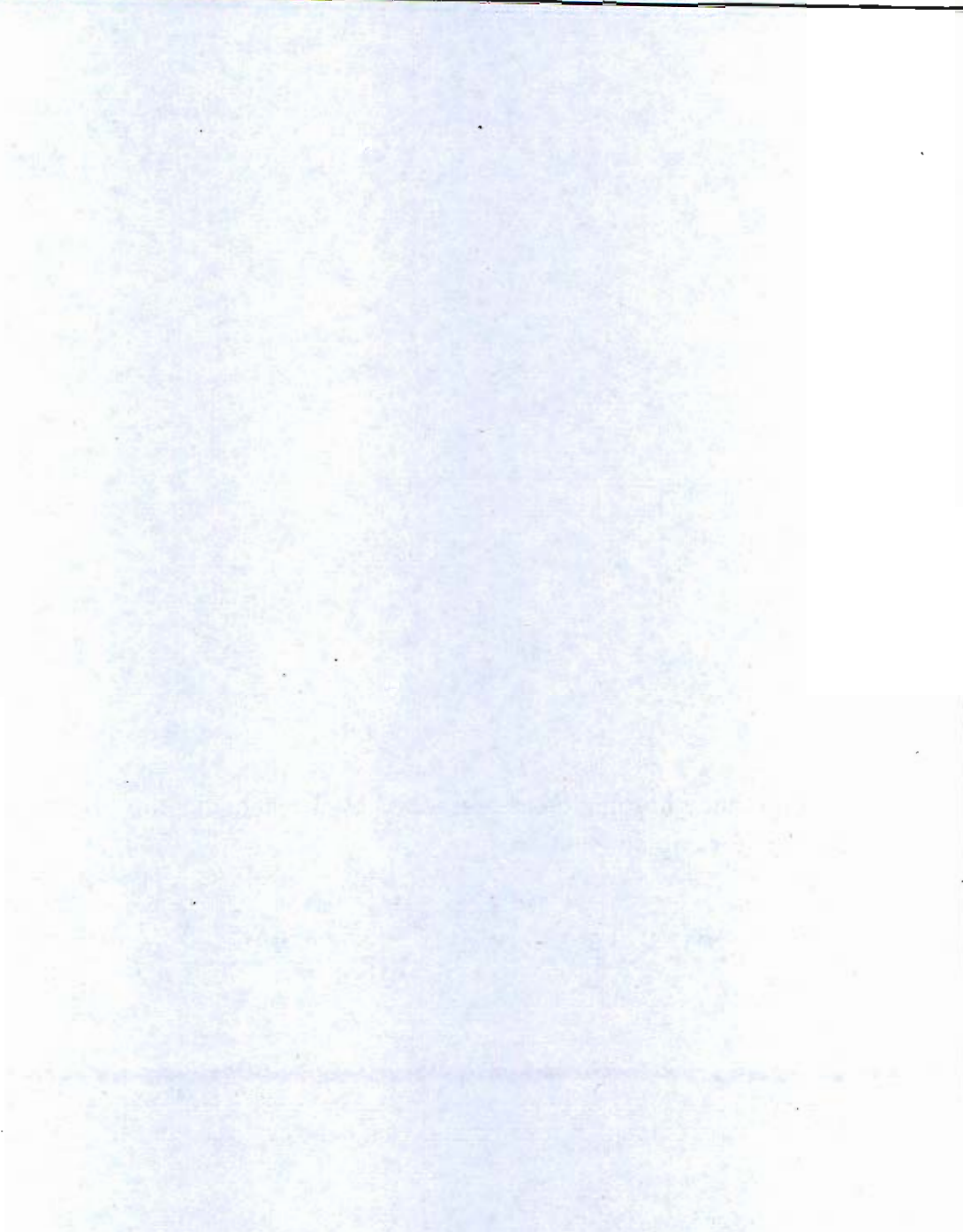
[20 marks]



- 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]



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- Q.2 (c) A voltmeter having a sensitivity of  $1000 \Omega/\text{V}$  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]





- Q.3 (a) The law of deflection of a moving-iron ammeter is given by  $I = 4\theta^n$  ampere, where  $\theta$  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.
- Determine an expression for self-inductance of the meter as a function of  $\theta$  and  $n$ .
  - 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  $\pm 1$  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]





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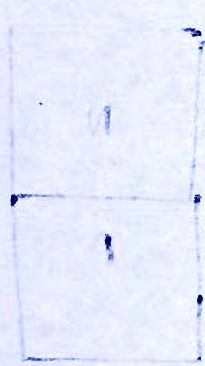
• having equal total...

• equal numbers...

• total of 10 dots

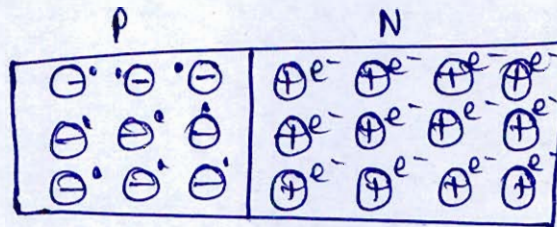


... of the solution has to be for...  
 ... having equal total...  
 ... equal numbers...  
 ... total of 10 dots



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

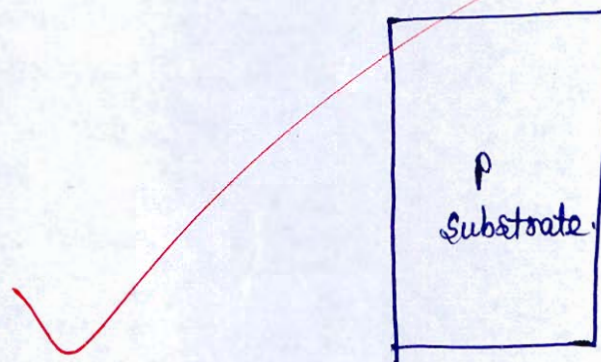
[20 marks]



at the Junction due to hole pair recombination  
 Depletion layer formed.

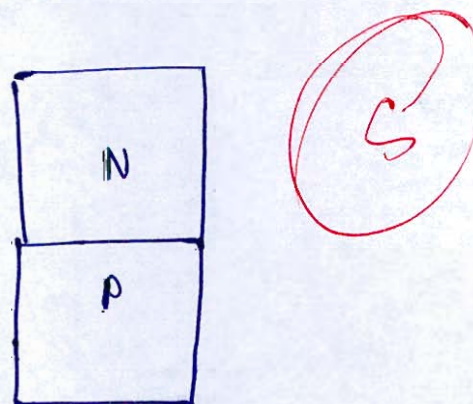
Fabrication Process :

Step 1 : take P-type substrate.

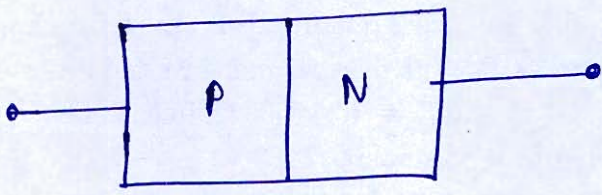


Step 2 :

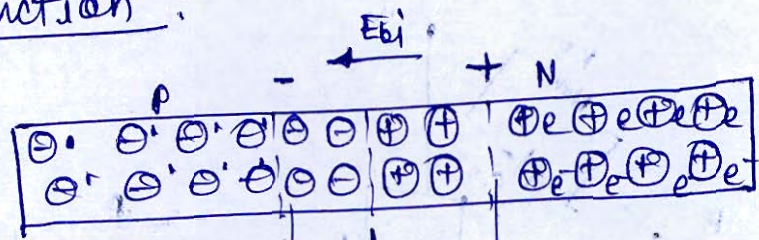
deposited N-type silicon over P-type using  
 chemical vapour deposition



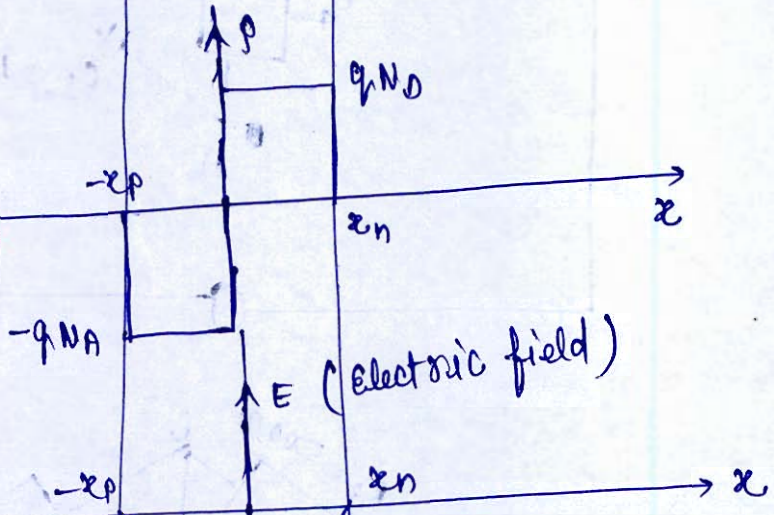
Metallisation: deposit Aluminium using CVD process at ~~base~~ P & N side.



Diode Junction:



*not required*



$$\phi_{bi} = V_T \ln \left( \frac{N_A N_D}{n_i^2} \right)$$

$$\phi = -\frac{\partial E}{\partial x}$$

$$x_n = \sqrt{\frac{2\epsilon_s}{q} \cdot \frac{N_A}{N_D} (\phi_{bi} + V_{BR})}$$

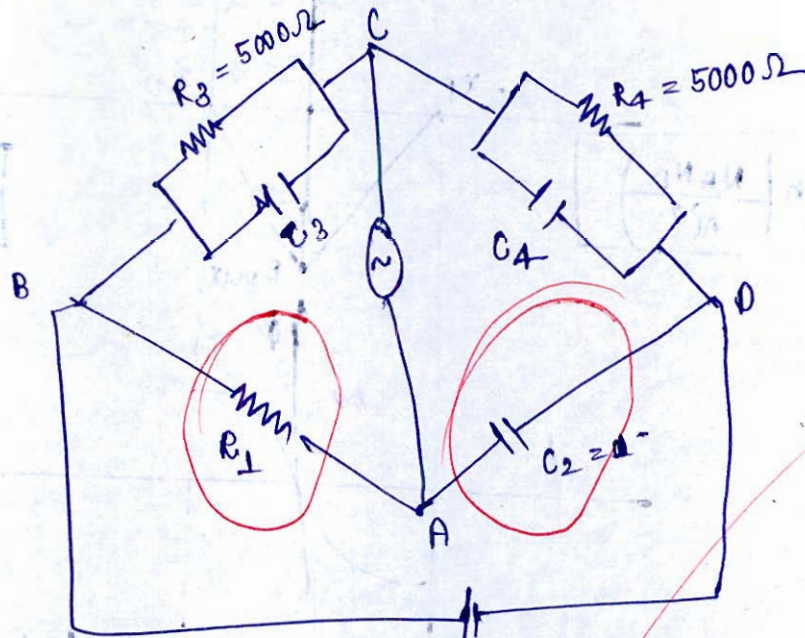
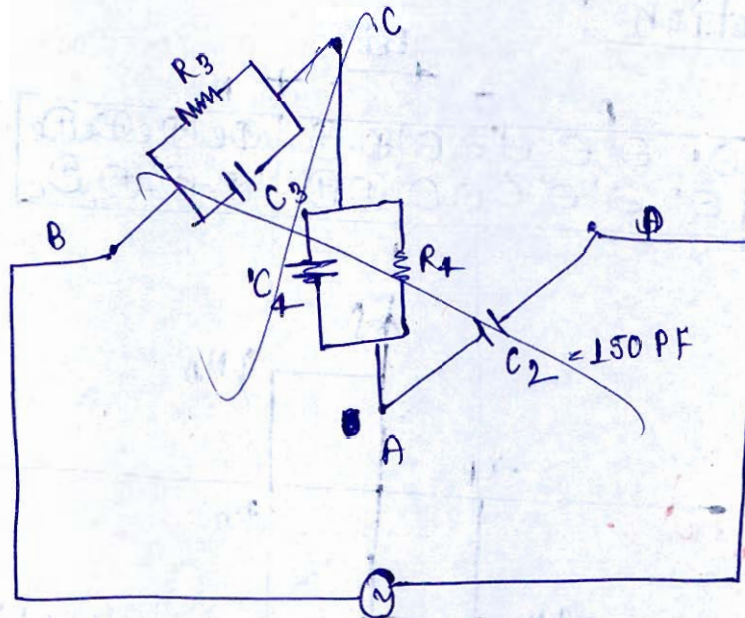
$$x_p = \sqrt{\frac{2\epsilon_s}{q} \cdot \frac{N_D}{N_A} (\phi_{bi} + V_{BR})}$$

depletion width  
 $w = x_n + x_p$

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;  $C_3 = C_4 = 120 \text{ pF}$ ,  $C_2 = 150 \text{ pF}$ ,  $R_3 = R_4 = 5000 \Omega$ . With the specimen inserted these values become  $C_3 = 200 \text{ pF}$ ,  $C_4 = 1000 \text{ pF}$ ,  $C_2 = 900 \text{ pF}$  and  $R_3 = R_4 = 5000 \Omega$ . In each test,  $\omega = 5000 \text{ rad/sec}$ . Find the relative permittivity of the specimen.

[20 marks]



Bridge Balance :

$$Z_3 Z_2 = Z_1 Z_4$$

$$\left[ \frac{R_3 \times \frac{1}{C_3 s}}{R_3 + \frac{1}{C_3 s}} \right] \times \frac{1}{C_2 s} = R_1 \left[ \frac{R_4 \times \frac{1}{C_4 s}}{R_4 + \frac{1}{C_4 s}} \right]$$

$$\frac{R_3}{(R_3 C_3 s + 1) C_2 s} = \frac{R_1 R_4}{R_4 C_4 s + 1}$$

$$R_3 R_4 C_4 s + R_3 = (R_1 R_3 R_4 C_3 s + R_1 R_4) C_2 s$$

$$R_3 R_4 C_4 s + R_3 = R_1 R_3 R_4 C_2 C_3 s^2 + R_1 R_4 C_2 s$$

Comparing  $s^0$ ,  $s^1$ ,  $s^2$  coefficient both side,

$$R_3 R_4 C_4 = R_1 R_4 C_2$$

$$R_3 = -\omega^2 R_1 R_3 R_4 C_2 C_3$$

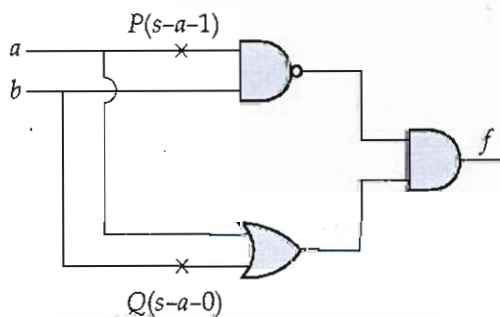


Q.4 (c) Consider the logic circuit shown in the figure below. Two specific faults are identified in the circuit:

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

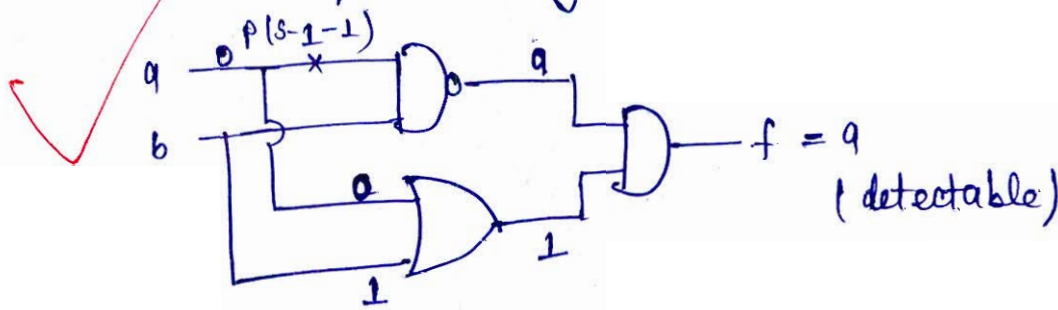
Fault Q: Line  $b$  at the input of the OR gate is stuck-at-0 ( $s-a-0$ )

- (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]

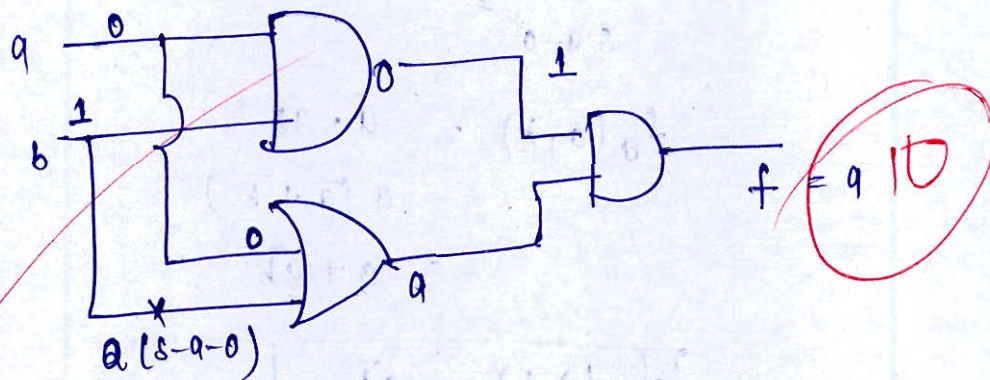
(i) Case (1) Consider fault P only.



drive opposite to fault and try to make fault come at o/p.

Test vector  $(a, b) = (0, 1)$

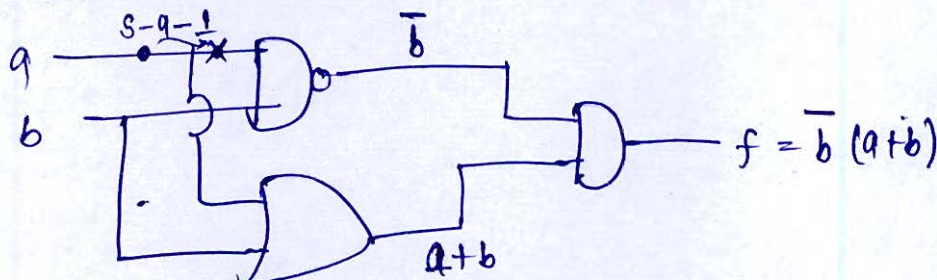
Case (ii) Consider fault a only :



drive '1' at 'b', and make fault out

Test vector,  $(a, b) = (0, 1)$

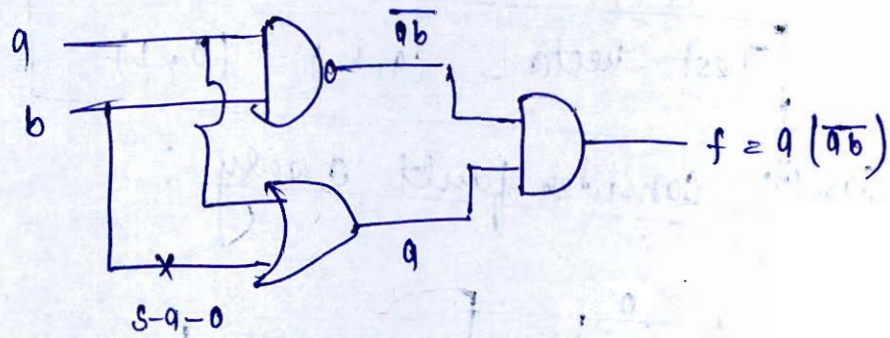
(ii) These two faults are not indistinguishable.  $\therefore$  both the faults have same Test vector and also both are having same output faulty function as shown below, when fault at P consider :



$$f_p(a, b) = \bar{b}(a+b) = a\bar{b} + b\bar{b}$$

$$f_p(a, b) = a\bar{b}$$

When fault  $a$  is considered,



$$\begin{aligned} f_a(a, b) &= a \cdot \overline{ab} \\ &= a(\overline{a} + \overline{b}) \\ &= 0 + a\overline{b} \end{aligned}$$

$$f_a(a, b) = a\overline{b}$$

Hence proved,  $\therefore f_p(a, b) = f_a(a, b) = a\overline{b}$

10

V. Good

**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  $\epsilon_0 = \frac{1}{36\pi} \times 10^{-9}$  F/m.

[12 marks]

Given,

$$r = 0.1 \text{ m}$$

$$\epsilon_r = 1$$

$$d = 0.05 \text{ m}$$

$$V = 50 \cos 10^4 t$$

Maxwell Equation,

$$\nabla \times \vec{H} = \vec{J} + \frac{\partial D}{\partial t}$$

$$\nabla \times \vec{H} = \vec{J} + \frac{\partial D}{\partial t}$$

(!! air)

$$\nabla \times \vec{H} = j\omega \epsilon E$$

Displacement current,

$$I_d = \omega \epsilon E \cdot A$$

$$I_d = \omega \epsilon \cdot \frac{V}{d} \times \pi r^2$$

$$I_d = 10^4 \times \frac{1}{36\pi} \times 10^{-9} \times \frac{50}{0.05} \times \pi \times (0.1)^2$$

$$I_d = 2.77 \times 10^{-6} \text{ A}$$

$$I_d = 2.77 \mu\text{A}$$

$$10.96 \text{ mA}$$

From Eq :

$$J_d = \frac{\partial D}{\partial t}$$

$$[ \because D = \epsilon E \\ \therefore E = \frac{V}{d}$$

*Go through this*

$$J_d = \frac{\epsilon}{d} \frac{\partial V}{\partial t}$$

$$\text{then } I_d = J_d \times \text{Area} = \left( \frac{\epsilon}{d} \pi r^2 \right) \cdot \frac{\partial V}{\partial t}$$

$$I_d = \frac{1}{36\pi} \times 10^{-9} \times \frac{1}{0.05} \times \pi \times (0.1)^2 \frac{d}{dt} 50 \cos(10^4 t)$$

$$I_d = 2.77 \times 10^{-10} (-10^4) \sin(10^4 t)$$

$$I_d = -2.77 \times 10^{-6} \sin(10^4 t) \text{ A}$$

$$I_d = -2.77 \mu\text{A} \sin(10^4 t)$$

$$|I_d| = 2.77 \mu\text{A}$$

- 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  $\cong 2$ )

[12 marks]

Core loss,  $W_I = 2800 \text{ W}$  @ 400 V, 50 Hz

$W_I = 1000 \text{ W}$  @ 200 V, 25 Hz.

As we can see that  $\frac{V}{f} = \text{const}$   $\left[ \frac{400}{50} = \frac{200}{25} = 8 \right]$

$W_I = W_h + W_e$  (where  $W_e = Af^2$ )

$W_h = Bf$

$2800 = A(50)^2 + B(50)$  — (1)

$1000 = A(25)^2 + B(25)$  — (2)

By solving (1) & (2)

$A = 0.64$

$B = 24$

Hysteresis and eddy current loss at  $V = 400 \text{ V}$ ,  $f = 50 \text{ Hz}$ ,

$W_e = Af^2 = 0.64 \times (50)^2 = 1600 \text{ watt}$

$$W_h = 0.8 f = 24 \times 50$$

$$W_h = 1200 \text{ watt}$$

~~hysteresis and eddy current at~~

$$V = 000 \text{ V}, f = 25 \text{ Hz}$$

$$\frac{V}{f} = \frac{000}{25} = 0.2 \text{ (Not const.)}$$

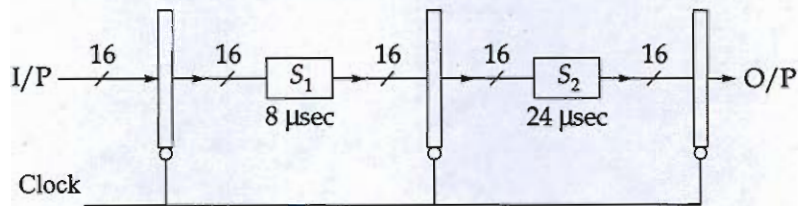
$$W_e = k_1 V_1^2 f^{0.6}$$

$$W_h = k_2 V_1^2 f^{-2}$$

*incomplete esb*



- 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]

$$\begin{aligned}
 & \frac{1}{(x^2-1)^2} = \frac{1}{(x-1)^2(x+1)^2} \\
 & \frac{1}{(x^2-1)^2} = \frac{A}{x-1} + \frac{B}{(x-1)^2} + \frac{C}{x+1} + \frac{D}{(x+1)^2} \\
 & \frac{1}{(x^2-1)^2} = \frac{A(x-1)(x+1)^2 + B(x+1)^2 + C(x-1)^2 + D(x-1)(x+1)}{(x-1)^2(x+1)^2} \\
 & \frac{1}{(x^2-1)^2} = \frac{A(x^2-1)(x+1) + B(x^2+2x+1) + C(x^2-2x+1) + D(x^2-1)}{(x-1)^2(x+1)^2} \\
 & \frac{1}{(x^2-1)^2} = \frac{A(x^3+x^2-x-1) + B(x^2+2x+1) + C(x^3-2x^2+x+1) + D(x^2-1)}{(x-1)^2(x+1)^2} \\
 & \frac{1}{(x^2-1)^2} = \frac{(A+C)x^3 + (A+B-2C+D)x^2 + (-A+2B+C-D)x - (A+B+C-D)}{(x-1)^2(x+1)^2} \\
 & \frac{1}{(x^2-1)^2} = \frac{(A+C)x^3 + (A+B-2C+D)x^2 + (-A+2B+C-D)x - (A+B+C-D)}{(x-1)^2(x+1)^2}
 \end{aligned}$$

fact x^2-1 = (x-1)(x+1) = (x-1)^2(x+1)^2

$$\frac{1}{(x^2-1)^2} = \frac{A}{x-1} + \frac{B}{(x-1)^2} + \frac{C}{x+1} + \frac{D}{(x+1)^2}$$

$$\frac{1}{(x^2-1)^2} = \frac{A(x-1)(x+1)^2 + B(x+1)^2 + C(x-1)^2 + D(x-1)(x+1)}{(x-1)^2(x+1)^2}$$



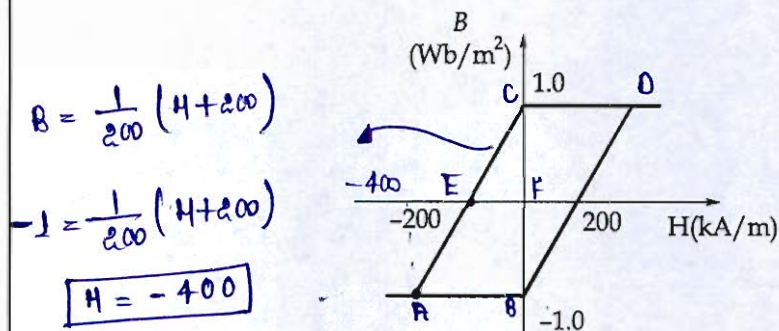
$$\frac{1}{(x^2-1)^2} = \frac{A(x^2-1)(x+1) + B(x^2+2x+1) + C(x^2-2x+1) + D(x^2-1)}{(x-1)^2(x+1)^2}$$

Equating coefficients of like terms

$$\frac{1}{(x^2-1)^2} = \frac{(A+C)x^3 + (A+B-2C+D)x^2 + (-A+2B+C-D)x - (A+B+C-D)}{(x-1)^2(x+1)^2}$$

Equating coefficients of like terms

- 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]

① Hysteresis loss per cycle = Area under hysteresis loop.  
 = Area  $\Delta ABC$  + Area  $\Delta BCD$

= 2 Area  $\Delta ABC$

= 2 [Area  $\Delta CEF$  + Area  $\square EFAB$ ]

= 2 [  $\frac{1}{2} \times 200 \times 10^3 \times 1 + \frac{1}{2} (200 + 400) \times 10^3 \times 1$  ]

=  $800 \times 10^3$  watt

=  $800 \text{ kW}$

6

$(BH)_{\max}$  will be at point D :

$(BH)_{\max} = 1 \times 400 \times 10^3$

$(BH)_{\max} = 400 \text{ kW}$

$\therefore$  Max  $(BH)$  will get at saturation point.

Q.5 (e) Explain the following phenomena with respect to superconductors:

- (i) Meissner effect    (ii) Silsbee rule    (iii) Frequency effect

[4 + 4 + 4 marks]

Meissner effect : According to Meissner effect superconductor is a perfectly diamagnetic material.

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

$$\chi_m = \frac{\vec{M}}{H} = \mu_r - 1$$

$$\chi_m = \frac{\vec{M}}{H} = -1$$

$$\boxed{\vec{M} = -H}$$

Susceptibility  $\boxed{\chi_m = -1}$

Silsbee Rule : According to Silsbee rule not only external magnetic field but due to current flow in to superconductor develops a electric field if it reaches more than critical magnetic field it can destroy the superconductivity property of superconductor.

Frequency Effect : At high frequency superconductor loses their superconductivity property.

At low temp entropy decreases in superconducting state.

And entropy increases from superconducting state to normal state.

At high frequency superconductor loses their superconductivity property.

At low temp entropy decreases in superconducting state.

And entropy increases from superconducting state to normal state.



At high frequency superconductor loses their superconductivity property.

At low temp entropy decreases in superconducting state.

And entropy increases from superconducting state to normal state.

- 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]



- 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]





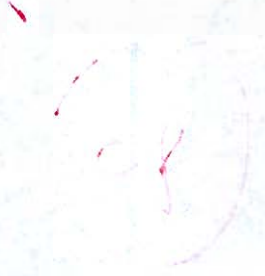
- Q.6 (c) A particular lossless material has  $\mu_r = 4$  and  $\epsilon_r = 9$ . A 10 MHz uniform plane wave is propagating in the  $\hat{a}_y$  direction with  $E_{x_0} = 400$  V/m and  $E_{y_0} = E_{z_0} = 0$  at  $P(0.6, 0.6, 0.6)$  and  $t = 60$  ns.

Determine:

- (i)  $\beta, \lambda, v_p$  and  $\eta$       (ii)  $E(t)$       (iii)  $H(t)$

[20 marks]

Q. 100



100. A circle of radius 5 cm is shown.

A horizontal line segment is drawn from the center to the circumference.

The length of this segment is 3 cm.

Find the length of the chord.

$$r = 5 \text{ cm}$$

$$OC = 3 \text{ cm}$$

$$AC^2 = r^2 - OC^2$$

$$AC^2 = 5^2 - 3^2$$

$$AC^2 = 25 - 9$$

$$AC^2 = 16$$

$$AC = 4$$



Q. 101

A circle of radius 5 cm is shown.

A horizontal line segment is drawn from the center to the circumference.

The length of this segment is 3 cm.

Find the length of the chord.

$$r = 5 \text{ cm}$$

$$OC = 3 \text{ cm}$$

$$AC^2 = r^2 - OC^2$$

$$AC^2 = 5^2 - 3^2$$

$$AC^2 = 25 - 9$$

$$AC^2 = 16$$

$$AC = 4$$

∴ Length of chord AB = 8 cm

Q. 102

Q. 103

Q. 104

$$AB^2 = AC^2 + BC^2$$

$$AB^2 = 4^2 + 3^2$$

$$AB^2 = 16 + 9$$

$$AB^2 = 25$$

$$AB = 5$$

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]

Given,

$$T_{st} = 100\% \cdot T_{FL}$$

$$T_{st} = T_{FL} \quad \text{--- (1)}$$

$$T_{max} = 200\% \cdot T_{FL}$$

$$T_{max} = 2 T_{FL} \quad \text{--- (2)}$$

$$\text{Eq. (1)} \div \text{(2)}$$

$$\frac{T_{st}}{T_{max}} = \frac{1}{2}$$

We know

$$\frac{T}{T_{max}} = \frac{2}{\frac{s}{s_{max}} + \frac{s_{max}}{s}}$$

then

$$\frac{1}{2} = \frac{2}{\frac{s=1}{s_{max}} + \frac{s_{max}}{s=1}}$$

[ $\because s_{st} = 1$ ]  
slip at starting

$$s_{max} \times 4 = 1 + s_{max}^2$$

$$s_{max}^2 - 4s_{max} + 1 = 0$$

By solving

$$s_{max} = 3.73, 0.268 \quad (\because s < 1)$$

(i)

$$\boxed{s_{max} = 0.268}$$

From Eq (2)

$$\frac{T_{F.L}}{T_{max}} = \frac{1}{2} = \frac{2}{\frac{s_{F.L}}{s_{max}} + \frac{s_{max}}{s_{F.L}}}$$

$$\frac{s_{F.L}}{0.260} + \frac{0.260}{s_{F.L}} = 4$$

$$s_{F.L}^2 + (0.260)^2 = 4 \times 0.260 \times s_{F.L}$$

$$s_{F.L}^2 - 1.072 s_{F.L} + 0.0710 = 0$$

By solving

$$s_{F.L} = 1.0002, 0.0710 \quad (\because s < 1)$$

(ii)

$$s_{F.L} = 0.0710$$

(iii)

We know  $s_{F.L} \left( \frac{I_{st}}{I_{F.L}} \right)^2 = \frac{T_{st}}{T_{F.L}}$

By putting value,

$$0.0710 \left( \frac{I_{st}}{I_{F.L}} \right)^2 = 1$$

$$\frac{I_{st}}{I_{F.L}} = \sqrt{\frac{1}{0.0710}}$$

$$I_{st} = 3.731 I_{F.L}$$

$$I_{st} = 3.731 \text{ p.u. of } I_{F.L}$$

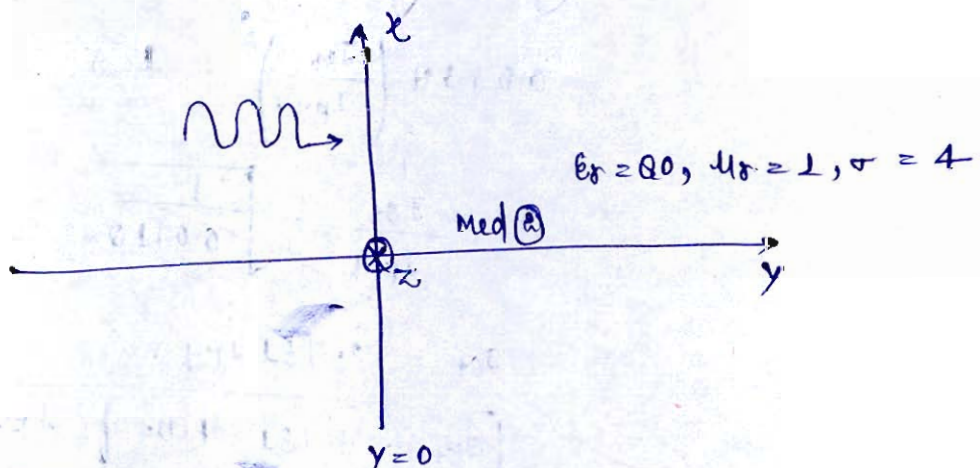
- Q.7 (b) The magnetic field intensity of a linearly polarized uniform plane wave propagating in the +Y-direction in sea water ( $\epsilon_r = 80$ ,  $\mu_r = 1$ ,  $\sigma = 4 \text{ S/m}$ ) at  $y = 0$  is

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

At  $y = 0$ , determine the following :-

- The attenuation constant, intrinsic impedance, the wavelength and skin depth.
- The location at which the amplitude of  $\vec{H}$  is  $0.01 \text{ A/m}$ .
- The expression for  $E(y, t)$  and  $H(y, t)$  at  $y = 0.5 \text{ m}$  as functions of  $t$ .

[20 marks]



medium check:

$$\frac{\sigma}{\omega \epsilon} = \frac{4}{10^{10} \pi \times 80 \times 8.85 \times 10^{-12}}$$

$$= 0.1789$$

$$\therefore 0.01 \leq \frac{\sigma}{\omega \epsilon} < 100$$

So medium is partially conducting.

Attenuation Const,

$$\alpha = \frac{\omega}{c} \sqrt{\frac{\mu_r \epsilon_r}{2} \left[ \sqrt{1 + \left(\frac{\sigma}{\omega \epsilon}\right)^2} - 1 \right]}$$

$$\alpha = \frac{10^{10} \pi}{3 \times 10^8} \sqrt{\frac{80}{2} \left( \sqrt{1 + (0.1789)^2} - 1 \right)}$$

$$\alpha = \frac{100\pi}{3} \sqrt{40 \times 0.0158}$$

$$\alpha = 93.452 \text{ NP/m}$$

Intrinsic Impedance,

$$\eta = \frac{120\pi \sqrt{\frac{\mu_r}{\epsilon_r}}}{\left[ 1 + \left(\frac{\sigma}{\omega \epsilon}\right)^2 \right]^{1/4}} \angle \frac{1}{2} \tan^{-1} \left( \frac{\sigma}{\omega \epsilon} \right)$$

$$\eta = \frac{120\pi \sqrt{\frac{1}{80}}}{\left[ 1 + (0.1789)^2 \right]^{1/4}} \angle \frac{1}{2} \tan^{-1} (0.1789)$$

$$\eta = 41.818 \angle 5.071^\circ \Omega$$

$$\beta = \frac{\omega}{c} \sqrt{\frac{\mu_r \epsilon_r}{2} \left[ \sqrt{1 + \left(\frac{\sigma}{\omega \epsilon}\right)^2} + 1 \right]}$$

$$\beta = \frac{100\pi}{3} \sqrt{40 \left( \sqrt{1 + (0.1789)^2} + 1 \right)}$$

$$\beta = 940.35 \text{ rad/m}$$

$$\beta = \frac{2\pi}{\lambda} \Rightarrow \text{wavelength } \lambda = \frac{2\pi}{\beta}$$

$$\lambda = 6.68 \times 10^{-3} \text{ m}$$

$$\text{skin depth, } \delta = \frac{1}{\sqrt{\pi f \mu \sigma}} = \frac{1}{\alpha}$$

$$\delta = \frac{1}{0.3452}$$

$$\delta = 0.01190 \text{ m}$$

(ii)

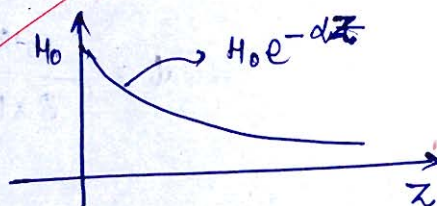
$$H = H_0 e^{-\alpha z}$$

$$0.01 = 0.1 e^{-\alpha y}$$

$$e^{\alpha y} = 10$$

$$\alpha y = \ln 10$$

$$y = \frac{\ln 10}{0.3452} \Rightarrow y = 0.02759 \text{ m}$$



(iii)

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

$$\text{at } y=0.5: H(y=0.5, t) = 0.1 \sin\left(10^{10} \pi t - \frac{\pi}{3} - 470.175\right) \hat{a}_x \text{ A/m}$$

$$\begin{array}{l} a_x \rightarrow a_y \\ \uparrow a_z \end{array}$$

$$\begin{array}{l} a_E \rightarrow a_H \\ \uparrow a_K \end{array}$$

$$E(y, t) = \eta [\vec{H} \times \hat{a}_K]$$

$$= 41.010 \angle 5.071^\circ \left[ 0.1 \sin(10^{10} \pi t - 60^\circ - 470.175) \hat{a}_x \times \hat{a}_y \right]$$

$$= 4.1010 \sin(10^{10} \pi t - 65.071^\circ - 470.175) \hat{a}_z$$

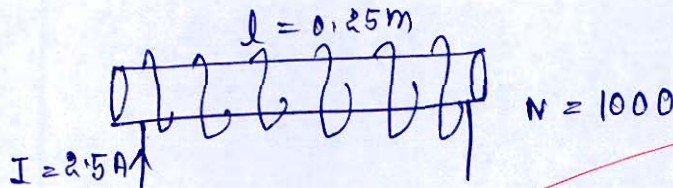
$$E(0.5, t) = 4.1010 \sin(10^{10} \pi t - 1.135 - 470.175) \hat{a}_z$$

$$E(0.5, t) = 4.1010 \sin(10^{10} \pi t - 471.31) \hat{a}_z$$

- 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  $1.04 \times 10^{-8} \text{ Wb/m}^2$ . Find the magnetic susceptibility of oxygen.
- (ii) Write a short note on optical properties of semiconducting nanoparticles.

[10 + 10 marks]

①



In vacuum,  $H = \frac{NI}{l} = \frac{1000 \times 2.5}{0.25}$

$$H = 10,000 \text{ A/m}$$

Increase of magnetic density  $\Delta B = 1.04 \times 10^{-8} \text{ Wb/m}^2$

$$\therefore B = \mu_0 \mu_r H$$

$$\mu_r = \frac{B}{\mu_0 H}$$

$$\mu_r = \frac{1.04 \times 10^{-8} + 4\pi \times 10^{-7} \times 10000}{4\pi \times 10^{-7} \times 10000}$$

$$\mu_r = 0.276 \times 10^{-7}$$

$$\mu_r = 1.000000020$$

$$\chi_m = \mu_r - 1$$

$$\chi_m = 0.276 \times 10^{-7}$$

magnetic  
Susceptibility



$$\frac{3 \times 10^4 \times 10^4}{10^4} = 10^4$$

$$\boxed{10^4 \times 10^4 = 10^8}$$

Handwritten text, possibly a question or a note, mentioning '10^4' and '10^8'.

$$\frac{10^4 \times 10^4}{10^4} = 10^4$$

$$\boxed{10^4 \times 10^4 = 10^8}$$

$$\frac{10^4 \times 10^4}{10^4} = 10^4$$

$$\boxed{10^4 \times 10^4 = 10^8}$$

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

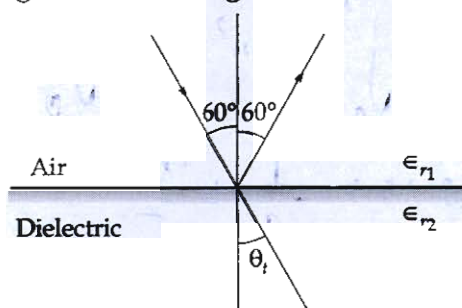
$$\vec{E} = \frac{100}{r} \sin \theta \cos(\omega t - \beta r) \hat{a}_\theta \text{ V/m}$$

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

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  $r = 1 \text{ km}$   $\left(0 \leq \theta \leq \frac{\pi}{2}\right)$ .

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



[10 + 10 marks]

We know from Poynting vector theorem,

$$P_{avg} = \frac{1}{2} [\vec{E} \times \vec{H}^*]$$

$$= \frac{1}{2} \left[ \frac{100 \sin \theta}{r} \hat{a}_\theta \times \frac{0.265 \sin \theta}{r} (-\hat{a}_\phi) \right]$$

$$P_{avg} = -\frac{13.25}{r^2} \sin^2 \theta \hat{a}_r \text{ watt/m}^2$$

New Avg power crossing,  $r = 1 \text{ km}$  ( $0 \leq \theta \leq \frac{\pi}{2}$ )

cy. co. sy  $(\hat{a}_r \hat{a}_\theta \hat{a}_\phi) \mid dr \underline{d\theta} \underline{d\phi} \mid \mid r \underline{r \sin \theta}$

$$P_{avg} = \oint P_{avg}(\vec{r}) \cdot \vec{ds}$$

$$\text{where } \vec{ds} = r^2 \sin \theta d\theta d\phi \hat{a}_r$$

$$P_{avg} = \int \frac{-13.25}{r^2} \sin^2 \theta \cdot r^2 d\theta d\phi$$

$$= \int -13.25 \sin^2 \theta d\theta d\phi$$

$$= -13.25 \int_0^{\pi/2} \sin^2 \theta \cdot d\theta \int_0^{2\pi} d\phi$$

$$= -13.25 \times \frac{1}{2} \times \frac{\pi}{2} \times 2\pi$$

$$P_{avg} = -65.306 \text{ watt}$$

$$|P_{avg}| = 65.306 \text{ watt}$$

(ii) From Snell's law,

$$\sqrt{\epsilon_{r_1}} \sin \theta_i = \sqrt{\epsilon_{r_2}} \sin \theta_t$$

$$\sqrt{1} \sin 60^\circ = \sqrt{\epsilon_{r_2}} \sin \theta_t$$

$$\frac{\sqrt{3}}{2} = \sqrt{\epsilon_{r_2}} \sin \theta_t \quad \text{--- (1)}$$

$\therefore$  Reflected wave is linearly polarised.

$$\boxed{\theta_i = \theta_B}$$

We know  $\tan \theta_B = \sqrt{\frac{\epsilon_{r_2}}{\epsilon_{r_1}}}$

$$\tan 60^\circ = \sqrt{\frac{\epsilon_{r_2}}{1}}$$

$$\sqrt{3} = \sqrt{\epsilon_{r_2}}$$

$$\boxed{\epsilon_{r_2} = 3}$$

10

from eq (1)

$$\frac{\sqrt{3}}{2} = \sqrt{3} \sin \theta_t$$

$$\theta_t = \sin^{-1} \left( \frac{1}{2} \right)$$

$$\boxed{\theta_t = 30^\circ}$$

Brewster Angle  $\boxed{\theta_B = 60^\circ}$

*[Faint handwritten notes and diagrams are visible in the main body of the page, including mathematical expressions and small sketches.]*

- 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]

Given,  $\eta_{F.L.} = \eta_{\frac{1}{2} F.L.} = 0.98$  (at unity p.f.)

We know 
$$\eta = \frac{x(\text{kVA}) \cos \phi}{x(\text{kVA}) \cos \phi + x^2 (w_{Cu} + w_I)}$$

$$\frac{1 \times 0.200 \times 1}{0.200 \times 1 + (w_{Cu})_{F.L.} + w_I} = \frac{0.5 \times 200}{0.5 \times 200 + \frac{(w_{Cu})_{F.L.}}{4} + w_I} = 0.98$$

From this :

$$200 + w_{Cu} + w_I = 204.0816$$

$$w_{Cu} + w_I = 4.0816 \quad \text{--- (1)}$$

Another relation,

$$100 + 0.25 w_{Cu} + w_I = 102.040816$$

$$0.25 w_{Cu} + w_I = 2.040816 \quad \text{--- (2)}$$

By solving (1) & (2)

$$w_{Cu, F.L.} = 2.72104 \text{ kW}$$

$$w_I = 1.36055 \text{ kW}$$

p.f. at No load,  $\cos \phi_0 = 0.2$  lag

Regulation, at  $\cos \phi_2 = 0.8$

$$\frac{I_2 (R_{eq}) \cos \phi_2 + I_2 (X_{eq}) \sin \phi_2}{V_{rated}} = 0.04$$

$$I_2 = \frac{200000}{304}$$

$$I_2 = 520.03 \text{ A}$$

$$\frac{I_2 (0.8(\text{Req})_{\text{ev}} + 0.6(\text{Xeq})_{\text{ev}})}{304} = 0.04$$

$$0.8(\text{Req})_{\text{ev}} + 0.6(\text{Xeq})_{\text{ev}} = 0.02949 \quad \text{--- (1)}$$

From copper loss,  $I_2^2(\text{Req})_{\text{ev}} = 2721.04$

$$(\text{Req})_{\text{ev}} = \left[ \frac{2721.04}{520.03^2} \right]$$

$$(\text{Req})_{\text{ev}} = 10.427 \text{ m}\Omega$$

From Eq (1)

$$(\text{Xeq})_{\text{ev}} = 35.247 \text{ m}\Omega$$

From Iron loss,

$$W_I = 1360.55 = V_1 I_0 \cos \phi_0$$

$$I_0 = \frac{1360.55}{6600 \times 0.2}$$

$$I_0 = 1.0307 \text{ A}$$

$$I_w = I_0 \cos \phi_0$$

$$I_w = 0.2061 \text{ A}$$

$$R_w = \frac{V_1}{I_w} = \frac{6600}{0.2060}$$

$$R_w = 32023.28 \Omega$$

$$I_m = I_0 \sin \phi_0$$

$$I_m = 1.0098 \text{ A}$$

$$X_m = \frac{V_1}{I_m} = \frac{6600}{1.0098}$$

$$X_m = 653.947 \Omega$$

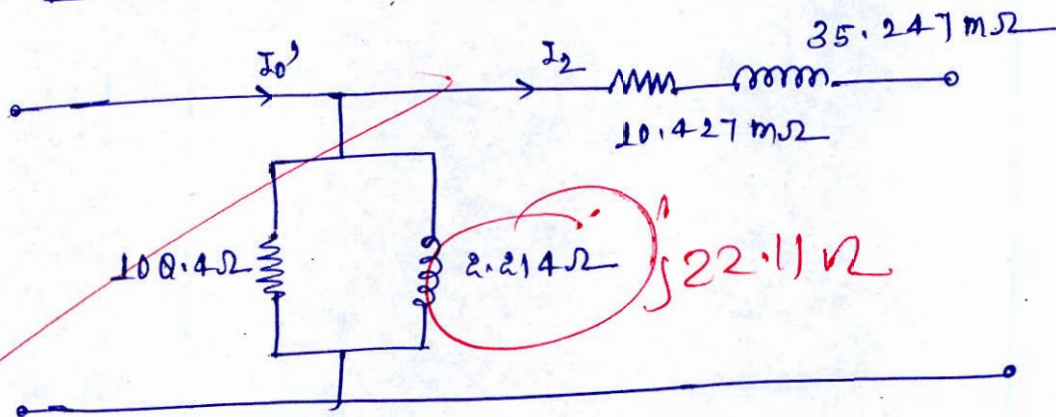
Referring to  $lv$  side.

$$R_w' = R_w \left( \frac{V_2}{V_1} \right)^2$$

$$R_w' = 100.4 \Omega$$

$$X_m' = X_m \left( \frac{V_2}{V_1} \right)^2$$

$$X_m = 2.214 \Omega$$



- 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]

$(\frac{1}{2})^2 = \frac{1}{4}$   
 $(\frac{1}{3})^2 = \frac{1}{9}$   
 $(\frac{1}{4})^2 = \frac{1}{16}$

$(\frac{1}{5})^2 = \frac{1}{25}$   
 $(\frac{1}{6})^2 = \frac{1}{36}$   
 $(\frac{1}{7})^2 = \frac{1}{49}$

$(\frac{1}{8})^2 = \frac{1}{64}$   
 $(\frac{1}{9})^2 = \frac{1}{81}$   
 $(\frac{1}{10})^2 = \frac{1}{100}$

$(\frac{1}{11})^2 = \frac{1}{121}$

$(\frac{1}{12})^2 = \frac{1}{144}$

$(\frac{1}{13})^2 = \frac{1}{169}$   
 $(\frac{1}{14})^2 = \frac{1}{196}$   
 $(\frac{1}{15})^2 = \frac{1}{225}$

$(\frac{1}{16})^2 = \frac{1}{256}$   
 $(\frac{1}{17})^2 = \frac{1}{289}$   
 $(\frac{1}{18})^2 = \frac{1}{324}$

$(\frac{1}{19})^2 = \frac{1}{361}$   
 $(\frac{1}{20})^2 = \frac{1}{400}$



**Space for Rough Work**

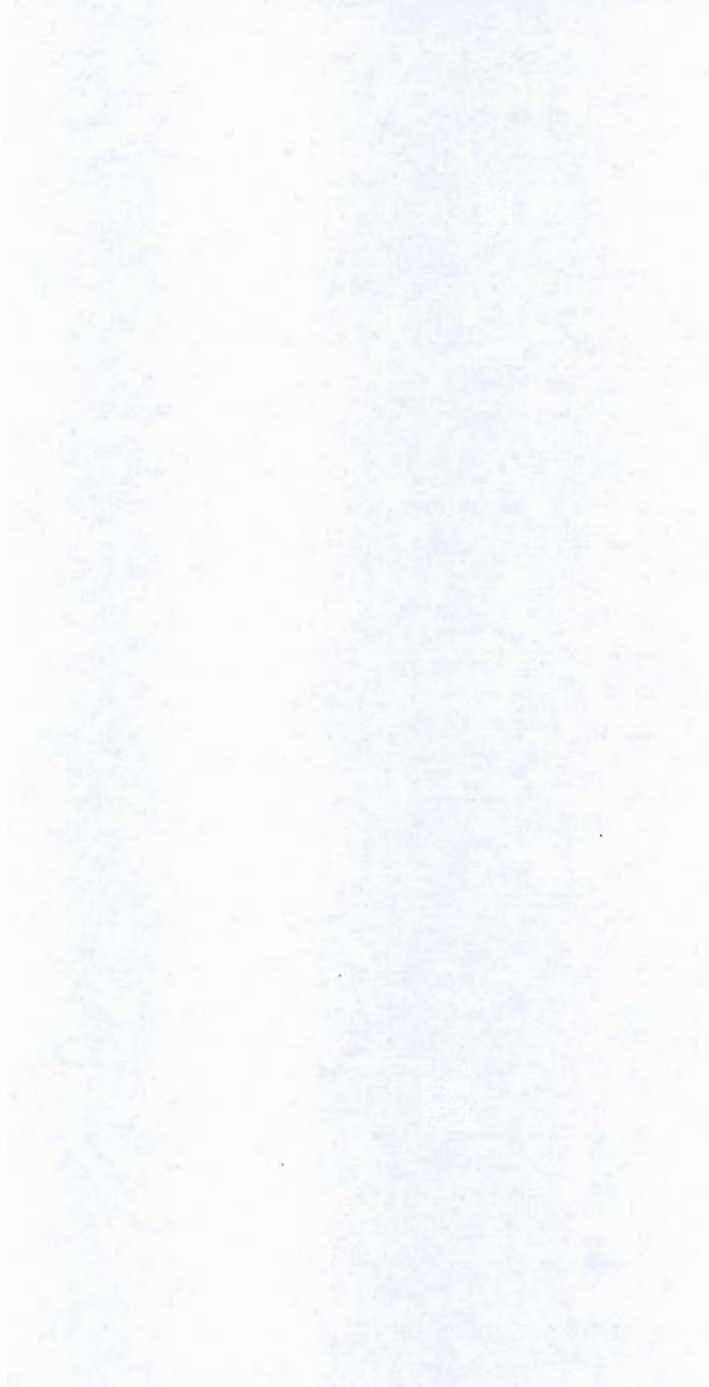
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**Space for Rough Work**

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**Space for Rough Work**

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**Space for Rough Work**

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**Space for Rough Work**

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