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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	21
Q.2	33
Q.3	18
Q.4	
Section-B	
Q.5	48
Q.6	40
Q.7	
Q.8	
Total Marks Obtained	150

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

o Good - - you can do better
o keep it up —
o revise some theory.

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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.

Do not write in this margin

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%

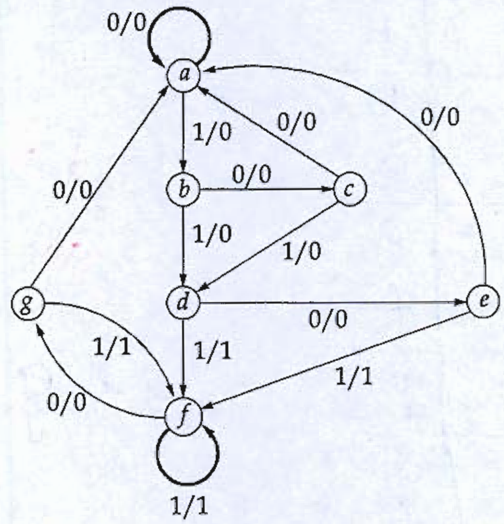
The dial is set at 4639 Ω.

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

[12 marks]

decade a ~~of~~ 10×1000Ω ±.1% Max : ~~9000~~Ω

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]

State	Present state input	output	Next state
a	0	0	a
	1	0	b
b	0	0	c
	1	0	d
c	0	0	a
	1	0	d
d	0	0	e
	1	1	f
e	0	0	a
	1	1	f
f	0	0	g
	1	1	f
g	0	0	a
	1	1	f

(b, c) same

(d, e) same

5

from this table

– State d and e have same output and next state

– b & c also have same,

State	PS. input	output	NS
a	0	0	a
	1	0	b
b	0	0	b
	1	0	d
d	0	0	a
	1	1	f
f	0	0	g
	1	1	f
g	0	0	a
	1	1	f

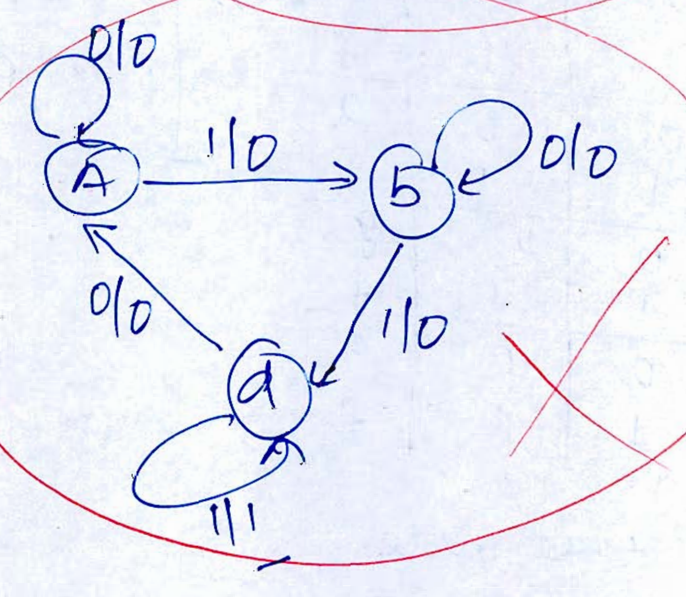
d & f are equivalent

d & g have same.

→ Table

State	PS inp	PS o/p	N.S
a	0	0	a
	1	0	b
b	0	0	b
	1	0	d
d	0	0	a
	1	1	f
~~b~~ f	0	0	d
	1	1	f

] Same.



e => 0

Do not write in this margin

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]

$B = 1.1\ mWb/m^2$, $D = 2.5\ cm$, $N = 500$

$V = 100V$, $R = 2000\Omega$

current in moving coil

$I = \frac{V}{R} = \frac{100}{2000} = 0.05A$

$A = \frac{\pi d^2}{4} = \frac{\pi(2.5)^2}{4} = 4.91\times10^{-4}\ m^2$

Torque = $BINA\sin\theta$

$T = 1.1\times10^{-3}\times500\times0.05\times4.91\times10^{-4}\times\sin45^\circ$

$= 9.55\times10^{-6}\ Nm$

at $\theta = 90^\circ$

$T = 1.1\times10^{-3}\times500\times0.05\times4.91\times10^{-4}\times\sin90^\circ$

$= 1.35\times10^{-5}\ Nm$

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

[12 marks]

Diffusion.

Movement of particles from high concn to low concn due to random motion.

Fick's first law.

$$J = -D\frac{dC}{dx}$$

where

$\frac{dc}{dx}$: concn gradient

D : Diffusion constant

J : flux

Fick's 2nd law.

$$\frac{\partial c}{\partial t} = D\frac{d^2c}{\partial x^2}$$

- describes how conc^n changes with time.

✓ (3)

Incomplete.

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]

at $T = 0^\circ C = 273K$ = $R_1 = 3980$

at $T = 50^\circ C = 323K$ $R_2 = 794\ \Omega$

$$R_T = aR_0 e^{b/T}$$

at $T = 273K$

$$3980 = ae^{b/273} \quad -(I)$$

at $T = 323K$ $\quad 794 = ae^{b/323} \quad -(II)$

divide eqn (I) from (II)

$$e^{b\left[\frac{1}{273}-\frac{1}{323}\right]} = \frac{3980}{794}$$

$$b\left[5.67\times10^{-4}\right] = \ln 5.01$$

$$\boxed{b = 2842.03}$$

put value of b in eqn (I)

$$a = \frac{3980}{e^{\frac{2842.03}{273}}}$$

$$a = \frac{3980}{e^{10.41}}$$

$$a = 0.1199$$

$$\boxed{a = 0.12}$$

$$\boxed{b = 2842.03}$$

12

Do not write in this margin

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]

$N_A = 10^{17} cm^{-3}$, $N_0 = 10^{22} cm^{-3}$, $t = 1$ hour
$= 60 \times 60 s$
$= 3600$

(1)

$Q = 2N_0 \sqrt{\frac{Dt}{\pi}}$

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

$= 6.76 \times 10^{16}$ atom/cm²

10

Junction depth

$N_A = N_0 \, erfc\left(\frac{x_j}{2\sqrt{Dt}}\right)$

$10^{17} = 10^{22} \, erfc\left(\frac{x_j}{2\sqrt{Dt}}\right)$

$10^{-5} = erfc\left(\frac{x_j}{2\sqrt{Dt}}\right)$

$x_j = 3.12 \times 2\sqrt{Dt}$

$= 6.24\sqrt{10^{-14} \times 3600}$ cm

$= 3.75 \times 10^{-5}$ cm

(ii) $t = 1 + 2 = 3$ hrs

$= 10800$ second

New junction depth

$x_j = 3.12 \times 2\sqrt{Dt}$

$= 6.24\sqrt{10^{-14} \times 10800}$

$x_j = 6.48 \times 10^{-5}$ cm

Surface concentration

$N_s = \frac{Q}{\sqrt{\pi D t}}$

$= \frac{6.76 \times 10^{16}}{\sqrt{\pi \times 10^{-14} \times 10800}}$

$= \frac{6.76 \times 10^{16}}{1.84 \times 10^{-5}}$ cm³

$= 3.67 \times 10^{21}$ /cm³

final surface concentration

$= 3.67 \times 10^{21}$ /cm³

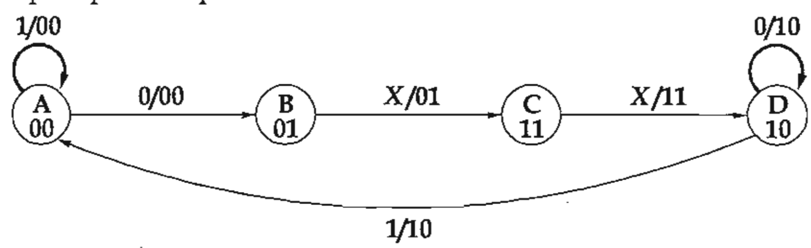
Go through solution.

$t = 7200$ sec

$t = 2$ hours

1

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]

PS	Input	NS	Output
A(00)	0	B	00
	1	A	00
B(01)	0	C	01
	1	C	01
C(11)	0	D	11
	1	D	11
D(10)	0	D	10
	1	A	00

1

Incomplete

S-R flip flop excitation table.

Q_n	Q_{n+1}	S	R
0	0	0	X
0	1	1	0
1	0	0	1
1	1	X	0

✓ (1)

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:

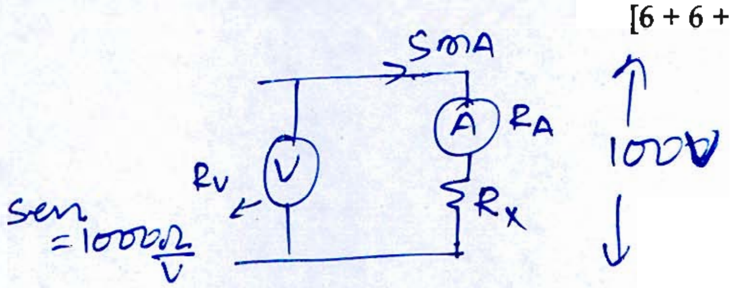
1. Apparent resistance of the unknown resistor.
2. Actual resistance of the unknown resistor.
3. %error in the measurement.

(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]



(1) Sensitivity of voltmeter = 1000Ω/V

Resistance of voltmeter = 1000×150

= 150 KΩ

Ammeter reads = 5mA

Apparent resistance = $\frac{V}{I_m}$

= $\frac{100V}{5mA}$

1. Apparent resist. = 20KΩ

2. Actual resistance = ~~20K || 150K~~
Voltmeter R_V || with R

R_{app} = R_{actual} || R_V

20K = R || 150K

$\frac{1}{20K} = \frac{1}{R} + \frac{1}{150K} \Rightarrow \frac{1}{R} = \frac{1}{20} - \frac{1}{150}$

Do not write in this margin

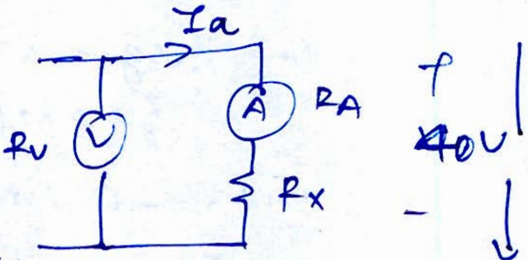
$R_{actual} = 23.07\,\Omega$

(iii) $error = \frac{R_{app} - R_{actual}}{R_{actual}} \times 100 = \frac{20-23}{23} \times 100$

$= -13.37\%$

(b) When milliammeter reads 800mA & volt. reads 40V on its scale.

Voltmeter reads – 40V



~~RD = 1000×150~~
~~= 50kΩ~~

$R_V = 150k\Omega$

$I_a = 800mA$

(i). Apparent resistance of the unknown

$\Rightarrow \frac{40}{800} k\Omega$

$= \frac{1}{20} k\Omega$

$= 0.05\, k\Omega = 50\,\Omega$

(ii) Actual resistance

$\frac{1}{50} = \frac{1}{R} + \frac{1}{150K}$

$\frac{1}{R} = \frac{1}{50} - \frac{1}{150000}$

$R = \frac{50 \times 150 \times 10^3}{149950}\,\Omega$

$= 50.01$

20

$error = \frac{50 - 50.01}{50.01} \times 100$

$= 0.0334\%$

Cause of error:

- voltmeter draws a current
  - loading effect

Minimization:

use high sensitivity of resistance
- high value of voltmeter resistance.
- use ammeter (low resistance)

→

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]

$I = 4\theta^n \qquad K = 0.16$ N-m/rad

Moving Iron ammeter

Deflection Torque $T_d = \frac{I^2}{2}\frac{dL}{d\theta}$

and controlling torque $T_c = K\theta$

$T_d = T_c$

$\theta = \frac{1}{2}\frac{I^2}{K}\frac{dL}{d\theta}$

put $I = 4\theta^n$

$\theta = \frac{1 \times 16\theta^{2n}}{2}\frac{}{K}\frac{dL}{d\theta}$

$dL = \frac{K}{8}\theta^{1-2n}d\theta$

$$dL = \frac{0.16}{8}\theta^{1-2n}\, d\theta$$

at $I=0$, $L = 10\,mH$, $\theta = 0$

$$\int_{10mH}^{L} dL = 0.02\int_{\theta=0}^{\theta}\theta^{1-2n}\, d\theta$$

$$[L - 10\times10^{-3}] = 0.02\left|\frac{\theta^{2-2n}}{2-2n}\right|_0^{\theta}$$

$$L = 10\times10^{-3} + 0.02\left|\frac{\theta^{2-2n}}{2(1-n)}\right|$$

$$\boxed{L = 10\times10^{-3} + 0.01\left(\frac{\theta^{2-2n}}{1-n}\right)}$$

(ii) $n = 0.75$

$L = 60\,mH$

$$60\times10^{-3} = 10\times10^{-3} + 0.01\left(\frac{\theta^{2-1.5}}{1-0.75}\right)$$

$$50\times10^{-3} = \frac{0.01}{0.25}\theta^{1/2}$$

$$\theta^{1/2} = 1.25$$

$$\boxed{\theta = 1.5625 \text{ rad}}$$

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Meter current.

$$\theta = \frac{I^2}{2K}\frac{dL}{d\theta}$$

$$1.5625 = \frac{I^2}{2\times0.16}\ \frac{50}{1.5625}$$

$$I^2 = \frac{(1.5625)^2 \times 0.32}{50}$$

$$I^2 = 0.015625$$

$$\boxed{I = 0.125\ A}$$

Calculation mistake.

Do not write in this margin

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]

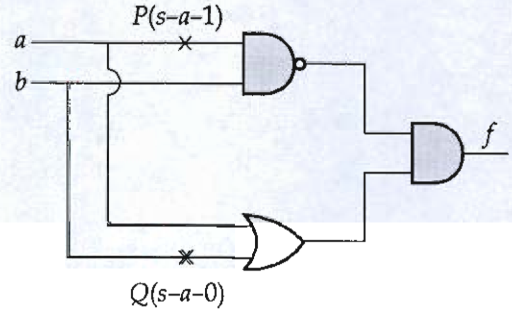
Q.4 (c) Consider the logic circuit shown in the figure below. Two specific faults are identified in the circuit:

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]

$r = 0.1 m$, $d = 0.05$, $V(t) = 50\cos 10^4 t$ volt

$A = \pi r^2 = \pi (0.1)^2 = 0.0191\ m^2$

$C = \frac{\varepsilon_0 A}{d} = \frac{10^{-9}}{36\pi} \frac{\times 0.01\pi}{0.05}$ farad

$= 5.55 \times 10^{-12}$ farad

$i(t) = C \frac{dV}{dt}$

$i(t) = 5.55 \times 10^{-12} \times \frac{d(50\cos 10^4 t)}{dt}$

$= 5.55 \times 10^{-12} \times 50 \times 10^4 \sin(10^4 t)$

$= 2.78 \times 10^{-6} \sin(10^4 t)$ A

5

$$I_{rms} = \frac{2.78\times10^{-6}}{\sqrt{2}} A$$

$$\boxed{I_{rms} = 1.96\,\mu A}$$

using Maxwell's equation

$$I = \omega C V_{rms}$$

$$I_{rms} = 10^4 \times 5.55\times10^{-12} \times \frac{50}{\sqrt{2}}$$

$$= 1.96\times10^{-6} A$$

$$= 1.96\,\mu A$$

Same is both cases

7

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]

Given

Total loss

2800 W at 400 V, 50 Hz
1000 W at 200 V, 25 Hz

12

$P_h \propto B^2 f$, $P_e \propto f^2 B^2$

└ Hysteresis loss └ eddy current loss

$B \propto \frac{V}{f}$

core loss

$P_i = P_h + P_e = K_1 \frac{V^2}{f} + K_2 V^2$

at 400 V & 50 Hz

$2800 = K_1 \frac{V^2}{f} + K_2 V^2$

$2800 = K_1 \times \frac{160000}{50} + K_2 160000$

$28 = 32K_1 + 1600K_2$ —— (I)

at 200 V, 25 Hz

$1000 = K_1 \times \frac{40000}{25} + K_2 \times 40000$

$10 = 16K_1 + 400K_2$ —— (II)

solve eqn (I) & (II)

$K_1 = 0.375$, $K_2 = 0.01$

At 400 V and 50 Hz

$P_h = \frac{K_1 V^2}{f} = \frac{0.375 \times (400)^2}{50} = 1200\,W$

$P_e = K_2 V^2 = 0.01 \times (400)^2 = 1600\,W$

At 800 V and 25 Hz

$P_h = \frac{K_1 V^2}{f} = \frac{0.375 (800)^2}{25} = 9600\,W$

$P_e = K_2 V^2 = 0.01 (800)^2 = 6400\,W$

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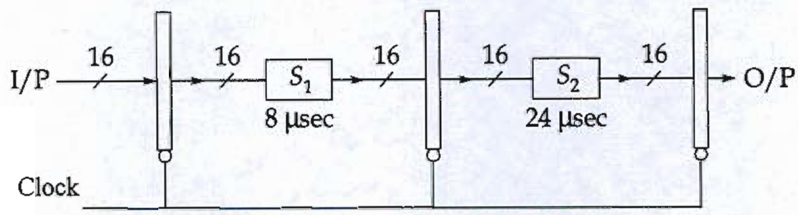
Q.5 (c) The figure shown below indicates a two-stage pipeline with stage delays indicated below the stages. Latch delays are to be ignored.



(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]

Stage $S_1 = 8\mu s$
$S_2 = 24\mu s$

(i) clk time = Max (S_1, S_2)
= $24\mu s$

Throughput = $\frac{1}{24\mu s} = 41.67\times10^3$ /sec

Latency = 2 × clk time
= $48\mu s$

(ii) Stage 2
split in 3 stages.

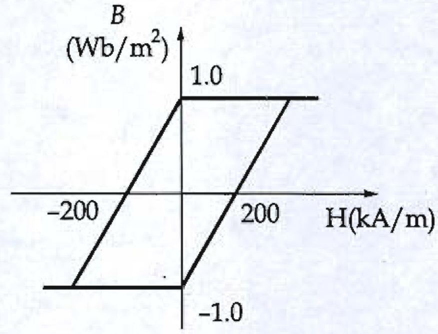
Total ~~= 8+24~~

clk time = Max $(S_1, S_{21}, S_{22}, S_{23})$
= $8\mu s$

Throughput = $\frac{1}{8\mu s} = 125\times10^3$ /sec

Latency = 4 × 8
= $32\mu s$

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]

(i) Total Hysteresis loss / cycle

= Area of B-H curve

= $400 \times 2 \ \frac{KA\text{-}Wb}{m^3}$

= 800 J/m³ per cycle

6

8×10^5 J/m³

Avoid silly mistake

(ii) (BH)max product.

= 1 × 200

= 200 J/m³

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

[4 + 4 + 4 marks]

(I) Meissner effect.
- Magnetic field completely expelled from superconductor

6

(II) Silsbee rule.
- Superconductivity destroyed when magnetic field exceeds critical value

(III) A high freq → losses increases

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]

M.M = 4MB = $2^{20} \times 2$ bytes = 2^{22} bytes

Block size = 64 bytes = 2^6

Tag = 10 bits

20

Very Good

(i)

← 22 →

Tag	Index	offset
10	6	6

Index = 22 − (10 + 6)
= 6

(ii) No of M.M block = $\frac{2^{22}}{2^6}$
= 2^{16} blocks

(iii) Cache size

No. of set = 2^6

each set has 4 blocks (4-way set)

Total blocks = $2^6 \times 4$ = 256

Cache size = 256 × 64 bytes
= $2^8 \times 2^6$ bytes
= 2^4 KBytes
= 16KB

(IV) Tag directory size
- Total block = 256
Tag = 10

Tag directory size = 256 × 10 bits
= 2560 bits.

(V) No. of comparator needed -

4 way set associative.
- 4 comparators

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]

(1)

	Carbon dotes	Quantom dots
Material -	carbon based	semiconductor based
cost -	Low	High
Toxicity	Low	often toxic (Cd,Pd)
Emission	Broad	Sharp
Stability	High	Moderate

2

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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]

$\mu_r = 4, \ \varepsilon_r = 9, \ f = 10\,MHz$

(I) $\beta = \omega\sqrt{\mu\varepsilon}$

$= \dfrac{\omega\sqrt{\mu_r\varepsilon_r}}{c} = \dfrac{2\pi \times 10 \times 10^6 \times \sqrt{4\times 9}}{3\times 10^8}$ rad/m.

$= 1.25$ rad/m

$\lambda = \dfrac{2\pi}{\beta} = \dfrac{2\pi}{1.25}$ m $= 5.026$ m

$v_p = \dfrac{c}{\sqrt{\mu_r\varepsilon_r}} = \dfrac{3\times 10^8}{\sqrt{4\times 9}} = 0.5\times 10^8$ m/s

$\eta = \sqrt{\dfrac{\mu}{\varepsilon}} = \sqrt{\dfrac{\mu_0\mu_r}{\varepsilon_0\varepsilon_r}} = \sqrt{\dfrac{\mu_0}{\varepsilon_0}} \times \sqrt{\dfrac{4}{9}}$

$= \dfrac{120\pi \times 2}{3}$

$\boxed{\eta = 80\pi\ \Omega}$

(II) wave propagating in $\hat{a}_y$ dirn

$E(t) = E_{x0}\cos(\omega t - \beta y)\hat{a}_x + E_{y0}\cos(\omega t - \beta y)\hat{a}_y$
$+ E_{z0}\cos(\omega t - \beta z)\hat{a}_z$

at $P(0.6, 0.6, 0.6)$ and $t = 60$ ns

$E_{y0} = E_{z0} = 0$

$E(t) = E_{x0} \cos(\omega t - \beta y)\hat{a}_x$

$= 400 \cos(2\pi \times 10^7 t - 1.25y)\hat{a}_x$ V/m

$\eta = 80\pi$

$H_{x0} = \frac{E_{x0}}{\eta}$

$= \frac{400}{80\pi} = \frac{5}{\pi}$

18 Exl

$H(t) = \frac{5}{\pi} \cos(2\pi \times 10^7 t - 1.25y)\hat{a}_H$

$\hat{a}_H = \hat{a}_k \times \hat{a}_E$

$= a_y \times a_x$

$= -a_z$

$H(t) = -\frac{5}{\pi} \cos(2\pi \times 10^7 t - 1.25y) a_z$ A/m

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]

Q.7 (b) The magnetic field intensity of a linearly polarized uniform plane wave propagating in the $+Y$-direction in sea water ($\in_r = 80$, $\mu_r = 1$, $\sigma = 4$ 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]

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]

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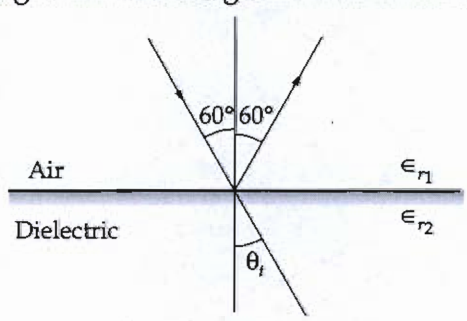
Q.8 (a) (i) In spherical co-ordinates, let $\hat{a}_\theta, \hat{a}_\phi$ denotes unit vectors along the θ, ϕ directions.

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

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

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 $\left(0 \le \theta \le \dfrac{\pi}{2}\right)$.

(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 ($\in_{r2}$) and the corresponding Brewster's angle for this interface.



[10 + 10 marks]

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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

Space for Rough Work

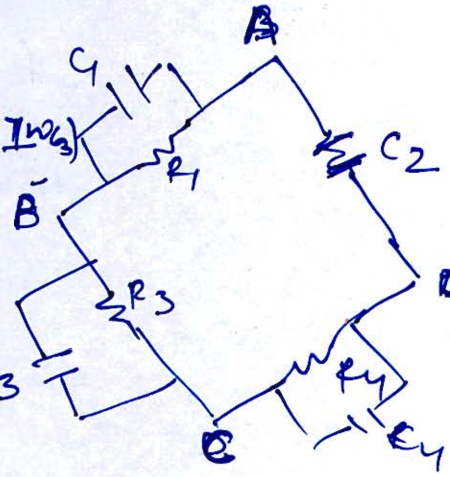
Space for Rough Work

$Y_1 = \frac{1}{R_1} + j\omega C_1$

Space for Rough Work

$Y_1 Y_4 = Y_2 Y_3$

$\left(\frac{1}{R_1} + j\omega C_1\right)\left(\frac{1}{R_4} + j\omega C_4\right) = j\omega C_2\left(\frac{1}{R_3} + j\omega C_3\right)$



$\frac{1}{R_1 R_4} + j^2\omega^2 C_1 C_4 = j^2 \omega^2 C_2 C_3$

$\frac{j\omega C_4}{R_1} + \frac{j\omega C_1}{R_4} = \frac{j\omega C_2}{R_3}$

$\frac{C_4}{R_1} + \frac{C_1}{R_4} = \frac{C_2}{R_3}$

(3)

$C' = \varepsilon C_1$

$\frac{1}{R_1 R_4} = \omega^2 (C_1 C_4 - C_2 C_3)$

$\frac{1}{R_1 R_4} = \omega^2 (C_1 C_4 - C_2 C_3)\,\varepsilon^2$