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Leading Institute for ESE, GATE & PSUs

ESE 2026 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electrical Engineering

Test-7 : Computer Fundamentals + Elec. & Electro. Measurements + Power Electronics & Drives-1 + Engineering Mathematics-1 + B.E.E.-2 + Analog Electronics-2 + Electrical Materials-2

Name ....

Roll No :

Test Centres			Student's Signature
Delhi ☑	Bhopal ☐	Jaipur ☐	
Pune ☐	Hyderabad ☐		

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	38
Q.2	33
Q.3	
Q.4	
Section-B	
Q.5	36
Q.6	41
Q.7	41
Q.8	
Total Marks Obtained	189

Signature of Evaluator: Sourabh kumar ....

Cross Checked by: ....

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 : Computer Fundamentals + Electrical & Electronic Measurements

Q.1 (a) Assume that a main memory with only 4 pages, each of 16 bytes, is initially empty. The CPU generates the following sequence of virtual addresses and uses the Least Recently Used (LRU) page replacement policy.

0, 4, 8, 20, 24, 36, 44, 12, 68, 72, 80, 84, 28, 32, 88, 92

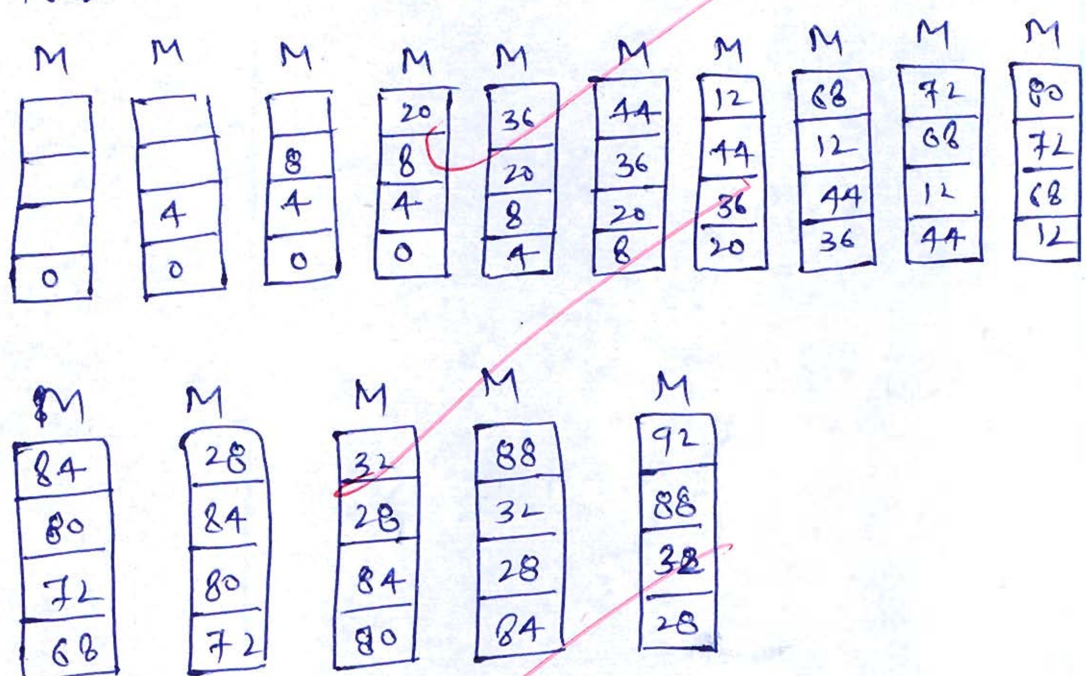
How many page faults does this sequence cause? What are the page numbers of the pages present in the main memory at the end of the sequence?

[12 marks]

Solution

By using LRU policy then

Let ⇒ M – Miss
H – Hit



As there is no page fault.

No. of page fault (Hit) = 0

No. of miss (M) = 15

Hit Ratio = 0/15 = 0

After end of sequence page number present are, 92, 88, 32, 28

5

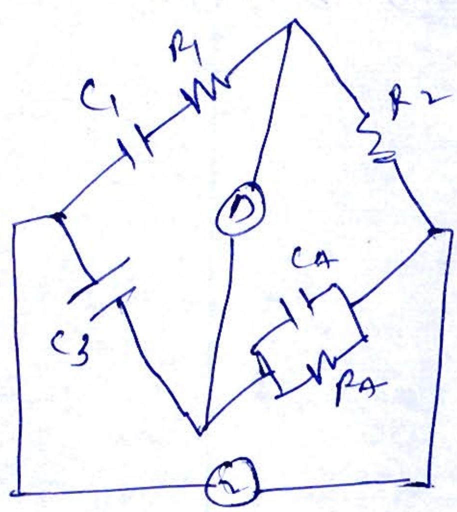
Paging calculation incorrect

Q.1 (b) In a test on a Bakelite sample at 20 kV, 50 Hz by schering bridge, having a standard capacitor of 106 pF, balance was obtained with a capacitance of 0.35 mF in parallel with a non-inductive resistance of 318 Ω, the non-inductive resistance in the remaining arm of the bridge is 130 Ω. Calculate the power factor and equivalent series resistance of the capacitor. Also derive the balance condition of the bridge.

[12 marks]

Solution

Schering Bridge



given

$R_2 = \sout{318\Omega}\ 130\Omega$

$C_3 = 106\,pF$

$C_4 = 0.35\,mF$

$R_4 = 318\Omega$

At balance condition

$$\left(R_1 + \frac{1}{j\omega C_1}\right) \times \left(\frac{R_4}{1+j\omega C_4 R_4}\right) = \frac{R_2}{j\omega C_3}$$

$$(1+j\omega C_1 R_1)(j\omega C_3) R_4 = R_2 j\omega C_1 (1+j\omega C_4 R_4)$$

so

$$C_3 R_4 = R_2 C_1$$

so $C_1 = \frac{C_3 R_4}{R_2} = \frac{106 \times 318}{130}$

$$\boxed{C_1 = 259.29\,pF}$$

and

$$\omega C_1 R_1 C_3 R_4 = R_2 C_1 \omega C_4 R_4$$

$$R_1 C_3 = R_2 C_4$$

$R_1 = \frac{R_2 C_4}{C_3} = \frac{130 \times 0.35 \times 10^{-3}}{106 \times 10^{-12}}$

$$\boxed{R_1 = 429.25\,M\Omega}$$

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Series Impedance at $f = 50Hz$

$Z_1 = R_1 + \frac{1}{j\omega C} = 429.25\times10^6 - j\frac{1}{2\pi\times50\times259.29\times10^{-12}}$

$Z_1 = 429.25\times10^6 - j12.28\times10^6$

so ~~power~~ $Z_1 = 429.42\times10^6 \angle -1.1638$

So power factor $= \cos(1.1638) = 0.999$

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Q.1 (c) Given the following binary number in 32-bit (single precision) IEEE-754 format:

00111110011011010000000000000000

Determine the decimal value closest to this floating-point number.

[12 marks]

Solution

IEEE-754 (32-bit) format

S	BE	Mantissa
1 bit	8 bit	23 bit

S	BE	M
0	01111100	11011010000000000000000

As Bias $= 2^{n-1} = 2^{8-1} = 2^{8}-1 = 255$

$(255)_{10} = (11111111)_2$

So Actual exponent will be

AE = BE − Bias

AE = 01111100 − 11111111 = 01111101

By taking 1's complement

10000010

exponent = −131

So

$0.M * 10^{-131}$

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Q.1 (d) A moving iron voltmeter designed to read up to 100 V has resistance of 2000 Ω and inductance of 0.6 H. How it can be modified to read up to 300 V? How the modified voltmeter can be made to read without error on both dc and 50 Hz ac?

[12 marks]

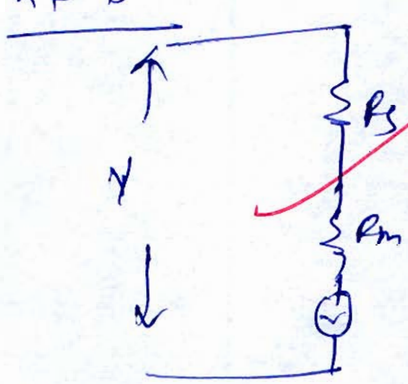
At DC

~~$R_s = \frac{R_m}{m-1}$~~ = 2000

series resistance $R_s = R_m(m-1)$

$$R_s = 2000\left(\frac{300}{100} - 1\right) = 4000\,\Omega$$

At DC



for AC, f = 50 Hz

So $X_L = 2\pi \times 50 \times 0.6 = 188.4\,\Omega$.

for without error, there must be a capacitor Across Resistance R_s

~~$\frac{L_{sh}}{R_{sh}} = \frac{L_m}{R_m}$~~

So

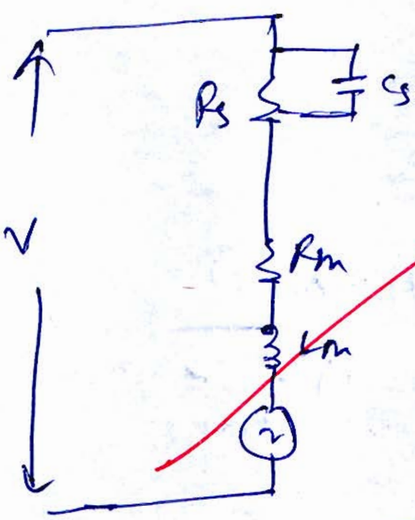
$$C = 0.41 \frac{L_s}{R_s^2}$$

$$C = 0.41 \times \frac{0.6}{(4000)^2}$$

$$C = 1537 \times 10^{-11}\,F$$

$$\boxed{C = 15.37\,nF}$$

So Arrangement at Ac



$R_s = 4000\,\Omega$ $C_s = 15.37\,nF$
$R_m = 2000\,\Omega$, $L_s = 0.6\,H$,

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Good Approach

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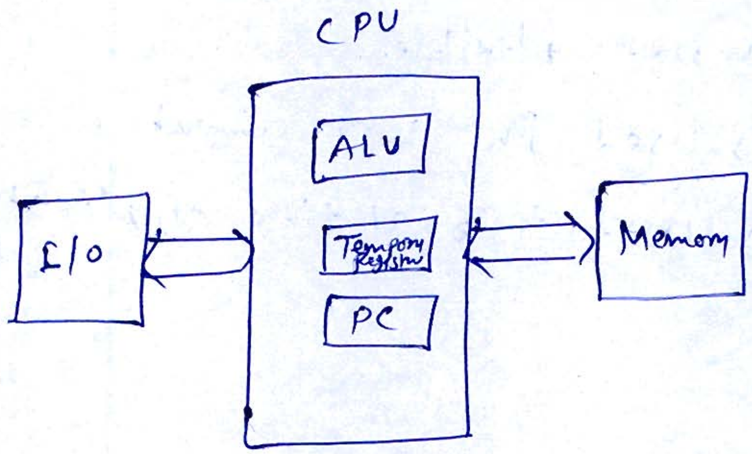
Q.1 (e) What does "computer architecture" term means in regards to computing system? Enumerate properties of reduced instruction set computer architecture.

[12 marks]

Solution

Computer Architecture



It is Architecture of a combination of memory, CPU and Input-output devices.

These are connected by various Buses.

CPU contains various component and it is mind of computer.

There are various Buses like, Data Bus, Address Bus, control Bus.

CPU contains Airthmetic logic unit which is responsible for Airthmetic operation and also store the results. Two types of Architecture.

① Reduced Instruction set computer Architecture (RISC)

② CISC

properties of RISC

① It has fixed length of Instruction

② It has successful pipeline

③ It has CPI = 1

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- It supports less number of registers
- It supports large number of Address.
- It is very expensive Architecture
- It is used in Hardwired computer
- It is not flexible.
- It is used in super computers.
- It is used in real time Application

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Q.2 (a) Explain file access method and file allocation method with diagram.

[20 marks]

Solution

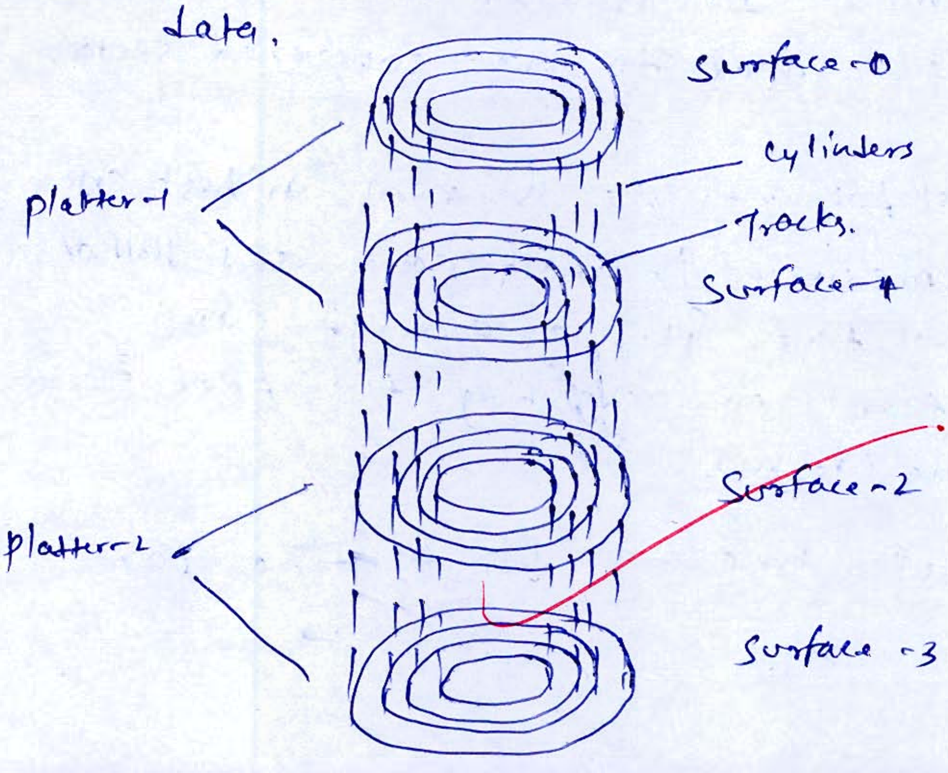
There are two types of file Access method

① Direct file Access method
- Hard Disc
- CD
- DVD
- ~~Pot~~

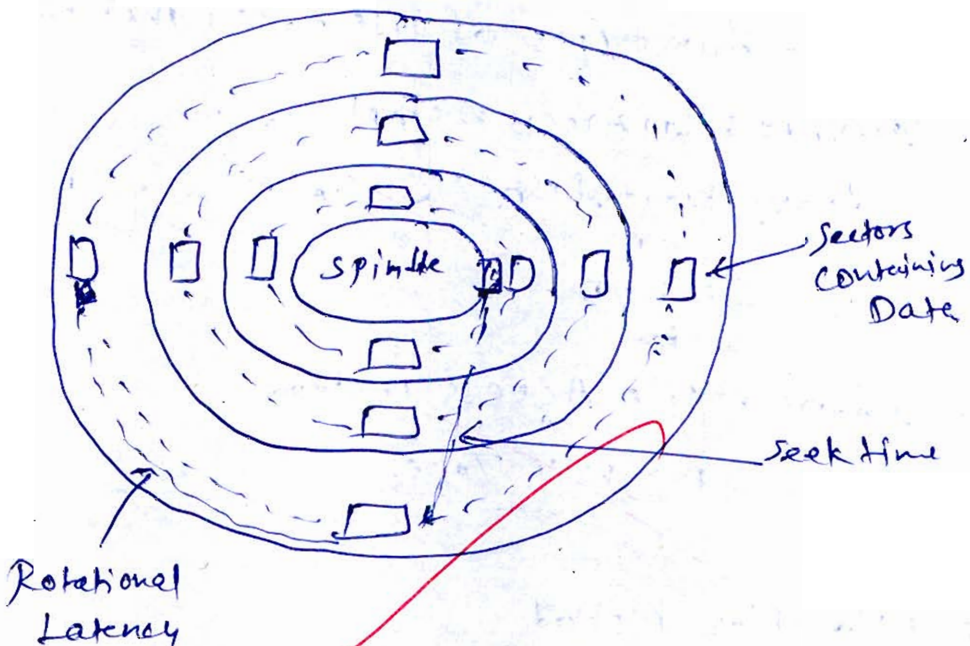
② Indirect file Access method
- magnetic Tape

File Allocation Method

- A secondary memory is used for file mangement system and operating system is responsible for file mangement.
- It contains platters.
- each platter contains two surfaces
- Each surfaces contain tracks
- Tracks contain sectors and sector contain data.



Now - surface 1.



As Total time taking for executing the data will be sum of seek time, Rotational Latency, transfer time and overhead time.

Tavg = Seek time + Rotational Latency + Transfer Time + Overhead Time

① Seek time — It is time taken for moving the head to the concerned sector.

② Rotational Latency — It is zero in best case and maximum in worst case and Half of rotational time for an average case. It is time for adjusting the head to the Data (sector).

③ Transfer time — It is time for

transfer the data from main memory to cache memory or time taken to access the data.

(4) Overhead time – This is the extra delay while accessing the data.

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Q.2 (b) **(i)** Explain briefly the terms: Translator software, assembler, compiler and interpreter. Differentiate between a compiler and an interpreter.

[10 marks]

Translator Software

- It is a Basic term for a translator which translate a given Language code into other required Language code.

Assembler

- It is also a translator which convert assembly level language into machine level language.

Compiler

- It convert a complete programming Code into machine Language at a time.
- Also it provide error into a code.
- It is faster than interpreter.

Interpreter

- It convert assembly program into machine level program line by line.
- It does not convert a complete program in single go.

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Compiler	Interpreter
- It convert a complete program at a time.	It convert a program line by line
- It take less time for conversion	- It takes more time to convert a program
- It also provide error into program	- It is simply convert program, not provide details of error in program

8

Elaborate it more

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Q.2 (b) **(ii)** Explain how ROM is related to BIOS in relation to operation of computer. What are steps performed by BIOS, when computer is turned-on?
What are different types of ROM used in computer, enumerate and explain briefly? **[10 marks]**

- BIOS is related to turning-on of a computer.
- It is first operation while turn-on a computer.
- Types of ROM

(1) PROM (Programmable ~~Random~~ Read only memory)
- In this ROM, data cannot be earasble only use once if data is written

(2) EEPROM (Electrically erasable ROM)
- In this ROM, data can be erased, if we want, by using electrow.

(3) ERPOM (Electrical ROM)
- this ROM can be erasalle but ~~not~~ after earasble not much useful.

6

Elaborate it more

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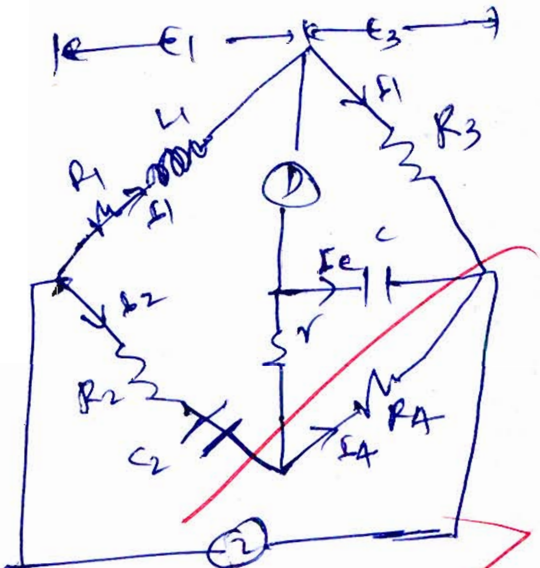
Q.2 (c) (i) Draw the circuit of Anderson bridge. Derive the null conditions and represent with help of phasor diagram. Show that Maxwell bridge is the special case of this bridge.

[10 marks]

Solution

Anderson Bridge



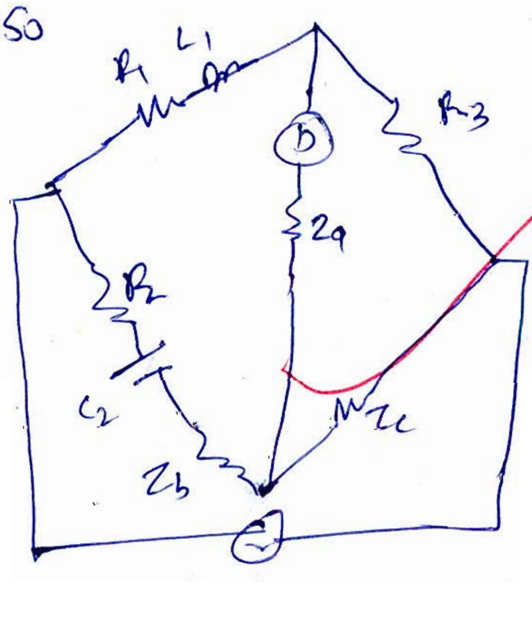
By converting Delta into star

$$Z_a = \frac{r \cdot \frac{1}{j\omega C}}{r + R_A + \frac{1}{j\omega C}}$$

$$Z_b = \frac{R_A \cdot \frac{1}{j\omega C}}{r + R_A + \frac{1}{j\omega C}}$$

$$Z_c = \frac{r \cdot R_A}{r + R_A + \frac{1}{j\omega C}}$$

So

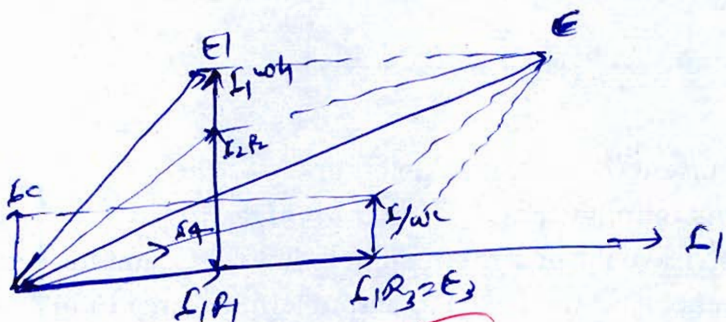


(Fig-2)

At Null Condition

$$(R_1 + j\omega L_1) Z_C = R_3 \times \left(R_2 + \frac{1}{j\omega C_1} + Z_b\right)$$

Now By using Phasor



As from figure-2, we can see that Maxwell's Bridge is the special case of Anderson Bridge.

5

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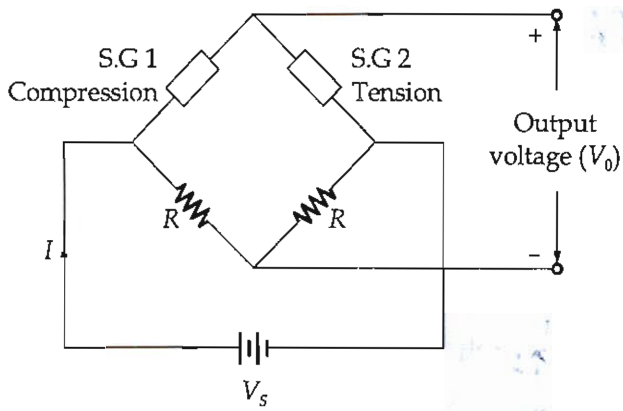
Q.2 (c) **(ii)** A bridge circuit shown in the figure, has two fixed resistors and two strain gauges all of which have a value of 120 Ω each. The gauge factor is 2 and strain applied to twin strain gauges, one in tension and the other in compression is 150×10^{-6} respectively



If the battery current (I) is 100 mA, determine:

1. Open circuit output voltage (V_0) of the bridge.
2. The sensitivity of the bridge circuit in millivolt per unit microstrain.
3. If the galvanometer connected to output terminals read 1 mV per scale division and if $1/10^{th}$ of a division can be read with confidence, determine the resolution.

[10 marks]

Q.3 (a) (i) Mention the advantages and disadvantages of a LVDT.

(ii) The output of an LVDT is connected to a 5 V voltmeter through an amplifier whose amplification factor is 250. An output of 2 mV appears across the terminals of LVDT when the core moves through a distance of 0.5 mm. Calculate the sensitivity of the LVDT and that of the whole setup. The millivoltmeter has 100 divisions. The scale can be read to $1/5^{th}$ of a division. Determine the resolution of the instrument.

[10 + 10 marks]

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Q.3 (b) (i) Explain "Demand paging" in detail.

[8 marks]

Q.3 (b) (ii) What is "peer-to-peer" computing? Explain its models.

[12 marks]

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Q.3 (c) **(i)** A potential transformer has a turn ratio 1000/100 V and following parameters :
Primary resistance : 96 Ω, Secondary resistance = 0.88 Ω
Primary reactance : 67.2 Ω, Total equivalent reactance = 115 Ω
No load current is 0.03 A at 0.4 power factor lagging.

Calculate :

1. Phase angle error at no load.
2. Burden in VA at unity power factor at which phase angle will be zero.

[15 marks]

Q.3 (c) (ii) Briefly explain the elements of an analog data acquisition system.

[5 marks]

Q.4 (a) (i) What is input-output interface? Explain the different modes of data transfer with example.

[10 marks]

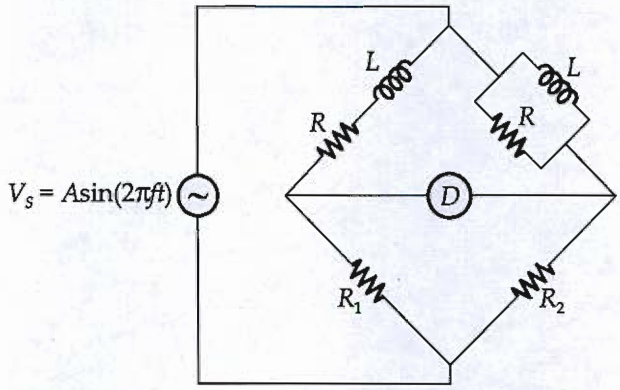
Q.4 (a) (ii) Write a C-program that takes a 4 × 4 matrix as input and gives transpose of input matrix as output.

[10 marks]

Q.4 (b) (i) Explain briefly the term "Multi Threading" in context to operating system. Give few advantages of multi-threading. How multi-threading is different from multitasking?

[10 marks]

Q.4 (b) **(ii)** Consider an AC bridge shown in the figure with $R = 300\ \Omega$, $R_1 = 1000\ \Omega$, $R_2 = 500\ \Omega$, $L = 30$ mH and a detector D. At the bridge balance condition, find the frequency of the excitation source V_S.



[10 marks]

Q.4 (c) What are the sources of errors in an electrodynamometer type wattmeter? A dynamometer type wattmeter connected normally to read power in a single phase circuit. Indicating value P_1, a second reading P_2 is obtained when a capacitor of reactance equal to the pressure coil resistance is connected in series with the pressure coil. Show that the phase angle of the load can be obtained from the expression, $\tan\phi = 1 - \frac{2P_2}{P_1}$.

[20 marks]

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Section B : Power Electronics & Drives-1 + Engineering Mathematics-1 + B.E.E.-2 + Analog Electronics-2 + Electrical Materials-2

Q.5 (a) Show that matrix, $A = \begin{bmatrix} 2 & 3+4i \\ 3-4i & 2 \end{bmatrix}$ is a Hermitian matrix. Find its eigen values and eigen vectors.

[12 marks]

Solution

for Hermitian matrix $A = A^{\theta}$

where A^{θ} = tranjugate of A

So

$$A^T = \begin{bmatrix} 2 & 3-4i \\ 3+4i & 2 \end{bmatrix}$$

Now

$$\overline{A^T} = A^{\theta} = \begin{bmatrix} 2 & 3+4i \\ 3-4i & 2 \end{bmatrix} = A$$

So $A = A^{\theta}$ - Hermitian matrix

Now for eijen value

$|A - \lambda I| = 0$

$$\left| \begin{bmatrix} 2-\lambda & 3+4i \\ 3-4i & 2-\lambda \end{bmatrix} \right| = 0 \Rightarrow (2-\lambda)^2 - (3+4i)(3-4i) = 0$$

$4 + \lambda^2 - 4\lambda - (9+16) = 0$

$\lambda^2 - 4\lambda - 21 = 0$

So $\lambda = -3, 7$ (eijen values)

eijen vector

$AX = \lambda X$

for eigen value $\lambda_1 = -3$

$$\begin{bmatrix} 2 & 3-4i \\ 3+4i & 2 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = -3\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

$$2x_1 + 3x_2 - 4ix_2 = -3x_1$$

$$5x_1 + x_2(3-4i) = 0 \quad \text{—(1)}$$

and

$$(3+4i)x_1 + 2x_2 = -3x_2$$

$$(3+4i)x_1 + 5x_2 = 0$$

6

0

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Q.5 (b) How nano materials differ from normal materials in their characteristics? State the reasons behind change in their nature at nano-scale. What is buckminister fluorene? Give important application of this nano material.

[12 marks]

Solution

Nano material

- A material which has one dimension less than 100 nm. is called nano material.
- these are different from normal material
- these have larger surface Area which is more useful.
- Nano material can be formed any useful ~~..~~ device.

  ex. Carbon Nano tube, Nano Atom

Buckminister flourene structure

- It is given by Buckminister Fluorene.
- It contain two C-60 capped material.
- It is a graphite ~~structure~~ which capped by C-60

6

Elaborate it more

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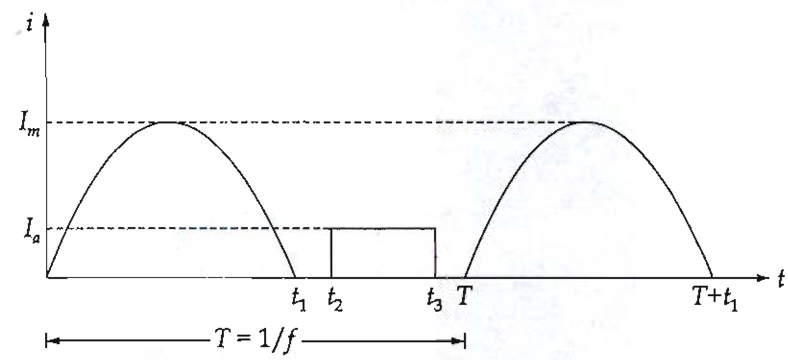
Q.5 (c) The current passing through a diode is shown in waveform.

Determine :

(i) rms current;

(ii) average diode current

if $t_1 = 100\ \mu s$, $t_2 = 350\ \mu s$, $t_3 = 500\ \mu s$, $f = 250$ Hz, $f_s = 5$ kHz, $I_m = 450$ A and $I_a = 150$ A.



[12 marks]

Solution (i)

for $0 < t < t_1$, $I_m = 450$ A , $T = \frac{1}{250} = 4000\,\mu sec$

So $i_{1rms} = \frac{I_m}{\sqrt{2}}\left(\frac{t_1}{T}\right)^{1/2} = \frac{450}{\sqrt{2}}\left(\frac{100}{4000}\right)^{1/2}$

$i_{1rms} = 50.31$ Amp.

for $t_2 < t < t_3$

$i_{2rms} = I_a\left(\frac{t_3 - t_2}{T}\right)^{1/2} = 150\left(\frac{500-350}{4000}\right)^{1/2}$

$i_{2rms} = 29.047$ Amp.

So, for $0 < t < T$

$i_{rms} = \sqrt{i_{1rms}^2 + i_{2rms}^2} = \sqrt{50.31^2 + 29.047^2}$

$i_{rms} = 58.09$ Amp.

(ii) Average diode current

$i_{avg.} = \frac{1}{T}\left[\int_0^{t_1} I_m \sin \omega t\, dt + \int_{t_2}^{t_3} I_a\, dt\right]$

$$i_{avg.} = \frac{I_m}{\pi}\left(\frac{t_1}{T}\right) + I_a\left(\frac{t_3 - t_2}{T}\right)$$

$$i_{avg} = \frac{450}{\pi}\left(\frac{100}{4000}\right) + 150\left(\frac{500-350}{4000}\right)$$

$$i_{avg} = 3.582 + 5.625$$

$$i_{avg} = 9.2078 \text{ Amp.}$$

(9)

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Q.5 (d) Urn *A* contains 6 red and 4 black balls and Urn *B* contains 4 red and 6 black balls. One ball is drawn at random from Urn A and placed in Urn *B*. Then one ball is drawn at random from Urn *B* and place in Urn *A*. If one ball is now drawn at random from Urn *A*, find the probability that it is red.

[12 marks]

Solution

Urn A	Urn B
6-Red 4-Black	4-Red 6-Black

Case-1 Let 1 Red Ball is placed in A from B

So Urn A have 7-Red
4-Black

Now 1 Black Ball is placed into B from A

So

A	B
7-Red	3-Red
3-Black	7-Black

Now probability of Red Ball from A

$P_1 = \frac{7}{10}$

Case-2 Let 1 Black Ball is placed in A from B and 1 Red Ball is placed in B from A

A	B
5-Red	5-Red
5-Black	5-Black

So, probability of Red Ball from A

$P_2 = \frac{5}{10}$

So Total probability of getting red from urn A

$P = \frac{5}{10} \times \frac{7}{10} = 0.35$

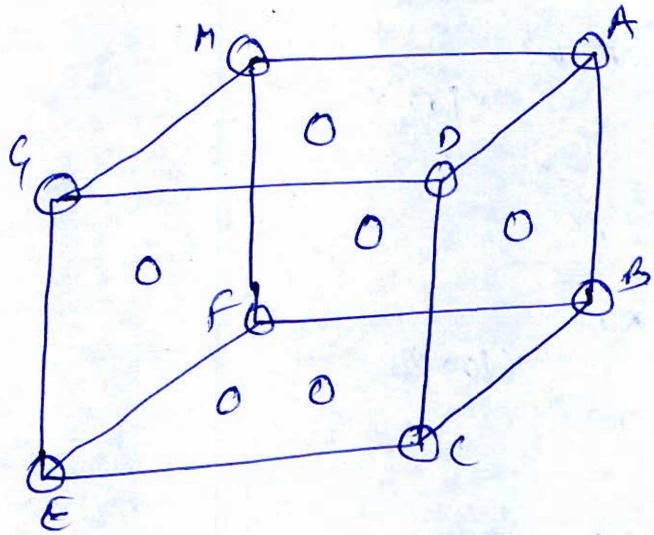
4

Wrong value calculated

Q.5 (e) How are the atoms arranged in FCC crystal structure? Derive atomic packing factor of FCC materials.

[12 marks]

Atoms Arrangement in FCC

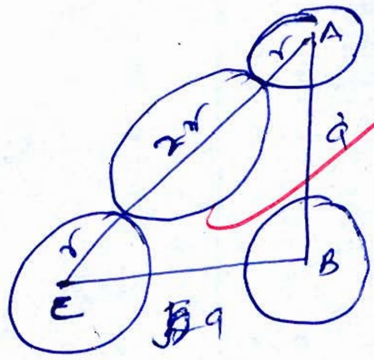


8 Atoms are at each corner of crystal,
6 Atoms are at each face of crystal.

So effective No. of Atom

$$N = \frac{1}{8}\times 8 + \frac{1}{2}\times 6 = 4$$

Now Radius and crystal Parameter (a) Relation



So $AE^2 = AB^2 + BE^2$

$(4r)^2 = a^2 + a^2$

$16r^2 = 2a^2$

$$\boxed{r = \frac{a}{2\sqrt{2}}} \quad \text{—(1)}$$

Now Atomic packing factor is given by

$$= \frac{N \times \text{Volume of Atom}}{\text{Volume of crystal}} \times 100\%$$

$$= \frac{4 \times \frac{4}{3}\pi r^3}{a^3} \times 100\%$$

By putting $a = 2\sqrt{2}r$

$$= \frac{4 \times 4/3\, \pi r^3}{16\sqrt{2}\, r^3} \times 100\%$$

Atomic packing factor = 74.01 %

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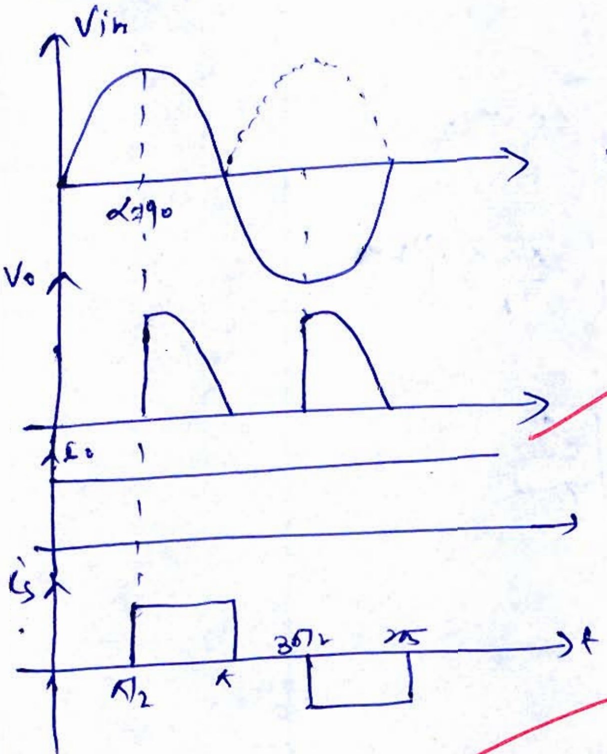
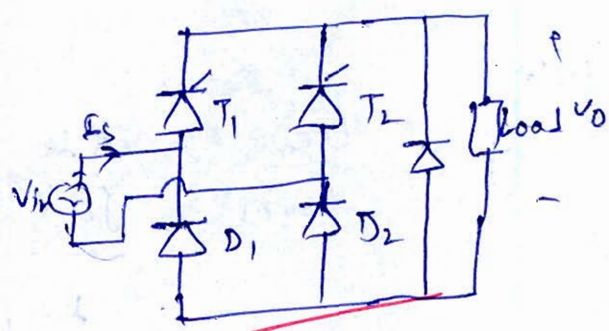
Good Approach

Q.6 (a) A 1-ϕ semi converter is connected to 240 V, 50 Hz supply. The load current I_0 can be assumed to be continuous and ripple free. Calculate the harmonic factor of input current for $\alpha = \frac{\pi}{2}$ rad. Derive all the relevant formulae used using Fourier series analysis. Also obtain the expression for rms value of supply current and rms value of fundamental current in term of I_0 and α.

[20 marks]

Solution





Now from Above wave form we can written fourier series as, as $a_n = 0$, $a_0 = 0$, $b_n \neq 0$

$$b_n = \frac{4 I_0}{n\pi} \cos\frac{n\alpha}{2}$$

Now

$$i_s = \sum_{n=1,3,5}^{\infty} \frac{4 I_0}{n\pi} \cos\frac{n\alpha}{2} \sin(n\omega t - n\alpha/2)$$

So

$$i_{s_1\,rms} = \frac{4 I_0}{\sqrt{2}\pi} \cos\alpha/2$$

Rms value of supply current

$$i_{s\,rms} = I_0 \left(\frac{\pi-\alpha}{\pi}\right)^{1/2}$$

Now

$$g = \frac{i_{s1\,rms}}{i_{s\,rms}} = \frac{\frac{4 I_0}{\sqrt{2}\pi}\cos\alpha/2}{I_0\left(\frac{\pi-\alpha}{\pi}\right)^{1/2}}$$

$$g = \frac{4}{\sqrt{2}\pi}\cos\alpha/2 \times \sqrt{\frac{\pi}{\pi-\alpha}}$$

So for $\alpha = \pi/2$

$$g = \frac{4}{\sqrt{2}\pi}\,\frac{\cos\pi/4}{\sqrt{\pi-\pi/2}}$$

$$g = 0.9$$

Now Harmonic factor (THD)

$$THD = \sqrt{1/g^2 - 1}$$

$$THD = \sqrt{1/0.9^2 - 1}$$

$$THD = 48.34\%$$

(15)

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Q.6 (b) **(i)** Find the solution of differential equation

$$x^2\frac{d^2y}{dx^2}-2y = x^2+\frac{1}{x}$$

(ii) Find the area common to the parabola $y^2 = ax$ and the circle $x^2 + y^2 = 4ax$.

[10 + 10 marks]

Solution (i)

$$x^2\frac{d^2y}{dx^2}-2y = x^2+1/x$$

$$\frac{d^2y}{dx^2}-2y/x^2 = 1+1/x^3$$

$$\frac{d^2y}{dx^2}+Py = Q$$

So By comparing

$$P=-2/x^2, \quad Q = 1+1/x^3$$

So, Integrating factor

$$IF = e^{\int P\,dx} = e^{\int -\frac{2}{x^2}dx}$$

Let $x^2\frac{d^2y}{dx^2} = D_1(D_1-1)$ where $D_1 = d/dz$, $x = e^z$

So

$$D_1(D_1-1)-2 = e^{2z}+e^{-z}$$

By solving, complementary part

$$D_1^2-D_1-2=0$$

By solving $D_1 = -1, 2$

So $Y_{cf} = c_1e^{-z}+c_2e^{2z}$ —— (1)

Now for particular Integral part

$$Y_{PI} = \frac{1}{D_1^2-D_1-2}\cdot(e^{2z}+e^{-z})$$

$$Y_{PI} = \frac{e^{2z}}{D_1^2 - D_1 - 2} + \frac{1}{D_1^2 - D_1 - 2} e^{-z}$$

$$Y_{PI} = \frac{1}{4-2-2} e^{2z} + \frac{1}{(-1)^2+1-2} e^{-z}$$

$$Y_{PI} = \frac{1}{0} e^{2z} + \frac{1}{0} e^{-z}$$

$$Y_{PI} = \frac{z\, e^{2z}}{2D_1 - 1} + \frac{z\, e^{-z}}{2D_1 - 1}$$

$$Y_{PI} = \frac{z e^{2z}}{3} + \frac{z e^{-z}}{-3} \quad \text{—(2)}$$

So

$$y = Y_{CF} + Y_{PI}$$

$$y = c_1 e^{-z} + c_2 e^{2z} + \frac{z}{3}\left(e^{2z} - e^{-z}\right)$$

Now as $x = e^{z}$, so, $z = \log x$

$$\boxed{y = \left(c_1 x^{-1} + c_2 x^2\right) + \frac{\log x}{3}\left(x^2 - 1/x\right)}$$

9

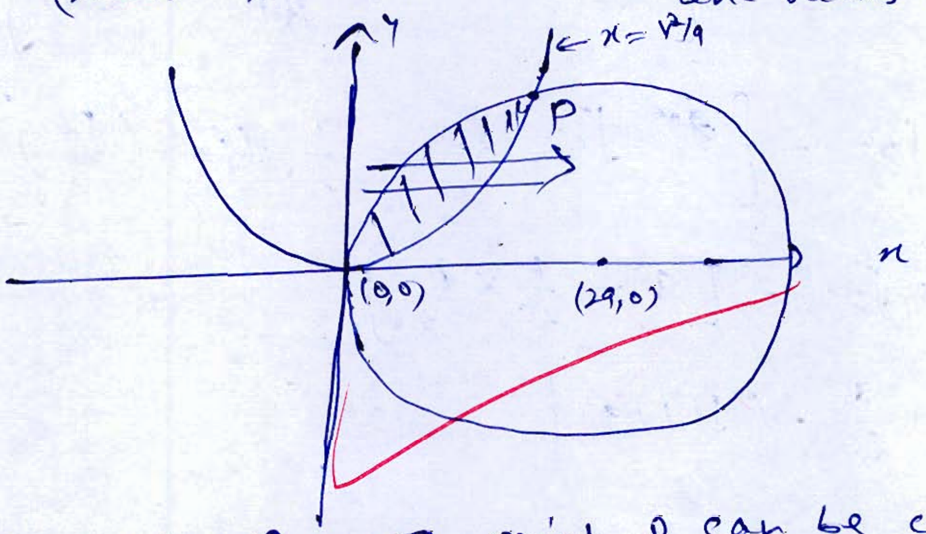
Good Approach

(ii) $y^2 = ax$, —(1) $x^2 + y^2 = 4ax$ —(2)

as $x^2 + y^2 - 4ax = 0$

$(x-2a)^2 + y^2 = 4a^2$ (Circle with centre $(2a, 0)$ and radius $2a$)

So



By solving (1) and (2) point P can be calculated as $P(3a, \sqrt{3}a)$

So Marked Area

$$A = \int_0^{\sqrt{3}a} \int_{2a+\sqrt{4a^2-y^2}}^{y^2/a} dx\, dy$$

$$A = \int_0^{\sqrt{3}a} \left(\frac{y^2}{a} - \left[2a + \sqrt{4a^2-y^2}\right]\right) dy$$

$$A = \int_0^{\sqrt{3}a} \frac{y^2}{a} dy - \int_0^{\sqrt{3}a} 2a\, dy - \int_0^{\sqrt{3}a} \sqrt{4a^2-y^2}\, dy$$

$$A = \frac{y^3}{3a}\Big|_0^{\sqrt{3}a} - \left[2ay\right]_0^{\sqrt{3}a} - \int_0^{\sqrt{3}a} \sqrt{4a^2-y^2}\, dy$$

$$A = \frac{(\sqrt{3}a)^3}{3a} - 2a \times \sqrt{3}a - \int_0^{\sqrt{3}a} \sqrt{4a^2-y^2}\, dy$$

$$A = \sqrt{3}a^2 - 2\sqrt{3}a^2 - \left[\frac{B^2}{2}\sqrt{B^2-y^2} + \frac{1}{B}\sin^{-1}\frac{y}{B}\right]_0^{\sqrt{3}a}$$

~~A =~~ (Where $B = 2a$

$$A = -\sqrt{3}a^2 - \left[\frac{a^2}{2}\sqrt{4a^2-y^2} - \frac{1}{2a}\sin^{-1}\left(\frac{y}{2a}\right)\right]_0^{\sqrt{3}a}$$

$$A = -\sqrt{3}a^2 - \left[\frac{a^2}{2}\sqrt{4a^2-3a^2} - \frac{1}{2a}\sin^{-1}\left(\frac{\sqrt{3}}{2}\right)\right]$$

$$A = -\sqrt{3}a^2 - \left[a^2 - \frac{1}{2a} \times \frac{\pi}{3}\right]$$

$$\boxed{A = \frac{\pi}{6a} - (\sqrt{3}-1)a^2}$$

(6)

Q.6 (c) **(i)** Find the eigen values and eigen vectors of matrix

$$A = \begin{bmatrix} 3 & 1 & 4 \\ 0 & 2 & 6 \\ 0 & 0 & 5 \end{bmatrix}$$

(ii) A paramagnetic substance contains 6.5×10^{25} atoms per m^3 and the magnetic moment of each atom is one Bohr magneton. Find the susceptibility at 300 K temperature.

[12 + 8 marks]

Solution (i)

eigen value of A

$|A - \lambda I| = 0$

$$\begin{vmatrix} 3-\lambda & 1 & 4 \\ 0 & 2-\lambda & 6 \\ 0 & 0 & 5-\lambda \end{vmatrix} = 0 \Rightarrow (3-\lambda)[(2-\lambda)(5-\lambda)] = 0$$

$\lambda = 2, 3, 5$

eigen vector

for $\lambda_1 = 2$

$(A - \lambda)X = 0$

$$\begin{bmatrix} 1 & 1 & 4 \\ 0 & 0 & 6 \\ 0 & 0 & 3 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = 0$$

$x_1 + x_2 + 4x_3 = 0$

$6x_3 = 0$, $3x_3 = 0$

$x_3 = 0$

Let $x_2 = K$, $x_3 = 0$ then

$x_1 + K + 0 = 0$

$x_1 = -K$

So eigen vector for $\lambda = 2$ $\quad X = \begin{bmatrix} -1 \\ 1 \\ 0 \end{bmatrix}$

for $\lambda_2 = 3$

$$\begin{bmatrix} 0 & 1 & 4 \\ 0 & -1 & 6 \\ 0 & 0 & 2 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = 0 \Rightarrow$$

$x_2 + 4x_3 = 0$ — (1)

$-x_2 + 6x_3 = 0$ — (2)

$2x_3 = 0$

$x_3 = 0$

Let $x_2 = k$

By
$$\begin{bmatrix} 0 & 1 & 4 \\ 0 & 0 & 10 \\ 0 & 0 & 2 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = 0 \Rightarrow$$

$2x_3 = 0$, $10x_3 = 0$

$x_3 = 0$

$x_2 + 4x_3 = 0$

$x_3 = k$

then $x_2 = -4k$

$$X = \begin{bmatrix} 0 \\ -4 \\ 1 \end{bmatrix}$$

for $\lambda = 5$

$$\begin{bmatrix} -2 & 1 & 4 \\ 0 & -3 & 6 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = 0$$

$-2x_1 + x_2 + 4x_3 = 0$, $-3x_2 + 6x_3 = 0$

$x_2 = 2x_3$ Let $x_3 = k$

then $x_2 = 2k$

and $-2x_1 = -2k - 4k$

$x_1 = 3k$

So
$$X = \begin{bmatrix} 3 \\ 2 \\ 1 \end{bmatrix}$$

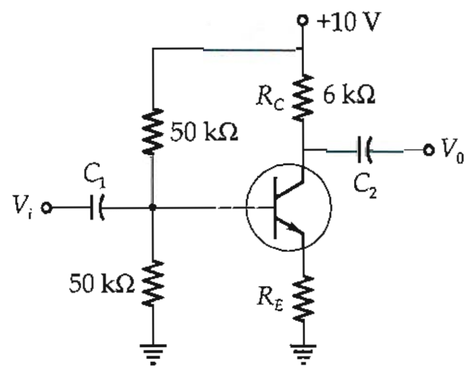
So eigen vector are

$$\begin{bmatrix} -1 \\ 1 \\ 0 \end{bmatrix}, \begin{bmatrix} 0 \\ -4 \\ 1 \end{bmatrix} \begin{bmatrix} 3 \\ 2 \\ 1 \end{bmatrix}$$

11

Good Approach

Q.7 (a) (i) Common emitter (CE) amplifier shown in figure has voltage gain of 200 when $R_E = 0$. Stability is brought through negative feedback by adding resistor R_E. Calculate the value of resistor R_E using feedback concepts so that final voltage gain (A_{FB}) is equal to 100.

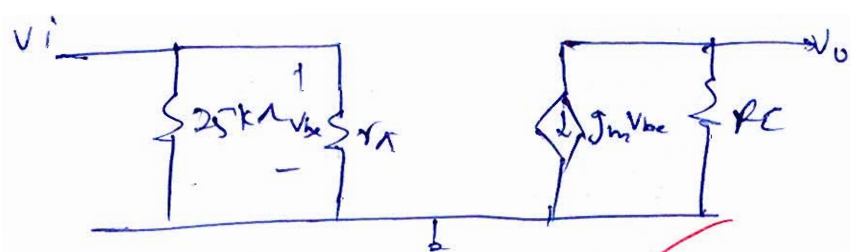


[10 marks]

Solution

By AC equivalent circuit

Case-1 $R_E = 0$, $R_B = 50 \| 50 = 25\,k\Omega$



So $V_o = -g_m R_C V_{be}$, $V_{be} = V_i$

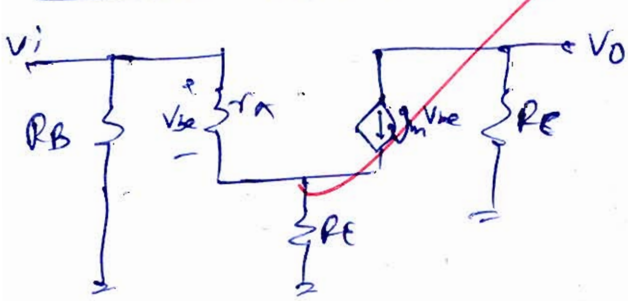
So $A = \frac{V_o}{V_i} = -g_m R_C$

Given $A = 200$, $R_C = 6\,k\Omega$

So $-g_m = 200/6 = \frac{1}{30}$ A/V

Now

Case-2 ($R_E \neq 0$)



As $V_o = -g_m V_{be} R_C$

$V_i = V_{be} + g_m V_{be} R_E \Rightarrow V_i = V_{be}(1 + g_m R_E)$

So

$$\frac{V_o}{V_i} = \frac{-g_m R_C}{1 + g_m R_E} = 100 \quad \text{(given)}$$

or, so

$$\frac{V_o}{V_i} \quad 100 = \frac{1/30 \times 6}{1 + 1/30 \times R_E}$$

$$1 + \frac{R_E}{30} = \frac{6}{3000}$$

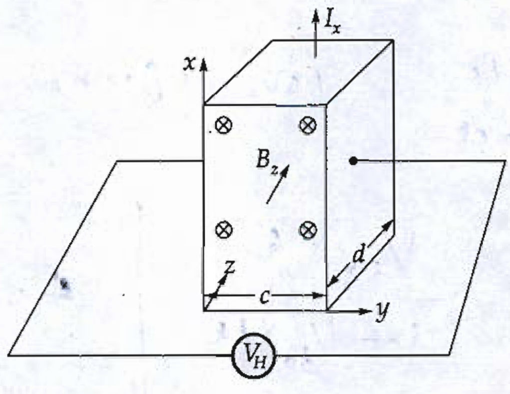
$R_E \approx 60\ \Omega$

$$A = \frac{-g_m R_C}{1 + g_m R_E}$$

$$A \simeq \frac{R_C}{R_E}$$

3

Q.7 (a) (ii) What is Hall effect? For a parallelepiped specimen having one corner situated at origin and externally applied electric field causing current in positive x-direction as shown below :



State what happens when magnetic field B_z is applied in positive z-direction in reference to Hall voltage. Determine electron mobility relation using Hall coefficient and conductivity (σ).

[10 marks]

Solution

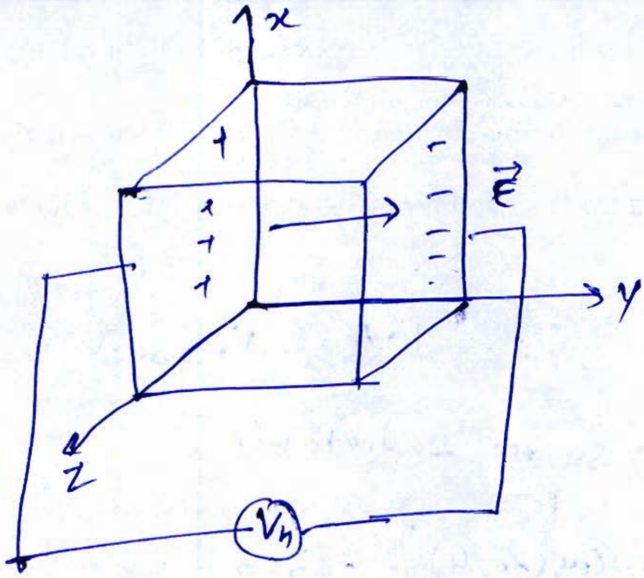
Hall effect

- When a material placed in magnetic ~~material~~ field and a current is passed perpendicular to magnetic ~~stren~~ field, then there will be an electric field, which will be perpendicular to both current and magnetic field.

This is called Hall effect.

Hall effect is used for
- finding type of semiconductor
- concentration of e^-/hole
- conductivity
- Resistivity.

when B_z is applied in +ve z-direction and current is passing through +ve x-direction then electric direction will be in y-direction.



As we know using Hall effect, Hall voltage is given by

$$V_H = R_H \cdot \frac{IB}{d}$$

Now $R_H = \frac{1}{ne}$

$$V_H = \frac{1}{ne}\frac{IB}{d}$$

As conductivity is given by

$\sigma = ne\mu$, and $R_H = 1/ne$

So $\boxed{\sigma = \frac{\mu}{R_H}}$

8

Q.7 (b) (i) A three-phase fully-controlled bridge converter is connected to three-phase a.c. supply of 400 V, 50 Hz and operates with a firing angle $\alpha = \frac{\pi}{4}$. The load current is maintained constant at 10 A and the load voltage is 360 V. Find source inductance, L_S and overlap angle μ.

[12 marks]

Solution $\alpha = \frac{\pi}{4}$, $I_0 = 10A$, $V_0 = 360V$

As we know, due to source Inductance.

$$V_0 = \frac{3V_{ml}}{2\pi}\left[\cos\alpha + \cos(\alpha+\mu)\right] = 360$$

$$\frac{3\times 400\sqrt{2}}{2\pi}\left[\cos 45 + \cos(45+\mu)\right] = 360$$

By solving $\cos(45+\mu) = 0.625$

$$\boxed{\mu = 6.31^\circ}$$

Now, As we know, drop due to source Inductance

$$\Delta V_{d0} = 6fL_sI_0$$

or

$$\frac{3V_{ml}}{2\pi}\left[\cos\alpha - \cos(\alpha+\mu)\right] = 6fL_sI_0$$

so

$$\frac{3\times 400\sqrt{2}}{2\pi}\left[\cos 45 - \cos(45+6.3)\right] = 6\times 50\times L_s\times 10$$

$$\boxed{L_s = 7.38\ mH}$$

So

$L_s = 7.38\ mH$

$\mu = 6.310$

11

Good Approach

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Q.7 (b) (ii) A magnetizing field of 500 Am^{-1} produces a magnetic flux of 2.4×10^{-5} weber in an atom bar of 0.2 cm^2 cross-sectional area. Compute the permeability and susceptibility of the bar.

[8 marks]

Solution $\vec{H} = 500$ A/m, $\phi = 2.4 \times 10^{-5}$

$A = 0.2 \, cm^2$

As $B = \phi/A = \frac{2.4 \times 10^{-5}}{0.2 \times 10^{-4}} = 1.2$ Tesla

Now

$B = \mu_0 \mu_r H$

$1.2 = 4\pi \times 10^{-7} \times \mu_r \times 500$

$\boxed{\mu_r = 1910.82}$

As we know, susceptibility is given by

$\chi = \mu_r - 1$

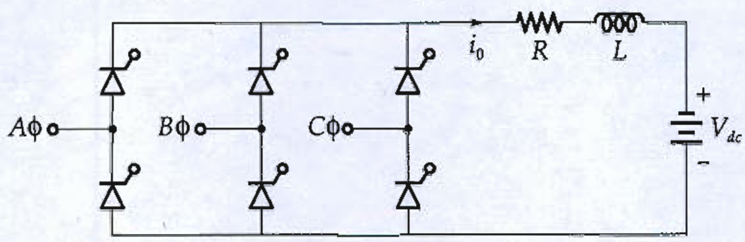
$\chi = 1910.82 - 1$

$\boxed{\chi = 1909.82}$

8

Good Approach

Q.7 (c) (i) The six pulse converter shown in figure has a delay angle $\alpha = 120°$. The three-phase ac system is 4160 V rms line to line. The dc source is 3000 V, $R = 2\ \Omega$ and L is large enough to consider the current to be purely dc. Determine the power transferred to the ac source from the dc source and the value of L such that the peak to peak variation in load current is 10 percent of the average load current.



[12 marks]

Solution $\alpha = 120°$

As $V_0 = \frac{3 V_{ml}}{\pi} \cos\alpha = \frac{3 \times 4160\sqrt{2}}{\pi} \cos 120$

$V_0 = -2810.41$ Volt

As $I_0 = \frac{E - V_0}{R} = \frac{3000 - 2810.41}{2}$

$I_0 = 94.8$ Amp.

As continuous conduction, $I_{or} = I_0 = 94.8$ Amp.

power delivered by Battery to AC source will be

$P_{ac} = E_b I_0 - I_{or}^2 R$

$P_{ac} = 3000 \times 94.8 - 94.8^2 \times 2$

P_{ac} (source power) $= 266.425$ kW

(5)

given $\Delta I_L = \frac{10}{100} \times I_0 = \frac{10}{100} \times 94.8$

$\Delta I_L = 9.48$ Amp.

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Q.7 (c) (ii) For a specimen of V_3Ga, the critical fields are respectively 0.176 T and 0.528 T for 14 K and 13 K represents. Calculate the transmission temperatures and critical fields at 0 K and 4.2 K.

[8 marks]

Solution

$H_{c_1} = 0.176\,T$ at $T = 14K$

$H_{c_2} = 0.528$ at $T = 13K$

As $H_c = H_0\left[1 - \left(\frac{T}{T_c}\right)^2\right]$ —①

So

$$\frac{H_{c_2}}{H_{c_1}} = \frac{\left[1-\left(\frac{T_2}{T_c}\right)^2\right]}{\left[1-\left(\frac{T_1}{T_c}\right)^2\right]} \Rightarrow \frac{0.528}{0.176} = \frac{\left[1-\left(\frac{13}{T_c}\right)^2\right]}{\left[1-\left(\frac{14}{T_c}\right)^2\right]}$$

$$3\left[1-\left(\frac{14}{T_c}\right)^2\right] = 1-\left(\frac{13}{T_c}\right)^2$$

$$3 - 1 = 3\frac{(14)^2}{T_c^2} - \frac{13^2}{T_c^2}$$

$$2T_c^2 = 3(14)^2 - 13^2$$

$$\boxed{T_c = 14.47\,K}$$

from ①

$$0.176 = H_0\left[1-\left(\frac{14}{14.47}\right)^2\right]$$

So

$$H_0 = 2.75\ A/m\ (T)$$

So

at $T = 0K$

$H_c = H_0$

$$\boxed{H_0 = 2.75\,T}$$

At $T = 4.2K$

$$H = 2.75\left[1 - \left(\frac{4.2}{14.47}\right)^2\right]$$

$$\boxed{H = 2.52\,T}$$

6

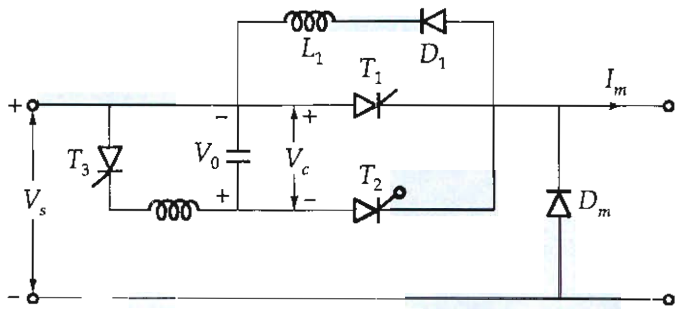
Q.8 (a) A 3-phase full converter, fed from 3-phase, 400 V, 50 Hz source is connected to a load having a series $R = 10\ \Omega$, $E = 350$ V and a large inductance so that the output current is ripple free. Calculate the power delivered to the load and input power factor for

(i) firing angle of 30°.

(ii) firing advance angle of 60°.

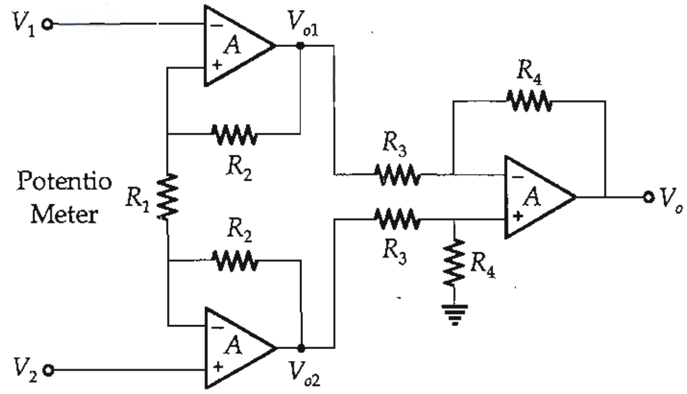
[20 marks]

Q.8 (b) (i) Consider the commutation circuit as shown in figure. It has capacitance $C = 20\ \mu F$ and recharging inductor $L_1 = 25\ \mu H$. The initial capacitor voltage is equal to the input voltage, $V_o = V_s = 200$ V. If the load current, I_m varies between 50 A and 200 A, determine the variations of the circuit turn-off time. Also comment upon the result.



[10 marks]

Q.8 (b) (ii) Design an instrument amplifier to have a variable differential gain in range 5 to 200. Use a 50 kΩ potentiometer.



[10 marks]

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Q.8 (c) Explain with circuit diagram the advantages of clapp oscillator over colpitt oscillator. If in the circuits $C_1 = C_2 = 150$ pF and $L_3 = 50$ μH and the value of additional capacitor used in clapp oscillator $C_S = 10$ pF. Find the frequency of oscillations for:

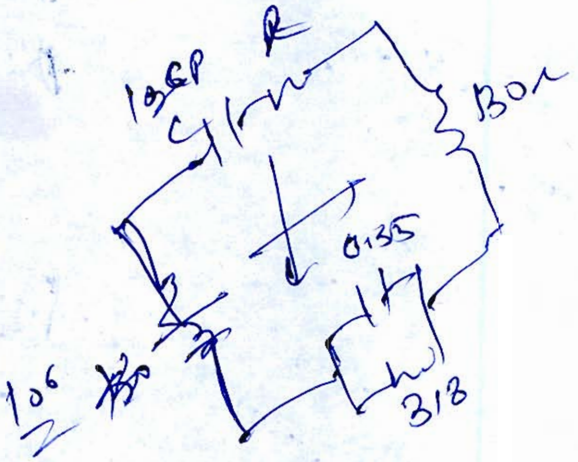
(i) Colpitt oscillator.

(ii) Clapp oscillator.

[20 marks]

OOOO

Space for Rough Work



$x = 29 + \sqrt{49^2 - 4^2}$

$x^2 + 9x = 49x$

$x^2 = 39x$

$x = \sqrt{30}$

$x = 39$

$y^2 = 9.39$

$y = \sqrt{39}$

$x^2 = 39x$

$x = 39$

$y^2 = 35$

Space for Rough Work

$-g_m R_C$

$\frac{-g_m R_C}{R_e + R_E}$

$\frac{R_C}{R_E}$

$\frac{d^2y}{dx^2} = \frac{2y}{x^2} + 1 + 1/x^3$

$D_1(D_1-1) - 2 =$

$\sqrt{4a^2 - y^2} = t^2$

$4a^2 - y^2 = t^2$

$-2y\,dy = 2t\,dt$

$dy = -\frac{t}{y}dt$

x^{-2}

$-2 \times \frac{x^{-2+1}}{-2+1}$

$+2\frac{x^{-1}}{+1}$

$2/x$

$e^{\frac{2}{x}} \cdot y = \int (1 + 1/x^3)\, e^{2/x}$

$\frac{1}{R} = RC$

$C =$

$\sqrt{4a^2 - t^2}$

$x^2 - 4ax + 4a^2 - 4a^2$

$16r^2 = 3a^2$

$r = \frac{\sqrt{3}a}{4}$

$\frac{a}{2} \times \frac{1}{\sqrt{2}}$

$16r^2 = 2a^2$

$\frac{a}{2\sqrt{2}} = 2r$

$\frac{a}{2} \times \frac{\sqrt{3}}{2}$

$\frac{a}{2}$