• Improve presentation

• Try to avoid calculation mistake

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Leading Institute for ESE, GATE & PSUs

ESE 2026 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electrical Engineering

Test-6 : Power Electronics & Drives + Engineering Mathematics + B.E.E.-1 + Analog Electronics-1 + Electrical Materials-1 + Electrical Machines-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	34
Q.2	
Q.3	42
Q.4	
Section-B	
Q.5	38
Q.6	47
Q.7	33
Q.8	
Total Marks Obtained	194

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.

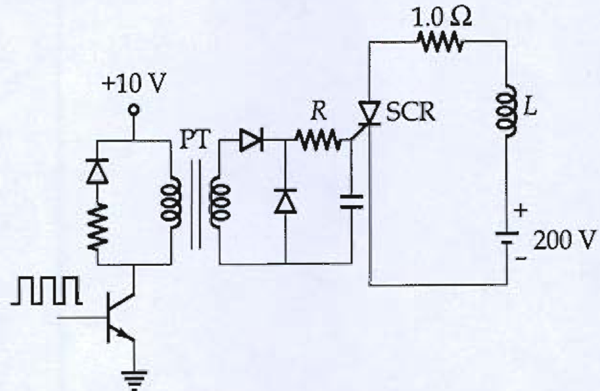
DO'S

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.

Section A : Power Electronics & Drives + Engineering Mathematics

Q.1 (a) A 1 : 1 Pulse transformer (PT) is used to trigger the SCR in the figure. The SCR is rated at 1.5 kV, 250 A with I_L = 250 mA, I_H = 150 mA, and I_{Gmax} = 150 mA with I_L = 250 mA, I_{Gmin} = 100 mA. The SCR is connected to an inductive load, where L = 150 mH in series with a small resistance and the supply voltage is 200 V DC. The forward drops of all transistors / diodes and gate-cathode junction during ON state are 1.0 V.

(i) Find the resistance R.



(ii) Find the minimum approximate volt-second rating of the pulse transformer suitable for triggering the SCR (Volt-second rating is the maximum of product of the voltage and the width of the pulse that may be applied).

[12 marks]

i) SCR becomes ON when anode current becomes greater than latching current I_L.

So $I_A = I_L = 250 \times 10^{-3}$ A $= 0.25$ A

Let t_{min} be the ~~pull~~ time upto which pulse is applied on gate.

by KVL:

$$200 = i_A \times 1 + L\frac{di_A}{dt} + 1V$$

3

$$200 = 0.25 + 150 \times 10^{-3} \times \frac{i_A}{t_{min}} + 1V$$

Incomplete solution

$$\Rightarrow t_{min} = \frac{150 \times 10^{-3} \times 0.25}{198.75}$$

$$\boxed{t_{min} = 0.189 \text{ ms}}$$

is the time for which pulse is applied.

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Q.1 (b) Find the area of that part of the surface of the paraboloid of the paraboloid $y^2 + z^2 = 2ax$, which lies between the cylinder, $y^2 = ax$ and the plane $x = a$.

[12 marks]

area of the paraboloid that lies between cylinder $y^2 = ax$ and the plane $x = a$ is given by projecting the paraboloid on xy plane.

$z = 0$

$A = \iint dx\,dy$

~~y~~ intersection of cylinder and paraboloid is:

$y^2 + z^2 = 2ax$ and $y^2 = ax$

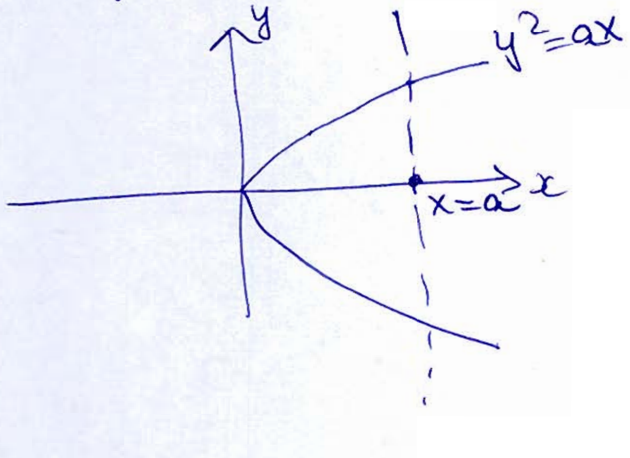
$z^2 = ax \Rightarrow z = \pm\sqrt{ax}$

and $y = \pm\sqrt{ax}$

and intersection of plane $x = a$ & paraboloid is

$y^2 + z^2 = 2a^2$ is a circle of radius $\sqrt{2}\,a$

3



Incomplete soleetion

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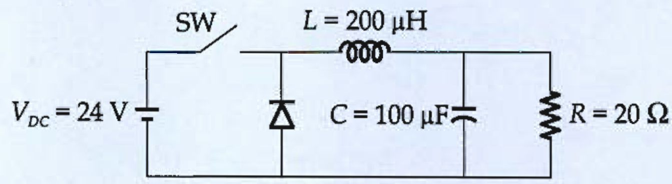
Q.1 (c) A buck converter is shown below. For the switching frequency of 10 kHz and duty ratio of 0.4, find the output voltage.

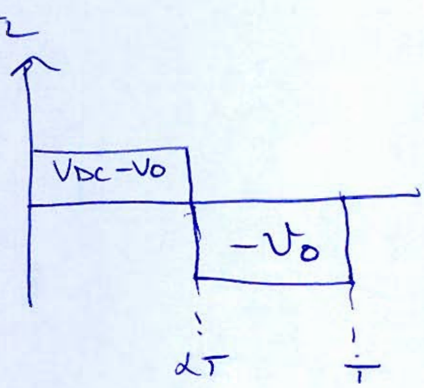


[12 marks]

Given: $f = 10\,KHz$
and $\alpha = 0.4$

when SW → ON:

$V_L = V_{DC} - V_o$



and when SW → OFF

$v_L = -v_o$

assuming continuous conduction

$V_o = \alpha V_{DC} = 0.4 \times 24$
$= 9.6\,V$

and $I_o = \frac{V_o}{R} = \frac{9.6}{20} = 0.48\,A$

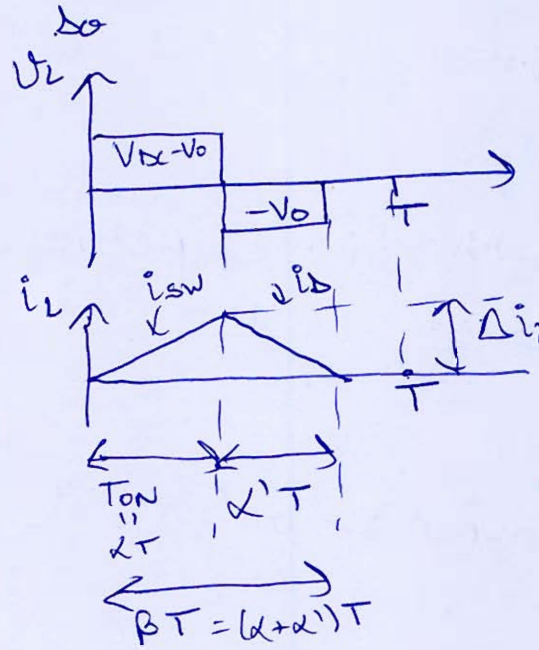
now

$I_{LB} = I_{oB} = \frac{\Delta I_L}{2} = \frac{\alpha(1-\alpha)V_{DC}}{2fL}$

$\Rightarrow I_{oB} = \frac{\cancel{0.4}^{0.1} \times 0.6 \times 24}{\cancel{2} \times 1\cancel{0} \times 1\cancel{0^3} \times \cancel{200} \times 1\cancel{0^{-6}}}$

$I_{oB} = 1.44$

as $I_o < I_{oB} \Rightarrow$ discontinuous conduction mode.



so $(i_D)_{avg} = \dfrac{\frac{1}{2}\times \Delta i_L \times \alpha' \cancel{T}}{\cancel{T}}$

$= \frac{1}{2}\Delta i_L \times \alpha'$

and

$(i_{SW})_{avg} = \dfrac{\frac{1}{2}\times \Delta i_L \times \alpha T}{T}$

$= \frac{1}{2}\Delta i_L \times \alpha$

also

$\Delta i_L = \dfrac{(V_{DC}-V_o)\cdot \alpha T}{L} = \dfrac{V_o \cdot \alpha' T}{L}$

and $(i_L)_{avg} = \dfrac{\frac{1}{2}\times \Delta i_L \times (\alpha+\alpha')\cancel{T}}{\cancel{T}} = I_{oavg} = \dfrac{V_o}{R}$

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$\Rightarrow \frac{1}{2}\times(\alpha+\alpha')\times \dfrac{\cancel{V_o}\cdot\alpha'}{fL} = \dfrac{\cancel{V_o}}{R}$

$0.4\alpha' + \alpha'^2 = \dfrac{2fL}{R} = \dfrac{2\times 10^4 \times 200\times 10^{-6}}{20}$

Good Approach

$\alpha'^2 + 0.4\alpha' - 0.2 = 0$

$\Rightarrow \alpha' = 0.289,\ \cancel{-0.689}$

$\Rightarrow \boxed{\alpha' = 0.289}$

so from $\Delta i_L = \dfrac{(V_{DC}-V_o)\cdot\alpha \cancel{T}}{\cancel{L}} = \dfrac{V_o\,\alpha'\cancel{T}}{\cancel{L}}$

$(24 - V_o)\times 0.4 = V_o \times 0.289$

$24\times 0.4 = V_o\,(0.4 + 0.289)$

$\Rightarrow V_o = \dfrac{24\times 0.4}{0.689}$

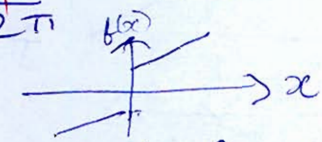
$\Rightarrow \boxed{V_o = 13.93\,V}$

Do not write in this margin

Q.1 (d) Find the Fourier series of the function defined as $f(x) = \begin{cases} x+\pi & \text{for } 0 < x < \pi \\ -x-\pi & -\pi < x < 0 \end{cases}$ and $f(x + 2\pi) = f(x)$.

[12 marks]

f(x) is periodic with time period 2π. $\Rightarrow \omega_0 = \frac{2\pi}{T} = \frac{2\pi}{2\pi} = 1$



F-S is given by:

$$f(x) = a_0 + \sum_{n=1}^{\infty} a_n \cos n\omega_0 x + b_n \sin n\omega_0 x$$

where

$$a_0 = \frac{1}{T}\int_T f(x)\,dx = \frac{1}{2\pi}\left[\int_0^{\pi}(x+\pi)\,dx + \int_{-\pi}^{0}(-x-\pi)\right]$$

$$= \frac{1}{2\pi}\left[\frac{x^2}{2}+\pi x\Big|_0^{\pi} - \left[\frac{x^2}{2}+\pi x\Big|_{-\pi}^{0}\right]\right]$$

$$= \frac{1}{2\pi}\left[\frac{\pi^2}{2} + \cancel{\pi^2} + \frac{\pi^2}{2} - \cancel{\pi^2}\right]$$

$$\boxed{a_0 = \pi/2}$$

and

$$a_n = \frac{2}{T}\int_T f(x)\cos nx\,dx$$

$$= \frac{2}{2\pi}\left[\int_{-\pi}^{0}(-x-\pi)\cos nx\,dx + \int_0^{\pi}(x+\pi)\cos nx\right]$$

$$= \frac{1}{\pi}\left[\int_0^{\pi}(x+\pi)\cos nx\,dx + \int_0^{\pi}(x+\pi)\cos nx\,dx\right]$$

$$= \frac{2}{\pi}\left[\int_0^{\pi} x\cos nx\,dx + \pi\int_0^{\pi}\cos nx\,dx\right]$$

$$= \frac{2}{\pi}\left[\left(\frac{x\sin nx}{n} + \frac{\cos nx}{n^2}\right)\Big|_0^{\pi} + \pi\,\frac{\sin nx}{n}\Big|_0^{\pi}\right.$$

$$= \frac{2}{\pi}\left[\frac{\cos n\pi}{n^2} - \frac{1}{n^2}\right] = \frac{2}{\pi n^2}[\cos n\pi - 1]$$

now $\cos n\pi = (-1)^n$

$$\Rightarrow \boxed{a_n = \begin{cases} 0 & , n = \text{even} \\ -\frac{4}{\pi n^2} & , n = \text{odd} \end{cases}}$$

and

$$b_n = \frac{2}{T}\int_T f(x)\sin nx\,dx = \frac{2}{2\pi}\left[\int_{-\pi}^{0}(-x-\pi)\sin nx\,dx + \int_0^{\pi}(\pi)\sin nx\,dx\right]$$

$$= \frac{2}{\pi}\left[\int_0^{\pi} x\sin nx\,dx + \pi\int_0^{\pi}\sin nx\,dx\right]$$

$$= \frac{2}{\pi}\left[-\frac{x\cos nx}{n} + \frac{\sin nx}{n^2}\Big|_0^{\pi} - \frac{\pi\cos nx}{n}\Big|_0^{\pi}\right]$$

$$= \frac{2}{\pi}\left[-\frac{\pi\cos n\pi}{n} + 0 - \frac{\pi}{n}[\cos n\pi - \cos 0]\right]$$

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$$= -\frac{2\pi}{n\pi}[2\cos n\pi]$$

Wrong value calculated

$$= -\frac{4}{n}\cos n\pi = -\frac{4}{n}(-1)^n$$

$$\Rightarrow \boxed{b_n = \begin{cases} -\frac{4}{n} & , n = \text{even} \\ \frac{4}{n} & , n = \text{odd} \end{cases}}$$

$$\Rightarrow f(x) = \frac{\pi}{2} - \sum_{n=2,4,6,\ldots}^{\infty} \frac{4}{n}\sin nx \quad \text{when } n = \text{even}$$

$$= \frac{\pi}{2} + \sum_{n=1,3,5,\ldots}^{\infty} -\frac{4}{\pi n^2}\cos nx + \frac{4}{n}\sin nx \quad \text{when } n = \text{odd}$$

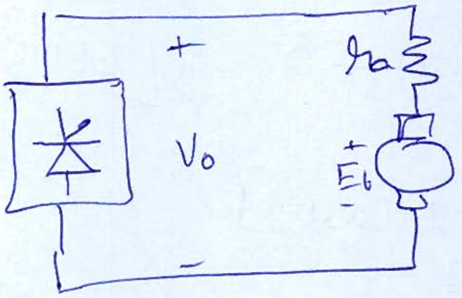
Q.1 (e) A single-phase full-controlled thyristor converter bridge is used for regenerative braking of a separately excited DC motor with the following specifications:

Rated armature voltage	210 V
Rated armature current	10 A
Rated speed	1200 rpm
Armature resistance	1 Ω
Input to the converter bridge	240 V at 50 Hz
The armature of the DC motor is fed from the full-controlled bridge and the field current is kept constant.	

Assume that the motor is running at 600 rpm and the armature terminals of the motor are suitably reversed for regenerative braking. If the armature current of the motor is to be maintained at the rated value, find the triggering angle of the converter bridge in degrees.

[12 marks]

Given: $I_f \rightarrow$ const. $\Rightarrow \phi =$ const.



Motor running at 600 rpm

I_a maintained at rated value

$\Rightarrow I_a = 10A$

so in regen. braking power fed back to supply.

$-E_b + I_o R_a = V_o$ — (1)

for rated: $V_o = 210V$

$\Rightarrow E_{b\,rated} = 210 - 10\times1 = 200V$ @ 1200 rpm

$E_b \propto N\phi \Rightarrow E_b \propto N$

so @ 600 rpm $E_{b0} = 200 \times \frac{600}{1200}$

$$\boxed{E_{b0} = 100V}$$

as full converter bridge
continuous conduction

$$V_0 = \frac{2V_m}{\pi}\cos\alpha$$

so in equation ①

$$-100 + 10\times 1 = \frac{2\times 240\sqrt{2}}{\pi}\cos\alpha$$

$$-90 = \frac{2\times 240\sqrt{2}}{\pi}\cos\alpha$$

$$\Rightarrow \cos\alpha = -0.4165$$

$$\Rightarrow \boxed{\alpha = 114.615^\circ}$$

so triggering angle of bridge
is <u>114.615°</u>

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Good
Approach

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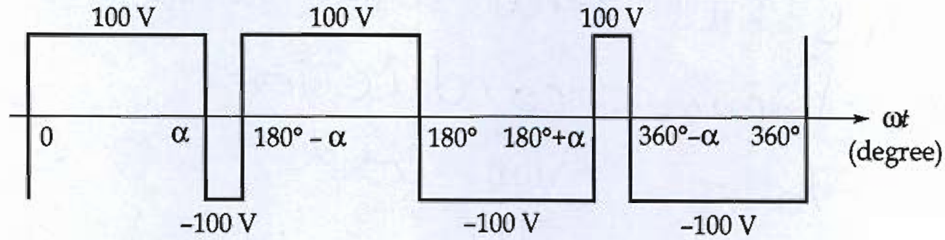
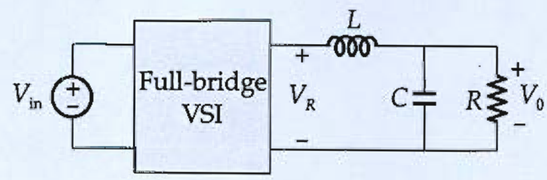
Q.2 (a) (i) The figure shows below, one period of the output voltage of an inverter. α should be chosen such that $60° < \alpha < 90°$. If rms value of the fundamental component is 50 V, find the value of α in degree.



[10 marks]

Q.2 (a) **(ii)** The single-phase full-bridge voltage source inverter (VSI), shown in the figure below, has an output frequency of 50 Hz. It uses unipolar pulse width modulation with switching frequency of 50 kHz and modulation index of 0.7. For V_{in} = 100 V DC, L = 9.55 mH, C = 63.66 mF and R = 5 Ω. Find the amplitude of the fundamental component in the output voltage V_0 (in Volt) under steady-state. Also calculate the power absorbed by load 'R'. Considering only fundamental frequency.



[10 marks]

Q.2 (b) (i) Solve:

$$\frac{dx}{dt} + y = \sin t;\ \frac{dy}{dt} + x = \cos t, \text{ where } y(0) = 0,\ x(0) = 2.$$

[10 marks]

Q.2 (b) **(ii)** Prove that orthogonal matrices of order two are of the form,

$$\begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \text{ or } \begin{bmatrix} \cos\theta & \sin\theta \\ \sin\theta & -\cos\theta \end{bmatrix}$$

[10 marks]

Q.2 (c) (i) Using Runge-Kutta method of fourth order, solve $\frac{dy}{dx} = \frac{y^2 - x^2}{y^2 + x^2}$, with $y(0) = 1$ at $x = 0.2, 0.4$.

[10 marks]

Q.2 (c) **(ii)** Assuming that the following values of y belong to a polynomial of degree 4, compute the next three values:

x:	0	1	2	3	4	5	6	7
y:	1	–1	1	–1	1	–	–	–

[10 marks]

Q.3 (a) (i) Apply factorization method to solve the equations:

$3x + 2y + 7z = 4; \quad 2x + 3y + z = 5; \quad 3x + 4y + z = 7$

[10 marks]

representating equations in matrix form.

$$\begin{bmatrix} 3 & 2 & 7 \\ 2 & 3 & 1 \\ 3 & 4 & 1 \end{bmatrix}\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 4 \\ 5 \\ 7 \end{bmatrix}$$

$R_3 \rightarrow R_3 - R_1$

$$\begin{bmatrix} 3 & 2 & 7 \\ 2 & 3 & 1 \\ 0 & 2 & -6 \end{bmatrix}\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 4 \\ 5 \\ 3 \end{bmatrix}$$

$R_2 \rightarrow R_2 - \frac{2}{3} R_1$

$$\begin{bmatrix} 3 & 2 & 7 \\ 0 & \frac{5}{3} & -11/3 \\ 0 & 2 & -6 \end{bmatrix}\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 4 \\ 7/3 \\ 3 \end{bmatrix}$$

$R_3 \rightarrow R_3 - \frac{6}{5} R_2$

$$\begin{bmatrix} 3 & 2 & 7 \\ 0 & 5/3 & -11/3 \\ 0 & 0 & -\frac{8}{5} \end{bmatrix}\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 4 \\ 7/3 \\ +\frac{9}{5} \end{bmatrix}$$

so expanding along R_3 and comparing

$$-\cancel{6}\frac{8}{5} z = +\cancel{6}\frac{9}{5}$$

$$z = \frac{9}{8} \Rightarrow z = -\frac{1}{8}$$

$$\boxed{z = -0.125}$$

and $3x + 2y + 7z = 4$ — ①

and $\frac{5}{3}y - \frac{11}{3}z = \frac{7}{3}$

$\frac{5}{3}y = \frac{11}{3} \times \left(-\frac{1}{8}\right) + \frac{7}{3}$

$\Rightarrow \boxed{y = 1.125}$

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Go through the made easy solution

substitute in ①

$\Rightarrow \boxed{x = 0.875}$

Hence $x = 0.875$, $y = 1.125$
and $z = 0.875$

Q.3 (a) (ii) Apply Gauss-Jordan method to solve the equations:
$x + y + z = 9$; $2x - 3y + 4z = 13$; $3x + 4y + 5z = 40$

[10 marks]

Let initial guess value be $x_0 = 0$
writing in matrix form ~~is~~

$$\begin{bmatrix} 1 & 1 & 1 \\ 2 & -3 & 4 \\ 3 & 4 & 5 \end{bmatrix}\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 9 \\ 13 \\ 40 \end{bmatrix}$$

$R_3 \to R_3 - 3R_1$; $R_2 \to R_2 - 2R_1$

$$\begin{bmatrix} 1 & 1 & 1 \\ 0 & -5 & 2 \\ 0 & 1 & 2 \end{bmatrix}\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 9 \\ -5 \\ 13 \end{bmatrix}$$

$R_2 \to -\frac{1}{5}R_2$

$$\begin{bmatrix} 1 & 1 & 1 \\ 0 & 1 & -2/5 \\ 0 & 1 & 2 \end{bmatrix}\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 9 \\ 1 \\ 13 \end{bmatrix}$$

Do not write in this margin

$R_1 \to R_1 - R_2$ and $R_3 \to R_3 - R_2$

$$\begin{bmatrix} 1 & 0 & \frac{7}{5} \\ 0 & 1 & -2/5 \\ 0 & 0 & \frac{12}{5} \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 8 \\ 1 \\ 12 \end{bmatrix}$$

$R_3 \to \frac{5}{12} R_3$

$$\begin{bmatrix} 1 & 0 & 7/5 \\ 0 & 1 & -2/5 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 8 \\ 1 \\ 5 \end{bmatrix}$$

$R_2 \to R_2 + \frac{2}{5} R_3$

$R_1 \to R_1 - \frac{7}{5} R_3$

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 1 \\ 3 \\ 5 \end{bmatrix}$$

Do by Gauss Jordon Method

$\boxed{x = 1, y = 3 \text{ and } z = 5}$

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Try to avoid over writing

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Q.3 (b) (i) Find the positive root of $x^4 - x - 10$ correct to the three decimal places, using Newton-Raphson method.

[10 marks]

equation of Newton Raphson method

$$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}$$

now $f(x) = x^4 - x - 10$

$f'(x) = 4x^3 - 1$

let initial guess value $x_0 = 2$

so $f(x_0 = 2) = 2^4 - 2 - 10 = 16 - 12 = 4$

$f'(x_0 = 2) = 4 \times 2^3 - 1 = 31$

so

$$x_1 = 2 - \frac{4}{31} = 1.8709$$

so $f(x_1) = 1.8709^4 - 1.8704 - 10 = 0.3809$

$f'(x_1) = 25.1945$

so

$$x_2 = 1.8709 - \frac{0.3809}{25.1945}$$

$x_2 = 1.8557$

now $f(x_2) = 0.0028$

$f'(x_2) = 24.561$

$$x_3 = x_2 - \frac{f(x_2)}{f'(x_2)}$$

$$= 1.8557 - \frac{0.0028}{24.561}$$

$x_3 = 1.8555$

so $f(x_3) = 3.608 \times 10^{-5}$

$f'(x_3) = 24.5566$

so $x_4 = x_3 - \frac{f(x_3)}{f'(x_3)} = 1.8555 - \frac{3.608\times10^{-5}}{24.5566}$

$\Rightarrow \quad x_4 = 1.8555$

as $x_3 = x_4$

Hence positive root of given polynomial is $\boxed{x = 1.8555}$

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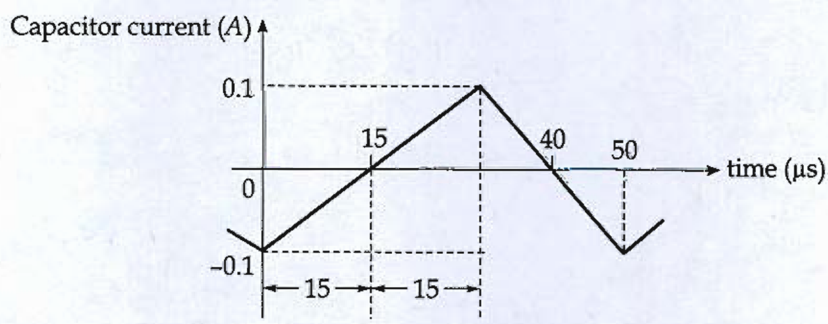
Good Approach

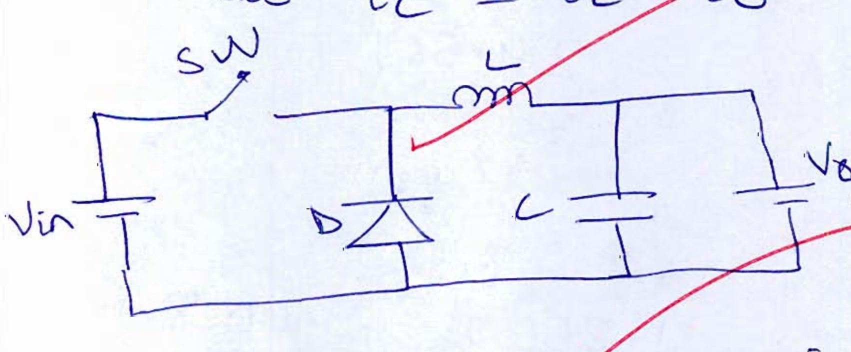
Q.3 (b) **(ii)** The steady state capacitor current of a conventional DC-DC buck converter, working in CCM, is shown in one switching cycle. If the input voltage is 30 V, find the value of the inductor used in mH.

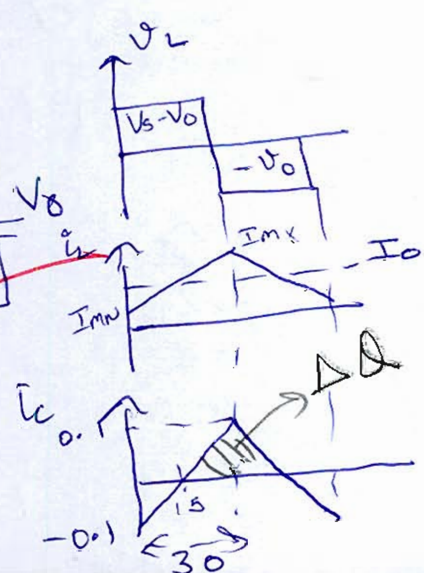


[10 marks]

Given: $V_{in} = 30\,V$

as $i_C = i_L - i_O$





so ripple current $\Delta I_L = 0.1 - (-0.1)$

$\Delta I_L = 0.2\,A$

and $T_{ON} = 30\,\mu s$

$T = 50\,\mu s$

so $\alpha = \frac{T_{ON}}{T} = \frac{3\cancel{0}}{5\cancel{0}} = \underline{\underline{0.6}}$

so area under $i_c = \Delta Q$

$\Rightarrow \Delta Q = \frac{1}{2} \times 0.1 \times 25 \times 10^{-6}$

$= \frac{1}{2} \times \frac{\Delta i_L}{2} \times \frac{T}{2}$

$\Delta Q = 1.25\,\mu C$

also $\Delta I_L = \frac{(V_s - V_o) \cdot \alpha T}{L} = 0.2$

as buck convertor $V_o = \alpha V_s$

$\Rightarrow V_o = \frac{30 \times 0.6}{\cancel{0.6}} = 18\,V$

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so $\frac{(30-18) \times 0.6 \times 50 \times 10^{-6}}{L} = 0.2$

Good Approach

$\Rightarrow L = \frac{\cancel{12}^{6} \times 0.6 \times 50 \times 10^{-6}}{\cancel{0.2}}$

$\Rightarrow \boxed{L = 1.8\,mH}$

Do not write in this margin

Q.3 (c) A 4-pole, 3-phase, 400 V, 50 Hz, Y-connected induction motor is fed from an inverter such that the phase voltage of inverter is a six-step waveform. The motor speed is controlled by maintaining V/f constant a value corresponding to rated voltage and rated frequency.

(i) Determine the expression for fundamental voltage and harmonics of the inverter output voltage.

(ii) Calculate the DC input voltage required to feed the inverter for operating the motor at 60 Hz, 50 Hz and 40 Hz.

(iii) Calculate the firing angles if the DC input voltage to the inverter is obtained from a 3-phase semi-converter from a 500 V (line to line), 50 Hz source while the inverter output corresponding to 60 Hz.

[20 marks]

Phase voltage of inverter → 6 step waveform so 180° mode

i) so

$$v_{ph} = \sum_{n=6K\pm1}^{\infty} \frac{6x}{n\pi} \sin n\omega t$$

where $x = \frac{V_s}{3}$

$$\Rightarrow v_{ph} = \sum_{n=6K\pm1}^{\infty} \frac{2V_s}{n\pi} \sin n\omega t$$

considering 400V as input to inverter.

2) so

$$v_{ph1} = \frac{2V_s}{\pi} \sin n\omega t$$

4

$$\hat{v}_{ph1} = \frac{2V_s}{\pi} = \frac{2\times400}{\pi} = 254.65V$$

$$v_{ph1rms} = \frac{\hat{v}_{ph1}}{\sqrt{2}} = 180.06V$$

and

$$\hat{v}_{ph5} = \frac{2V_s}{5\pi}$$

$$\Rightarrow v_{ph5rms} = \frac{180.06}{5} = 36.01V$$

$$\hat{v}_{ph7} = \frac{2V_s}{7\pi}$$

$$\hat{v}_{ph7rms} = \frac{180.06}{7} = 25.722V$$

and $v_{ph\,11\,rms} = 180 \cdot \frac{2V_s}{11\pi\sqrt{2}} = 16.37V$

$v_{ph\,13\,rms} = \frac{2V_s}{13\pi\sqrt{2}} = 13.85V$

ii) as $\frac{V}{f} \rightarrow$ const.

o/p $V_{line} = 400V$ @ 50 Hz

line V → quasi square wave : $\frac{4V_s}{n\pi} \sin n d \sin n\omega t$

where $d = \frac{\pi}{3}$

or as 180° mode inverter

$V_{Line} = \sqrt{\frac{2}{3}}\, V_s$ where V_s is input voltage of inverter.

now for 50Hz:

$V_s = \sqrt{\frac{3}{2}} \times 400 = 489.897V \simeq 490V$

$\boxed{V_s = 490V}$

for 60 Hz:

$V_{line} = 400 \times \frac{60}{50} = 480V$

4

$\Rightarrow V_s = \sqrt{\frac{3}{2}} \times 480 \simeq 588V$

for 40Hz:

$V_{line} = 400 \times \frac{40}{50} = 320V$

$V_s = \sqrt{\frac{3}{2}} \times 320$

$\Rightarrow V_s \simeq 392V$

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(ii) $V_{DC} \xrightarrow{\text{from}}$ 3ϕ semi convertor [500V line to line] 50Hz

o/p corresponds to 60Hz

ie $V_s = V_{DC} = 588V$

for 3ϕ semiconvertor

$$V_{DC} = \frac{3V_{mL}}{2\pi} \cancel{\cos\alpha} [1+\cos\alpha]$$

$$588 = \frac{3 \times 500 \times \sqrt{2}}{2\pi} [1+\cos\alpha]$$

$$1+\cos\alpha = 1.7416$$

$$\Rightarrow \cos\alpha = 0.7416$$

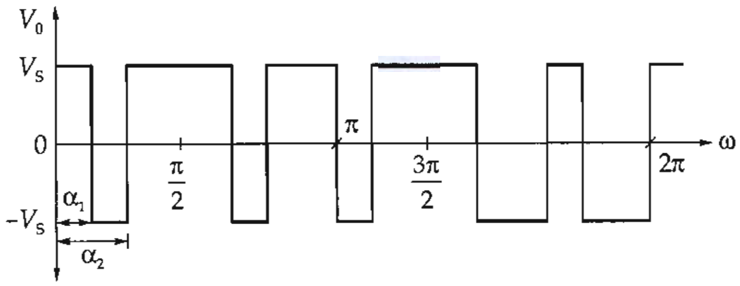
$$\Rightarrow \boxed{\alpha = 42.13^\circ}$$

2

Wrong value calculated

Q.4 (a) (i) A single phase full bridge bipolar PWM inverter employs selective harmonics elimination technique. The output voltage waveform of the inverter is shown in the figure below. For $\alpha_1 = 23.62°$ and $\alpha_2 = 33.3°$, 3^{rd} and 5^{th} harmonics have been eliminated.

1. Find the magnitude of 7^{th}, 9^{th} and 11^{th} harmonics.
2. By how much percentage inverter has been derated? What are the disadvantages of this method?



[12 marks]

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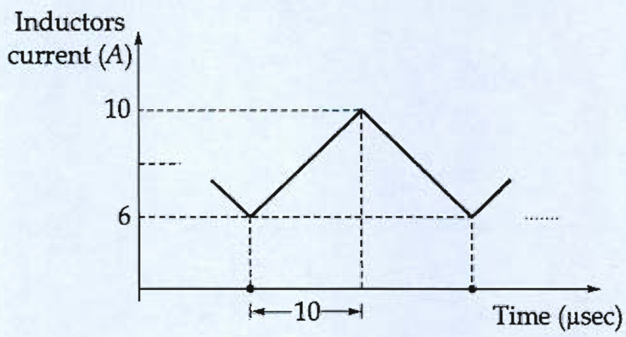
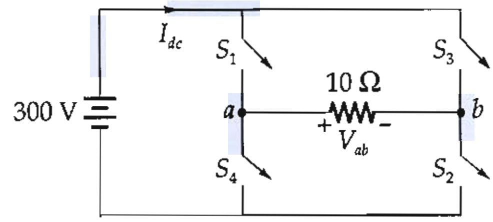
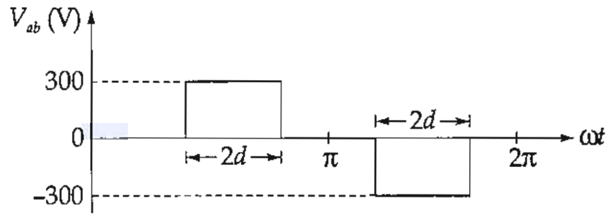
Q.4 (a) **(ii)** The steady state current flowing through the inductor of a DC-DC boost converter is given in the figure below. The value of the output capacitor is 150 μF. If the peak-to-peak ripple in the output voltage of the converter is 0.2 V. Find the switching frequency of the converter, in kHz.



[8 marks]

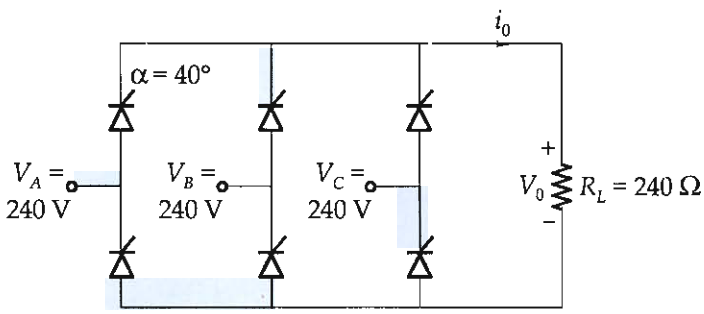
Q.4 (b) (i) A single-phase full bridge inverter fed by a 300 V DC produces a symmetric quasi-square waveform across '*ab*' as shown in figure below. The switch control signals of the converter are generated using sinusoidal pulse width modulation index, $M = 0.8$. Find the input voltage current I_{dc}, in amps.





[8 marks]

Q.4 (b) **(ii)** For the three-phase full controlled bridge rectifier circuit shown with purely resistive load :



1. Sketch the output voltage and current waveforms.
2. Derive the expression for average output voltage and current.

[12 marks]

Q.4 (c) (i) Using Newton-Raphson method evaluate to two decimal figures, the root of the equation $e^x = 3x$ lying between 0 and 1.

[10 marks]

Q.4 (c) **(ii)** A tennis match of best of 5 sets is played by two players A and B. The probability that first set is won by A is $\frac{1}{2}$ and if he loses the first, then probability of his winning the next set is $\frac{1}{4}$, otherwise it remains same. Find the probability that A wins the match.

[10 marks]

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Section B : Basic Electronics Engineering-1 + Analog Electronics-1 + Electrical Materials-1 + Electrical Machines-2

Q.5 (a) A Ge diode has resistivity of 2 Ω-cm and 1 Ω-cm on *p*-side and *n*-side respectively. Assume typical Ge parameters and find the built- in potential of the diode. What will be the built- in potential if the material is Si instead of Ge?

[12 marks]

for Ge diode:

$\rho_p = 2\ \Omega\text{-cm}$; $\rho_n = 1\ \Omega\text{-cm}$

$V_{bi} = ? = \frac{KT}{q} \ln \frac{N_A N_D}{n_i^2}$

$\sigma = \frac{1}{\rho} = nq\mu_n + pq\mu_p$

also $n + N_A = p + N_D$

and $np = n_i^2$

for Si: $n_i = 1.5 \times 10^{10} /cm^3$

2

Incomplete solution

Q.5 (b) A 28 slots, 2 pole, lap wound dc machine has 16 turns per coil. The effective axial length of machine 20 cm and radius of armature is half of the axial length. The pole cover 75% of armature periphery. Determine the value of induced emf in the armature for armature moving with the speed of 1750 rpm. Assuming average flux density per pole to be 1.08 T, and winding to be double layered.

[12 marks]

$B = 1.08\,T$

so effective area $= 0.75 \times \frac{\pi D l}{P}$

$= 0.75 \times \frac{\pi \times 20\times10^{-2} \times 20\times10^{-2}}{2}$

$= 0.0471\ m^2$

so flux per pole $\phi = BA = 1.08 \times 0.0471$

$= 0.051$

as lap wound DC machine double layered

$\#\text{coils} = \#\text{slots} = 28$

so no of conductors $Z = 28 \times 16 \times 2$

$Z = 896$

11

$N = 1750\ rpm$

so induced emf:

Good Approach

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

as lap wound $A = P = 2$

$\Rightarrow E = \frac{0.051 \times 1750 \times 896}{60}$

$\Rightarrow \boxed{E = 1332.8\,V}$

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Q.5 (c) In a factory, the following are the loads:

Induction motors : 1000 hp
0.7 lagging power factor
0.85 average efficiency

Lighting and heating load : 100 kW

A 3-ϕ synchronous motor is installed to provide 300 hp to a new process. The synchronous motor operates at 92% efficiency. Determine the kVA rating of the synchronous motor if the overall factory power factor is to be raised to 0.95 lag. Determine the power factor of the synchronous motor.

(Take 1 hp = 746 W)

[12 marks]

for Induction Motor load : I/P Power $= \frac{1000 \times 746}{0.85}$

$= 877.647$ KW

& PF = 0.7 lagg.

$\Rightarrow S = P + jQ \Rightarrow P = \cancel{614.35 KW}$ 877.647

$S = 1253.78$ KVA & $\cancel{Q = 626.765 KVA}$

$Q = 895.38$ KVAR

Lightning load → Pure resistive load

$P = 100$ KW

so

Total Load $= (100 + \cancel{614.35}\ 877.647) + j\ \cancel{626.765}\ 895.38$

$= 977.647 + j895.38$ ~~= 714.35 + j626.765~~

$= 1325.7\angle 42.48$ ~~= 950.33∠41.26°~~

so combined PF $= \cancel{0.751}$ 0.737 lagg.

when Synchronous Motor installed:

Pout $= 300 \times 746 = 223.8$ KW

so $P_{in} = \frac{223.8}{0.92} = 243.26$ KW

Let Q_{in} be the reactive power input of Synchronous Motor

so $S_{motor} = 243.26 + jQ_{in}$

so overall load = IM + SM + Lighting

$S = 977.647 + 243.26 + j(895.38 + Q_{in})$

Given combined Pf = 0.95 lag.

$\phi = 18.194°$

as $\tan\phi = \frac{Q}{P} = \frac{895.38 + Q_{in}}{1220.9}$

$\Rightarrow 895.38 + Q_{in} = 401.272$

$\Rightarrow \boxed{Q_{in} = -494.10 \text{ KVAR}}$

ie synchronous motor supply reactive power and operate at leading power factor.

so for Synch. M :

$S = 243.26 - j494.10$

$\boxed{S_m = 550.736\angle -63.78°}$

so KVA of Synch. M = 550.736 KVA

and $Pf = \cos 63.78 = 0.442$ lead

11

Good Approach

Q.5 (d) A 440 V, 50 Hz, Δ-connected, 4-pole alternator has a direct axis reactance of 0.1 Ω and quadrature axis reactance of 0.075 Ω. Its armature resistance may be neglected. At full load, this generator supplies 1000 A at 0.85 lagging power factor. Calculate the active and reactive power developed in this generator.

[12 marks]

440V, 50Hz, Δ connected

$X_d = 0.1$ & $X_q = 0.075$

@ full load $I_a = 1000A$ & $pf = 0.85$

$\Rightarrow \phi = 31.78°$ lagg.

as lagg. Pf $\Rightarrow$ overexcited machine

so $\tan\psi = \dfrac{V\sin\phi + I_aX_q}{V\cos\phi + I_aR_a}$

$= \dfrac{440 \times 0.526 + 1000 \times 0.075}{440 \times 0.85}$

$\Rightarrow \psi = 39.33°$

as $\psi = \phi + \delta \Rightarrow \boxed{\delta = 7.55°}$

and $I_d = I_a\sin\psi = 1000\sin 39.33 = 633.785$

$|E| = V\cos\delta + \underbrace{I_qR_a}_{0} + I_dX_d$

$= 440\cos 7.55 + 633.785 \times 0.1$

$|E| \approx 500V$ as Δ connected $E_{line} = E_{ph}$

so

$P = \dfrac{EV}{X_d}\sin\delta + \dfrac{V^2}{2}\sin 2\delta\left(\dfrac{1}{X_q} - \dfrac{1}{X_d}\right)$

$P_{phase} = \dfrac{500 \times 440}{0.1}\sin 7.55 + \dfrac{440^2}{2}\sin 2\times7.55 \times \left(\dfrac{1}{0.075} - \dfrac{1}{0.1}\right)$

$\Rightarrow P_{phase} = 373.117\ KW$

$$\Rightarrow \boxed{P = \cancel{1\#\#}\ 1119.35\ KW}$$

and

$$Q = \frac{EV}{X_d}\cos\delta - V^2\left[\frac{\sin^2\delta}{X_q} + \frac{\cos^2\delta}{X_d}\right]$$

$$= \frac{500\times440}{0.1}\cos 7.55 - 440^2\left[\frac{\sin^2 7.55}{0.025} + \frac{\cos^2 7.55}{0.1}\right]$$

$Q_{ph} = 233.786\ KVAR$

$$\boxed{Q = 701.36\ KVAR}$$

5

Wrong Value calculated

Do not write in this margin

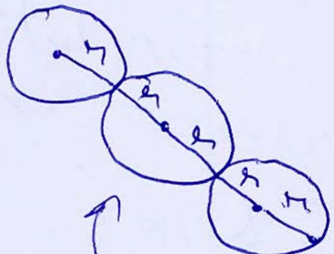
Q.5 (e) (i) Derive relation for atomic radius of unit cell for BCC crystal system and FCC crystal system.

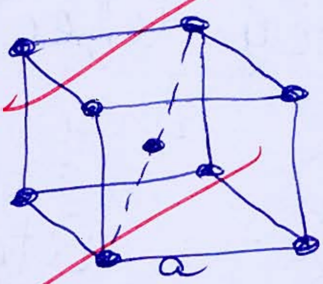
(ii) Enumerate different type of physical properties which get affected by structural imperfection in a crystal. Explain briefly about different types of point defects and line defects.

[12 marks]

i) in BCC crystal structure 1 atom is placed inside unit cell & atoms are placed at the corner.

so





let edge length = a

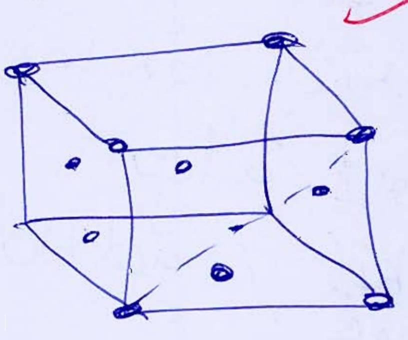
diagonal length = $a\sqrt{3}$

ie $a\sqrt{3} = r + r + r + r$

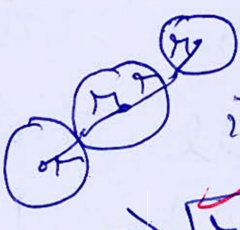
ie $4r = a\sqrt{3}$

$\Rightarrow \boxed{r = \frac{a\sqrt{3}}{4}}$ where r is atomic radius

in FCC crystal structure atoms are placed at corner and atoms are placed at centre of each phase of unit cell.



face diagonal $= a\sqrt{2}$



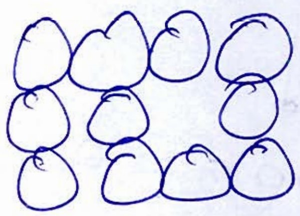
ie $4r = a\sqrt{2}$

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

ii) with crystal defects the shape may change, the melting and boiling point of crystal changes.

Types of Point defects are:

1) Vacancy defect:



when an ion is missing from lattice site creates vacancy defect.

$$N_v = N_0 e^{-Q_v/KT}$$

as temperature increases vacancy defect increases.

2) Interstitial defect:

when an ion occupies an interstitial site.

eg: Carbon when added to iron.

3) Substitutional defect:

when ~~Ef~~ an impurity ion completely replaces the host atom.

eg: when Nickel is added to copper.

Line defects type: are called dislocation

1) Edge Dislocation: When Burger vectors are perpendicular to dislocation line.

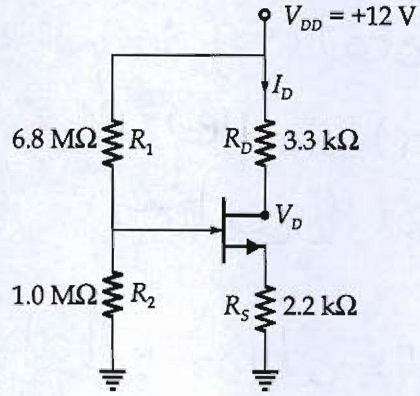
2) Screw Dislocation: When Burgers vectors are parallel to dislocation line.

3) Mixed dislocation: When burger vectors are both ⊥r and ||lel to dislocation line.

9

Elaborate it more

Q.6 (a) (i) Determine I_D and V_{GS} for JFET with voltage divider bias as shown in figure. The internal parameter values of this JFET are such that $V_D \approx 7$ V.



[12 marks]

so $V_G = \frac{R_2}{R_1+R_2} \times 12 = \frac{1}{1+6.8} \times 12 = 1.538\text{ V}$

$V_S = I_D R_S = 2.2 I_D$

so $V_{GS} = 1.538 - 2.2 I_D$

$\Rightarrow \boxed{I_D = \frac{1.538 - V_{GS}}{2.2K}}$ — (1)

given $V_D = 7V$

so $I_D = \frac{V_{DD} - V_D}{R_D} = \frac{12-7}{3.3K} = 1.515\text{mA}$

and for JFET

$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$

for $I_D = 1.515$

$\Rightarrow V_{GS} = 1.538 - 2.2 \times 1.515$

$\boxed{V_{GS} = -1.795\text{V}}$

and $V_{DS} = 7 - 2.2 \times 1.515$

$\boxed{V_{DS} = 3.667\text{ V}}$

as $V_{DS} > V_{GS} \Rightarrow$ saturation mode only.

11 Good Approach

Q.6 (a) **(ii)** Certain metal works as superconductor below the critical temperature $T_C = 7.2°K$. The critical magnetic field for the metal at 0°K is 7.8×10^5 Amp/m. What is the critical magnetic field for the metal to be usable as superconductor at 5°K?

[8 marks]

$T_C = 7.2° K$

$H_{C0} = 7.8 \times 10^5 \text{ A/m}$

$H_C = H_{C0}\left[1 - \left(\frac{T}{T_C}\right)^2\right]$

at $T = 5 K$

$H_C = 7.8 \times 10^5 \left(1 - \left(\frac{5}{7.2}\right)^2\right]$

$= 7.8 \times 10^5 \times 0.5177$

$\Rightarrow \boxed{H_C = 4.038 \times 10^5 \text{ A/m}}$

Hence critical magnetic field of metal at $T = 5\,K$ is
$4.038 \times 10^5\,A/m$.

7

Good Approach

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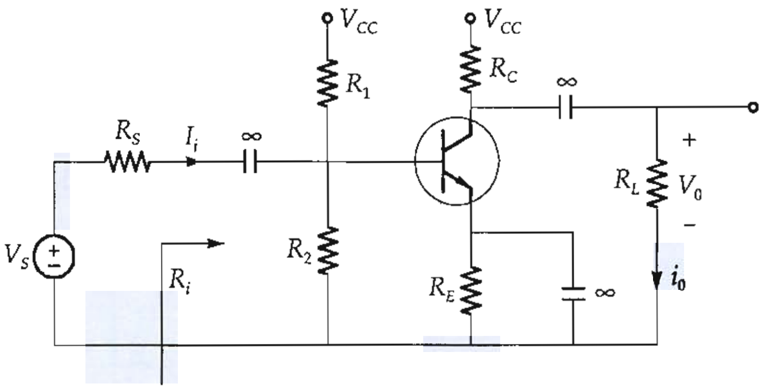
Q.6 (b) Consider common emitter amplifier shown below with following specification:
$V_{CC} = 10$ V, $R_1 = 27$ kΩ, $R_2 = 15$ kΩ, $R_E = 1.2$ kΩ and $R_C = 2.2$ kΩ, $\beta = 100$ and early voltage $V_A = 100$ V.

(i) Determine the dc bias current I_E, if the amplifier operates between a source for which $R_s = 10$ kΩ and a load of 2.5 kΩ.

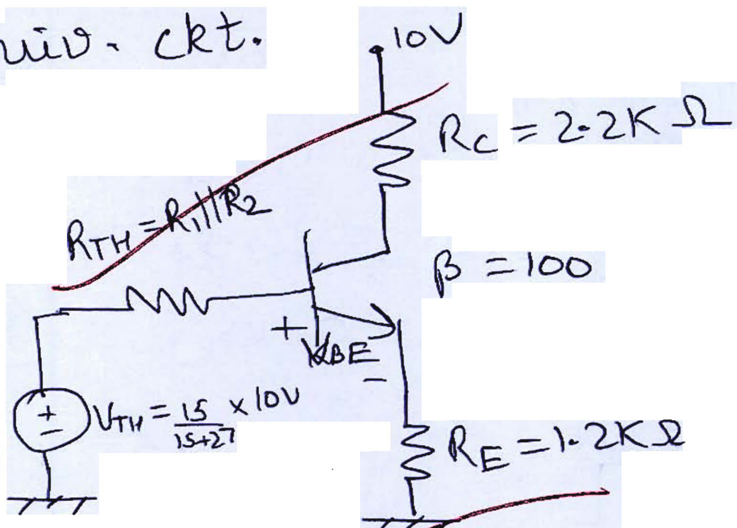
(ii) Obtain hybrid-π model of transistor and find values of R_i and voltage gain V_0/V_S. [(Assume, $V_{BE} = 0.7$ V, V_T (Thermal voltage) = 25 mV].



[20 marks]

DC Analysis : $C \rightarrow OC$

so equiv. ckt.



$V_{TH} = \frac{15}{42} \times 10 = 3.57V$ & $R_{TH} = 15||27$

$\boxed{R_{TH} = 9.64 \, K\Omega}$

KVL in Base loop:

$V_{TH} - I_B R_{TH} - I_E R_E - 0.7 = 0$

also $I_E = I_B + I_C = I_B + \frac{I_B \times \beta}{\beta}$

$\Rightarrow I_B = \frac{I_E}{1+\beta}$

$\Rightarrow I_E R_E + \frac{I_E}{1+\beta} R_{TH} = 3.57 - 0.7$

$$I_E[1.2] + \frac{I_E}{101}[9.64] = 2.87$$

$$\Rightarrow I_E = \frac{2.87}{1.2 + \frac{9.64}{101}}$$

$$\boxed{I_E = 2.215\,mA}$$ $V_E = I_E R_E = 2.658V$

so $I_C = \alpha I_E = \frac{\beta}{1+\beta} I_E = \frac{100}{101} \times 2.215$

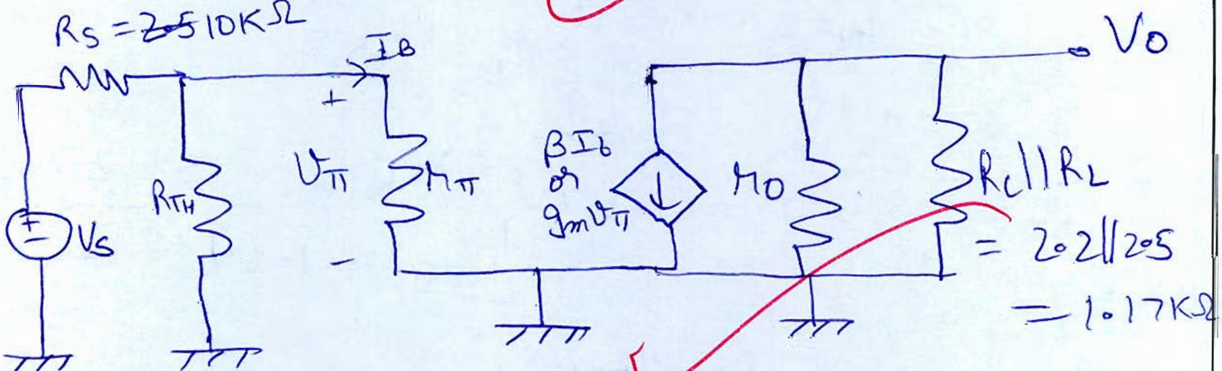
$I_C = 2.193\,mA$; $V_C = V_{CC} - I_C R_C = 5.1754V$

and $g_m = \frac{I_C}{V_T} = \frac{2.193}{25} = 0.0877$ $\boxed{V_{CE} = 2.517V}$

so $r_\pi = \frac{\beta}{g_m} = \frac{100}{0.0877} = 1140\,\Omega = 1.14\,K\Omega$

AC Analysis : $C \rightarrow$ short ckt

ii) Replacing the transistor with its small signal model:



$$r_o = \frac{V_A + V_{CE}}{I_C} = \frac{100 + 2.517}{2.215} = 46.28\,K\Omega$$

$$r_{out} = r_o \| R_C \| R_L = 46.28 \| 1.17$$

$$\boxed{r_{out} = 1.151\,K\Omega}$$

$V_o = -g_m v_\pi r_{out}$

and $v_\pi = \dfrac{R_{TH}||r_\pi}{R_s + R_{TH}||r_\pi} v_s$

$R_{TH}||r_\pi = 9.64 || 1.14 = 1.02 k\Omega$

$\Rightarrow v_\pi = \dfrac{1.02}{1.02+10} \times v_s = 0.9255 v_s$

$\Rightarrow \dfrac{V_o}{V_s} = -g_m \times 0.9255 \times r_{out}$

$= -0.0877 \times 0.9255 \times 1.151 \times 10^3$

$\Rightarrow \boxed{\dfrac{V_o}{V_s} = -9.343}$

18

Good Approach

Q.6 (c) (i) A field test on two similar series machine gave the following data:

Motor :

Armature current = 50 A
Voltage across armature = 400 V
Voltage across field = 25 V

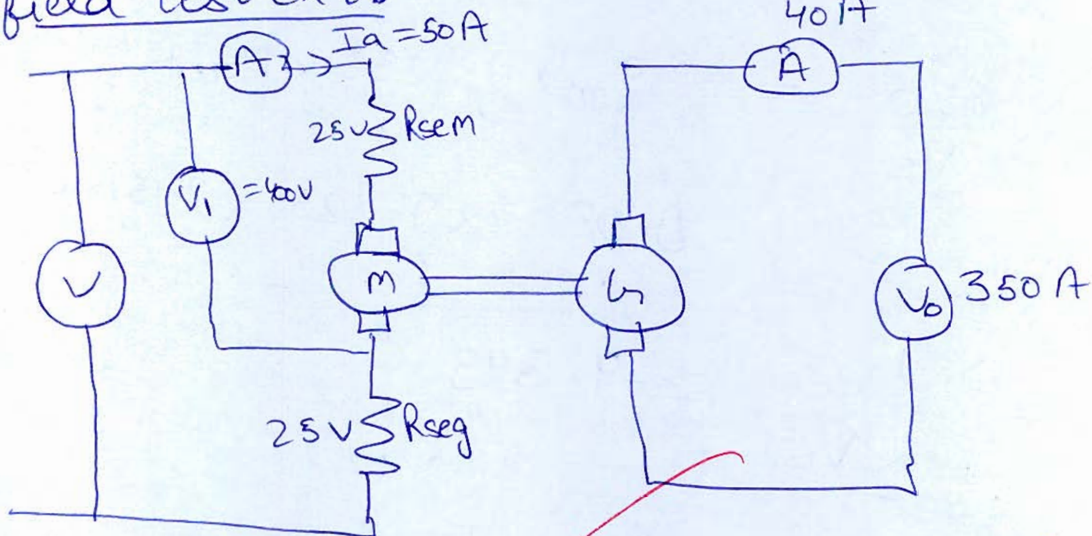
Generator :

Terminal voltage = 350 V
Output current = 40 A
Voltage across field = 25 V

Armature resistance (including brushes) of each machine is 0.5 Ω. Calculate the efficiency of both machines.

[10 marks]

field test ckt:



so Total losses = Input − Output

$= V I_1 - V_0 I_0$

$= (400 + \cancel{20}) \times 50 - 350 \times 40$

$= \cancel{8000\,W}\ 7250\,W$

Total losses = Rotational losses of Both + field loss of Both machine

$\Rightarrow$ Rotational loss of Both Machine $= 7250 - 50\times25 - 50\times25$

$= 4750\,W$

Rot. loss of each M/c $= \frac{4750}{2} = 2375\,W$

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so $\eta_{Gen} = \frac{O/P}{O/P + losses} = \frac{350\times40}{350\times40 + 2375 + 50\times25} \times 100$

$\eta_{Gen} = 79.43\%$

$\eta_{motor} = \frac{I/P - losses}{I/P} \times 100$; $I/P = 400\times50$ (V, I_a)

$losses = 2375 + 25\times50$

6

$= \frac{400\times50 - 2375 - 25\times50}{400\times50} \times 100$

$\boxed{\eta_{motor} = 81.875\%}$

Q.6 (c) (ii) A 220 V, 20 kW dc shunt motor running at its rated speed of 1200 rpm is to be braked by reverse current braking. The armature resistance is 0.1 Ω and the rated efficiency of the motor is 88 per cent.

Calculate:

1. the resistance to be connected in series with the armature to limit the initial braking current to twice the rated current,
2. the initial braking torque, and
3. the torque when the speed of the motor falls to 400 rpm.

[10 marks]

$P_{I/P}$ to Motor $= \frac{20}{0.88} = 22.727\,kW$

so I_a rated $= \frac{22.727\times10^3}{220} = 103.305A$

$\Rightarrow E_b = 220 - I_a\times0.1 = 209.67V$ @ 1200 rpm

i) let R_{se} be series connected resistance & reverse current braking used.

$I_{Br} = 2I_{a\,rated} = 2\times103.305$

$= 206.61A$

so $V_0 = -E_b + I_{BR}(r_a + r_{ext})$

$\Rightarrow 0.1 + r_{se} = \frac{220 + 209.67}{206.61}$

$\Rightarrow r_{se} = 2.08 - 0.1$

$\boxed{r_{se} = 2.07\,\Omega}$

ii) initial Braking T = $T_{fl} + T_{plug}$

$T_{fl} = \frac{60}{2\pi \times 1200} \times 209.67 \times 103.305$

$T_{fl} = 172.364$ Nm

$T_{plug} = \frac{60}{2\pi \times 1200} \times 220 \times 206.61$

$= 361.71$ Nm

$T_{Br} = T_{plug} + T_{fl} \Rightarrow \boxed{T_{BR} = 534.07\,Nm}$

iii) T @ N = 400 rpm

$E_b \propto N\phi$ $\quad \phi \rightarrow$ const.

& $T \propto \phi I_a$

5

$E_{b2} = 209.67 \times \frac{400}{1200} = 69.89$ V

Wrong value calculated

$I_a = \frac{220 - 69.89}{\cancel{2.08}\ 0.1} = 1501.1$ A

$\Rightarrow T = 172.364 \times \frac{1501.1}{103.305} = 2504.58$ Nm

Q.7 (a) **(i)** A salient pole synchronous motor (with negligible armature resistance and $X_d = 25.4\,\Omega$ and $X_{eq} = 15.4\,\Omega$/phase) can be loaded to maximum load of 540 kW without field excitation running at 1000 rpm. If the motor is now excited with nominal field current and motor is loaded with a load torque of 3.5 kN-m and the motor draws armature current at 0.8 p.f. (leading) then determine excitation emf and corresponding power angle (δ).

(ii) Obtain power angle characteristic and derive expression for electrical power output of salient pole synchronous machine with help of phasor diagram.

[20 marks]

i) $X_d = 25.4\,\Omega$ & $X_q = 15.4\,\Omega$

$$P = \frac{EV}{X}\sin\delta + \frac{V^2}{2}\sin 2\delta\left(\frac{1}{X_q} - \frac{1}{X_d}\right)$$

when $E = 0$ max^m load $= 540\,kW$
occurs @ $\delta = 45°$

$$\Rightarrow \quad 540\times10^3 = 0 + \frac{V^2}{2}\left(\frac{1}{15.4} - \frac{1}{25.4}\right)$$

$$\Rightarrow \boxed{V_{line} \simeq 6500\,V}$$

now Motor excited with nominal field current
& $T_L = 3.5\,kN\text{-}m$
@ $I_a = \_\_\_$ @ 0.8 pf lead.

$E = ?$, $\delta = ?$

@ steady state

$$T_{dev} = T_L = \frac{3\times60}{2\pi N_s}\sqrt{3}V_L\times I_a\cos\phi = 3.5\times10^3$$

as synch. (m) speed same $N_s = 1000$

$$\Rightarrow \frac{\cancel{3}\times60}{2\pi\times1000}\times\cancel{3}\sqrt{3}\times6500\times I_a\times0.8 = 3.5\times10^3$$

$$\Rightarrow \boxed{I_a = 40.7\,A}$$

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$\phi = \cos^{-1}(0.8) = 36.87$ lead

overexcited M

$\tan\psi = \dfrac{V\sin\phi + I_a X_q}{V\cos\phi + I_a R_a}$

$= \dfrac{\frac{6500}{\sqrt{3}} \times 0.6 + 40.7 \times 15.4}{\frac{6500}{\sqrt{3}} \times 0.8}$

$\Rightarrow \boxed{\psi = 54.084^\circ}$

so $\delta = \psi - \phi = 17.21^\circ$

so

$E = V\cos\delta + I_q R_a + I_d X_d$

$I_d = I_a \sin\psi = 32.96\,A$

$E = \dfrac{6500}{\sqrt{3}} \cos 17.21 + \cancel{40.7} \times 32.96 \times 25.4$

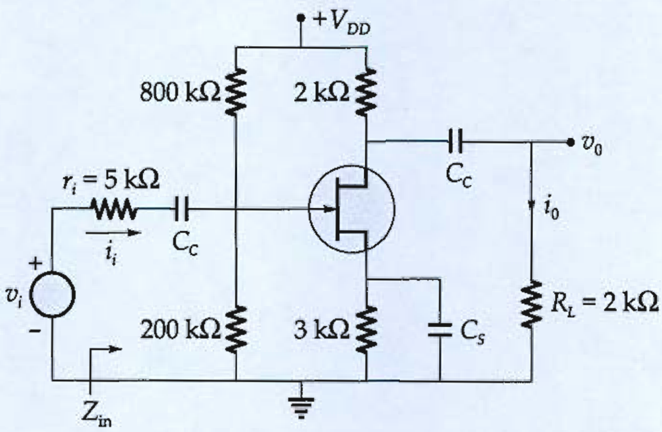
$E = 4422V$

$\boxed{E_{line} = 7659.02V}$ & $\boxed{\delta = 17.21^\circ}$

Wrong Value calculated

12

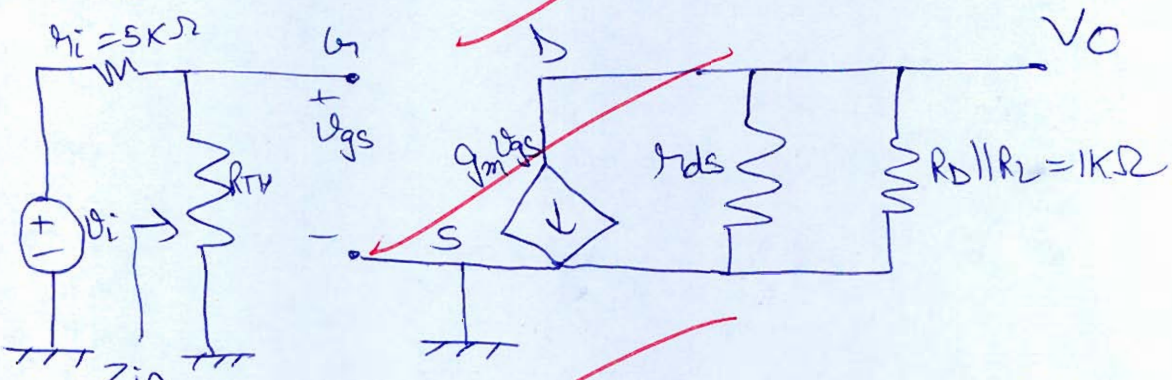
Q.7 (b) For the JFET amplifier shown in the figure below has $g_m = 2\text{ mS}$, $r_i = 5\text{ k}\Omega$ and $r_{ds} = 30\text{ k}\Omega$. If C_C and C_S are large and the amplifier is biased in the pinch off region, find Z_{in}, $A_V = V_0/V_i$ and $A_I = i_0/i_i$.



[20 marks]

AC analysis: C → short ckt.

replacing the JFET with its equivalent π model:



$R_{TH} = 800K \| 200K = 160K\Omega$

$g_m = 2\times10^{-3}\,S$

so $Z_{out} = r_{ds} \| R_D \| R_L = 30K \| 1K$
$= 0.9677K\Omega$

and

$Z_{in} = R_{TH} \| \infty$

$\Rightarrow \boxed{Z_{in} = R_{TH} = 160K\Omega}$

and $v_o = -g_m v_{gs} Z_{out}$

and $v_{gs} = \frac{R_{TH}}{R_{TH}+R_i} \times v_i = \frac{160}{160+5} \times v_i$

$v_{gs} = \frac{160}{165} v_i$

$\Rightarrow v_o = -g_m \frac{160}{165} \times Z_{out} \times v_i$

$\Rightarrow A_v = \frac{V_o}{V_i} = -2\times10^{-3} \times \frac{160}{165} \times 0.9677\times10^{3}$

$\boxed{A_v = -1.8768}$ — (1)

and $A_I = \frac{i_o}{i_i}$ where $i_o = \frac{v_o}{R_L} = \frac{v_o}{2K}$

and $i_i = \frac{v_i}{r_i+R_{TH}} = \frac{v_i}{165K}$

18

$\Rightarrow A_I = \frac{v_o/2K}{v_i/r_i+R_{TH}} = \frac{v_o}{v_i} \times \frac{165}{2}$

using (1)

Good Approach

$\Rightarrow A_I = -1.8768 \times \frac{165}{2}$

$\boxed{A_I = -154.838}$

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Q.7 (c) Define dielectric strength. Discuss different types of dielectric breakdowns in solids.

[20 marks]

Dielectric strength is defined as the maximum electric field that it can withstant btw its contacts.

Types:

1) Electrochemical
2) Intrinsic → electronic in nature
3) Thermal breakdown

3

Incomplete solution

Q.8 (a) A 100-MVA, 14.4 kV, 0.8 pf lagging, Y-connected synchronous generator has a negligible armature resistance and a synchronous reactance of 1.0 per unit. The generator is connected in parallel with a 60 Hz, 14.4 kV infinite bus that is capable of supplying or consuming any amount of real or reactive power with no change in frequency or terminal voltage.

(i) What is the synchronous reactance of the generator in ohms?

(ii) What is the internal generated voltage E_A of this generator under rated conditions?

(iii) What is the armature current I_A in this machine at rated conditions?

(iv) Suppose that the generator is initially operating at rated conditions. If the internal generated voltage E_A is decreased by 5 percent, what will the new armature current I_A be?

(v) Repeat part (iv) for 10, 15, 20 and 25 percent reductions in E_A.

[20 marks]

Q.8 (b) **(i)** Explain about dependence of the loss tangent on temperature and frequency.

(ii) The magnetic moment of gadolinium of 7.1 μ_B. Calculate the magnetic moment per gram if its atomic weight is 157.3.

(iii) A certain paramagnetic substance has 1.2×10^{28} atoms/m^3. Assuming that each atom has moment of one Bohr Magneton, calculate the susceptibility at 27° C and also the intensity of magnetization when a field of 10^5 A/m is applied.

[10 + 6 + 4 marks]

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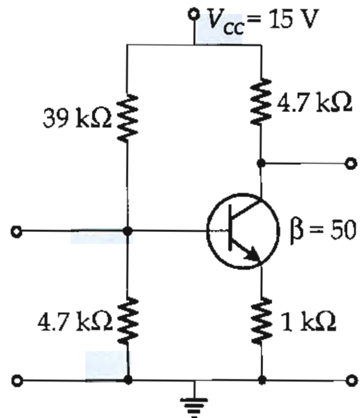
Q.8 (c) For the circuit shown in figure below, determine the operating point. Find the stability factor. Given: $V_{BE} = 0.6$ V, $\beta = 50$, $V_{CC} = 15$ V



[20 marks]

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Space for Rough Work

Space for Rough Work

$x = 1$
$y = 3$
$z = 5$

$x = 0.875$
$y = 1.125$
$z = -0.125$

$8 - \frac{\cancel{7}}{\cancel{8}} \times \frac{\overset{12}{\cancel{60}}}{\cancel{7}} = -4$

$3 - \frac{6 \times 4}{5} = 3 - \frac{24}{5}$

$\frac{15-24}{5}$

$= -\frac{9}{5}$

$3 - \frac{\overset{2}{\cancel{6}}}{5} \times \frac{7}{\cancel{3}}$

$\frac{15-14}{5} = \frac{1}{5}$

$-6 + \frac{11}{\cancel{3}} \times \frac{\overset{2}{\cancel{6}}}{5} = \frac{22}{5}$

$\frac{-30+22}{5}$

$= -\frac{8}{5}$