- Try to avoid calculation mistake

- Improve presentation

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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 ☐	
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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	19
Q.2	
Q.3	31
Q.4	
Section-B	
Q.5	39
Q.6	36
Q.7	40
Q.8	
Total Marks Obtained	165

Signature of Evaluator: Sourabh kumar ....

Cross Checked by: ....

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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.

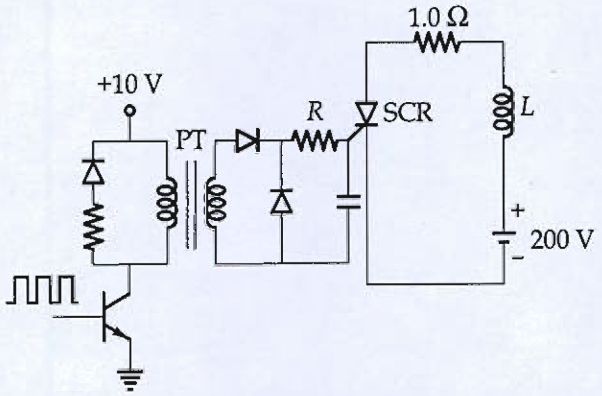
DO'S

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.

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).

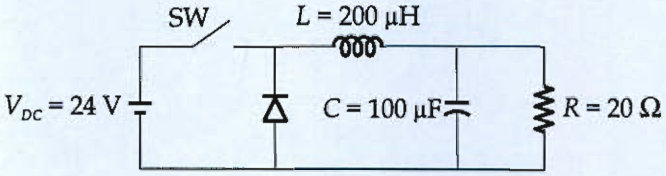
[12 marks]

Do not write in this margin

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]

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]

$V_o = \alpha V_s = 0.4\times 24 = 9.6$

$I_o = \frac{9.6}{20} = 0.48$ amp

$I_{oB} = \frac{\alpha(1-\alpha)V_s}{2fL}$ → output current during boundary condⁿ

$= \frac{0.4\times 0.6\times 24}{2\times 10\times 10^3\times 200\times 10^{-6}} = 1.44$ amp

$I_{oB} > I_o \Rightarrow$ discontinuous condⁿ.

Boundary current > output current

∴ It is working in discontinuous condⁿ

$$\therefore V_o = \frac{V_s}{2}\sqrt{1+\left(\frac{2D^2R}{Lf}\right)}$$

③

$$= \frac{24}{2}\sqrt{1+\frac{2\times 0.4\times 0.4\times 20}{200\times 10^{-6}\times 10\times 10^3}}$$

$$= \frac{24}{2}\sqrt{1+3.2}$$

$$= 12\sqrt{4.4}$$

$$\boxed{V_o = 25.1714 \text{ volts}}$$

Wrong Value Calculated

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]

$f(x+2\pi) = f(x)$ $\quad \therefore$ FTP $= 2\pi$ $\quad \frac{2\pi}{x} = 2\pi$ $\boxed{x=1}$

$$f(x) = a_0 + \sum_{n=1}^{\infty} a_n \cos n w_0 x + \sum_{n=1}^{\infty} b_n \sin n w_0 x$$

~~$a_0 = \frac{1}{2\pi}\int_0^{2\pi} f(x)\,dx$~~ ~~let $x = t$~~

~~$= \frac{1}{2\pi}\int_0^{2\pi}$~~ $\quad \therefore$ ~~$w_0 = 2\pi$~~ ~~$\frac{2\pi}{T} = 2\pi$~~

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

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

$$= \frac{1}{2\pi}\left\{-\left[(0) - \left(\frac{\pi^2}{2} - \pi^2\right)\right] + \left[\left(\frac{\pi^2}{2}+\pi^2\right) - (0)\right]\right\}$$

$$= \frac{1}{2\pi}\left\{-\frac{\pi^2}{2} + \frac{\pi^2}{2} + \pi^2\right] = \boxed{\frac{\pi}{2} = a_0}$$

$$a_n = \frac{2}{2\pi}\int_0^{2\pi} f(x)\cos nx\,dx$$

$$= \frac{1}{\pi}\left[\int_{-\pi}^{0} -(x+\pi)\cos nx\,dx + \int_0^{\pi}(x+\pi)\cos nx\,dx\right]$$

$$= \frac{1}{\pi}\left[\int_{-\pi}^{0} -x\cos nx\,dx - \int_{-\pi}^{0} \pi\cos nx\,dx + \int_0^{\pi} x\cos nx\,dx + \int_0^{\pi} \pi\cos nx\,dx\right]$$

$$= \frac{1}{\pi}\left[-\left(\frac{x\sin nx}{n} + \frac{\cos nx}{n^2}\right)_{-\pi}^{0} - \left(\frac{\pi\sin nx}{n}\right)_{-\pi}^{0} + \left(\frac{x\sin nx}{n} + \frac{\cos nx}{n^2}\right)_0^{\pi} + \left[\frac{\pi\sin nx}{n}\right]_0^{\pi}\right\}$$

$$= \frac{1}{\pi}\left\{ -\left[\left(0 + \frac{1}{n^2}\right) - \left(0 + \frac{\cos n\pi}{n^2}\right)\right] + \left[\left(\frac{\pi \sin n\pi}{n} + \frac{\cos n\pi}{n^2}\right) - \left(0 + \frac{1}{n^2}\right)\right]\right\}$$

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

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

for $n = 1, 3, 5, 7 \ldots$ $a_n = \frac{1}{\pi}\left(\frac{-2}{n^2}\right) = \frac{-2}{n\pi^2}$

for $n = 2, 4, 6, 8 \ldots$ $a_n = 0$

$$b_n = \frac{2}{2\pi}\int_0^{2\pi} f(x)\sin(nx)\,dx.$$

$$= \frac{1}{\pi}\left[\int_{-\pi}^{0} -(\pi+x)\sin(nx)\,dx + \int_0^{\pi}(\pi+x)\sin(nx)\,dx\right]$$

$$= \frac{1}{\pi}\left[-\int_{-\pi}^{0} \pi\sin(nx)\,dx \mp \int_{-\pi}^{0} x\sin nx\,dx + \int_0^{\pi} \pi\sin(nx)\,dx + \int_0^{\pi} x\sin(nx)\,dx\right]$$

$$= \frac{1}{\pi}\left[\left(\frac{\pi\cos nx}{n}\right)_{-\pi}^{0} - \left(\frac{\pi\cos nx}{n}\right)_{0}^{\pi} + \left(\frac{x\cos nx}{n} + \frac{\sin nx}{n^2}\right)_{-\pi}^{0} - \left(\frac{x\cos nx}{n} + \frac{\sin nx}{n^2}\right)_{0}^{\pi}\right]$$

$$= \frac{1}{\pi}\left\{\frac{\pi(\cancel{1} - \cos n\pi)}{n} - \pi\left(\frac{\cos n\pi - 1}{n}\right) + (0+0) - \left(-\frac{\pi\cos n\pi}{n} + -\frac{\sin n\pi}{n^2}\right) - \left[\left(\frac{\pi\cos n\pi}{n} + \underset{0}{\frac{\sin n\pi}{n^2}}\right) - \left(0 + \frac{\sin 0}{n^2}\right)\right]\right\}$$

$$= \frac{1}{\pi}\left[\frac{\pi\cos n\pi}{\cancel{n}} - \frac{\pi\cos n\pi}{\cancel{n}}\right] = 0$$

5

$$\boxed{b_n = 0}$$

$$\therefore \boxed{f(x) = \frac{\pi}{2} + \sum_{n=1,3,5}^{\infty} \frac{1}{\pi}\,\frac{-2}{n\pi^2}}$$

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]

$E_b = V - I_a R_a.$

$E_b = 210 - 10 \times 1 = 200$ volts.

$E_b = K\phi N$

$200 = K\phi \times 1200 \Rightarrow \boxed{K\phi = 0.166 \text{ V/RPM}}$

now armature terminals are reversed for regenerative braking.

$\therefore$ Converter works in <u>inversion mode</u>.

$E_b = +K\phi N = +0.166 \times 600$

$= +100$ volts.

$V_o = -E_b + I_o R_a$

$= -100 + 10 \times 1 = -90$ V

for 1φ full converter $V_o = \frac{2V_m}{\pi} \cos\alpha$.

$\frac{2V_m}{\pi} \cos\alpha = -90$

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

$$\cos\alpha = -\frac{90\pi}{480\sqrt{2}}$$

$$\cos\alpha = -0.4165$$

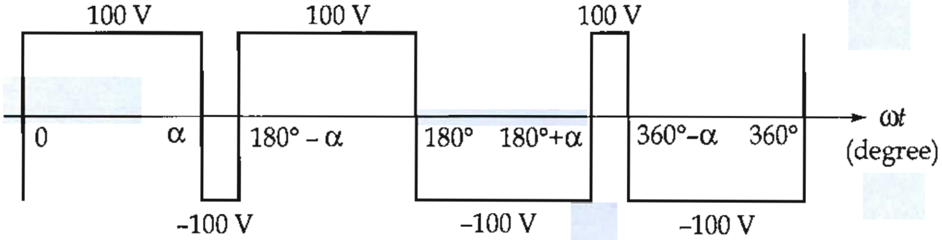
$$\boxed{\alpha = 114.615^\circ}$$

$$\boxed{\alpha = 2\text{ radians}}$$

⑪

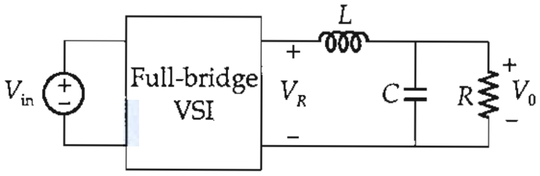
Good Approach

Q.2 (a) **(i)** The figure shows below, one period of the output voltage of an inverter. α should be chosen such that 60° < α < 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]

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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]

0.875, 1.125, -0.126

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

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

[10 marks]

$3x + 2y + 7z = 4$

$2x + 3y + z = 5$

$3x + 4y + z = 7$

using factorization method.

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

$$\left[\begin{array}{ccc|c} 3 & 2 & 7 & 4 \\ 2 & 3 & 1 & 5 \\ 3 & 4 & 1 & 7 \end{array}\right]$$

$R_2 \rightarrow R_2 - \frac{2}{3} R_1$, $R_3 \rightarrow R_3 - R_1$

$$\left[\begin{array}{ccc|c} 3 & 2 & 7 & 4 \\ 0 & 1.66 & -3.66 & 2.33 \\ 0 & 2 & 6 & 3 \end{array}\right]$$

$R_3 \rightarrow R_3 - 1.2 R_1$

$$\left[\begin{array}{ccc|c} 3 & 2 & 7 & 4 \\ 0 & 1.66 & -3.66 & 2.33 \\ 6 & 0 & 10.4 & 0.2 \end{array}\right]$$

6

$\therefore$ on solving $\boxed{x = 0.875}$ $\quad x = 7/8$

$\boxed{y = 1.125}$ $\quad y = 9/8$

$\boxed{z = -0.125}$ $\quad z = -1/8$

Go through the made easy solution

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]

By applying gauss jordan method.

$$\left[\begin{array}{ccc|c} 1 & 1 & 1 & 9 \\ 2 & -3 & 4 & 13 \\ 3 & 4 & 5 & 40 \end{array}\right]$$

$\cdot R_3 \to R_3 - 3R_1$, $R_2 \to R_2 - 2R_1$

$$\left[\begin{array}{ccc|c} 1 & 1 & 1 & 9 \\ 0 & -5 & 2 & -5 \\ 0 & 1 & 2 & 13 \end{array}\right]$$

$R_3 \to R_3 + R_2/5$

$$\left[\begin{array}{ccc|c} 1 & 1 & 1 & 9 \\ 0 & -5 & 2 & -5 \\ 0 & 0 & 2.4 & 12 \end{array}\right]$$

$$\therefore \begin{bmatrix} 1 & 1 & 1 \\ 0 & -5 & 2 \\ 0 & 0 & 2.4 \end{bmatrix} \begin{bmatrix} \cancel{x_1}\, x \\ \cancel{x_2}\, y \\ z \end{bmatrix} = \begin{bmatrix} 9 \\ -5 \\ 12 \end{bmatrix}$$

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

7

Go through the made easy colection

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]

$$x^4 - x - 10 = 0$$

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

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

let initial guess value $\boxed{x_1 = -1}$

$$x_{n+1} = -1 - \left(\frac{x^4 - x - 10}{4x^3 - 1}\right)\Bigg|_{x=-1}$$

$$x_{n+1} = -1 - \left(\cancel{\frac{-10}{4}}\right)\left(\frac{1+1-10}{-5}\right)$$

$$x_{n+1} = -1 - \left(2\frac{1}{3}\right)$$

$\boxed{\cancel{x_2 = -4.33}}$

$\boxed{x_2 = -3}$

$$x_3 = x_2 - \frac{f(x)}{f'(x)}\Bigg|_{x=x_2}$$

$$= -4.333 - \frac{(x^4 - x - 10)}{(4x^3 - 1)}\Bigg|_{x=-3}$$

$$= -4.333 - \left[\frac{81+3-10}{107}\right]$$

$$= -4.333 + 0.691$$

$$= -3.6414.$$

$$x_4 = x_3 - \frac{f(x)}{f'(x)}\Bigg|_{x=x_3}$$

$$= -3.6414 - \left(\frac{x^4 - x - 10}{4x^3 - 1}\right)_{x=-3.6414.}$$

$$= -2.089.$$

$$x_5 = x_4 - \left.\frac{f(x)}{f'(x)}\right|_{x=x_4}$$

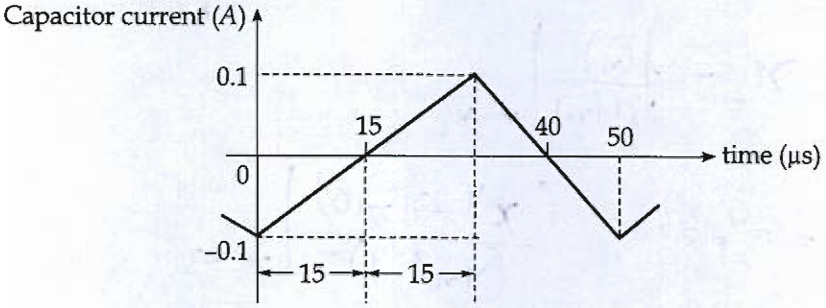
$$= -2.08 - \left(\frac{x^4 - x - 10}{4x^3 - 1}\right)_{x=-2.08}$$

$$\boxed{x_5 = -1.697}$$

$\therefore$ roots are $\boxed{x = -1.697}$

3

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]

for buck converter $\Delta I_L = \Delta I_C$.

$(\Delta I_L)_{\text{peak to peak}} = 0.2$ Amp.

$T_{ON} = 30\,\mu sec$, $T_{OFF} = 20\,\mu sec$.

$$\alpha = \frac{T_{ON}}{T_{ON}+T_{OFF}} = \frac{30}{30+20} = \frac{30}{50} = 0.6$$

for buck converter $\Delta I_L = \dfrac{\alpha(1-\alpha)V_s}{fL}$

$$0.2 = \frac{0.6 \times 0.4 \times 30}{f \times L}$$

$T = T_{on} + T_{off} = 50\ \mu sec$

$f = \frac{1}{T} = \frac{1}{50\times10^{-6}} = 20\ kHz$

$0.2 = \frac{0.6\times0.4\times30}{20\times10^{3}\times L}$

$L = \frac{0.6\times0.4\times30}{20\times0.2\times10^{3}}$

$L = 1.8\times10^{-3}$ Henry

$\boxed{L = 1.8\ mH}$

⑨

Good Approach

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]

i) $$V_o(t) = \sum_{n=6k\pm1}^{\infty} \frac{2V_s}{n\pi} \sin(n\omega_o t)$$

$$V_s = \sqrt{\frac{3}{2}}\, V_o$$
$$= 489.89.$$

$\hookrightarrow$ output fourier for line to line voltag.

$$\cancel{V_{o1}}\left(V_{o1}\right)_{peak} = \frac{2V_s}{\pi} \Rightarrow \left(V_o\right)_{RMS} = \frac{\sqrt{2}V_s}{\pi}$$

$$\left(V_{o}\right)_{RMS} = \frac{\sqrt{2}\times 489.89}{\pi} = \cancel{180\text{ volts}}\ 220.531$$

$$V_o(t) = \sum_{n=6k\pm1}^{\infty} \frac{2\times 489.89}{n\pi} \sin(n\,100\pi t)$$

$$V_o(t) = \sum_{n=6k\pm1}^{\infty} \frac{\overset{979.79}{\cancel{800}}}{n\pi} \sin(100\pi n t)$$

$$\boxed{V_o(t) = \sum_{n=6k\pm1}^{\infty} \cancel{254.64}\ 311.878 \sin(314 n t)}$$

the output contains $(6k\pm1)$ harmonics i.e 1, 5, 7, 11, 13 ....

& output (line & phase voltage) is free from triplen harmonics

ii) $\frac{V}{f}$ = constant. $\therefore$ for 60 Hz

$$V_o = \frac{400}{50}\times 60 = 480\text{ volts}$$

$$\left(V_{Line}\right)_{RMS} = \sqrt{\frac{2}{3}}\, V_s$$

$$480 = \sqrt{\frac{2}{3}}\, V_p \Rightarrow \boxed{V_s = 587.87\text{ volts}}$$

for 50 Hz , $V_o = 400$ Volts

$$V_o = \sqrt{\frac{2}{3}}\, V_r \Rightarrow V_s = \sqrt{\frac{3}{2}} \times V_o$$

$$\boxed{V_s = 489.89 \text{ volts}}$$

for 40 Hz , $V_o = \frac{400}{50} \times 40 = 320\ V_o$

$$V_o = \sqrt{\frac{2}{3}}\, V_r \Rightarrow V_s = \sqrt{\frac{3}{2}} \times 320$$

$$\boxed{V_s = 391.91 \text{ volts}}$$

for 60 Hz ⟶ $V_s = 587.87$ volt.
for 50 Hz ⟶ $V_s = 489.89$ volts
for 40 Hz ⟶ $V_s = 391.91$ volts

iii) for 60 Hz at ~~source~~ output $V_s = 587.87$ volts

for 3 ϕ semi converter

$$V_o = \frac{3 V_{mL}}{2\pi}(1 + \cos\alpha)$$

$$\frac{3 \times 500\sqrt{2}}{2\pi}(1 + \cos\alpha) = 587.87 \text{ volts}$$

⑥

$$1 + \cos\alpha = \frac{587.87 \times 2\pi}{1500\sqrt{2}}$$

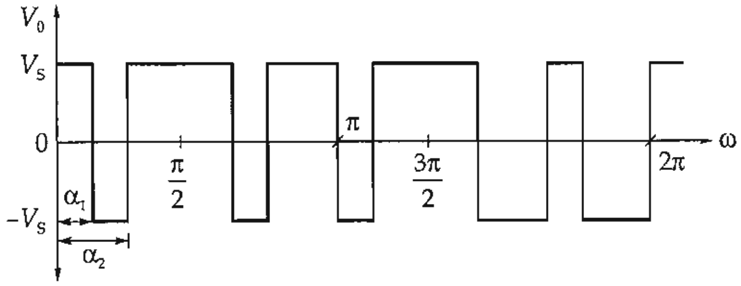
$$1 + \cos\alpha = 1.7412$$

$$\cos\alpha = 0.7412$$

$$\boxed{\alpha = 42.162^\circ} \quad \text{or} \quad \boxed{\alpha = 0.735 \text{ radians}}$$

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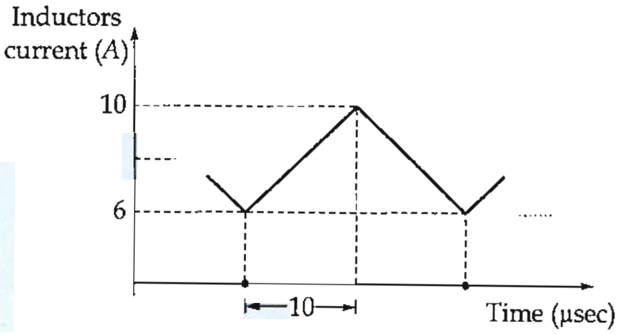
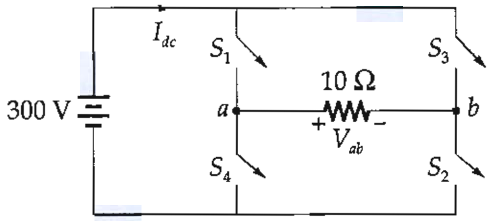
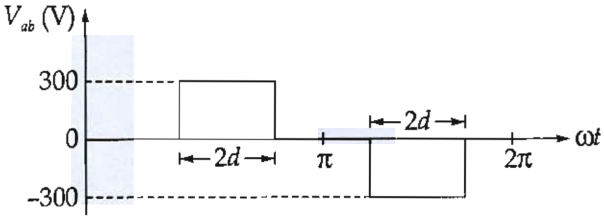
Q.4 (a) **(ii)** The steady state current flowing through the inductor of a DC-DC boost converter is given in the figure below. The value of the output capacitor is 150 μF. If the peak-to-peak ripple in the output voltage of the converter is 0.2 V. Find the switching frequency of the converter, in kHz.



[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]

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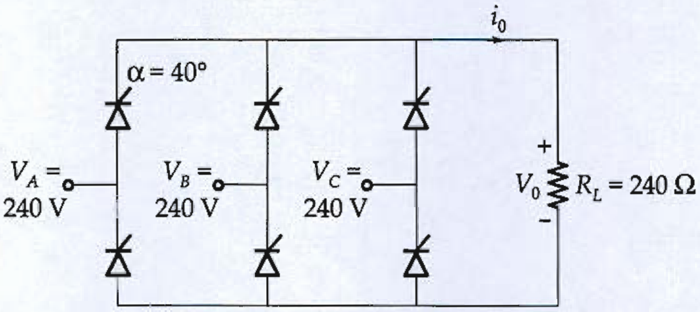
Q.4 (b) **(ii)** For the three-phase full controlled bridge rectifier circuit shown with purely resistive load :



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]

Do not write in this margin

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]

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]

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]

$$E = \frac{NP\phi Z}{60A}$$ for Lap wound $P = A$

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

$\phi = B_m \times A \rightarrow$ area.

↳ average flux density

$$\phi = 1.08 \times \frac{\pi D l}{P} = 1.08 \times \frac{\pi \times 0.2 \times 0.2\cancel{8}}{2} \times 0.75$$

$$= 0.0162\,\pi = 0.05 \text{ Wb}$$

$$\phi = B_m \times A \times \frac{\text{pole arc}}{\text{pole pitch}}$$

$$\boxed{\phi = 0.05 \text{ wb}}$$

for double layer winding coil = slots.

no. of turns = 16 × 28 = 448

no. of conductor = 2 × turns = 448 × 2 = 896

$$E = \frac{N\phi Z}{60} = \frac{1750 \times 0.05 \times 896}{60}$$

$$\boxed{E = 1330.56 \text{ volts}}$$

11

Good Approach

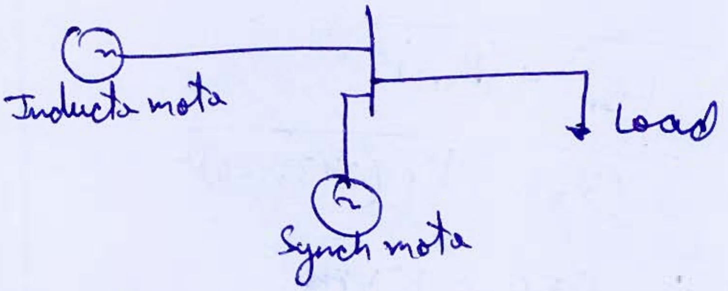
Q.5 (c) In a factory, the following are the loads:

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 motors

$P_o = 746$ KW $\qquad P_{in} = \frac{P_o}{\eta} = \frac{746}{0.85}$

$= 877.647$ KW

$P_1 = P_{in} = 877.647$ Kw

for synchronous motor

P ~~S~~ $P_o = 223.8$ KW

~~P~~ $P_i = \frac{S_{output}}{\eta} = \frac{223.8}{0.92} = 243.26$ KW

$P_{sm} = P_i$ of sync $= 243.26$ KW

θ_1 = initial pf angle $= \cos^{-1}(0.7) = 45.57°$

θ_2 = final pf angle $= \cos^{-1}(0.95) = 18.194°$

$Q_c = P_1 \tan\theta_1 - (P_1 + P_{sm}) \tan\theta_2$

↳ Q_c is reactive power supplied by synchronous motor

$$q_c = 877.647 \tan 45.57 - (877.647 + 243.26) \tan 18.194°$$

$$q_c = 895.379 - (368.424)$$

$$\boxed{Q_c = 526.9543 \text{ KVAR}}$$

$\Downarrow$

Reactive power supplied by synch. motor

$$S = \sqrt{(Q_{SM})^2 + (P_{SM})^2}$$

$$= \sqrt{(526.95)^2 + (243.26)^2}$$

$$\boxed{S = 580.4 \text{ KVA}}$$

∴ Rating of synchronous motor = 580.4 KVA

$$pf = \frac{P}{S} = \frac{243.26}{580.4} = 0.42 \text{ lead.}$$

$$\boxed{\text{Pf of synchronous motor} = 0.42 \text{ lead}}$$

$$S_{\text{sync motor}} = (580.4 \angle 65.22°) \text{ KVA}$$

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]

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

where ~~ψ=i~~ ψ ⇒ internal pf angle

$$\tan\psi = \frac{440 \times 0.526 + \frac{1000}{\sqrt{3}} \times 0.075}{440 \times 0.85}$$

$$\tan\psi = \frac{231.78 + 25\sqrt{3}}{374}$$

$$\tan\psi = 0.7355$$

$$\boxed{\psi = 36.335^\circ}$$

~~Id~~

$$\psi = \phi + \delta \Rightarrow 36.335 = 31.8 + \delta$$

$$\boxed{\delta = 4.547^\circ}$$

$$E_{ph} = V\cos\delta + I_q R_a + I_d X_d$$

$$= 440\cos 4.547 + \frac{1000}{\sqrt{3}}(\sin 36.335) \times 0.1$$

$$= 438.615 + 34.2085$$

$$\boxed{E_{ph} = 472.82 \text{ volts}}$$

$$P_{out} = 3\left[\frac{E_{ph}V}{X_d}\sin\delta + \frac{V^2}{2}\left(\frac{1}{X_q} - \frac{1}{X_d}\right)\sin 2\delta\right]$$

$$= 3\left[\frac{472.82 \times 440}{0.1}\sin 4.547 + \frac{(440)^2}{2}\left(\frac{1}{0.075} - \frac{1}{0.1}\right)\sin 9.09\right]$$

$$= 3\,(164928.18 + 50976.7284)$$

$P_{1\phi} = 215.9$ KW

$P_{3\phi} = 3 \times 215.9 \Rightarrow \boxed{P_{3\phi} = 647.71 \text{ KW}}$

$$Q_{ph} = \frac{E_f V}{X_d} \cos\delta - V^2\left(\frac{\sin^2\delta}{X_q} + \frac{\cos^2\delta}{X_d}\right)$$

$$= \frac{472.82 \times 440}{0.1} \cos 4.54 - (440)^2\left[\frac{(\sin 4.54)^2}{0.075} + \frac{(\cos 4.54)^2}{0.1}\right]$$

$$= 2073793.829 - 440^2(0.08 + 9.93)$$

$$= 137793.829$$

$Q_{1\phi} = 137.793$ KVAR

$Q_{3\phi} = 3 \times 137.793$

$\Rightarrow \boxed{Q_{3\phi} = 413.38 \text{ KVAR}}$

10

Improve presentation

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]

ii) The properties that get affected by structural imperfection are -:

(1) Conductivity/Resistivity

The conductivity decreases & resistivity ↑ increase with. change in structure properties.

(2) Tensile strength

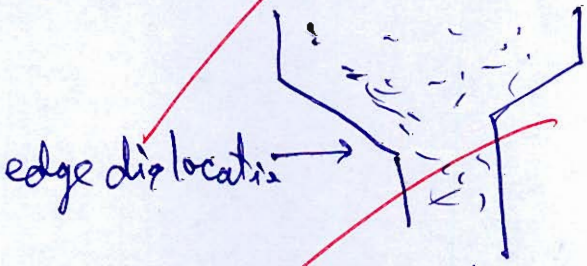
The strength of the material to absorb the stress and strain due to change in dimension also ~~dectsa~~ decreases.

(3) Dielectric strength

Dielectric strength also decreases due to structural imperfectio.

Different types of line defect are -:

i) Edge dislocation -: It occurs due to the imbalance of load on the edge of the. material. This causes change in physical appearance of the material

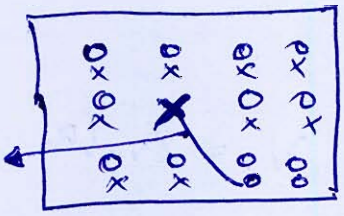


ii) Screw dislocation -: This type of dislocation occurs due to the circulation motion of the material and causes a change in appearance of crystal.

screw dislocation
due to circular motion.

Different types of point defect are.

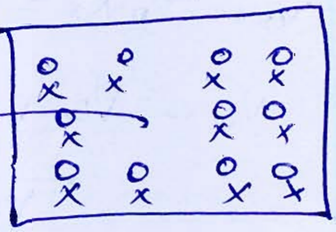
① Schottky defect



anion takes
cation
position

This type of defect occur when anion (+ve charge) take cation position (-ve charge).

② Frenkel's defect



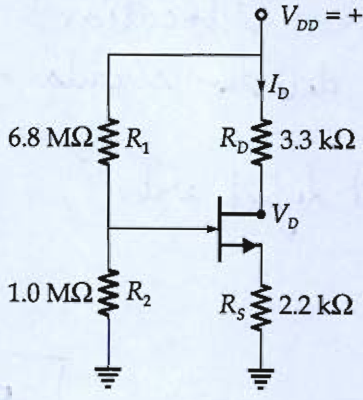
Vacancy.
of anion

This type of defect occur due to vacancy of anion in the crystal. This causes the crystal to gain (-ve) charge.

7

Improve presentation

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]

$V_D = 7$ volts. $\quad I_D = \dfrac{V_{DD} - V_D}{R_D}$

$I_D = \dfrac{12-7}{3.3} = \dfrac{6}{3.3} \Rightarrow \boxed{I_D = 1.818\ mA}$

$V_G = \dfrac{V_{DD} \times R_2}{R_1 + R_2} = \dfrac{12 \times 1}{6.8+1} = \dfrac{12}{7.8} = 1.538$ volt

$V_s = I_D R_s = 1.818 \times 2.2 = 4$ volts

$V_{GS} = V_G - V_s = 1.538 - 4$

$\boxed{V_{GS} = -2.4615 \text{ volts}}$

②

Wrong Value calculated

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]

$$H_c = H_o\left[1-\left(\frac{T}{T_o}\right)^2\right]$$

H_o → critical mag field at 0° K.

T → temperature for metal to be superconductor

T_o → critical temperature

$$H_c = 7.8\times10^5\left[1-\left(\frac{5}{7.2}\right)^2\right]$$

$$= 7.8\times10^5\left[1-(0.694)^2\right]$$

$$\boxed{H_c = 4.038\times10^5 \text{ Amp/m}^2}$$

⑦

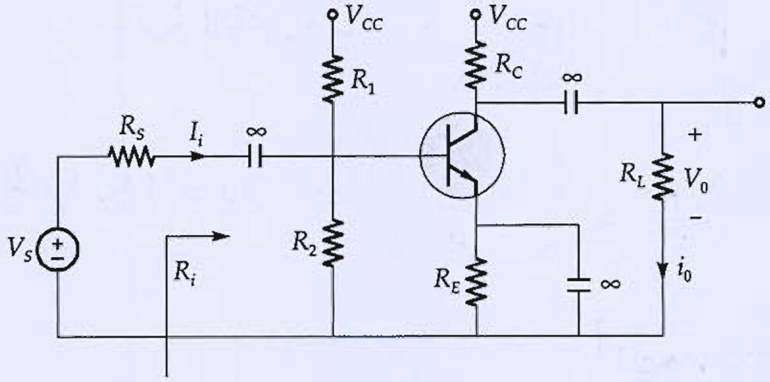
Good Approach

H_c → critical magnetic field of super conductor

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]

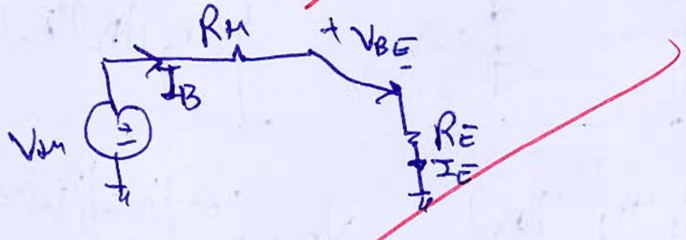
i) for DC analysis → Cap = OC

$$V_{th} = \frac{V_{cc} \times R_2}{R_1 + R_2} = \frac{10 \times 15}{15 + 27} = \frac{150}{42} = 3.571 \text{ volts}$$

$$= \frac{25}{7} \text{ volts}$$

$$R_{th} = (R_1)||(R_2) = (27)||(15)$$

$$= 9.6428 \text{ k}\Omega = \frac{135}{14} \text{ k}\Omega.$$



$$V_{th} = I_B R_{th} + V_{BE} + I_E R_E$$

$$3.571 = I_B \times 9.6428 + 0.7 + (\beta+1) \times I_B \times 1.2$$

$$3.571 - 0.7 = 9.6428 I_B + (101 \times 1.2) I_B$$

$$2.871 = I_B(121.2 + 9.6428)$$

$$I_B = 0.02194 \text{ mA}$$

$$I_E = (\beta+1) I_B = 101 \times 0.02194 \text{ mA}$$

$$= 2.2165 \text{ mA}$$

ii) $I_C = \frac{I_E}{\alpha} = \frac{2.2165 \times 100}{101} = 2.19 mA$

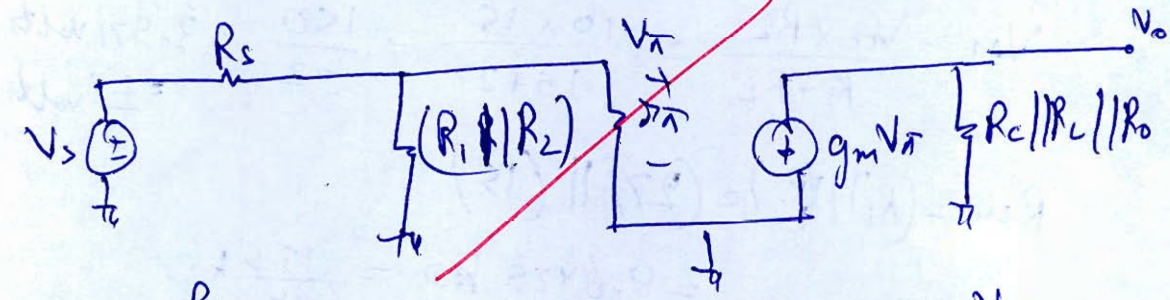
~~$r_\pi = \frac{\beta}{g_m}$~~ $g_m = \frac{I_c}{V_T} = \frac{2.19}{25} = 87.78 m℧$

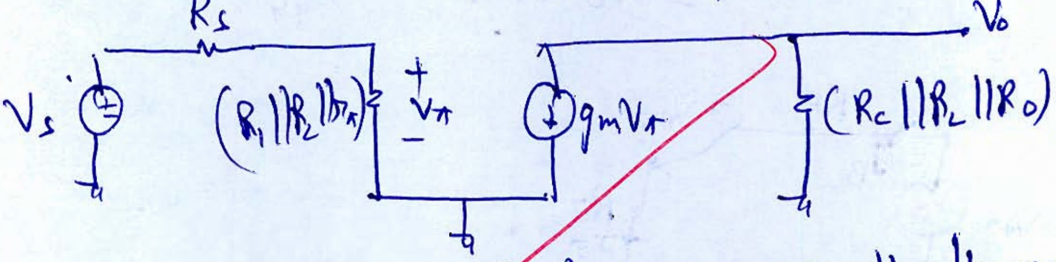
$r_\pi = \frac{\beta}{g_m} = \frac{100}{87.78} = 1.139 k\Omega$

$r_o = \frac{V_A}{I_c} = \frac{100}{2.19} \Rightarrow r_o = 45.56 k\Omega$

using r_π model

AC analysis Cap- SC





$$V_\pi = \frac{V_s \times (R_1 || R_2 || r_\pi)}{(R_s) + (R_1 || R_2 || r_\pi)} = \frac{V_s \times (27 || 15 || 1.139)}{10 + (27 || 15 || 1.139)}$$

$$V_\pi = \frac{V_s \times 1.0188}{10 + 1.0188} \Rightarrow \boxed{V_\pi = 0.0924 V_s} \rightarrow ①$$

$V_o = -g_m V_\pi (R_c || R_L || R_o)$

$V_o = -87.78 \times 0.0924 V_s (R_c || R_L || R_o)$

$\frac{V_o}{V_s} = -8.1 (R_c || R_L || R_o)$

$R_L' = R_L || R_c || r_o$

$= (2.5) || (2.2) || (45.56)$

$R_L' = 1.14\,k$

$\frac{V_o}{V_i} = -8.1 \times 1.14$

$\frac{V_o}{V_i} = -9.241$

$\boxed{\checkmark\; A_v = -9.241}$

$R_{in} = R_1 || R_2 || r_\pi$

$= (27 || 15 || 1.139)$

$\boxed{\checkmark\; R_{in} = 1.018\,k\Omega}$

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]

for motor $V = 400\text{ V}$, $I_a = 50\text{ A}$, $R_a = 0.5\ \Omega$.

$E = V - I_a R_a \Rightarrow 400 - 50 \times 0.5 = 375\text{ volts}$

$\boxed{E = 375\text{ volts}}$

$P_{output} = 375 \times 50$

$P_{input} = 400 \times 50$

assume field winding resistance = 1 Ω

P_{loss} in field wdg $= (\cancel{I_f^2}) (V)^2/R_f = 625$

$\text{losses} = 625 + (50)^2 \times 0.5 = 1875\text{ W}$

$$\eta = \frac{P_{output}}{P_{output} + \text{loss}} = \frac{375 \times 50}{375 \times 50 + 1875} \times 100$$

$\boxed{\eta = 90.9\%}$ → motor

for ~~mot~~ generator $V = 350$, $I_a = 40\text{ A}$

$E = V + I_a R_a$

$= 350 + 40 \times 0.5 = 370\text{ volts}$

$P_{output} = 350 \times 40 = 14000\text{ watts.}$

$\text{losses} = (I_a)^2 R_a + (V_f)^2/R_f$

$= (40)^2 \times 0.5 + 625/1$

$= 1425\text{ watts}$

$$\eta = \frac{P_{output}}{P_{output} + Loss} = \frac{14000}{14000 + 1425} \times 100$$

$$\boxed{\eta_{gen} = 90.76\ \%}$$

⑤

Go through the made easy solution.

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]

$P_{OUT} = 20 KW$ $\qquad P_{in} = \frac{20}{0.88} = 22.72 KW$

$P_{in} = VI \Rightarrow 22.72 \times 10^3 = 220 \times I$

$$\boxed{I = 103.3 \Omega}$$

~~R_E~~ $loss = 22.72 - 20 = 2.72 Kw$

$(I_a)^2 R_a + (I_F)^2 R_F = 2.72 Kw$

$E = V - I_a R_a = 220 - 0.1 I_a$

$E_b I_a = (220 - 0.1 I_a) I_a$

$20 \times 10^3 = 220 I_a - 0.1 I_a^2$

$0.1 I_a^2 - 220 I_a + 20 \times 10^3 = 0$

$I_a^2 - 2200 I_a + 2 \times 10^5 = 0$

~~$I_a = 21.54$~~ $I_a = 2104.98$ Amp (neglect), 95.0124 Am

$\therefore E = 220 - 0.1 I_a = 220 - 0.1 \times 95.01$

$\boxed{E = 210.5 \text{ volts}}$

i) $(I_a)_{new} = \frac{-V + E_b}{(R_a + R_{ext})}$ ⇒ armature terminal reversed.

$I_{a\,new} = 2 I_a \Rightarrow 190$ Amp

$190 = \frac{-220 + 210.5}{0.1 + R_{ext}}$

$0.1 + R_{ext} = -\frac{9.5}{190}$

$0.1 + R_{ext} = -0.05$ $\boxed{R_{ext} = 0.15\Omega}$

ii) $T_{Braking} = T_{Load} + T_{plugging}$

$= \frac{E_b I_a}{\frac{2\pi}{60} \times N_1} + \frac{E_b (I_a)_{new}}{\frac{2\pi}{60} \times N_2}$

$E \propto N\phi \Rightarrow \phi \propto I_a$

$E \propto N I_a \Rightarrow N_1 I_{a_1} = N_2 I_{a_2}$

$1200 \times I_{a_1} = N_2 \times 2 I_{a_2}$

$N_2 = 600$ rpm → during braking

④

$T_{braking} = \frac{20000}{\frac{2\pi}{\cancel{60}} \times \cancel{1200}^{20}} + \frac{210.5 \times 190}{\frac{2\pi}{\cancel{60}} \times \cancel{600}^{10}}$

$= \frac{20 \times 10^3}{40\pi} + \frac{40 \times 10^3}{20\pi}$

$= 10^3 \left(\frac{1}{2\pi} + \frac{2}{\pi}\right) = 795.77$ Nm

$\boxed{T_{braking} = 795.774 \text{ Nm}}$

iii) $E \propto N\phi \Rightarrow E \propto N \Rightarrow \frac{E_1}{E_2} = \frac{N_1}{N_2}$

$E_2 = \frac{210.5}{3} = 70.1666$ volt

$T = \frac{E_2 I_a}{\frac{2\pi}{60} \times 400} = \frac{70.166 \times 95 \times 60}{2\pi \times 400}$

$\boxed{T = 159.135 \text{ Nm}}$

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]

$P_{max} = 540\ \text{KW} \quad (E_F = 0)$

$$\frac{V_t^2}{2}\left(\frac{1}{X_q} - \frac{1}{X_d}\right) = 540 \times 10^3$$

$$\frac{V_t^2}{2}\left(\frac{1}{15.4} - \frac{1}{25.4}\right) = 540 \times 10^3$$

$$V_t^2 \times 0.01278 = 540 \times 10^3$$

$$V_t = 6500\ \text{volts}$$

$$\boxed{V_t = 6.5\ \text{KV}}$$

$$\text{Torque} = 3500 \Rightarrow \frac{P_{OUT}}{\frac{2\pi}{60} \times 1000}$$

$$P_{OUTPUT} = \frac{2\pi}{60} \times 1000 \times 3500$$

$$\boxed{P_{OUTPUT} = 0.3666\ \text{MW.}} = 366.66\ \text{KW}$$

without excitation $= 540\text{KW}$

$$\sqrt{3} \times V_L I_L \times \cos\phi = 540$$

$$\boxed{I_L = 47.96\ \text{A}}$$

~~E_f~~ $$\tan\psi = \frac{V\sin\phi + I_a X_q}{V\cos\phi + I_a R_a}$$

$$= \frac{6500 \times 0.6 + 47.96 \times 15.4}{6500 \times 0.8}$$

$$\tan\psi = 0.89$$

$$\boxed{\psi = 44.88^\circ}$$

for moto at leading p.f

$\psi = \phi + \delta$

$44.88 = 36.86 + \delta$

~~$\delta = 8.06^\circ$~~ ~~→ load angle.~~

$\boxed{\delta = 8^\circ}$

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

$= \frac{6500}{\sqrt{3}} \cos\delta + 42.56(\sin 44.88) \times 25.4$

$= 3716.11 + 854.2$

$= 4570.311$ Volt

$\boxed{(E_F)_{line} = 7.916 \text{ KV}}$

9

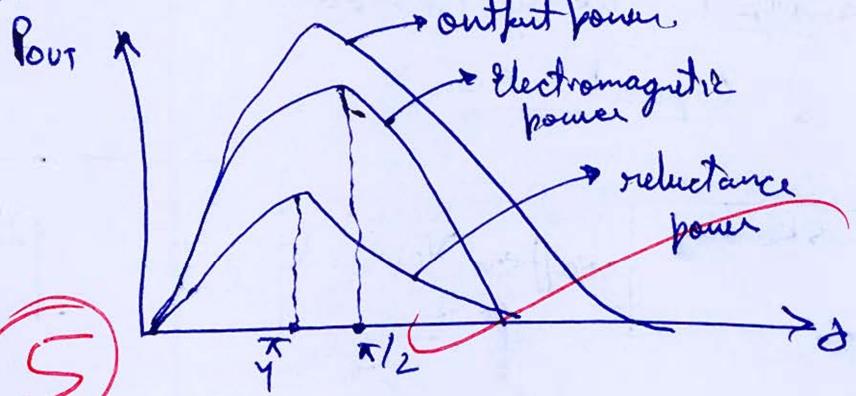
Improve presentation

ii) $$P_{OUT} = \underbrace{\frac{E_F V_T}{X_d}\sin\delta}_{\text{Electromagnetic power}} + \underbrace{\frac{V_T^2}{2}\left(\frac{1}{X_q} - \frac{1}{X_d}\right)\sin 2\delta}_{\text{Reluctance power}}$$

<u>Reluctance power</u> → It is maximum power output at ~~with~~ without field excitation

<u>Electromagnetic power</u>:- It is output power with field excitation.

$$\boxed{P_{OUT} = P_{electromagnetic} + P_{reluctance}}$$



5

Improve presentation

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

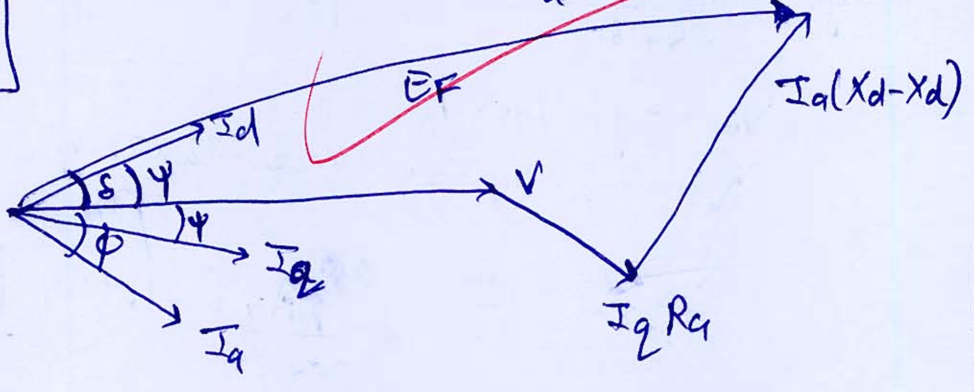
$= V\cos\delta + I_a(X_d - X_q) + I_a R_a$

where δ → load angle

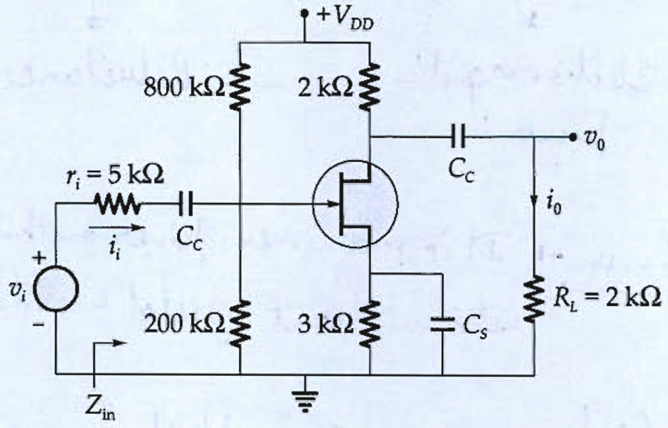
X_q → quadrature axis reactance

X_d → direct axis reactance

$$\boxed{\psi = \phi + \delta}$$



Q.7 (b) For the JFET amplifier shown in the figure below has $g_m = 2$ mS, $r_i = 5$ kΩ and $r_{ds} = 30$ kΩ. 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 $A_I = i_0/i_i$.



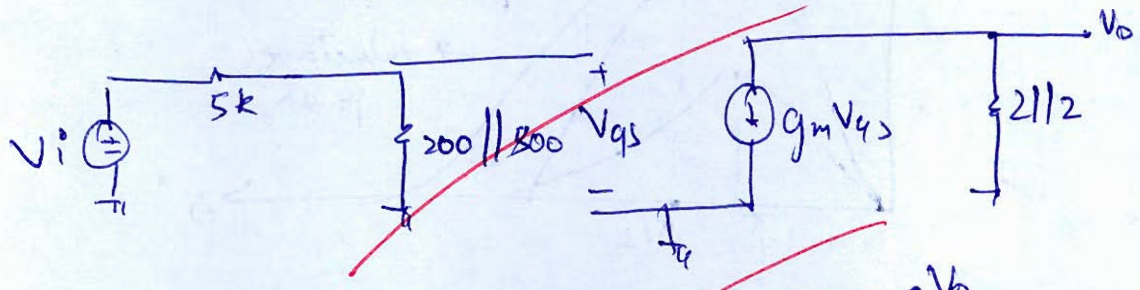
[20 marks]

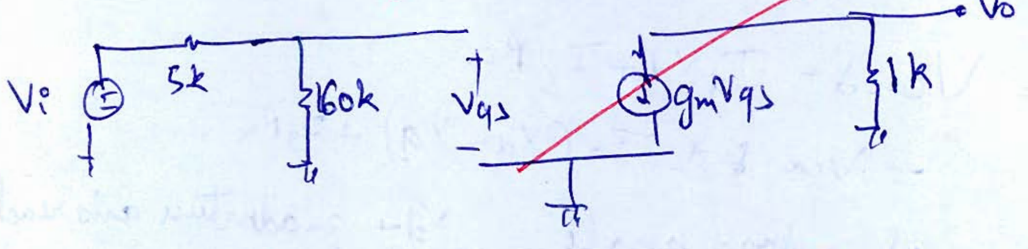
under DC analysis. Cap → O C.

$g_m = 2mS$

AC analysis using rπ model

Capacitor OC





$$V_{gs} = \frac{V_i \times 160}{5+160} = V_i \times \frac{160}{165} = \frac{32 V_i}{33}$$

$$V_o = -g_m V_{gs} \times 1$$

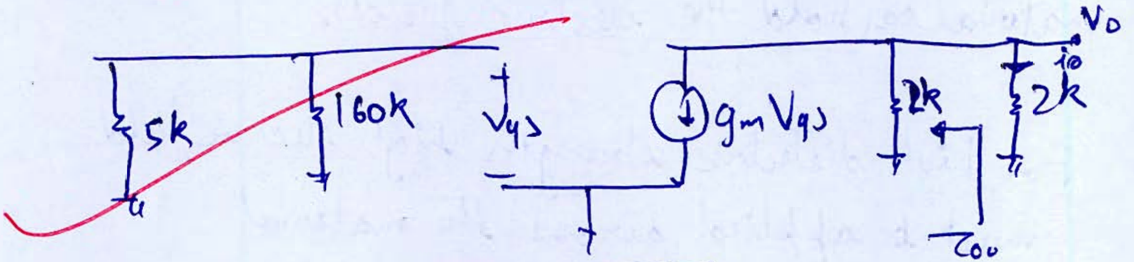
$$V_o = -2 \times V_{gs} \Rightarrow V_o = -\frac{2 \times 32 V_i}{33}$$

$$\frac{V_o}{V_i} = -\frac{64}{33} \qquad \boxed{A_V = -1.939}$$

$Z_{in} = 200 || 1800$

$\boxed{Z_{in} = 160k}$ → input resistance.

To calculate output impedance deactivate all independent source



$V_{gs} = 0$ ∴ $\boxed{Z_{OUT} = 2k}$

$$\frac{V_o}{V_i} = \frac{I_o}{I_{in}} \times \frac{Z_o}{Z_{in}}$$

$$-1.939 = \frac{I_o}{I_{in}} \times \frac{2}{160} \Rightarrow$$

$$\frac{I_o}{I_{in}} = -1.939 \times 80$$

$$\boxed{\frac{I_o}{I_{in}} = -155.1515}$$

17

Q.7 (c) Define dielectric strength. Discuss different types of dielectric breakdowns in solids. **[20 marks]**

- Dielectric strength of the material is the ~~[illegible]~~ strength upto which an insulator or non magnetic material can hold the electric field.

- For high dielectric strength high electric field must be applied across the material.

- Some example of dielectric are - glass, air, vaccum, etc.

An ideal dielectric must have following properties.

→ ~~E~~high dielectric ~~le~~ strength
→ ~~[illegible]~~ low permeability
→ Low dissipation factor.
→ high insulation resistance etc.

Different types of dielectric break down in solids are:-

① Thermal breakdown

* This breakdown occur in dielectrics due to high temperature applied across the material.

* This can even cause permanent damage of dielectric material.

② High electric field

On application of high electric field the dielectric fails to hold the charges and hence dielectric breakdown occurs.

③ Mechanical stress / force

The stress or force on the material can cause its dielectric to be breakdown.

⑨

Elaborate it more

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]

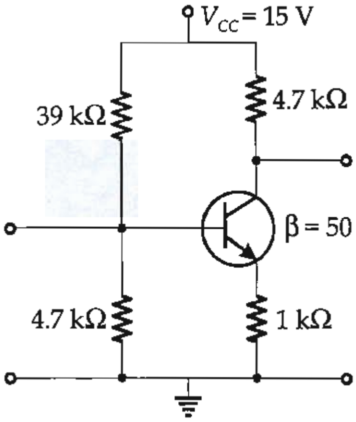
Q.8 (b) (i) Explain about dependence of the loss tangent on temperature and frequency.

(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]

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]

OOOO

Space for Rough Work

Space for Rough Work

$$\begin{tikzcd} x \arrow[dr] & -1 \arrow[dr] & 0 \\ \cos nx & \frac{\sin nx}{n} & -\frac{\cos nx}{n^2} \end{tikzcd}$$

$$\frac{x\sin nx}{n} + \frac{\cos nx}{n^2}$$

$$x \sin nx$$

$$\begin{tikzcd} x \arrow[dr] & -1 \arrow[dr] & 0 \\ \sin nx & -\frac{\cos nx}{n} & \frac{\sin nx}{n^2} \end{tikzcd}$$

$$-\frac{x\cos nx}{n} - \frac{\sin nx}{n^2}$$