



12 Pages

1. Please give the information requested in the boxes below.
2. Enter your name in the space provided to the right, fold over and seal down (using the label provided) to hide your name.
3. The answers must be legibly written. The Examiners can either ignore illegible script or have it typed and the expense of typing charged to the candidate.
4. Write your answers in ink.
5. Begin each answer on a fresh page. Do all rough work in the answer book and cross it through.
6. No part of this book is to be torn out; it must be handed in complete.
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Complete, fold and seal
(see note 2 below)

SURNAME: Booth

FORENAME(S): Jason, Christopher

1	Student Number	130 2736
2	Title of Examination Paper	Power + Machine
3	Module Code	SGEE 5006
4	Date and Time of Examination	4/5/23 9:30
5	Examination Venue	CSG
6	Seat Number	31
7	Number of Answer Books handed in	

[illegible]

(Gweler yr ochr arall am y fersiwn Cymraeg)

MARK
AGREED

Q1

- a) 1. Hysteresis losses - minimized by choosing the core material
 2. Eddy current losses - minimized by laminating the core.

(4)

✓

$$ii) E_2 = 4.44 f N_2 \phi_{max}$$

$$\therefore N_2 = \frac{E_2}{4.44 f \phi_{max}} = \frac{200}{4.44 \times 60 \times 0.075} = 10 \text{ turns}$$

(4)

✓

$$N_1 = N_2 \times \frac{E_1}{E_2} = 10 \times \frac{5500}{200} = 275 \text{ turns}$$

b)

$$i) \text{ For } M1: |S_1| = 5.5 \text{ kVA}, P_1 = 5500 \times 0.78 = 4290 \text{ W}, Q_1 = \sqrt{5500^2 - 4290^2} = 3441.79 \text{ VAR}$$

$$\text{For } M2: |S_2| = 15.2 \text{ kVA}, P_2 = 15200 \times 0.85 = 12920 \text{ W}$$

$$Q_2 = \sqrt{15200^2 - 12920^2} = 8007.01 \text{ VAR}$$

$$\text{Total power of 3 single phase loads} = 3.5 \text{ k} \times 3 = 10500 \text{ W}$$

$$\text{Total } Q = Q_1 + Q_2 = 3441.79 + 8007.01 = 11448.8 \text{ VAR}$$

$$\text{Total } |S| = \sqrt{P^2 + Q^2}$$

$$\text{Total power} = 10500 + 4290 + 12920 = 27710 \text{ W}$$

$$\text{Total } |S| = \sqrt{P^2 + Q^2} = \sqrt{27710^2 + 11448.8^2} = 29981.98 \text{ VA}$$

$$|I| = \frac{|S|}{\sqrt{3} \times E_1} \quad |I| \text{ line current (primary)} = \frac{|S|}{\sqrt{3} \times E_1} = \frac{29981.98}{\sqrt{3} \times 5500} = 3.15 \text{ A}$$

(11)

✓

$$|I| \text{ line current (secondary)} = \frac{29981.98}{\sqrt{3} \times 200} = 36.55 \text{ A}$$

$$p.f. = \frac{P}{|S|} = \frac{27710}{29981.98} = 0.924 \text{ lagging}$$

(2)

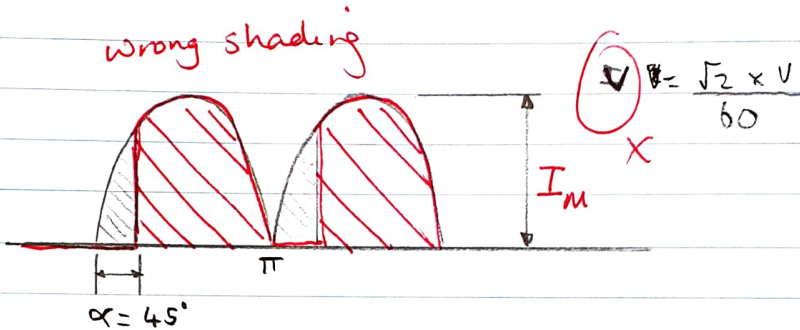
✓

Q2a)

- i) di/dt indicates the max rate of rise of current where it will not cause unequal current distribution that can cause heat spots and damage the device.
 dv/dt indicates the max rate of rise of anode-cathode voltage that will not trigger the device.

- ii) di/dt can be limited by placing an inductor in series.
 dv/dt can be ~~controlled~~ limited by ~~adding~~ adding a series RC 'snubber network' inbetween the device's anode and cathode.

b)i)



ii) $I_{rms}^2 = \frac{P}{R} = \frac{870}{60} = 14.5 \text{ A}$

$I_{rms} = \sqrt{14.5} = 3.81 \text{ A}$

iii) $I_{mean} = \frac{1}{\pi} \int_{\alpha}^{\pi} I_m \sin \theta d\theta$ where $I_m = \frac{V_m}{R}$

$I_{mean} = \frac{1}{\pi} \frac{V_m}{R} \int_{\alpha}^{\pi} \sin \theta d\theta$

$I_{mean} = \frac{V_m}{\pi R} [-\cos \theta]_{\alpha}^{\pi} = \frac{V_m}{\pi R} [1 + \cos \alpha]$

$I_{mean} = \frac{\sqrt{2} \times 240}{\pi \times 60} [1 + \cos 45^\circ] = 2.17 \text{ A}$

Q3

$$i) \omega_m = \frac{2\pi}{60} \times N = \frac{2\pi}{60} \times 2100 = 219.9 \text{ rad/s}$$

$$T_m = T_L + b \omega_m = 68 + (0.02 \times 219.9) = 72.4 \text{ Nm}$$

$$T_m = k_m I_a$$

$$\therefore k_m = \frac{T_m}{I_a} = \frac{72.4}{74.5} = 0.972 \text{ Nm per amp}$$

$$V_a = E_a + I_a R_a$$

$$\therefore E_a = V_a - I_a R_a = 250 - (74.5 \times 0.48) = 214.24 \text{ V}$$

$$E_a = k_e \omega_m$$

$$\therefore k_e = \frac{E_a}{\omega_m} = \frac{214.24}{219.9} = 0.974 \text{ V per rad/s}$$

$$ii) T_m = T_L + b \omega_m \quad \text{where } T_m = k_m I_a$$

$$0.97 I_a = 80 + 0.02 \omega_m$$

$$* \quad I_a = \frac{80 + 0.02 \omega_m}{0.97} \quad \text{--- (1)}$$

$$V_a = E_a + I_a R_a \quad \text{where } E_a = k_e \omega_m$$

$$250 = 0.974 \omega_m + I_a 0.48 \quad \text{--- (2)}$$

Sub (1) into (2)

$$250 = 0.974 \omega_m + 0.48 \left(\frac{80 + 0.02 \omega_m}{0.97} \right)$$

$$250 = 0.974 \omega_m + 39.59 + 9.9 \times 10^{-3} \omega_m$$

$$250 = 0.984 \omega_m + 39.59$$

$$250 - 39.59 = 0.984 \omega_m$$

$$210.41 = 0.984 \omega_m$$

$$\frac{210.41}{0.984} = \omega_m$$

$$213.83$$

$$\therefore \omega_m = 213.83 \text{ rad/s} \quad \text{--- sub back into (1)}$$

Sub (2) into (1)

$$I_a = \frac{80 + 0.02(213.83)}{0.97} = 86.88 \text{ A}$$

iii) Load 1 = 68 Nm Load 2 = 80 Nm

$$P_m =$$

$$P_e = VI$$

Load 1

$$P_m = T_m \omega_m = 72.4 \times 219.9$$

$$P_e = VI = 250 \times 74.5 = 18625 \text{ VA}$$

$$P_m = T_m \omega_m = 72.4 \times 219.9 = 15920.76 \text{ W}$$

$$\% \eta = \frac{P_m \times 100}{P_e} = \frac{15920.76}{18625} = 85.48\%$$

Load 2

$$P_e = 250 \times 86.88 = 21720 \text{ VA}$$

$$P_m =$$

$$T_m = 80 + 0.02 \times 213.83 = 84.28 \text{ Nm}$$

$$P_m = 84.28 \times 213.83 = 18021.59 \text{ W}$$

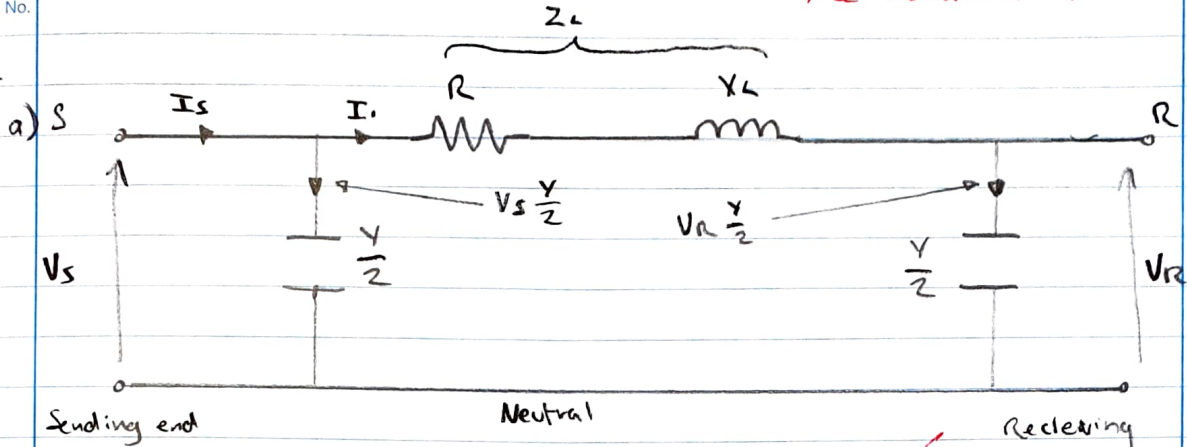
$$\% \eta = 82.97\%$$

(4)

(5)

This is the wrong circuit, should be the nominal T

Q4



$$X_L = 2\pi f L = 2\pi \times 50 \times 200 \times 10^{-3} = j62.83 \Omega$$

$$Z_L = R + jX_L = 25 + j62.83 \Omega = 67.62 \angle 68.3^\circ \Omega$$

$$Y = j\omega C = j \times 2\pi \times 50 \times 1.4 \times 10^{-6} = 439.82 \times 10^{-6} \angle 90^\circ \text{ Siemens}$$

b) $V_R = 76200 \angle 0^\circ \text{ V}$

$$I_R = 213 \angle -36.87^\circ \text{ A} = 218.4 - j163.8 \text{ A}$$

Wrong method but question does not state nominal T must be used.

$$V_{R \frac{Y}{2}} = 76200 \angle 0^\circ \times 219.91 \times 10^{-6} \angle 90^\circ = 16.76 \angle 90^\circ \text{ A} = 0 + j16.76 \text{ A}$$

$$I_1 = I_R + V_{R \frac{Y}{2}} = 218.4 - j163.8 + j16.76 = 218.4 - j147.04 = 263.29 \angle -33.95^\circ \text{ A}$$

$$\begin{aligned} V_S &= V_R + I_1 Z_L = 76200 + 263.29 \angle -33.95^\circ \times 67.62 \angle 68.3^\circ \\ &= 76200 + 17803.67 \angle 34.35^\circ \\ &= 76200 + 14698.82 + j10045.66 \\ &= 90898.82 + j10045.66 \\ &= 91452.23 \angle 6.31^\circ \text{ V} \end{aligned}$$

close answers with round differences

$$\begin{aligned} I_S &= I_1 + V_{S \frac{Y}{2}} = 218.4 - j147.04 + 91452.23 \angle 6.31^\circ \times 219.91 \times 10^{-6} \angle 90^\circ \\ &= 218.4 - j147.04 + 20.11 \angle 96.31^\circ \\ &= 218.4 - j147.04 - 2.21 + j19.99 \\ &= 216.19 - j127.05 \text{ A} \\ &= 250.76 \angle -30.44^\circ \text{ A} \end{aligned}$$

close answers with rounding differences

$$p.f. = \cos(6.31 - (-30.44)) = 0.80, \text{ lagging.}$$

0

3

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