

Instructions to Candidates

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.

7. If more books than one are used, fasten them together using the tags available from the invigilator(s).

8. Every book must be handed in. In no circumstances may answer books, used or unused, be taken out of the examination venue.

7	Number of Answer Books handed in	1
6	Seat Number	
5	Examination Venue	G43
4	Date and Time of Examination	3/5/2024 09:30
3	Module Code	SGEE6001
2	Title of Examination Paper	POWER ELECTRONICS
1	Student Number	2017197

[illegible]

(Gweler yr ochr arall am y fersiwn Cymraeg)

75%

Complete, fold and
(see note 2 below)

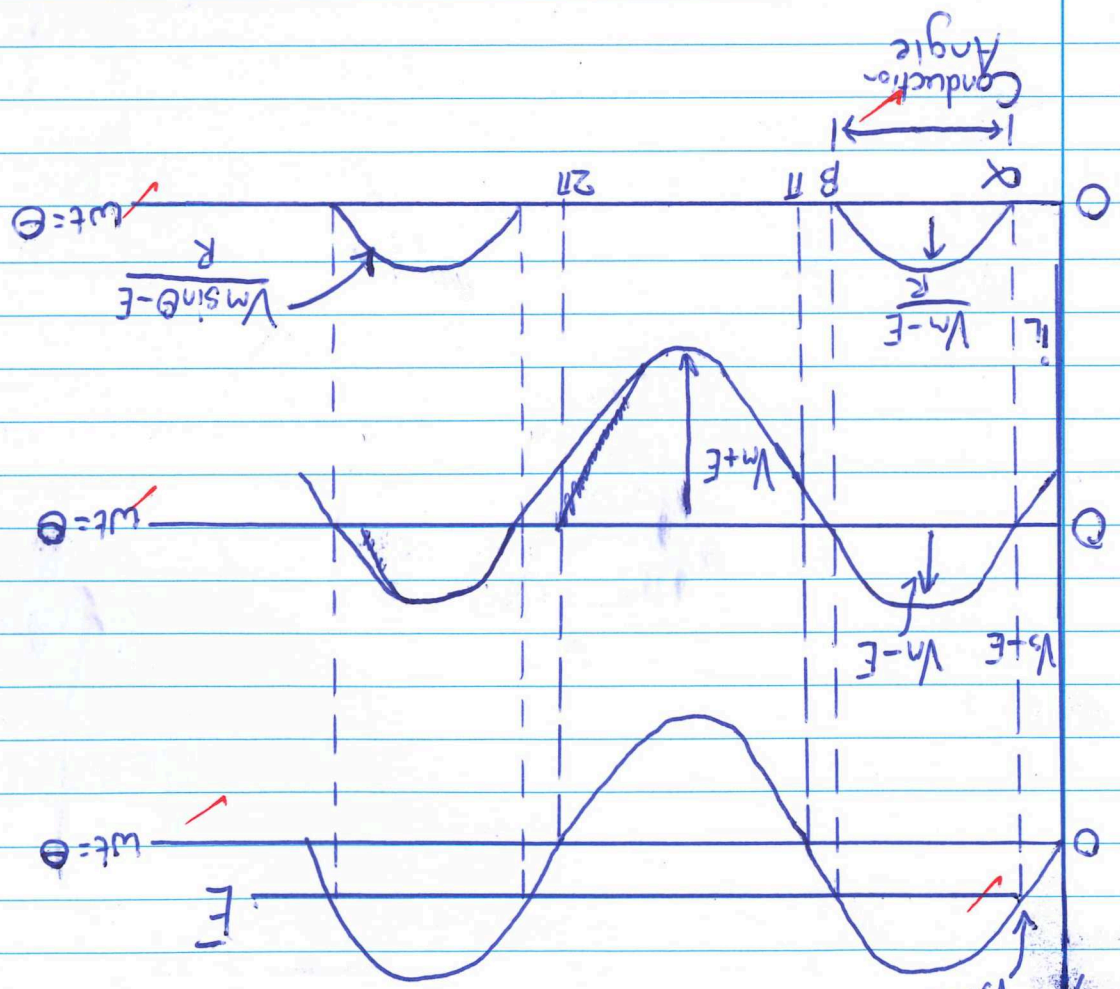
SURNAME:

SMITHAM

FORENAME(S):

AERON

1a) V_s
 $V_s = E$
 $V_s = V_m \sin \omega t$



Diode D_1 begins conducting when $V_s \geq E$ and when $\theta = \alpha$
 α can be found when $V_s = E$

$$i_L = \frac{V_m \sin \theta - E}{R}$$

$$\alpha = \sin^{-1} \left(\frac{E}{V_m} \right)$$

Conduction Angle = $\beta - \alpha$

$$\beta = \pi - \alpha$$

Diode blocking missing!

8

8

1b)

$$\begin{aligned}
 V_p &= 120V \\
 V_s &= V_p \div 2 \\
 &= 120 \div 2 \\
 &= 60V \\
 V_m &= V_s \times \sqrt{2} \\
 &= 60 \times \sqrt{2} \\
 &= 84.85V
 \end{aligned}$$

$$\begin{aligned}
 \alpha &= \sin^{-1} \left(\frac{24}{84.85} \right) \\
 &= 0.287 \text{ rads}
 \end{aligned}$$

$$\begin{aligned}
 \beta &= \pi - \alpha \\
 &= \pi - 0.287 \\
 &= 2.855 \text{ rads}
 \end{aligned}$$

$$\begin{aligned}
 \text{Conduction Angle} &= \beta - \alpha \\
 &= 2.855 - 0.287 \\
 &= 2.568 \text{ rads}
 \end{aligned}$$

$$E = 24V$$

1bii)

$$I_L = \frac{1}{2\pi} \int_B^{\alpha} V_m \sin[\theta] - E \cdot d\theta$$

$$= \frac{1}{2\pi R} [-V_m \cos[\theta] - E[\theta]]_B^{\alpha}$$

$$= \frac{1}{2\pi R} [-84.85 \cos] -$$

$$= \frac{1}{2\pi R} [-V_m \cos[\beta] - E[\beta]] - [-V_m \cos[\alpha] - E[\alpha]]$$

$$= \frac{1}{2\pi R} [-84.85 \cos(2.855) - 14(2.855) + 84.85 \cos(0.287) + 24(0.287)]$$

$$= \frac{1}{2\pi R} [81.39 - 68.52 + 81.38 + 6.89]$$

$$= \frac{1}{2\pi R} [101.14]$$

$$I_L = \frac{101.14}{2\pi R}, \quad S = \frac{101.14}{2\pi \times R}$$

$$\therefore R = \frac{101.14}{2\pi \times 5}$$

$$R = 3.22 \Omega$$

$$1biii) PIV = V_m + E = 84.85 + 24 = 108.85 V$$

2

8

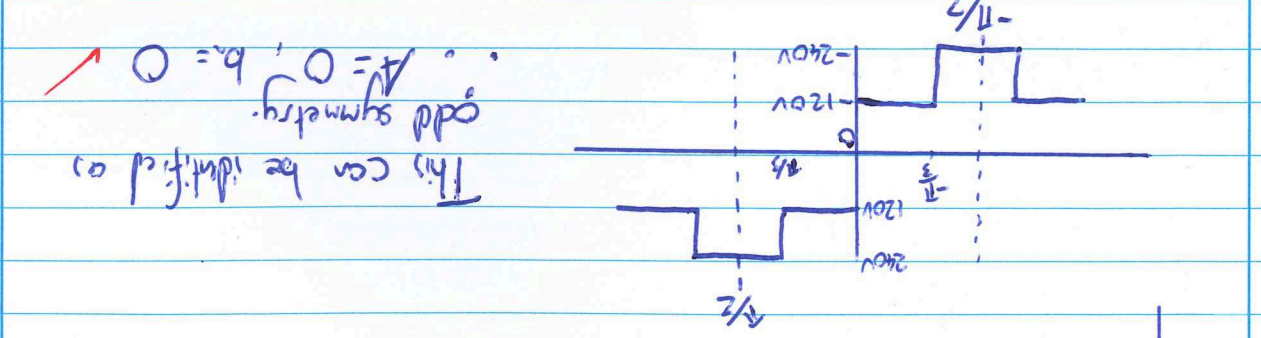
$$a_n = \frac{1}{2} \int_{-\pi/2}^{\pi/2} \left(\int_{-\pi/3}^{\pi/3} -240 \sin(n\theta) d\theta + \int_{\pi/3}^{\pi/2} -120 \sin(n\theta) d\theta + \int_{-\pi/2}^{-\pi/3} 120 \sin(n\theta) d\theta + \int_{-\pi/3}^0 240 \sin(n\theta) d\theta \right) d\theta$$

$$a_n = \frac{1}{2} \int_{-\pi/2}^{\pi/2} \left[-240 \sin(n\theta) d\theta - (120 \sin(n\theta) d\theta + (120 \sin(n\theta) d\theta + (240 \sin(n\theta) d\theta) \right]$$

$-\pi/2$ to $-\pi/3$	$= -240V$
$-\pi/3$ to 0	$= -120V$
0 to $\pi/3$	$= 120V$
$\pi/3$ to $\pi/2$	$= 240V$

$$a_n = \frac{1}{2} \int_{-\pi/2}^{\pi/2} 2V(\theta) \sin(n\theta) d\theta$$

$$= \frac{\pi}{2} \int_{-\pi/2}^{\pi/2} V(\theta) \sin(n\theta) d\theta$$



$$a_n = \frac{\pi}{2} \int_{-240}^{240} [240 \cos(n\theta)] \frac{n}{2} d\theta + \int_{-120}^{-120} [-120 \cos(n\theta)] \frac{n}{2} d\theta + \int_{120}^{120} [-120 \cos(n\theta)] \frac{n}{2} d\theta$$

$$a_n = \frac{\pi}{2} \left[240 \cos(n\theta) - \cos(n\theta) - \cos(n\theta) + (120 \cos(n\theta) - \cos(n\theta) - \cos(n\theta)) \right] + (-120 \cos(n\theta) + 120 \cos(n\theta)) + (-240 \cos(n\theta) + 240 \cos(n\theta))$$

constant should be outside brackets!

$$\cos(n\theta) = \cos(n\theta), \cos(n\theta) = \cos(n\theta), \cos(n\theta) = 1$$

$$a_n = \frac{\pi}{2} \left[240 \cos(n\theta) - 240 \cos(n\theta) + (120 - 120) + (-120 \cos(n\theta) + 120 \cos(n\theta)) \right]$$

$$(-120 \cos(n\theta) + 120) + (-240 \cos(n\theta) + 240 \cos(n\theta))$$

$$a_n = \frac{\pi}{2} \left[(240 - 120 - 120 + 240) \cos(n\theta) + (-240 - 240) \cos(n\theta) \right]$$

$$a_n = \frac{\pi}{2} \left[(240 \cos(n\theta) - \frac{3}{2}) - 480 \cos(n\theta) + 240 \right]$$

3a) (cont)

Question No.

$\cos n\pi$ is 0 due to the odd symmetry

$$\therefore a_n = \frac{1}{2} \left[240 \cos n\pi + 240 \right]$$

$$= \frac{1}{2} \left[240 (1 + \cos n\pi) \right]$$

$$= \frac{1}{2} \left[240 (1 + \cos n\pi) \right]$$

$$a_1 = \cos \frac{\pi}{3} = 0.5$$

$$a_3 = \cos \frac{3\pi}{3} = -1$$

$$a_5 = \cos \frac{5\pi}{3} = 0.5$$

$$a_7 = \cos \frac{7\pi}{3} = 0.5$$

$$a_{n1} = \frac{1}{480} (1 + 0.5) = 229.18V$$

$$a_3 = \frac{3\pi}{480} (1 - 1) = 0V$$

$$a_5 = \frac{5\pi}{480} (1 + 0.5) = 45.84V$$

$$a_7 = \frac{7\pi}{480} (1 + 0.5) = 32.74V$$

$$v[t] = 229.18 \sin(\omega t) + 45.84 \sin(5\omega t) + 32.74 \sin(7\omega t)$$

3b)

$$Z = R + jX_L$$

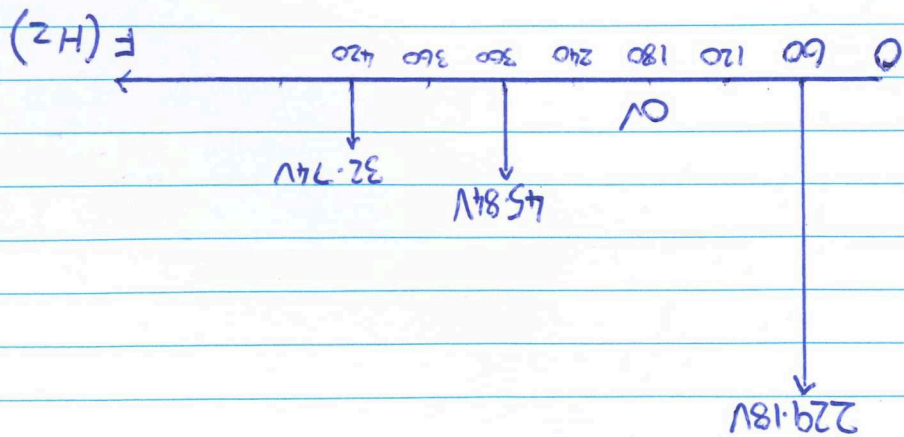
$$jX_L = 2\pi fL$$

$$jX_L = 2\pi \times 60 \times 0.003 = 1.131 \Omega$$

$$jX_3 = 2\pi \times 180 \times 0.003 = 3.39 \Omega$$

$$jX_5 = 2\pi \times 300 \times 0.003 = 5.65 \Omega$$

$$jX_7 = 2\pi \times 420 \times 0.003 = 7.92 \Omega$$



3

$$Z_1 = 0.2 + j1.131 = \sqrt{0.2^2 + 1.131^2} \angle \tan^{-1}(1.131/0.2) = 1.15 \angle 79.97^\circ$$

$$Z_3 = 0.2 + j3.39 = \sqrt{0.2^2 + 3.39^2} \angle \tan^{-1}(3.39/0.2) = 3.4 \angle 86.62^\circ$$

$$Z_5 = 0.2 + j5.65 = \sqrt{0.2^2 + 5.65^2} \angle \tan^{-1}(5.65/0.2) = 5.65 \angle 87.97^\circ$$

$$Z_7 = 0.2 + j7.92 = \sqrt{0.2^2 + 7.92^2} \angle \tan^{-1}(7.92/0.2) = 7.92 \angle 88.55^\circ$$

$$I = \frac{Z}{\sqrt{2}}$$

$$\therefore I_1 = \frac{1.15}{229.18} = 199.29 \angle -79.97^\circ \text{ A}$$

$$I_3 = 0 \text{ A}$$

$$I_5 = \frac{5.65}{45.84} = 8.11 \angle -87.97^\circ \text{ A}$$

$$I_7 = \frac{7.92}{32.74} = 4.13 \angle -88.55^\circ \text{ A}$$

$$I_{ms} = \frac{6 \times \sqrt{2}}{\sqrt{2}}$$

$$I_{ms} = 199.29 \times \sqrt{2} = 140.92 \text{ A}$$

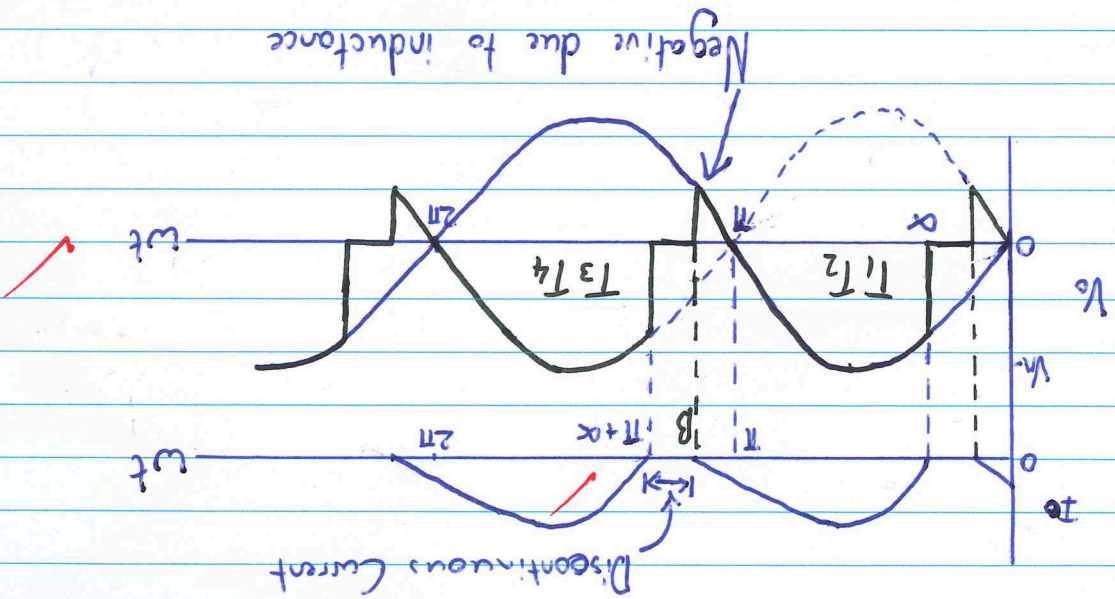
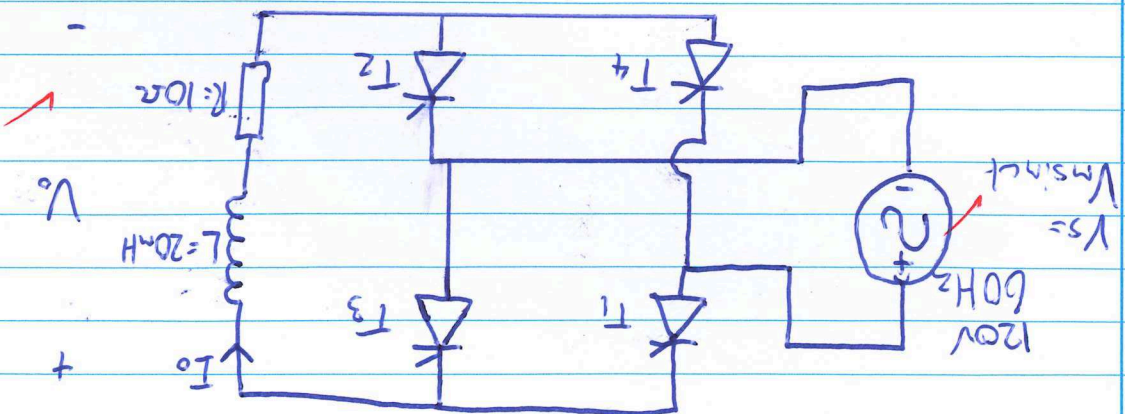
$$I_{rms} = 0 \text{ A}$$

$$I_{rms} = 8.11 \div \sqrt{2} = 5.73 \text{ A}$$

$$I_{rms} = 4.13 \div \sqrt{2} = 2.92 \text{ A}$$

$$I_{rms} = \sqrt{140.92^2 + 5.73^2 + 2.92^2}$$

$$I_{rms} = 141.07 \text{ A}$$



Current becomes zero at $\omega t = \beta$ and remains there until $\omega t = \pi + \alpha$ when T_3 and T_4 have a gate signal applied to them to fire and conduct in forward bias.

An expression for discontinuous current can be given $\beta < [\pi + \alpha]$ To get continuous current the following changes could be made:

- Large inductor value
- Small α firing angle

$$\text{4bii) } V_{\text{avg}} = \frac{1}{\pi} \int_{\beta}^{\alpha} V_m \sin \omega t \cdot d\omega t$$

$$= \frac{V_m}{\pi} \left[-\cos \omega t \right]_{\beta}^{\alpha}$$

$$= \frac{V_m}{\pi} \left[-\cos \beta - (-\cos \alpha) \right]$$

$$= \frac{V_m}{\pi} \left[\cos \alpha - \cos \beta \right]$$

$$\text{4bi) } \alpha = 60^\circ = 1.047 \text{ rad} \quad \omega L = 2\pi f L = 2\pi \times 60 \times 0.02 = 7.54 \Omega$$

$$\theta = \tan^{-1} \left(\frac{\omega L}{R} \right) = \tan^{-1} \left(\frac{7.54}{10} \right) = 0.646 \text{ rad}$$

$$V_m = 120 \times \sqrt{2} = 170 \text{ V}$$

$$\beta = \pi + \theta = \pi + 0.646 = 3.79$$

$$V_{\text{avg}} = \frac{170}{\pi} \left[\cos(1.047) - \cos(3.79) \right]$$

$$= 70 \text{ V}$$

$$I_{\text{avg}} = \frac{170}{10\pi} \left[\cos(1.047) - \cos(3.79) \right]$$

$$= 7 \text{ A}$$

$$P = I_{rms} \cdot R$$

$$V_{rms} = \sqrt{\frac{1}{T} \int_0^T [V_m \sin \omega t]^2 \cdot dt}$$

$$= \sqrt{\frac{V_m^2}{2\pi} \left[\beta - \alpha - \frac{1}{2} \sin(2\beta) + \frac{1}{2} \sin(2\alpha) \right]}$$

$$Z = \sqrt{R^2 + \omega L^2} = \sqrt{10^2 + 7.5^2} = 12.5 \Omega$$

$$I_{rms} = \frac{1}{12.5} \times \sqrt{\frac{170^2}{2\pi} \left[3.79 - 1.047 - \frac{1}{2} \sin(2 \times 3.79) + \frac{1}{2} \sin(2 \times 1.047) \right]}$$

$$= 8.9 A$$

$$P = 8.9^2 \times 10 = 792 W$$

