



Complete, fold and seal
(see note 2 below)

SURNAME: Gough

FORENAME(S): JORDAN MARC

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.**

1	Student Number	1708174
2	Title of Examination Paper	POWER ELECTRONICS AND DRIVES
3	Module Code	SGEE 6001
4	Date and Time of Examination	20/05/2022 09:30
5	Examination Venue	COLEG SIR GAR
6	Seat Number	15
7	Number of Answer Books handed in	

List the numbers of the questions you have attempted	Office Use
Q2	22
Q4	22
Q5	20
Total	64.

Mark confirmed as 64

2.

a) $V_s = 440V$

$V_{max} = 622.25V$

$f_s = 50Hz$

$V_a = 198.06V$

$R_a = 0.25\Omega$

$V_f = 396.14V$

$R_f = 175\Omega$

$I_a = 45A$

$\frac{V}{I \times R}$

$K_v = 1.4 V/A \text{ rad/s}$

$\alpha = 60^\circ$

$$(i) V_{max} = V_s \times \sqrt{2}$$

$$= 440 \times \sqrt{2} = 622.25V$$

$$V_a = \frac{2 V_{max} \cos \alpha}{\pi}$$

$$= \frac{2 \times 622.25 \times \cos 60}{\pi} = 198.06V$$

$$V_f = \frac{2 V_{max} \cos 0}{\pi}$$

$$= \frac{2 \times 622.25 \times \cos 0}{\pi} = 396.14V$$

$$I_f = \frac{V_f}{R_f}$$

$$= \frac{396.14}{175} = 2.26A$$

$$T_e = K_v I_f I_a$$

$$= 1.4 \times 2.26 \times 45 = 142.38 \text{ Nm}$$

3

$$(ii) \omega = \frac{E}{k_v I_f}$$

$$E = V_a - (I_a R_a) \\ = 198.06 - (45 \times 0.25) = 186.81V$$

$$\omega = \frac{186.81}{1.4 \times 2.26} = 59.04 \text{ rad/s}$$

$$(iii) P_{in} = (V_a I_a) + (V_f I_f) \\ = (198.06 \times 45) + (396.14 \times 2.26) = 9807.98W$$

$$VA = V_s I_s$$

$$I_s = \sqrt{I_a^2 + I_f^2} \\ = \sqrt{45^2 + 2.26^2} = 45.06A$$



$$\therefore VA = 440 \times 45.06 = 19826.4VA$$

$$\cos \phi = \frac{P_{in}}{VA} \\ = \frac{9807.98}{19826.4} = 0.495 \text{ lagging}$$

2.

b)

$$(i) \quad V_a = -E + (I_a R_a) \\ = -186.81 + (45 \times 0.25) = -175.56 \text{ V}$$

$$\cos \alpha = \frac{V_a \pi}{2 V_{max}}$$

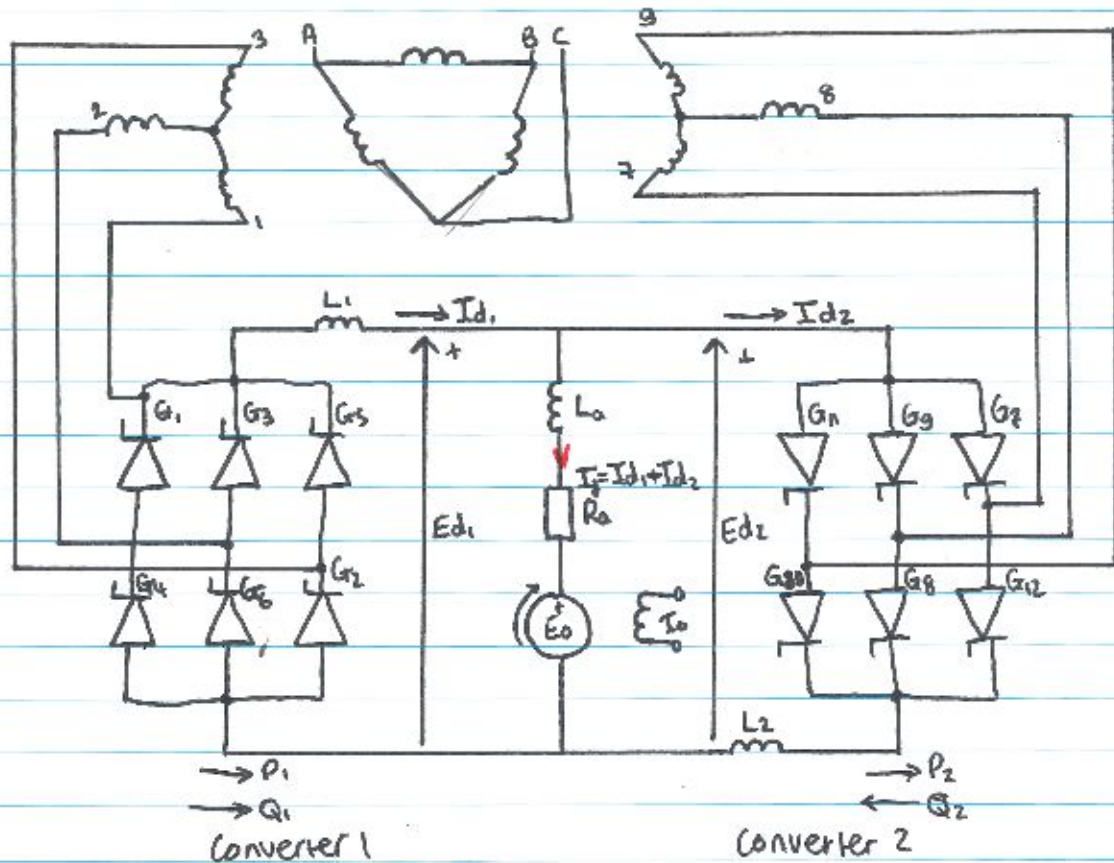
$$\alpha = \cos^{-1} \left(\frac{V_a \pi}{2 V_{max}} \right) \\ = \cos^{-1} \left(\frac{-175.56 \times \pi}{2 \times 622.25} \right) = 116.31^\circ \quad \checkmark$$

$$(ii) \quad P_{in} = I_a V_a \\ = 45 \times -175.56 = -7900.2 \text{ W}$$

3

1.

2.
c)



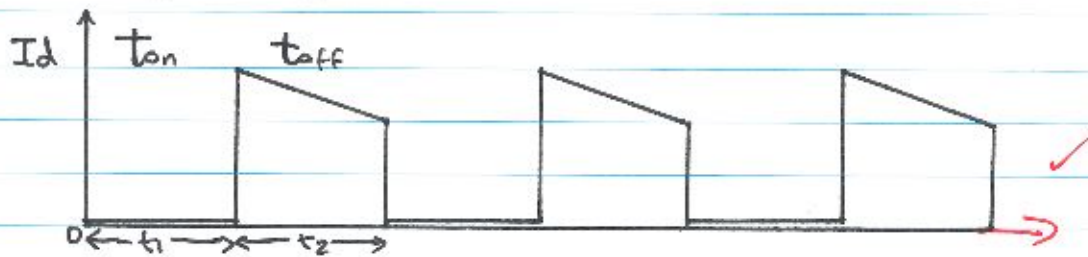
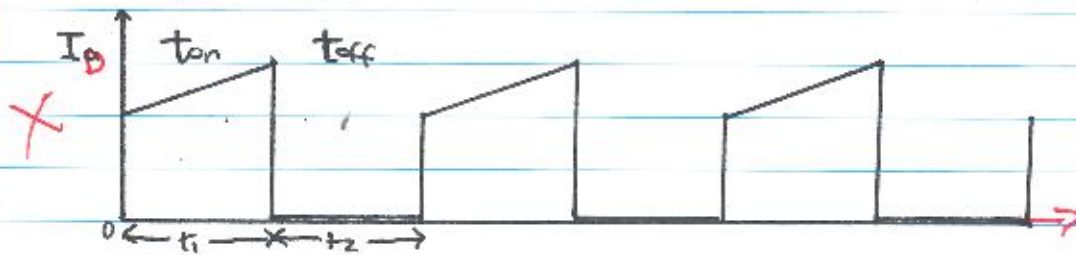
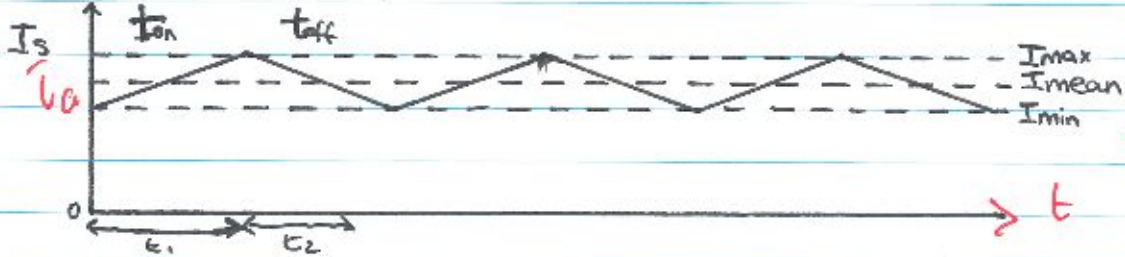
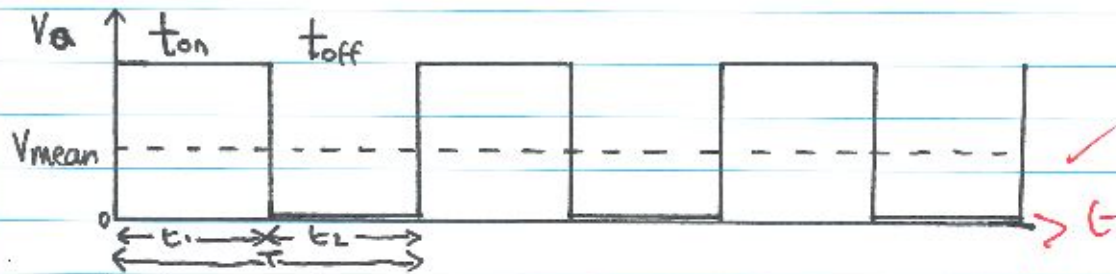
Converter 1 allows for operation in quadrant 1 (forward motoring) and quadrant 2 (Reverse generating).

Converter 2 allows for operation in quadrant 3 (reverse motoring) and quadrant 4 (forward generating).

Both converters run simultaneously, with Converter 1 acting as a rectifier and Converter 2 acting as an inverter. This is possible because of L_1 and L_2 .

4.

a)



$$D = \frac{t_{on}}{t_{on} + t_{off}} = \frac{t_{on}}{T}$$

$$V_{mean} = \frac{1}{T} \int_0^{t_{on}} V_s \cdot dt + \frac{1}{T} \int_{t_{on}}^{t_{off}} 0 \cdot dt$$

$$= \frac{1}{T} \left[V_s \cdot dt \right]_0^{t_{on}} = \frac{V_s t_{on}}{T}$$

$$V_{mean} = V_s D$$

(3)

(1)

(2)

4.

b) $V_s = 96V$

$f = 1kHz$

$T = \frac{1}{1 \times 10^3} = 1ms$

$L_a = 0.05H$

$k_b = 0.6V/rad/s \text{ (Nm/A)}$

$\omega = 100rad/s$

$T_L = 6Nm$

(i) When $R_a = 0$, $V_{mean} = E$.

$E = k_b \omega$

$= 0.6 \times 100 = 60V$ ✓

$D = \frac{E}{V_s} = \frac{60}{96} = 0.625$ ✓

$t_{on} = t_1 = DT$

$= 0.625 \times 1 \times 10^{-3}$

$= 0.625 \times 10^{-3} = 0.625ms$ ✓

$t_{off} = t_2 = (1-D)T$

$= (1-0.625) \times 1 \times 10^{-3}$

$= 0.375 \times 10^{-3} = 0.375ms$ ✓

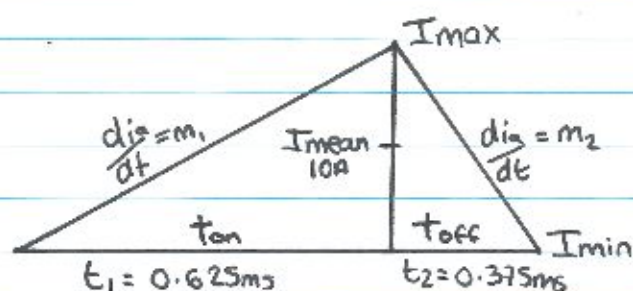
(ii) $I_a = \frac{T_L}{k_b}$

$I_{mean} = \frac{T_L}{k_b} = \frac{6}{0.6} = 10A$ ✓

$I_{mean} = \frac{I_{max} + I_{min}}{2}$

$I_{max} + I_{min} = 2I_{mean}$

$I_{max} + I_{min} = 20A \quad \text{Eq (1)}$



For t_1 ,

$$\frac{di_a}{dt} = m_1 \text{ and } R_a = 0$$

$$\therefore V_s - E = i_a R_a + L_a \frac{di_a}{dt}$$

$$V_s - E = 0 + L_a m_1$$

$$m_1 = \frac{V_s - E}{L_a}$$

$$= \frac{96 - 60}{0.05} = 720 \text{ A/s} \quad \checkmark$$

(2)

For t_2 ,

$$\frac{di_a}{dt} = m_2, \text{ and } R_a = 0 \text{ and } V_s = 0$$

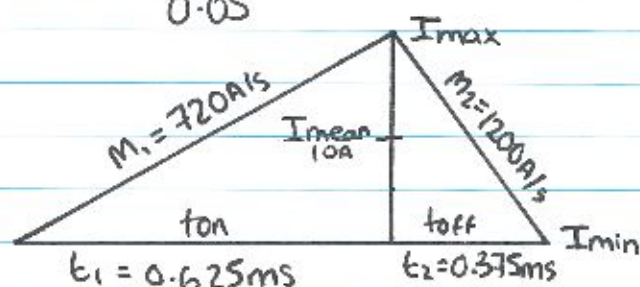
$$\therefore V_s - E = i_a R_a + L_a \frac{di_a}{dt}$$

$$V_s - E = 0 + L_a m_2$$

$$m_2 = \frac{V_s - E}{L_a}$$

$$= \frac{0 - 60}{0.05} = -1200 \text{ A/s} \quad \checkmark$$

(2)



(1)

$$m_1 = \frac{di}{dt} = \frac{I_{\max} - I_{\min}}{t_1}$$

$$m_1 t_1 = I_{\max} - I_{\min}$$

$$\therefore I_{\max} - I_{\min} = 720 \times 0.625 \times 10^{-3}$$

$$I_{\max} - I_{\min} = 0.45A \quad \text{Eq (2)}$$

$$\text{Eq (1)} + \text{Eq (2)}$$

$$I_{\max} + I_{\min} + I_{\max} - I_{\min} = 20 + 0.45$$

$$2I_{\max} = 20.45$$

$$I_{\max} = \frac{20.45}{2} = 10.225A$$

$$I_{\min} = \overset{20}{\text{Mean}} - I_{\max}$$

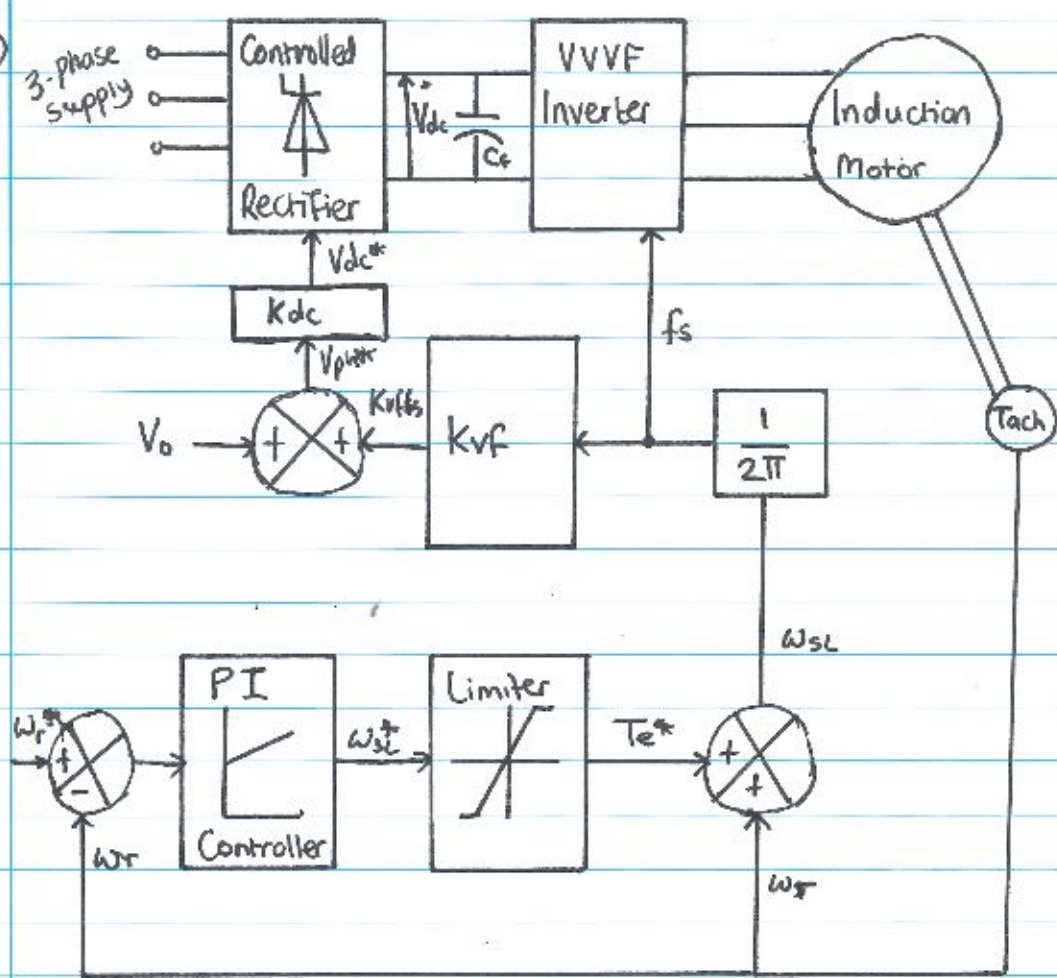
$$= 20 - 10.225 = 9.775A$$

$$I_{\max} = 10.225A \quad \checkmark, \quad I_{\min} = 9.775A \quad \checkmark$$

(iii)

(7)

5.
a)



5

5

The ~~start~~ rotor speed is measured on the induction motor by the tachometer. This speed is fed-back to the summing blocks using closed loop feedback. The actual speed is subtracted from the desired speed to create an error, which is put through the PI controller. This controller generates a slip speed demand. This demand is put through a limiter to determine the desired electromagnetic torque. This is added to the rotor speed to find the current slip speed. The slip speed is divide by 2π to produce a frequency, which is split between the VVVF inverter and the motor constant. The motor constant is multiplied by the frequency and added to the offset voltage to produce a phase voltage demand. Another constant, K_{dc} , is used to produce a dc link voltage demand. This, along with the frequency, drive the rectifier and inverter to vary the voltage on the motor. A smoothing capacitor is also present.

Equations ?

5.

b)

$P_m = 6 \text{ hp}$	$R_s = 0.281 \Omega$
$V_{\text{line}} = 220 \text{ V}$	$R_r = 0.185 \Omega$
$f_s = 50 \text{ Hz}$	$X_m = 21.1 \Omega$
$\cos \phi = 0.87$	$X_{ls} = 0.56 \Omega$
$\eta = 0.83$	$X_{lr} = 0.853 \Omega$

(i) $\omega_{SL} = \frac{R_r}{L_r + L_s}$

$$L_r = \frac{X_{lr}}{2\pi f}$$

$$= \frac{0.853}{2 \times \pi \times 50} = \cancel{0.00272} \text{ H } 0.00272 \text{ H} \checkmark$$

$$L_s = \frac{X_{ls}}{2\pi f}$$

$$= \frac{0.56}{2 \times \pi \times 50} = \cancel{0.00178} \text{ H } 0.00178 \text{ H} \checkmark$$

$$\omega_{SL} = \frac{0.185}{\cancel{0.00272} + \cancel{0.00178}} = \cancel{41.1} \text{ rad/s } 41.1 \text{ rad/s} \checkmark$$

(ii) $I_s = \frac{P_e}{3V_{ph} \cos \phi}$

$$P_e = \frac{P_m}{\eta}$$

$$= \frac{6 \times 745.6}{0.83} = 5389.88 \text{ W}$$

$$V_{ph} = \frac{V_{\text{line}}}{\sqrt{3}}$$

$$= \frac{220}{\sqrt{3}} = 127.02 \text{ V}$$

(4)



$$I_s = \frac{5389.88}{3 \times 127.02 \times 0.87} = 16.26 \text{ A}$$

$$\begin{aligned} \text{(iii)} \quad V_o &= I_s R_s \\ &= 4.57 \text{ V} \end{aligned}$$

$$\begin{aligned} \text{(iv)} \quad K_{vf} &= \frac{(V_{ph} - V_o)}{f_s} \\ &= 2.45 \text{ V/Hz} \end{aligned}$$

$$\begin{aligned} \text{(v)} \quad V_{dc} &= 2.22 (V_o + K_{vf} f_s) \\ &= 2.22 (4.57 + 2.45 f_s) \\ &= 10.15 + 5.44 f_s \end{aligned}$$

At 50Hz,

$$\begin{aligned} V_{dc} &= 10.15 + 5.44 (50) \\ &= 282.15 \text{ V} \end{aligned}$$