

SURNAME: WILHANS

FORENAME(S): LIESER

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.
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	1202933/1
2	Title of Examination Paper	Power Elec & Drives .
3	Module Code	PSDE 6016
4	Date and Time of Examination	24.5.18 9.30 .
5	Examination Venue	C27
6	Seat Number	

7	Number of Answer Books handed in	
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(Gweler yr ochr arall am y fersiwn Cymraeg)

List the numbers of the questions you have attempted	Office Use
Q1 .	27½
Q2	21
Q4	23½
Total	72

72	71%
71	70%

(See the other side for English version)

7	Nifer y Llyfrau Atebion a gyflwynwyd	
6	Rhif Sedd	
5	Lleoliad yr Arholiad	
4	Dyddiad ac Amser yr Archoliad	
3	Cod y Modwl	
2	Tittl y Papur Arholiad	
1	Rhif Myfyrwr	

[illegible]

guddio'ch enw.

- Rhaid i'r atebion fod mewn llawysgriften ddarlennadwy. Gall yr Arholwyr naill ai anwybyddu sgrïpt annarlenadwy, neu drefnu iddi gael ei theipio a chael yr ymgeisydd i dalu.
- Ysgrifennwch eich atebion mewn Inc.
- Dechreuwch bob ateb ar dudalen newydd. Gwnewch unrhyw fras nodiadau yn y llyfr atebion a thynnu llinell drwyddynt.
- Ni ddylid rhwgo unrhyw ran o'r llyfr hwn; rhaid ei gyflwyno yn gyfan.
- Os defnyddir mwy nag un llyfr, rhwymwch hwy gyda'i gilydd gan ddefnyddio'r tagiau sydd ar gael oddi wrth y gwyllwyr/gwylwyr.
- Rhaid dychwelyd pob llyfr. Ni chaniateir mynd â llyfrau atebion, wedi eu defnyddio neu heb eu defnyddio, allan o'r lleoliad arholi o dan unrhyw amgylchadau.

1. Rhwch yr holl wybodaeth y gofynnir amdani yn y blychau isod.
2. Rhwch eich enw yn lle a ddarparwyd ar y dde, plygch ef a'i selio i lawr (gan ddefnyddio'r label a ddarparwyd)!

Cyfarwyddiadau i Ymgeiswyr

12 Tudalen

Llyfr Atebion Arholiadau



Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

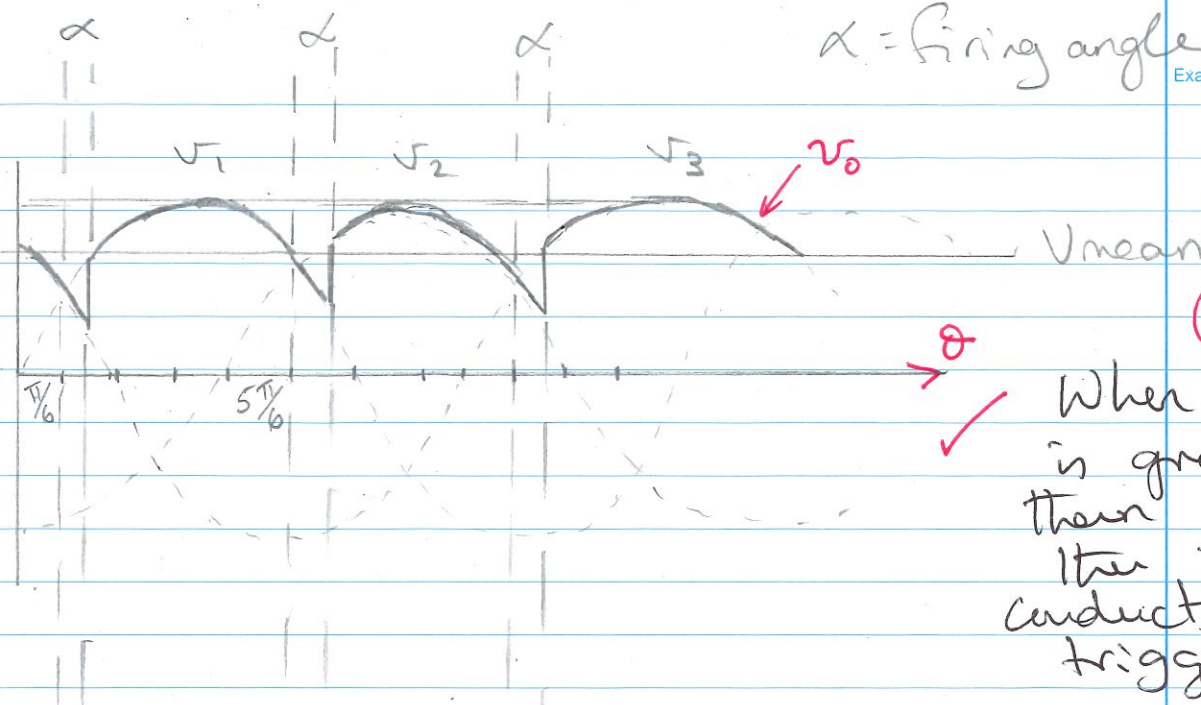
Llenwch, plygwrch a seilwch
(gweler nodyn 2 isod)

CYFENW:

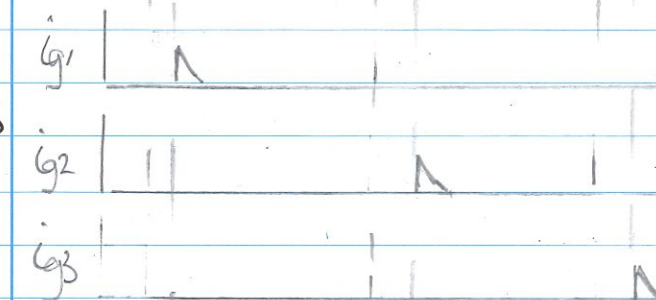
ENW(AU) CYNTAF:

1 a)

3 ϕ supply



gate pulses



SCR currents



load current



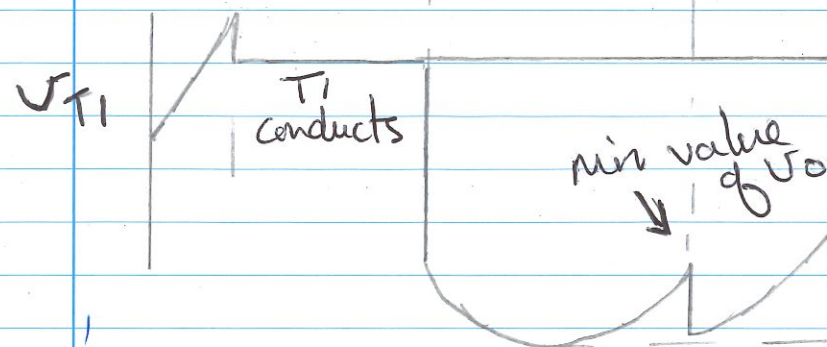
Each SCR is triggered after a delay angle α which is measured from the cross-over point.

Each ~~diode~~ SCR conducts when its instantaneous voltage is highest

$$I_o = I_1 + I_2 + I_3$$

$I_o =$ load current

$$V_{T1} = V_o - V_1$$



SCR must be rated for PRV of $\sqrt{3} V_{max}$

1.

- b) The mean voltage is found by looking at one SCR conduction period. The conduction occurs between $\frac{\pi}{6} + \alpha$ and $\frac{5\pi}{6} + \alpha$

$$V_{\text{mean}} = \frac{1}{\frac{4\pi}{6}} \int_{\frac{\pi}{6} + \alpha}^{\frac{5\pi}{6} + \alpha} V_{\text{max}} \sin(\theta) d\theta \quad \checkmark$$

$$= \frac{3}{2\pi} V_{\text{max}} \left[-\cos \theta \right]_{\frac{\pi}{6} + \alpha}^{\frac{5\pi}{6} + \alpha} \quad \checkmark$$

$$= \frac{3 V_{\text{max}}}{2\pi} \left[-\cos\left(\frac{5\pi}{6} + \alpha\right) - -\cos\left(\frac{\pi}{6} + \alpha\right) \right] \quad \checkmark$$

Using the trig identity

$$\cos(A+B) = \cos A \cos B - \sin A \sin B \quad \checkmark$$

$$\cos\left(\frac{5\pi}{6} + \alpha\right) = \cos \frac{5\pi}{6} \cos \alpha - \sin \frac{5\pi}{6} \sin \alpha \quad \checkmark$$

$$= -\frac{\sqrt{3}}{2} \cos \alpha - \frac{1}{2} \sin \alpha \quad \checkmark$$

$$\cos\left(\frac{\pi}{6} + \alpha\right) = \cos \frac{\pi}{6} \cos \alpha - \sin \frac{\pi}{6} \sin \alpha \quad \checkmark$$

$$= \frac{\sqrt{3}}{2} \cos \alpha - \frac{1}{2} \sin \alpha \quad \checkmark$$

$$\therefore V_{\text{mean}} = \frac{3 V_{\text{max}}}{2\pi} \left[\frac{\sqrt{3}}{2} \cos \alpha + \frac{1}{2} \sin \alpha + \frac{\sqrt{3}}{2} \cos \alpha - \frac{1}{2} \sin \alpha \right] \quad \checkmark$$

$$= \frac{3 \sqrt{3} V_{\text{max}}}{2\pi} \cos \alpha \quad \checkmark$$

$$V_{\text{rms}} = \frac{V_{\text{max}}}{\sqrt{2}} \quad V_{\text{rms(LINE)}} = \sqrt{3} \frac{V_{\text{max}}}{\sqrt{2}}$$

$$\therefore V_{\text{max}} = \frac{\sqrt{2}}{\sqrt{3}} V_{\text{rms(LINE)}} \quad \checkmark$$

$$\therefore V_{\text{mean}} = \frac{3 \sqrt{3}}{2\pi} \frac{\sqrt{2}}{\sqrt{3}} V_{\text{rms(LINE)}} \cos \alpha \quad \checkmark$$

$$= \frac{3}{\sqrt{2}\pi} V_{\text{rms(LINE)}} \cos \alpha \quad \checkmark$$

(12)

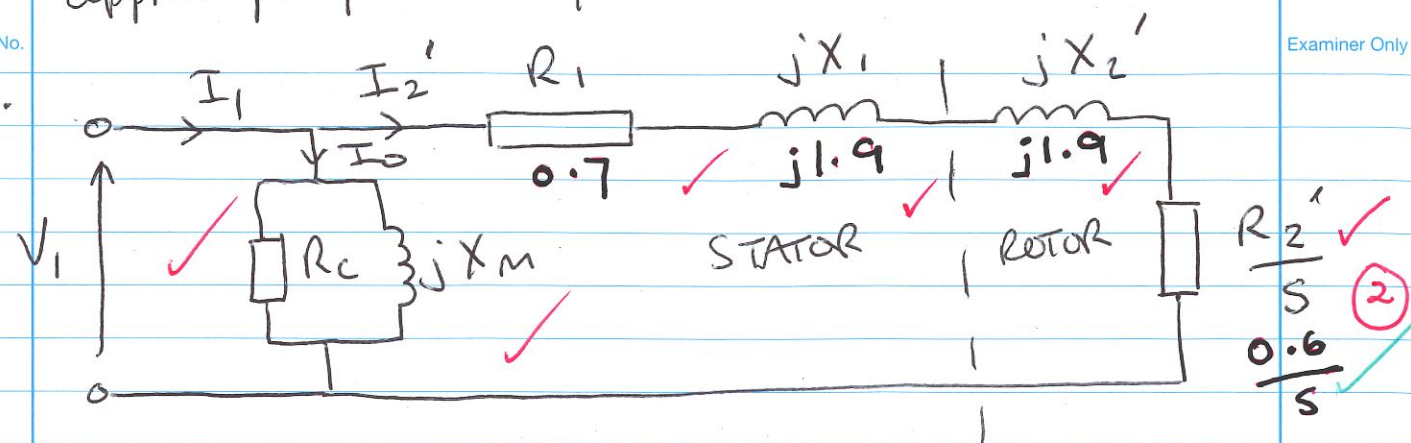
- c) When α is greater than 90° then power ^{voltage} is negative and flows back from load to supply. The polarity is changed and with positive current, negative voltage this means the ckt acts as a generator. This is regenerative braking. Energy is recovered from load to supply.

(3)

$$I_{\text{Omax}} = 27\frac{1}{2}$$

2.

approx per-phase equivalent ckt referred to stator



$$I_2' = \frac{V_1}{(R_1 + \frac{R_2'}{s}) + j(X_1 + X_2')} \quad \text{Ohm's law} \quad (1)$$

$$|I_2'| = \frac{V_1}{\sqrt{(R_1 + \frac{R_2'}{s})^2 + (X_1 + X_2')^2}} \quad \text{Use pythag for modulus} \quad (1)$$

P_G , Gross Mechanical Power = Power transferred to rotor - Power loss in rotor

$$P_G = |I_2'|^2 \frac{R_2'}{s} - |I_2'|^2 R_2' = |I_2'|^2 R_2' (\frac{1}{s} - 1) = |I_2'|^2 R_2' (\frac{1-s}{s}) \quad (1)$$

$$T_G = \frac{P_G}{\omega_R} \quad \text{where } \omega_R = \omega_s (1-s)$$

$$\therefore T_G = \frac{|I_2'|^2 R_2' (1-s)}{\omega_s (1-s) s} = \frac{|I_2'|^2 R_2'}{\omega_s s}$$

Substitute for $|I_2'|^2$

$$T_G = \frac{V_1^2 R_2'}{[(R_1 + \frac{R_2'}{s})^2 + (X_1 + X_2')^2] \omega_s s} \quad (1)$$

The total torque is 3 times this value.

$$\text{Total } T_G = \frac{3 V_1^2 R_2'}{\omega_s s [(R_1 + \frac{R_2'}{s})^2 + (X_1 + X_2')^2]} \quad (2)$$

$$b) n_s = \frac{f_s}{p} = \frac{60}{3} = 20 \text{ rps} \quad \omega_s = 2\pi n_s = 125.66 \text{ rad/s} \quad (1)$$

$$\omega_s = \frac{60 \times 60}{3} = 1200 \text{ rpm} \quad \text{rad/s.} \quad (1)$$

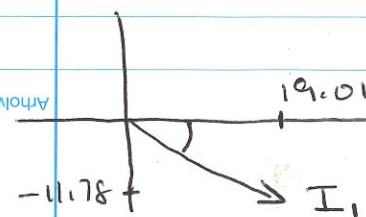
$$s = \frac{\omega_s - \omega_R}{\omega_s} = \frac{1200 - 1140}{1200} = 0.05 \quad (1)$$

$$\text{Star } \therefore V_1 = \frac{415}{\sqrt{3}} = 240 \text{ V. (239.6 V)} \quad (1)$$

$$I_0 = 1.7 - j6.6 \text{ A/phase} \quad I_p = I_L \text{ for star.}$$

$$I_2' = \frac{239.6}{(0.7 + \frac{0.6}{0.05}) + j(1.9 + 1.9)} = \frac{239.6}{12.7 + j3.8} = \frac{239.6}{13.26 \angle 16.66^\circ} = 18.07 \angle -16.66^\circ = 17.31 - j5.18 \text{ A} \quad (2)$$

$$I_1 = I_2' + I_0 = 17.31 - j5.18 + 1.7 - j6.6 = 19.01 - j11.78 \text{ A} \quad (1)$$



$$T_G = \frac{3 \times 239.6^2 \times 0.6}{125.66 \times 0.05 \left[\left(\frac{0.7}{0.05} + \frac{0.6}{0.05} \right)^2 + (3.8)^2 \right]}$$

$$= \frac{103334.69}{6.283 [12.7^2 + 3.8^2]}$$

$$= 93.59 \text{ Nm}$$

c) At standstill $s = 1$ ✓

At $N_R = N_s$ $s = 0$ ✓

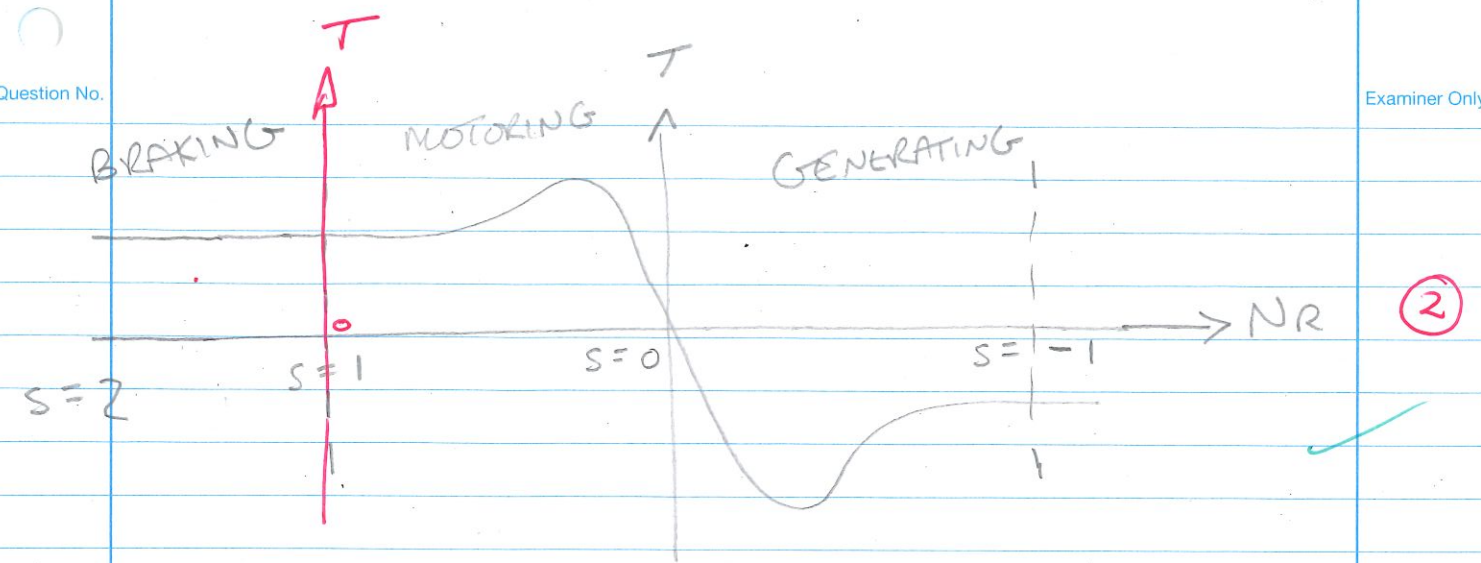
At $N_R = 2N_s$ $s = -1$ ✓

At $N_R = -N_s$ $s = 2$ ✓

See graph above

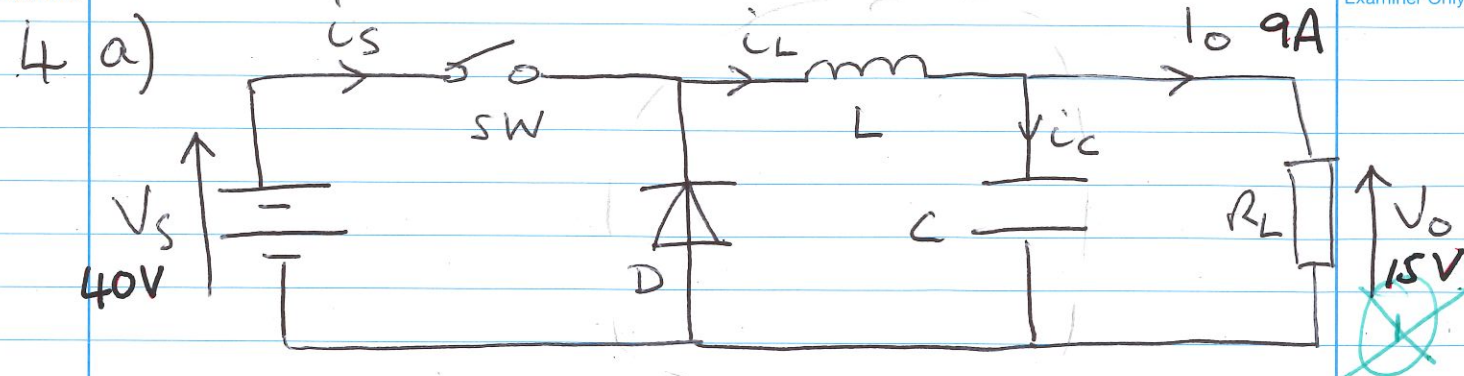
$$s = \frac{\omega_s - \omega_r}{\omega_s}$$

$$\omega_r = \omega_s(1-s)$$



Evaluation?

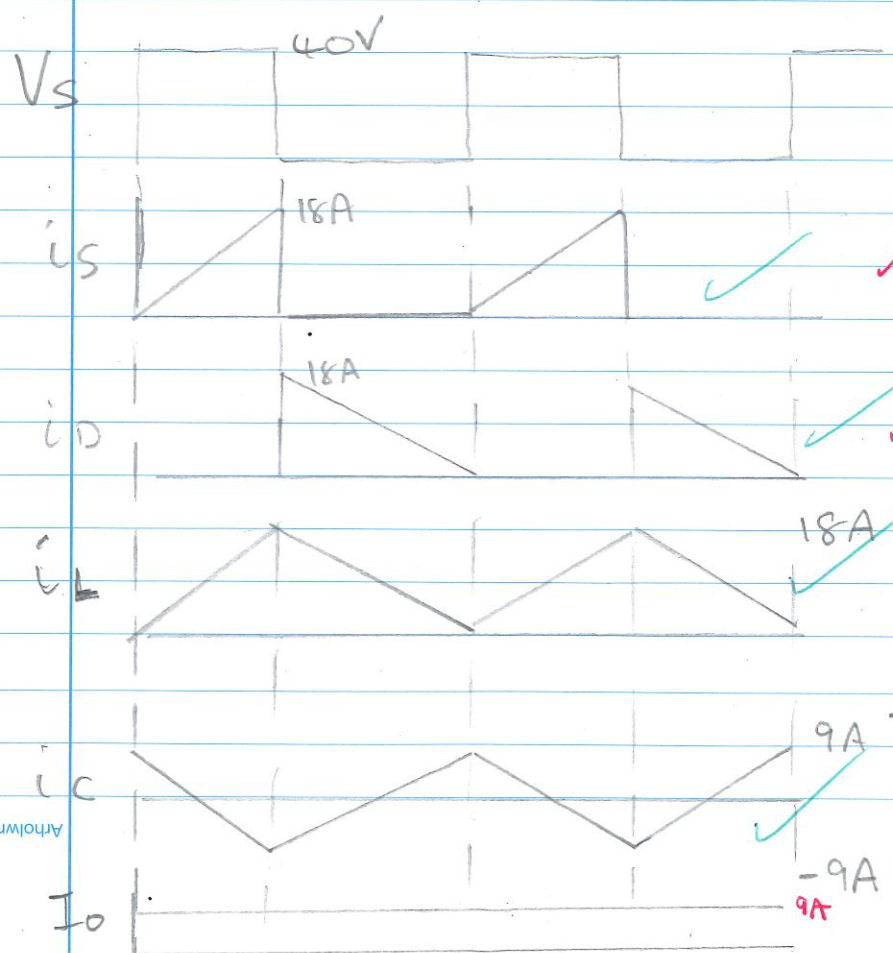
$$10 \text{ Nm} = 21$$



When the switch is closed the supply pushes current through the inductor. D blocks.

When the switch is open current continues through the flywheel part Diode, and capacitor and load. as V_L swaps polarity and keeps the current flowing to load. When most of the energy is released the capacitor takes over and supplies to the load.

c)



For load current to be continuous the i_L must rise to $2 \times I_o$ and fall to zero.

ie i_L is just continuous.

18A

9A $I_{C(max)}$

-9A $I_{C(min)}$

b) $f = 125 \text{ kHz}$ $T = 8 \mu\text{s}$ ✓

i) $D = \frac{V_o}{V_s} = \frac{15}{40} = 0.375$ ✓

$D = \frac{t_1}{t_1 + t_2}$

$t_1 = DT$
 $= 0.375 \times 8 \times 10^{-6}$
 $= 3 \mu\text{s}$ ✓

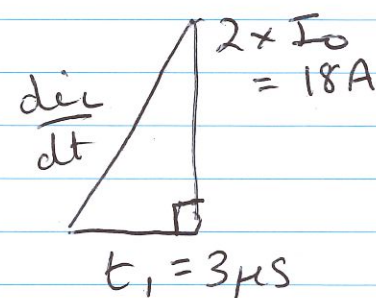
ii) $i_L = 2 \times I_o = 18 \text{ A}$ $\therefore t_2 = 5 \mu\text{s}$ ✓

When switch is closed (Kirchoff)

$L \frac{di_L}{dt} = V_s - V_o = 40 - 15$

$\therefore \frac{di_L}{dt} = \frac{40 - 15}{L} = \frac{25}{L}$ ✓

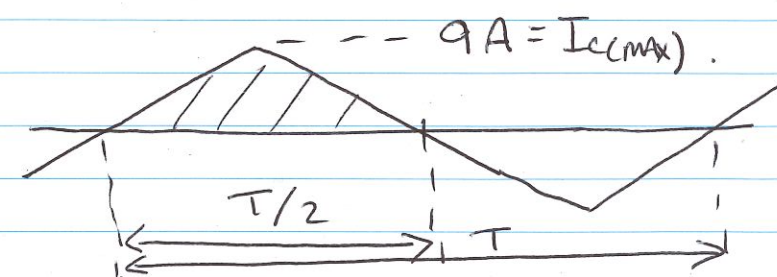
d)



$\therefore \frac{25}{L} = \frac{18}{3 \times 10^{-6}}$

$L = \frac{25 \times 3 \times 10^{-6}}{18}$
 $= 4.17 \mu\text{H}$

2)



Δq is the area of the triangle (shaded)

$\therefore \Delta q = \frac{1}{2} \times \frac{T}{2} \times 9 = \frac{1}{2} \times \frac{8 \times 10^{-6}}{2} \times 9 = 18 \times 10^{-6} \text{ C}$

$\Delta v = \frac{\Delta q}{C} = \frac{18 \times 10^{-6}}{150 \times 10^{-6}} = 0.12 \text{ V}$
 $10 \text{ mV} = 22 \frac{1}{2}$



SURNAME: Lewis

FORENAME(S): Michael

12 Pages

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2	Title of Examination Paper	Power elec's & drives.
3	Module Code	PSDE 6016
4	Date and Time of Examination	24 th may 2018
5	Examination Venue	
6	Seat Number	
7	Number of Answer Books handed in	

List the numbers of the questions you have attempted	Office Use
Q1	21
Q2	15
Q4	13
Total	49

(Gweler yr ochr arall am y fersiwn Cymraeg)

48% ✓



Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

Llyfr Atebion Arholiadau

12 Tudalen

Cyfarwyddiadau i Ymgeiswyr

1. Rhwch yr holl wybodaeth y gofynnir amdani yn y blychau isod.
2. Rhwch eich enw yn y lle a ddarparwyd ar y dde, plygwch ef a'i selio i lawr (gan ddefnyddio'r label a ddarparwyd) i guddio'ch enw.

3. Rhaid i'r atebion fod mewn llawysgriften ddarllenadwy. Gall yr Arholiwr naill ai anwybyddu sgript annarllenadwy, neu drefnu iddi gael ei theipio a chael yr ymgaisydd i dalu.
4. Ysgrifennwch eich atebion mewn inc.
5. Dechreuwch bob ateb ar dudalen newydd. Gwnewch unrhyw fras nodiadau yn y llyfr atebion a thynnu llinell drwyddynt.
6. Ni ddylid rhwgo unrhyw ran o'r llyfr hwn; rhaid ei gyflwyno yn gyfan.
7. Os defnyddir mwy nag un llyfr, rhwymwch hwy gyda'i gilydd gan ddefnyddio'r tagiau sydd ar gael oddi wrth y gwyllwyr/gwyliwyr.
8. Rhaid dychwelyd pob llyfr. Ni chaniateir mynd â llyfrau atebion, wedi eu defnyddio neu heb eu defnyddio, allan o'r lleoliad arholi o dan unrhyw amgylchadau.

[illegible]

7	Nifer y Llyfrau Atebion a gyflwynwyd	
6	Rhif Sedd	
5	Lleoliad yr Arholiad	
4	Dyddiad ac Amser yr Arholiad	
3	Cod y Modwl	
2	Teitl y Papur Arholiad	
1	Rhif Myfyriwr	

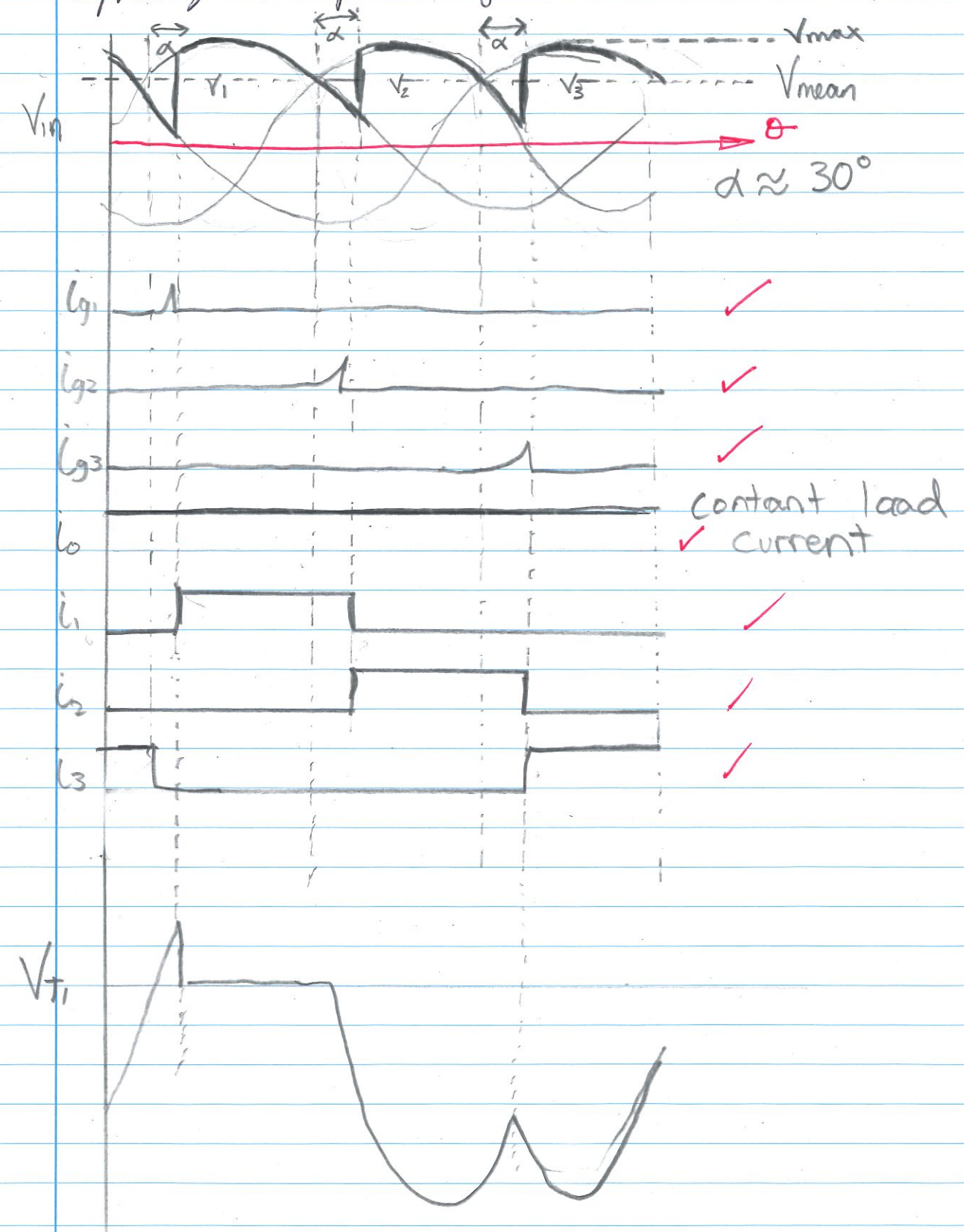
(See the other side for English version)

Llenwch, plygwrch a seilwch
(gweler nodyn 2 isod)

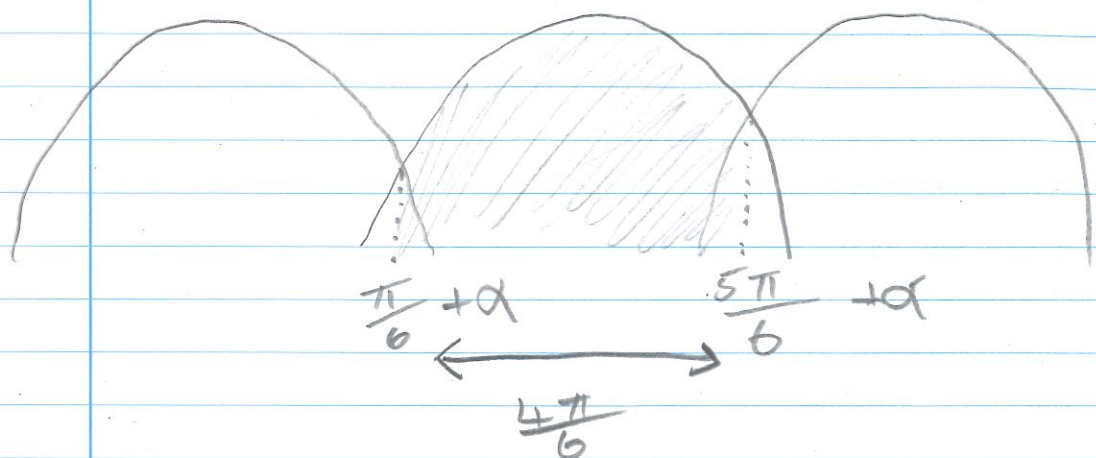
CYFENN:

ENW(AU) CYNTAF:

Q1 a The circuit shown in figure 1 is a Three-phase half-wave controlled rectifier. The waveform explaining the function of the circuit is shown below:



Q1. b To find the average load voltage, the conduction period of a single diode must be found.



The conduction angle is $\frac{4\pi}{6}$ with the limits being $\frac{\pi}{6} + \alpha$ & $\frac{5\pi}{6} + \alpha$.

V_{mean} can now be found by integration.

$$V_{mean} = \frac{1}{\frac{4\pi}{6}} \int_{\frac{\pi}{6} + \alpha}^{\frac{5\pi}{6} + \alpha} V_{max} \sin(\theta) d\theta$$

$$V_{mean} = \frac{3V_{max}}{2\pi} \left[-\cos(\theta) \right]_{\frac{\pi}{6} + \alpha}^{\frac{5\pi}{6} + \alpha}$$

$$= \frac{3V_{max}}{2\pi} \left[-\cos\left(\frac{5\pi}{6} + \alpha\right) - \left(-\cos\left(\frac{\pi}{6} + \alpha\right)\right) \right]$$

$$\cos(A+B) = \cos A \cos B - \sin A \sin B$$

$$\begin{aligned} \text{Using } \cos\left(\frac{5\pi}{6}\right) &= -\frac{\sqrt{3}}{2} \\ \cos\left(\frac{\pi}{6}\right) &= \frac{\sqrt{3}}{2} \\ \sin\left(\frac{5\pi}{6}\right) &= \frac{1}{2} \\ \sin\left(\frac{\pi}{6}\right) &= \frac{1}{2} \end{aligned}$$

Q1B

Continued

~~$$\cos\left(\frac{5\pi}{6} + \alpha\right) = \cos\left(\frac{5\pi}{6}\right)\cos(\alpha) - \sin\left(\frac{5\pi}{6}\right)\sin(\alpha)$$~~

$$\cos\left(\frac{5\pi}{6} + \alpha\right) = \cos\left(\frac{5\pi}{6}\right)\cos(\alpha) - \sin\left(\frac{5\pi}{6}\right)\sin(\alpha)$$

$$= -\frac{\sqrt{3}}{2}\cos(\alpha) - \frac{1}{2}\sin(\alpha)$$

$$\cos\left(\frac{\pi}{6} + \alpha\right) = \cos\left(\frac{\pi}{6}\right)\cos(\alpha) - \sin\left(\frac{\pi}{6}\right)\sin(\alpha)$$

$$= \frac{\sqrt{3}}{2}\cos(\alpha) - \frac{1}{2}\sin(\alpha)$$

$$V_{mean} = \frac{3V_{max}}{2\pi} \left[\frac{\sqrt{3}}{2}\cos(\alpha) - \frac{1}{2}\sin(\alpha) + \frac{\sqrt{3}}{2}\cos(\alpha) - \frac{1}{2}\sin(\alpha) \right]$$

$$V_{mean} = \frac{3V_{max}}{2\pi} \left[\frac{\sqrt{3}}{2}\cos(\alpha) + \frac{\sqrt{3}}{2}\cos(\alpha) \right]$$

$$V_{mean} = \frac{3V_{max}}{2\pi} \left[\sqrt{3}\cos(\alpha) \right]$$

$$V_{mean} = \frac{3\sqrt{3}V_{max}}{2\pi} \cos(\alpha)$$

$$V_{men} = \frac{3V_{RMS}}{\sqrt{2}\pi} \cos(\alpha)$$

11 1/2

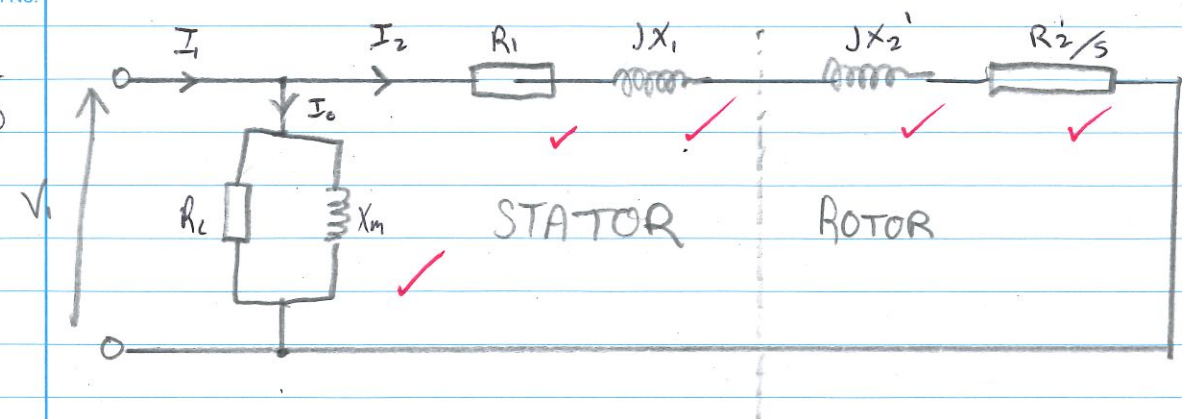
Total = 21

Q1.c Regenerative braking is the method of slowing the motor without wasting more energy.

As the name suggests, a large part of the energy can be recovered with the correct equipment.

If the stator freq. is forced lower ^{dc load} the rotor freq. this will create a braking effect. With the rotor freq. temporarily spinning faster than stator freq. the ~~slip~~ fractional slip will become negative until the braking effect corrects the difference in freq.

Q2
(a)



$$I_2' \text{ per phase} = \frac{V_{in}}{Z_T}$$

It can be seen from the diagram above that $Z_T = \left(R_1 + \frac{R_2'}{s}\right) + j(X_1 + X_2)$

$$\text{So: } I_2' = \frac{V_{in}}{\left(R_1 + \frac{R_2'}{s}\right) + j(X_1 + X_2')}$$

To find total torque:

$$T_G = \frac{|I_2'|^2 R_2}{\omega_s s} \quad \omega_s = n_s \times 2\pi \text{ rad/s}$$

$$s = \frac{n_s - n_r}{n_s}$$

Take magnitude of Z_T :

$$I_2' = \frac{V_{in}}{\sqrt{\left(R_1 + \frac{R_2'}{s}\right)^2 + (X_1 + X_2')^2}}$$

then combine with T_G

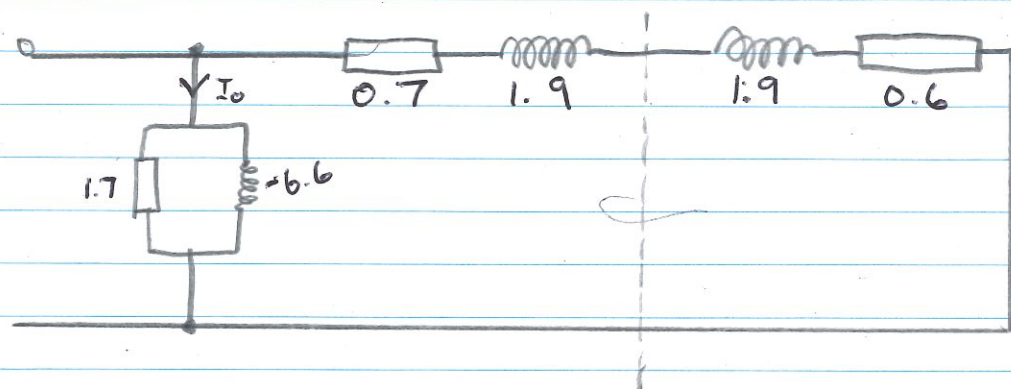
$$T_G = \frac{V_{in}^2}{\left(R_1 + \frac{R_2'}{s}\right)^2 + (X_1 + X_2')^2} \times \frac{R_2}{\omega_s s}$$

Q2 (a)
continued

$$\text{Total } T = \frac{3 \times V_{in}^2 \times R_2}{\omega_s S \left[\left(R_1 + \frac{R_2'}{S} \right)^2 + j \left(X_1 + X_2 \right)^2 \right]}$$

X ✓ CE

Q2 (B)



$$N_s = \frac{f_s}{P_p} = \frac{60}{3} = 20 \text{ RPS} \times 60 = 1200 \text{ RPM}$$

$$\omega_s = 20 \times 2\pi = 125.66 \text{ rad/s} \quad \checkmark$$

$$S = \frac{1200 - 1140}{1200} = 0.05 \quad \checkmark$$

$$V_{in} = 415 / \sqrt{3} = 239.6 \text{ V} \quad \checkmark$$

$$I_2' \text{ per phase} = \frac{239.6}{\left(0.7 + \frac{0.6}{0.05} \right) + j(3.8)} \quad \checkmark$$

$$I_2' \text{ " " } = \frac{239.6}{12.7 + j3.8} \xrightarrow{\text{Polar}} \frac{239.6}{13.26} \angle -16.7^\circ \quad \checkmark$$

$$I_2' \text{ per phase} = 18.1 \angle -16.7^\circ \text{ A} \quad \checkmark$$

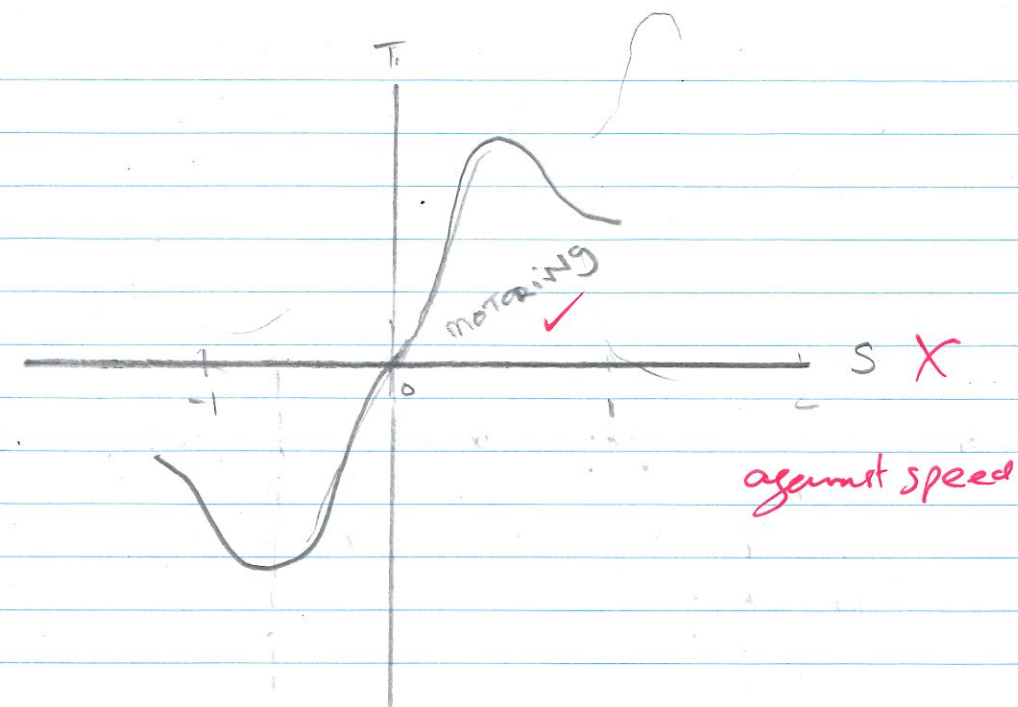
$$\text{Total } T = \frac{3 \times 239.6^2 \times 0.6}{125.66 \times 0.05 \left[(12.7)^2 + j(3.8)^2 \right]}$$

X

$$\text{Total } T = 93.6 \text{ NM} \quad \checkmark$$

Q2 (c)

①



Motoring - Positive torque, Positive $S > 0$ ✓

~~Braking~~ -

if $S = 1$ motor at standstill ✓

if $S > 1$ Rotor turning opposite direction to stator e.g. regenerative braking ✓

if $S < 0$ Rotor is turning faster than stator and is therefore being driven generating ✓

$$T_{\text{max}} = 15$$

①

Q4. The circuit shown in Q4 is a Buck converter.

(a) A buck converter is used whenever the output voltage needs to be lower than the DC source.

When TR turn 'closed', the diode is reverse biased and doesn't conduct. Current flows through the inductor, which stores current in a magnetic field as well as charging the capacitor.

Once TR is 'opened', the inductor L becomes the main source of current, flowing through the load and back through the diode.

Once the majority of the inductor current has been used the capacitor then becomes the source of current.

The cycle starts over once TR closes.

Varying the on-off times of TR will effectively control the output voltage.

(b) $D = \frac{V_o}{E} = \frac{15}{40} = 0.375$

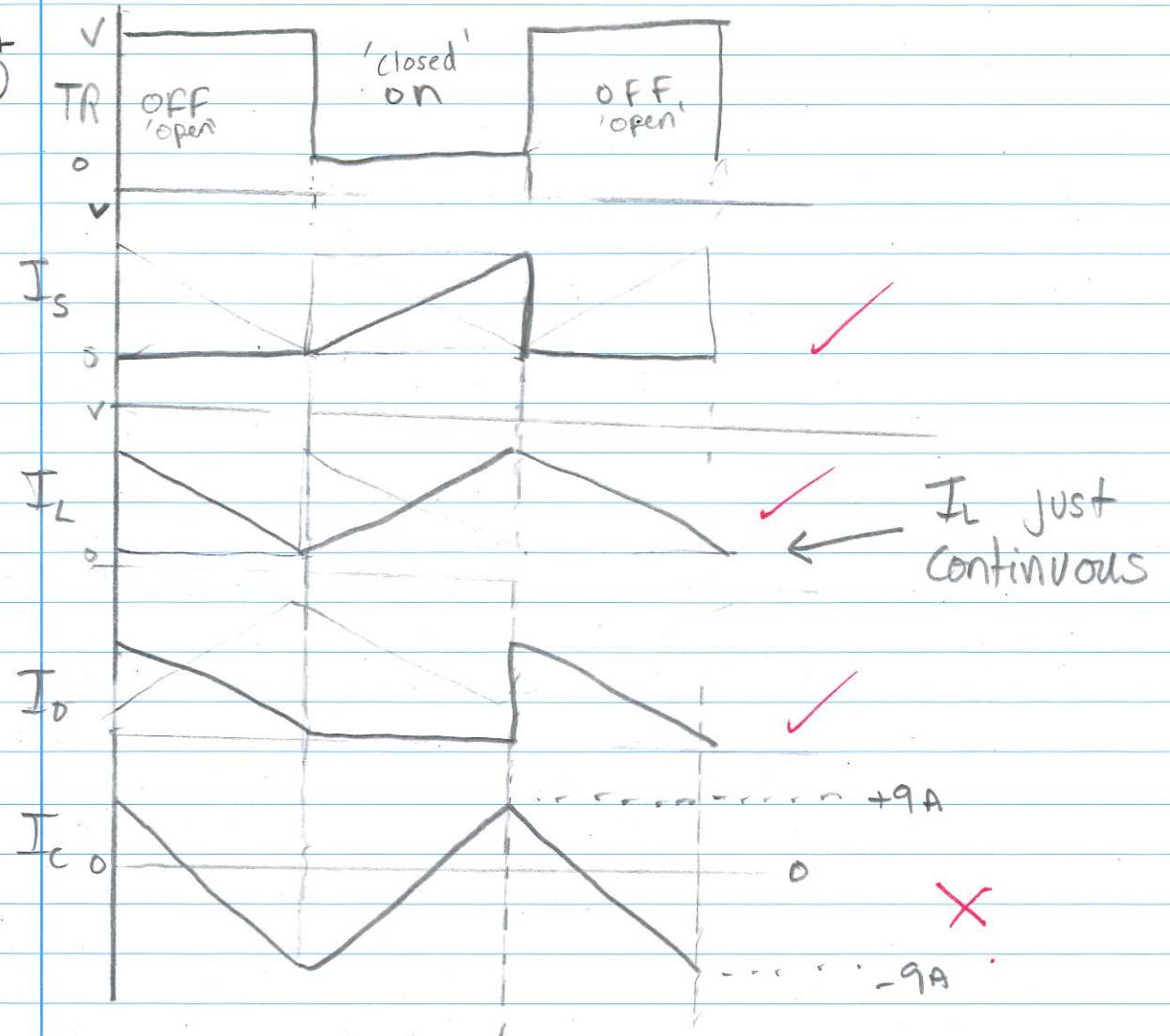
(i) $\frac{t_1}{t_1 + t_2} = \frac{V_o}{E}$ $t_1 + t_2 = \frac{1}{f_s} = \frac{1}{125 \text{ kHz}} = 8 \mu\text{s}$

$\frac{t_1}{8 \mu\text{s}} = 0.375 \rightarrow t_1 = 0.375 \times 8 \mu\text{s} = 3 \mu\text{s}$

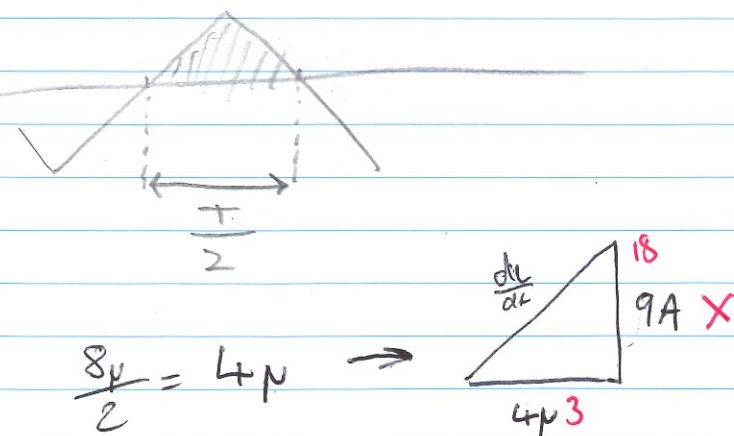
$t_2 = (t_1 + t_2) - t_1 = 8 \mu\text{s} - 3 \mu\text{s} = 5 \mu\text{s}$

(ii) for current to be just continuous, $I_L = 2 \times I_o$ from -9A to 9A
So $I_L = 18\text{A}$ max.

Q4
(c)



(d)



Gradient = $\frac{9}{4\mu} =$

$10\text{kHz} = 13$