



Complete, fold and seal
(see note 2 below)

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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.**

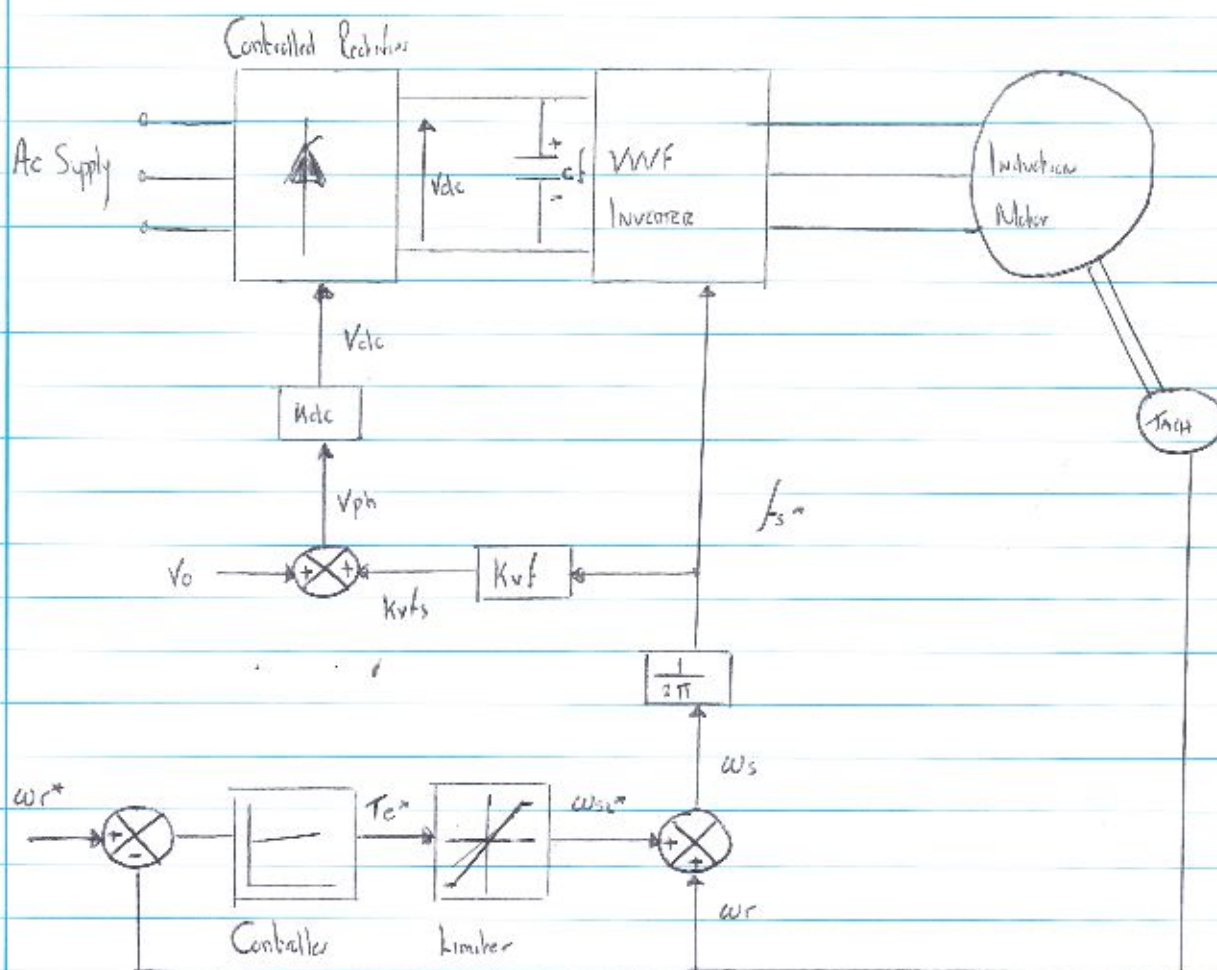
1	Student Number	
2	Title of Examination Paper	Power Electronics + Devices.
3	Module Code	SEE 6001
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5	Examination Venue	Coley Sir Gar
6	Seat Number	14
7	Number of Answer Books handed in	

[illegible]

Mark confirmed as 79

5)

A)



Explanation ?

$$B) P_{mech} = 6 \text{ Hp}$$

$$V_s = 220 \text{ V} \quad \cdot \quad 3 \text{ phase } \wedge \quad 4 \text{ pole}$$

$$f_s = 50 \text{ Hz}$$

$$\cos \phi = 0.37$$

$$\eta = 0.33$$

$$R_s = 0.241 \Omega$$

$$R_r = 0.125 \Omega$$

$$X_m = 21.1 \Omega$$

$$X_{ls} = 0.56 \Omega$$

$$X_{lr} = 0.53 \Omega$$

$$B1) \omega_{se} = \frac{R_r}{L_r + L_s}$$

$$L_s = \frac{X_{ls}}{2 \times \pi \times f_s} = \frac{0.56}{2 \times \pi \times 50} = 1.783 \times 10^{-3} = 1.78 \text{ mH}$$

$$L_r = \frac{X_{lr}}{2\pi f_s} = \frac{0.853}{2\pi \times 50} = 2.715 \times 10^{-3} = 2.72 \text{ mH.}$$

$$\omega_c = \frac{R_r}{L_s + L_r} = \frac{0.185}{1.78 \times 10^{-3} + 2.72 \times 10^{-3}} = 41.1 \text{ rad/s}$$

B2) $P_c = 3 \text{ vph} \times I_s \times \cos \phi$

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

$$P_c = \frac{P_{mech}}{\eta} = \frac{(6 \times 745.6)}{0.83} = 5389.88 \text{ W}$$

$$I_s = \frac{P_c}{3 \text{ vph} \times \cos \phi} = \frac{5389.88}{3 \times 127.02 \times 0.87} = 16.26 \text{ A}$$

B3) $V_o = I_o \times R_s = 16.26 \times 0.281 =$

$$V_o = I_o \times R_s = 16.26 \times 0.281 = 4.57 \text{ V}$$

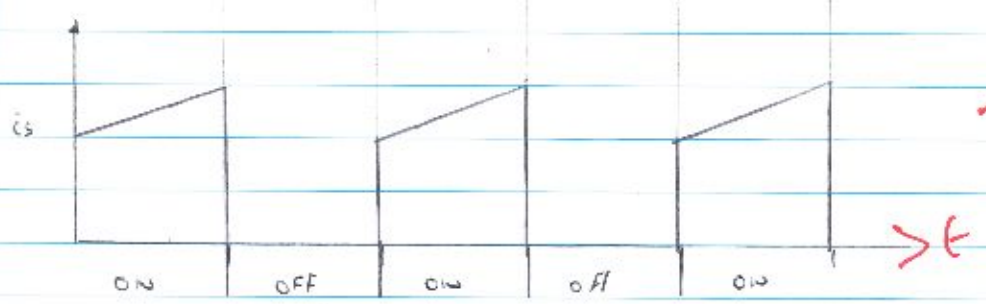
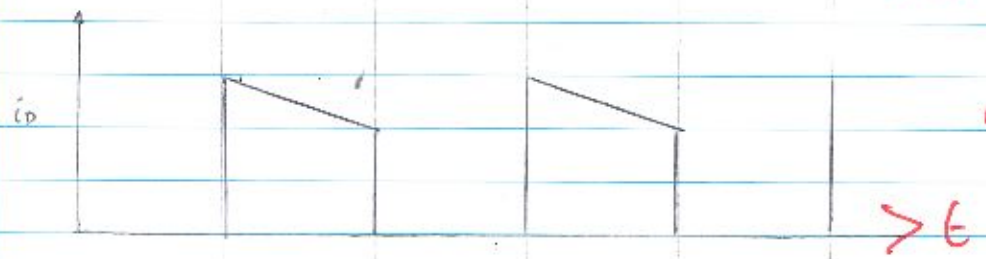
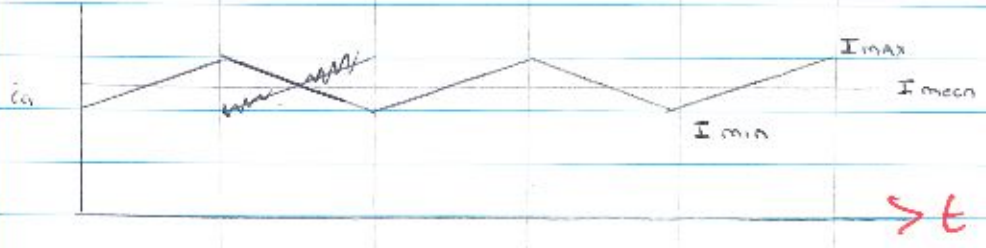
B4) $K_v f_s = \frac{(V_{ph} - V_o)}{f_s} = \frac{127.02 - 4.57}{50} = 2.45 \text{ V/Hz}$

B5) $V_{dc} = 2.22 \left(V_o + K_v f_s \right)$
 $= 2.22 \left(4.57 + 2.45 f_s \right)$
 $= 10.15 + 5.44 f_s$

or $5.44 f_s + 10.15 \text{ V}$

@ 50 Hz

$$(5.44 \times 50) + 10.15 = 282.15 \text{ V.}$$



t_{on} t_{off}
 T

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

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

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

$$V_{mean} = DV_s$$

4

1

2

B) $V_s = 96 \text{ V}$
 $f_s = 1 \text{ kHz}$
 $L_a = 0.05 \text{ H}$
 $k_b = 0.6 \text{ V/rad/s (Nm/A)}$
 $\omega = 100 \text{ rad/s}$
 $T_L = 6 \text{ Nm}$

$$T = \frac{1}{1000} = 1 \times 10^{-3}$$

B1) $E = \omega \times k_b = 100 \times 0.6 = 60 \text{ V}$ ✓

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

$$\text{ON time} = D \times T = 0.625 \times 1 \times 10^{-3} = 0.625 \text{ ms}$$
 ✓

$$\text{off time} = (1 - D) \times T = (1 - 0.625) \times 1 \times 10^{-3} = 0.375 \text{ ms}$$
 ✓

B2) $T_L = I_a(\omega) \times k_b$

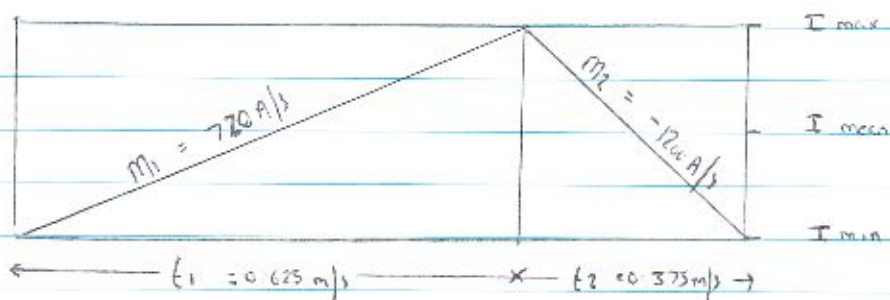
$$I_a(\omega) = \frac{T_L}{k_b} = \frac{6}{0.6} = 10 \text{ A}$$
 ✓

$$\text{ON period} = V_s - E = L_a \frac{di_a}{dt}$$

$$= \frac{di_a}{dt} = \frac{V_s - E}{L_a} = \frac{96 - 60}{0.05} = 720 \text{ A/s}$$
 ✓

$$\text{off period} = -E = L_a \frac{di_a}{dt}$$

$$= \frac{di_a}{dt} = \frac{-E}{L_a} = \frac{-60}{0.05} = -1200 \text{ A/s}$$
 ✓



$$I_{max} \xrightarrow{t_1} I_{min} \xrightarrow{t_2} I_{max}$$

$$I_{max} = I_{min} + (m_1 \times t_1)$$

$$I_{max} = I_{min} + (720 \times 0.625 \times 10^{-3})$$

$$I_{max} = I_{min} + 0.45$$

$$I_{mean} = \frac{I_{max} + I_{min}}{2} = 10 \text{ A}$$

$$I_{max} + I_{min} = 2 \times I_{mean} = 20 \text{ A}$$

$$2 I_{max} = 2 \times I_{mean} + (m_1 \times t_1)$$

$$2 I_{max} = 20 + 0.45 = 20.45 \text{ A}$$

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

$$I_{min} = 2 \times I_{mean} - I_{max}$$

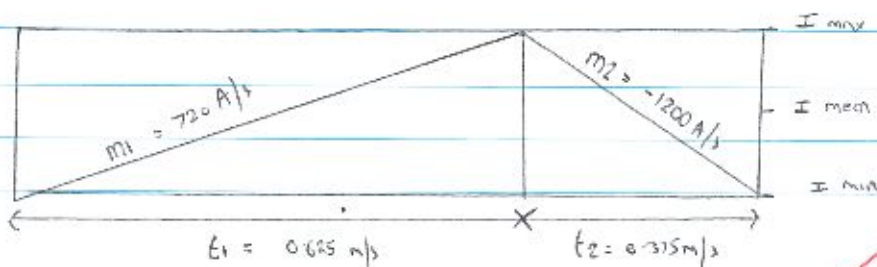
$$I_{min} = 20 - 10.225 = 9.775 \text{ A}$$

$$I_{min} = 9.775 \text{ A}$$

$$I_{max} = 10.225 \text{ A}$$

e) On period = $9.775 + 720 \text{ t A}$

off period = $10.225 - 1200 \text{ t A}$



7

2

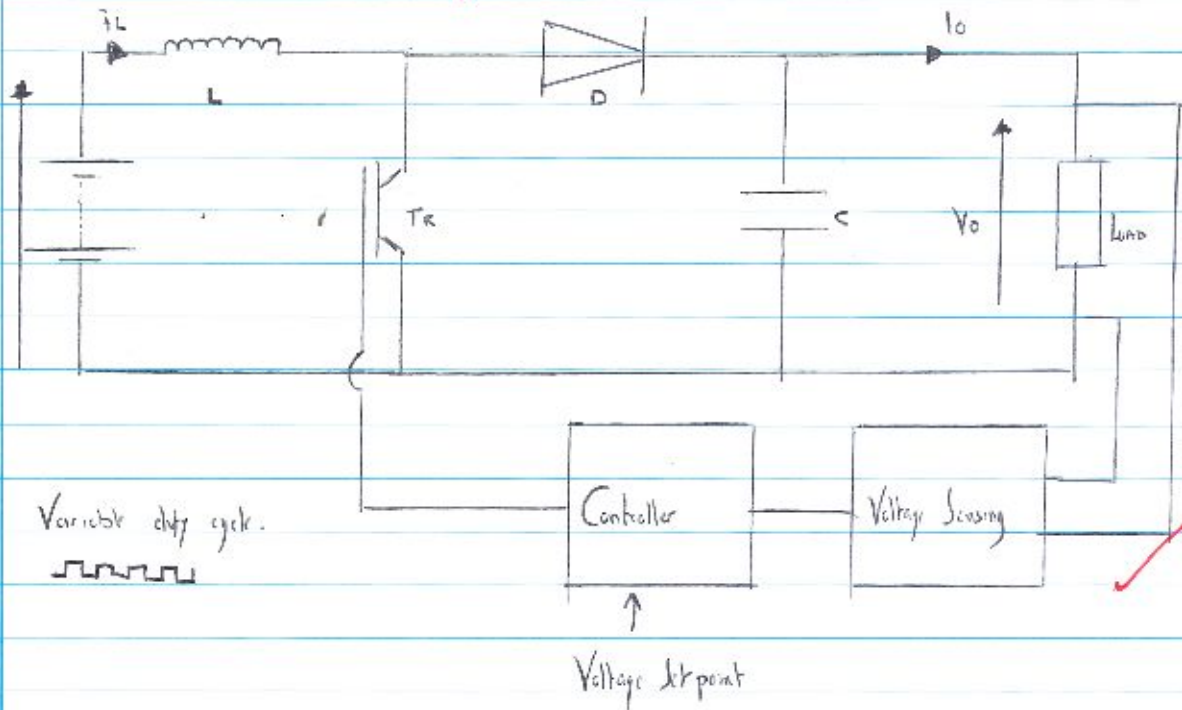
1

3) a) The DC to DC converter is a boost converter, where Voltage is increased to $V_o > V_s$ *built up*

The field is *charged* when the transistor is on.

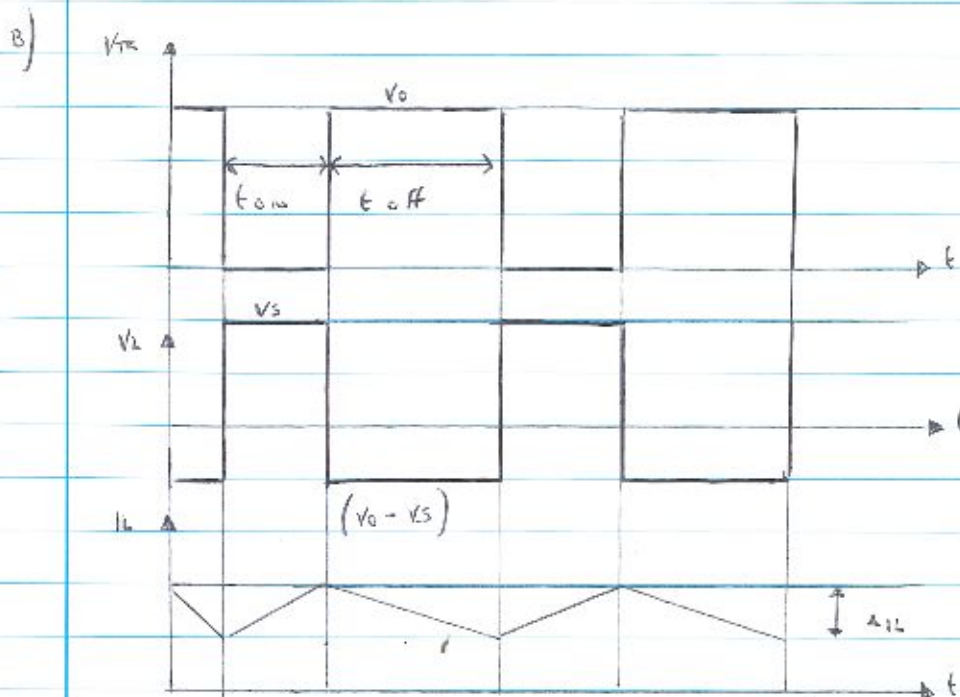
When the transistor is off current in the coil passes through the diode charging the capacitor to $V_o > V_s$.

After the transient period the *inductance* is determined by the switching duty of the transistor.



Voltage is fed back to the controller where V_o is compared to the setpoint voltage.

The duty cycle for voltage output is controlled by the voltage setpoint.



6

c)

$$V_s = 12\text{V}$$

$$V_o = 20\text{V}$$

$$I_o = 1.5\text{A}$$

$$L = 150\text{ }\mu\text{H}$$

$$C = 270\text{ }\mu\text{F}$$

$$f = 20\text{ kHz}$$

$$T = \frac{1}{20000} = 50 \times 10^{-6}$$

i) ~~$V_s t_{on} - (V_o - V_s) t_{off} = 0$~~

Therefore -

$$= V_s DT = (V_o - V_s)(1-D)T$$

$$\frac{V_o}{V_s} = \frac{1}{1-D} \quad D = 1 - \frac{V_s}{V_o} = 1 - \frac{12}{20} = 0.4$$

ii) $\Delta i_L = \frac{V_s t_{on}}{L} = \frac{V_s DT}{L}$

$$= \frac{12 \times 0.4 \times 50 \times 10^{-6}}{150 \times 10^{-6}} = 1.6\text{A}$$

5

3

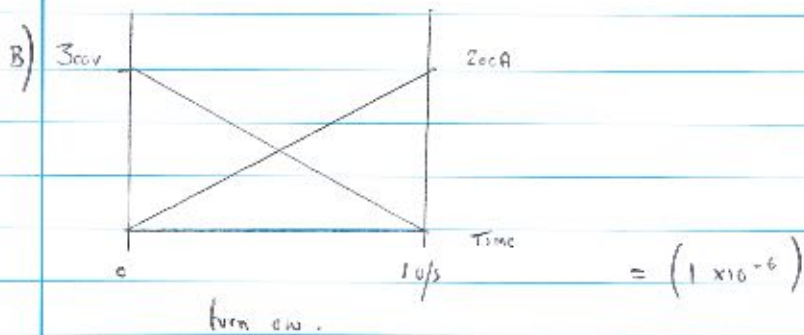
$$iii) V_s I_L(av) = V_o I_o$$

$$I_L(av) = \frac{V_o}{V_s} \times I_o = \frac{20}{12} \times 1.5 = 2.5A$$

$$I_L(peak) = I_L(av) + \frac{\Delta I_L}{2} = 2.5 + \frac{1.6}{2} = 3.3A$$



(3)

1)
A)

Instantaneous values between 0 and T

$$i = \frac{I}{T} t$$

$$v = -\frac{V}{T} t + V = V \left(1 - \frac{t}{T} \right)$$

$$\text{Instantaneous power } v i = V \left(1 - \frac{t}{T} \right) \times \frac{I}{T} t$$

$$= VI \left(1 - \frac{t}{T} \right) \frac{t}{T} = VI \left(\frac{t}{T} - \frac{t^2}{T^2} \right)$$

3

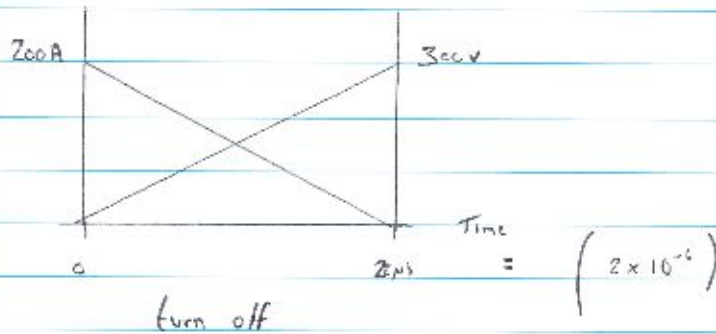
Energy loss

$$\int_0^T v i \, dt = \int_0^T v i \left(\frac{t}{T} - \frac{t^2}{T^2} \right) dt$$

$$v i \left[\frac{t^2}{2T} - \frac{t^3}{3T^2} \right]_0^T = v i \left[\frac{t^2}{2T} - \frac{t^3}{3T^2} \right]_0^T = v i \left[\frac{T}{2} - \frac{T}{3} \right]$$

$$= \frac{v i T}{6} \quad \text{Joules}$$

you cannot cancel yet



Instantaneous values between 0 and T

$$v = \frac{V}{T} t$$

$$i = -\frac{I}{T} t + I = I \left(1 - \frac{t}{T} \right)$$

Instantaneous power between 0 and T



Instantaneous power $V I =$

$$\frac{V}{T} t \times I \left(1 - \frac{t}{T} \right)$$

$$= V I \frac{t}{T} \left(1 - \frac{t}{T} \right)$$

$$V I \left(\frac{t}{T} - \frac{t^2}{T^2} \right)$$

(2)

off is the same as on $= \frac{V I T}{6}$

ii) turn on $= \frac{V I T}{6} = \frac{300 \times 200 \times 1 \times 10^{-6}}{6} = 0.01 \text{ J}$ ✓

(2)

turn off $= \frac{V I T}{6} = \frac{300 \times 200 \times 2 \times 10^{-6}}{6} = 0.02 \text{ J}$ ✓

Mean switching power loss $= \frac{\text{Total switching energy loss}}{\text{Switching period}}$

$= \text{Total switching energy loss} \times \text{Switching frequency}$

$= (0.01 + 0.02) \times 10 \times 10^3 = 300 \text{ W}$ ✓

iii) Conduction loss $= V_{CE} \times I_C \times \text{duty cycle}$
 $= 2.1 \times 200 \times 0.5 = 210 \text{ W}$ ✓

(5)

iv) Total loss $= \text{conduction loss} + \text{switching loss}$

$= 210 + 300 = 510 \text{ W}$ ✓