UNIVERSITY OF JOHANNESBURG

PROGRAM	:	BACCALAUREUS TECHNOLOGIAE *ENGINEERING: ELECTRICAL*
SUBJECT	:	**POWER ELECTRONICS IV**
CODE	:	**EEP 411**
DATE	:	MID-YEAR EXAMINATION 03 JUNE 2019
DURATION	:	08:30- 12:30
WEIGHT	:	40: 60
TOTAL MARKS	:	68

EXAMINER	:	Ms. T.F. MAZIBUKO
MODERATOR	:	MR. REGINALD NETSHIKWETA
NUMBER OF PAGES	:	5 PAGES

INSTRUCTIONS	:	ANSWER ALL QUESTIONS NEATLY.
	:	ONE NON-PROGRAMMABLE CALCULATOR PER CANDIDATE.
REQUIREMENTS	:	ONE ANSWER SHEET PER CANDIDATE.

<u>QUESTION 1</u> [10Marks]

1.1 For the given voltage and current waveforms across a device shown below in figure 1, determine:

1.1.1 The energy absorbed by the device in one period. (2)
1.1.2 The average power absorbed by the device in one period. (2)
1.1.3 The RMS voltage across the device. (2)
1.1.4 The RMS current through the device. (2)
1.1.5 The power factor of the device. (2)

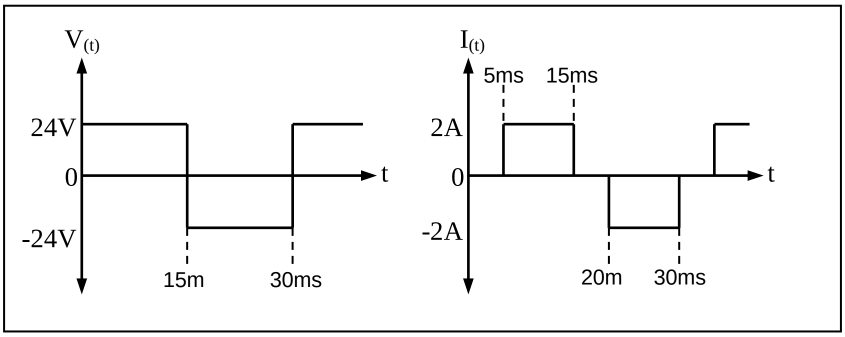

Figure 1

<u>QUESTION 2</u> [15Marks]

2.1 Design a buck converter to produce an output power of 18W at a constant output voltage of 12V. The voltage ripple must not exceed 0.5% of the output voltage.
The input dc supply is 48V and the switching frequency must be 20 kHz. Ensure that the buck converter will operate in continues conduction mode by selecting the inductor value to be a 100 times larger then the critical inductor value
Assume the switch and diode losses to be negligible.

2.1.1 Sketch and label the circuit diagram of a buck converter. (3)
2.1.2 Determine the duty cycle ratio, the output resistance, the value of the inductor and capacitor. (8)
2.1.3 For the selected inductor value, what will the inductor ripple current be? (2)
2.1.4 What peak current must the switching device be able to handle? (2)

<u>QUESTION 3</u> [14Marks]

3.1 A battery powered car is driven by a separately excited dc motor. The armature is connected to a power and regenerative brake control, two-quadrant dc-dc converter. The field current is at maximum and constant. The battery voltage is 120V and the armature resistance is 0.4Ω. After the vehicle has been running at the maximum armature voltage in power control mode for some time, it is required to implement regenerative braking. The armature current prior to the commencement of braking was 80A. Assume that the switching losses are negligible.

3.1.1 Sketch a two-quadrant dc-dc converter circuit connected to a separately excited dc motor. (3)
3.1.2 Making use of the labeled switches and diodes, explain how the converter operates in the power mode and then in the regenerative brake mode. (6)

3.2 A dc-dc converter is used in regenerative braking of a dc series motor. The dc supply is 220V. The armature resistance is 0.05Ω and the field resistance is 0.15Ω. The back emf constant is 15mV/A-rad/s. The average armature current is maintained constant at 150A and is continuous and has negligible ripple. The duty cycle of the dc-dc converter is 40%.

3.2.1 Sketch the circuit diagram. (3)
3.2.2 Determine the average voltage across the chopper. (2)

QUESTION 4 [15Marks]

4.1 The average DC input voltage of the switch mode DC power supply circuit shown in figure 2, is 310V. The output ripple current is negligible and the load resistance is 2Ω. The transformer turns ratio (N_S/N_P) is 0.16 and the duty cycle is set to 50%. The on state voltage drops of the IGBT's and diode's is 1.2V and 0.7V respectively. Assume the transformer losses to be negligible.

4.1.1 Determine the average input current of the switch mode DC power supply. (8)
4.1.2 Determine the efficiency of the switch mode DC power supply. (2)
4.1.3 Determine the peak current through the IGBT switches. (2)
4.1.4 Determine the required open circuit withstand voltage rating of the IGBT's. (2)
4.1.5 What is this circuit topology in figure 2, commonly referred to as? (1)

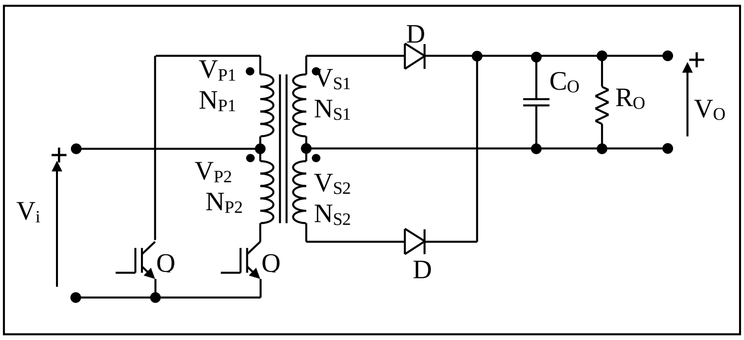

Figure 2

QUESTION 5 [14Marks]

5.1 The open-loop drive control of a separately excited dc motor is illustrated in figure 3.

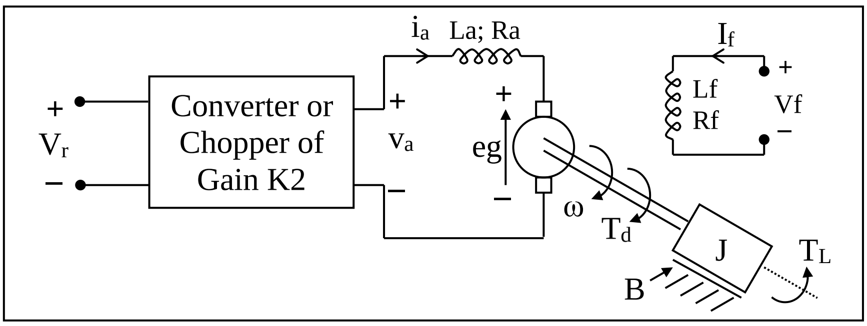

Figure 3

5.1.1 Derive the required steady state equations and sketch the open loop block diagram of the dc motor drive. (8)

5.1.2 From the open loop block diagram, derive the transfer function for the steady state change in speed due to a step change in load torque. (6)

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$$W = \int_{t_1}^{t_2} p(t)dt$$

$$P_{ave} = \frac{1}{T}\int_{t_o}^{t_o+T} v(t)i(t)dt$$

$$\theta_J = P_D(R_{JC} + R_{CS} + R_{SA}) + \theta_A$$

$$R_{eq} = \frac{V_s}{I_a}(1-K) + R_m$$

$$V_{rms} = \sqrt{\frac{1}{T}\int_0^T v^2(t)dt}$$

$$I_{b-ave} = I_{a-pk}(1-k)$$

$$I_{L-max} = V_i \cdot K\left[\frac{1}{R_o(1-K)^2} + \frac{T}{2L}\right]$$

$$I_{C\,max} = \frac{N_s}{N_p}I_{L1} + \frac{V_p \cdot K \cdot T}{L_p}$$

$$I_{o-ave} = K \cdot I_{s-pk}$$

$$R_{eq} = \frac{V_s}{K \cdot I_{a-ave}}$$

$$T_d = K_t I_f I_a$$

$$P_{o-ave} = V_{o-ave} I_{s-pk}$$

$$V_{dc} = \frac{3\sqrt{2}V_L}{\pi}cos\,\alpha$$

$$V_{dc} = \frac{2V_m}{\pi}cos\,\alpha$$

$$Q_{gt} = C_{gt}V_{gs}$$

$$V_{o-rms} = \sqrt{K} \cdot V_{s-pk}$$

$$V_{o-ave} = K \cdot V_{s-pk}$$

$$V_{b-ave} = I_{a-pk}(1-K)R_b$$

$$T_d = B \cdot \omega + T_L$$

$$P_d = E_g \cdot I_a$$

$$R_s = R_o / K$$

$$Q_{gt} = I_{gq}T_{gq}$$

$$I_{c-ave} = K \cdot I_{ipk}$$

$$V_{dc} = \frac{3\sqrt{2}V_L}{2\pi}(1 + cos\,\alpha)$$

$$V_{dc} = \frac{2V_m}{\pi}(1 + cos\,\alpha)$$

$$I_{ch-ave} = K \cdot I_{apk}$$

$$\Delta I_L = \frac{V_{i-ave} \cdot K}{f \cdot L}$$

$$P_{o-ave} = V_{s-pk} I_{o-ave}$$

$$P_{Lp} = \frac{(V_p \cdot K)^2}{2f \cdot L_p}$$

$$I_{c-max} \geq \frac{2P_{Lp}}{V_p \cdot K}$$

$$\frac{I_{i-pk}}{I_{o-ave}} = \frac{V_{o-ave}}{V_{i-pk}} = \frac{K}{1-K}$$

$$V_{ce-off} \geq 2V_{i-max}$$

$$L_{crit} = \frac{R_o(1-K)^2}{2f}$$

$$P_b = I_{a-pk}^2(1-K)R_b$$

$$K_{max} = \frac{1}{1 + N_r / N_p}$$

$$P_{ch} = V_{ch-on} \cdot I_{a-pk} \cdot K$$

$$I_{p-pk} = \frac{V_p \cdot K}{f \cdot L_p}$$

$$V_o = K \cdot V_s$$

$$I_{o-rms} = \sqrt{K} \cdot I_{s-pk}$$

$$I_{c-max} \geq I_{i-pk}$$

$$E_g = K_v \cdot \omega \cdot I_f$$

$$C_{crit} = \frac{(1-K)}{16Lf^2}$$

$$\Delta V_c = \frac{K \cdot V_{o-ave}}{R_o \cdot C \cdot f}$$

$$f = \frac{1}{2 \cdot R \cdot C \cdot ln(3)}$$

$$V_f = R_f \cdot I_f$$

$$I_{s-ave} = K \cdot I_{a-ave}$$

$$P_g = I_a V_s(1-K)$$

$$V_{dc} = \frac{V_m}{2\pi}(1 + cos\,\alpha)$$

$$V_a = E_g \pm R_a \cdot I_a$$

$$\omega_{min} = \frac{R_m \cdot I_a}{K_v \cdot I_f}$$

$$\Delta I_L = \frac{V_{o-ave}(1-K)K}{f \cdot L}$$

$$R_{eq} = R_b(1-K) + R_m$$

$$P_d = T_d \cdot \omega$$

$$V_{ce-off} \geq 2 \cdot V_{i-max}$$

$$P_d = C_{gt}V_{gs}^2 f$$

$$V_{ch-off} = (1-K)V_s$$

$$m_a = \frac{V_{pk-ref}}{V_{pk-carrier}}$$

$$m_f = \frac{f_{carrier}}{f_{output}}$$

$$V_{o-rms} = V_{dc}\sqrt{\frac{\delta}{\pi}}$$

$$V_n = \frac{4 \cdot V_{dc}}{n \cdot \pi} sin\left(\frac{n\delta}{2}\right)$$

$$I_{L-min} = V_i \cdot K\left[\frac{1}{R_o(1-K)^2} - \frac{T}{2L}\right]$$

$$I_{dc} = \frac{I_{pk}}{2\pi}(1 + cos\,\alpha)$$

$$PF = \frac{P_{ave}}{V_{rms}I_{rms}}$$

$$V_{rms-fc} = \sqrt{3} \times V_m \times \sqrt{\frac{1}{2} + \frac{3 \times \sqrt{3} \times cos(2\alpha)}{4\pi}}$$

$$V_{o-ave} = \frac{V_{s-pk}}{1-K}$$

$$\omega_{max} = \frac{V_s}{K_v \cdot I_f} + \frac{R_m \cdot I_a}{K_v \cdot I_f}$$

$$V_{rms-sc} = \sqrt{3} \times V_m \times \sqrt{\frac{1}{2} + \frac{3 \times \sqrt{3} \times cos^2\,\alpha}{4\pi}}$$