The Open University of Sri Lanka

Faculty of Engineering Technology

Department of Mechanical Engineering

General Instructions

1. Read all instructions carefully before answering the questions

2. This question paper consists of **Seven (7)** questions in Six (7) pages.

3. Answer any **Five (5)** questions only. All questions carry equal marks.

4. Answer for each question should commence from a new page.

5. This is a Closed Book Test (**CBT**).

6. The symbols used in this paper have their usual meanings.

7. Clearly state any assumptions that you may make.

8. Answers should be in clear handwriting.

9. Do not use red color pen.

Question 01

a. Breifly explain what is power electronics by highlighting its major considerable areas.

[2 marks]

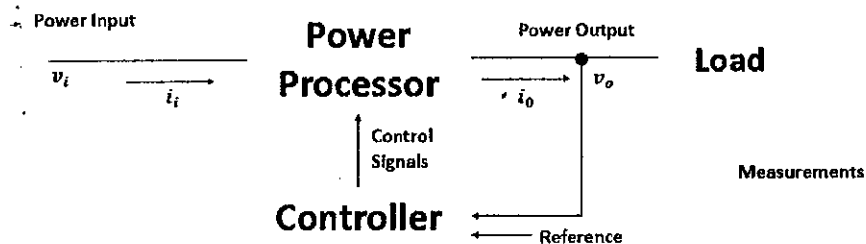b. Refer the diagram given in Figure Q1_01. What are the types of the output of the power processor? [4 marks]

Figure Q1_01

c. Describe the characteristics of a SCR with the help of its V- I characteristic curve. (State all the essential points on the V-I characteristic curve.) [6 marks]

d. Describe the construction and operation of the SCR using appropriate diagrams. Clearly mention all three working states of the SCR. [8 marks]

Question 02

a. Distinguish between SCR and SCS with reference to power electronics. [4 marks]

b. Identify major components of an UPS (refer figure Q2_01) and briefly explain the operation of each component. [4 marks]
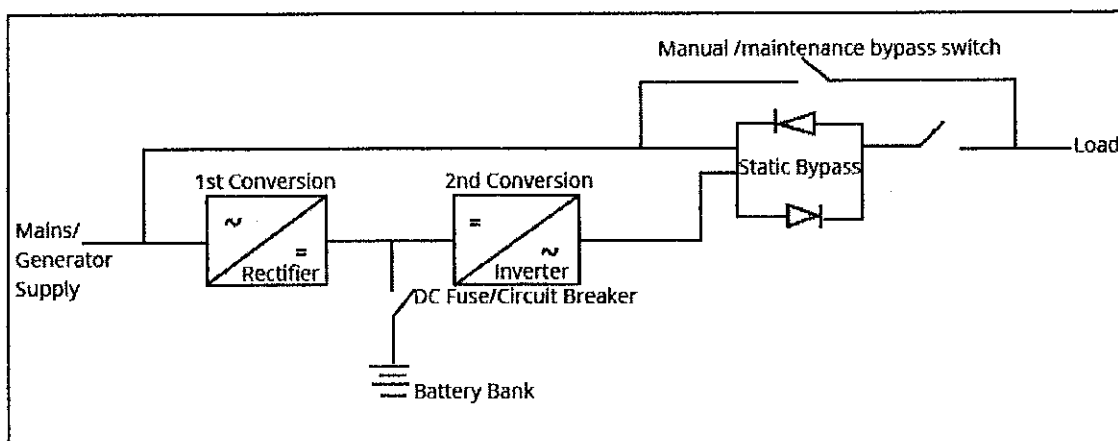

Figure Q2_02

c. For a particular plant, the load list which needs uninterrupted power protection is given below (Table 01).

Table 01: Load List

Load	Voltage (V)	Current (C)	Volt-Amp (VA) Load Demand	Hours (h)	Amp-Hr (Ah)	Energy (VAh)
Computer Console	220	0.86		3		
DSC (Distributed Control System)	220	1.72		6		
Communication	220	1.5		8		

Total				

Complete the table 01 and answer to following questions. [12 marks]

  i.) Draw the load profile (graph showing how the load demand changes with respect to time).
  ii.) Find VA rating for the UPS.
  iii.) Find the battery capacity for the UPS
  iv.) What is the nominal battery voltage?

Question 03

a. Identify the differences of given pairs based on their operation (use appropriate graphs).
  i.) Ideal switch vs Normal Switch
  ii.) Switching Losses in Resistive Load vs Switching Losses in Inductive Load

[4 marks]

b. Consider the power transistor switch with the following characteristics.

$V_{rated} = 220V$, $I_{rated} = 18A$, $V_{CE(sat)}=1.5V$, $t_{SW(on)}= 1.2$ µs, $t_{SW(off)}= 4$ µs, $I_{leakage}=1mA$

If the switching frequency is 150Hz with 50% duty cycle find: [10 marks]

  i.) On-state and Off-state energy losses
  ii.) Maximum power losses during On-state
  iii.) Energy losses during Turn-on and Turn-off
  iv.) Total Energy loss
  v.) Average power loss

c. The thermal resistance from the junction to case and the thermal resistance from the case to the heat of a MOSFET are 1.87 ^{0}C/W and 0.50 ^{0}C/W.
  i.) If the device is mounted on a heat sink that has a thermal resistance of 7.2 ^{0}C/W, determine the maximum power that can be absorbed without exceeding a junction temperature of 150 ^{0}C when the ambient temperature is 40 ^{0}C.
  ii.) Determine the junction temperature when the absorbed power is 15 W.
  iii.) Determine $R_{\theta,SA}$

[6 marks]

Question 04

a. Explain the importance of use of a freewheeling diode in below rectifier circuit (Figure Q4_01) by using appropriate graphs (i.e. input, output, diode currents). [6 marks]
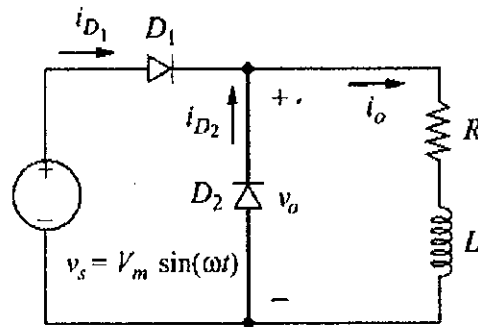
Figure Q4_01

b. Explain the following areas related to snubber circuit. [6 marks]
    i.)   Importance of use of snubber circuits in switching
    ii.)   State types of snubber circuits and explain their operation with the help of diagrams.

c. Consider the step-down converter circuit shown in Figure Q4_02 without the turn-on snubber. The dc input voltage V_d is 500 V, the load current $I_0 = 500$ A, and the switching frequency is 1 kHz. The free-wheeling diode has a reverse-recovery time $t_{rr} = 10$ μs. The GTO (Gate Turn-off Thyristor) has a current fall time $t_{fi} = 1$ μs, a maximum reapplied voltage rate $dv/dt = 50$ V/μs, and a maximum controllable anode current $I_{AM} = 1000$ A.

    i.)   Find the appropriate values for resistance R_s and capacitance C_s for the turn-off snubber circuit.
    ii.)   Estimate the power dissipated in the snubber resistance.
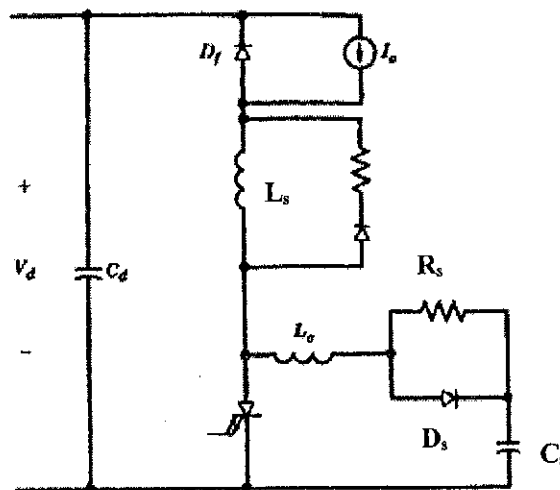
[8 marks]

Figure Q4_02

Question 05

a. Why controllable rectifiers are better than uncontrollable rectifiers? [2 marks]
b. The full-wave controlled bridge rectifier of has an ac input of 120 V rms at 60 Hz and a 20 Ω load resistor. The delay angle is 40^0. Determine: [8 marks]
    i.)   The average current in the load

ii.) The power absorbed by the load

iii.) The source volt-amperes.

iv.) Draw input and output voltage graphs (Clearly mention all essential points)

c. The dc-dc converters are widely used in regulated switch-mode dc power supplies and in dc motor drive applications. List down four types of DC-DC converters available and explain two of them. [6 marks]

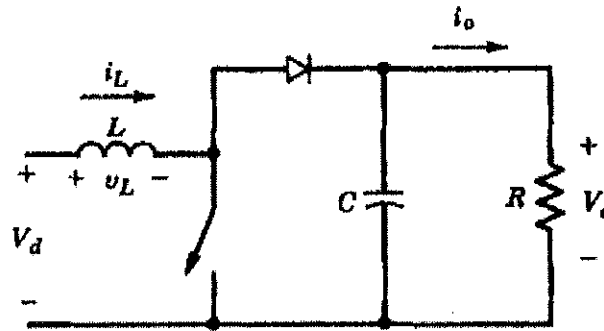d. Consider the step-up DC-DC converter given in Figure Q5_1.

Figure Q5_01

Draw waveforms for following conditions. Clearly mention each essential points and assumptions you made. [4 marks]

i.) At the boundary of continuous-discontinuous conduction

ii.) At the discontinuous conduction

Question 06

a. The Voltage Source Inverters (VSI) can be divided into the following three general categories.
- Pulse-width-modulated inverters
- Square-wave inverters
- Single-phase inverters with voltage cancellation.

Explain each type by considering their differences. [6 marks]

b. What is meant by ripple in single phase inverter-output? [2 marks]

c. The full-bridge inverter has a switching sequence that produces a square wave voltage across a series R-L load. The switching frequency is 60 Hz, V_{dc} =100 V, R=10 Ω and L=25 mH. Determine: [12 marks]

i.) An expression for load current

ii.) The power absorbed by the load

iii.) The average current in the dc source.

Question 07

a. What is VFD/VSD (Variable Frequency Drive/Variable Speed Drive) and why is it useful? [2 marks]

b. State and briefly explain main three types of motor drives. [6 marks]

c. A separately excited DC motor has the following parameters:

$R_a = 3\ \Omega$, $K_e = 0.52$ V/rpm.Wb , Φ (flux per pole) = 150 mWb.

The motor speed is controlled by a full wave bridge rectifier. The firing angle α is set at 60°, and the average speed is 1250 rpm. The applied a.c. voltage to the bridge is 230 V at 50 Hz . Assuming the motor current is continuous; calculate the armature current drawn by the motor and the steady-state torque for the cases of:
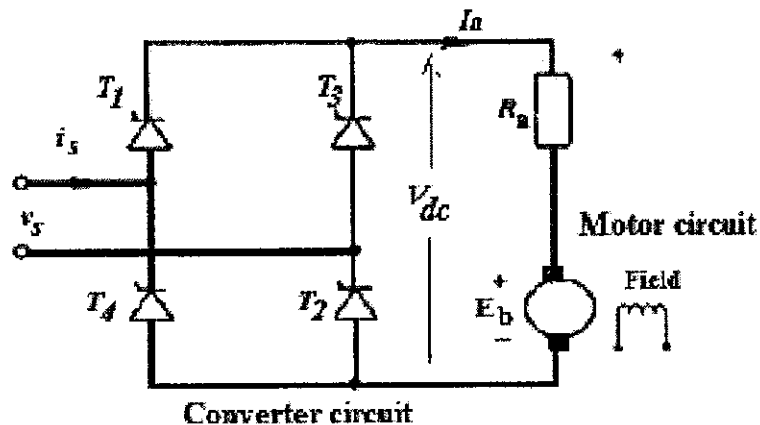
[12 marks]

i.) Fully- controlled bridge

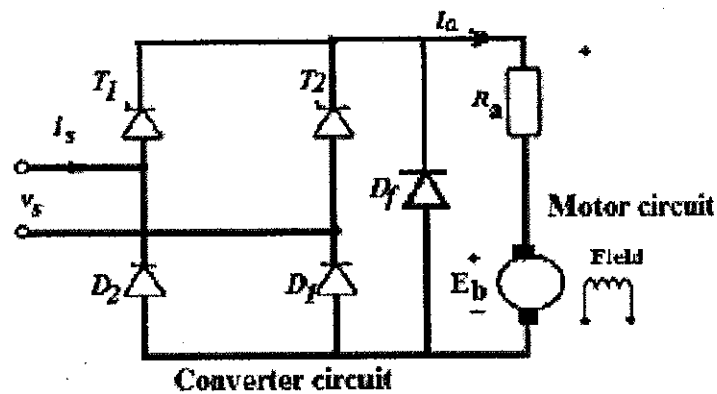Figure Q07_1

ii.) Half-controlled (semi-converter) bridge.

Figure Q07_02