Question 1:  

Objectives: Understanding the principles of power electronics circuit and devices.

Choose the correct answer for the following:

1. For a certain applications of power amplifier a power semiconductor switch is required to operate with 100V, 20A load and switching frequency of 10kHz. The power switching device suitable for this task is:
   (a) GTO  (b) BJT  (c) IGBT  (d) Triac

2. In a single-phase half-wave controlled rectifier, if the input voltage is $v_s = 320 \sin \omega t$ and the delay angle $\alpha = 60^\circ$ the average output dc voltage is:
   (a) 76.4V  (b) 100.0V  (c) 120.9V  (d) 85.6V

3. A single-phase full-wave controlled rectifier supplying highly inductive load such that the load current is assumed continuous, the input voltage has an r.m.s. value of 230 V, if the load resistance $R = 20$ ohms and the delay angle $\alpha = 60^\circ$ then the average current $I_{dc}$ is:
   (a) 3.3A  (b) 5.1A  (c) 10.3 A  (d) 20A

4. In a 3-phase full-wave uncontrolled bridge rectifier, if per phase peak input voltage is $V_m$, then the average output voltage is $V_{dc}$, then the average output voltage is given by:
   (a) $V_m/2\pi$  (b) $\sqrt{3}V_m/2\pi$  (c) $3\sqrt{3}V_m/2\pi$  (d) $3 \sqrt{3}V_m/\pi$

5. Each diode of a hexa-phase uncontrolled diode rectifier conducts for:
   (a) 60°  (b) 120°  (c) 180°  (d) 90°.

6. Each thyristor of a 3-phase, half – wave controlled rectifier conducts for
   (a) 60° - $\alpha$  (b) 90° - $\alpha$  (c) 120° - $\alpha$  (d) 180° - $\alpha$

7. For the hexa-phase (6-pulse) controlled rectifier, the average output voltage is given by:
   (a) $V_{dc} = (V_m/\pi) \cos \alpha$  (b) $V_{dc} = (3 \sqrt{3}V_m/2\pi) \cos \alpha$
   (c) $V_{dc} = (V_m/\pi) (1+\cos \alpha)$  (d) $V_{dc} = (3V_m/\pi) \cos \alpha$, 


(8) A dc chopper is fed from 100V d.c. Its load consists of R=6 Ω and L=20 mH.

The average output voltage is 60 V, and $t_{off} = 1$ msec., then $I_{max}$ and $I_{min}$ are:

(a) 13.5A , 7.5 A  
(b) 11.5 A , 8.5 A  
(c) 7.5A, 6.5A  
(d) 10.5A, 8.5A

(9) For a single–phase AC chopper loaded with RL load of impedance angle $(\phi = 60^\circ)$ then the approximate current extinction angle $\beta$ is:

(a) 207.5$^\circ$  
(b) 214.5$^\circ$  
(c) 222.5$^\circ$  
(d) 225.5$^\circ$

(10) A single-phase AC-AC converter is connected to a load of resistance 50 ohms and a supply voltage of $v_s = 100 \sin 314t$ volts. For a firing angle of 90$^\circ$, the r.m.s value of the load current is:

(a) 13.2 A  
(b) 3.4 A  
(c) 1.0 A  
(d) 5 A

**Question 2:**  
(Objectives: Understanding the characteristics of DC drive.)

A single-phase semiconverter, shown in Fig.1, is used to control the speed of small separately excited d.c. motor rated at 4.5 kW, 220V, 1500 rpm. The converter is connected to a single–phase 220 V, 50 Hz supply. The armature resistance is $R_a = 0.50$ ohm and the armature circuit inductance is $L_a = 10$ mH. The motor voltage constant is $K_e \Phi = 0.1$ V/rpm.

With the converter operates as a rectifier, the d.c. motor runs at 1200 rpm and carries an armature current of 16 A. Assume that the motor current is continuous and ripple-free, determine:

(a) The firing angle $\alpha$.
(b) The power delivered to the motor.
(c) The supply power factor.

Note: $E_a = K_e \Phi n$, $T = K_T \Phi_{ia}$, $K_T = 9.55 K_e$, $n = \text{speed in rpm}$.
Question 3: Understanding the principles of single-phase AC-AC converter.

A single-phase a.c. voltage controller with two inverse-parallel thyristors, has a 120 V (r.m.s.), 50 Hz source. The load resistance R is 15 Ω, and the relation between the normalized r.m.s. load voltage and the delay angle α for a single-phase a.c. voltage controller with a resistive load is given in Fig. 2.

(a) Sketch the controller circuit diagram.
(b) Sketch appropriate waveforms for the supply voltage, load voltage and current.
(c) Prove that the power dissipation in the load is given by:

\[ P = \left( \frac{V_s^2}{2\pi R} \right) \left[ 2(\pi - \alpha) + \sin2\alpha \right] \]

Where \( V_s \) is the rms value of the supply voltage.

(d) Determine the delay angle \( \alpha \) required to deliver 500 W.
(e) Calculate the r.m.s. source current and the r.m.s. and average current in the thyristors.

Note that:

\[ V_{o,\text{normalized}} = \frac{V_{o,r.m.s.}}{V_m / \sqrt{2}} \]
**Question 4:**
(10 Mark)

**Objectives: Understanding the performance of the DC-to-AC converter.**

For the single-phase bridge inverter circuit shown in Fig. 3, we have $V_s=100\text{V}$, load resistance is $R=10\Omega$, load inductance is $L=25\text{mH}$ and output voltage frequency $f=50\text{Hz}$. The control logic for power electronics devices is also shown on the same figure.

(a) Determine the amplitude of the Fourier series terms for the square load voltage waveform, (consider up to the 9th order harmonic)

(b) Compute the rms value of the output voltage waveform in terms of the harmonic components.

(c) Determine the maximum value $i_{omax}$ for the load current, and

(d) Find the total power absorbed by the load.

(e) Draw the frequency spectrum of the output voltage waveform and hence calculate the total harmonic distortion factor (THD).

Note: The waveforms of the load voltage and current for a purely inductive load are shown in the following figure (Fig.4):