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CONTENTS

ELECTRICAL ENGINEERING

Objective Practice Sets

Power Electronics

1 CHAPTER
Power Semiconductor Diode and Transistor

MCQ and NAT Questions

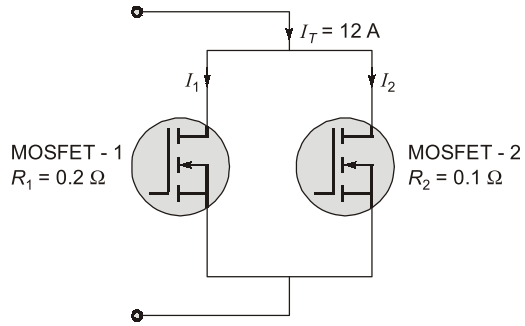
Q.1 The correct sequence of the among semiconductor devices is (decreasing order) of speed
(a) Power BJT, Power MOSFET, IGBT, SCR
(b) IGBT, Power MOSFET, Power BJT, SCR
(c) SCR, Power BJT, IGBT, MOSFET
(d) MOSFET, IGBT, Power BJT, SCR

Q.2 Choose the correct statements among the following according to choice:
1. Switching losses in BJT is more than MOSFET
2. Conduction losses in BJT is less than MOSFET
3. SCRs have lower power losses than MOSFET and IGBT

(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3

Q.3 Turn-on and turn-off times of transistor depend on
(a) static characteristic
(b) junction capacitances
(c) current gain
(d) none of the above

Q.4 The power loss in MOSFET-1 and MOSFET-2 for the circuit shown below are respectively



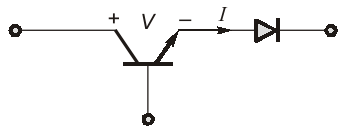
(a) 6.4 W and 3.2 W (b) 2.8 W and 7.2 W
(c) 3.2 W and 6.4 W (d) 7.2 W and 2.8 W

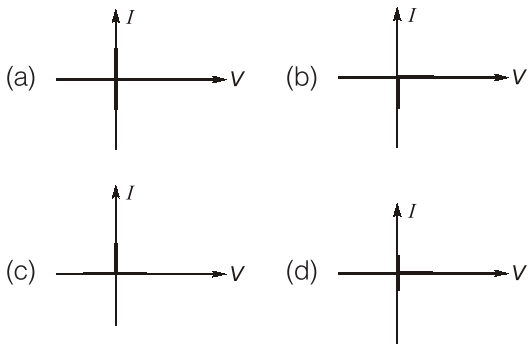
Q.5 A diode and a FET is parallel combination blocks:
(a) Bidirectional voltage of passes unidirectional current.
(b) Bidirectional voltage and passes bidirectional current.
(c) Unidirectional voltage and passes unidirectional current.
(d) Unidirectional voltage and passes bidirectional current.

Q.6 For MOSFET:
(a) they are easy for parallel connection for higher current.
(b) leakage current is relatively high.
(c) have more linear characteristics.
(d) overload and perk current handling capability are high.

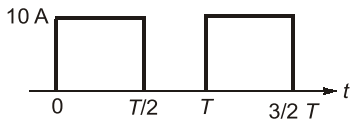
Q.7 For which transistor the symmetry is obtained as the emitter and collector or source and drain can be interchanged?
(a) BJT (b) IGBT
(c) SCR (d) MOSFET

Q.8 The V-I characteristics for the switch shown is (Devices are ideal)





Q.9 A MOSFET rated for 20 A, carries a periodic current as shown in the figure. The on-state resistance of the MOSFET is 0.2 ohm. What is the average on-state power loss of device per cycle?

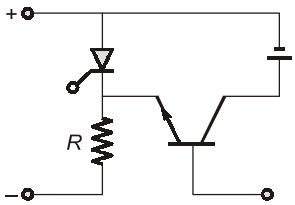


(a) 20 W (b) 15 W
(c) 10 W (d) 5 W

Q.10 For a BJT as a power control switch by biasing it in the cut-off region (off state) or in the saturation region (on state). In the on state, for the BJT (B-Base, E-Emitter, C-Collector)
(a) Both junctions are reverse biased.
(b) B-E junction reversed and B-C junction forward.
(c) B-E junction forward and B-C junction reversed.
(d) Both the base emitter and base-collector junctions are forward biased.

Q.11 A fast conducting switch is rated for high switching applications. If it is IGBT then consider the following statements:
1. It combines the attributes of MOSFET and BJT.
2. It has low forward voltage drop.
3. Its switching speed is very much lower than MOSFET.
4. It has high input impedance.
(a) 1, 2, 3 and 4 are correct.
(b) 1, 2, and 4 are correct.
(c) 1, 2, and 3 are correct.
(a) 3 and 4 are correct.

Q.12 For the shown circuit the objective function of BJT is

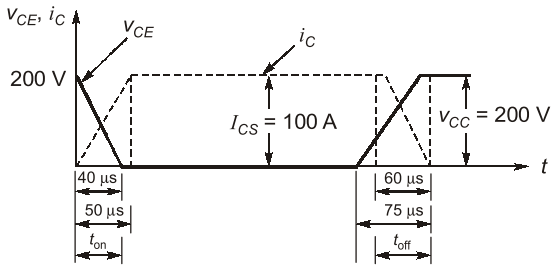


(a) to given control signal to trigger SCR
(b) to make SCR on
(c) to make SCR off
(d) to amplify anode current

Q.13 Which one of the following does **not** exhibit negative resistance characteristic is
(d) FET (b) UJT
(c) Tunnel diode (d) SCR

Q.14 **Assertion (A):** MOSFETs have larger power handling capability in linear applications.
Reason (R): This can be attributed to their excellent thermal stability due to their positive temperature co-efficient.
(a) Both A and R are true, and R is the correct explanation of A.
(b) Both A and R are true, but R is not a correct explanation of A.
(c) A is true, but R is false.
(d) A is false, but R is true.

Q.15 A power transistor has its switching waveforms as shown in figure. If the average power loss in the transistor is limited to 300 W, the switching frequency at which the transistor can be operated is approximately equal to

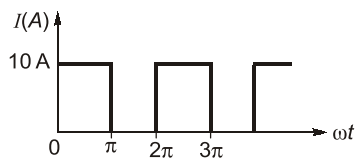


(a) 0.98 kHz (b) 1.25 kHz
(c) 1.12 kHz (d) 1.65 kHz

Q.16 The reduction in the on-static voltage drop in IGBT is due to
(a) added Si layer in the IGBT structure
(b) conductivity modulation
(c) the *n*-drift layer
(d) all of the above

Q.17 Which device is used for current protection?
(a) the fuse (b) R-C network
(c) snubber network (d) none of these

Q.18 A MOSFET rated for 15 A, carries a periodic current as shown in the below figure. The ON state resistance of the MOSFET is 0.15 ohm. What is the average ON state loss in the MOSFET?



(a) 3.75 W (b) 7.5 W
(c) 15.0 W (d) 30.0 W

Q.19 The conduction loss versus device current characteristic of a power MOSFET is best approximated by
(a) a parabola
(b) a straight line
(c) a rectangular hyperbola
(d) an exponentially decaying function

Q.20 Which one of the following is **not** a current triggered device?
(a) SCR (b) GTO
(c) TRIAC (d) MOSFET

Q.21 Power MOSFET has higher on state voltage drop than that of power BJT. Which one of the following reason is right?
(a) Its current capacity is higher.
(b) It has no drift layer.
(c) Conductivity modulation is absent.
(d) It is a majority carrier device.

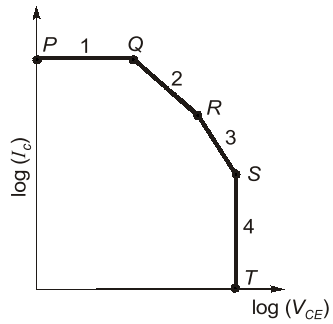
Q.22 The reverse recovery time of a diode is $t_{rr} = 8$ μsec and rate of fall of diode current with respect to time is 10 A/μsec. If the value of softness factor is 0.5, the reverse recovery charge stored will be ___ μC.

Q.23 Match **List-I** (Limiting factor) with **List-II** (Safe Operating Area Portion) and select the correct answer using the code given below the lists:

List-I
A. The peak voltage limit
B. Secondary breakdown limit
C. Power dissipation limit
D. Peak current limit

List-II

1. PQ
2. QR
3. RS
4. ST



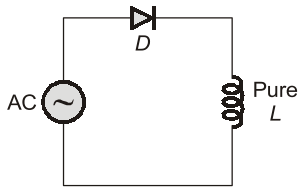
Codes:

	A	B	C	D
(a)	2	1	4	3
(b)	4	3	2	1
(c)	2	3	4	1
(d)	4	1	2	3

Q.24 **Statement (I):** The 'turn-on' and 'turn-off' time of a MOSFET is very small.

Statement (II): the MOSFET is a majority carrier device.
(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I).
(c) Statement (I) is true but Statement (II) is false.
(d) Statement (I) is false but Statement (II) is true.

Q.25 In the circuit of adjacent figure the diode connects the ac source to a pure inductance *L*.



The diode conducts for
(a) 90° (b) 180°
(c) 270° (d) 360°

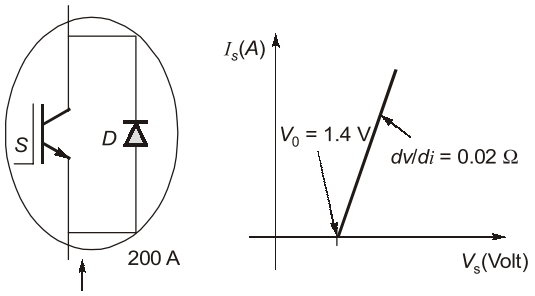
Q.26 In a power diode the rate of change of reverse current is 30 A/ms and charge involved in reverse recovery is 11 nC. The reverse recovery time for the diode will be _____ μsec.

Q.27 Consider the following statements with regard to power diodes:
1. The breakdown voltage is directly proportional to the doping density of the drift region.
2. Losses in the diode are less due to conductivity modulation of the drift region in the on-state.
3. The vertically oriented structure supports large blocking voltages.

Which of the above statements is/are correct?
(a) 1 only (b) 2 only
(c) 3 only (d) 1, 2 and 3

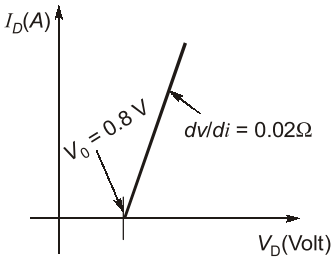
Q.28 A steady dc current of 200 A is flowing through a power module (*S*, *D*) as shown in Figure (a). The V-I characteristics of the IGBT (*S*) and the diode (*D*) are shown in Figures (b) and (c), respectively.

The conduction power loss in the power module (S, D) is _____ W.



(a) (b)

V-I characteristic of IGBT



V-I characteristic of diode

(c)

Q.29 For a diode, reverse recovery time is defined as the time between the diode current becomes zero and the instant reverse recovery current decays to

(a) 10% of reverse peak current I_{RM}
(b) 15% of I_{RM}
(c) zero
(d) 25% of I_{RM}

Q.30 The forward characteristics of a power diode can be represented by $V_f = 0.80 + 0.015\ i_f$. The average power loss and rms current for a constant current of 50 A for 2/3 of a cycle is x and y. Find x/y _____.

Q.31 The reverse recovery time of a diode is 3 m*s* and rate of fall $\left(\frac{di}{dt}\right)$ is 30 A/μs. The stored charge of the diode is

(a) 45 μC (b) 135 μC
(c) 270 μC (d) 540 μC

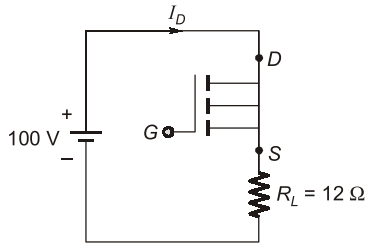
Q.32 Consider the following statements:

1. Power BJT is the fastest switching device.
2. The power electronic device that combines the characteristics of MOSFET and BJT is MCT.
3. Diac is two terminal bidirectional switch.

Which of the above statements is/are **not** correct?

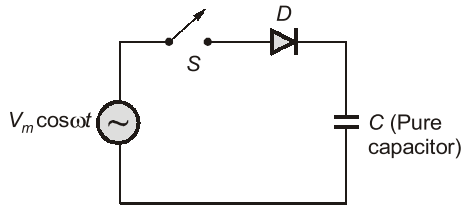
(a) 1 and 2 only (b) 2 and 3 only
(c) 1 and 3 only (d) all of the above

Q.33 For the circuit shown below, the power-loss in the on-state is (MOSFET parameters are: t_r = 2 μs, $R_{DS(on)}$ = 0.2 Ω, duty cycle D = 0.7 and f = 30 kHz)



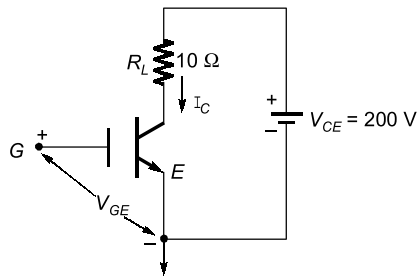
(a) 6.28 W (b) 9.41 W
(c) 5.00 W (d) 2.22 W

Q.34 In the circuits shown below,



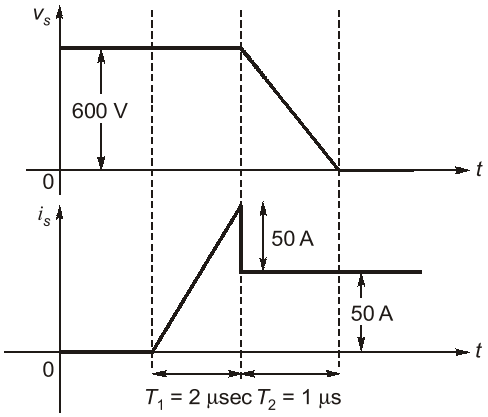
If switch in figure is closed at t = 0, then the diode 'D' conducts for _____(degree).

Q.35 The IGBT (Insulated Gate Bipolar Transistor) used in the circuit has the following data: t_{ON} = 3 μs t_{OFF} = 1.2 μs, Duty cycle (D) = 0.7, $V_{CE(sat)}$ = 2 V and f_s = 1 kHz.
What are the switching power losses during turn-on and turn-off, respectively?



(a) 1.98 W and 1.7 W
(b) 2.2 W and 1.7 W
(c) 1.98 W and 0.792 W
(d) 2.2 W and 0.792 W

Q.36 The voltage (v_s) across and the current (i_s) through a semiconductor switch during a turn-ON transition are shown in figure. The energy dissipated during the turn-ON transition, in mJ, is



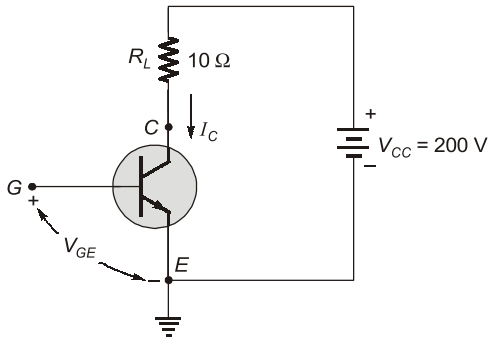
Q.37 The value of the on state resistance for low value of V_{ds} according to output characteristics of power MOSFET will be

(a) $\frac{V_{ds}}{I_g}$ (b) $\frac{V_{ds}}{I_d}$

(c) 0 (d) ∞

Q.38 The IGBT used in the circuit of given figure has the following data:

t_{ON} = 3 μs, t_{off} = 1.2 μs, D (duty cycle) = 0.7, $V_{CE(sat)}$ = 2 V and f_s = 1 kHz.



The switching power loss during turn-on is around

(a) 2 W (b) 1.5 W

(c) 1 W (d) 3.5 W

Q.39 Consider the following statements regarding IGBT:

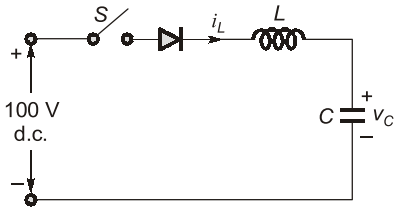
1. Injection layer in IGBT injects holes into n^- layer.
2. The voltage blocking capability of the IGBT is determined by the injection layer.
3. A latched up IGBT can be turned off by forced commutation of current only.

Which of the above mentioned statements is/are correct?

(a) 1 and 2 only (b) 2 and 3 only

(c) 1 and 3 only (d) 1, 2 and 3

Q.40 In the circuit of figure the switch 'S' is closed at t = 0 with $i_L(0)$ = 0 and $v_C(0)$ = 0. In the steady state v_C is equals _____ V.



Multiple Select Questions (MSQ)

Q.41 Which of these following devices possess bidirectional current capacity?

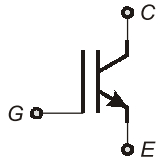
(a) Triac (b) GTO

(c) RCT (d) IGBT

Q.42 Which of the following is/are advantage of power MOSFET?

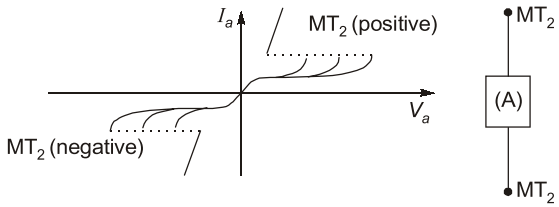
(a) Lower switching losses
(b) Lower conduction losses
(c) Easy parallel operation
(d) Occurrence of secondary breakdown

Q.43 Which of the following option(s) is/are correct regarding the device whose symbol is shown below:



(a) The device is power MOSFET.
(b) The device is known as metal oxide insulated gate transistor.
(c) It has high input impedance.
(d) It has low on state power loss.

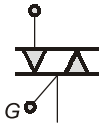
Q.44 The static VI characteristics of a device is shown. The correct option(s) regarding the device can be



(a) The device is UJT

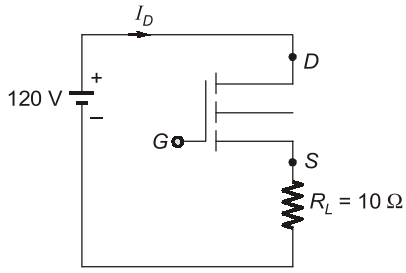
(b) The device is bidirectional in nature.

(c) The block A can be



(d) The device is extensively used for heat control, speed control of single phase induction motors.

Q.45 For the circuit shown, MOSFET parameters are $t_r = 2.5\ \mu sec$; $R_{DS(ON)} = 0.25\ \Omega$; duty cycle = 0.6; $f = 25$ kHz



Correct options is/are:

(a) drain current = 12 A

(b) on time period = 24 μsec

(c) Energy loss during ON time = 822.74 μJ

(d) Power loss during ON time = 21 μW

■■■■

Answers Power Semiconductor Diode and Transistor

1. (d)	**2.** (b)	**3.** (b)	**4.** (c)	**5.** (d)	**6.** (b)	**7.** (d)	**8.** (c)	**9.** (c)
10. (d)	**11.** (a)	**12.** (c)	**13.** (a)	**14.** (a)	**15.** (c)	**16.** (b)	**17.** (a)	**18.** (b)
19. (a)	**20.** (d)	**21.** (c)	**22.** (213.33)	**23.** (b)	**24.** (a)	**25.** (d)	**26.** (0.027)	**27.** (c)
28. (960)	**29.** (d)	**30.** (1.265)	**31.** (b)	**32.** (a)	**33.** (b)	**34.** **(0)**	**35.** (c)	**36.** (75)
37. (b)	**38.** (a)	**39.** (c)	**40.** (280)	**41.** (a,c)	**42.** (a,c)	**43.** (b,c,d)	**44.** (b,c,d)	**45.** (b,c)

Explanations Power Semiconductor Diode and Transistor

1. (d)

MOSFET has the highest operating speed (frequency).

2. (b)

(i) BJT has the better conduction hence less conduction losses. MOSFET has lower switching loss and high conduction losses.

(ii) IGBT: lower switching losses than BJT.

3. (b)

Turn-on and turn-off times of transistor depend on junction capacitance.

Because of charging and discharging of junction capacitance a transistor does not turn-on and turn off instantly.

4. (c)

During on state, MOSFET can be replaced resistors.

∴ Using current divider rule,

$$I_1 = \left(\frac{R_2}{R_1 + R_2}\right) I_T$$

or $$I_1 = \left(\frac{0.1}{0.3}\right) \times 12 = 4\ A$$

and $$I_2 = I_T - I_1 = 12 - 4 = 8\ A$$

∴ $$P_1 = I_1^2 \cdot R_1 = 4^2 \times 0.2 = 3.2\ W$$

and $$P_2 = I_2^2 \cdot R_2 = 8^2 \times 0.1 = 6.4\ W$$

5. (d)

If device has one antiparallel diode, entire circuit allows the bidirectional current and at the same time it blocks the unidirectional voltage.

6. (b)

Leakage current is relatively high.

7. (d)

MOSFET has this symmetry.

8. (c)

Because of diode current can never be negative.

When current flows the voltage across the switch is zero and if current is zero then these may be any voltage across the switch.

9. (c)

$$P_{avg.} = I_{rms}^2 \cdot R_{ON}$$

$$R_{ON} = 0.2\ \Omega$$

$$I_{rms} = \sqrt{\frac{1}{T}\int_0^{T/2} (10)^2\, dt} = \sqrt{50}\ \text{A}$$

$$P_{avg.} = (\sqrt{50})^2(0.2) = 10\ \text{W}$$

10. (d)

In the ON state of BJT (being used as a power control switch) both base emitter and base collector junction are forward biased.

11. (a)

All the statements are concerned with IGBT.

12. (c)

In the given circuit, objective function of BST is commutation of SCR.

13. (a)

FET's do not exhibit negative resistance characteristics

14. (a)

MOSFET has positive temperature coefficient which avoid problem of thermal runaway. Also MOSFET parallel operation is easy.

15. (c)

Energy loss during turn-on $= \int_0^{t_{on}} i_c \cdot v_{CE} dt$

$$= \int_0^{t_{on}} \left(\frac{I_{CS}}{50} \times 10^6 t\right)\left(V_{CC} - \frac{V_{CC}}{40} \times 10^6 t\right) dt$$

$$= \int_0^{t_{on}} (2 \times 10^6 t)(200 - 5 \times 10^6 t) dt$$

$= 0.1067$ Watt-sec

Energy loss during turn-off

$$= \int_0^{t_{off}} \left(100 - \frac{100}{60} \times 10^6 t\right) \times \left(\frac{200}{75} \times 10^6 t\right) dt$$

$= 0.1603$ Watt-sec

Total energy loss in one cycle

$= 0.1067 + 0.1603$

$= 0.267$ W-sec

Average power loss in transistor

= Switching frequency × energy loss in one cycle

$\therefore$ Allowable switching frequency

$$f = \frac{300}{0.267} = 1123.6\ \text{Hz} \approx 1.12\ \text{kHz}$$

16. (b)

The reduction in the ON stage static voltage drop in IGBT as compared to MOSFET's is due to the conductivity modulation phenomenon.

17. (a)

Generally, fuses are used for over current protection of the devices.

18. (b)

$$P_{avg.} = I_{rms}^2 \cdot R_{ON}$$

$$R_{ON} = 0.15\ \Omega$$

$$I_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{\pi} (10)^2\, dt} = \sqrt{50}\ \text{A}$$

$$P_{avg.} = (\sqrt{50})^2 \cdot 0.15 = 7.5\ \text{W}$$

19. (a)

Let, I = device current

R_{ON} = ON state resistance of power MOSFET

Conduction loss

$= P = I^2 R_{ON}$

Therefore, condition losses versus device current characteristics can be best approximated by a parabola.

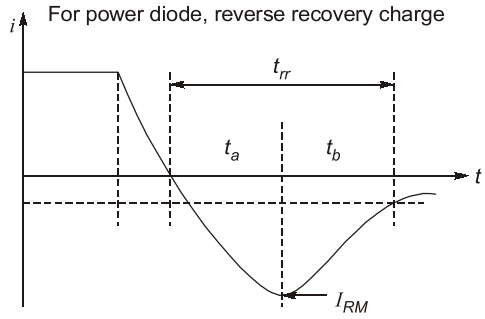
20. (d)

MOSFET is a voltage controlled device device whereas SCR, GTO, TRIAC all belong to thyristor family are current controlled devices.

21. (c)

Power MOSFET has higher ON state voltage drop as compared to power BJT because of absence of conductivity modulation.

22. Sol.



The value of softness factor,

$$\text{S.F.} = \frac{t_b}{t_a} = 0.5 = \frac{1}{2}$$

$$t_a = 2\,t_b$$

reverse recovery time,

$$t_{rr} = t_a + t_b = 8\ \mu\text{sec}$$

$$3\,t_b = 8\ \mu\text{sec}$$

$$t_b = \frac{8}{3}\mu\,\text{sec}$$

$$t_a = 2t_b = \frac{16}{3}\mu\,\text{sec}$$

$$\frac{di}{dt} = \frac{I_{RM}}{t_a}$$

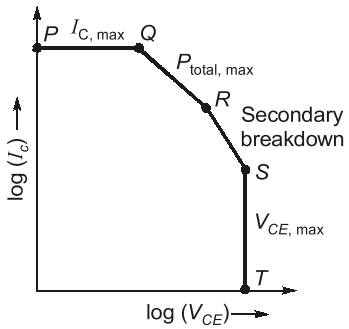
$$I_{RM} = t_a\frac{di}{dt} = \frac{16}{3}\mu\,\text{sec} \times 10\,\text{A/}\mu\text{sec}$$

$$= \frac{160}{3}\text{A}$$

$$Q_{RR} = \frac{1}{2} \times I_{RM} \times t_{rr}$$

$$= \frac{1}{2} \times \frac{160}{3} \times 8 = 213.33\ \mu\text{C}$$

23. (b)



Safe operating area of a power transistor specifies the safe operating limits of collector current I_C versus collector emitter voltage V_{CE}, for reliable operation of the transistor, the I_C and V_{CE} must always lie within this area.

24. (a)

The 'turn on' and 'turn off' of a MOSFET is very small. Because there are no minority carriers in the MOSFET. The minority carriers in the device take more time to settle down during turn off. So, here it is a majority carrier device the turn on and turn off is very small for MOSFET.

25. (d)

Given circuit,

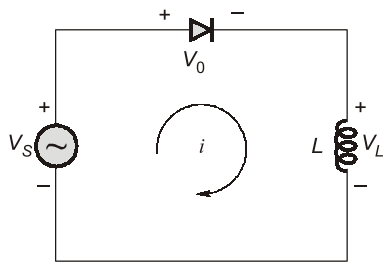
Now, $V_D + V_L - V_S = 0$

when diode $\rightarrow$ ON; $V_D = 0$

$$\therefore \quad V_S = V_m \sin\omega t = \frac{L\,di}{dt} = V_L$$

$$\Rightarrow \quad \int di = \frac{1}{WL}\int V_m \sin\omega t\, d(\omega t)$$

$$\Rightarrow \quad i = \frac{V_m}{WL}(-\cos\omega t) + k \qquad \ldots (i)$$



at $t = 0$, $i = 0$

$$\therefore \quad i = 0 = \frac{V_m}{WL}(-1) + k$$

$$\therefore \quad k = \frac{V_m}{WL} \qquad \ldots (ii)$$

Using (ii) in (i), $\quad i = \frac{V_m}{WL}(1 - \cos\omega t) \qquad \ldots (iii)$

Now diode will conduct till, $i = 0$

$\therefore$ Diode will conduct for 360° (Complete cycle)

26. Sol.

Reverse recovery time = t_{rr}

$$= \sqrt{\frac{2Q_R}{di/dt}} = \sqrt{\frac{2 \times 11 \times 10^{-9}}{\left(\frac{30}{10^{-6}}\right)}}$$

$$t_{rr} = 2.708 \times 10^{-8} = 0.027\ \mu\text{s}$$