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Internal Assessment Test 1 – Sept. 2020 (Scheme & Solution)

Sub:	POWER ELECTRONICS					Sub Code:	17EC73/ 15EC73	Branch:	ECE
Date:	15-09-2020	Duration:	90 mins (2pm-3.30pm)	Max Marks:	50	Sem/Sec:	VII A,B,C,&D		OBE

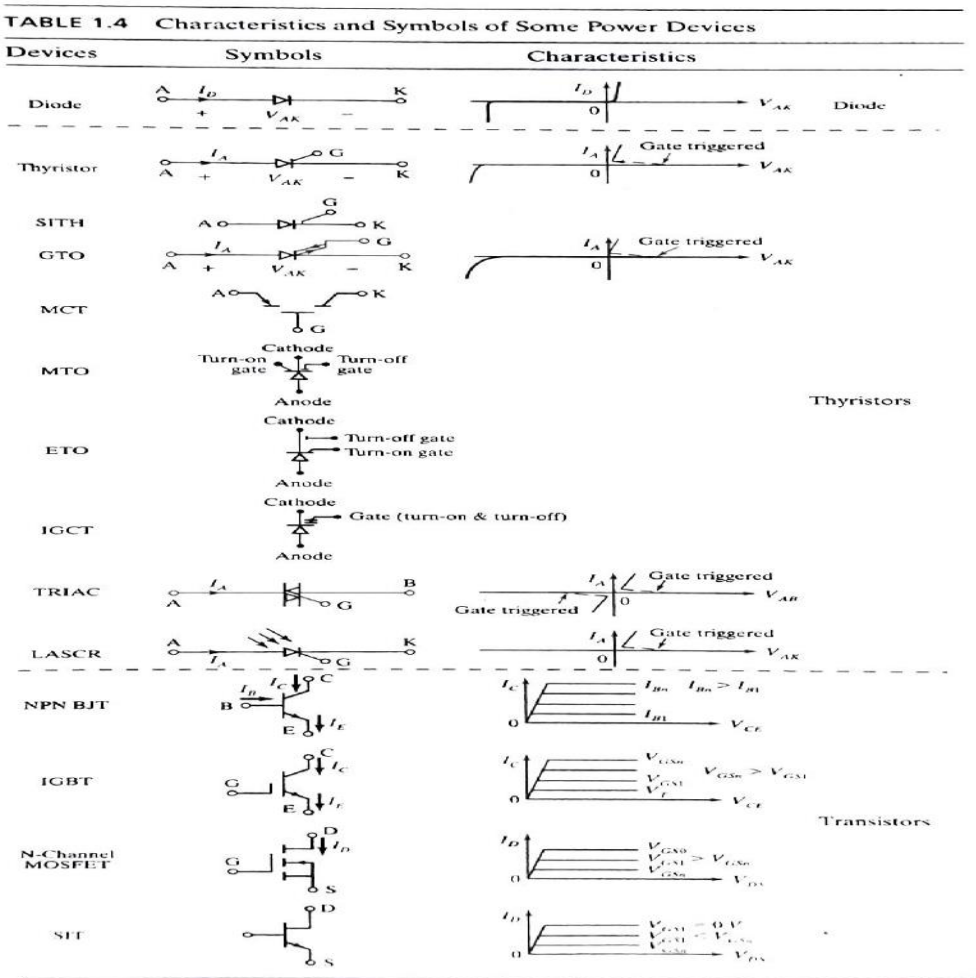
Answer any FIVE FULL Questions

		MARKS	CO	RBT
1	Give the characteristics features of following devices with symbols	[10]	CO1	L1

i) IGBT **ii)** TRIAC **iii)** MOSFET **iv)** MCT

v) LASCR

Sol.



Each characteristics=1 mark, Each Symbol= 1 mark; 2*5=10 marks.

2 With a neat diagram and waveforms, explain the steady state characteristics of BJT. [10] CO1 L2

Soln.

- There are 3 possible configurations – Common Collector, Comn Base & Common Emitter.
- The Common Emitter, shown in Figure 4.28a for an NPN transist is generally used in switching applications.
- The typical input characteristics of base current I_B against ba emitter voltage V_{BE} are shown in Figure 4.28b.
- Figure 4.28c shows the typical output characteristics of collec current I_C against collector-emitter voltage V_{CE}.
- For a PNP-transistor, the polarities of all currents and voltages reversed.

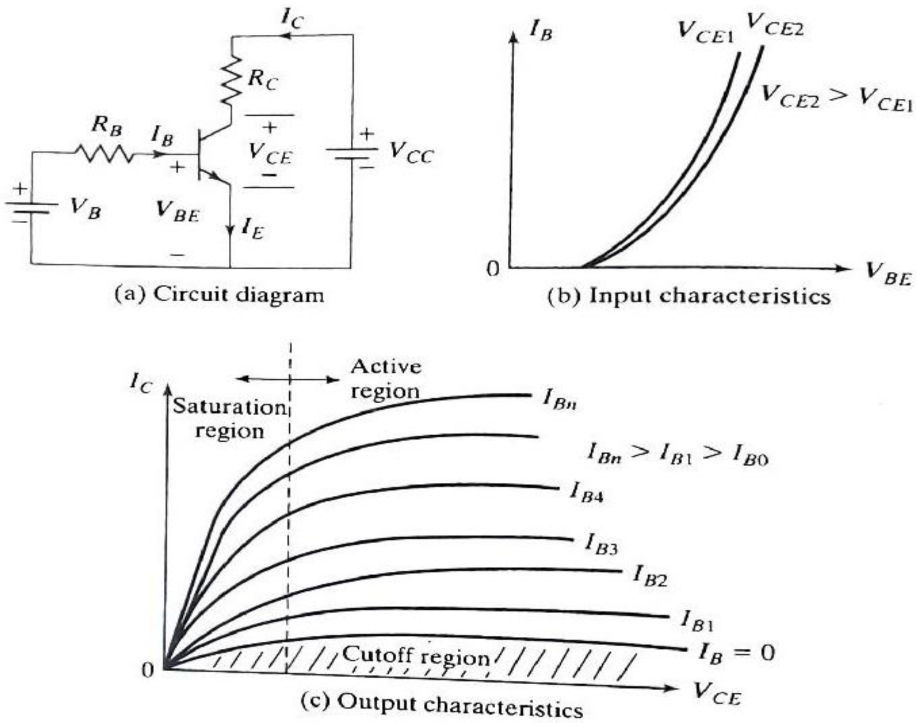


FIGURE 4.28

Characteristics of *NPN*-transistors.

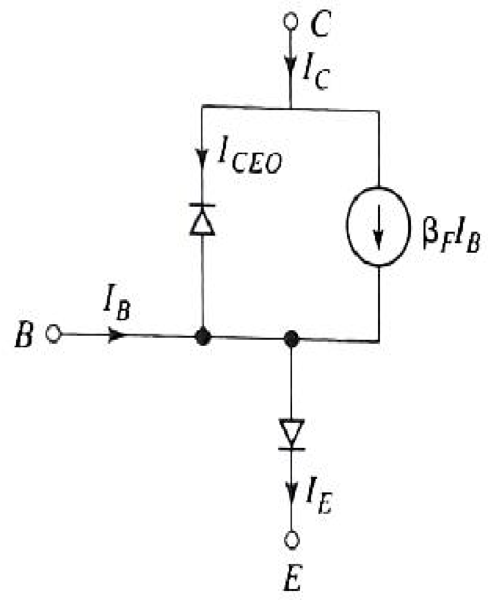


FIGURE 4.30
Model of *NPN*-transistors.

- There are 3 operating regions of a transistor : Cutoff, Activ Saturation.
- In the cutoff region, the transistor is off.
- The base current is not enough to turn it on & hence b junctions are reverse biased.
- In the active region, the transistor acts as an amplifier, where base current is amplified by a gain.
- The collector-emitter voltage decreases with the base current.
- The CBJ (Collector to Base Junction) is reverse biased & the (Base to Emitter Junction) is forward biased.
- In the saturation region, the base current is sufficiently high.
- The collector-emitter voltage is low, & the transistor acts a switch.
- Both junctions (CBJ & BEJ) are forward biased.
- The transfer characteristic, which is a plot of V_{CE} against I_B shown in Figure 4.29.

- The model of an NPN transistor is shown in Figure 4.30 unc large-signal dc operation.
- The equation relating the currents is

$I_E = I_C + I_B$ (4.14)

- The base current is effectively the input current & the collec current is the output current.
- The ratio of the collector current I_C to base current I_B is known the forward **current gain**, β_F :

$$\beta_F = h_{FE} = \frac{I_C}{I_B} \qquad (4.15)$$

• The collector current has 2 components : one due to base current & the other is the leakage current of the CBJ.	[10]	CO1	L1

$$I_C = \beta_F I_B + I_{CEO} \qquad (4.16)$$

- Where I_{CEO} is the collector-to-emitter leakage current with base open circuit & can be considered negligible compared to $\beta_F I_B$.
- From Eqs. (4.14) and (4.16), we have

$$I_E = I_B(1 + \beta_F) + I_{CEO} \quad (4.17)$$

$$\approx I_B(1 + \beta_F) \quad (4.18)$$

$$I_E \approx I_C\left(1 + \frac{1}{\beta_F}\right) = I_C \frac{\beta_F + 1}{\beta_F} \quad (4.19)$$

Because $\beta_F \gg 1$, the collector current can be expressed as

$$I_C \approx \alpha_F I_E \quad (4.20)$$

where the constant α_F is related to β_F by

$$\alpha_F = \frac{\beta_F}{\beta_F + 1} \quad (4.21)$$

or

$$\beta_F = \frac{\alpha_F}{1 - \alpha_F} \quad (4.22)$$

Let us consider the circuit of Figure 4.31, where the transistor is operated as a switch.

$$I_B = \frac{V_B - V_{BE}}{R_B} \quad (4.23)$$

$$V_C = V_{CE} = V_{CC} - I_C R_C = V_{CC} - \frac{\beta_F R_C}{R_B}(V_B - V_{BE})$$

$$V_{CE} = V_{CB} + V_{BE} \quad (4.24)$$

or

$$V_{CB} = V_{CE} - V_{BE} \quad (4.25)$$

Figures & Waveforms= 5 marks, Explanation & Eqns.= 5 marks.

3 Explain control characteristics of SCR, BJT, MCT and GTO.

Soln.

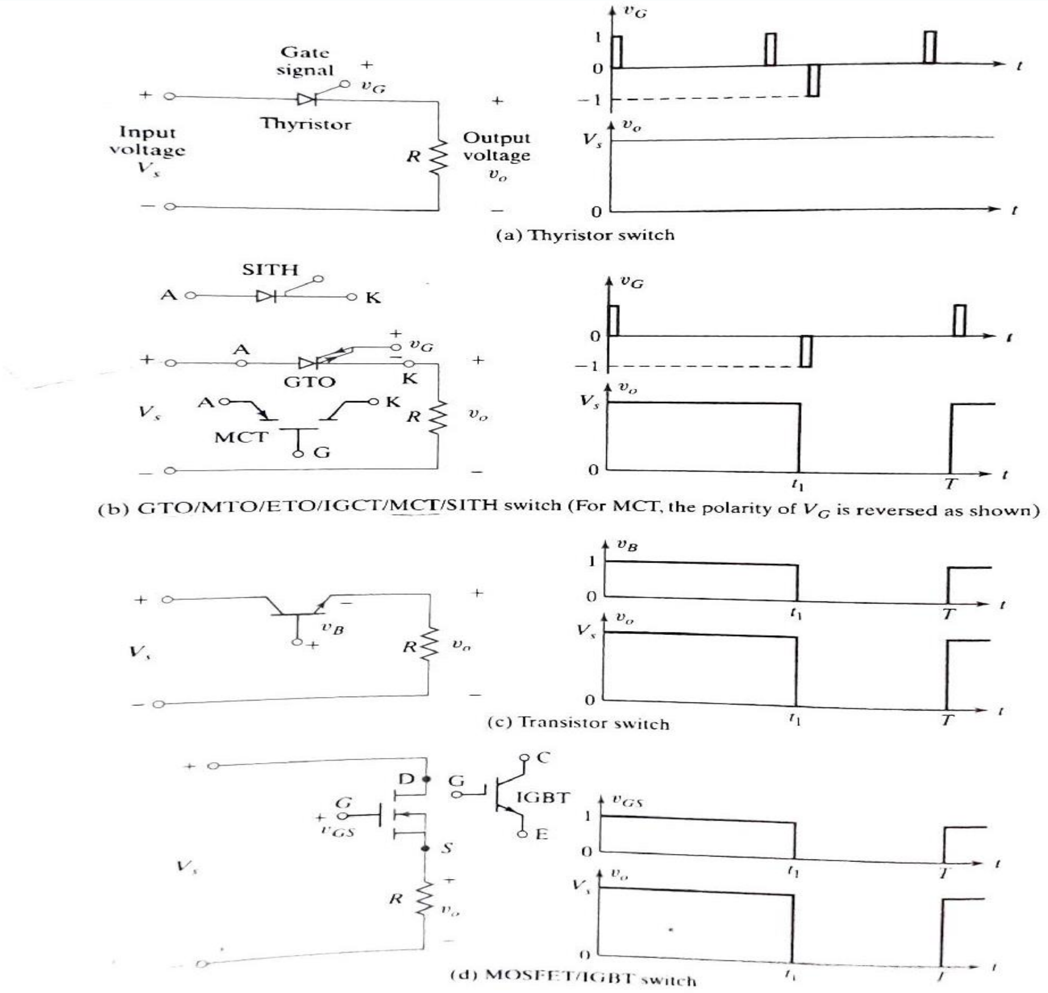


FIGURE 1.17
Control characteristics of power switching devices

Figure above and brief explanation of the control characteristics of Each subsection= 2.5 marks; 2.5*4= 10 marks. [10] CO1 L1

4 Mention and explain the different types of power electronic converter systems.

Soln.

- The power electronic circuits can be classified into 6 types :

1) Diode Rectifiers
2) DC-DC Converters (DC Choppers)
3) DC-AC Converters (Inverters)
4) AC-DC Converters (Controlled Rectifiers)
5) AC-AC Converters (AC Voltage Controllers)
6) Static Switches

Each type – Fig. & Explanation = 10 marks.

5 [05+05] CO1 L1

- Define power electronics and mention its different applications.
- Explain peripheral effects of thyristors.

Soln.

a)

- **<u>Power Electronics</u>** may be defined as the application of soli
electronics for the control & conversion of electric power.
- Also, it can be defined as the art of converting electrical energ
one form to another in an **efficient**, **clean**, **compact** & **robust** r
for the energy utilization to meet the desired needs.
- The interrelationship of power electronics with power, electron
control is shown in Figure 1.1.

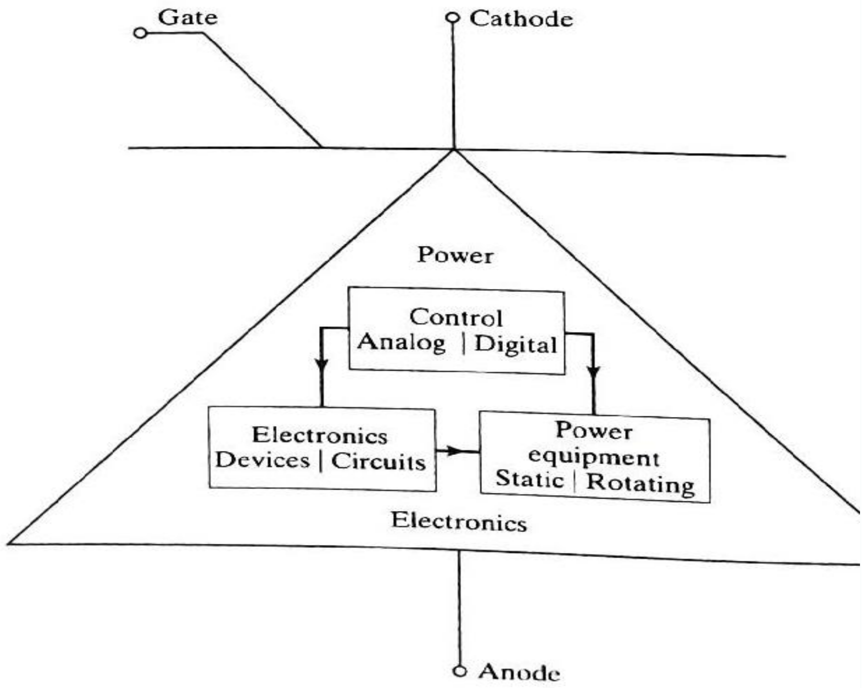


FIGURE 1.1

Relationship of power electronics to power, electronics, and control.

- The arrow points to the direction of current flow from anode
cathode (K).
- It can be turned on & off by a signal to the gate terminal (G).
- Without any gate signal, it normally remains in the off-state, beha
an open circuit, and can withstand a voltage across the terminals
K.

- Power electronics has revolutionized the concept of power control
- Power control is used for power conversion and for control of ele
motor drives.
- For many years, there was demand for control of electric power.
- This electric power was to be used for motor drive system
industrial controls.
- This demand gave rise to early development of the Ward-L
system.

- The Ward-Leonard system is used to obtain a variable dc voltage control of dc motor drives.
  (5 marks)

b)
Soln.

- The operations of the power converters are based mainly c switching of power semiconductor devices.
- This introduces current & voltage harmonics into the supply sys on the output of the converters.
- These can cause problems of :
- Distortion of the output voltage
- Harmonic generation into the supply system
- Interference with the communication & signaling circuits.
- It is normally necessary to introduce filters on the input & outpu converter system.
- This reduces the harmonic level to an acceptable magnitude.
- Figure 1.11 shows the block diagram of a generalized power conv
- The application of power electronics to supply the sensitive elec loads poses a challenge on the power quality issues.
- The input & output quantities of converters could be either ac or d
- Factors which are measures of the quality of a waveform are,
- Total Harmonic Distortion (THD).
- Displacement Factor (DF).
- Input Power Factor (IPF).
- To determine these factors, finding the harmonic content c waveforms is required.
- To evaluate the performance of a converter, the input & output vc & currents of a converter are expressed in a Fourier series.
- The quality of a power converter is judged by the quality of its v & current waveforms.
- The control strategy for the power converters plays an important p the harmonic generation & output waveform distortion.
- This control strategy can be aimed to minimize or reduce problems.
- The power converters can cause radio-frequency interference c electromagnetic radiation.
- This causes gating circuits to generate erroneous signals.
- This interference can be avoided by **grounded shielding**.
  (3 marks)

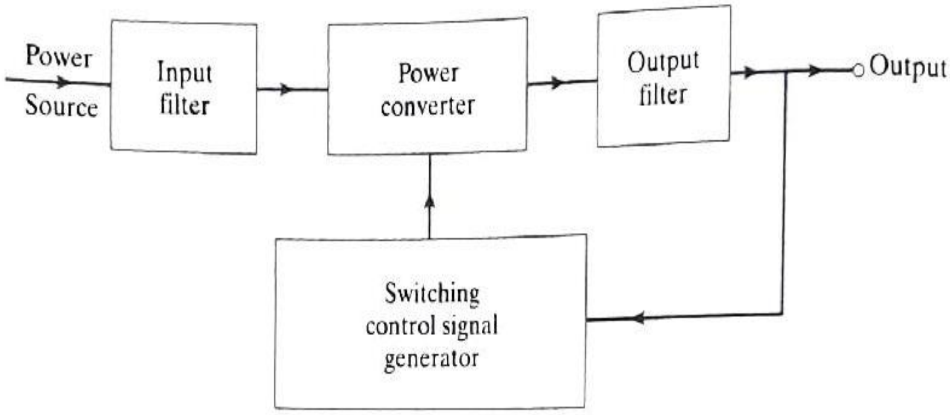


FIGURE 1.11

Generalized power converter system.

(2 marks)

6	With a neat circuit diagram and wave form , explain operation of power MOSFET and IGBT.	[10]	CO1	L2

Soln.

Power MOSFET (Circuit & explanation) = 5marks.

IGBT (Circuit & explanation) = 5 marks.

- A power MOSFET is a voltage-controlled device and requires only a small input current.
- The switching speed is very high and the switching times are of the order of nanoseconds.
- Power MOSFETs find increasing applications in low-power high-frequency converters.
- MOSFETs do not have the problems of second breakdown phenomena as do BJTs.
- But, MOSFETs have the problems of electrostatic discharge & require special care in handling.
- In addition, it is relatively difficult to protect them under short-circuited fault conditions.

- The 2 types of MOSFETs are :

1) Depletion MOSFETs and
2) Enhancement MOSFETs

- An n-channel depletion-type MOSFET is formed on a p-type silicon substrate as shown in Figure 4.1a.
- It has 2 heavily doped n+ silicon sections for low resistance connections.
- The gate is isolated from the channel by the thin oxide layer.
- The 3 terminals are called **gate**, **drain**, & **source**.
- The substrate is normally connected to the source.

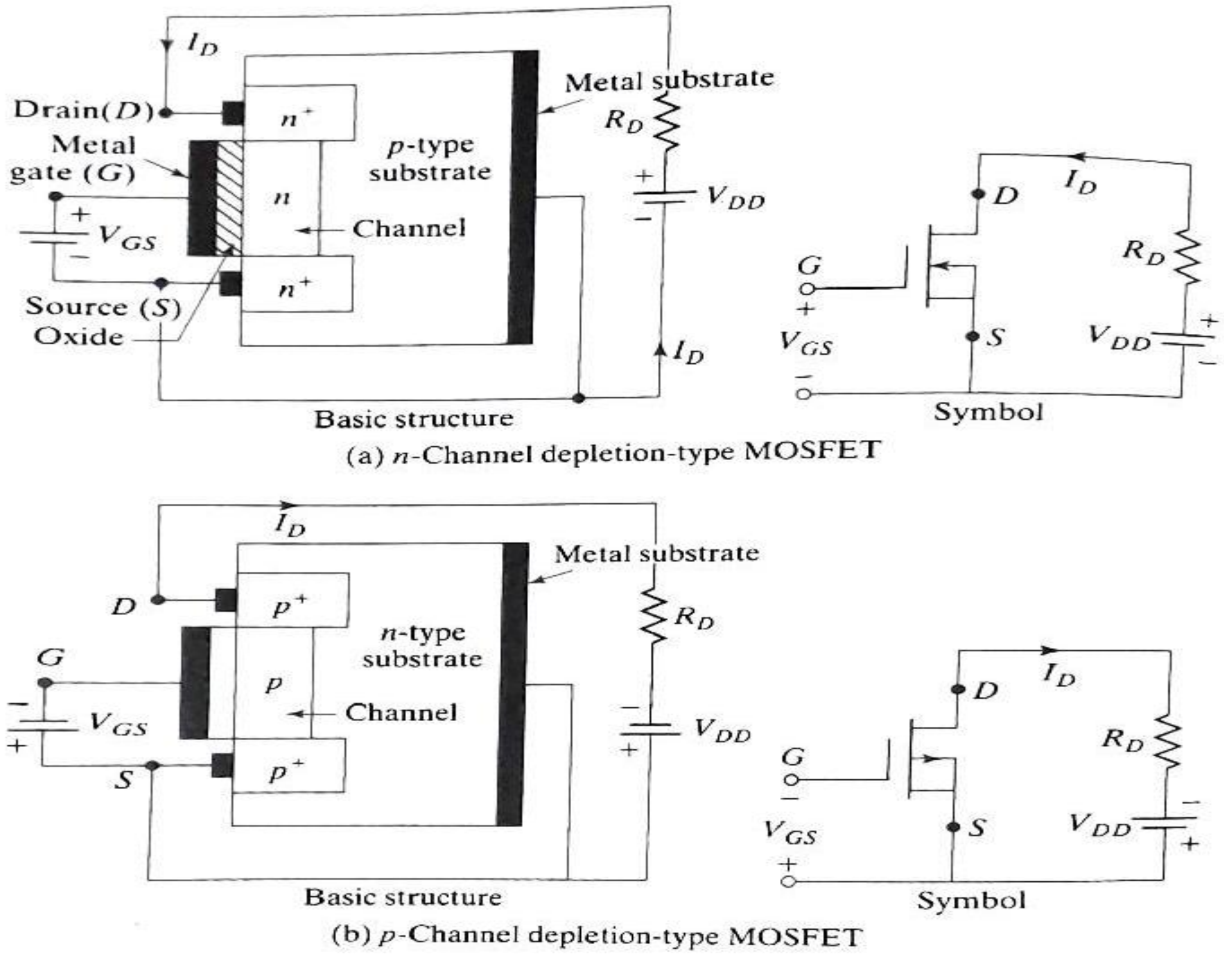
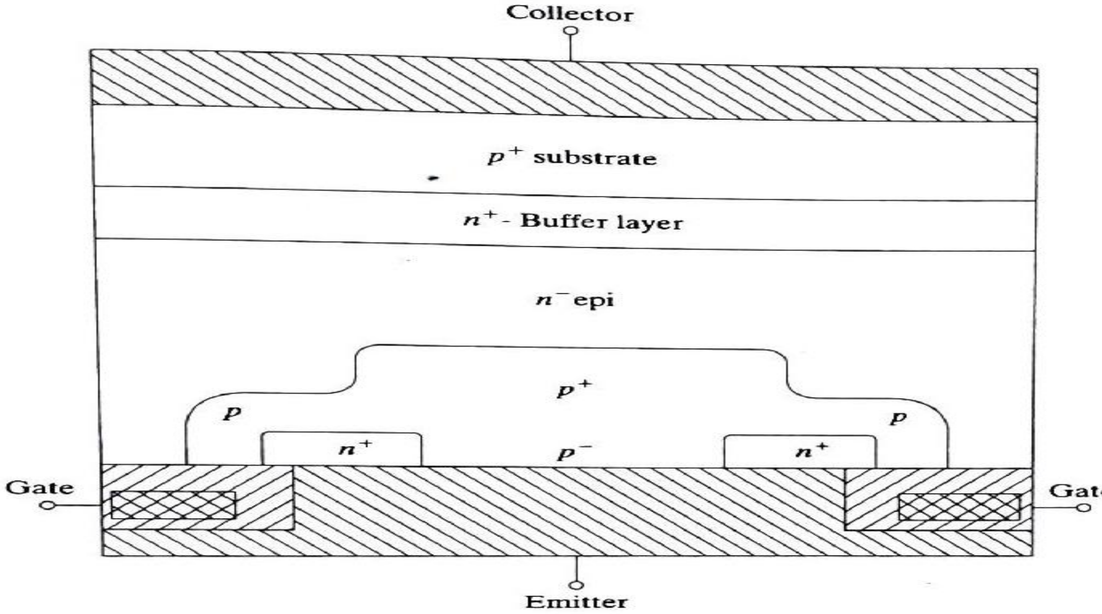
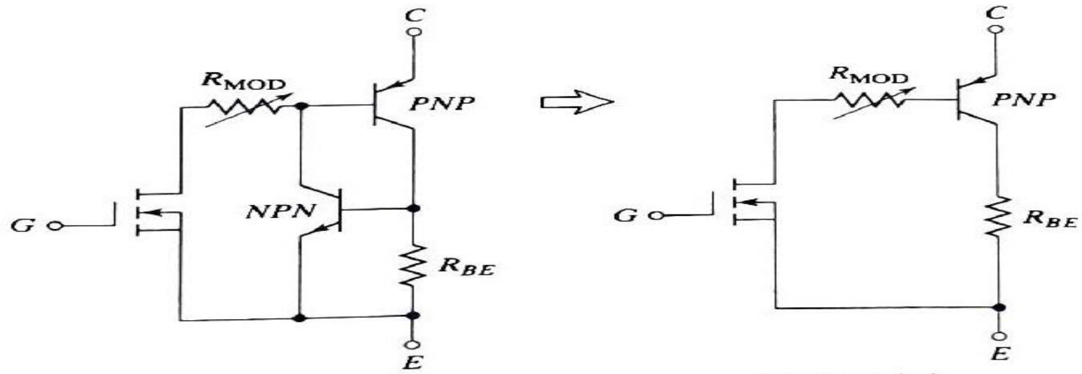


FIGURE 4.1
Depletion-type MOSFETs.

  - An IGBT combines the advantages of BJTs & MOSFETs.
  - An IGBT has high input impedance, like MOSFETs, and low on-state conduction losses, like BJTs.
  - However, there is no second breakdown problem, as with BJTs.
  - By chip design & structure, the equivalent drain-to-source resistance R_{DS} is controlled to behave like that of a BJT.
- The silicon cross section of an IGBT is shown in Figure 4.39a, which is identical to that of an MOSFET except for the p^+ substrate.
- The performance of an IGBT is closer to that of a BJT than an MOSFET.
- This is due to the p+ substrate, which is responsible for the minority carrier injection into the n-region.
- The equivalent circuit is shown in Figure 4.39b, which can be simplified to Figure 4.39c.



(a) Cross section



(b) Equivalent circuit

(c) Simplified circuit

FIGURE 4.39

Cross section and equivalent circuit for IGBTs.

NOTE : THE QUESTIONS SHOULD BE NEATLY WRITTEN & ANSWERED IN STUDENT'S OWN HANDWRITING. ON TOP OF EACH PAGE, WRITE YOUR NAME & USN BEFORE MAKING A PDF AND UPLOADING THE PDF IN GOOGLE CLASSROOM. TOTAL TIME TAKEN SHOULD NOT EXCEED 2 HOURS FOR BOTH ANSWERING & UPLOADING THE PDF (1.5 HOURS FOR ANSWERING + 0.5 HOURS FOR UPLOADING PDF). PDF SUBMITTED AFTER 2 HOURS OR NOT AS PER THE ABOVE INSTRUCTIONS WILL NOT BE VALUATED AND MARKS ALLOTED WILL BE ZERO FOR THE TEST.

ALL THE BEST