Chapter 3

Bipolar Junction Transistors

CHAPTER HIGHLIGHTS

- *Introduction*
- *Transistor Construction*
- *Transistor Current Components*
- *Transistor Current Components for p – n – p Transistor*
- *Operation Modes of Transistor*
- *Transistor Configurations*
- *Transfer Characteristics*
- *Early Effect or Base – Width Modulation*
- *Characteristic of a CE Configuration*
- *Comparison of Various Characteristics of Transistor*
- *Transistor and its Region of Operations*
- *Active Region*
- *Saturation Region*
- *Modes of Operation of BJT*
- *Thermal Run Away*
- *Power Rating of Transistor*

Introduction

When a third doped element is added to a diode, two P-N junctions are formed, and the resulting device is known as a transistor.

In 1948, J. Barden and W. H. Brattain of Bell Laboratories, USA, invented transistors, which are smaller than vacuum tubes.

Transistor Construction

A transistor consists of two P-N junctions formed by sandwiching either P-type or N–type semiconductor between a pair of opposite types. There are two types of transistors, namely N-P-N transistor and P-N-P transistor.

An N-P-N transistor is composed of two N–type semiconductor separated by a thin section of P-type.

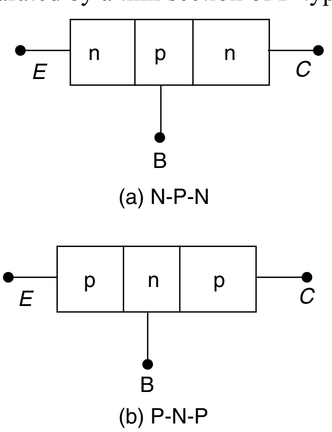


Figure 1 Types of transistors

1. The emitter is heavily doped, the base is lightly doped, and the collector is moderately doped. According to area, emitter is moderate, base is very thin, and collector is large to dissipate heat.
2. A transistor has two P-N junction, one junction is forward biased and the other junction is reverse biased. The forward-biased junction has a low resistance path, whereas a reverse-biased junction has a high-resistance path. The weak signal is introduced at the low-resistance circuit, and output is taken from the high-resistance circuit. Therefore, a transistor transfers a signal form low resistance to high resistance.

That is, Transistor → Transfer + Resistor

A transistor has three sections of doped semiconductors. The section on one side is the emitter and the section on the opposite side is the collector. The middle section is called the base. It forms two junctions between the emitter and collector.

(a) Emitter: The section on one side that supplies charge carriers (electrons or holes) is called the emitter. The emitter is always forward biased with refer to the base, so that it can supply a large number of majority carriers.

(b) Base: The middle section that forms two P-N junctions between the emitter and collector is called the base. The base–emitter junction is forward biased, thus allowing low resistance for the emitter circuit. The base–collector junction is reverse biased. Hence, it provides high resistance in the collector circuit.

(c) Collector: The section on the other side that collects the charges is called the collector. The collector is always reverse biased.

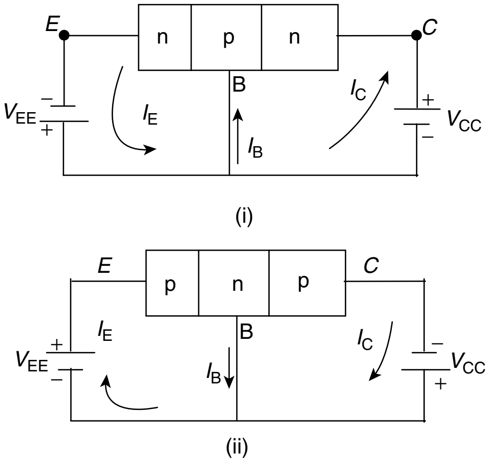


Figure 2 Types of transistors (i) N-P-N (ii) P-N-P

The transistor has two P-N junctions, that is, it is like two diodes. The junction between emitter and base may be called emitter–base diode, or emitter diode. The junction between the base and collector may be called collector–base diode, or collector diode. The emitter diode is always forward biased, and the collector diode is always reverse biased.

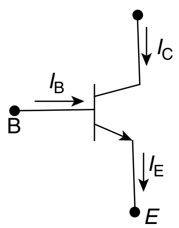
Therefore, the transistor offers very low-input impedance and high-output impedance.

$$R_{in} \rightarrow \text{low}$$

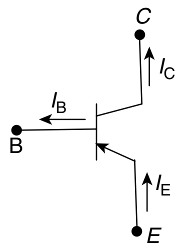
$$R_o \Rightarrow \text{High}$$

Transistor Symbols

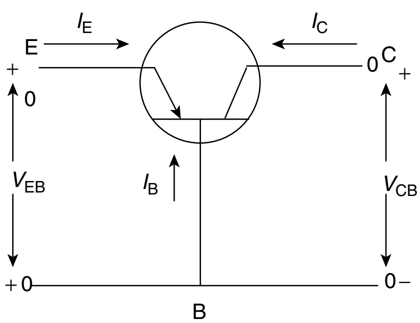
1. N-P-N transistor



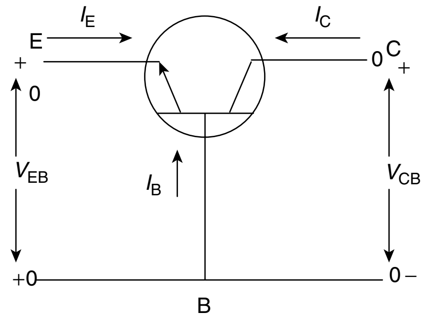
2. P-N-P transistor



Transistor Current Components



P-N-P

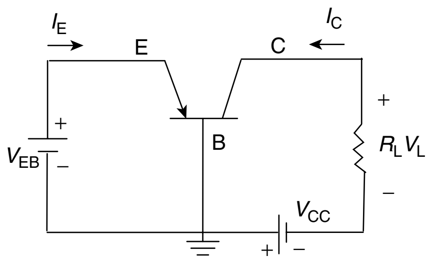


N-P-N

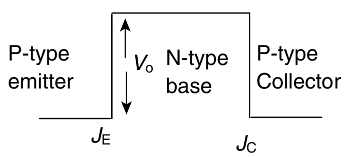
Circuit representation of the two transistor types

The emitter, base, and collector currents I_E, I_B, and I_C, respectively, are assumed to be positive when the current flows into the transistor.

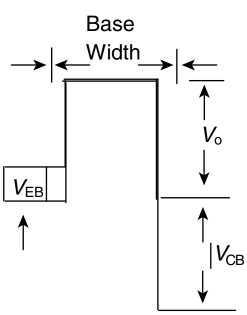
1. For P-N-P transistor
   I_E: positive (into)
   I_B: negative (away)
   I_C: negative (away)



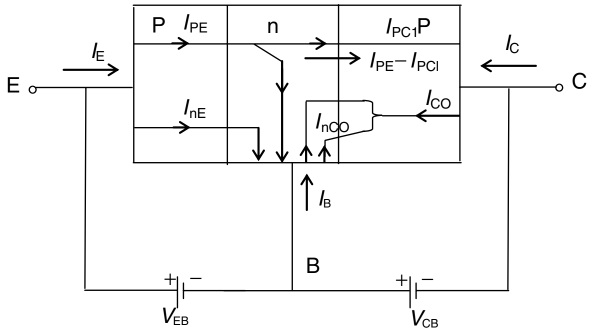
2. For N-P-N transistor:
   I_E: negative (away)
   I_B: positive (into)
   I_C: positive (into)
   Unbiased condition is shown as follows:



Biased condition is shown as follows:



Transistor Current Components for P-N-P Transistor



KCL at the input junction gives

$$I_E = I_{PE} + I_{nE}$$

Not all the holes crossing the emitter junction J_E reach the collector junction J_C, because some of them combine with the electrons in the N-type base.

$$-I_{CO} = I_{nco} + I_{PCO}$$

KVL at the collector junction gives

$$-I_C = I_{co} - I_{PCl} = I_{CO} - \alpha I_E$$

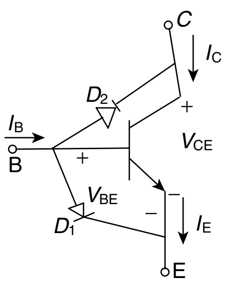
1. Emitter efficiency $\gamma^* = \dfrac{I_{PE}}{I_E}$

2. Transport factor $\beta = \dfrac{I_{PC}}{I_{PE}}$

3. Current gain $\alpha = \dfrac{I_{PC}}{I_{IE}} = \dfrac{I_{PC}}{I_{PE}} \times \dfrac{I_{PE}}{I_E}$

$$\therefore \boxed{\alpha = \beta\gamma^*}$$

Operation Modes of Transistor



$I_E = I_C + I_B$

$I_E \approx I_C$.

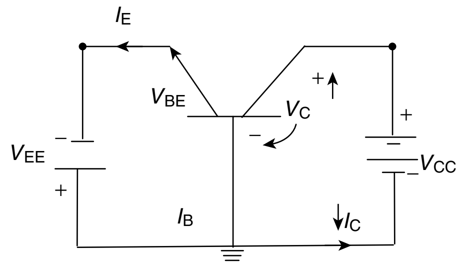
But $I_C < I_E$

1. Active region
   Base–emitter junction forward biased, and collector junction is reverse biased.
   i.e., $D_1 \rightarrow$ ON
   $D_2 \rightarrow$ OFF
   In this mode, transistor works as an amplifier
2. Cut-off region
   In this region, both emitter junction and collector junction are in reverse biased.
   $\therefore D_1 \rightarrow$ OFF
   $\Rightarrow D_2 \rightarrow$ OFF
   i.e., it is OFF switch
3. Saturation region
   In this region, both junctions are in forward biased.
   i.e., $D_1 \rightarrow$ ON
   $\Rightarrow D_2 \rightarrow$ ON
   At $V_{CE} = 0V \approx 0.2V$ for Si.

Transistor Configurations

Common Base Configuration

The base is common to both input and output sides of the configuration.



The arrow in the transistor symbol represents the direction of the emitter current. In this circuit, input is applied between emitter and base, and output is taken from collector and base.

$$I_E = I_C + I_B$$

$$\alpha = \frac{\Delta I_C}{\Delta I_E} \text{ at } V_{CB} \text{ constant}$$

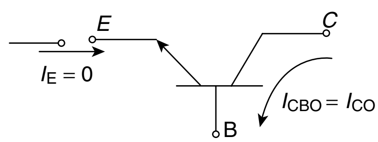
Where $\alpha \rightarrow$ current amplification factor.

It is the ratio of change in output current (I_C) to change in input current (I_E) at constant V_{CB}.

$$\therefore \quad \alpha = \frac{\Delta I_C}{\Delta I_E} \text{ at } V_{CB} = \text{constant}$$

$\alpha < 1$

α ranges from 0.9 to 0.99



Reverse saturation current

Where $I_{CBO} \Rightarrow$ collector to base emitter open circuit current

i.e., reverse saturation current

Total current $I_C = \alpha I_E + I_{CBO}$

but $I_E = I_C + I_B$

$$\therefore I_C = \alpha [I_C + I_B] + I_{CBO}$$

$$I_C(1-\alpha) = \alpha I_B + I_{CBO}$$

$$I_C = \frac{\alpha}{1-\alpha}.I_B + \frac{I_{CBO}}{1-\alpha}$$

Transfer Characteristics

1. Input characteristics

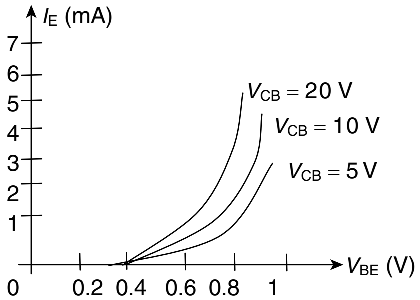


Figure 3 Input or driving point characteristics for a CB silicon transistor amplifier

It is the curve between the I_E and V_{BE} at constant V_{CB}. V_{CB} increases I_E curves moves towards left.

2. Output characteristics:

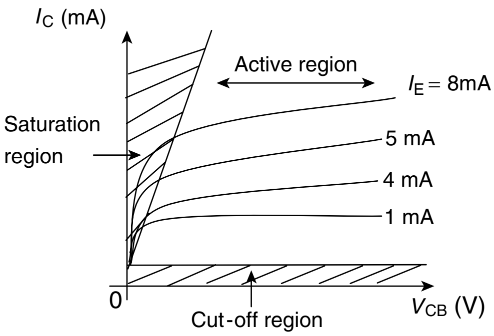


Figure 4 CB – output characteristics

From the characteristics, it is observed that for a constant value of I_E, I_C is independent of V_{CB} and the curves are parallel to the axis of V_{CB}. I_C flows even when V_{CB} is equal to zero.

Early effect or base–width modulation

As the collector voltage, V_{CB} is made to increase the reverse bias, the space charge width between the collector and base is increased, with the result that the effective width of the base decreases, this effect is known as early effect

$$\text{Input resistance, } r_i = \frac{\Delta V_{BE}}{\Delta I_E} \text{ at constant } V_{CB}$$

$$\text{Output resistance } r_0 = \frac{\Delta V_{CB}}{\Delta I_C} \text{ at constant } I_E$$

r_i of CB circuit quite small in the order of a few 'Ω's

r_0 is very large, in the order of $k\Omega$, that is, R_i small and R_0 high compare to others.

Solved Examples

Example 1

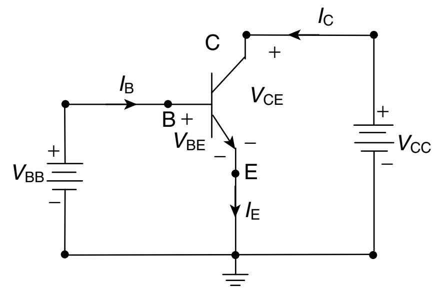
The early effect in a bipolar junction transistor is caused by

(A) Fast turnoff
(B) Fast turn on
(C) Large collector–base reverse bias
(D) Large V_{EB} forward bias

Solution: (C)

Common Emitter Configuration

1. N-P-N



2. P-N-P

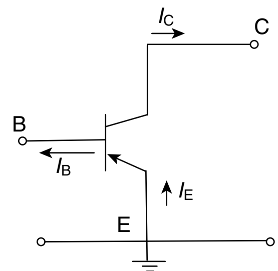


Figure 5 Notations and symbols used with the CE-configuration

In this circuit, input is applied between base and emitter, and output is taken form the collector and emitter.

Characteristic of a CE Configuration

1. Input or base characteristics

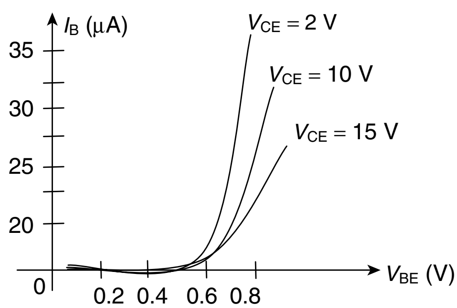


Figure 6 Si transistor input characteristics

Input resistance

$$R_i = \frac{\Delta V_{BE}}{\Delta I_B} \text{ at constant } V_{CE} \text{ and } T$$

The values of input resistance for a CE amplifier are in the order of a few hundreds of ohms.

2. Output or collector characteristics

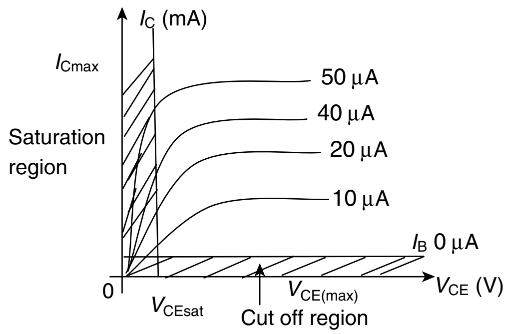
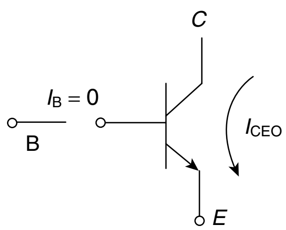


Figure 7 Collector characteristics

In the active region of a CE amplifier, the base emitter junction is forward biased, whereas the collector–base junction is reverse biased.

(a) Leakage current



Where I_{CEO} ⇒ base open circuit collector to emitter current in CE amplifier, a small current flows, even when the $I_B = 0$

This is called collector cut-off current and is denoted by I_{CEO}.

$$(I_{CEO} >> I_{CBO})$$

(b) Base current amplification factor (β)

The ratio of change in collector current (ΔI_C) to the change in base current (ΔI_B) is known as current amplification factor.

$$\beta = \frac{\Delta I_C}{\Delta I_B}$$

β ranges generally from 20 to 500.

If D. C. values are considered,

$$\beta = \frac{I_C}{I_B}$$

(c) Expression for collector current

We know

$$I_E = I_B + I_C$$

$$I_C = |\alpha I_E| + I_{CBO}$$

$$I_C = \alpha(I_B + I_C) + I_{CBO}$$

$$\therefore I_C = \frac{\alpha}{1-\alpha} \cdot I_B + \frac{I_{CBO}}{1-\alpha}$$

$$I_C = \beta I_B + I_{CEO}$$

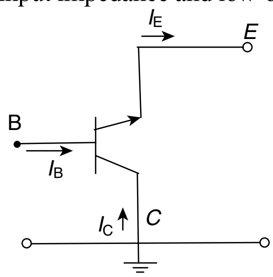
From the above equation

$$\beta = \frac{\alpha}{1-\alpha} \text{ and } I_{CEO} = \frac{I_{CBO}}{1-\alpha}$$

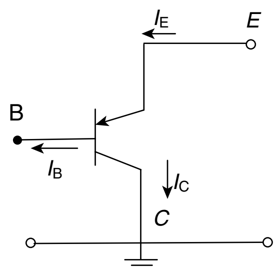
$$\text{or } I_{CEO} = (1+\beta) \,.\, I_{CBO}$$

Common Collector Configuration

The CC configuration is used for impedance matching circuits, and it has a high-input impedance and low-output impedance.



(a) N-P-N



(b) P-N-P

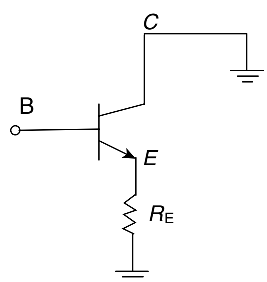


Figure 8 CC configuration used for impedance matching purpose

The maximum power dissipation is equal to $P_{C(max)} = V_{CE}$. I_C

1. Current amplification factor

   The ratio of change in emitter current (ΔI_E), to the change in base current (ΔI_B) is known as current amplification factor in common collector.

$$\gamma_{ac} = \frac{\Delta I_E}{\Delta I_B}$$

   The voltage gain of CC amplifier is always less than one

2. Relation between α, β, and γ

   For d. c

$$\alpha = \frac{I_C}{I_B}, \beta = \frac{I_C}{I_B}$$

And $\gamma = \dfrac{I_E}{I_B}$

$$\alpha = \frac{\beta}{1+\beta}\ ;\ \beta = \frac{\alpha}{1-\alpha}\quad \gamma = \frac{1}{1-\alpha}$$

and $\gamma = 1 + \beta$

The currents always following the below relation.

$I_E : I_B : I_C = 1 : (1 - \alpha) : \alpha$.

Comparison of Various Characteristics of Transistor

	Characteristics	CB	CE	CC
1.	R_i	Low (Ω's) < 100Ω	Low (Ω's) < 100Ω	Very high (kΩ's) < 100kΩ
2.	R_0	Very high (about 500kΩ)	High (about 50kΩ)	Low (about 50Ω)
3.	Voltage gain	Av ≈ 150	Av ≈ 500	Av < 1
4.	Current gain	$A_i < 1$ (α)	High (β)	High (γ)
5.	Applications	For high frequency applications	For audio frequency applications	Impedance matching

From the above analysis

$R_i \rightarrow$ Low for CB configuration (compare to others)

$R_i \rightarrow$ Very high for CC configuration

Output impedance (R_0)

$R_0 \rightarrow$ low for CC configuration

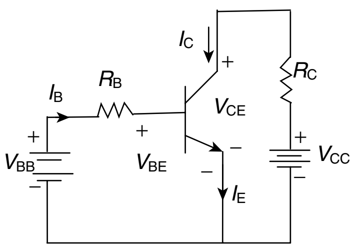
$R_0 \rightarrow$ very high for CB configuration

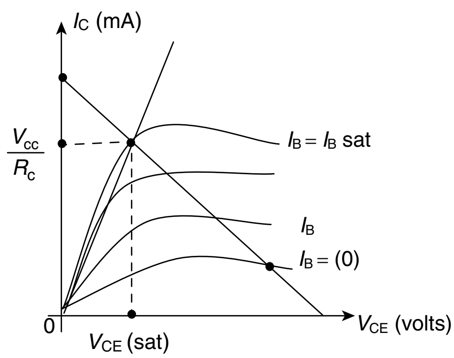
Out of the three transistor connections, the common emitter circuit is the most efficient and the main reasons for this usage are as follows:

1. High current gain
2. High-voltage and power gain
3. Moderate output to input ratio.
   (i.e., R_0/R_i less compare to others)

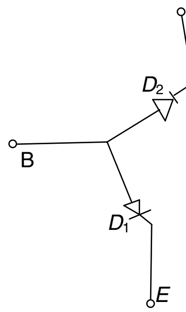
Transistor and its Region of Operations

CE transistor circuit and the output characteristic along with the d. c. load line.

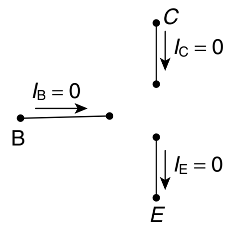




1. Cut-off



In this region, both emitter diode (D_1) and collector diode (D_2) are in OFF state. i.e.,



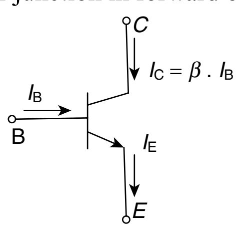
Transistor in cut-off mode

The point where the load line intersects the $I_B = 0$ curve is known as cut-off. At this point, $I_B = 0$ and only small collector current or leakage current I_{CEO} exists.

$$\therefore V_{CE\,(cut\text{-}off)} = V_{CC}.$$

2. Active region

The region between the cut-off and saturation is known as active region. In this region, collector–base junction remains reverse biased ($D_2 \rightarrow$ OFF) and base–emitter junction in forward biased ($D_1 \rightarrow$ ON).

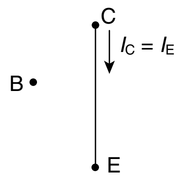


i.e., In active region, emitter diode is ON and collector diode is OFF.

NOTE

We provide biasing to the transistor to it operates in the active region.

3. Saturation region
   In this region, both the junctions are in forward biased and normal transistor action is lost.
   i.e., emitter diode and collector diodes are ON.
   At $V_{CE} \approx 0V$



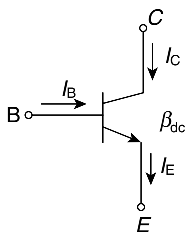
$$\therefore I_C\ (\text{sat}) = \frac{V_{CC}}{R_C}$$

$$V_{CE} = V_{CE}(\text{sat}) = V_{\text{knee}}.$$

V_{CE}(sat) or V_{knee} can be neglected as compared to V_{CC}.
At room temperature, V_{CE} drop of a silicon transistor at saturation is approximately $V_{CE(sat)} = 0.3V$

Example 2

If the transistor in the figure is in saturation, then



(A) $I_C = \beta_{dc} \cdot I_B$ (B) $I_C < \beta_{dc} \cdot I_B$
(C) $I_C \geq \beta_{dc} \cdot I_B$ (D) None of the above

Solution

In active region, $I_C = \beta \cdot I_B$

In saturation region, $I_{C(Sat)} < \beta \cdot I_B$.

Example 3

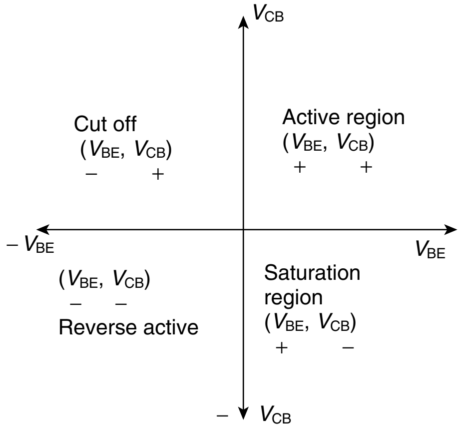
If for a si N-P-N transistor, the $V_{BE} = 0.7$ V and $V_{CB} = 0.2$ V, then the transistor is operating in the

(A) Cut-off region
(B) Active region
(C) Saturation region
(D) Inverse active mode

Solution

$V_{BE} = 0.7$ V
i.e., $V_B - V_E = 0.7$ V
$\therefore V_B > V_E \Rightarrow$ emitter diode forward bias
$V_{CB} = 0.2$ V
$\Rightarrow V_C > V_B \Rightarrow$ collector junction is in reverse bias.
Therefore, the transistor is in the normal active mode

Modes of Operation of BJT



NOTES

1. For a silicon transistor generally considered

$$V_{CE(sat)} = 0.2\ \text{V}$$
$$V_{BE(active)} = 0.7\ \text{V and}$$
$$V_{BE(sat)} = 0.8\ \text{V}$$

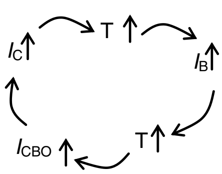
2. For Ge transistor,

$$V_{CE(sat)} = 0.1\ \text{V}$$
$$V_{BE(active)} = 0.2\ \text{V}$$
$$V_{BE(sat)} = 0.3\ \text{V and}$$
$$V_{BE(cut\ off)} = 0\ \text{V}$$

Thermal Run Away

The collector $I_C = \beta. I_B + (1 + \beta). I_{CBO}$. The three variables in the equation β, I_B, and I_{CBO} increases with rise in temperature. The reverse saturation current I_{C0} is more sensitive with temperature, it doubles for every 10°C raise in temperature, and as a result, I_C will increase still further.

Which will further rise the temperature at the collector–base junction. This process is called as 'thermal run away'.



The collector is normally larger in size than the others because to help dissipate the heat developed at the collector junction.

Example 4

To avoid thermal run away in the design of an analogue circuit, the operating point of the BJT should be such that it satisfies the condition.

(A) $V_{CE} = \frac{V_{CC}}{2}$ (B) $V_{CE} \geq \frac{V_{CC}}{2}$

(C) $V_{CE} < \frac{V_{CC}}{2}$ (D) None of the above

Solution: (C)

Power Rating of Transistor

The maximum power that a transistor can handle without destruction is known as power rating of the transistor.

The maximum power dissipated by

$$P_{max} = I_C \cdot V_{CE(max)}$$

If $V_{CE} > V_{CE(max)}$, the transistor will be destroyed due to excessive heat.

Example 5

The maximum power dissipation of a transistor is 80 mW. If V_{CE} = 10 V, the maximum collector current that can be allowed without destruction of the transistor is

(A) 5 mA. (B) 7 mA.
(C) 8 mA. (D) 10 mA.

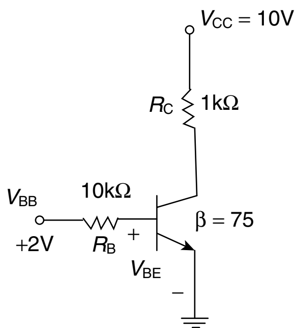
Solution

We know, $P_{D(max)} = I_{C(max)} \cdot V_{CE}$

$$I_{CE(max)} = \frac{80\text{mW}}{10\text{V}} = 8 \text{ mA}.$$

Example 6

For the circuit shown in figure



The power dissipation in the transistor is

(A) 2 mW. (B) –2.8 mW.
(C) 2.43 mW. (D) 3 mW.

Solution

Apply KVL to the input loop

$$I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{1.3}{10 \text{ k}\Omega} = 0.13 \text{ mA}$$

$$I_{C(active)} = \beta \,.\, I_B = 75 \times 0.13 \text{ mA.} = 9.75 \text{ mA}$$

$$V_{CE} = V_{CC} - I_C \,.\, R_C = 10 - 9.75 = 0.25 \text{ V}$$

$$P_D = I_C \,.\, V_{CE} = 9.75 \times 0.25 \text{ mW} = 2.43 \text{ mW}.$$

Example 7

In a CB configuration, current configuration factor is 0.9, if the emitter current is 1.8 mA. The value of I_B is

(A) 1.17 mA. (B) 0.18 mA.
(C) 13 μA. (D) 1.3 mA.

Solution

We know, $\alpha = \frac{I_C}{I_E}$

$$I_C = \alpha I_E = 0.9 \times 1.8 \text{ mA} = 1.62 \text{ mA}$$

$$I_B = I_E - I_C = 0.18 \text{ mA}$$

Example 8

For a certain transistor, I_B = 15 μA, I_C = 2 mA and β = 100. The value of leakage current I_{CBO} is

(A) 4.95 μA. (B) 5 μA.
(C) 3 μA. (D) 4.95 mA.

Solution

We know

$$I_C = \beta \,.\, I_B + (1 + \beta) \,.\, I_{CBO}$$

$$I_{CBO} = \frac{0.5}{101} \text{ mA} = 4.95 \text{ μA}.$$

Example 9

In a junction transistor, the collector cut-off current I_{CBO} reduces considerably by doping the

(A) emitter with low level of impurity.
(B) emitter with high level of impurity.
(C) collector with high level of impurity.
(D) base with high level of impurity.

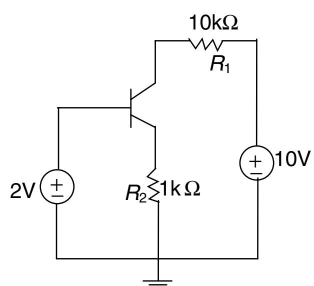
Solution

We know, $I_C = \alpha I_E + I_{CBO}$

$$\alpha = \frac{I_C - I_{CBO}}{I_E} \Rightarrow \alpha \uparrow \Rightarrow I_{CBO} \downarrow$$

Example 10

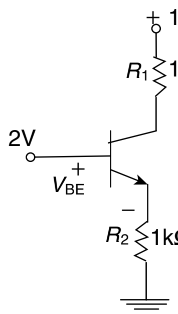
For a BJT circuit shown, assume that the 'β' of the transistor is very large of V_{BE} = 0.7 V. The mode of operation of the BJT is



(A) Cut-off region (B) Saturation region
(C) Normal active (D) Reverse active

Solution

Let us assume transistor is in saturation region.



$$I_{C(sat)} = \frac{10}{11} \text{mA}$$

Apply KVL in i/p loop

$$V_{BB} = V_{BE} + I_C \,.\, R_2$$

$$V_{BE} = 2 - 0.909 = 1.09 \text{ V}$$

$\therefore$ $V_{BE} > 0.7$ so transistor is in saturation mode.

Example 11

In a certain transistor, I_C = 0.98 mA and I_B = 20 mA. Determine (i) I_E , (ii) α, and (iii) β

Solution

(i) $I_E = I_B + I_C = 0.98 + 0.02$

$I_E = 1.0$ mA

(ii) $\alpha = \frac{I_C}{I_E} = \frac{0.98}{1.0} = 0.98$

(iii) $\beta = \frac{I_C}{I_B} = \frac{0.98}{0.02} = 49$

Example 12

A BJT has I_B = 10µA, β = 99 and I_{CO} = 1 µA. What is the collector current I_c

Solution

$$I_C = \beta I_B + (1 + \beta)\, I_{CBO}$$

$$= 99 \times 10 \times 10^{-6} + (1 + 99)\ 1 \times 10^{-6}$$

$$I_C = 1.09 \text{ mA}$$

Example 13

Determine the emitter current. I_E, collector current I_C for a transistor with α_{dc} = 0.97 and collector to base leakage current 10 µA, I_B is 50 µA.

Solution

$$I_C = \beta\, I_B + (\,1 + \beta)\, I_{CBO}$$

$$\beta = \frac{\alpha}{1 - \alpha} = \frac{0.97}{1 - 0.97}$$

$$\beta = 32.33$$

$$I_C = 32.33 \times 50 \times 10^{-6} + (1 + 32.33) \times 10 \times 10^{-6}$$

$$I_C = 1.95 \text{ mA}$$

$$I_E = I_B + I_C = 2 \text{ mA}$$

Example 14

In a particular transistor, the collector current is 5.6 mA and emitter current is 5.75 mA. Determine α_{dc}

Solution

$$I_C = 5.6 \text{ mA}$$

$$I_E = 5.75 \text{ mA}$$

$$\alpha_{dc} = \frac{I_C}{I_E} = 0.974.$$

Example 15

A BJT has a base current of 200 µA and emitter current of 20 mA. Determine collector current and β

Solution

$$I_B = 200\ \mu\text{A}$$

$$I_E = 20 \text{ mA}$$

$$I_c = I_E - I_B = 20 \times 10^{-3} - 200 \times 10^{-6}$$

$$I_C = 19.8 \text{ mA}$$

$$\beta = \frac{I_C}{I_B}$$

$$\beta = 99$$

Example 16

A BJT has a collector current of 4 mA and base current of 20 µA. Determine its β.

Solution

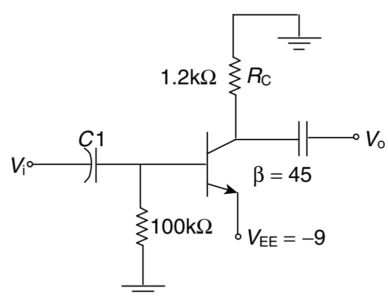
$$I_C = 4 \text{ mA}$$

$$I_B = 20\ \mu\text{A}$$

$$\beta = \frac{I_C}{I_B} = 200.$$

Example 17

Determine V_C and V_B for the network



Solution

$$-I_B R_B - V_{BE} + V_{EE} = 0$$

$$I_B = \frac{V_{EE} - V_{BE}}{R_B} = \frac{9-.7}{100k\Omega} = \frac{8.3}{100k\Omega} = 83\mu A$$

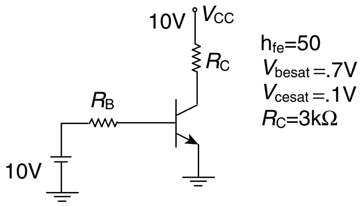
$$I_C = \beta I_B = 45 \times 83\ \mu A = 3.735\ mA$$

$$V_C = -I_C R_C = -(3.735mA)\ (1.2\ k\Omega) = -4.48\ V$$

$$V_B = -I_B R_B = -(83\mu A)\ (100k\Omega) = -8.3\ V.$$

Example 18

For the given circuit find the value of R_B that be just sufficient to drive the transistor to saturation?



Solution

The value of R_B required to drive the transistor to saturation.

$$I_C \le h_F \in \times \frac{V_{BB} - V_B sat}{R_B}$$

$$R_B \le 50 \times \frac{10-.7}{I_C}$$

$$V_{CC} = I_C R_C$$

$$I_C = \frac{10}{3k\Omega} = 3.33mA$$

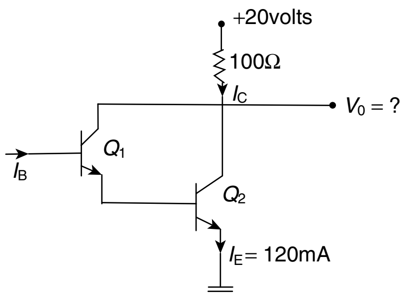
$$R_B \le \frac{50 \times 9.3}{3.33mA} = 139k\Omega\ \sim 140\ k\Omega$$

Exercises

Practice Problems I

Direction for questions 1 to 24: Select the correct alternative from the given choices.

Direction for questions 1 and 2:



Assume both transistors are in active region and neglect reverse saturation currents.

If $\alpha_1 = 0.99$ and $\alpha_2 = 0.98$

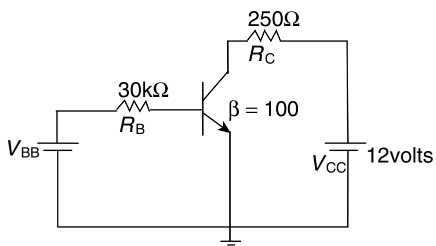
1. The value of V_0 shown is

(A) 6 volts (B) 12 volts
(C) 8 volts (D) 10 volts

2. The value of overall β is $\left(\frac{I_C}{I_B}\right)$ is

(A) 5000 (B) 5001
(C) 4999 (D) 4998

Direction for questions 3 and 4:



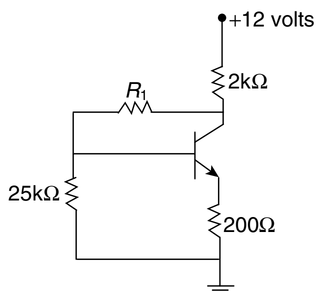
3. If $V_{CE} = 6$ volts, the value of V_{BB} required is ____

(A) 7 volts (B) 7.9 volts
(C) 8 volts (D) 7.8 volts

4. If V_{CC} is changed to 6 volts in the given circuit, the value of R_C required to achieve the Q – point Q(2 volts, 16 mA).

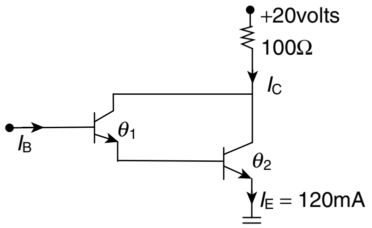
(A) 200 Ω (B) 250 Ω
(C) 2.5 kΩ (D) 2 kΩ

5.



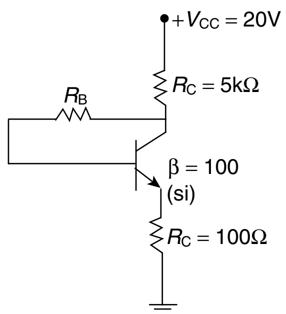
If $\alpha = 0.98$ and $V_{BE} = 0.7$ volts, the value of resistor R_1 for an emitter current of 2 mA is ______
(A) 81.1 kΩ (B) 8.11 kΩ
(C) 44 kΩ (D) 19.6 kΩ

6.



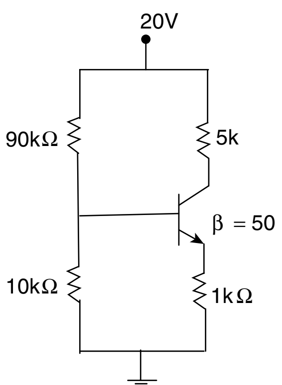
Assume both transistors are in active regions. If $\alpha_1 = 0.99$ and $\alpha_2 = 0.98$, then the value of overall $\alpha \left(\dfrac{I_C}{I_E}\right)$ is ______
(A) 0.99 (B) 0.9998 (C) 0.998 (D) 0.98

7.



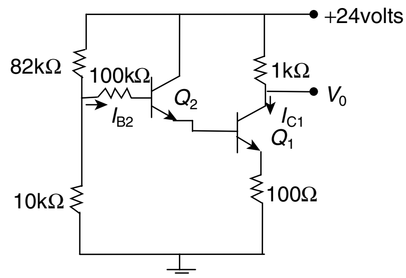
Assume the transistor is in active region. If V_{CE} = 4volts, find the value of R_B.
(A) 100 kΩ (B) 106 kΩ
(C) 104 kΩ (D) 98 kΩ

8.



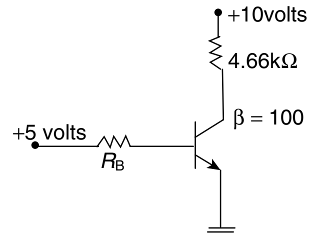
Assume the transistor is in active region. The value of collector current. I_C is ______
(A) 2 mA (B) 1.085 mA
(C) 1.85 mA (D) 0.021 mA

9.



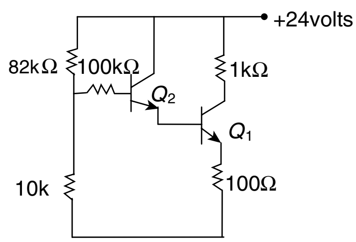
Assume both transistor are in active region with $V_{BE1} = V_{BE2} = 0.7$ volts. $\beta_1 = 100$ and $\beta_2 = 50$. The ratio of I_{C1}/I_{B2} is ______
(A) 5000 (B) 5100
(C) 4900 (D) 490

10.



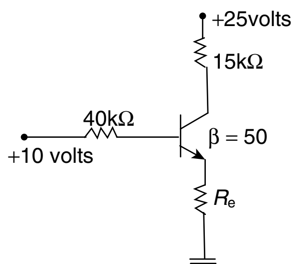
The maximum value of R_B for which the transistor remains at saturation is ______
(A) 20 kΩ (B) 2 kΩ
(C) 200 kΩ (D) 20 Ω

11.



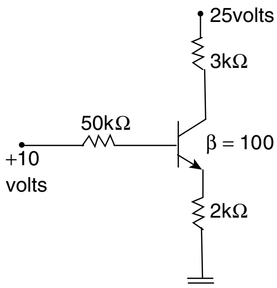
Assume both transistor are in active region with $\beta_1 = 100$, $\beta_2 = 50$ and $V_{BE1} = V_{BE2} = 0.7$volts. The value of V_{CE} of Q_1 is
(A) 14.1 volts (B) 13.1 volts
(C) 14.9 volts (D) 13.9 volts

12.



The value of R_e, for which the transistor just comes out of saturation region.
(A) 742 Ω (B) 7.42 kΩ
(C) 472 Ω (D) 4.72 kΩ

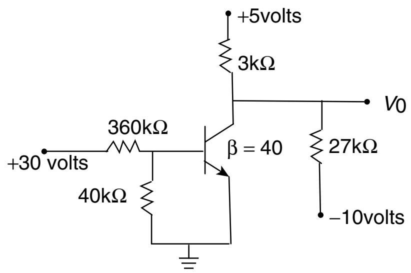
13.



Find the region of operation of transistor shown.

(A) cut-off (B) saturation
(C) Active (D) inverse active

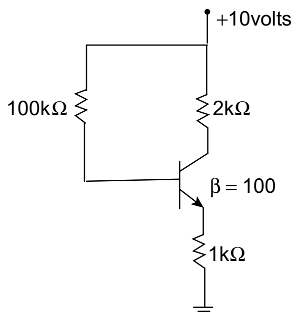
14.



Find the region of operation of the transistor, shown.

(A) Active (B) Saturation
(C) Cut-off (D) Reverse active

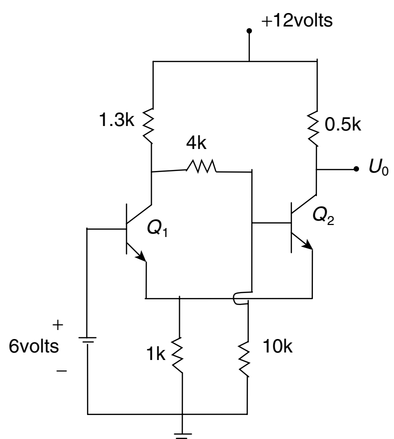
15.



Neglect the junction voltages. The transistor is operating in ———region.

(A) Active (B) Saturation
(C) Reverse Saturation (D) Cut-off

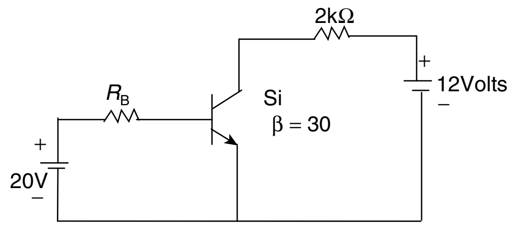
16.



Assume β of each transistor is 100. Find the value of V_0 is

(A) 8.5 volts (B) 12 volts
(C) 7.5 volts (D) 9 volts

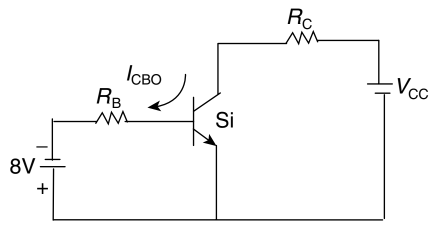
17.



For what values of R_B will the transistor remain below cut-off region if $I_{CBO} = 100\mu A$

(A) $R_B \leq 200$ kΩ (B) $R_B \geq 200$ kΩ
(C) $R_B \leq 100$ kΩ (D) $R_B \geq 10$ kΩ

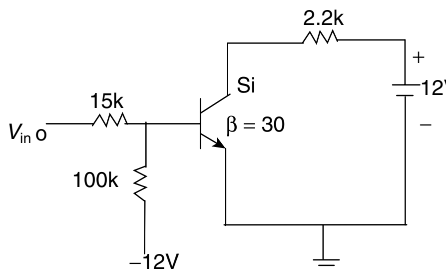
18.



If the reverse saturation current of Si transistor is 10nAmp at room temperature (25°C) and increases by a factor of 2 for each temperature increase of 10°C. The maximum allowable value for R_B if the transistor is to remain cut-off at a temperature of 185°C_______

(A) 122 kΩ (B) 12.2 kΩ
(C) 12.2 MΩ (D) 1.22 MΩ

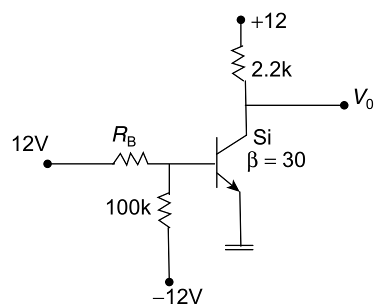
19.



Find V_{CE} if $V_{in} = 12$ volts

(A) 8.8 volts (B) 0.2 volts
(C) 11.8 volts (D) 3.8 volts

20.



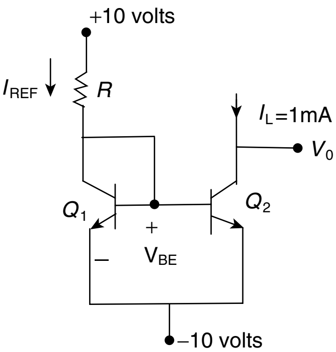
Find minimum value of R_1 for which the transistor is in the active region.

(A) 17 kΩ (B) 27 kΩ
(C) 37 kΩ (D) 33 kΩ

21. Find the punch through voltage of a NPN silicon Transistor of alloy type, if the width of base region is 2 μm and resistivity of base is 1Ωcm.

(A) 38 volts
(B) 10 volts
(C) 28 volts
(D) 18 volts

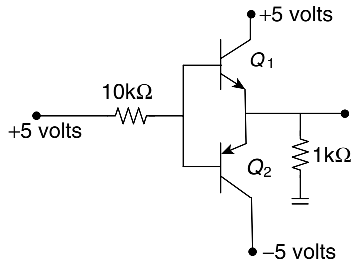
22.



Find the value R, such that load current is equal to 1mA.

(A) 10 kΩ (B) 9.3 kΩ
(C) 19.3 kΩ (D) 10.7 kΩ

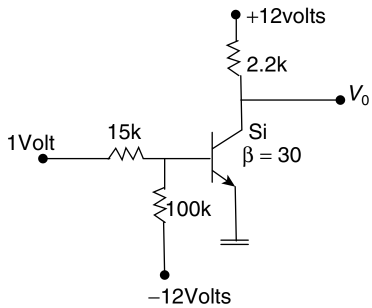
23.



If β of each transistor is 100, find V_0.

(A) +4 volts (B) +5 volts
(C) –4 volts (D) –5 volts

24.



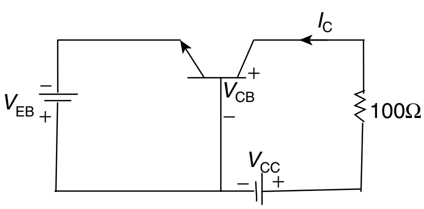
Assume reverse saturation current I_{CBO} = 10 nA at 25°C. Find the maximum tempt. At which transistor remains at cut-off.

(A) 129°C (B) 149°C (C) 124°C (D) 134°C

Practice Problems 2

Direction for questions 1 to 20: Select the correct alternative from the given choices.

1.



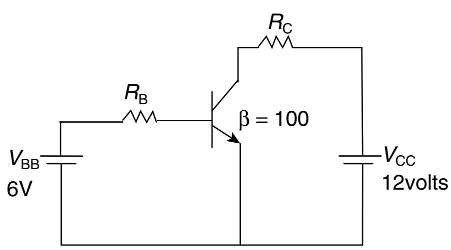
If I_C = 15mA and V_{CB} = 3volts, then the value of V_{CC} required is ______

(A) 4 volts
(B) 4.5 volts
(C) 3.15 volts
(D) 18 volts

2. Find the value of V_{CB}, if the supply voltage V_{CC} decreases by 1volt in part (i), and I_C remains the same,

(A) 3 volts
(B) 3.5 volts
(C) 2 volts
(D) 2.5 volts

Direction for questions 3 and 4:



3. Assume the transistor used is silicon with V_{BE} = 0.7volts, The values of R_C and R_B so that I_C = 12 mA and V_{CE} = 6volts.

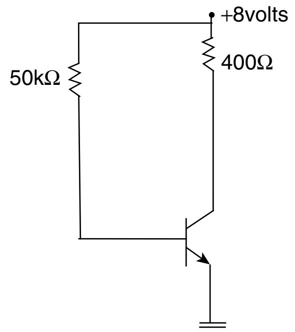
(A) 0.5 kΩ, 44 kΩ (B) 5 kΩ, 44 kΩ
(C) 4.4 kΩ, 50 kΩ (D) 4 kΩ , 50 kΩ

4. The values of R_C and R_B if a 200Ω emitter resistor is included so that I_C = 12 mA and V_{CE} = 6 volts.

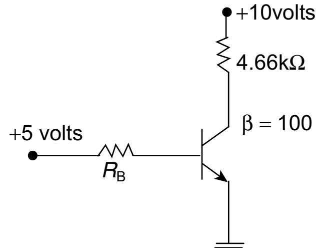
(A) 300 Ω, 24 kΩ (B) 0.3 kΩ, 42 kΩ
(C) 24 kΩ, 42 kΩ (D) 2.4 kΩ, 24 kΩ

5. Assume the transistor is in Active region. If I_C = 19.6 mA, then the value of V_{CB} is ______

(A) 0.55 volts (B) –0.55 volts
(C) 0.85 volt (D) –0.85 volts



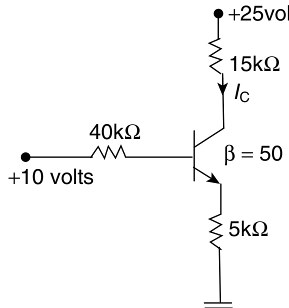
6.



The minimum value of R_B for which the transistor remains in active region is ______

(A) 200 kΩ (B) 205 kΩ (C) 20 kΩ (D) 21 kΩ

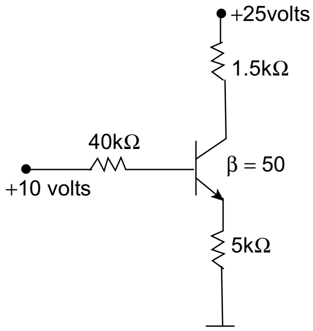
7.



The value of I_C is ______

(A) 1.57 mA (B) 3.15 mA
(C) 1.22 mA (D) 0.68 mA

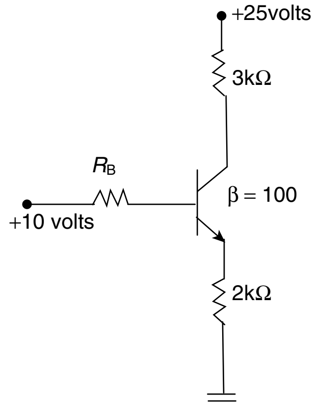
8.



Find the value of collector current, following through the circuit.

(A) 1.57 mA (B) 3.15 mA
(C) 1.75 mA (D) 3.51 mA

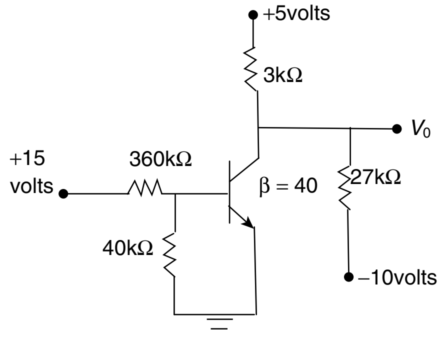
9.



The smallest value of R_B, such that the transistor is in active region.

(A) 24 kΩ (B) 2.4 kΩ
(C) 42 kΩ (D) 0Ω (zero)

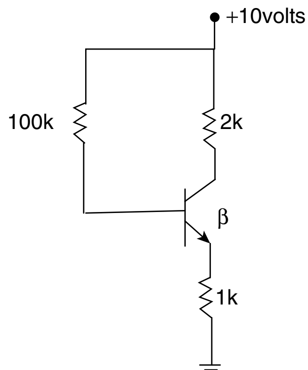
10.



Find the value of V_0.

(A) 3.5 volts
(B) +5 volts
(C) −10 volts
(D) 1.1 volts

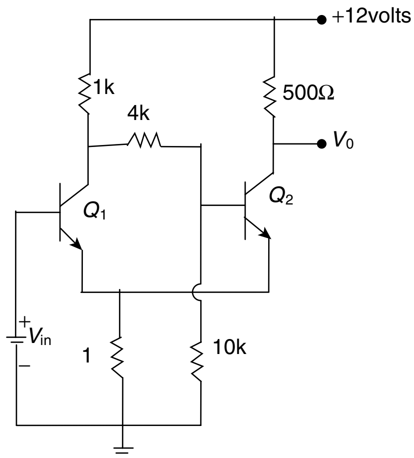
11.



Neglect junction voltages. Find the minimum value of β that will saturate the transistor

(A) 50 (B) 70
(C) 49 (D) 51

12.

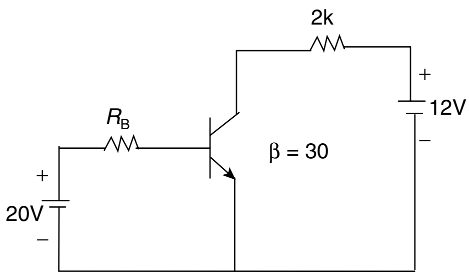


Neglect reverse saturation currents and assume each transistor has $\beta = 100$.

The value of V_0, if $V_{in} = 0$ volts

(A) 12 volts (B) 9 volts
(C) 8.5 volts (D) 7.5 volts

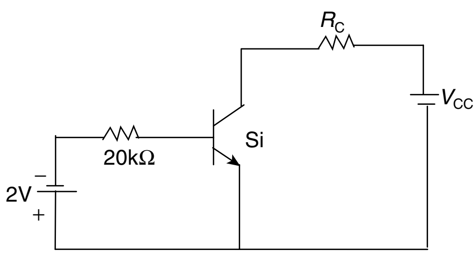
13.



The minimum value of R_B, which keeps the transistor in saturation region.

(A) 97 kΩ (B) 86 kΩ
(C) 125 kΩ (D) 68 kΩ

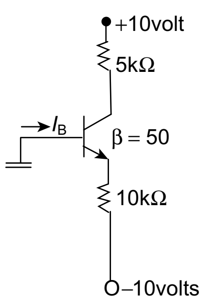
14.



If $I_{CBO} = 10$nA at 25°C, the maximum temperature that the transistor can with stand by keeping itself in cut-off region is

(A) 148°C (B) 208°C
(C) 168°C (D) 188°C

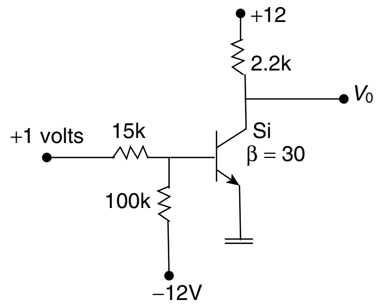
15.



If $V_{BE} = 0.7$ volts, find V_{CE}.

(A) 5.45 volts (B) 0.7 volts
(C) 0.2 volts (D) 6.15 volts

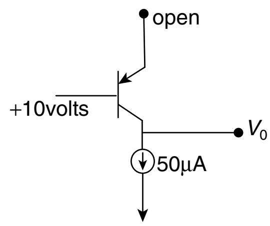
16.



Find the value of V_0

(A) 0.2 volts (B) 12 volts
(C) 7.6 volts (D) 9.8 volts

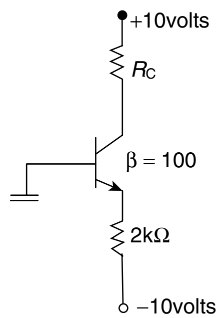
17.



Find the output voltage if the transistor has BV_{CBO} = 70 volts

(A) –70 volts (B) –10 volts
(C) –10.7 volts (D) –60 volts

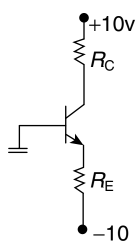
18.



Find the largest value of R_C while maintaining the transistor in active mode

(A) 2.28 kΩ (B) 2.42 kΩ
(C) 3.21 kΩ (D) 4.23 kΩ

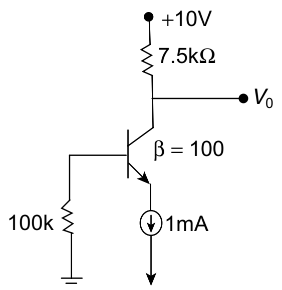
19.



Assume large value of β. Find the values of R_C and R_E, to achieve $I_C = 1$ mA and $V_{CB} = +4$volts.

(A) 9.3 K, 6 K (B) 6 K, 10.7 K
(C) 3.9 K, 10.7 K (D) 6 K, 3.9 K

20.



The value of V_0 for the given circuit is
(A) 2.5 volts
(B) 2.4 volts
(C) 2.6 volts
(D) 10 volts

Previous Years' Questions

1. If for a silicon N-P-N transistor, the base to emitter voltage (V_{BE}) is 0.7 V and the collector to base voltage (V_{CB}) is 0.2V, then the transistor is operating in the **[2004]**

(A) Normal active mode
(B) Saturation mode
(C) Inverse active mode
(D) Cut-off mode

2. Consider the following statements S_1 and S_2.

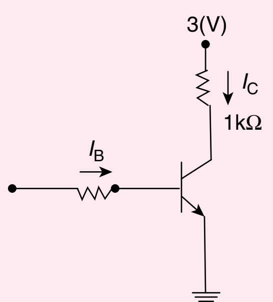
S_1: The β of a bipolar transistor reduces if the base width is increased.

S_2: The β of a bipolar transistor increases if the doping concentration in the base in increased

Which one of the following is correct? **[2004]**

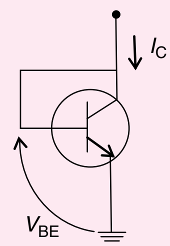
(A) S_1 is FALSE and S_2 is TRUE
(B) Both S_1 and S_2 are TRUE
(C) Both S_1 and S_2 are FALSE
(D) S_1 is TRUE and S_2 is FALSE

3. Assuming $V_{CEsat} = 0.2$ V and $\beta = 50$, the minimum base current (I_B) required to drive the transistor in Fig. Q. 12 to saturation is **[2004]**



(A) 56 μA (B) 140 μA
(C) 60 μA (D) 3 mA

4. For an N-P-N transistor connected as shown in figure $V_{BE} = 0.7$ volts. Given that reverse saturation current of the junction at room temperature 300°K is 10^{-13} A, the emitter current is **[2005]**



(A) 30 mA
(B) 39 mA
(C) 49 mA
(D) 20 mA

5. The phenomenon known as 'Early Effect' in a bipolar transistor refers to a reduction of the effective base width caused by **[2006]**

(A) electron hole recombination at the base
(B) the reverse biasing of the base–collector junction
(C) the forward biasing of emitter–base junction
(D) the early removal of stored base charge during saturation to cut-off switching.

6. The DC current gain β of a BJT is 50. Assuming that the emitter injection efficiency is 0.995, the base transport factor is: **[2007]**

(A) 0.980 (B) 0.985
(C) 0.990 (D) 0.995

7. A BJT is biased in forward active mode. Assume $V_{BE} = 0.7$ V, $kT/q = 25$ mV and reverse saturation current $I_s = 10^{-13}$ A. The transconductance of the BJT (in mA/V) is ________. **[2014]**

8. An increase in the base recombination of a BJT will increase **[2014]**
(A) the common emitter dc current gain β
(B) the breakdown voltage BV_{CEO}
(C) the unity-gain cut-off frequency f_T
(D) the transconductance g_m

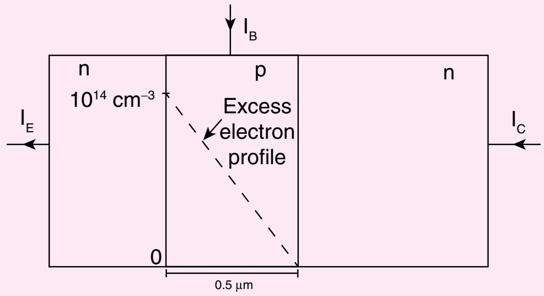
9. If the base width in a bipolar junction transistor is doubled, which one of the following statements will be TRUE? **[2015]**
(A) Current gain will increase
(B) Unity gain frequency will increase.
(C) Emitter-base junction capacitor will increase.
(D) Early voltage will increase.

10. In the circuit shown in the figure, the BJT has a current gain (β) of 50. For an emitter-base voltage V_{EB} = 600 mV, the emitter–collector voltage V_{EC} (in volts) is _______. **[2015]**

11. An npn BJT having reverse saturation current I_S = 10^{-15} A is biased in the forward active region with V_{BE} = 700 mV. The thermal voltage (V_T) is 25 mV and the current gain (β) may vary from 50 to 150 due to manufacturing variations. The maximum emitter current (in µA) is _______. **[2015]**

12. The Ebers Moll of a BJT is valid **[2016]**
(A) only in active mode.
(B) only in active and saturation modes.
(C) only in active and cut off modes.
(D) in active, saturation and cut off modes.

13. The injected excess electron concentration profile in the base region of an npn BJT, biased in the active region, is linear, as shown in the figure. If the area of the emitter base junction is 0.001 cm^2, m_n = 800 cm^2/(V – s) in the base region and depletion layer widths are negligible, then the collector current I_c(in mA) at room temperature is __________ . **[2016]**
(Given : Thermal voltage V_T = 26 m V at room temperature, electronic charge q = 1.6 ´ 10^{-19}C)



Answer Keys

Exercises

Practice Problems 1

1. C	**2.** C	**3.** B	**4.** B	**5.** A	**6.** C	**7.** B	**8.** B	**9.** B	**10.** C
11. B	**12.** B	**13.** C	**14.** B	**15.** B	**16.** B	**17.** A	**18.** B	**19.** B	**20.** C
21. A	**22.** C	**23.** A	**24.** B						

Practice Problems 2

1. B	**2.** C	**3.** A	**4.** A	**5.** B	**6.** B	**7.** C	**8.** A	**9.** D	**10.** D
11. A	**12.** C	**13.** A	**14.** B	**15.** D	**16.** B	**17.** D	**18.** A	**19.** B	**20.** C

Previous Years' Questions

1. A	**2.** D	**3.** A	**4.** C	**5.** B	**6.** B	**7.** 5.784	**8.** B	**9.** D	**10.** 2
11. 1465 to 1485		**12.** D	**13.** 6.656 mA						