Chapter 2

Bipolar Junction Transistors

LEARNING OBJECTIVES

After reading this chapter, you will be able to understand:

- Transistor construction
- Transistor symbols
- Transistor current Components
- Transistor configurations
- Common-base configuration
- Operation modes of transistor
- Common emitter configuration
- Common collector configuration
- Thermal run away
- Power rating of transistor

Introduction

When a third doped element is added to a diode in such a way that two pn junctions are formed, the resulting device is known as a transistor. Transistors are smaller than vacuum tubes. Invented in 1948 by J. Barden and W.H. Brattain of Bell Laboratories, USA.

Transistor Construction

A transistor consists of two-pn-junctions formed by sandwiching either p-type or n-type semi-conductor between a pair of opposite types. Accordingly there are two types of transistors,

Namely, (i) *n-p-n* transistor;

(ii) *p-n-p* transistor;

An *n-p-n* transistor is composed of two *n*-type semiconductor separated by a thin section of *p*-type.

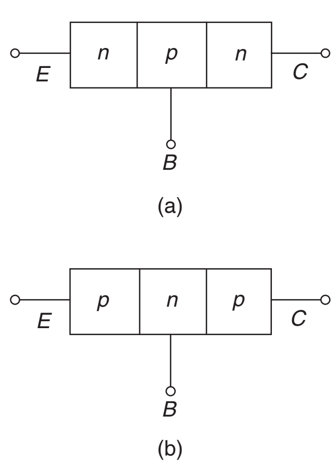


Figure 1 Types of transistors (a) *n-p-n*, and (b) *p-n-p*

- 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.
- A transistor has two pn-junction, one junction is forward biased and the other junction is reverse biased. The forward 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.

1. **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.
2. **Base:** The middle section which forms two pn-junctions between the emitter and collector is called the base. The base-emitter junction is forward biased andallowing low resistance for the emitter circuit. The base-collector junction is reverse biased. So it provides high resistance in the collector circuit.
3. **Collector:** The section on the other side that collects the charges is called the collector. The collector is always reverse biased.

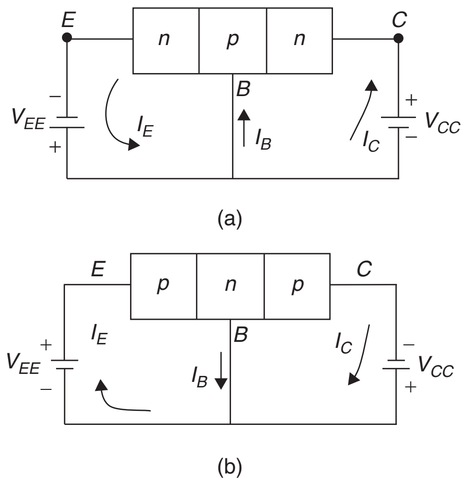


Figure 2 Types of transistors (a) *n-p-n*, (b) *p-n-p*

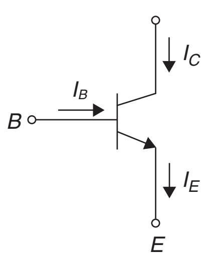
The transistor has two *pn* junctions i.e., it is like two diodes. The junction between emitter and base may be called emitter-base diode, or emitter diode. The junction between the base and collector may be called collector-base diode, or collector diode. The emitter diode is always forward biased and collector diode is always reverse biased.

The transistor offers Input Impedance very small and output Impedance high.

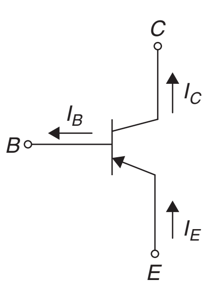
$$R_{in} \rightarrow \text{Small}$$
$$R_o \Rightarrow \text{High}$$

Transistor Symbols

(i) *n-p-n* transistor:



(ii) *p-n-p* transistor:



Transistor Current Components

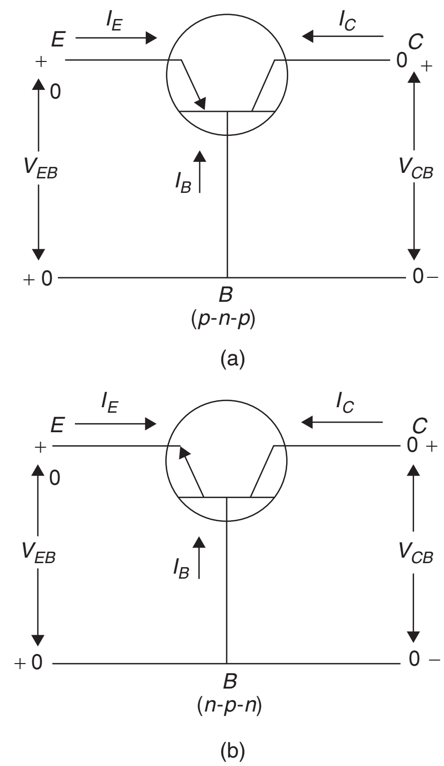
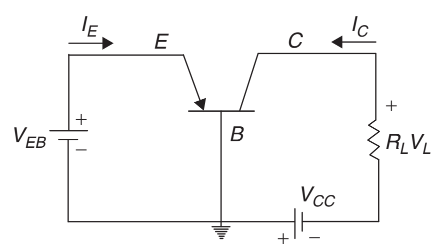


Figure 3 Circuitrepresentation of the two types of transistors (a) *p-n-p*, (b) *n-p-n*

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.

(i) **For *p-n-p* transistor:**

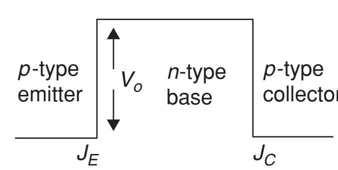
I_E : positive (into)
I_B : negative (away)
I_C : negative (away)



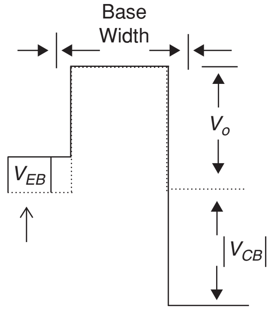
(ii) **For *n-p-n* transistor:**

I_E : negative (away)
I_B : positive (into)
I_C : positive (into)

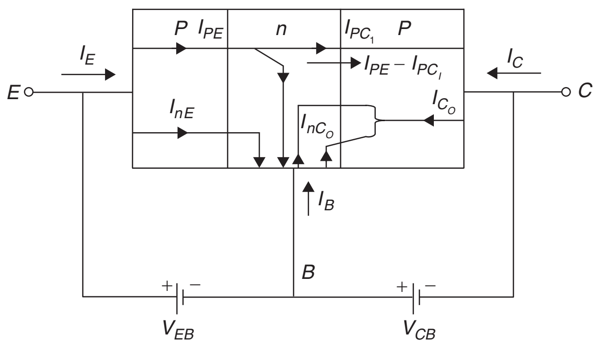
Un-biased Condition



Biased Condition



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.

$$-I_{C_O} = I_{nc_o} + I_{PC_O}$$

KVL at the Collector junction gives:

$$-I_C = I_{c_o} - I_{PC_l} = I_{C_O} - \alpha I_E$$

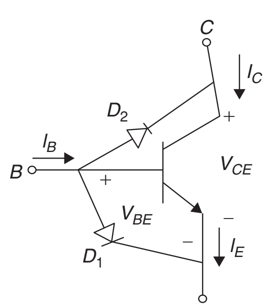
(i) Emitter efficiency $\gamma^* = \dfrac{I_{PE}}{I_E}$

(ii) Transport factor $\beta = \dfrac{I_{PC}}{I_{PE}}$

(iii) 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



$$I_E = I_C + I_B$$
$$I_E \approx I_C.$$

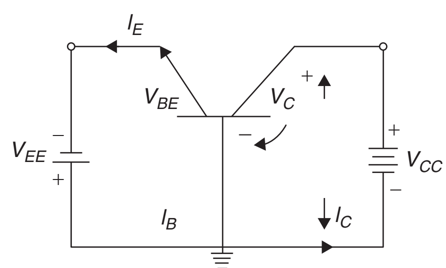
But $I_C < I_E$

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

Transistor Configurations

Common-base Configuration

The base is common to both the 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, $\alpha \to$ 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

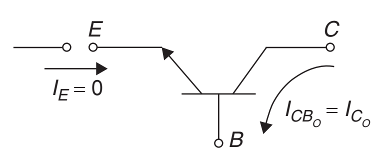


Figure 4 Reverse saturation current

Where $I_{CB_O} \Rightarrow$ collector to base emitter open circuit current.
i.e., Reverse saturation current

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

But $I_E = I_C + I_B$

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

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

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

Transfer characteristics

1. Input characteristics

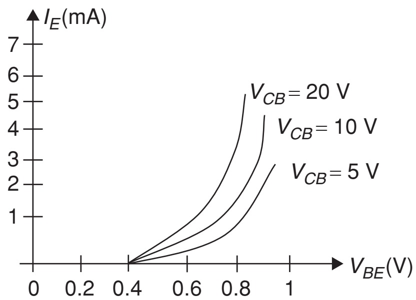


Figure 5 Input or driving point characteristics for a *CB* silicon transistor amplifier.

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

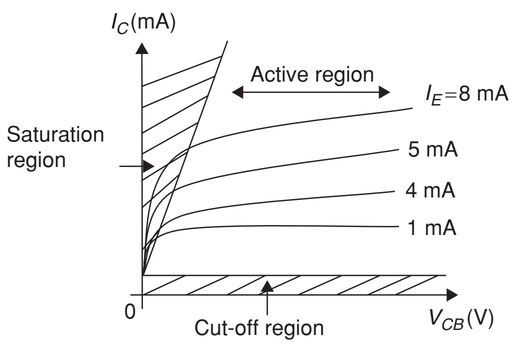


Figure 6 CB Output characteristics.

From the characteristics, it is seen 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.

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

Output resistance $r_0 = \dfrac{\Delta V_{CB}}{\Delta I_C}$ 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 kΩ i.e., R_i small and R_0 high compare to others.

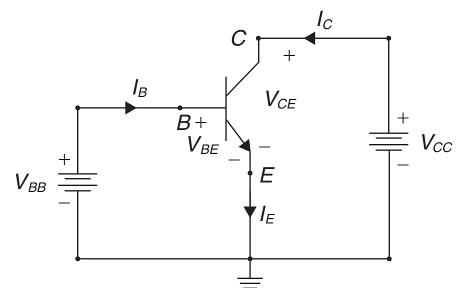
Example 1: The early effect in a bipolar junction transistor is caused by:

(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*

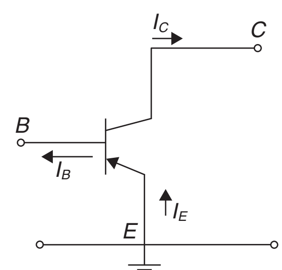


Figure 7 Notations and symbols used with the CE-configuration.

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

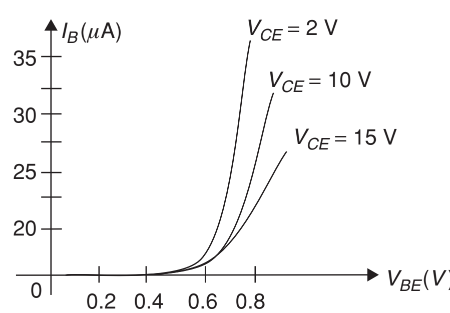


Figure 8 Si transistor input characteristics.

Input resistance

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

The values of input resistance for a *CE* amplifier arein the order of a few hundreds of ohms.

2. Output or collector characteristics

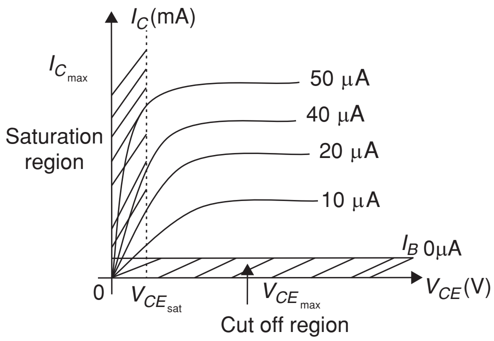
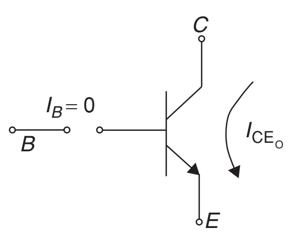


Figure 9 Collector characteristics

In the active region of a *CE* amplifier, the base emitter junction is forward-biased, where as the collector-base junction is reverse-biased.

Leakage current



Where, $I_{CE_O} \Rightarrow$ 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_{CE_O}.

$$(I_{CE_O} >> I_{CB_O})$$

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 *DC* values are considered,

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

Expression for collector current We know,

$$I_E = I_B + I_C$$

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

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

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

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

From the above equation, we get

$$\beta = \frac{\alpha}{1-\alpha} \text{ and } I_{CE_O} = \frac{I_{CB_O}}{1-\alpha}$$

or $I_{CEO} = (1 + \beta) \cdot I_{CB_O}$

Common Collector Configuration

The CC-configuration is used for Impedance matching circuitsit has a high input impedance and low output impedance.

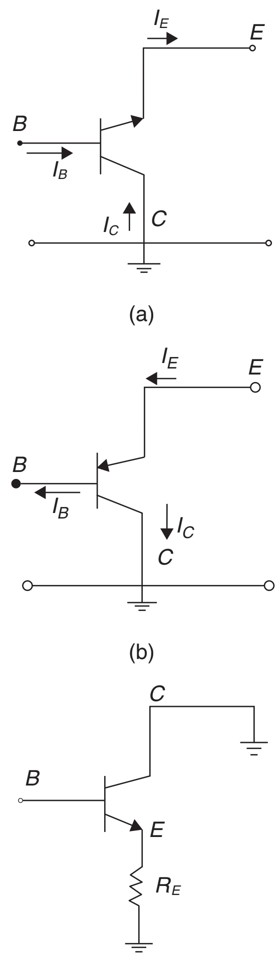


Figure 10 CC-configuration used for impedance matching purpose. (a) *n-p-n*, (b) *p-n-p*

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

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 *DC*

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

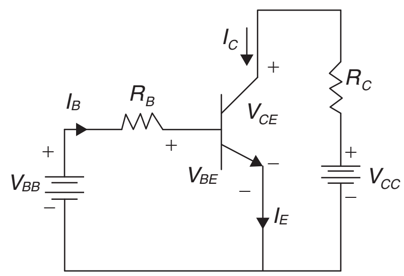
$$\gamma = \frac{I_E}{I_B}$$

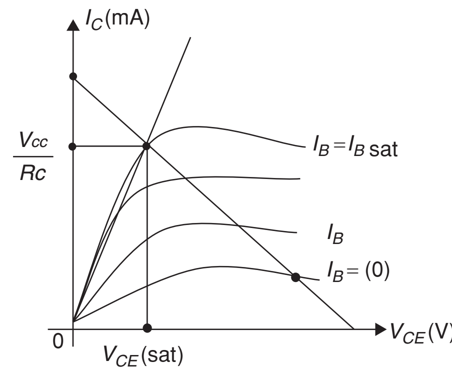
$$\alpha = \frac{\beta}{1+\beta};\ \beta = \frac{\alpha}{1-\alpha};\ \gamma = \frac{1}{1-\alpha}$$

$$\gamma = 1 + \beta$$

The currents are always following the below relation.

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





Comparison of Various characteristics of Transistor

Sl. No.	Characteristic	CB	CE	CC
1.	R_i	Low (Ω's) < 100 Ω	Low (Ω's) < 100 Ω	Very high (kΩ's) < 100 kΩ
2.	R_0	Very high (about 500 kΩ)	High (about 50 kΩ)	Low (about 50 Ω)
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;

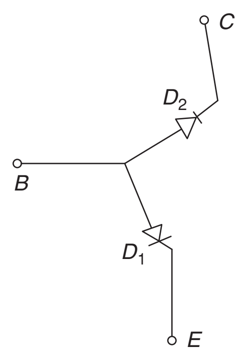
Out of the three transistor connections, the common emitter circuit is the most efficient, the main reason for this usage:

1. High current gain;
2. High voltage and power gain;
3. Moderate Output to Input ratio.
   That is R_0/R_i less compare to others.

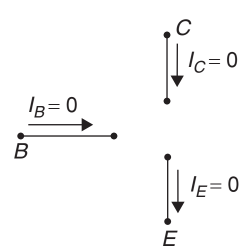
Transistor and Its Region of Operations

CE transistor circuit and the o/p characteristic along with the DC load line.

Cut-off



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

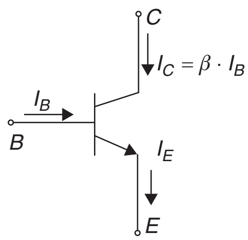


Transistor in cut-off mode: The point where the load line intersects the $I_B = 0$ curve is known as cut-off. At this point $I_B = 0$ and only small collector current or leakage current I_{CE_O} exists.

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

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).

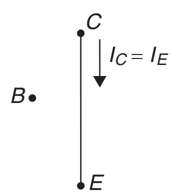


That is in active region emitter diode is ON and collector diode is OFF.

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

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 $V_{CE} \approx 0$ V

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

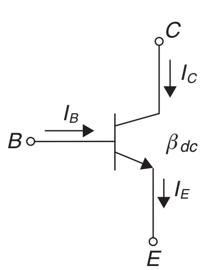
$$V_{CE} = V_{CE\,(\text{sat})} = V_{\text{knee}}.$$

$V_{CE(\text{sat})}$ or V_{knee} can be neglected as compared to V_{CC}.

$\Rightarrow$ At room temperature V_{CE} drop of a silicon transistor at saturation is approximately $V_{CE(\text{sat})} = 0.3$ V

Example 2: If the transistor in the figure is in saturation, then

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



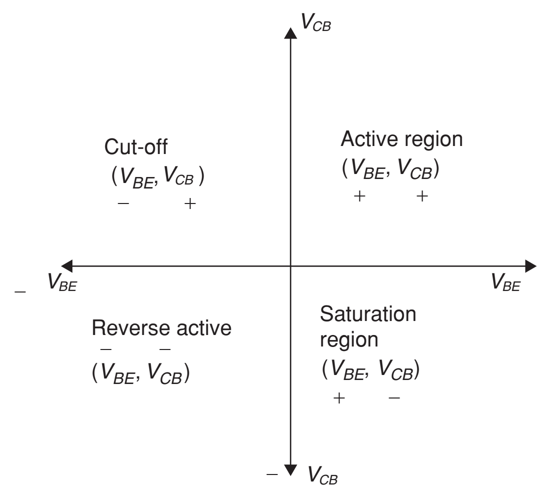
Solution: (B)
In active region $I_C = \beta \cdot I_B$
Saturation region $I_{C(\text{Sat})} < \beta \cdot I_B$.

Example 3: If for a *Si npn* 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: **(B)** $V_{BE} = 0.7$ V
That is $V_B - V_E = 0.7$ 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.
So, the transistor is in the normal active mode.

Modes of operation of BJT



Notes

1. For a silicon transistor generally considered:

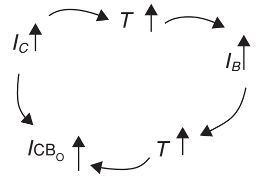
$$V_{CE(\text{sat})} = 0.2 \text{ V}$$
$$V_{BE(\text{active})} = 0.7 \text{ V and}$$
$$V_{BE(\text{sat})} = 0.8 \text{ V.}$$

2. For Ge transistor:

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

Thermal Run Away

The collector $I_C = \beta \cdot I_B + (1 + \beta) . I_{CB_O}$. The three variables in the equation β, I_B and I_{CB_O} increase with rise in temperature. The reverse saturation current I_{CO} is more sensitive with temperature, it doubles for every 10°C raise in temperature. 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 analog circuit, the operating point of the BJT should be such that it satisfies the condition.

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

(C) $V_{CE} < \dfrac{V_{CC}}{2}$ (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 is 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.

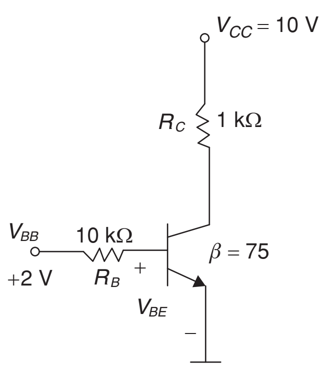
Example 5: The maximum power dissipation of a transistor is 80 mΩ. If $V_{CE} = 10$ V, the maximum collector current that can be allowed without destruction of the transistor is:

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

Solution: (C)
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 the Figure:



The power dissipation in the transistor is:

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

Solution: (C) Apply KVL to the input loop:

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

$$I_{C(\text{active})} = \beta \cdot I_B = 75 \times 0.13 \text{ mA} = 9.75 \text{ mA}$$
$$V_{CE} = V_{CC} - I_C \cdot R_C = 10 - 9.75 = 0.25 \text{ V}$$
$$P_D = I_C \cdot V_{CE}$$
$$= 9.75 \times 0.25 \text{ mW} = 2.43 \text{ mW}.$$

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: (B)

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

$$I_C = \alpha I_E = 0.9 \times 1.8 \text{ mA} = 1.62 \text{ mA}$$
$$I_B = I_E - I_C = 0.18 \text{ mA}.$$

Example 8: For a certain transistor, $I_B = 15$ μA, $I_C = 2$ mA and $\beta = 100$. The value of leakage current I_{CB_O} is:

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

Solution: (A)
We know, $I_C = \beta \cdot I_B + (1 + \beta) \cdot I_{CB_O}$

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

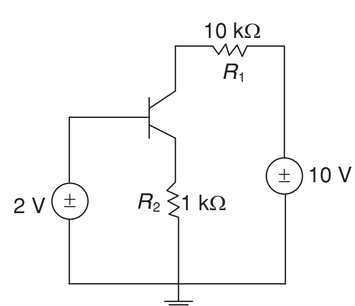
Example 9: In a junction transistor, the collector cut off current I_{CB_O} reduces considerably by doping the:

(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: (B)
We know, $I_C = \alpha I_E + I_{CB_O}$

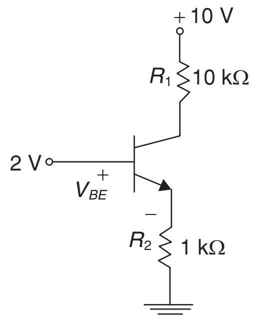
$$\alpha = \frac{I_C - I_{CB_O}}{I_E} \Rightarrow \alpha \uparrow \Rightarrow I_{CB_O} \downarrow.$$

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: (B)
Let us assume transistor is in saturation region.



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

Apply KVL in i/p loop

$$V_{BB} = V_{BE} + I_C \cdot R_2$$
$$V_{BE} = 2 - 0.909$$
$$= 1.09 \text{ V}$$

$\therefore V_{BE} > 0.7$. 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 $I_B = 10$ µA, $\beta = 99$ and $I_{C_O} = 1$ µA. What is the collector current I_C?

Solution: $I_C = \beta I_B + (1 + \beta)\, I_{CB_O}$
$= 99 \times 10 \times 10^{-6} + (1 + 99)\, 1 \times 10^{-6}$
$I_C = 1.09$ mA

Example 13: Determine the emitter current. I_E, collector current I_C for a transistor with $\alpha_{DC} = 0.97$ and collector to base leakage current 10 µA, I_B is 50 µA.

Solution: $I_c = \beta \cdot I_B + (1 + \beta)\, I_{CB_O}$

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

$\beta = 32.33$

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

$I_C = 1.95$ mA

$I_E = I_B + I_C = 2$ 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: $I_C = 5.6$ mA
$I_E = 5.75$ 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: $I_B = 200$ µA
$I_E = 20$ mA
$I_c = I_E - I_B$
$= 20 \times 10^{-3} - 200 \times 10^{-6}$
$I_C = 19.8$ mA

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

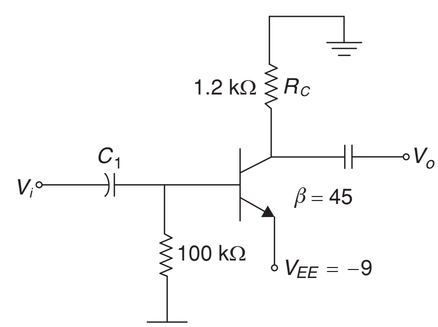
$\beta = 99$

Example 16: A BJT has a collector current of 4 mA and base current of 20 µA. Determine its β.

Solution: $I_C = 4$ mA
$I_B = 20$ µA

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

Example 17: Determine V_C and V_B for the network.

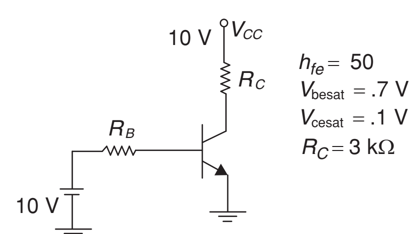


Solution: $-I_B R_B - V_{BE} + V_{EE} = 0$

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

$I_C = \beta I_B = 45 \times 83$ µA $= 3.735$ mA
$V_C = -I_C R_C = -(3.735 \text{ mA})(1.2 \text{ k}\Omega)$
$= -4.48$ V
$V_B = -I_B R_B$
$= -(83 \text{ µA})(100 \text{ k}\Omega) = -8.3$ V.

Example 18: For the given circuit find the value of R_B that would be just sufficient to drive the transistor to saturation?



Solution: The value of R_B required into drive the transistor to saturation.

$$I_C \le h_{F\in} \times \frac{V_{BB} - V_{B\text{sat}}}{R_B}$$

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

$$V_{CC} = I_C R_C$$

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

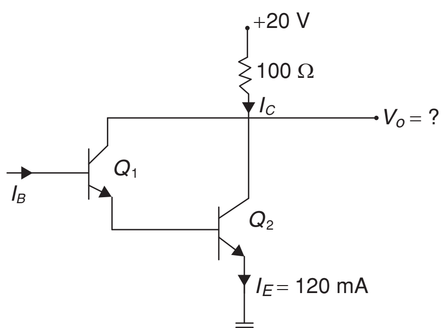
$$R_B \le \frac{50 \times 9.3}{3.33\ \text{mA}} = 139\ \text{k}\Omega \sim 140\ \text{k}\Omega$$

Exercises

Practice Problems 1

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

Common Data for Questions 1 and 2:

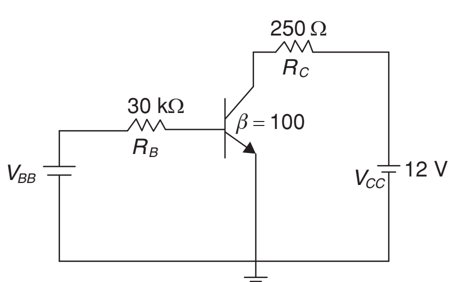


Assume both Transistors are in Active region and neglect reverse saturation currents. If $\alpha_1 = 0.99$ and $\alpha_2 = 0.98$

1. The value of V_o shown is:
   (A) 6 V (B) 12 V
   (C) 8 V (D) 10 V

2. The value of overall β is $\left(\frac{I_C}{I_B}\right)$ is:
   (A) 5000 (B) 5001
   (C) 4999 (D) 4998

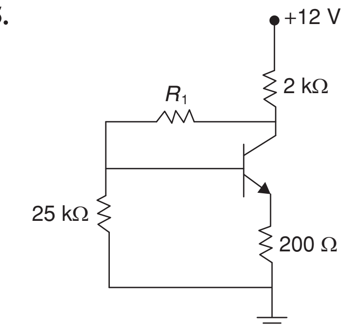
Common Data for Questions 3 and 4:



3. If V_{CE} = 6 V, the value of V_{BB} required is ________
   (A) 7 V (B) 7.9 V
   (C) 8 V (D) 7.8 V

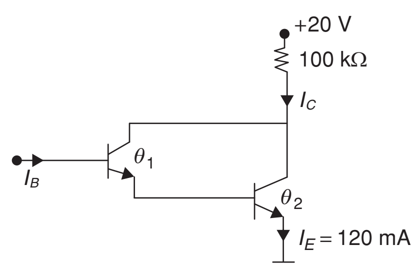
4. If V_{CC} is changed to 6 V in the given circuit, the value of R_C required to achieve the Q-point Q (2 V, 16 mA).
   (A) 200 Ω (B) 250 Ω
   (C) 2.5 kΩ (D) 2 kΩ

5.



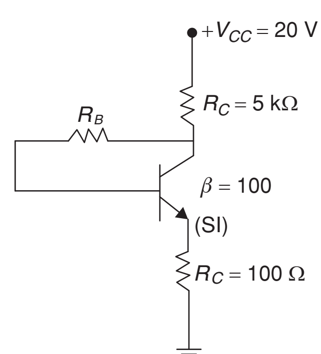
If $\alpha = 0.98$ and $V_{BE} = 0.7$ V, the value of resistor R_1 for an emitter current of 2 mA is ________
   (A) 81.1 kΩ (B) 8.11 kΩ
   (C) 44 kΩ (D) 19.6 kΩ

6.



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

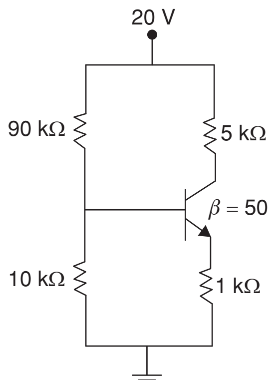
7.



Assume the transistor is in active region. If V_{CE} = 4 V, find the value of R_B.

(A) 100 kΩ
(B) 106 kΩ
(C) 104 kΩ
(D) 98 kΩ

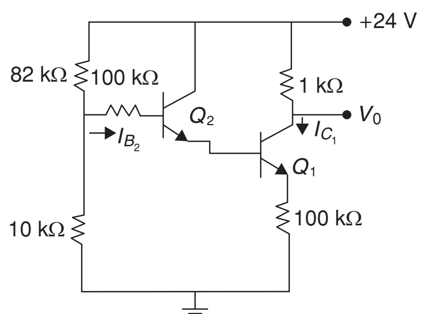
8.



Assume the transistor is in Active region. The value of thecollector current. I_C is ________

(A) 2 mA
(B) 1.085 mA
(C) 1.85 mA
(D) 0.021 mA

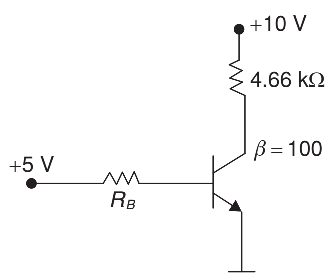
9.



Assume, both Transistors are in Active region with $V_{BE_1} = V_{BE2}$ = 0.7 V. β_1 = 100 and, β_2 = 50. The ratio of I_{C_1}/I_{B_2} is ________

(A) 5000
(B) 5100
(C) 4900
(D) 490

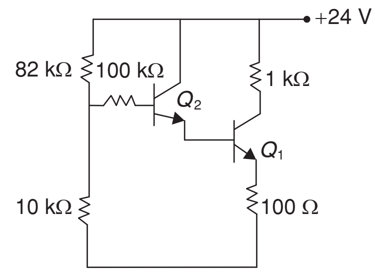
10.



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

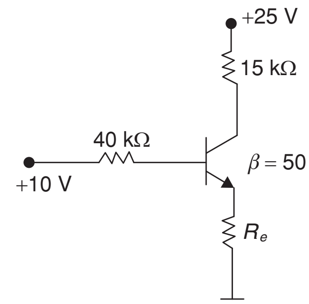
11.



Assume, both Transistor are in Active region with β_1 = 100, β_2 = 50 and $V_{BE_1} = V_{BE_2}$ = 0.7 V. The value of V_{CE} of Q_1 is

(A) 14.1 V (B) 13.1 V
(C) 14.9 V (D) 13.9 V

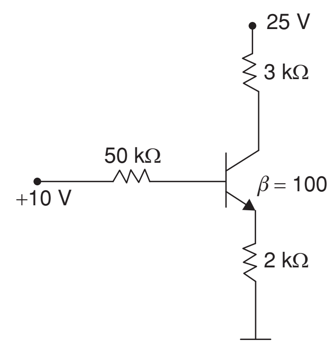
12.



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

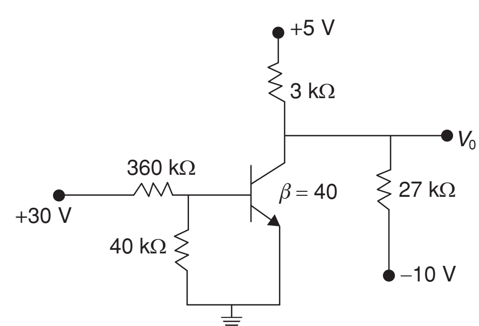
13.



Find the region of operation of transistor shown.

(A) Cut-off (B) saturation
(C) Active (D) inverse Active

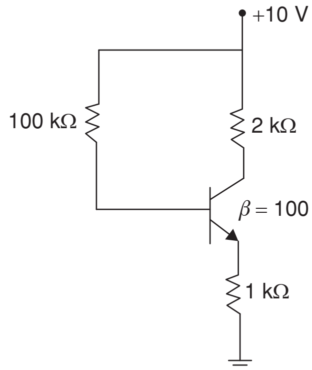
14.



Find the region of operation of the transistor, shown.

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

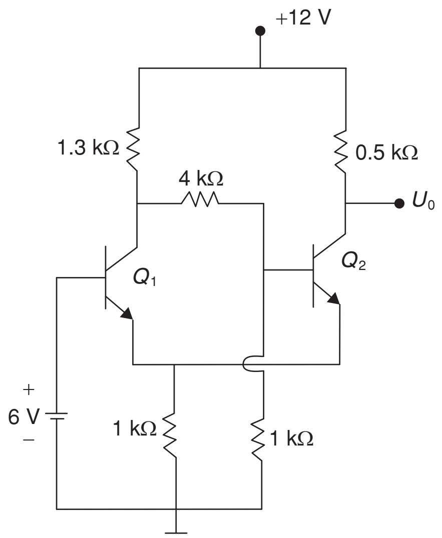
15.



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

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

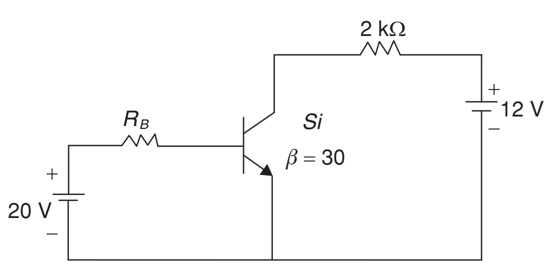
16.



Assume β of each transistor is 100. Find the value of V_o is:

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

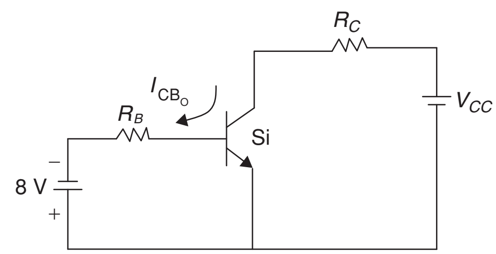
17.



For what values of R_B will the Transistor remain below cut off region if $I_{CB_O} = 100$ μA:

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

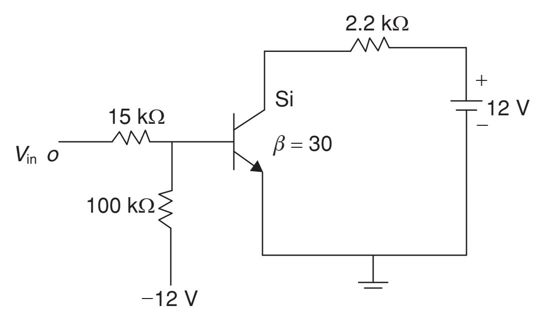
18.



If the reverse saturation current of Si Transistor is 10 nA 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

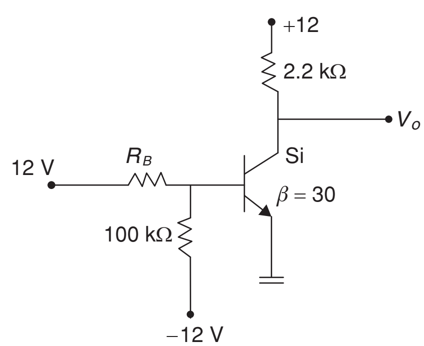
19.



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

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

20.



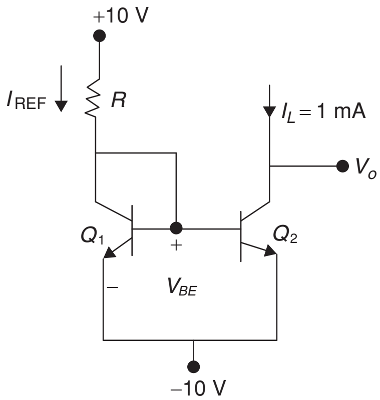
Find minimum value of R_1 for which the transistor is in the Active region.

(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 1 Ω cm.

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

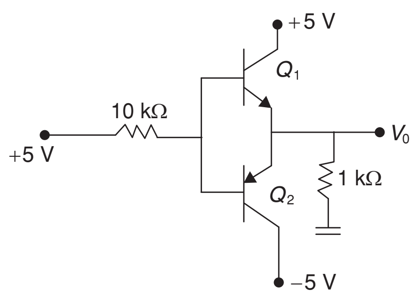
22.



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

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

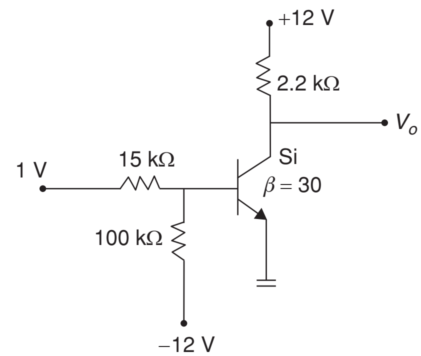
23.



If β of each transistor is 100, find V_o.

(A) +4 V
(B) +5 V
(C) –4 V
(D) –5 V

24.



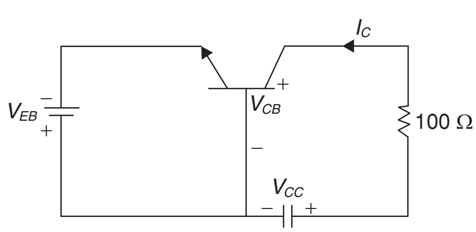
Assume reverse saturation current I_{CB_O} = 10 nA at 25°C. Find the maximum temperature. At which transistor remains at cut-off.

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

Practice Problems 2

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

1.



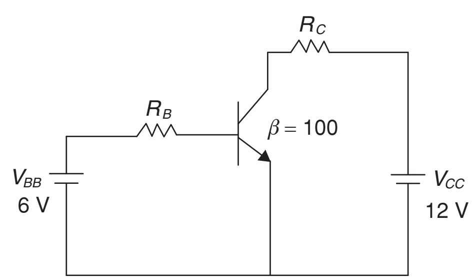
If I_C = 15 mA and V_{CB} = 3 V then the value of V_{CC} required is ________

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

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

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

Common Data for Questions 3 and 4:



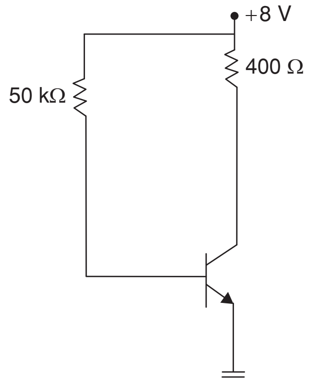
3. Assume the Transistor used is silicon with V_{BE} = 0.7 V, the values of R_C and R_B so that I_C = 12 mA and V_{CE} = 6 V.

(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 200 Ω emitter resistor is included so that I_C = 12 mA and V_{CE} = 6 V.

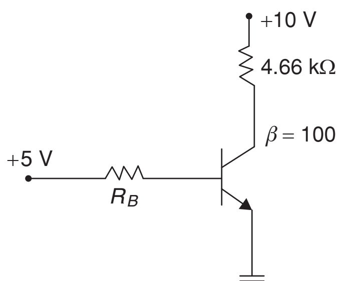
(A) 300 Ω, 24 kΩ
(B) 0.3 kΩ, 42 kΩ
(C) 24 kΩ, 42 kΩ
(D) 2.4 kΩ, 24 kΩ

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



(A) 0.55 V (B) –0.55 V (C) 0.85 V (D) –0.85 V

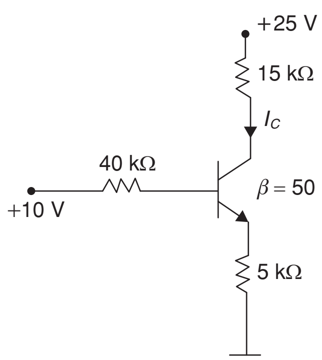
6.



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

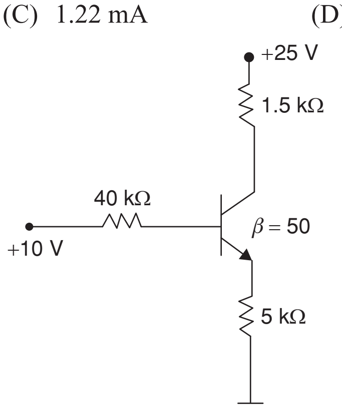
7.



The value of I_C is ________

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

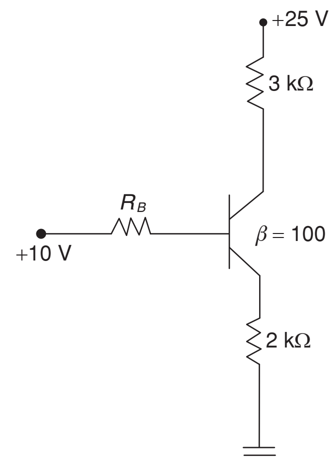
8.



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

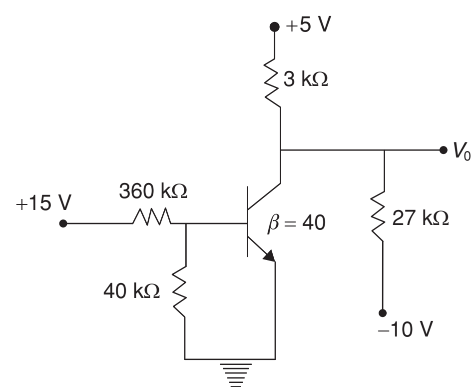
9.



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) 0 Ω (zero)

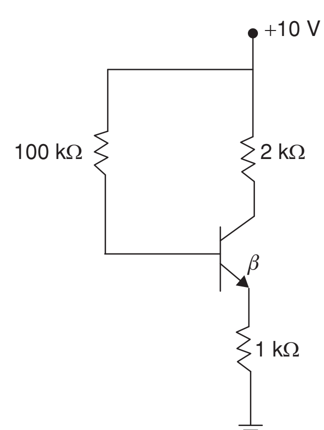
10.



Find the value of V_0.

(A) 3.5 V (B) +5 V
(C) –10 V (D) 1.1 V

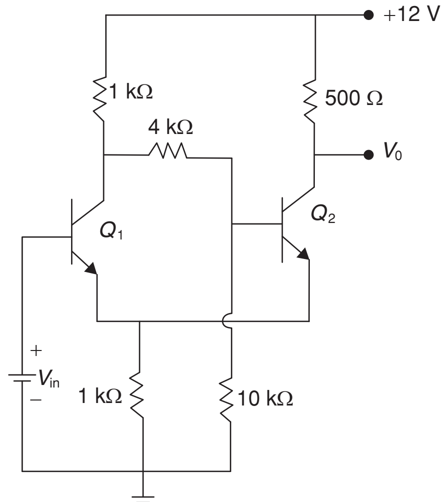
11.



Neglect junction voltages: Find the Minimum value of β, that will saturate the Transistor:

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

12.

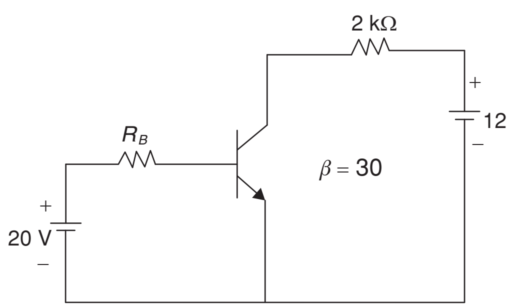


Neglect reverse saturation currents and assume each transistor has $\beta = 100$.

The value of V_o, if $V_{in} = 0$ V:

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

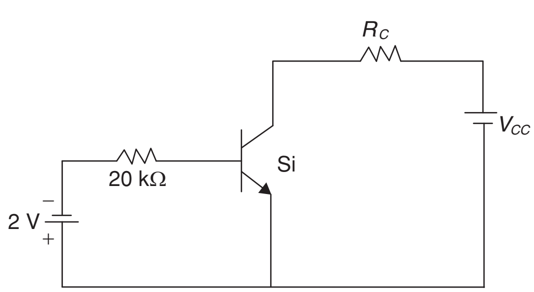
13.



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

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

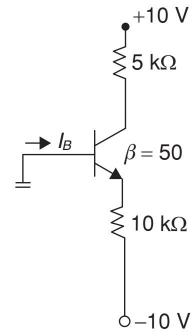
14.



If $I_{CB_O} = 10$ 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

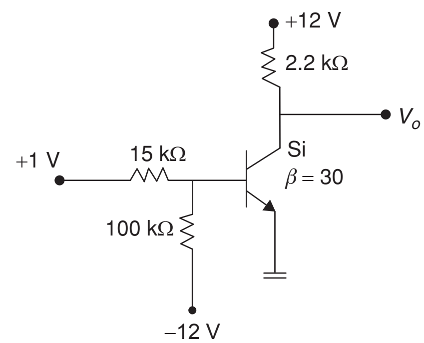
15.



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

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

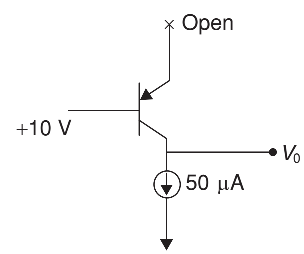
16.



Find the value of V_o

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

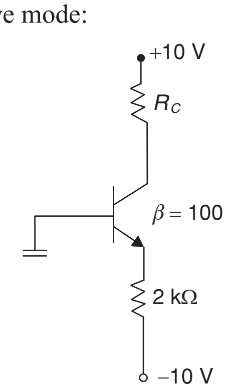
17.



Find the output voltage if the transistor has $BV_{CB_O} = 70$ V:

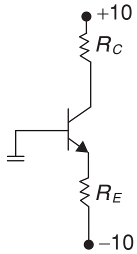
(A) –70 V (B) –10 V
(C) –10.7 V (D) –60 V

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

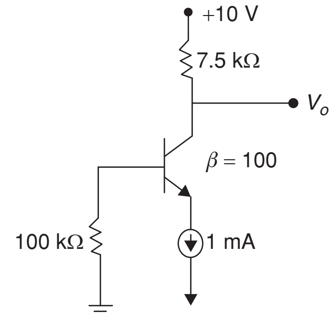
19.



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

(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

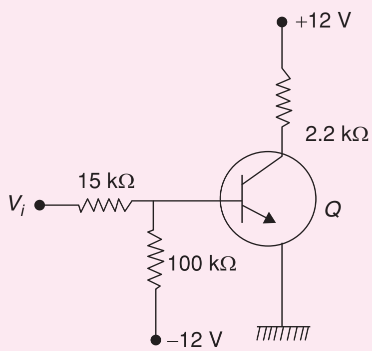
20.



The value of V_o for the given ckt is:
(A) 2.5 V
(B) 2.4 V
(C) 2.6 V
(D) 10 V

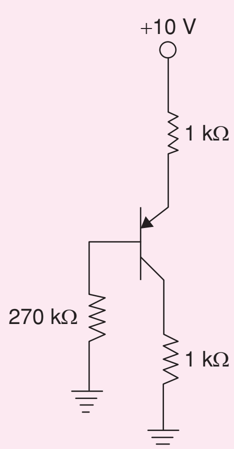
Previous Years' Questions

1. Consider the circuit shown in figure. If the β of the transistor is 30 and I_{CB_O} is 20 nA and the input voltage is +5 V, then transistor would be operating in: **[2006]**



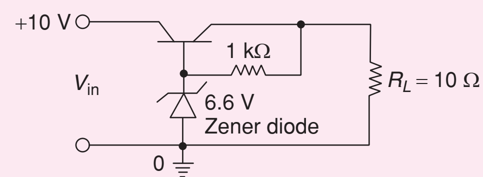
(A) Saturation region (B) Active region
(C) Breakdown region (D) Cut-off region

2. The common emitter forward current gain of the transistor shown is $\beta_F = 100$. **[2007]**



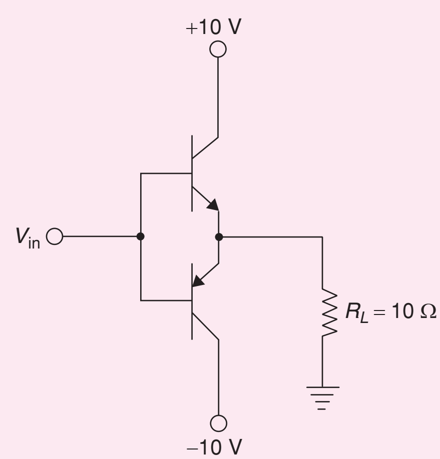
The transistor is operating in:
(A) Saturation region
(B) Cutoff region
(C) Reverse active region
(D) Forward active region

3. The three-terminal linear voltage regulator is connected to a 10 Ω load resistor as shown in the figure. If V_{in} is 10 V, what is the power dissipated in the transistor? **[2007]**



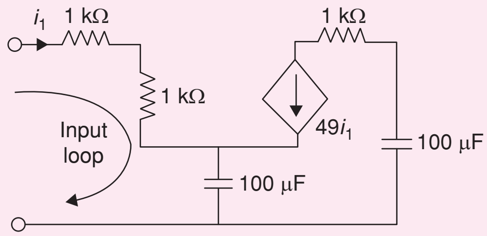
(A) 0.6 W (B) 2.4 W
(C) 4.2 W (D) 5.4 W

4. The input signal V_{in} shown in the figure is a 1 kHz square wave voltage that alternates between +7 V and –7 V with a 50% duty cycle. Both transistors have the same current gain, which is large. The circuit delivers power to the load resistor R_1. What is the efficiency of this circuit for the given input? Choose the closest answer. **[2007]**



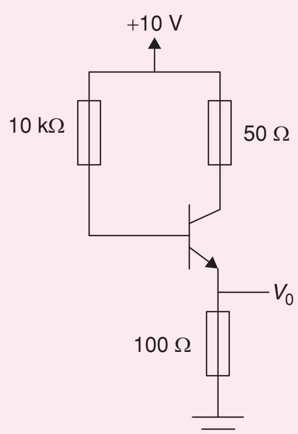
(A) 46% (B) 55%
(C) 63% (D) 92%

5. The equivalent capacitance of the input loop of the circuit shown is: **[2009]**



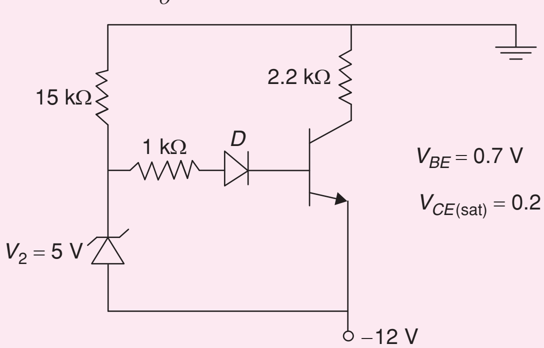
(A) 2 µF (B) 100 µF
(C) 200 µF (D) 4 µF

6. The transistor circuit shown uses a silicon transistor with $V_{BE} = 0.7$ V, $I_C \approx I_E$ and a DC current gain of 100. The value of V_o is: **[2010]**



(A) 4.65 V (B) 5 V
(C) 6.3 V (D) 7.23 V

7. The transistor used in the circuit shown below has a β of 30 and I_{CB_O} is negligible. **[2011]**



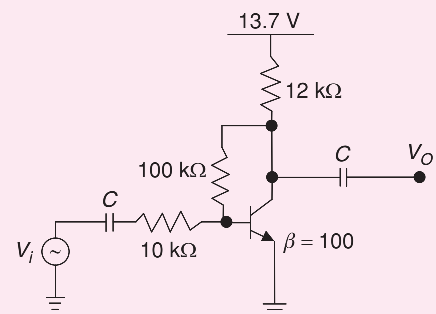
If the forward voltage drop of diode is 0.7 V, then the current through collector will be

(A) 168 mA (B) 108 mA
(C) 20.54 mA (D) 5.36 mA

8. Transformer and emitter follower can both be used for impedance matching at the output of an audio amplifier. The basic relationship between the input power P_{in} and output power P_{out} in both the cases is: **[2012]**

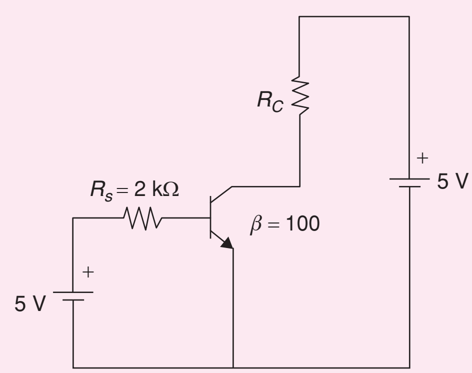
(A) $P_{in} = P_{out}$ for both transformer and emitter follower
(B) $P_{in} > P_{out}$ for both transformer and emitter follower
(C) $P_{in} < P_{out}$ for transformer and $P_{in} = P_{out}$ for emitter follower
(D) $P_{in} = P_{out}$ for transformer and $P_{in} < P_{out}$ for emitter follower

9. The voltage gain A_v of the circuit shown below is: **[2012]**

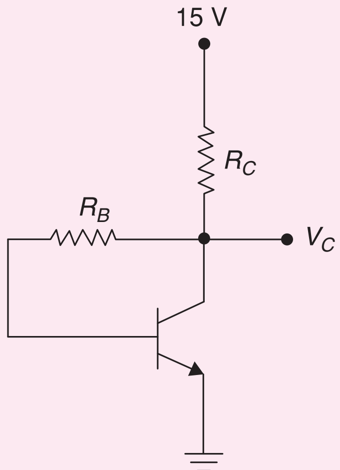


(A) $|A_v| \approx 200$ (B) $|A_v| \approx 100$
(C) $|A_v| \approx 20$ (D) $|A_v| \approx 10$

10. The transistor in the given circuit should always be in active region. Take $V_{CE(sat)} = 0.2$ V, $V_{BE} = 0.7$ V. The maximum value of R_c in Ω which can be used is ______. **[2014]**

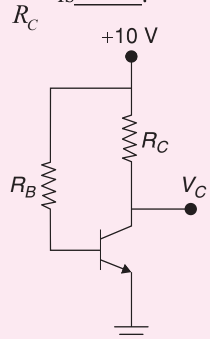


11. In the given circuit, the silicon transistor has $\beta = 75$ and a collector voltage $V_C = 9$ V. Then the ratio of R_B and R_C is ______. **[2015]**



12. The following circuit, the transistor is in active mode and $V_C = 2$ V. To get $V_C = 4$ V, we replace R_C with R'_C.

Then the ratio $\frac{R^1_C}{R_C}$ is______. **[2015]**



13. When a bipolar junction transistor is operating in the saturation mode, which one of the following statements is TRUE about the state of its collector-base (CB) and the base-emitter (BE) junctions? **[2015]**

(A) The CB junction is forward biased and the BE junction is reverse biased.

(B) The CB junction is reverse biased and the BE junction is forward biased.

(C) Both the CB and BE junctions are forward biased.

(D) Both the CB and BE junctions are reverse baised.

14. A transistor circuit is given below. The Zener diode breakdown voltage is 5.3 V as shown. Take base to emitter voltage drop to be 0.6 V. The value of the current gain β is __________. **[2016]**

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. B	**2.** D	**3.** B	**4.** B	**5.** A	**6.** A	**7.** D	**8.** D	**9.** D
10. 22.32	**11.** 105.133		**12.** 0.74 to 0.76		**13.** C	**14.** 18.0 to 20.0		