Pharos University in Alexandria

Faculty of Engineering

Computer Engineering Department

EE232&E232!! :Electronics

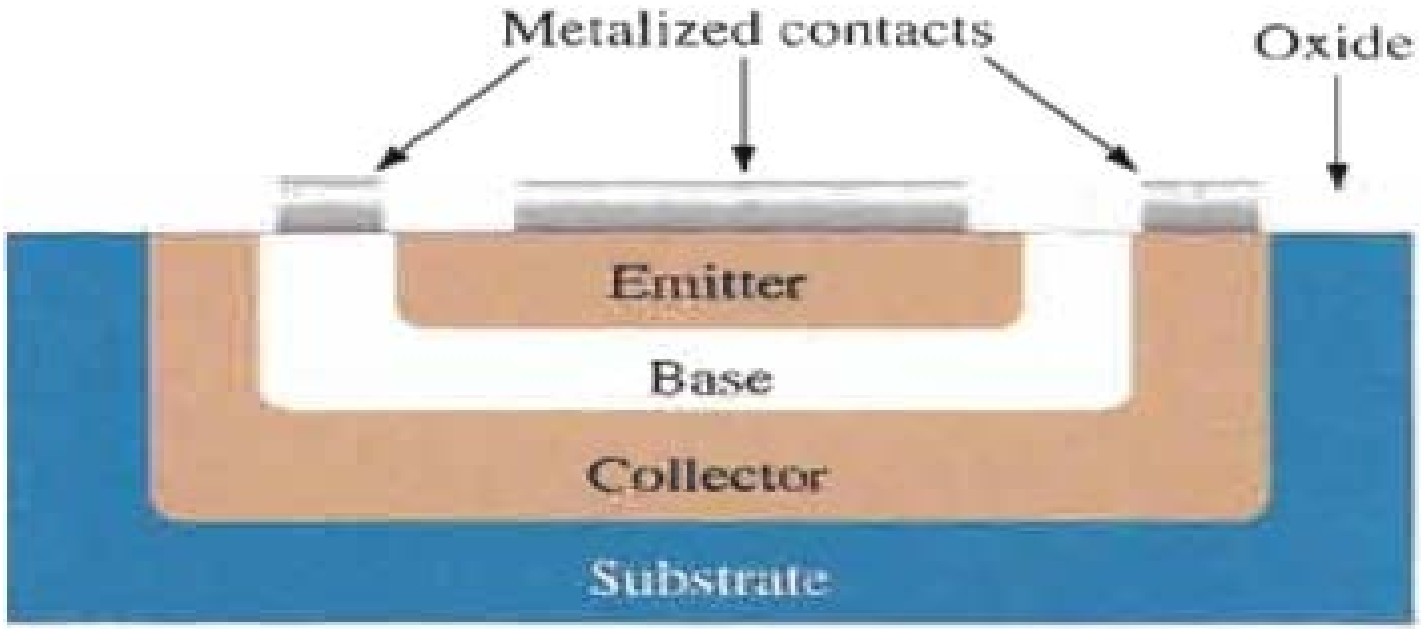
Chapter 5

Bipolar Junction Transistors

Lecture 9

Transistor Structure:

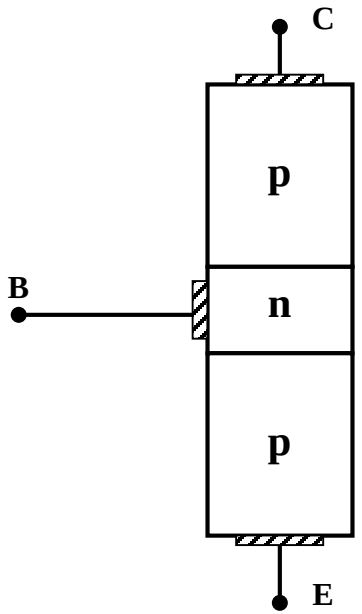
The Bipolar Junction Transistor (BJT) is constructed with three doped semiconductor regions separated by two PN junctions. The three regions are called emitter, base, and collector

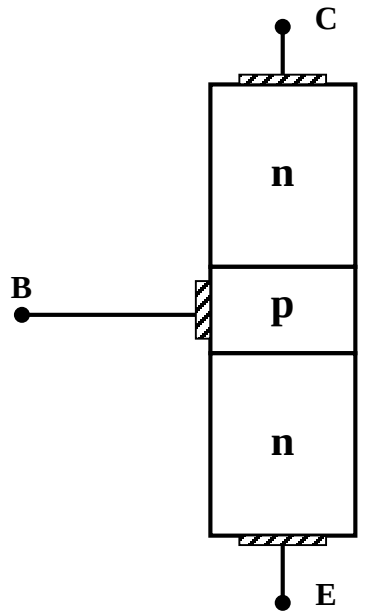


Two Types of BJTs:

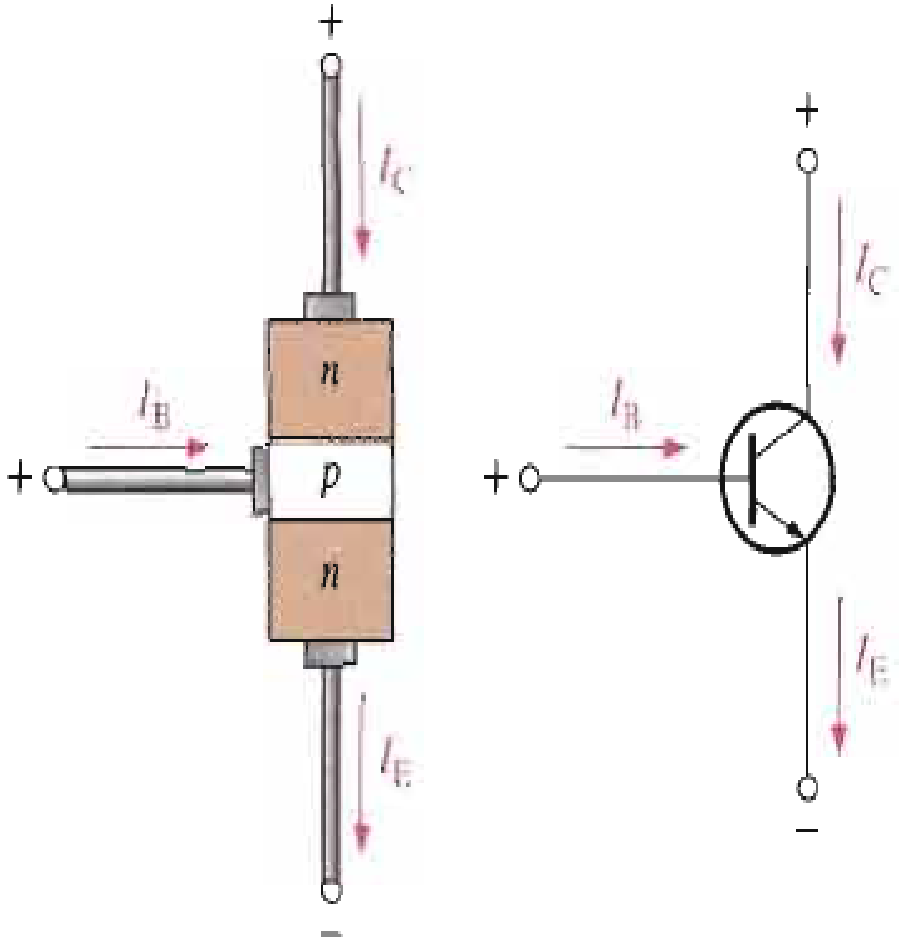
1. NPN consists of two n regions separated by a p region

2. PNP consists of two p regions separated by a n region

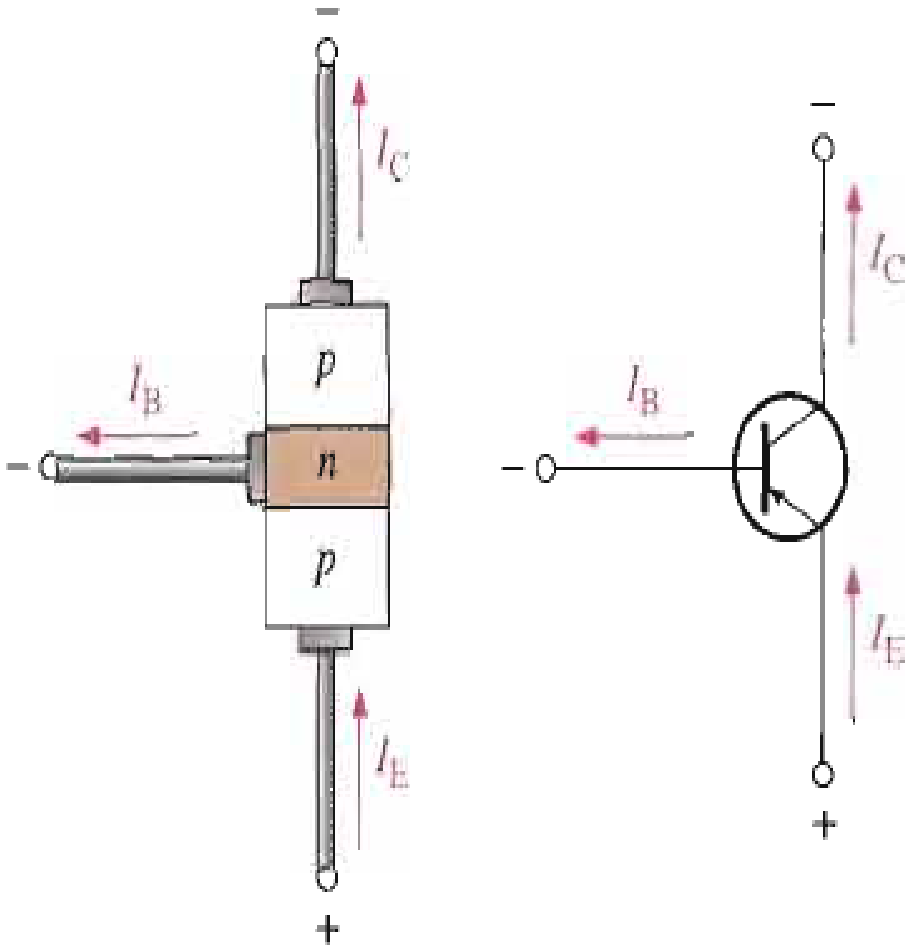




Standard BJT Symbols



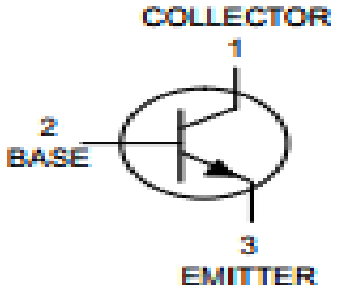
(a) *npn*



(b) *pnp*

BJT Data Sheets

Amplifier Transistors
NPN Silicon



P2N2222A

CASE 29–04, STYLE 17
TO–92 (TO–226AA)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector–Emitter Voltage	V_{CEO}	40	Vdc
Collector–Base Voltage	V_{CBO}	75	Vdc
Emitter–Base Voltage	V_{EBO}	6.0	Vdc
Collector Current — Continuous	I_C	600	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	625 5.0	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.5 12	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	−55 to +150	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	$R_{\theta JA}$	200	°C/W
Thermal Resistance, Junction to Case	$R_{\theta JC}$	83.3	°C/W

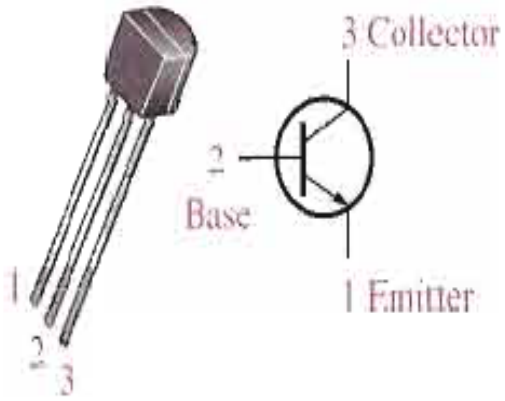
Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector–Emitter Breakdown Voltage (I_C = 10 mAdc, I_B = 0)	$V_{(BR)CEO}$	40	—	Vdc
Collector–Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	$V_{(BR)CBO}$	75	—	Vdc
Emitter–Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	$V_{(BR)EBO}$	6.0	—	Vdc
Collector Cutoff Current (V_{CE} = 60 Vdc, $V_{EB(off)}$ = 3.0 Vdc)	I_{CEX}	—	10	nAdc
Collector Cutoff Current (V_{CB} = 60 Vdc, I_E = 0) (V_{CB} = 60 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	 — —	 0.01 10	μAdc
Emitter Cutoff Current (V_{EB} = 3.0 Vdc, I_C = 0)	I_{EBO}	—	10	nAdc
Collector Cutoff Current (V_{CE} = 10 V)	I_{CEO}	—	10	nAdc
Base Cutoff Current (V_{CE} = 60 Vdc, $V_{EB(off)}$ = 3.0 Vdc)	I_{BEX}	—	20	nAdc

Transistor casing terminal identification

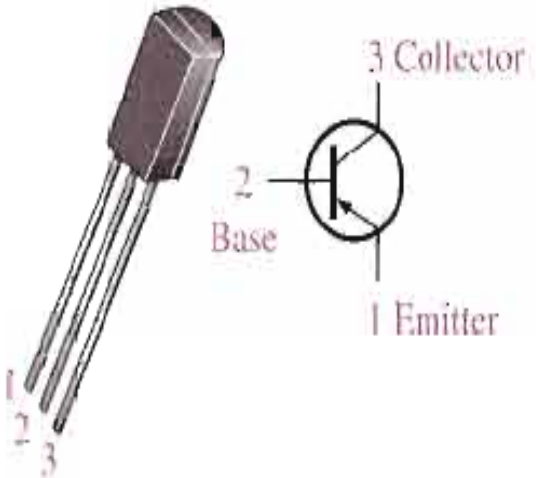
Gold , Aluminum, Nical, Plastic case

Types

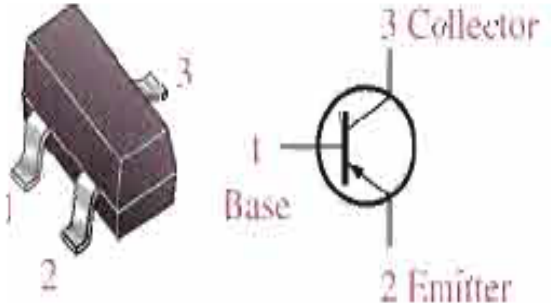
Plastic Cases for Small Signal Tr



(a) TO-92 or TO-226AA

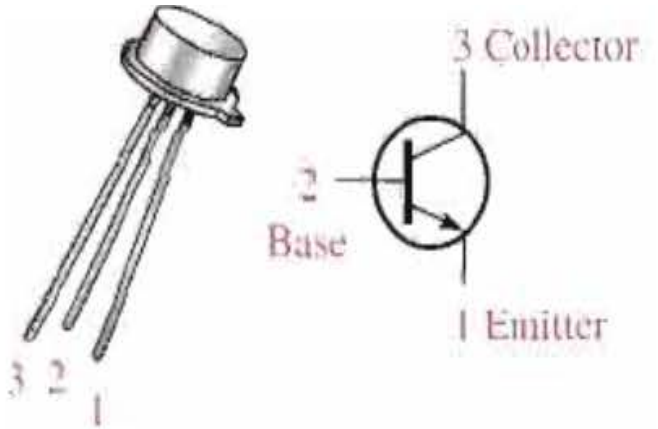


(b) TO-92 or TO-226AE

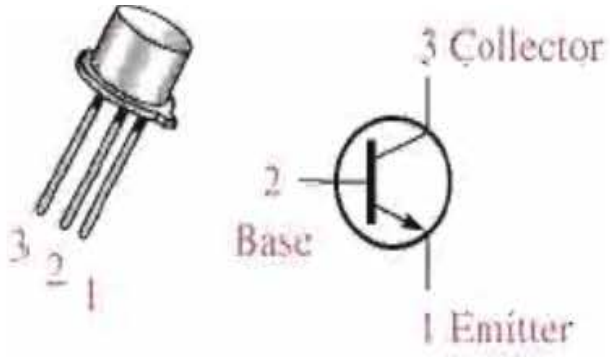


(c) SOT-23 or TO-236AB

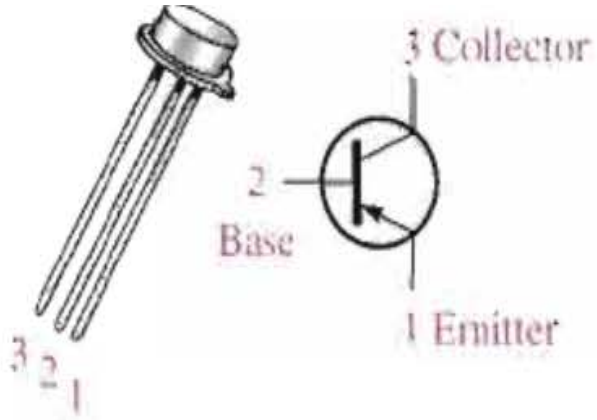
Metal Cases for Small Signal Tr



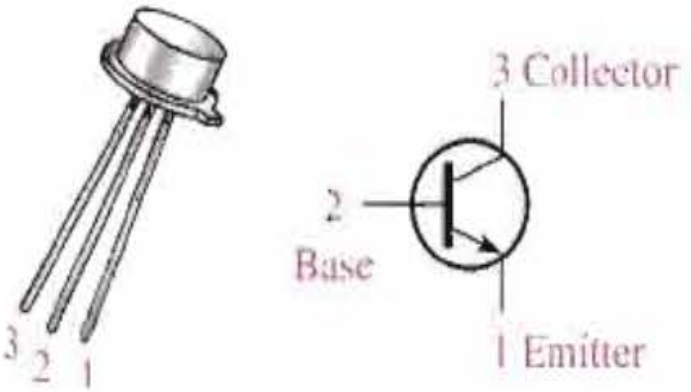
(a) TO-18 or TO-206AA



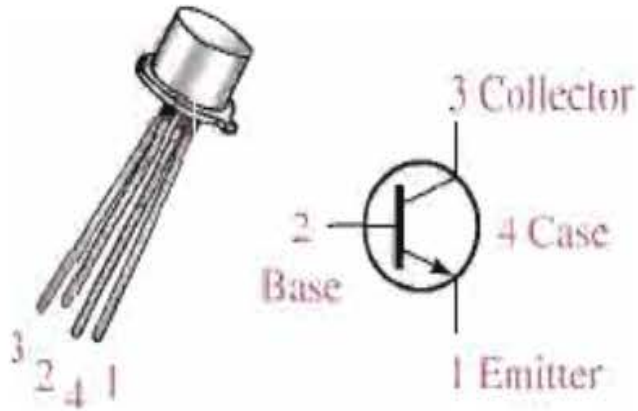
(b) TO-39 or TO-205AD



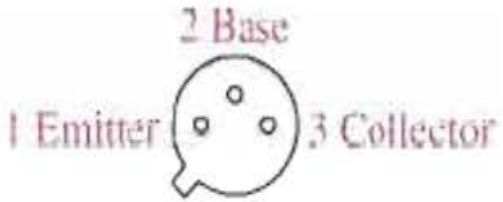
(c) TO-46 or TO-206AB



(d) TO-52 or TO-206AC

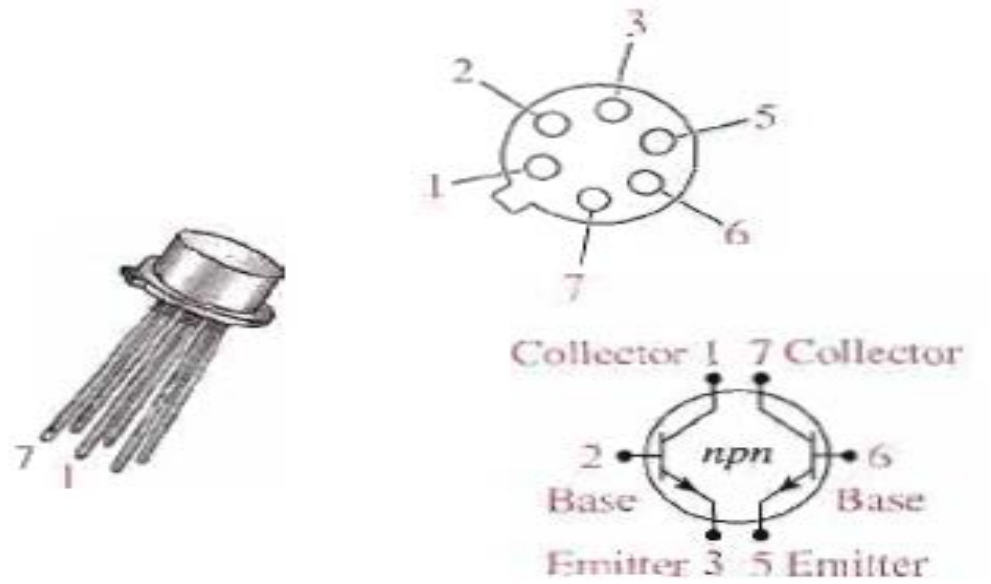


(e) TO-72 or TO-206AF

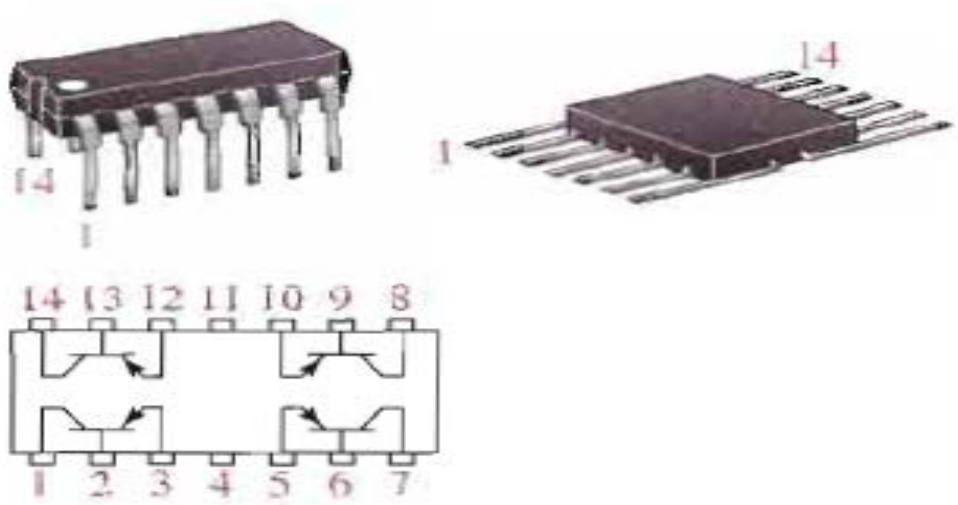


(f) Pin configuration (bottom view). Emitter is closest to tab.

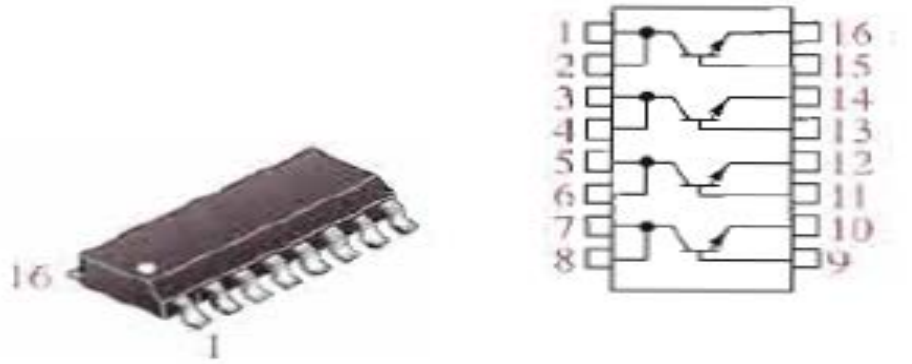
Typical Multiple Transistor Packages



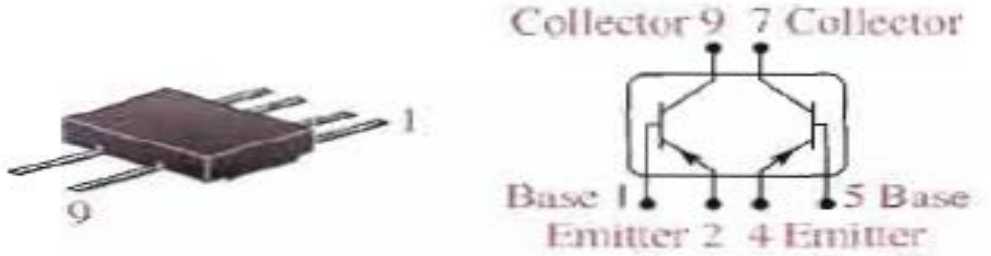
(a) Dual metal can



(b) Quad dual in-line (DIP) and quad flat-pack. Dot indicates pin 1.

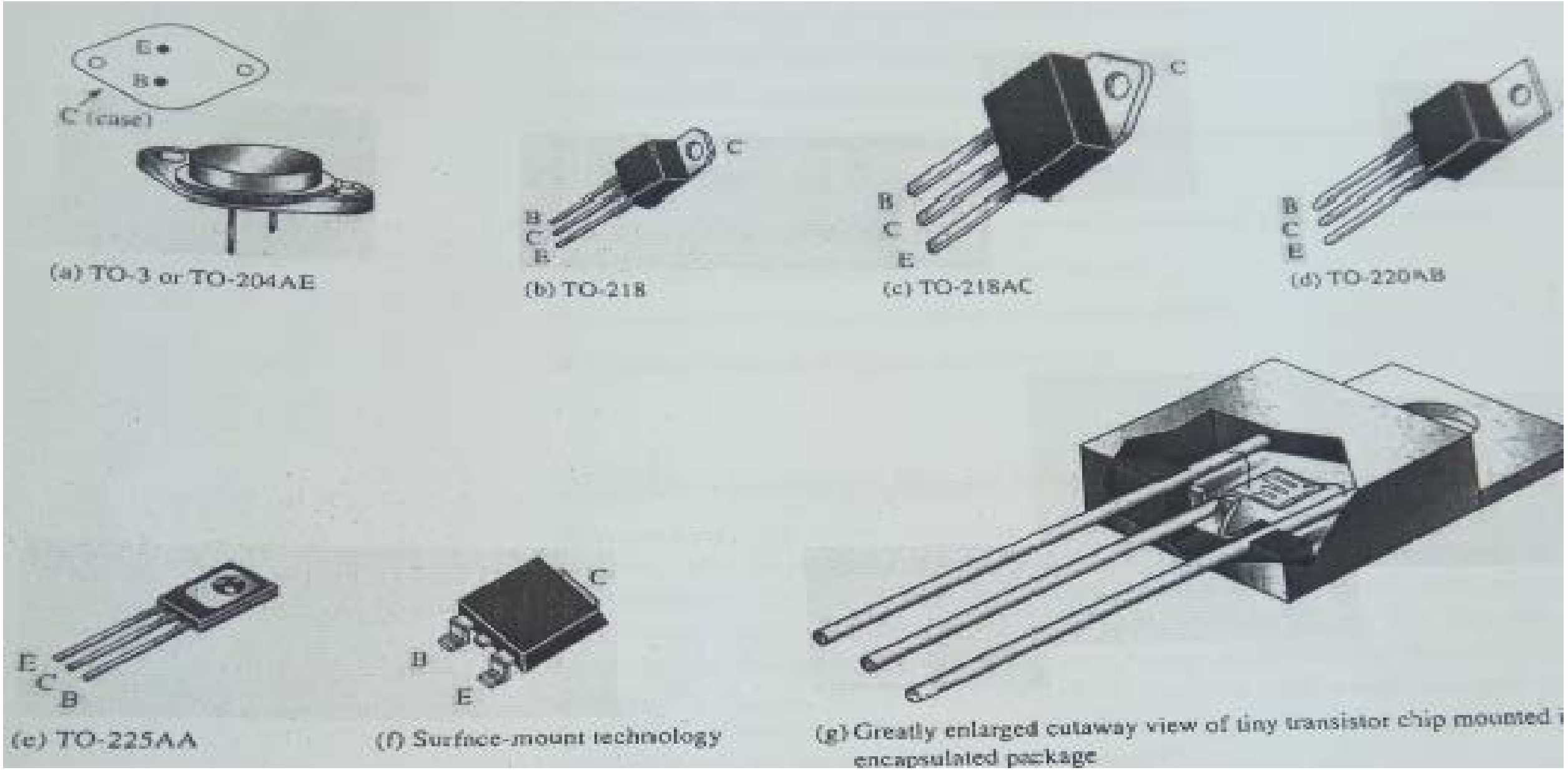


(c) Quad small outline (SO) package for surface-mount technology

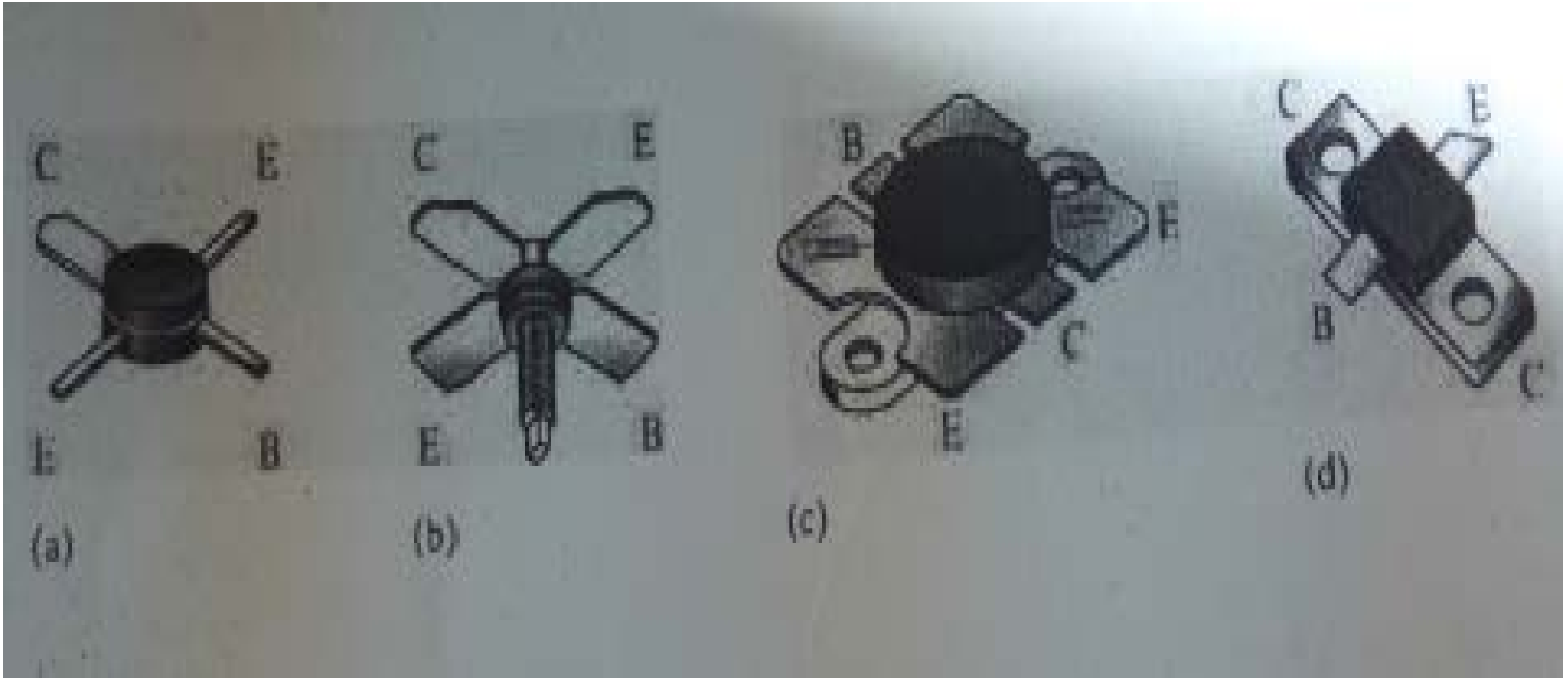


(d) Dual ceramic flat-pack

Typical Power Transistor



Typical RF Transistor



Transistor testing :

1. Curve tracer
2. digital meter
3. Ohmmeter

→ digital meter

For npn

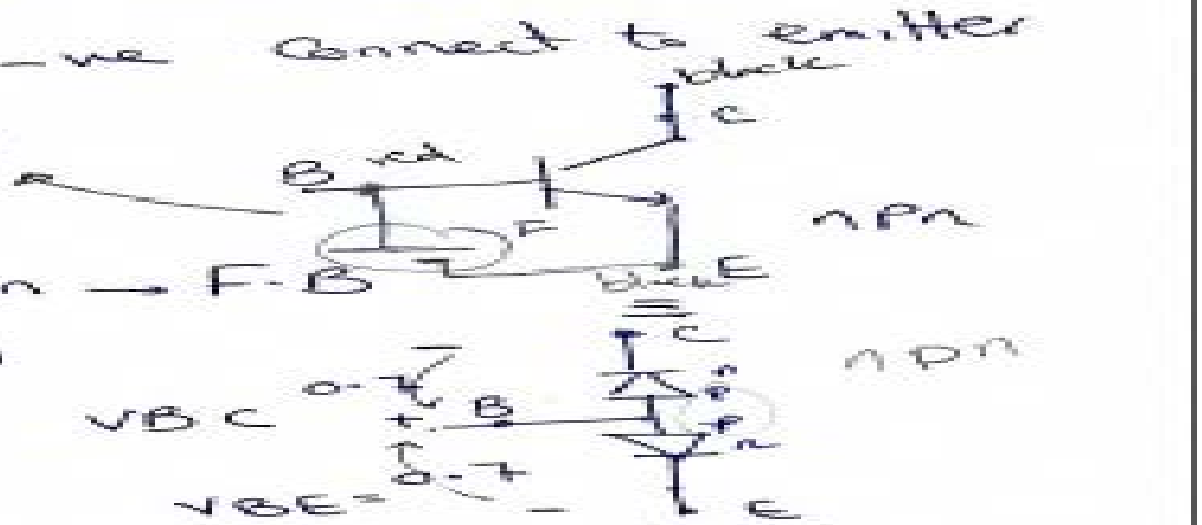
Collector open, B-E Junction → F-B → forward bi

+ve connect base, -ve connect to emitter

V_{BE} = (0.7V Si) (0.5V → 0.9V)

0.3 → Ge

1.2 → GaAs



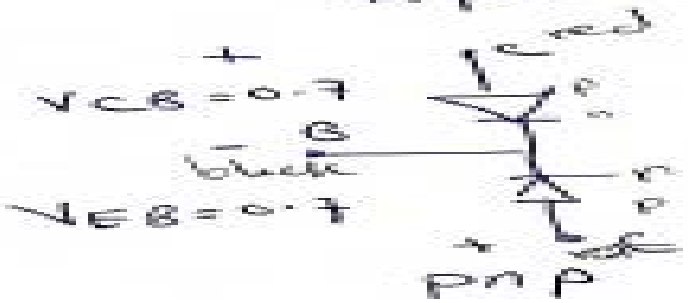
Emitter open, BC Junction → F-B

+ve → base, -ve → collector

V_{BC} = 0.7 (0.5V → 0.9V)

Reverse

Same Concept for PNP

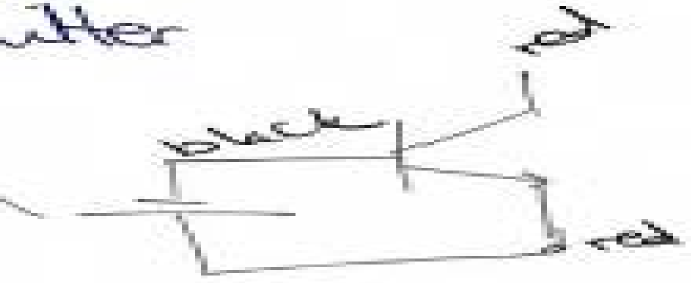


if npn

FOR R-B → BE

-ve → base , +ve → Emitter

V_{BE} → 2.6V



R-B → BC

-ve → Base , +ve → Collecter

V_{BC} = 2.6

كده نتأكد أن Tr سليم

مش نقول Tr بايظ

if F-B , R-B

$V_{BE} = V_{BC} = 2.6$

or $V_{BE} = V_{BC} =$ Zero

سيلكون ← مهم

→ ohmmeter

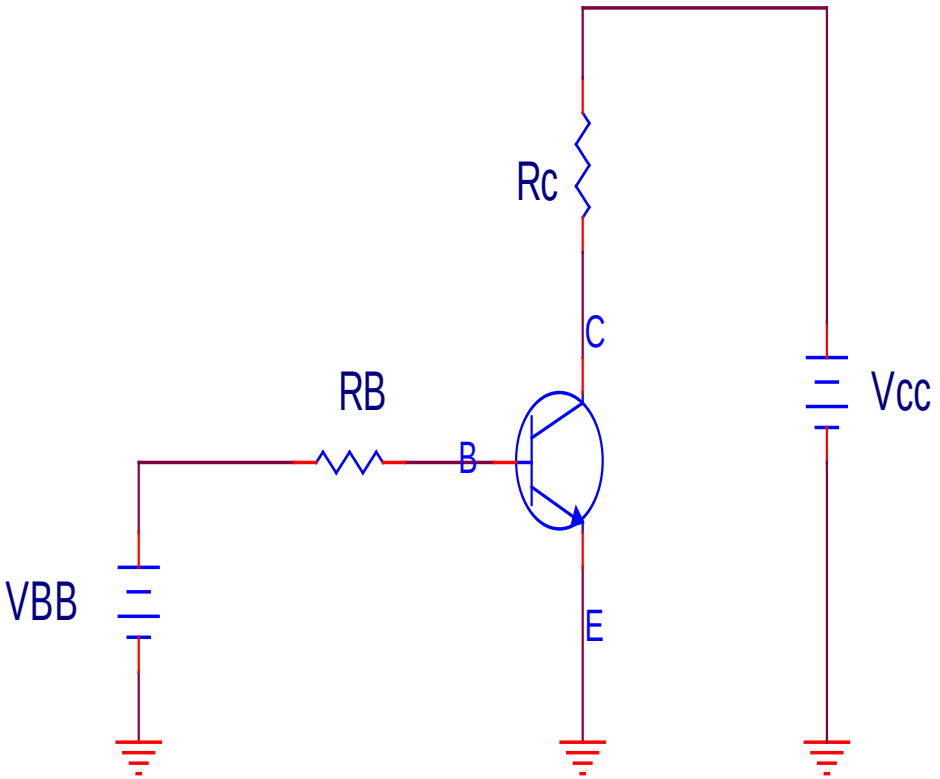
F-B → low resistance ≡ 100Ω to few Kilohms

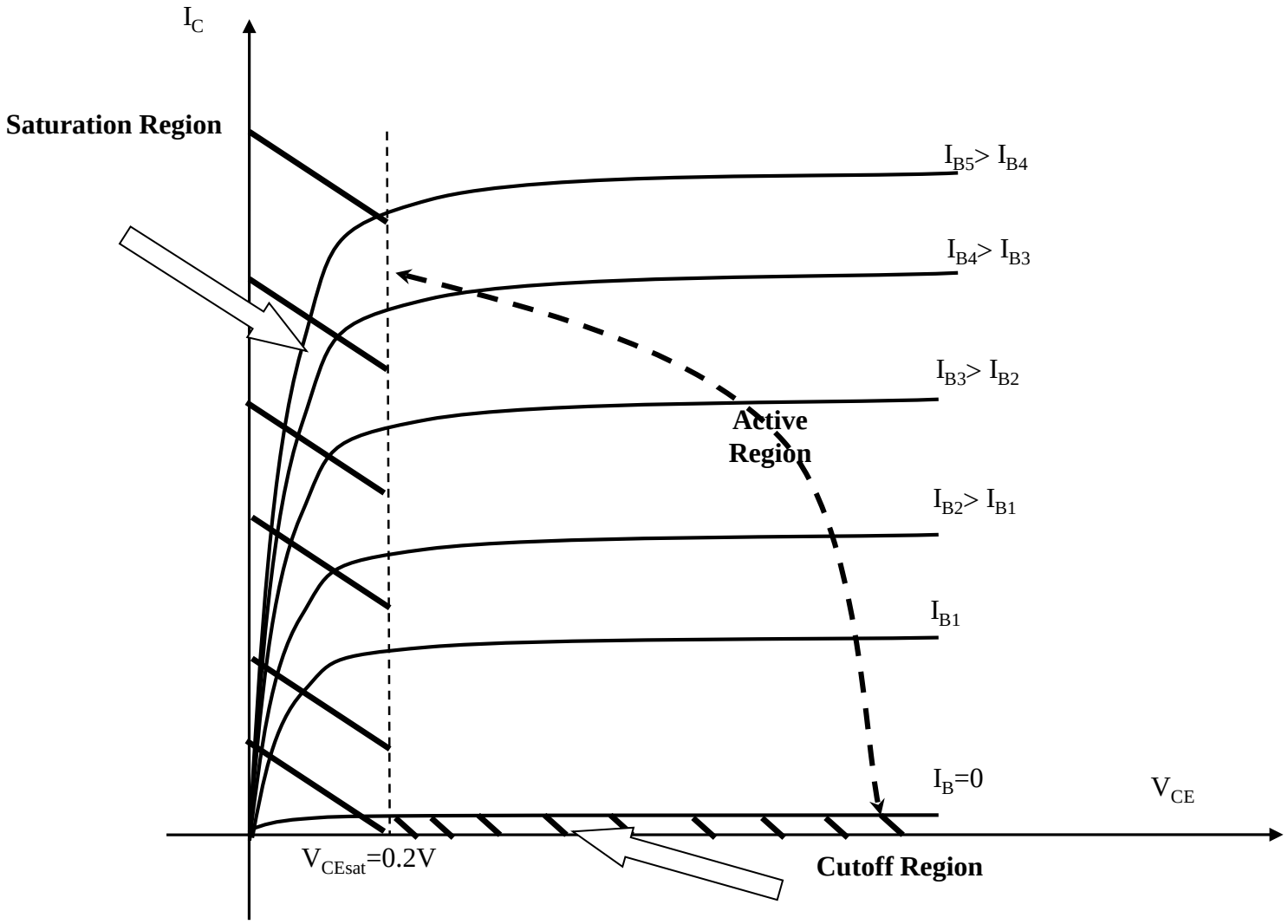
R-B → high resistance > 100kΩ

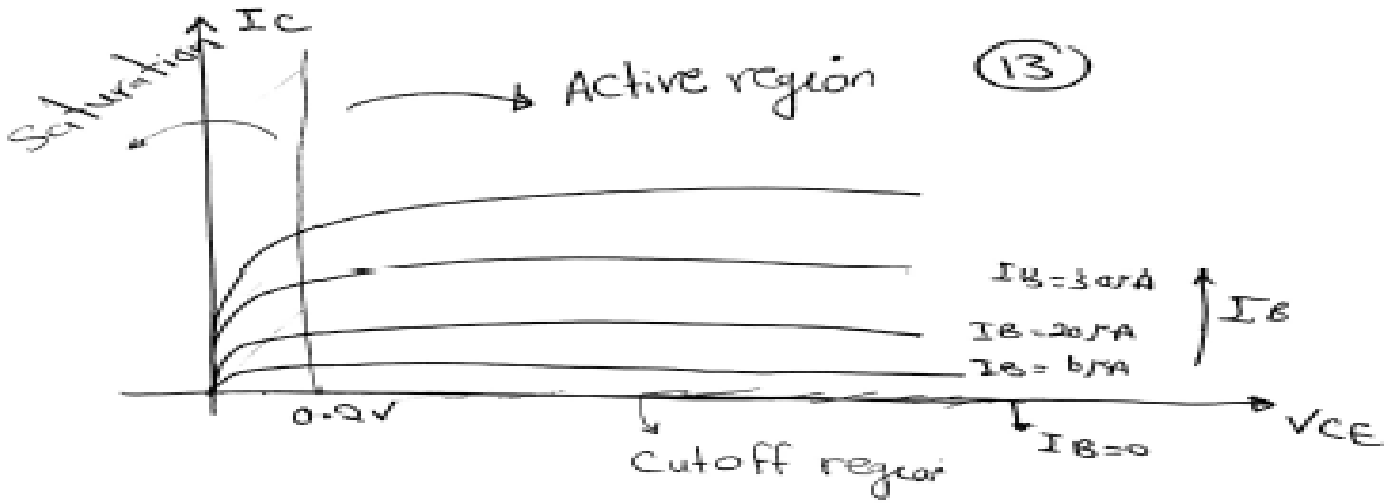
Transistor Under Bias

E-B	B-C	Mode of operation	Application
Forward	Reverse	Active mode	Amplifier
Forward	Forward	Saturation mode	Switch on (short circuit)
Reverse	Reverse	Cut- off mode	Switch off (open circuit)
Reverse	Forward	No use	No use

BJT O/P Characteristics and its Modes of Operation:







① Active region

used as amplifier

$V_{CE} > 0.2V \quad I_B > 0 \qquad V_{BE} = 0.7V$

$I_C \cong I_E \cong \beta I_B \quad , \quad \beta = \frac{\alpha}{1-\alpha}$

② Saturation region

$V_{CE} \leq 0.2$

$V_{CE\,sat} \cong 0.2\,V$

$V_{BE\,sat} = 0.7\,V$

$I_{C\,sat} \leq I_{E\,sat} \neq \beta I_B$

↳ (Constant for different I_B value)

③ Cut off region

$I_B = 0$

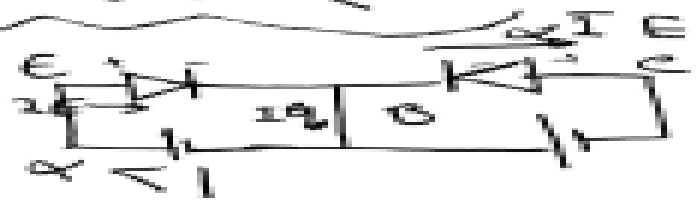
$I_C = I_E = 0$ No Current

BJT as amplifier:

E-B Junction F
B-C Junction R

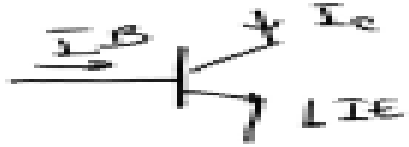
$$I_C = \alpha I_E$$

α : current transfer ratio $\quad 0 < \alpha < 1$



usually $\alpha = 1$

$$I_C \simeq I_E$$



β : amplification factor
depend on the operating temperature
its value increases with increasing temperature

$$I_C = \beta I_B$$

$$\alpha = \frac{\beta}{1+\beta}$$

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

$50 \leq \beta \leq 400$

if not given put $\beta = 100$

$$I_E = I_C + I_B = (1+\beta) I_B \simeq R_{To}$$

DC Solution & operating point (18)

Steps

① All capacitors must be open circuit (o.c)

② Assume that BJT in active mode (F-R) (Amplifie

$V_{BE} = 0.7$ $I_C = I_E = \beta I_B$ $\beta = \frac{\alpha}{1-\alpha}$

$\alpha = \frac{\beta}{1+\beta}$

③ We have 2 loops

④ Base - Emitter loop (B-E)

to get I_B

$I_C = I_E = R I_B$ - ✓

⑤ Collector - Emitter loop (C-E)

get V_{CE} = ✓

If $V_{CE} > 0.2$ V

our assumption

Correct

Active

$V_{CE} \leq 0.2$ V

our assumption wrong

BJT in Saturation

Steps

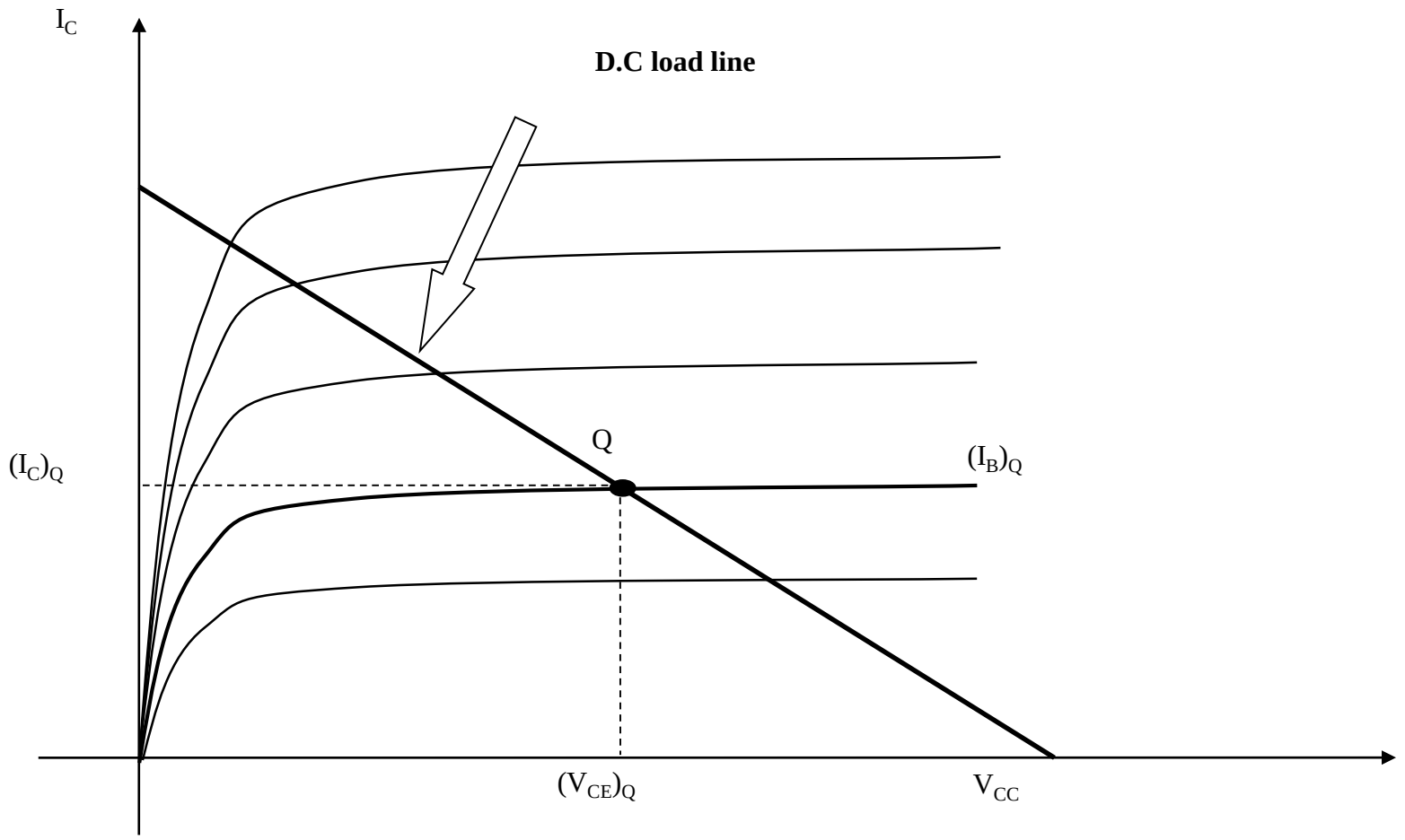
① E-C loop

$V_{CE_{sat}} = 0.2 \rightarrow I_{csat} = I_E$

② B-E loop

$\rightarrow I_B$

The DC Operating Point (Q–point):



BJT Amplifier Configurations:

The BJT amplifier has three circuit configurations:

a. **Common Emitter (CE):** The emitter is connected to the ground, the i/p signal is applied to the base and the o/p signal is on the collector.

b. **Common Base (CB):** The base is connected to the ground, the i/p signal is applied to the emitter and the o/p signal is on the collector.

c. **Common Collector (CC):** The collector is connected to the ground, the i/p signal is applied to the base and the o/p signal is on the emitter.

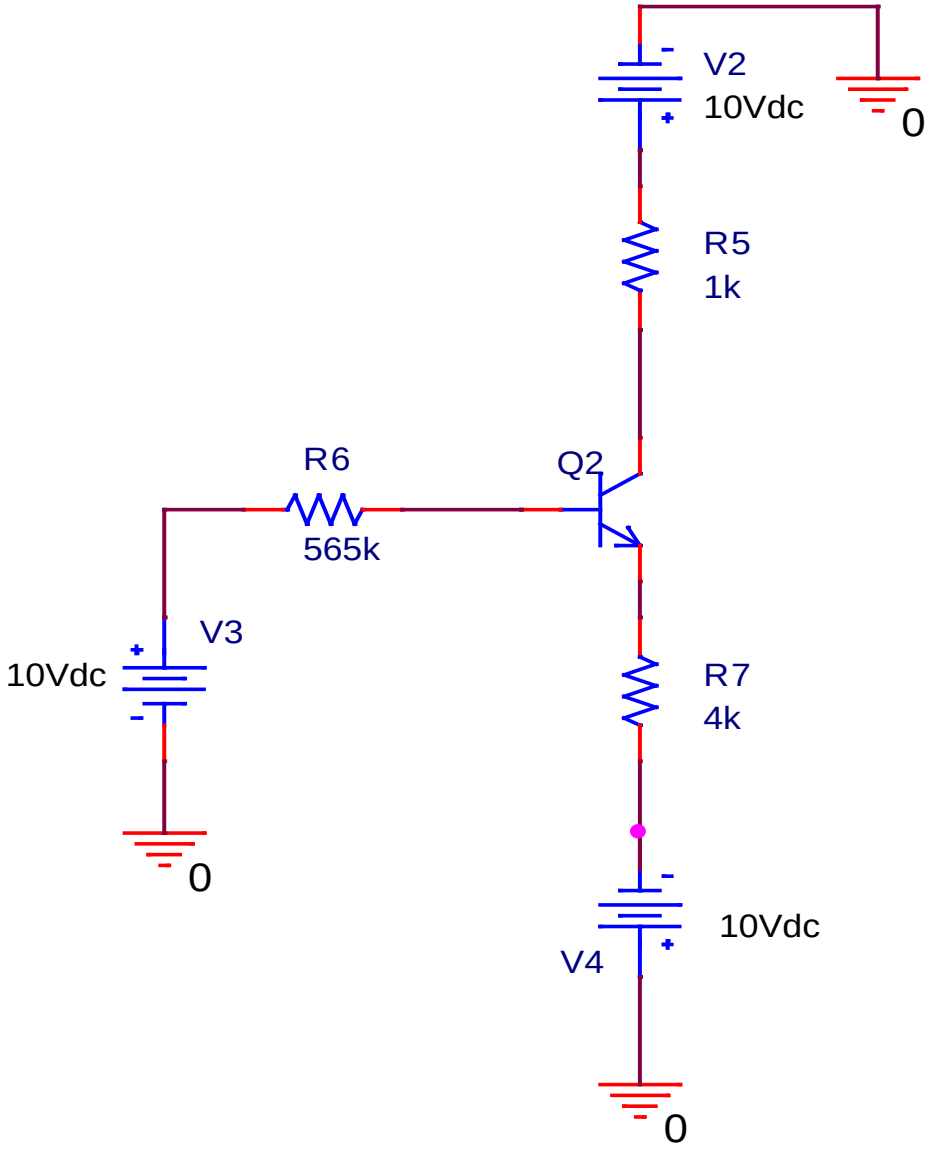
Example

$\beta = 100$

For the shown circuit,

a. Find IB, IE, IC, and sketch the DC load line and locate the operating point

b. Repeat if RC =11 kΩ



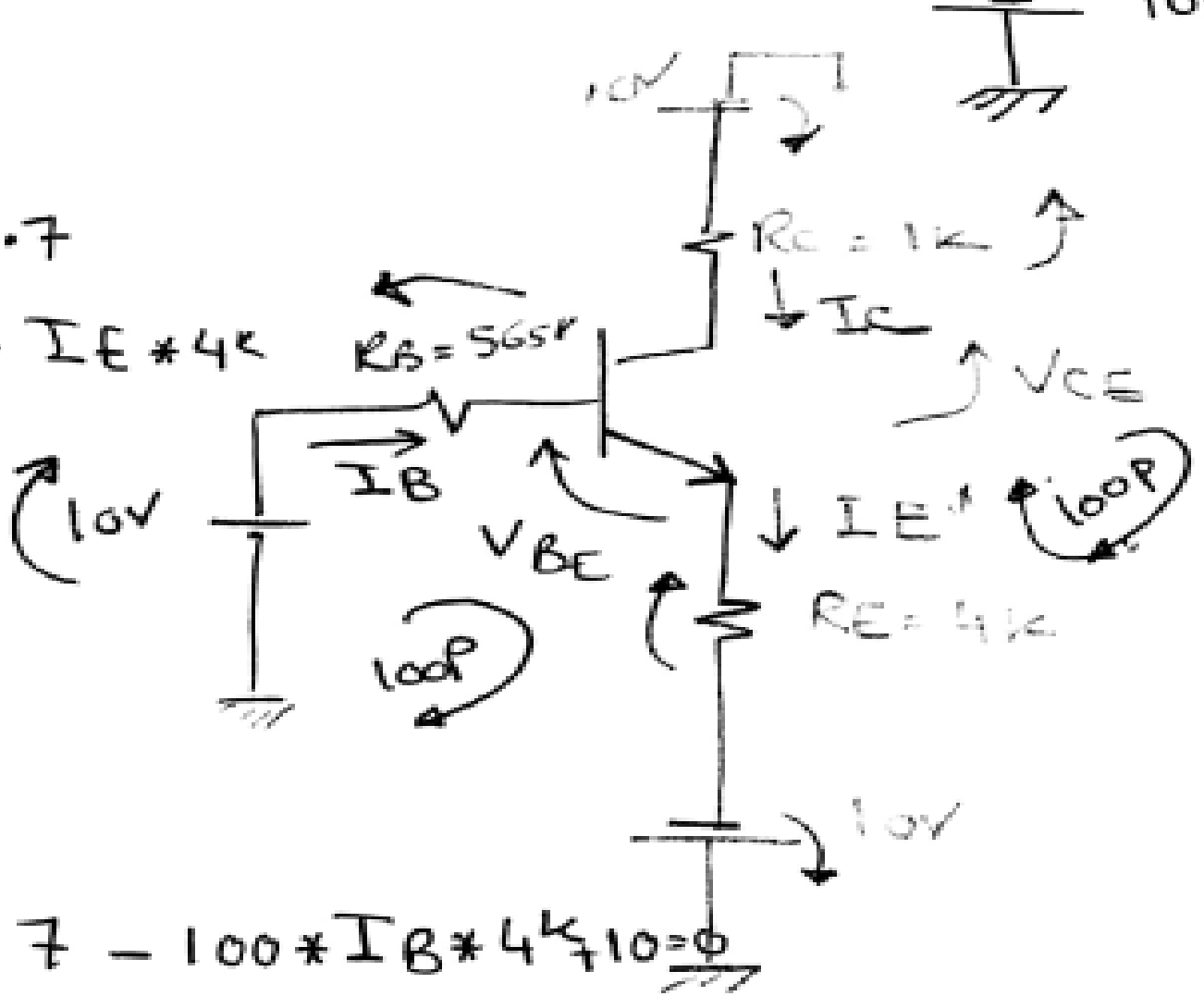
Sol

KVL at B-E loop

$10 - I_B * 565^K - 0.7 - I_E * 4^K + 10 = 0$

$I_E = \beta I_B$

100



$10 - I_B * 565^K - 0.7 - 100 * I_B * 4^K + 10 = 0$

$I_B = 0.02\ mA$

$I_C \simeq I_E = \beta I_B = 2mA$

KVL at EC loop

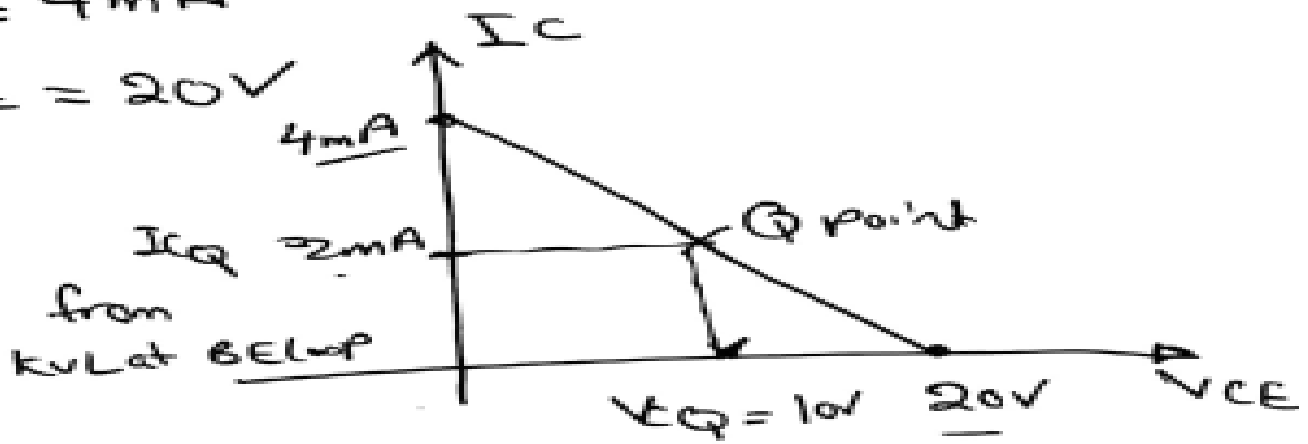
$$-10 + I_C * 1^K + V_{CE} + I_E * 4^K - 10 = 0$$

$I_C \cong I_E$

$$V_{CE} + 5^K I_C = 20$$ load line equation

if $V_{CE} = 0 \longrightarrow I_C = 4mA$

if $I_C = 0 \longrightarrow V_{CE} = 20V$



to get Q-point

$I_{CQ} \cong I_E = \beta I_B = 2mA$ from KVL at BE loop

$$V_{CEQ} + 5^K I_{CQ} = 20$$

$I_{CQ} = 2mA$

$V_{CEQ} = 10V > 0.2$

Correct assumption Active region

(ii) if $R_C = 11k\Omega$

B-E loop → No change from (i) $I_B = 0.02mA$, $I_C = I_E = 2mA$

E-C loop

$R_C = 11k\Omega$

$-10 + I_C * 11k + V_{CE} + I_E * 4k - 10 = 0$

$V_{CE} + 15 I_C = 20$ load line

to get Q-point

I_{CQ} 2mA → $V_{CEQ} = 10V < 0.2V$

∴ Assumption wrong

BJT in saturation

$V_{CEsat} = 0.2V$

E-C loop

$V_{CE_{sat}}$ is $I_{C_{sat}} = 20$

↘ 0.2V

$I_{Csat} = 1.32mA$

B-E loop

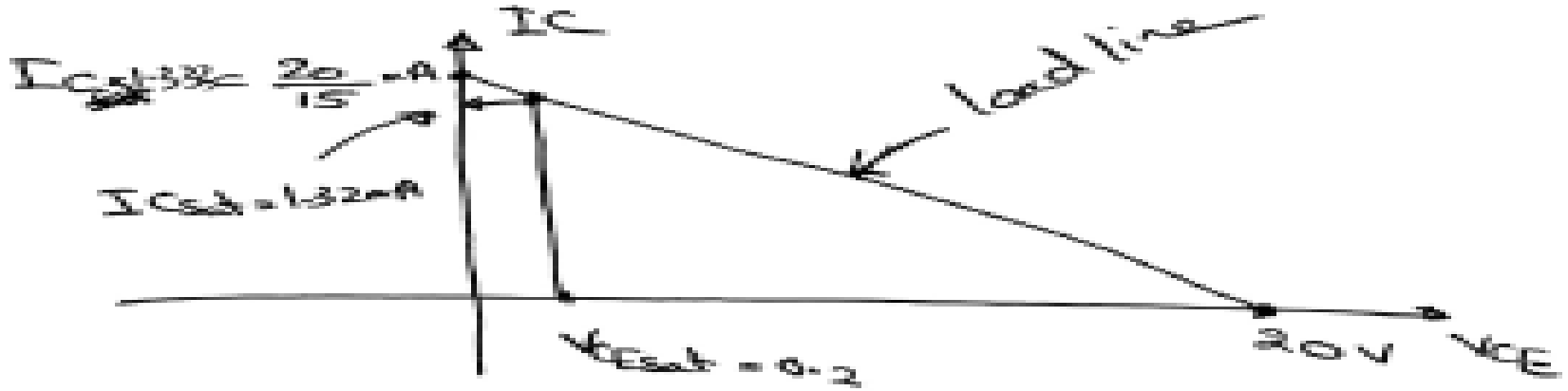
(13)

$$10 - I_{B_{sat}} * 565^{k} - V_{BE_{sat}} - I_{E_{sat}} * 4^{k} + 10 = 0$$

$V_{BE_{sat}} \rightarrow 0.7$

$I_{E_{sat}} \rightarrow I_{C_{sat}} = 1.32\,mA$

$$I_{B_{sat}} = 0.0248\,mA$$



$$V_{CE} + 15^{k} I_C = 20$$

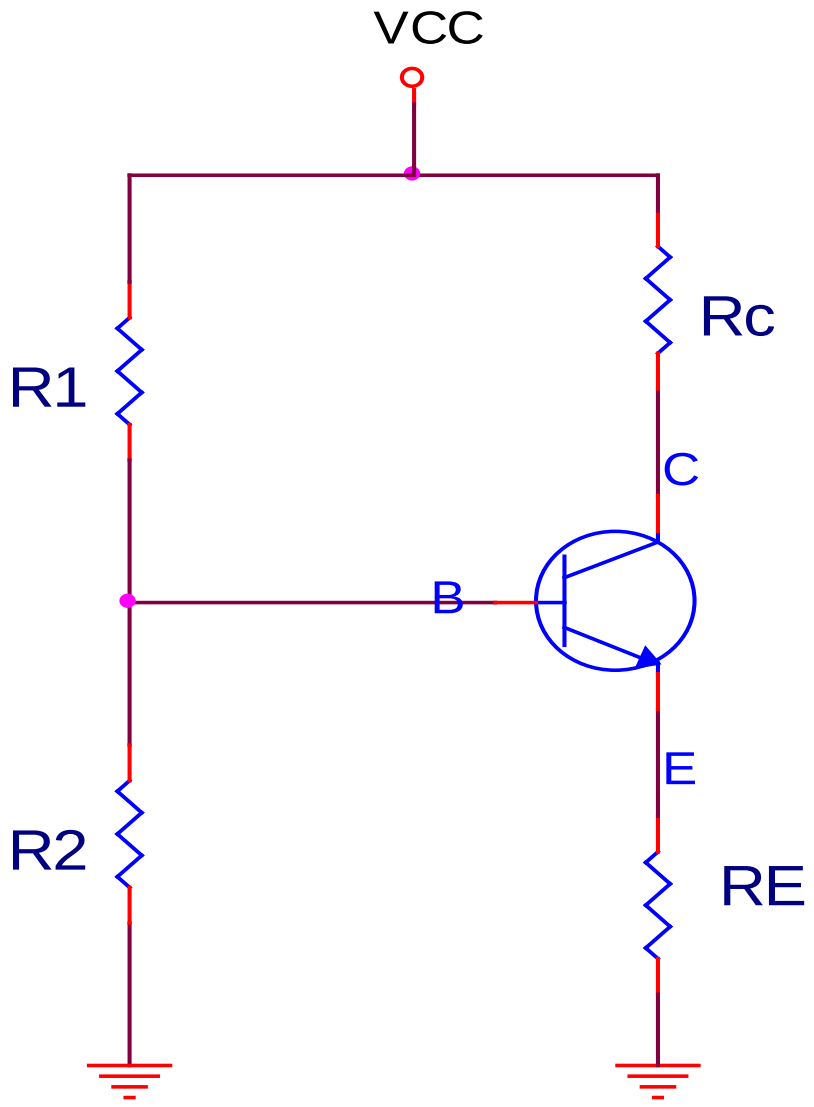
at $I_C = 0 \longrightarrow V_{CE} = 20$

at $V_{CE} = 0 \longrightarrow I_C = \frac{20}{15}$

Example

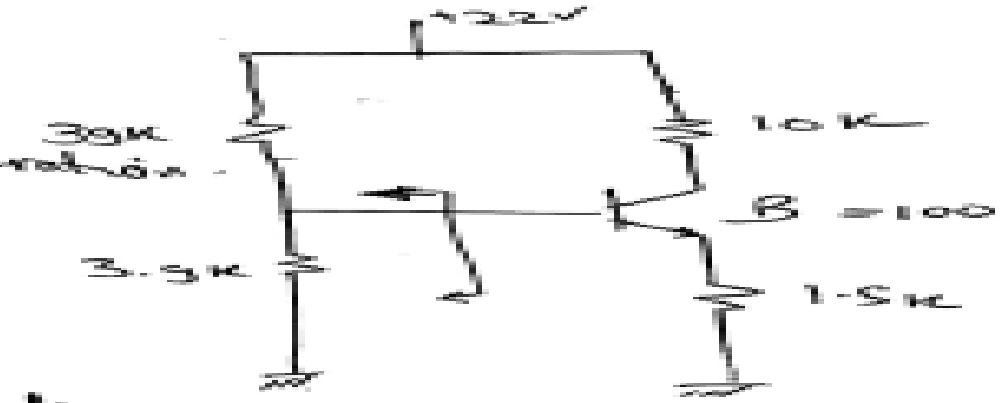
In the following fig, VCC= 22V, R1= 39 kΩ, R2 =3.9 kΩ, RE =1.5 kΩ , RC=10 kΩ, β =100.
Determine the dc bias voltage VCE and IC for voltage divider configuration

Solved in lecture



Example 2 of voltage divider bias configuration

Determine the dc bias voltage V_{CE} and I_C for voltage divider configuration

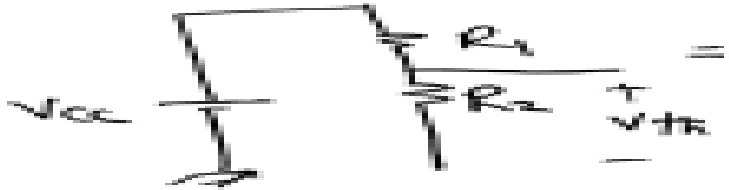


Sol

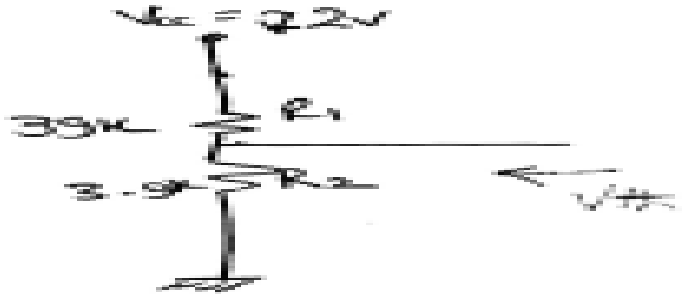
must make thevinin

$$V_{th} = V_{CC} \frac{R_2}{R_1 + R_2}$$ Voltage divider rule

$$V_{th} = 22 * \frac{3.9K}{3.9 + 39} = \boxed{3V}$$



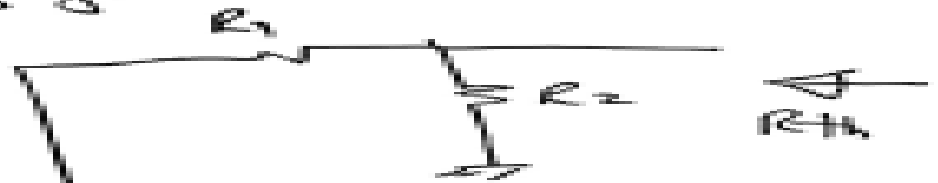
=



all dc sources ground

$$R_{th} = R_1 \,||\, R_2$$

$$\boxed{R_{th} = 3.56K\Omega}$$



KVL at B-E loop

$$V_{th} - I_B R_{th} - V_{BE} - I_E R_E = 0$$

$V_{th} \rightarrow 2$, $R_{th} \rightarrow 3.55$, $V_{BE} \rightarrow 0.7$, $R_E \rightarrow 1.5k$, $I_E \rightarrow \beta I_B$

$$I_B = \boxed{8.38\,\mu A}$$

$$I_C = I_E = \beta I_B = \boxed{0.84\,mA}$$

KVL E-C loop

$$-V_{CC} + I_C * 10^k + V_{CE} + I_E * 1.5^k = 0$$

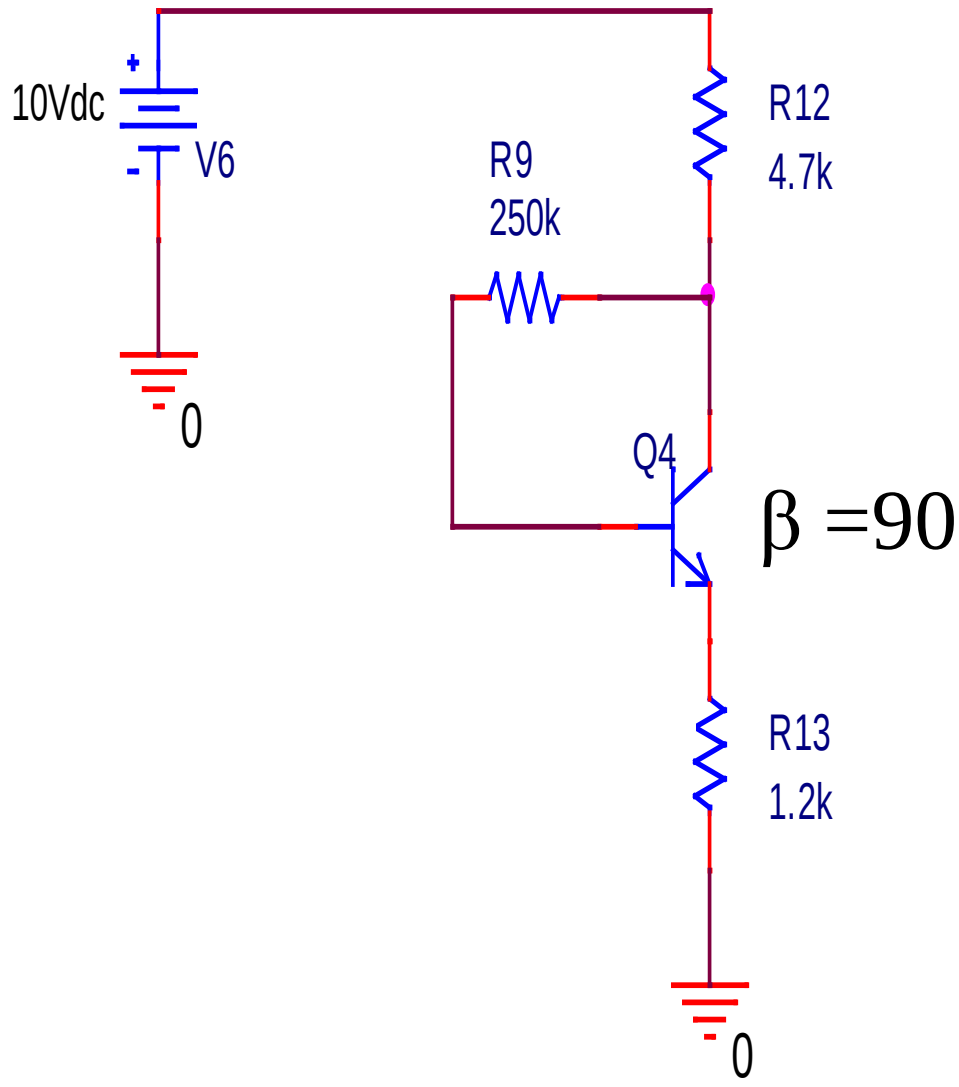
$V_{CC} \rightarrow 22$, $I_C \rightarrow 0.84$, $I_E = I_C = 0.84$

$$V_{CE} = 12.34\,V > 0.2$$

Active Region
Correct assumptio

Example

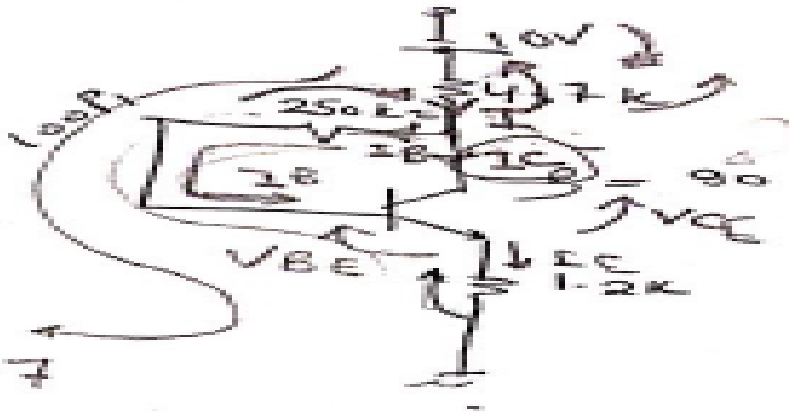
Determine the following for feed back configuration IC_Q and VCE_Q



Solved in lecture

Example: (feed back configuration)

Determine the I_{CQ}, V_{CEQ}



KVL loop 1

$$10 - 4.7k\, I_B - I_B * 250k - V_{BE} - I_E * 1.2k = 0$$

$$I = I_B + I_C = (1+\beta) I_B$$

$I_C = \beta I_B$ (1 mA or more)

$$I \approx \beta I_B$$

$$I_B = 11.91\ \mu A$$

$$I_{CQ} = \beta I_B = 1.43\ mA$$

KVL C-C loop

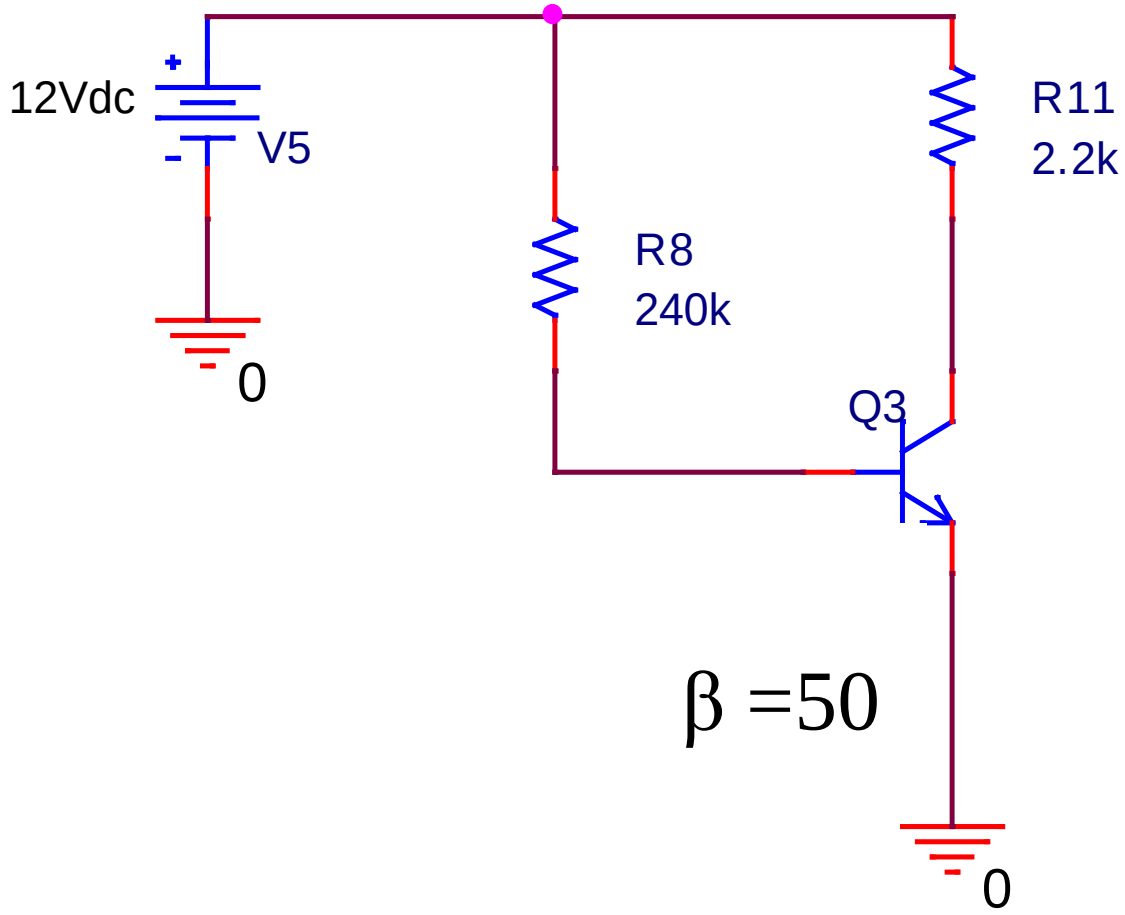
$$-10 + 4.7 I_C + V_{CEQ} + I_E * 1.2 = 0$$

$I_C \approx \beta I_B$, $I_E \approx I_C \approx \beta I_B$

$$V_{CEQ} = 3.69\ V$$

Example

Determine the following for fixed bias configuration IB_Q ,IC_Q, VCE_Q, VB , VC and VBC



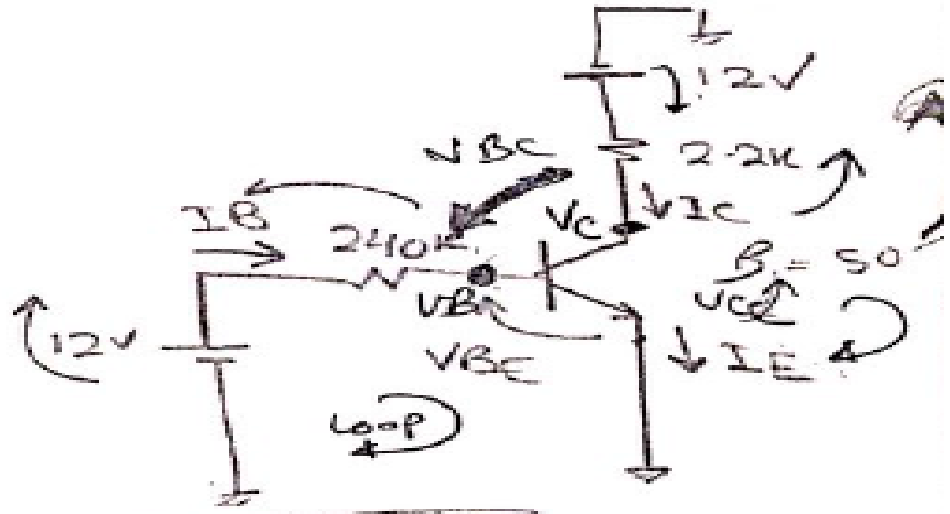
B - E loop

$12 - I_B * 240^K - V_{BE} = 0$ (0.7)

$$\boxed{I_{BQ} = 47.08\,\mu A}$$

$I_{CQ} = \beta I_{BQ} = (50)(47.08\,\mu A)$

$$\boxed{I_{CQ} = 2.35\,mA}$$



C - E loop

$-12 + I_{CQ} * 2.2^K + V_{CE_Q} = 0$ (I_{CQ} = 2.35 mA)

$$\boxed{V_{CEQ} = 6.83V} \quad > 0.2$$

Active mode

Amplifier

BE → F.B

BC → R.B

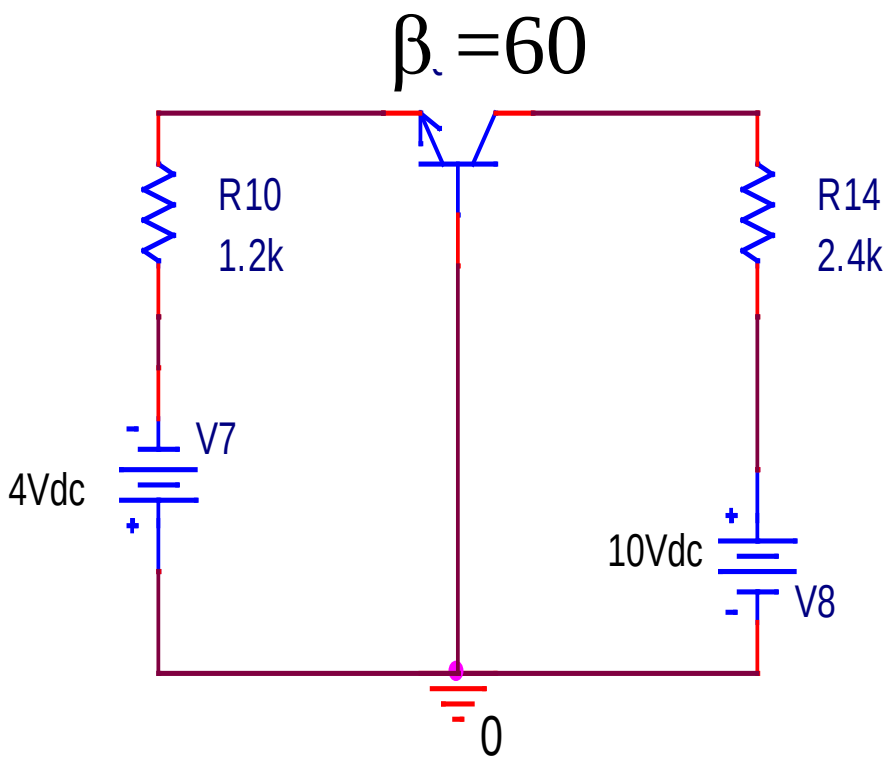
$V_C = V_{CE} = 6.83V$

$V_B = V_{BE} = 0.7V$

$V_{BC} = V_B - V_C = -6.13V$

Example

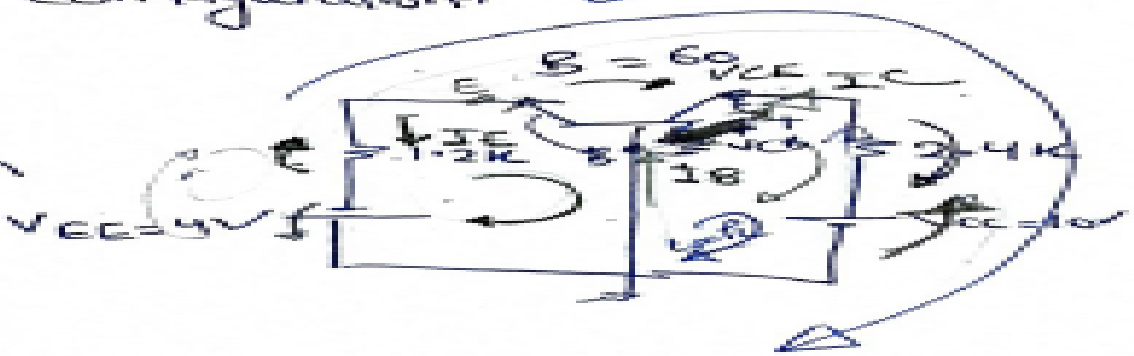
Determine the following for common base configuration IE, IB, VB , VCE and VCB



Solved in lecture

Examples of Common-Base Configuration

Determine I_E, I_B, V_{CE}, V_{CB} for Common-base configuration



KVL E-B loop

$$-4 + I_E * 1.2k + V_{BE} = 0$$

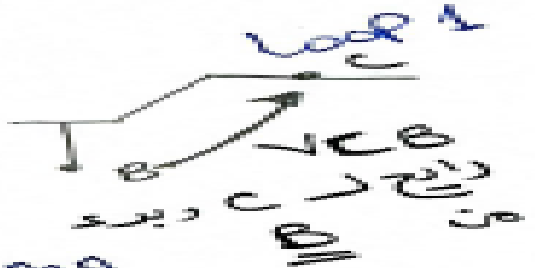
$V_{BE} = 0.7$

$I_E = 2.75\,mA$

$I_C = I_E = 2.75\,mA$

$I_C = \beta I_B$

$$I_B = \frac{I_C}{\beta} = \frac{2.75\,mA}{60} = 0.045833\,mA$$



KVL EC loop 1

$$-4 + I_E R_E + V_{CE} + I_C * R_C - V_{CC} = 0$$

$I_E = 2.75$, $R_E = 1.2k$, $I_C = 2.75$, $R_C = 2.4$, $V_{CC} = 0$

$$V_{CC} = 4.1\,V$$

KVL loop 2

$$V_{CB} + I_C \times 2.4 - V_{CC} = 0$$

$I_C = 2.75$, $V_{CC} = 10$

$$V_{CB} = 3.51\,V$$