1. Explain the different modes of operation of a PNP transistor with required conditions and a suitable diagram. Draw the symbol of a PNP transistor with proper labeling.

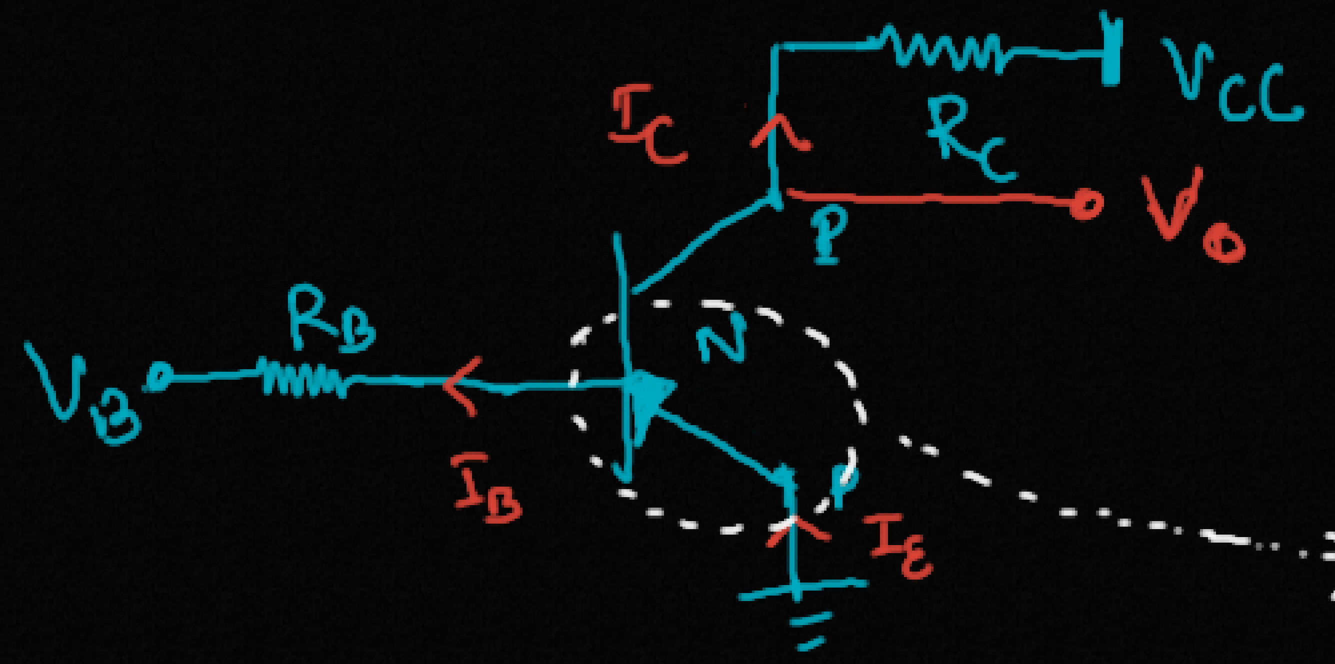
Solution:-

PNP transistor has four different modes of operation:-

(a) Cut off region (b) Active region (c) Saturation region (d) Reverse active region

(a) Cut off region:-

In this mode emitter base junction and collector base junction are mode, where there is no flow of current in transistor. This mode can be used in switching operation where we need to switch off the circuit.



$I_C = I_B = I_E = 0$

$V_0 = V_{CC} - I_C R_C$

$(V_{EB})_{o.c.} < 0.7V$ (for sillicon transistor)

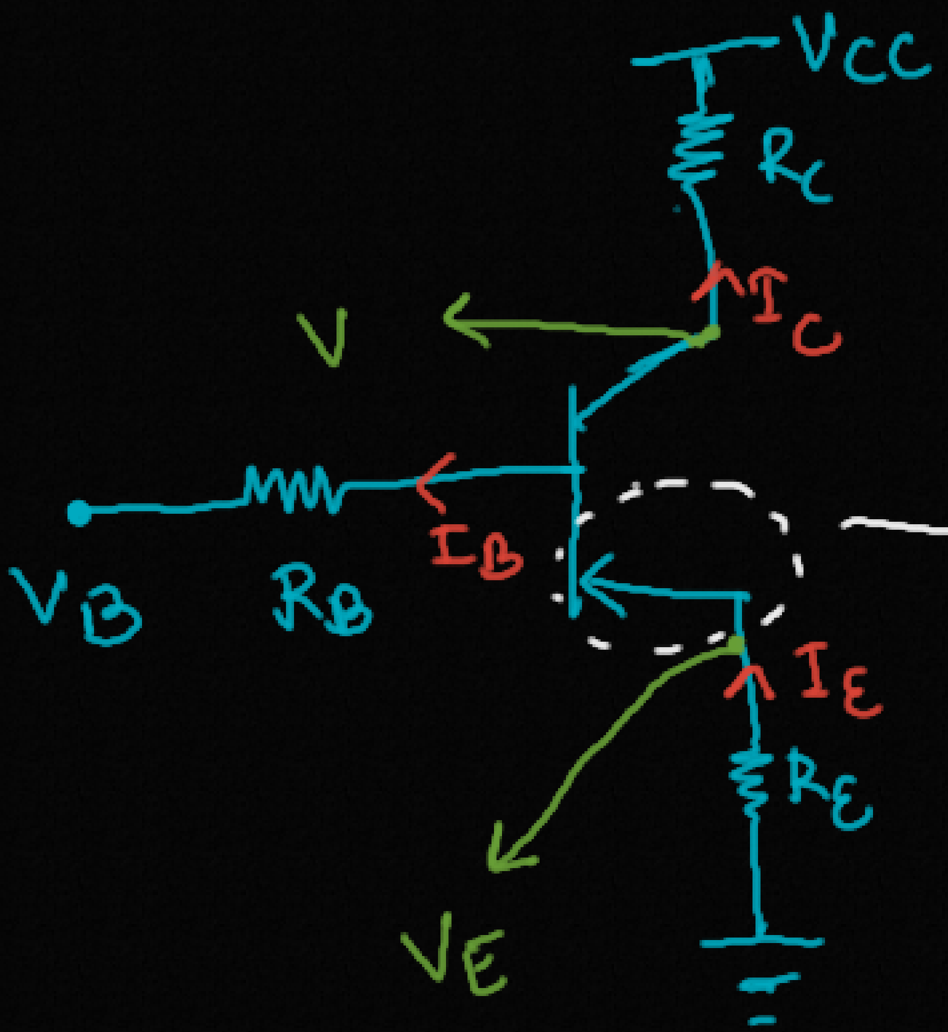
$(V_{EB})_{o.c.}$ = open circuit voltage of Emitter Base Junction

DC operating point

$(0, V_{CC})$

(b) Active Region :-

In this mode of configuration, the emitter base junction is forward biased and collector base junction is reverse-biased. In this mode we use the transistor as an amplifier.



$\boxed{I_E = I_B + I_C}$

$\boxed{I_C = \beta I_B}$ $\boxed{I_E = (\beta + 1) I_B}$

$\boxed{I_C = \alpha I_E}$

$(V_{EB})_{o.c.} > 0.7V$

(for sillicon transistor)

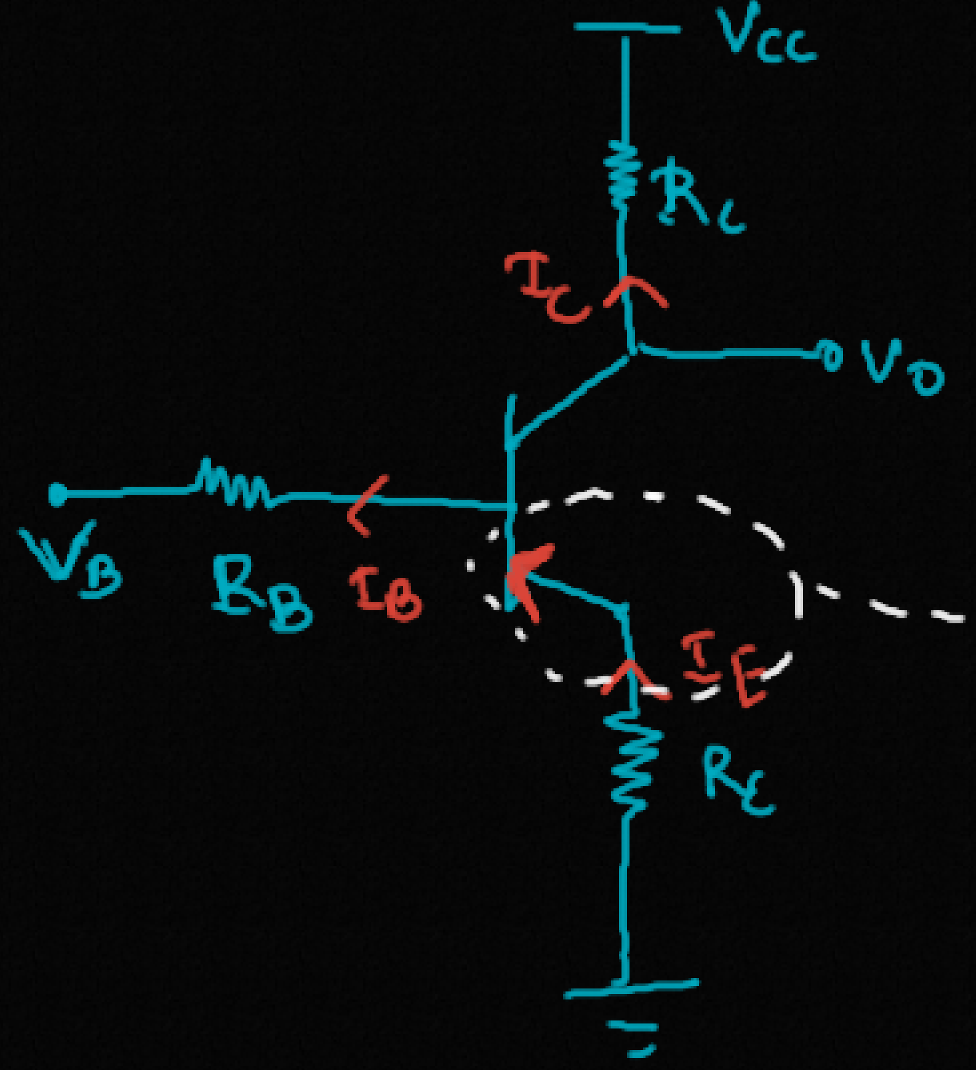
And also $(V_{CE}) > 0.2V$

V_{CE} = voltage of collector emitter junction

DC operating Point - $(I_C, V_{CC} - I_C R_C - V_E)$

(c) Saturation Region :-

In this mode of operation, both emitter base junction and collector base junction are forward biased. This can be used in switch application to turn on the switch.



$V_{EB} > 0.7V$

$I_C \neq \beta I_B$

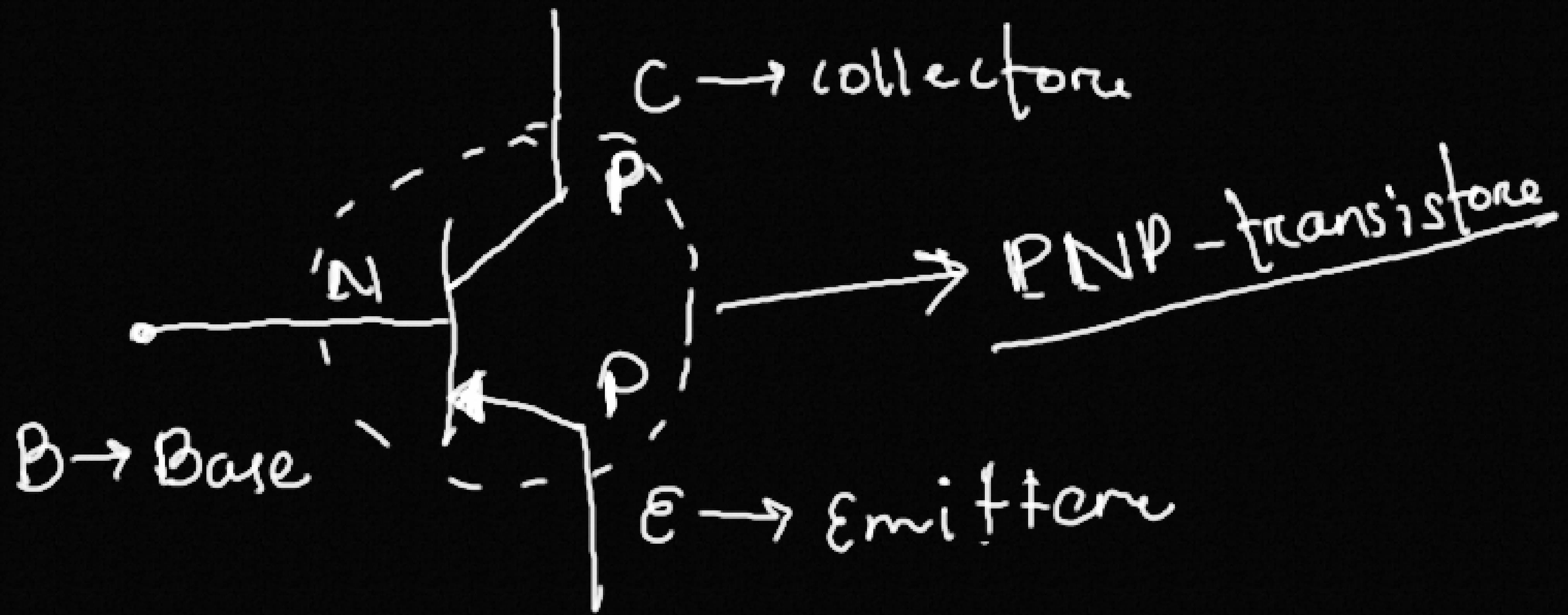
$I_E = I_B + I_C$

$(V_{CE})_{sat} = 0.2V$
(sillicon transistor)

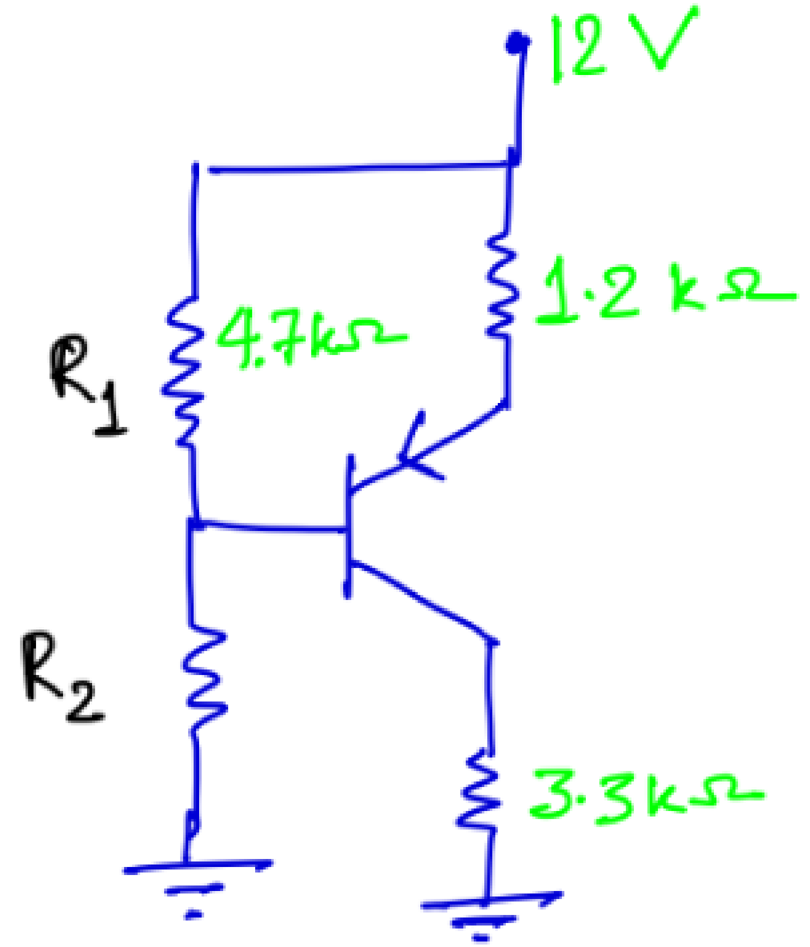
DC operating point
$-(I_C, 0.2V)$

(d) Reverse Active:-

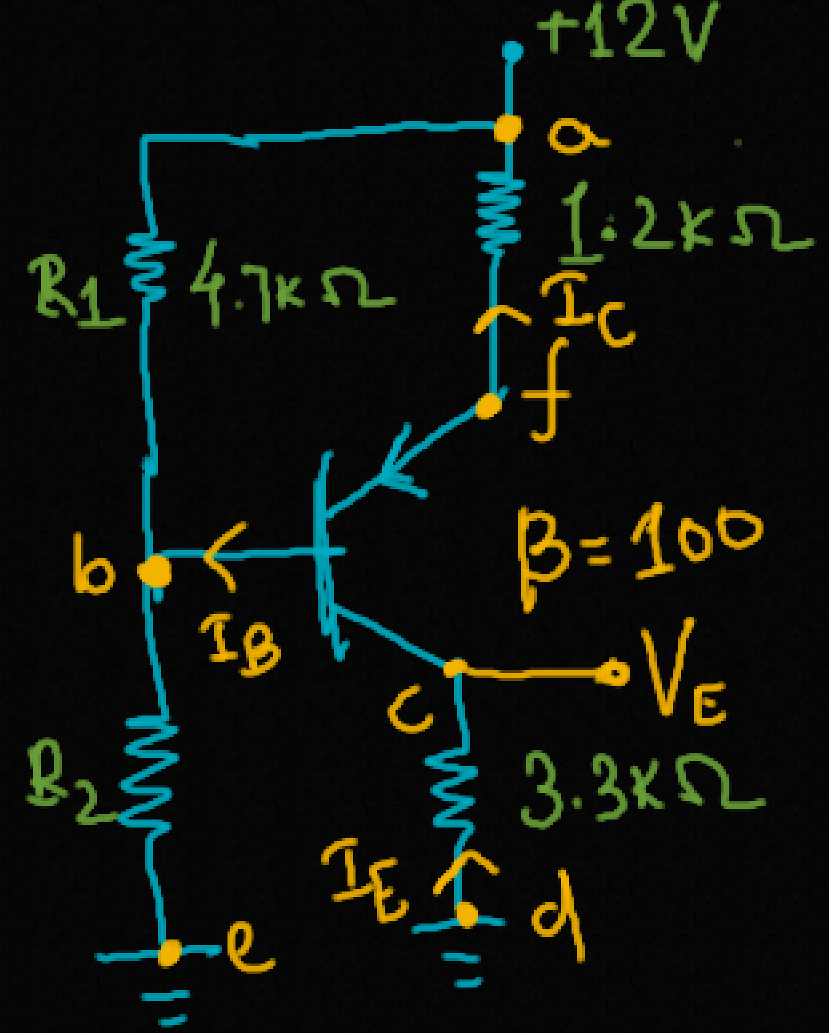
In this mode of operation, emitter base junction is forward biased where as the collector base junction is reverse-biased. This mode is generally not used.



For the given circuit, if the voltage across 3.3kΩ resistor is 5V, $V_{EB} = 0.7V$ and $\beta = 100$, then value of R_2 (in kΩ) is ____



Solution



Given, In the transistor (PNP),

$\beta = 100 \quad V_{CC} = 12V \quad V_E = 5V \quad V_{EB} = 0.7V$

$R_1 = 4.7k\Omega \quad R_C = 1.2k\Omega \quad R_E = 3.3k\Omega$

Assume the transistor is in active region.

Then by applying in the loop afcd,

$$V_{CC} - I_C R_C - V_E - I_E R_E = 0$$

$$\Rightarrow V_{CC} - \beta I_B R_C - V_E - (\beta+1) I_B R_E = 0 \quad (\because I_C = \beta I_B \text{ and } I_E = I_B + I_C)$$

$$\Rightarrow 12V - 100 I_B \times 1.2k\Omega - 5V - 101 I_B \times 3.3k\Omega = 0$$

$$\Rightarrow I_B = \frac{12V - 5V}{(100 \times 1.2 + 101 \times 3.3)k\Omega} = \frac{7V}{453.3k\Omega} = 0.015mA$$

Now, $I_C = \beta I_B = 100 \times 0.015 mA = 1.5 mA$ and $I_E = I_B + I_C = 1.515 mA$

Now, $I_C = 1.5mA$ $I_B = 0.015\ mA$ $I_E = 1.515\ mA$

Let I be the current flowing through $R_1 = 4.7K\Omega$.

Then by applying KVL in loop abcd,

$$V_{cc} - I \times R_1 - V_{BE} - I_E R_E = 0$$

$$\Rightarrow 12V - I \times 4.7k\Omega + V_{EB} - I_E R_E = 0$$

$$\Rightarrow 12V - I \times 4.7k\Omega + 0.7V - 1.515mA \times 3.3K\Omega = 0$$

$$\Rightarrow 12V + 0.7V - 5V = I \times 4.7k\Omega \Rightarrow I = \frac{12.7V - 5V}{4.7k\Omega}$$

$$\Rightarrow I = \frac{7.7V}{4.7k\Omega} = 1.64mA$$

If the current flowing through the resistore is I_0, then by applying KCL at node c,

$$I_0 = I_B + I = 0.015mA + 1.64mA = 1.655mA$$

If we apply KVL in loop abe,

$$V_{cc} - I \times R_1 - I_o \times R_2 = 0 \Rightarrow R_2 = \frac{V_{cc} - I \times R_1}{I_o}$$

$$\Rightarrow R_2 = \frac{12V - (1.64mA \times 4.7k\Omega)}{1.655\,mA} = \frac{12V - 7.71V}{1.655mA} = \frac{4.29V}{1.655mA} = 2.6\,k\Omega$$

$\therefore$ The resistance value will be (R_2) $2.6k\Omega$.