UNIT 2 BIPOLAR JUNCTION TRANSISTORS

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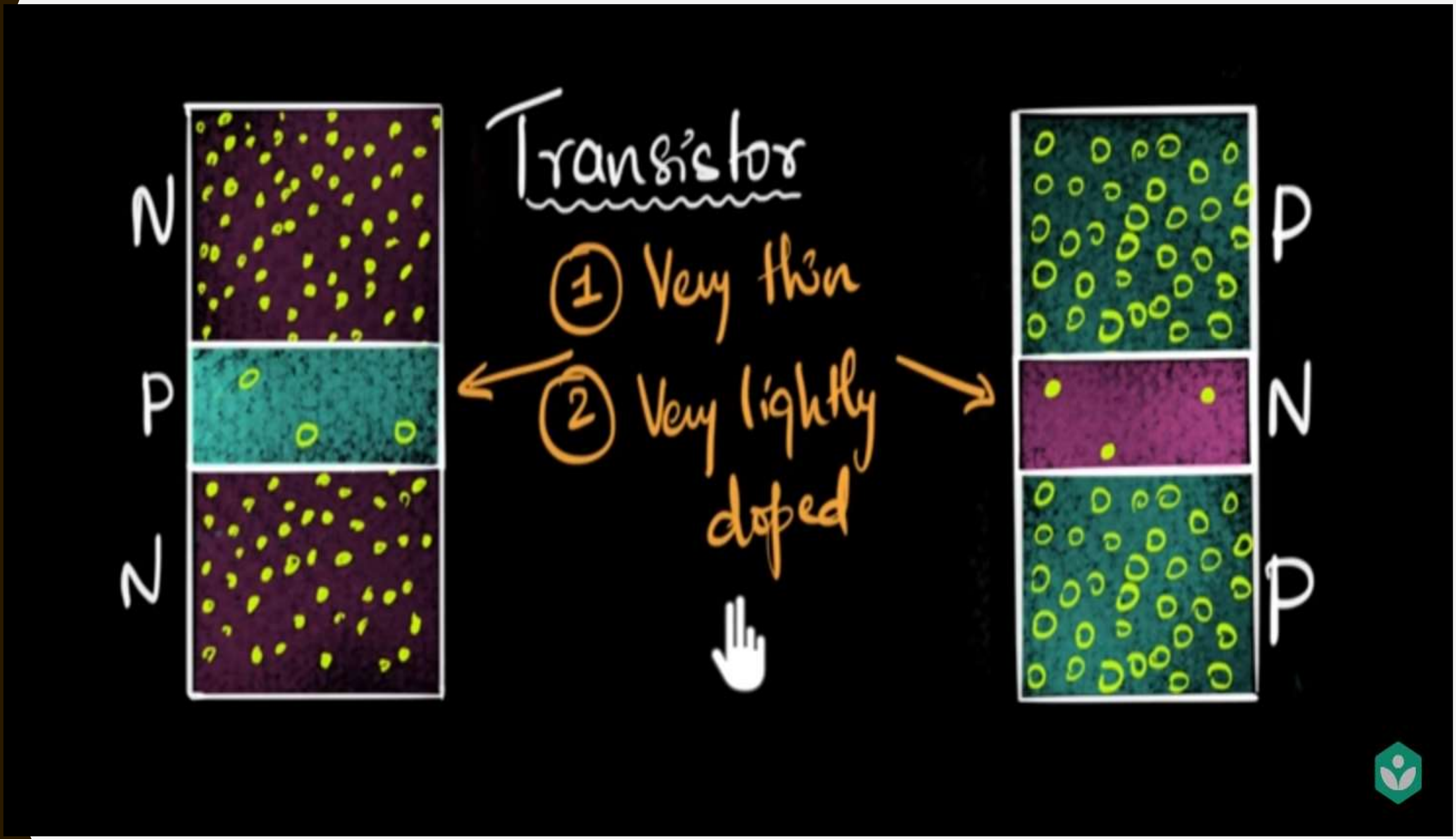
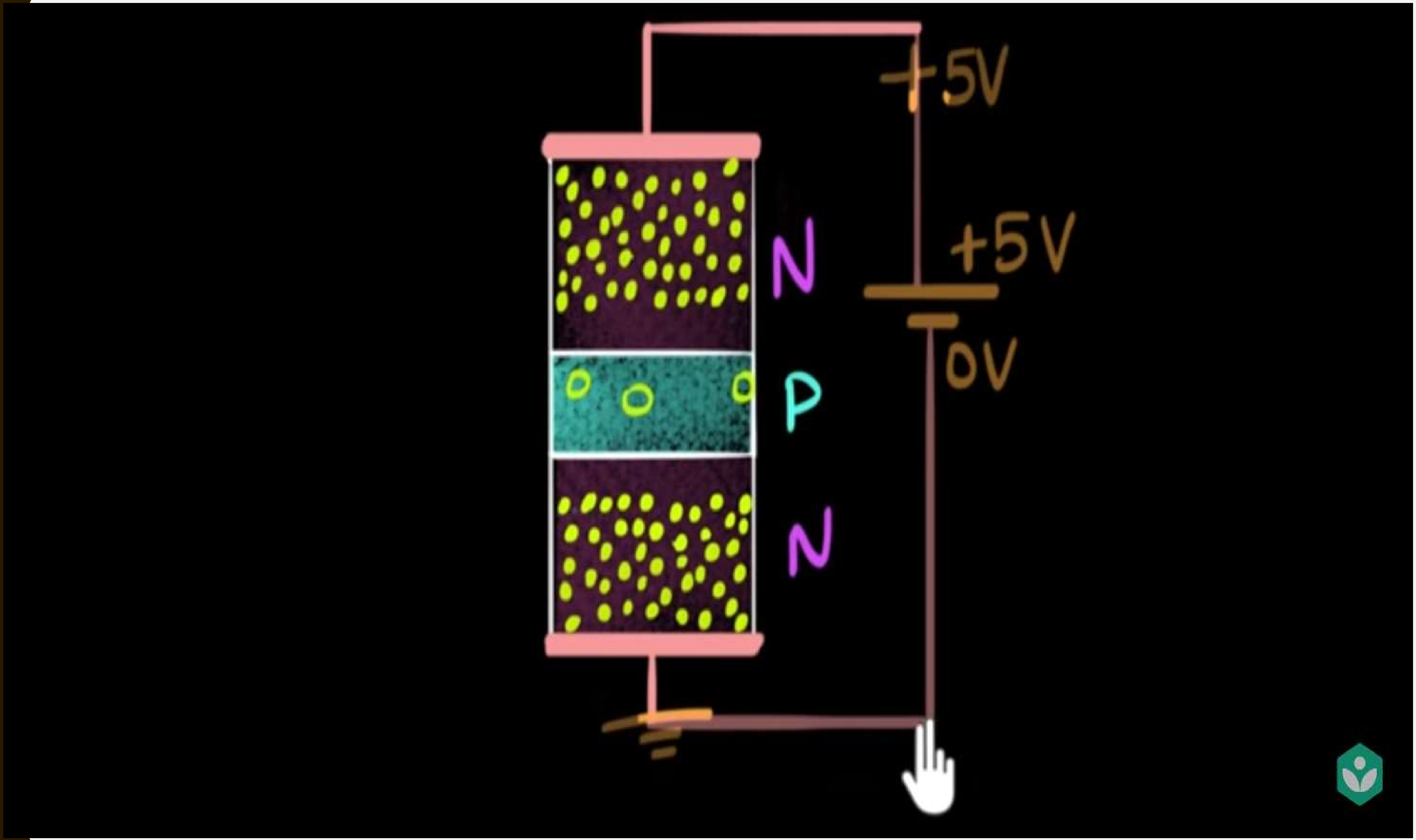
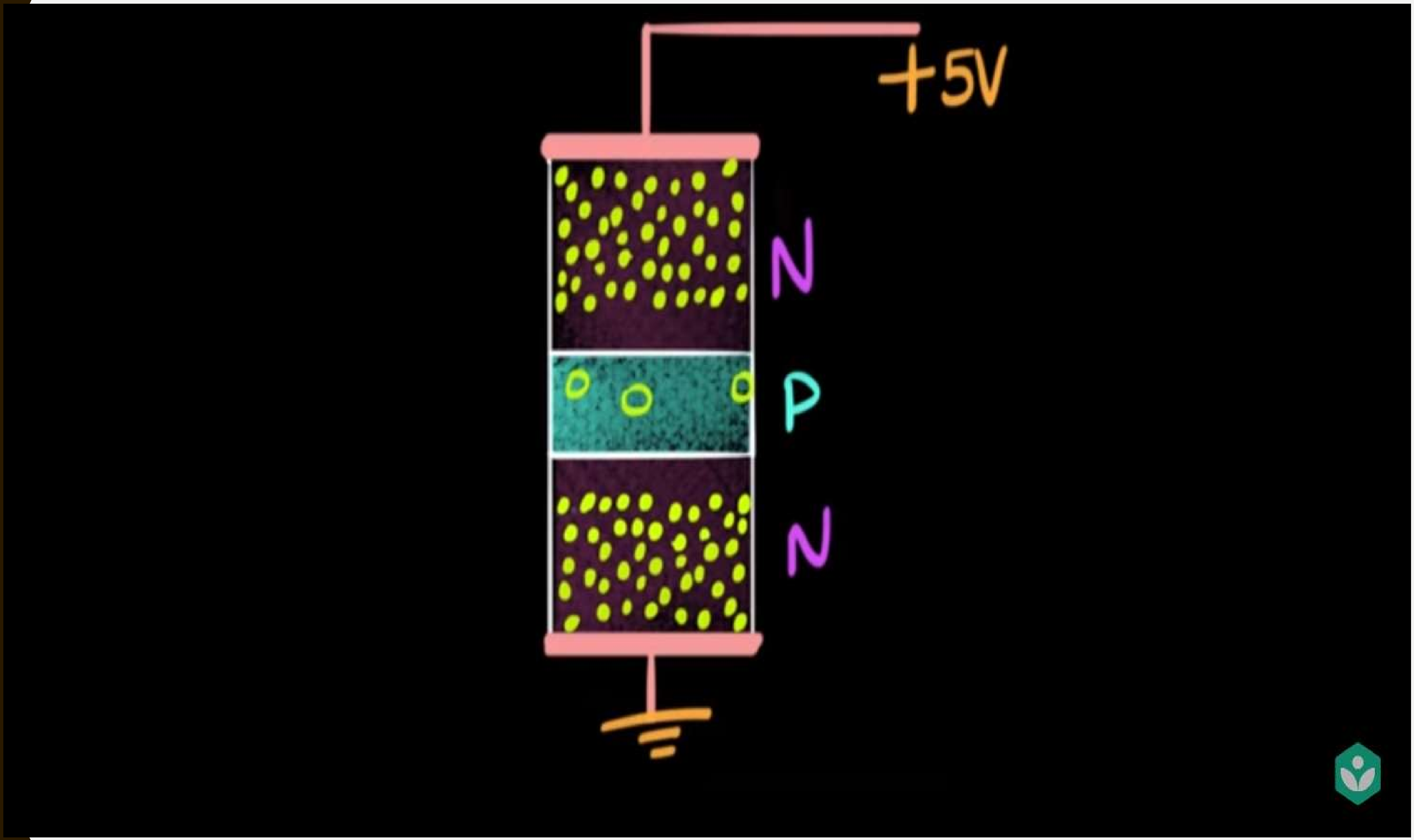
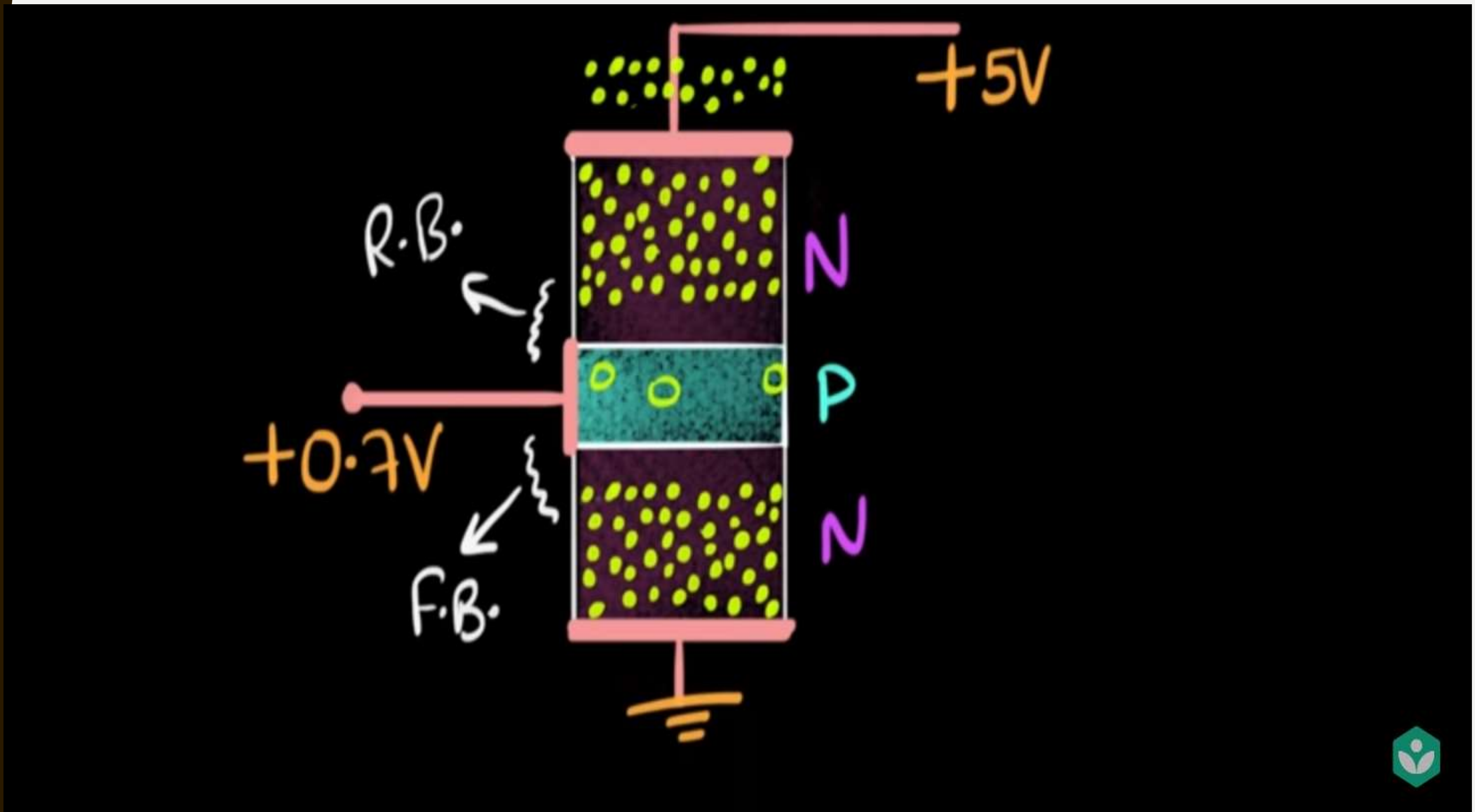


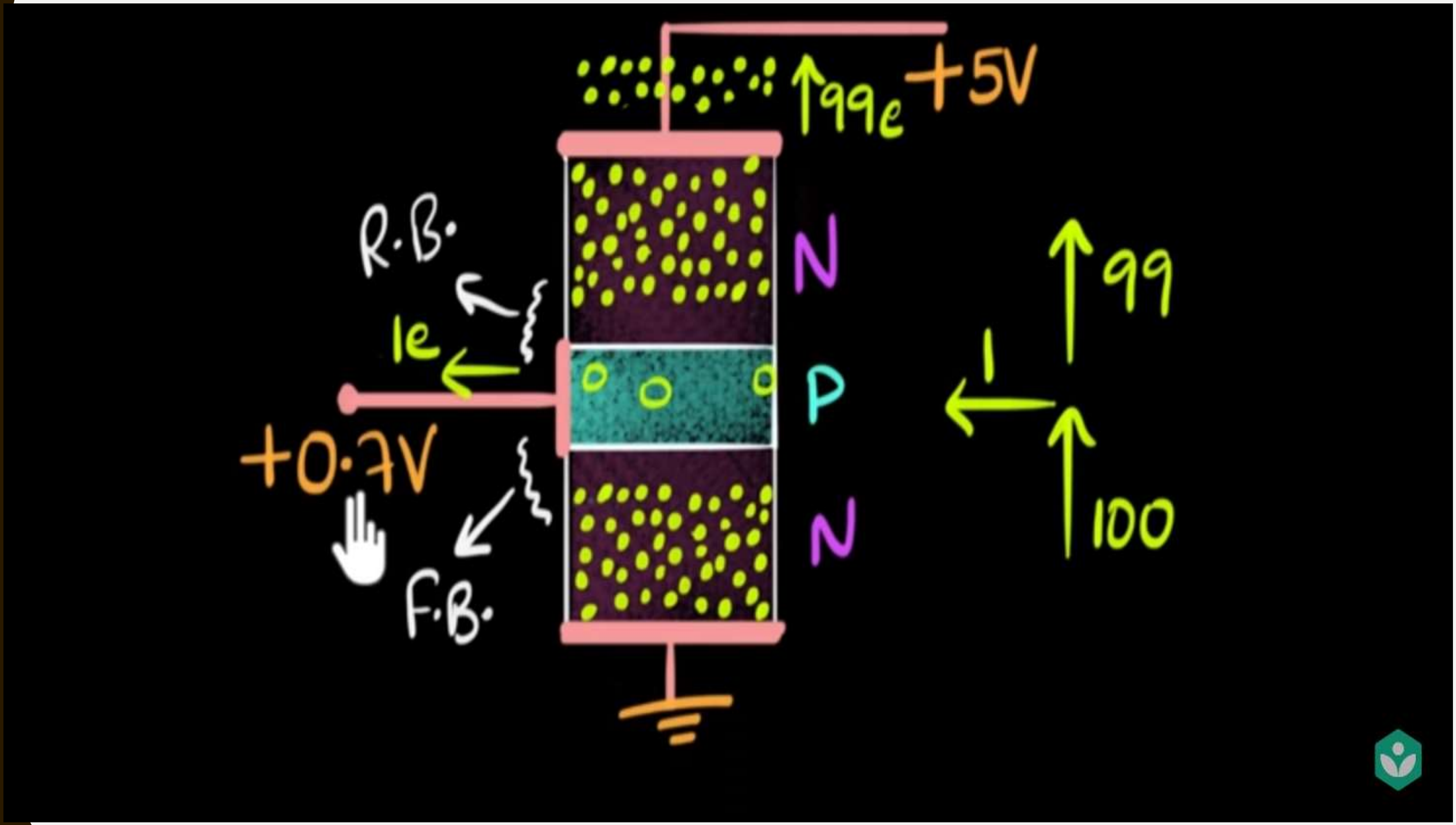
N
P
N
Transistor
① Very thin
② Very lightly doped
P
N
P


+5V
N
+5V
0V
P
N

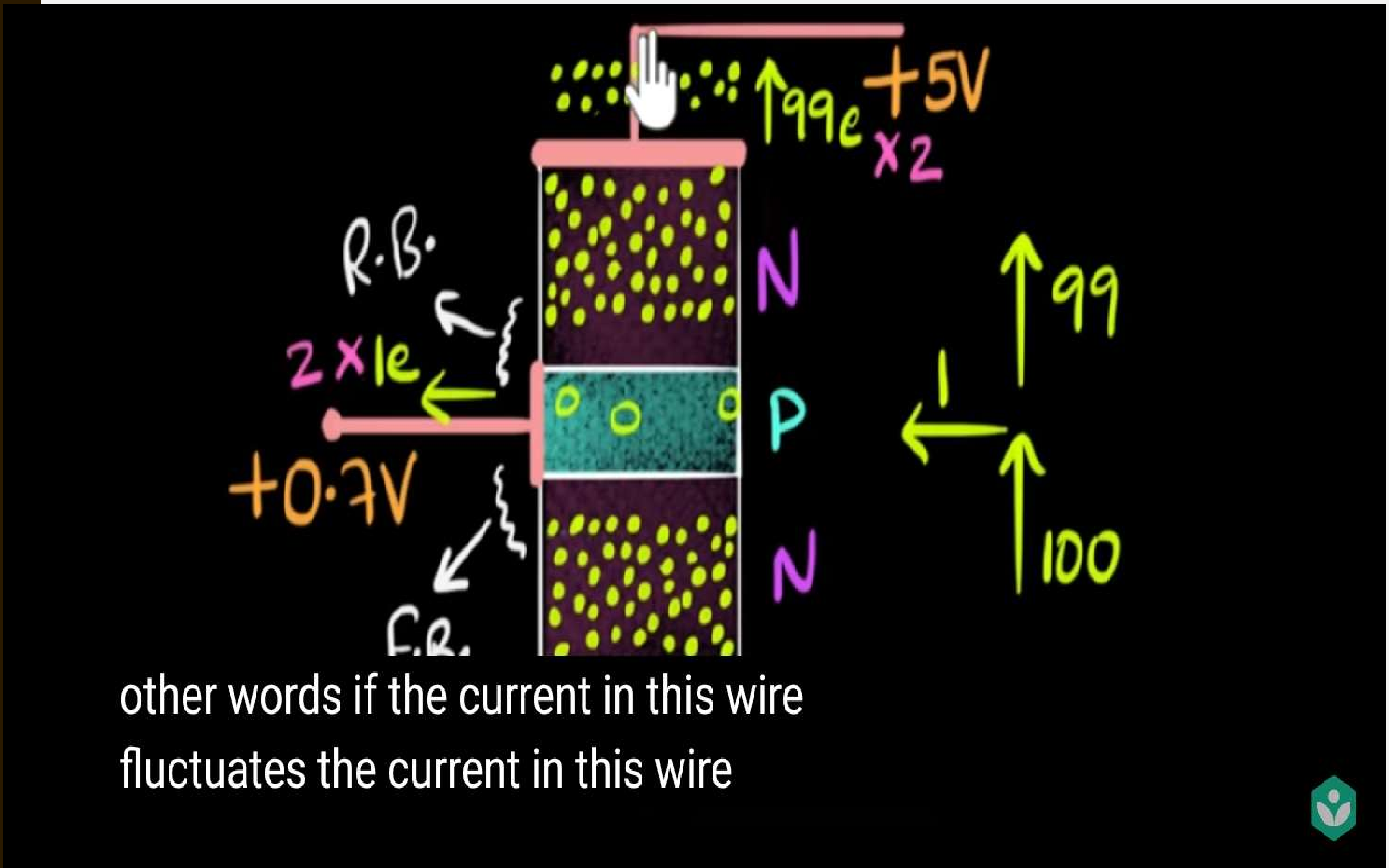

+5V
N
P
N



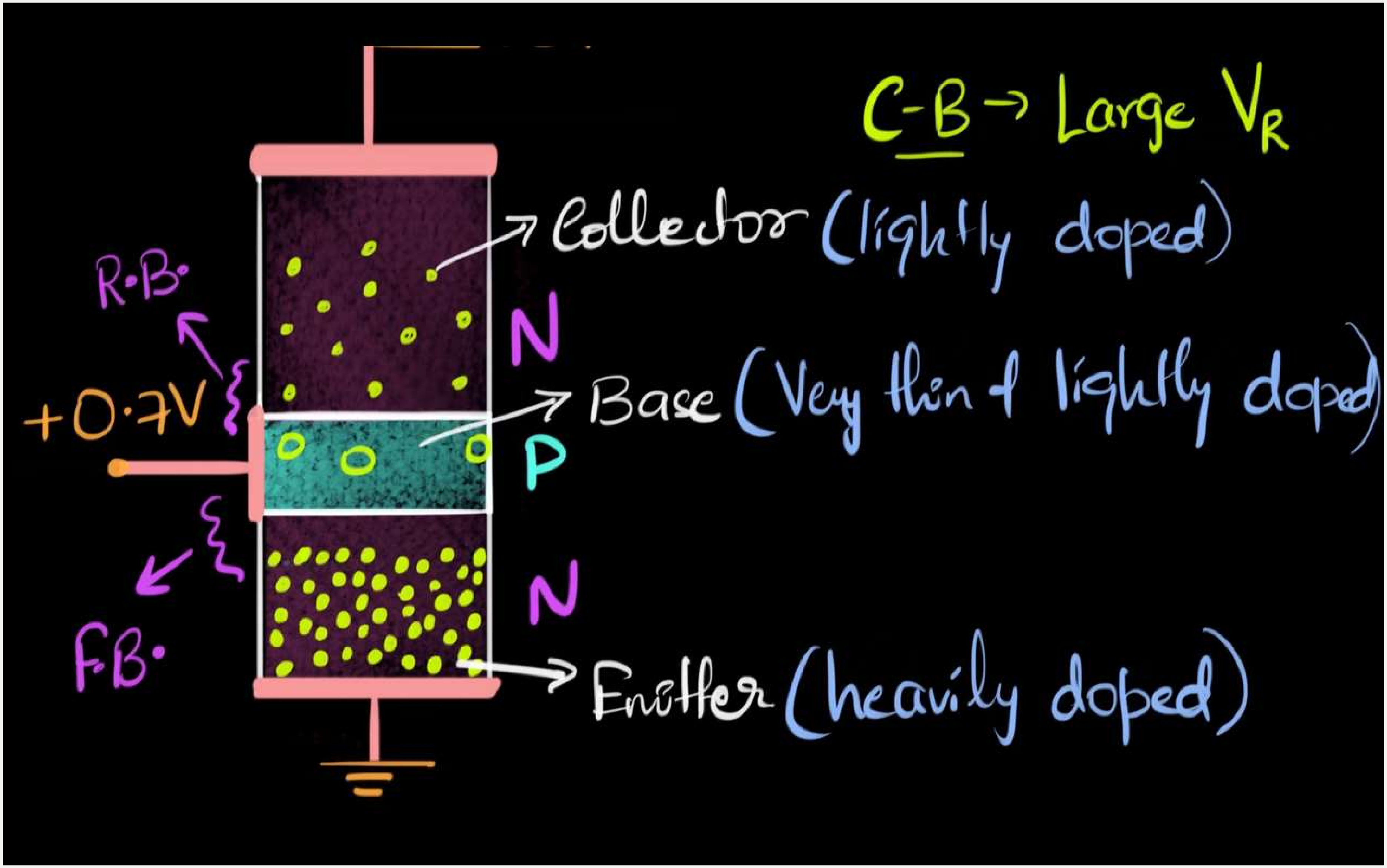
+5V
N
R.B.
P
+0.7V
N
F.B.

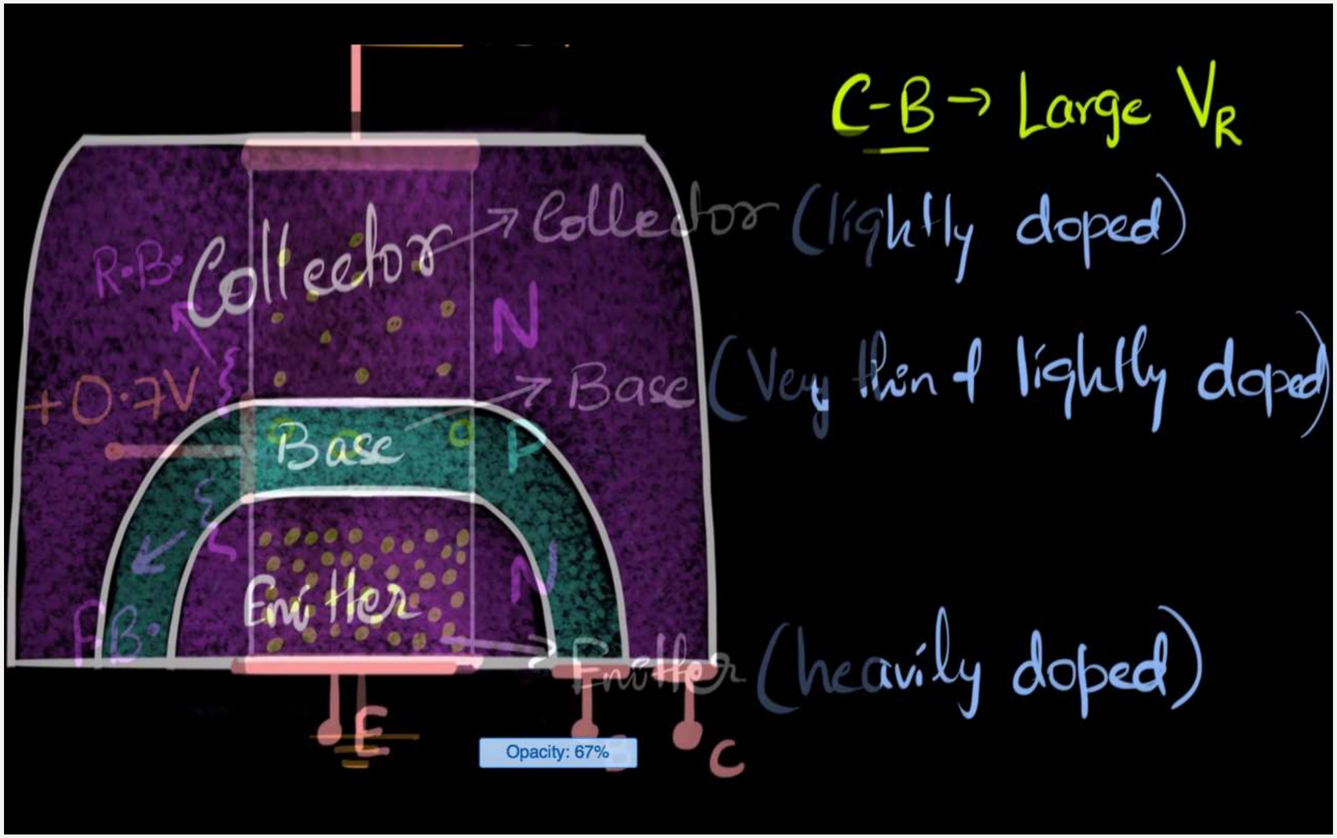


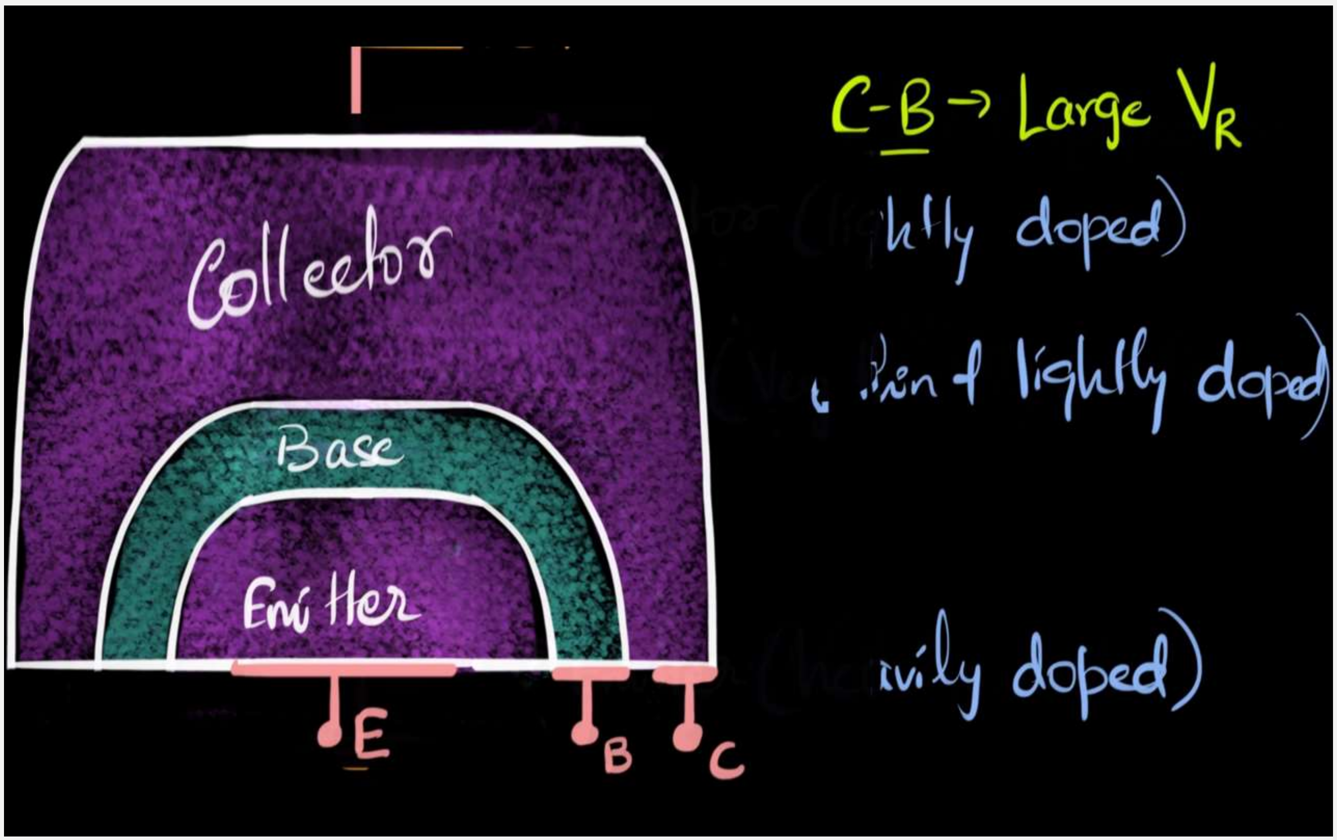
99e
+5V
R.B.
Ie
N
P
N
1
99
100
+0.7V
F.B.



99e
+5V
x2
R.B.
2 x 1e
N
P
N
+0.7V
99
1
100
other words if the current in this wire
fluctuates the current in this wire


C-B → Large V_R
Collector (lightly doped)
R.B.
N
+0.7V
Base (Very thin & lightly doped)
P
N
F.B.
Emitter (heavily doped)


C-B → Large V_R
→ Collector (lightly doped)
→ Base (Very thin & lightly doped)
→ Emitter (heavily doped)
R.B.
Collector
N
+0.7V
Base
P
Emitter
N
F.B.
E
C
Opacity: 67%


C-B → Large V_R
Collector
Base
Emitter
E
B
C
doped)
lightly doped
doped)

- Order of doping in ascending order

A E, B ,C

B C,B,E

C B,E,C

D B,C,E

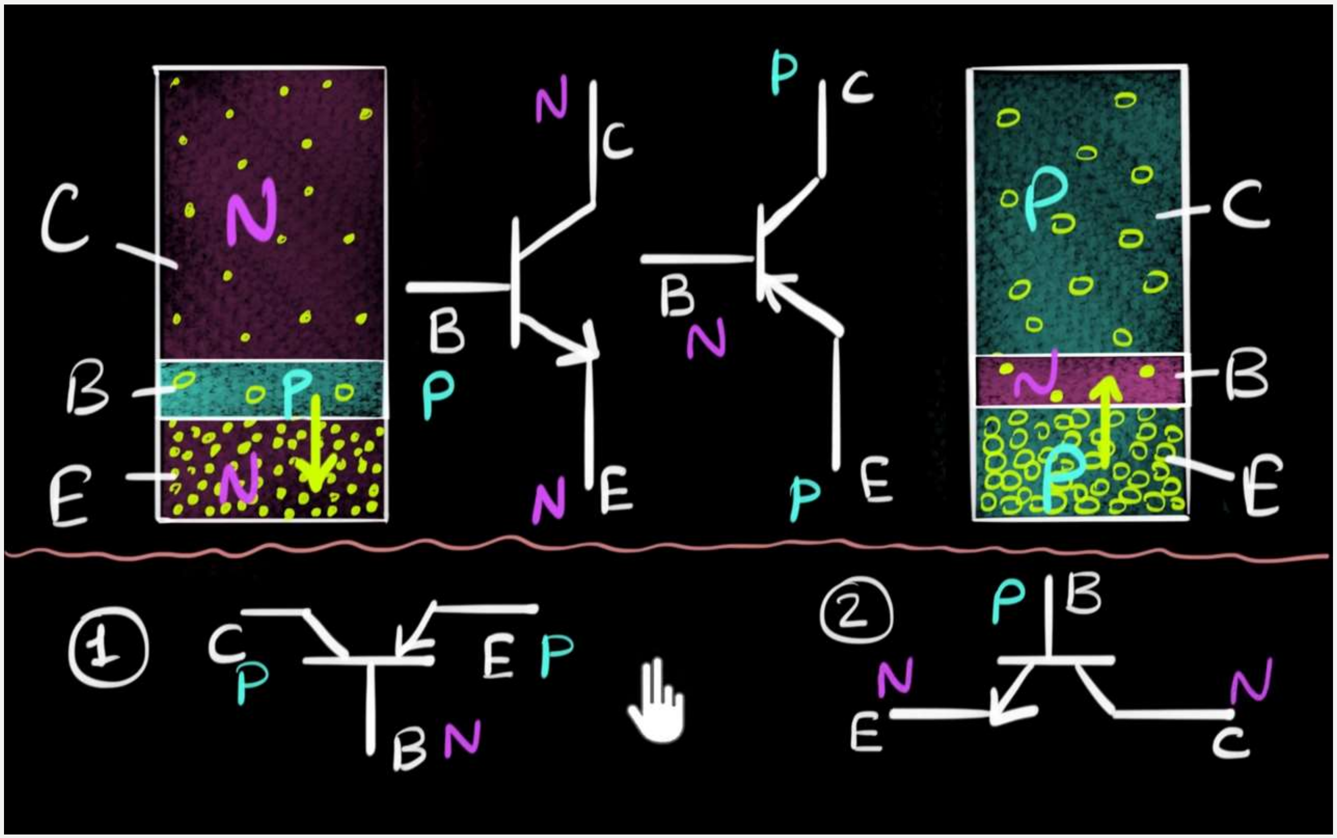
- Order of Width in ascending order

A E, B ,C

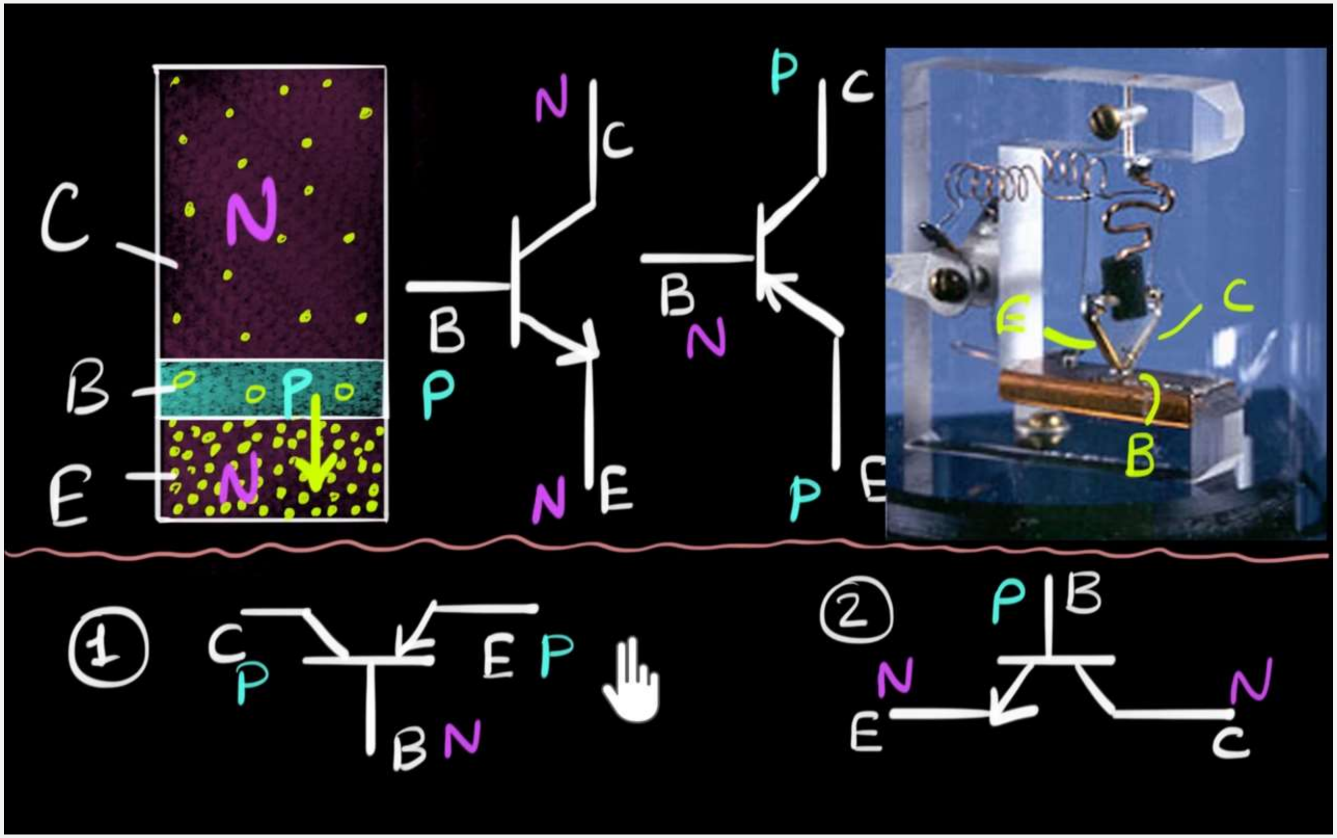
B C,B,E

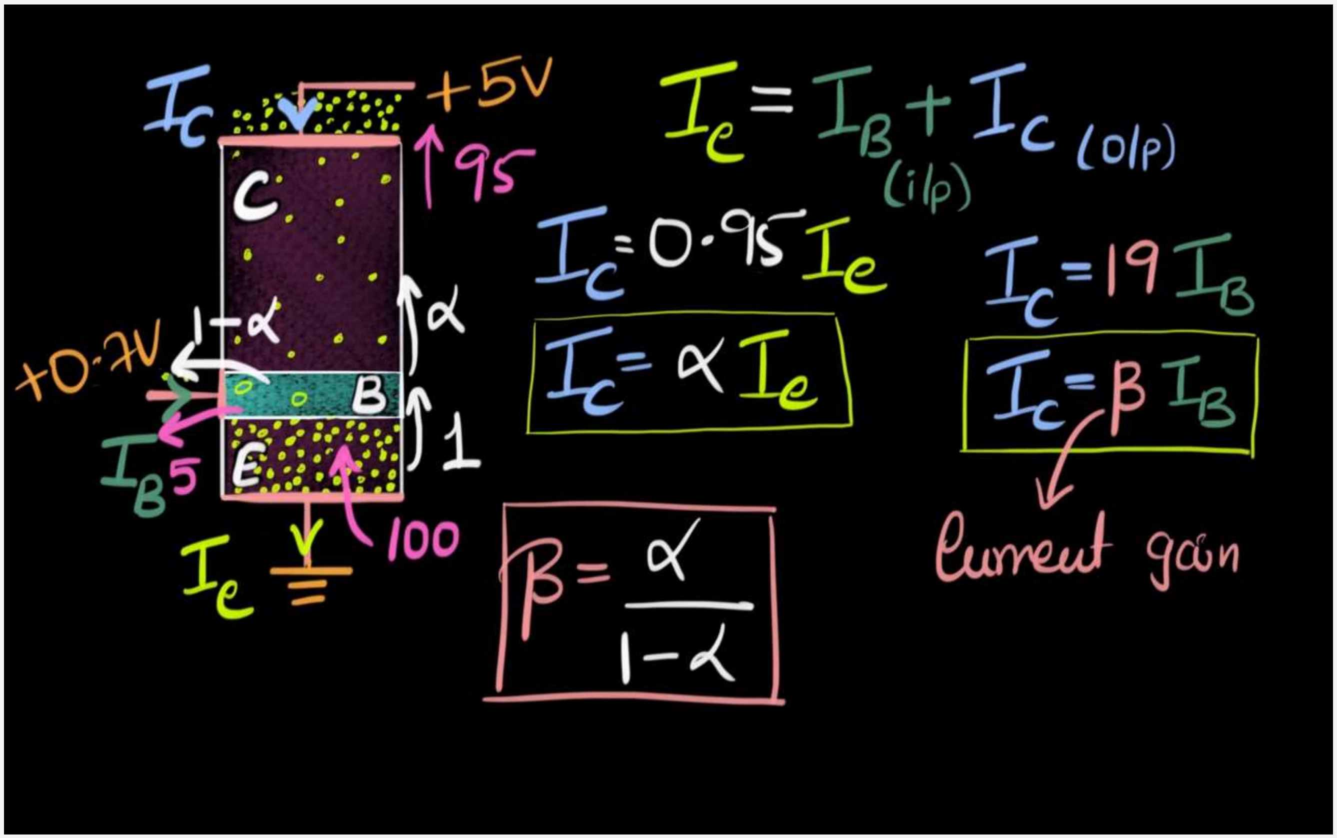
C B,E,C

D B,C,E

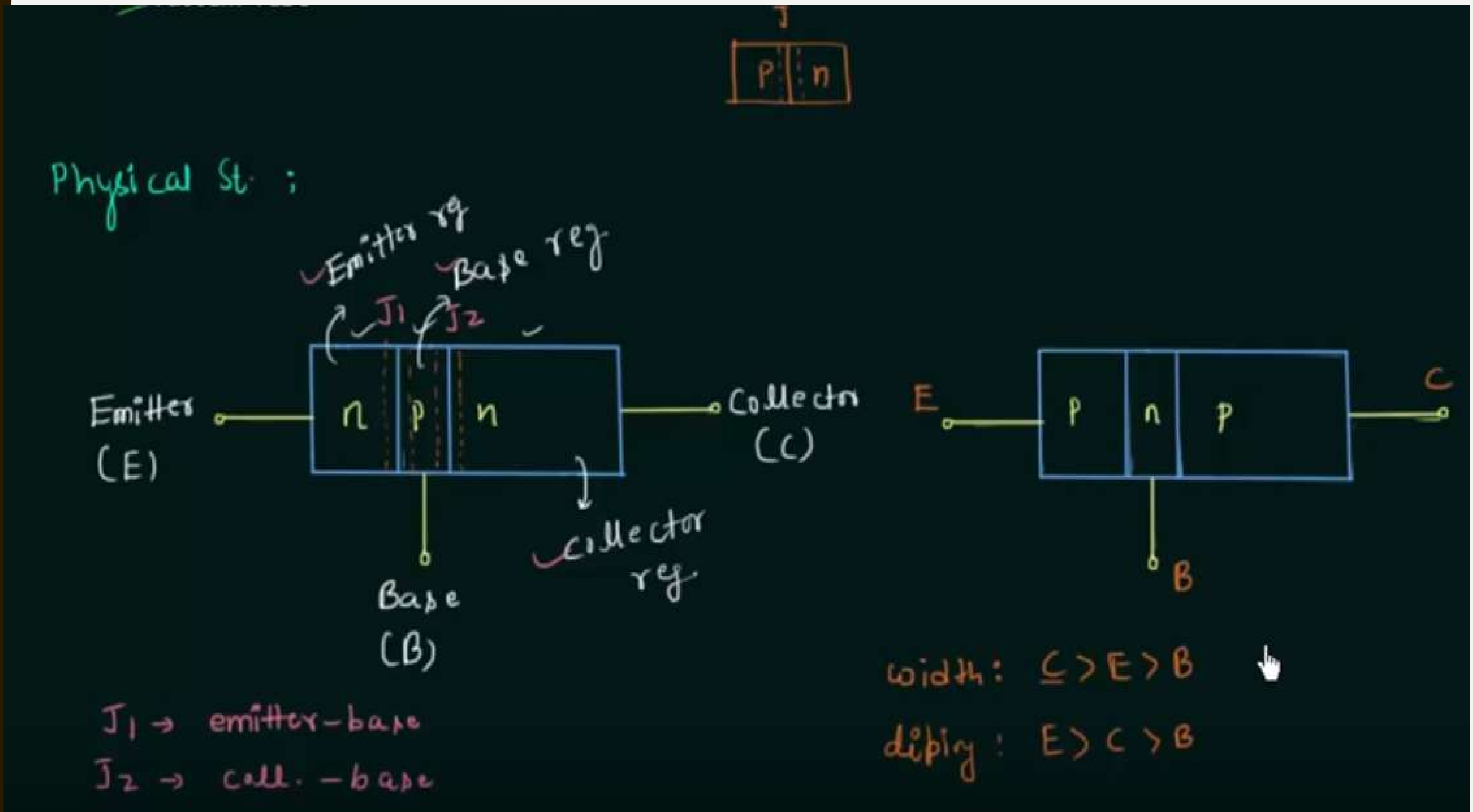


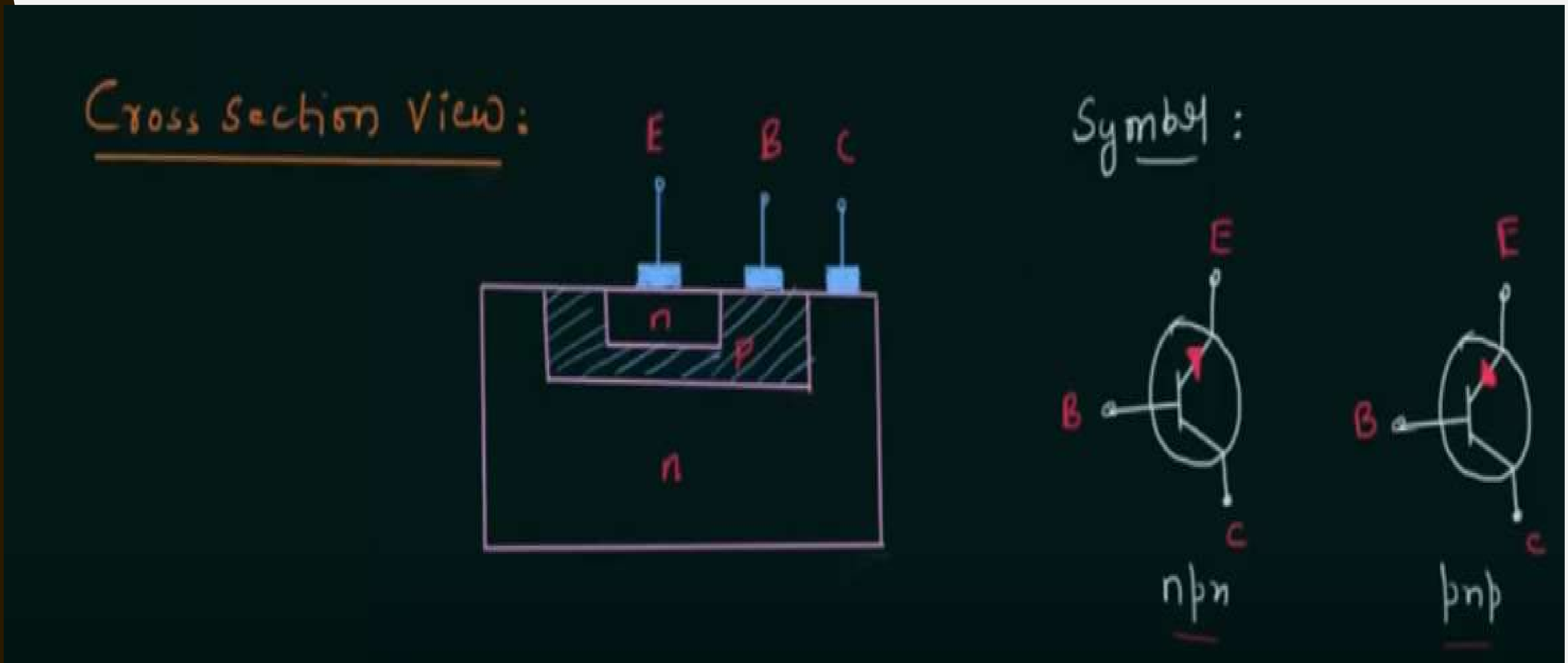
C
N
B
P
E
N
N
C
B
P
N
E
P
C
B
N
P
E
P
C
B
N
P
E
1
C
P
E
P
B
N
2
P
B
N
E
N
C


C
B
E
N
P
N
N
C
B
P
N
E
P
C
B
N
P
E
E
C
B
① C P E P B N
② P B N N E C


I_C
+5V
95
C
α
$1-\alpha$
+0.7V
B
1
I_B 5
E
100
I_e
$I_e = I_B + I_C$
(i/p)
(o/p)
$I_C = 0.95 I_e$
$I_C = \alpha I_e$
$I_C = 19 I_B$
$I_C = \beta I_B$
Current gain
$\beta = \frac{\alpha}{1-\alpha}$

BJT


p n
Physical St. :
Emitter rg
Base reg
J1
J2
Emitter (E)
n p n
Collector (C)
Base (B)
collector reg.
E
p n p
C
B
J1 → emitter-base
J2 → coll. - base
width: C > E > B
doping: E > C > B



Cross section view:
E
B
C
n
p
n
Symbol :
E
B
C
npn
E
B
C
pnp

Bipolar Jun. Tran

i) $\bar{e}$

ii) holes

Transistor = Transfer + Resistor

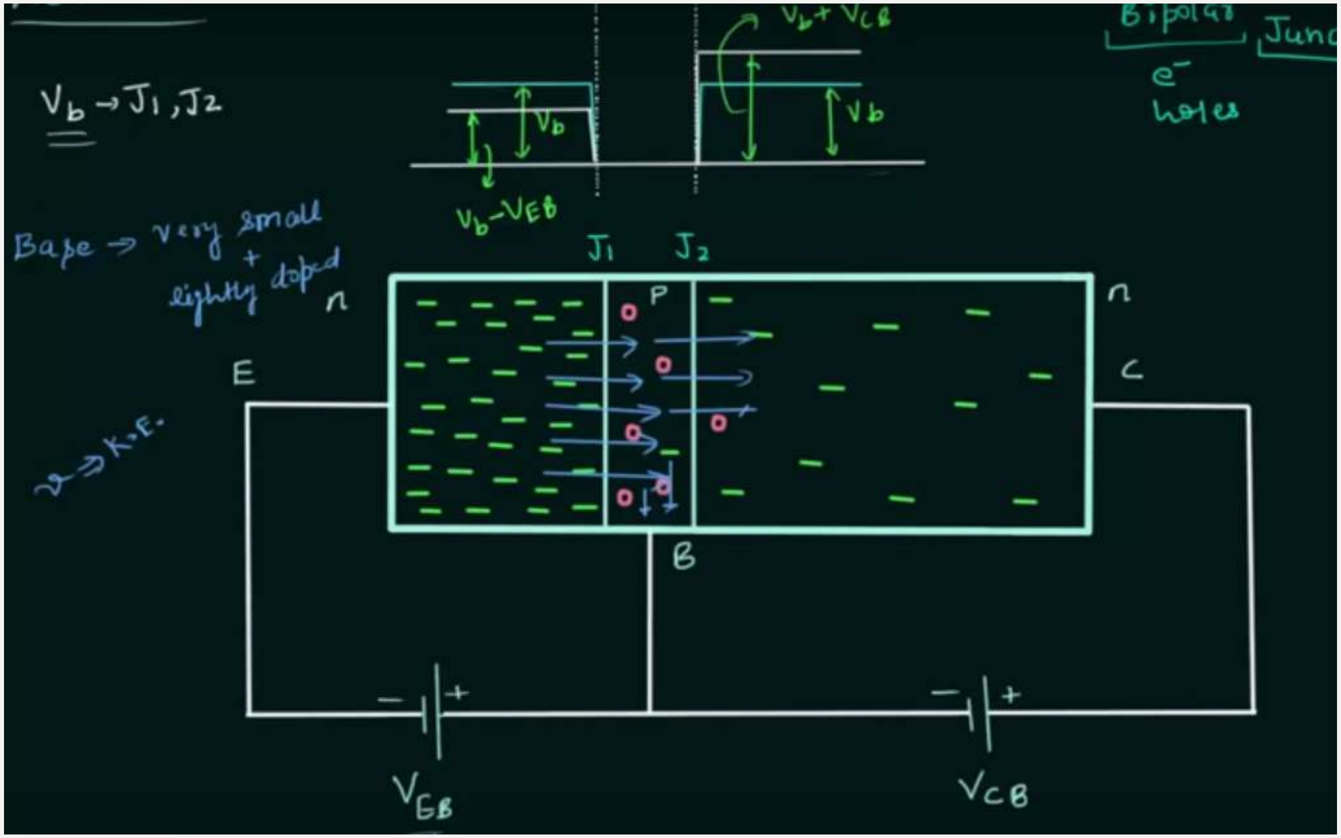
$J_1 \rightarrow$ f.b.

$J_2 \rightarrow$ r.b.

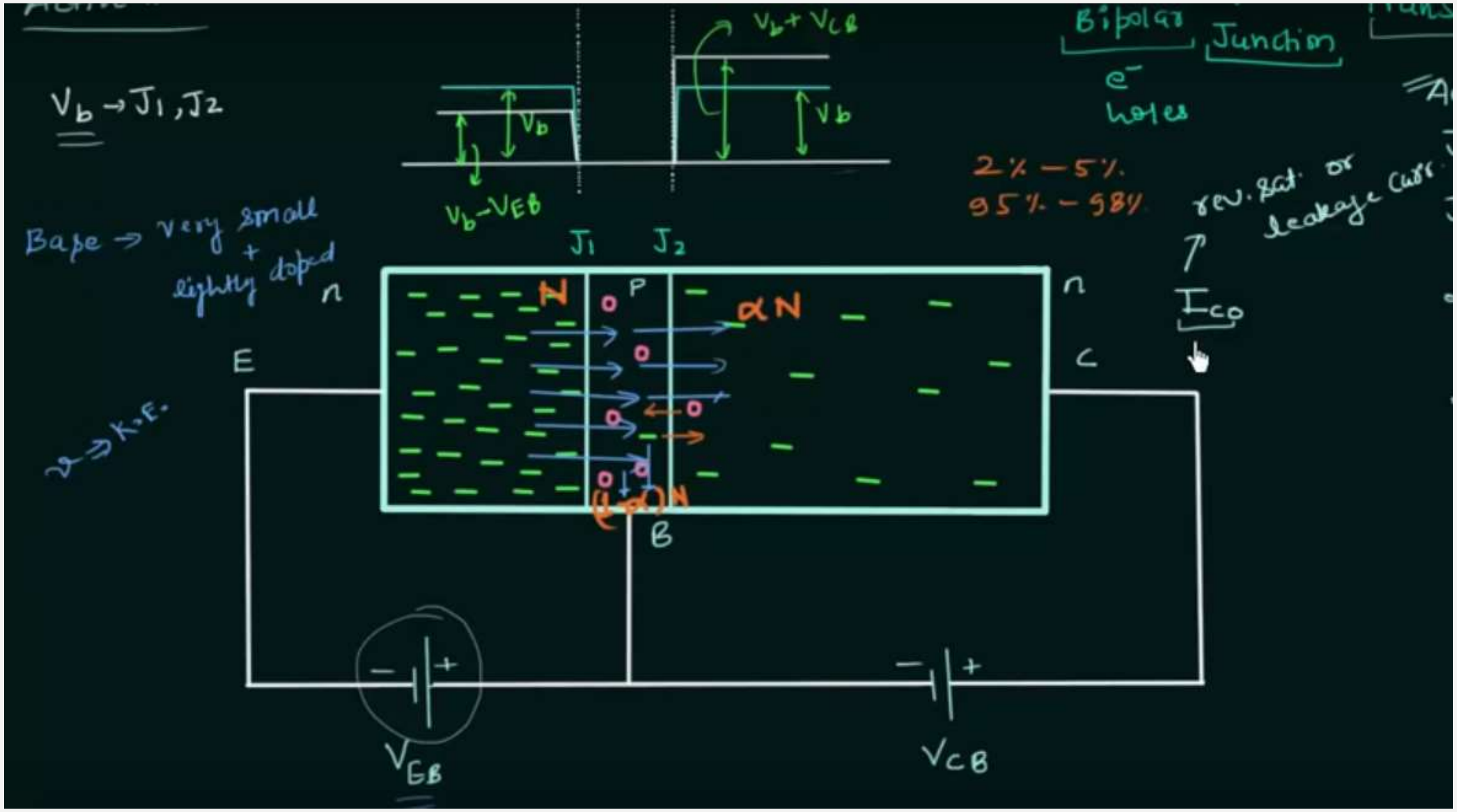
BJT

Regions of op :

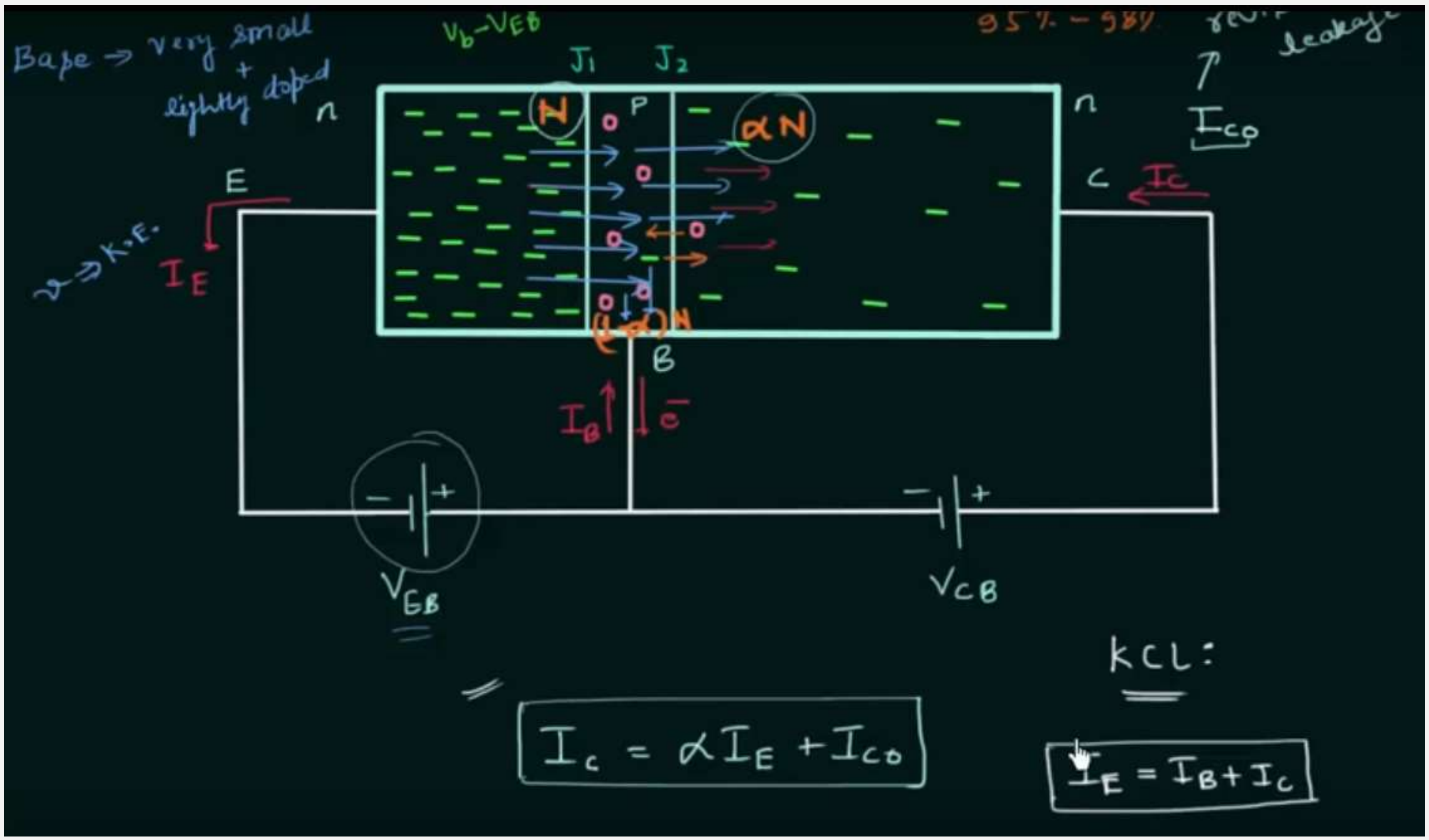
J_1	J_2	Region of op	
f.b.	r.b.	Active	→ Amplifier
f.b.	f.b	Sat.	→ "ON"
r.b.	r.b.	cutoff	→ off
r.b.	f.b.	Inverted	→ rarely used



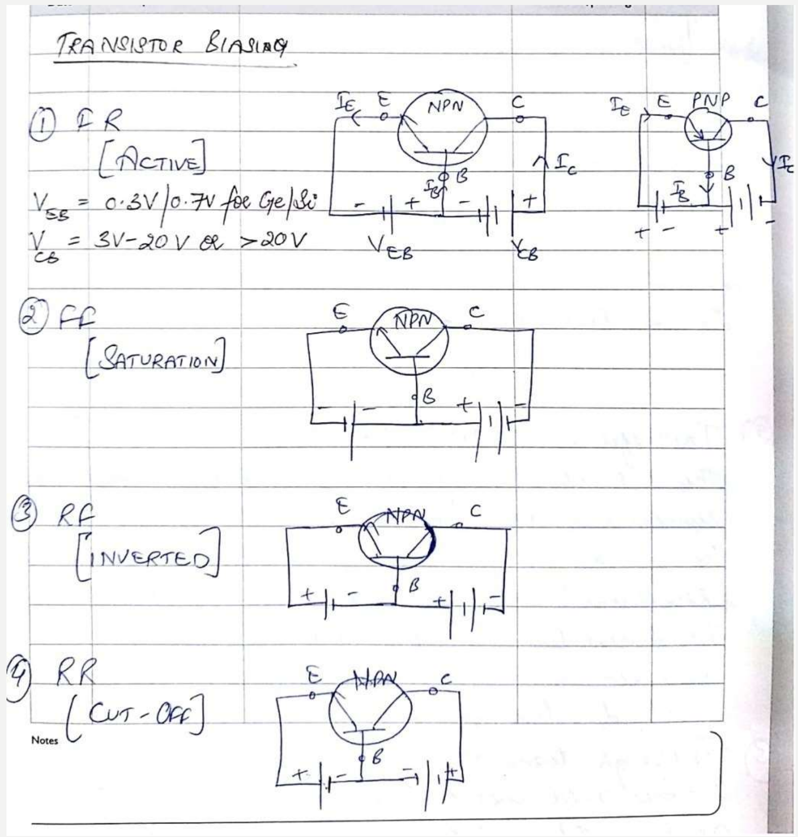
Vb → J1, J2
Base → very small + lightly doped
Vb - VEB
Vb
Vb + VCB
J1
J2
n
p
n
E
C
B
VEB
VCB
e⁻
holes
Bipolar
Junc



Vb → J1, J2
Vb
Vb - VEB
Vb + VCB
Vb
Bipolar
Junction
e⁻
holes
2% – 5%
95% – 98%
rev. sat. or
leakage curr.
Ico
Base → very small
+
lightly doped
J1
J2
n
N
P
αN
n
E
C
(1-α)N
B
VEB
VCB



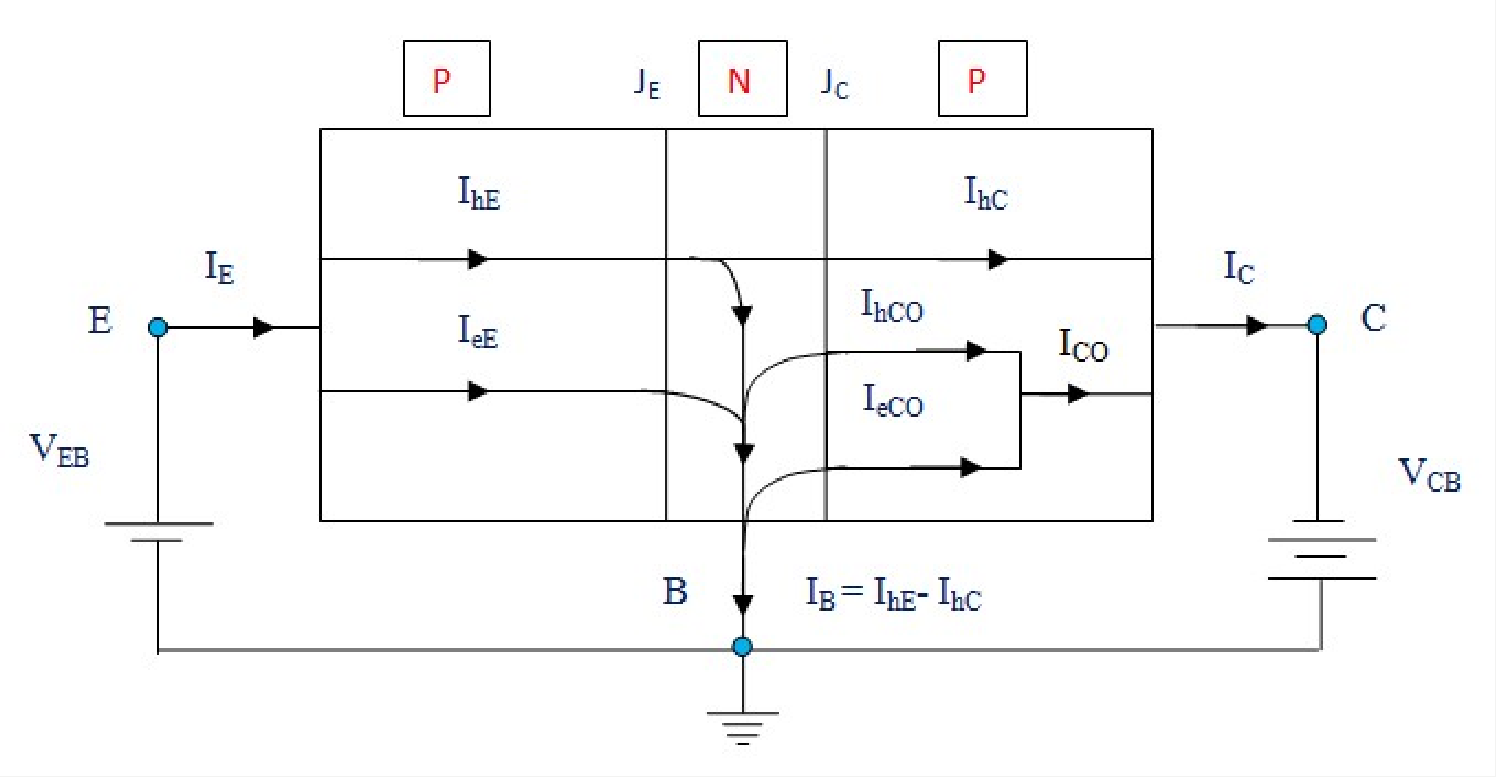
Base → very small + lightly doped
$V_b - V_{EB}$
95% – 98%
leakage
J_1
J_2
n
P
n
N
αN
E
C
I_E
I_C
I_{CO}
v → K.E.
(1-α)N
B
I_B
V_{EB}
V_{CB}
KCL:
$I_C = \alpha I_E + I_{CO}$
$I_E = I_B + I_C$



TRANSISTOR BIASING
① FR
[ACTIVE]
V_{EB} = 0.3V/0.7V for Ge/Si
V_{CB} = 3V-20V or >20V
NPN
PNP
② FF
[SATURATION]
③ RF
[INVERTED]
④ RR
[CUT-OFF]
Notes

- I_{CBO} is the collector **current** with collector junction reverse biased and base open-circuited.
- I_{CEO} is the collector **current** with collector junction reverse biased and emitter open-circuited.

TRANSISTOR CURRENT COMPONENTS



We know that, the current arrives the transistor through the emitter and this current is called emitter current (I_E). This current consists of two constituents – **Hole current** (I_{hE}) and **Electron current** (I_{eE}). I_{eE} is due to passage of electrons from base to emitter and I_{hE} is due to passage of holes from emitter to base.

$$I_E = I_{hE} + I_{eE}$$

Normally, the emitter is heavily doped compared to base in industrial transistor. So, the Electron current is negligible compared to Hole current. Thus we can conclude that, the whole emitter current in this transistor is due to the passage of holes from the emitter to the base.

Some of the holes which are crossing the junction J_E (emitter junction) combines with the electrons present in the base (N-type). Thus, every holes crossing J_E will not arrive at J_C. The remaining holes will reach the collector junction which produces the hole current component, I_{hC}. There will be bulk recombination in the base and the current leaving the base will be

$$I_B = I_{hE} - I_{hC}$$

The electrons in the base which are lost by the recombination with holes (injected into the base across J_E) are refilled by the electrons that enter into the base region. The holes which are arriving at the collector junction (J_C) will cross the junction and it will go into the collector region.

When the emitter circuit is open circuited, then $I_E = 0$ and $I_{hC} = 0$. In this condition, the base and collector will perform as reverse biased diode. Here, the collector current, I_C will be same as reverse saturation current (I_{CO} or I_{CBO}).

I_{CO} is in fact a small reverse current which passes through the PN junction diode. This is due to thermally generated minority carriers which are pushed by barrier potential. This reverse current increase; if the junction is reverse biased and it will have the same direction as the collector current. This current attains a saturation value (I_0) at moderate reverse biased voltage.

When the emitter junction is at forward biased (in active operation region), then the collector current will become

$$I_C = \alpha I_E + I_{CO}$$

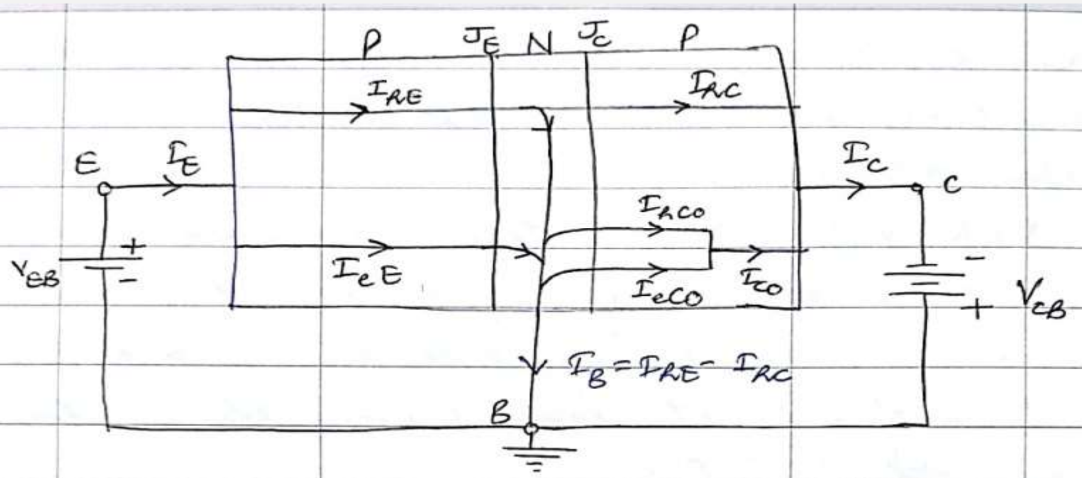
The α is the large signal current gain which is a fraction of the emitter current which comprises of I_{hC}.

When the emitter is at closed condition, then $I_E \neq 0$ and collector current will be

$$I_C = I_{CO} + I_{hC}$$

In a PNP transistor, the reverse saturation current (I_{CBO}) will comprises of the current due to the holes passing through the collector junction from the base to collector region (I_{hCO}) and the current due to the electrons which are passing through the collector junction in the opposite direction (I_{eCO}).

$$Therefore,\ I_{CO} = I_{hCO} + I_{eCO}$$

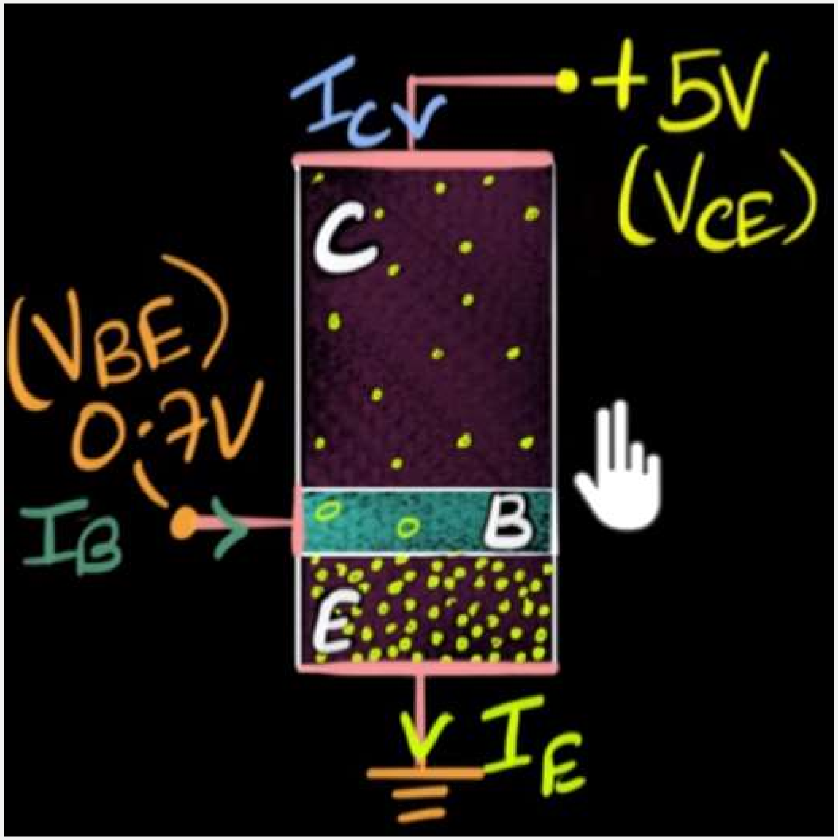


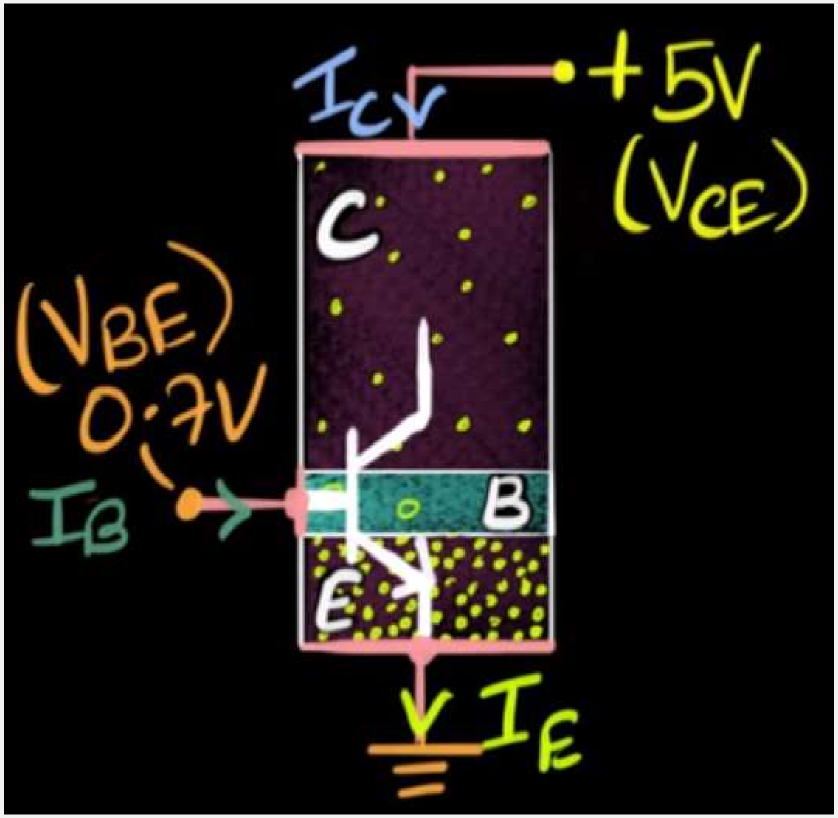
- Emitter effy. $\gamma = \dfrac{I_{pE}}{I_E}$
- Transport factor $\beta = \dfrac{I_{pC}}{I_{pE}}$
- Large signal current gain $\alpha = \dfrac{I_C - I_{CO}}{I_E} = \dfrac{I_{pC}}{I_E} = \dfrac{I_{pC}}{I_{pE}} \times \dfrac{I_{pE}}{I_E}$
- $0.95 \le \alpha \le 0.99$ $\quad \alpha < 1$ $\qquad [\alpha = \beta \times \gamma]$
- DC current gain $\alpha_{dc} = \dfrac{I_C}{I_E}$ = Current Amplification factor

Notes

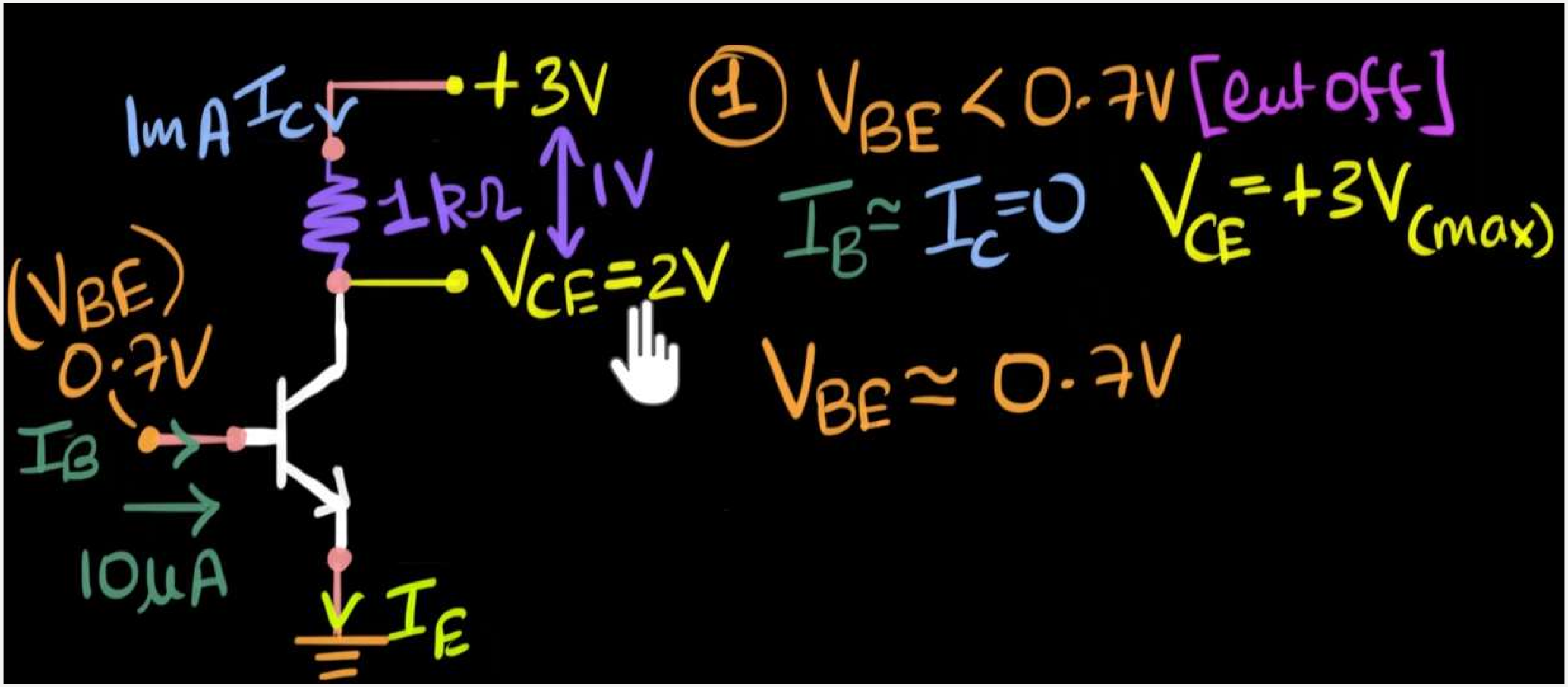
- Small signal current gain $\alpha_{ac} = \dfrac{\Delta I_C}{\Delta I_E}$
- Current gain factor $= \dfrac{\Delta I_C}{\Delta I_B}$ = Transport factor

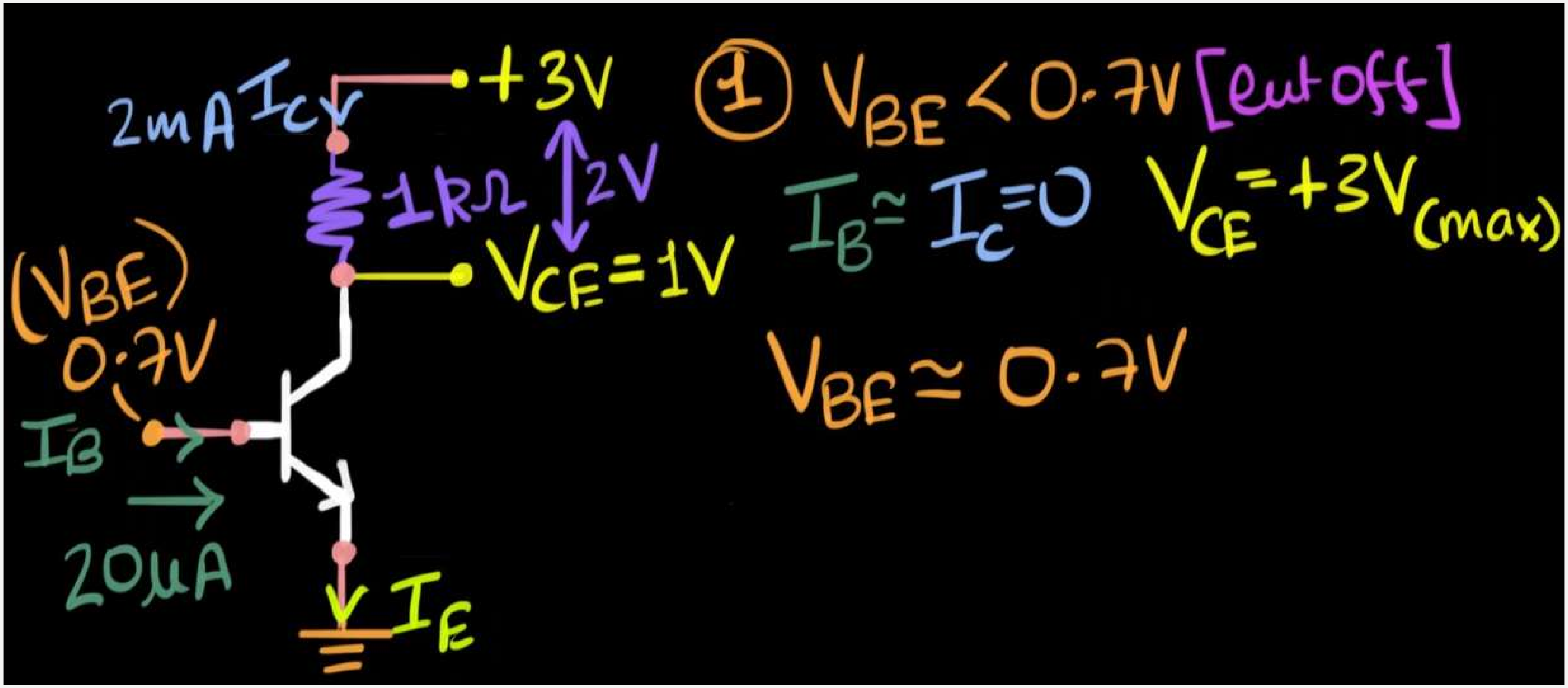
CUT-OFF, ACTIVE AND SATURATION REGIONS

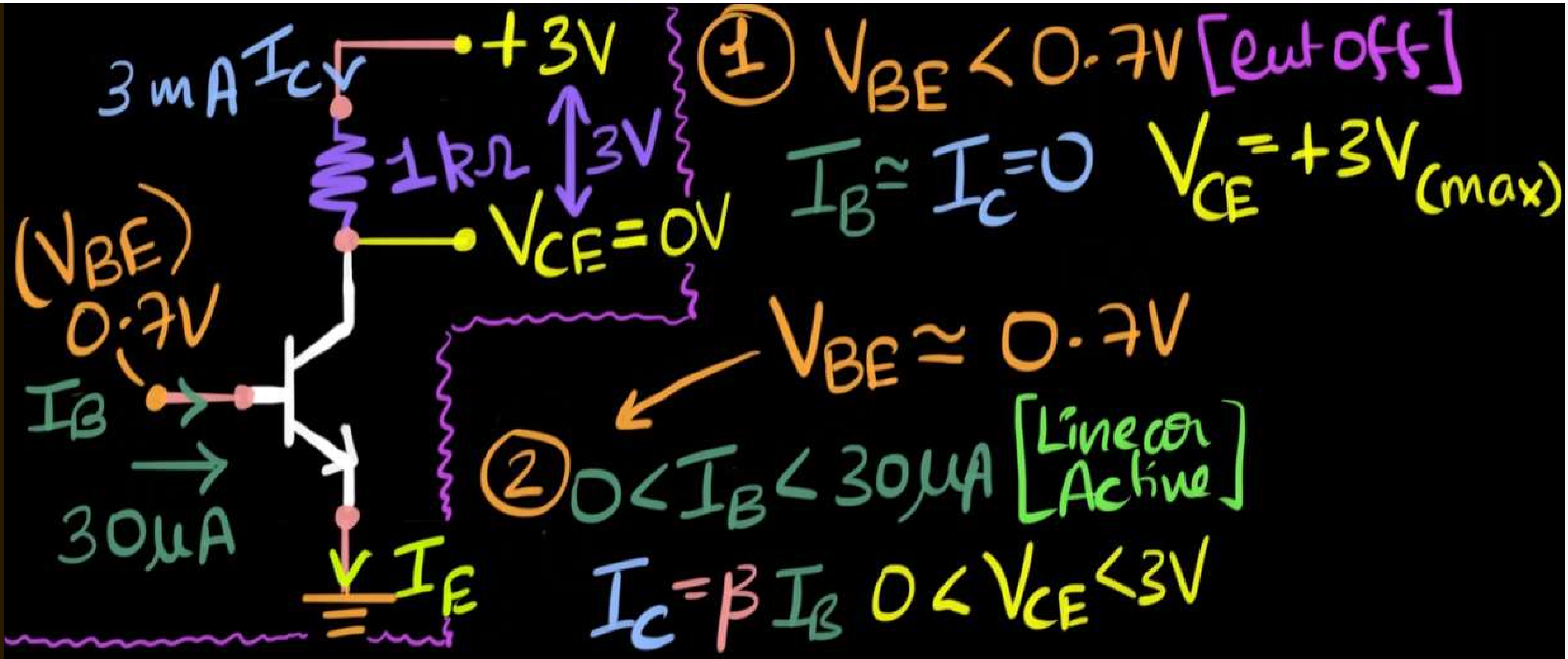




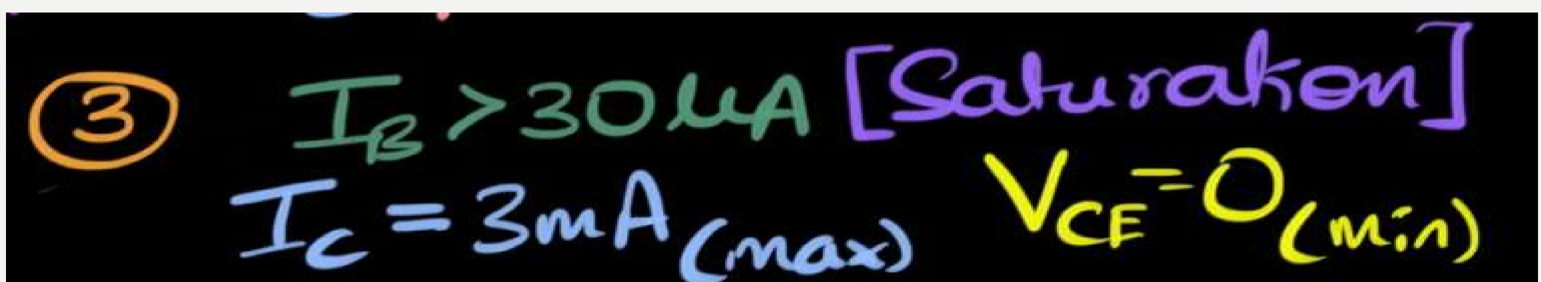
CUT-OFF AND ACTIVE




2mA I_C
+3V
1kΩ
2V
$V_{CE}=1V$
(V_{BE})
0.7V
I_B
20μA
I_E
① $V_{BE}<0.7V$ [cut off]
$I_B \simeq I_C = 0$ $V_{CE}=+3V_{(max)}$
$V_{BE} \simeq 0.7V$



IF CURRENT IS INCREASED BEYOND 30 MA, THE OUTPUT CURRENT REMAINS SAME BECAUSE IF THE CURRENT BECOMES 4MA, THE DROP AROUND THE RESISTOR BECOMES 4V BUT THE SUPPLY VOLTAGE IS ONLY 3 V AND SO IT CAN'T HAS A DROP MORE THAN 3 V. THUS EVEN IF THE INPUT CURRENT IS INCREASED, THE OUTPUT CURRENT STAYS AT 3MA ONLY.



- The collector of a transistor is …………. doped

a) heavily
b) moderately
c) lightly
d) none of the above

- In a transistor as an amplifier, the reverse saturation current

a) Doubles for every ºC rise in temperature

b) Doubles for every 10ºC rise in temperature

c) Decreases linearly with temperature

d) Increase linearly with temperature

- In a transistor if $\beta = 100$ and collector current is 10 mA, then I_E is …………

a) 100 mA

b) 100.1 mA

c) 110 mA

d) none of the above

- If the value of α is 0.9, then value of β is ………..

a) 9

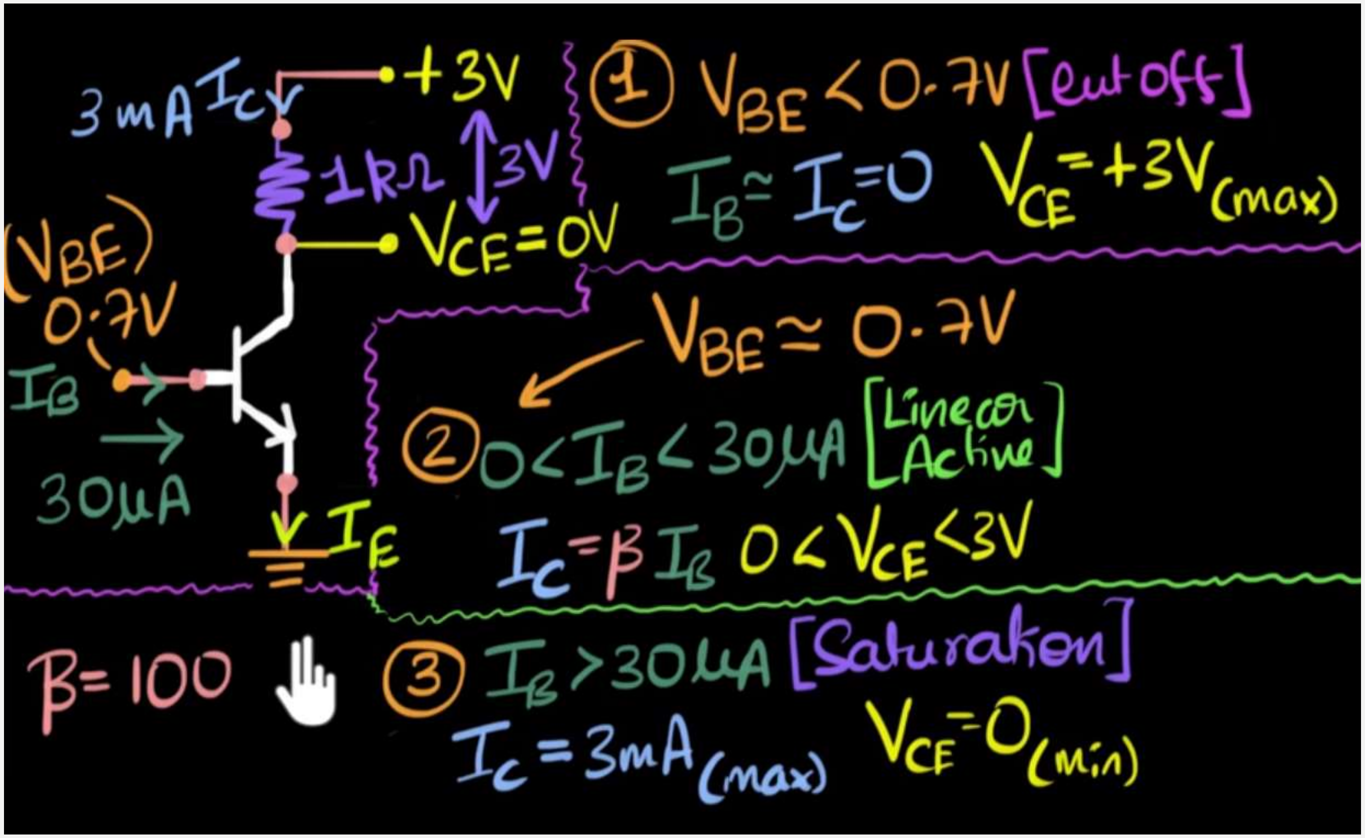
b) 0.9

c) 900

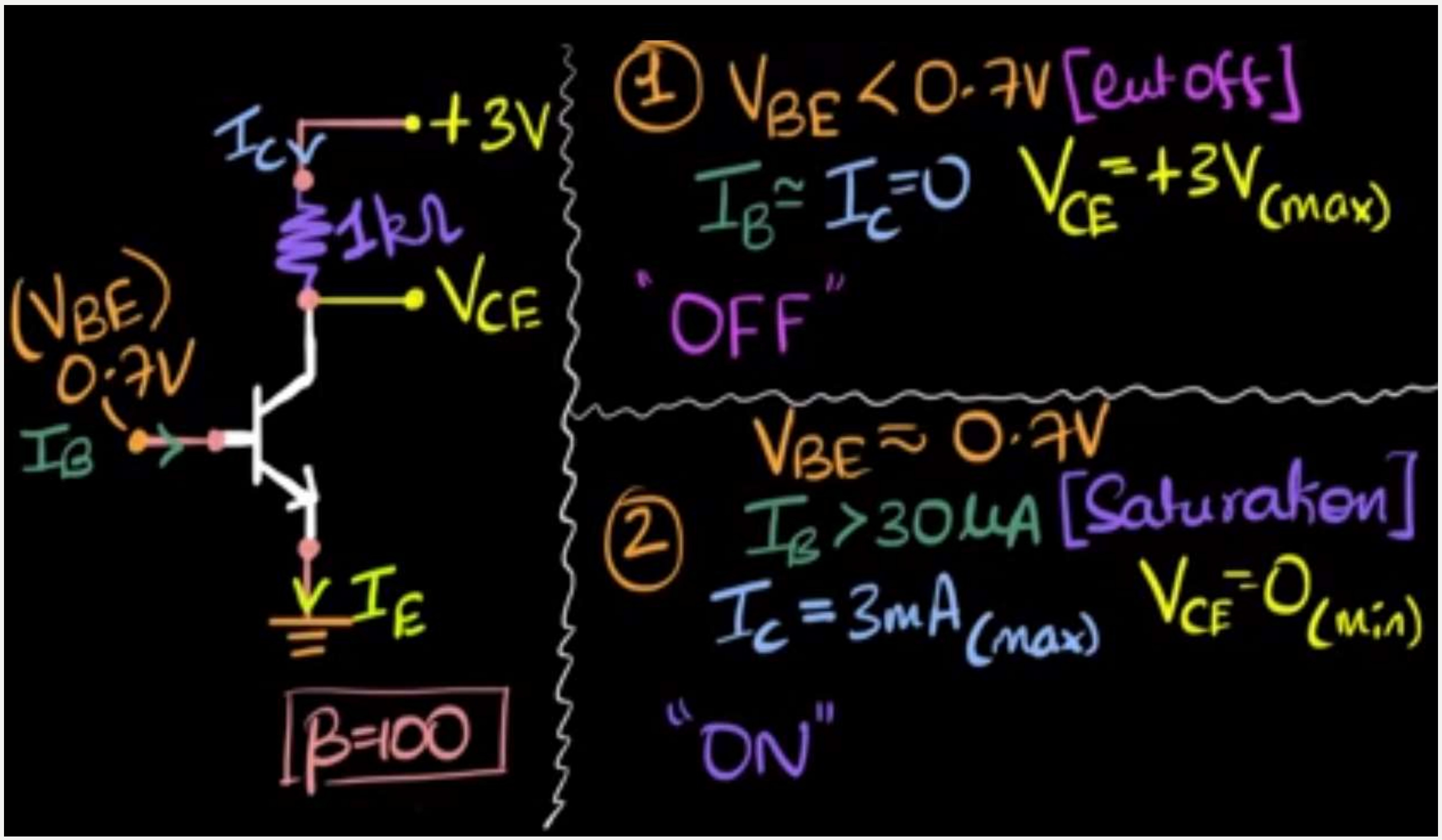
d) 90

USE OF CUT-OFF AND SATURATION REGIONS?

TRANSISTOR AS A SWITCH



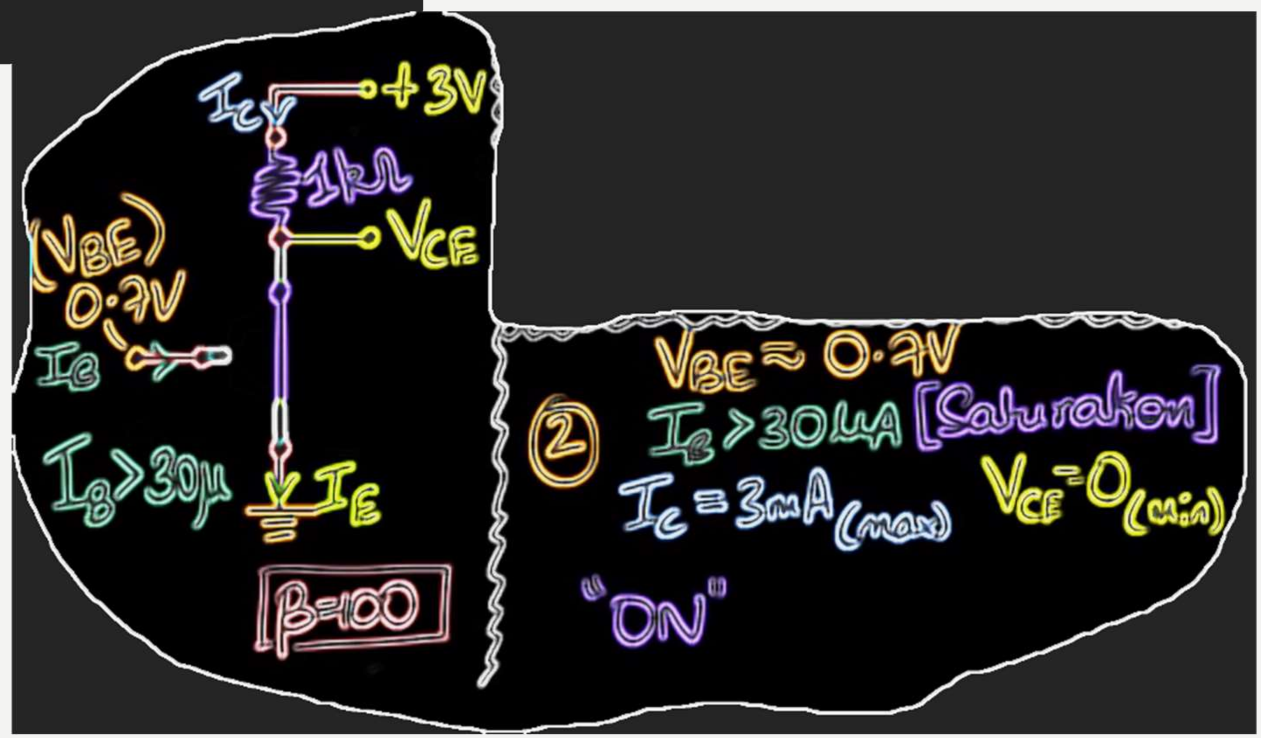
- When input current is within a particular range, the transistor acts as an amplifier.
- But outside that range, transistor exhibits other characteristics.
- Cut-off- O/P voltage is very high, I/P current is very low.
- Saturation- I/P current is very high but the O/P voltage is zero. When input current is increased beyond the limit, the output current does not increase at all further.



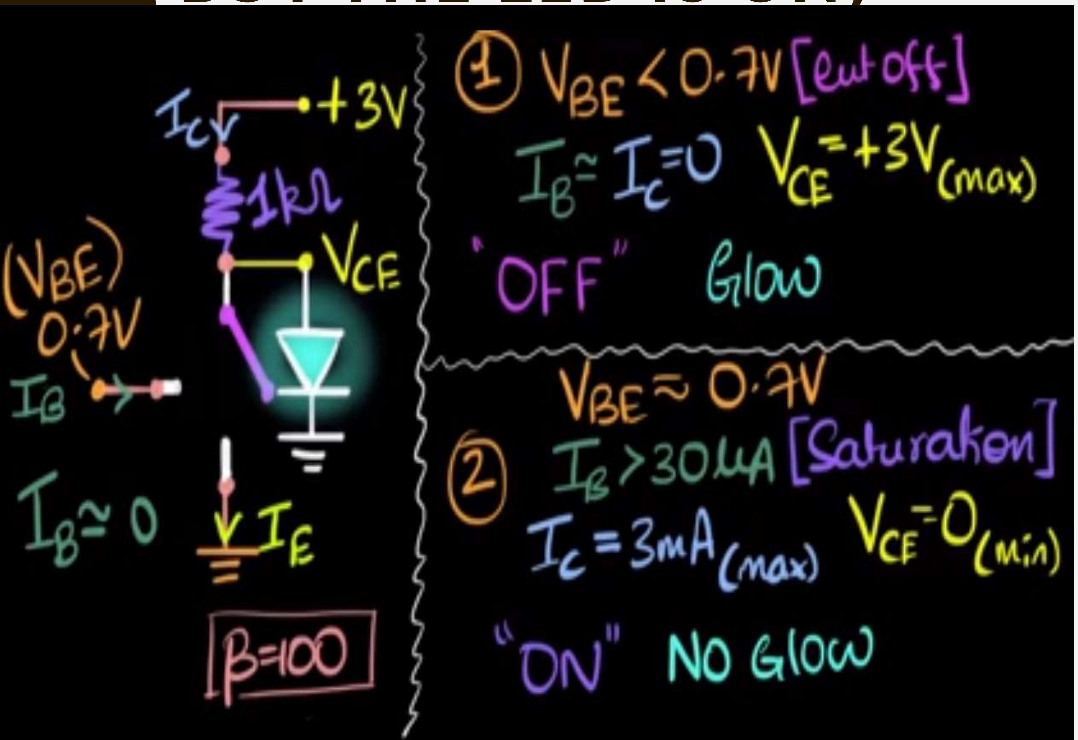
I_C
+3V
1kΩ
V_{CE}
(V_{BE})
0.7V
I_B
I_E
β=100
① $V_{BE} < 0.7V$ [cut off]
$I_B \simeq I_C = 0$ $V_{CE} = +3V_{(max)}$
"OFF"
$V_{BE} \approx 0.7V$
② $I_B > 30\mu A$ [Saturation]
$I_C = 3mA_{(max)}$ $V_{CE} = 0_{(min)}$
"ON"

CUT-OFF

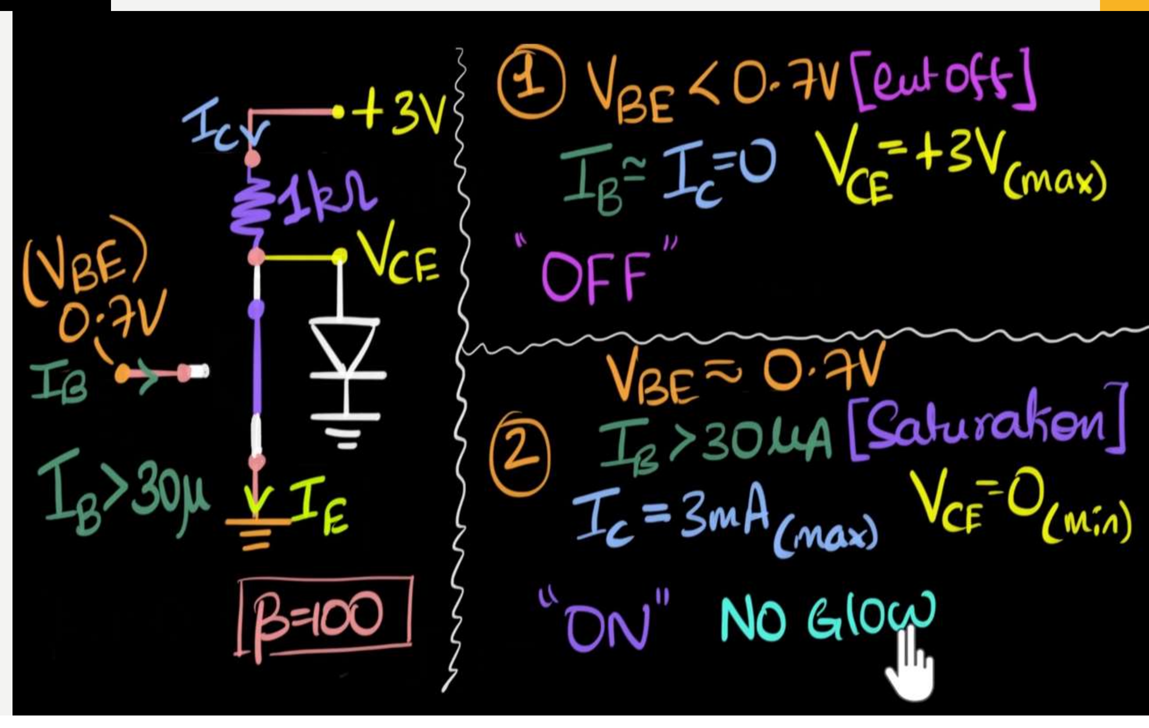
SATURATION



CUT-OFF (TRANSISTOR IS OFF BUT THE LED IS ON)



SATURATION (TRANSISTOR IS ON BUT THE LED IS OFF)



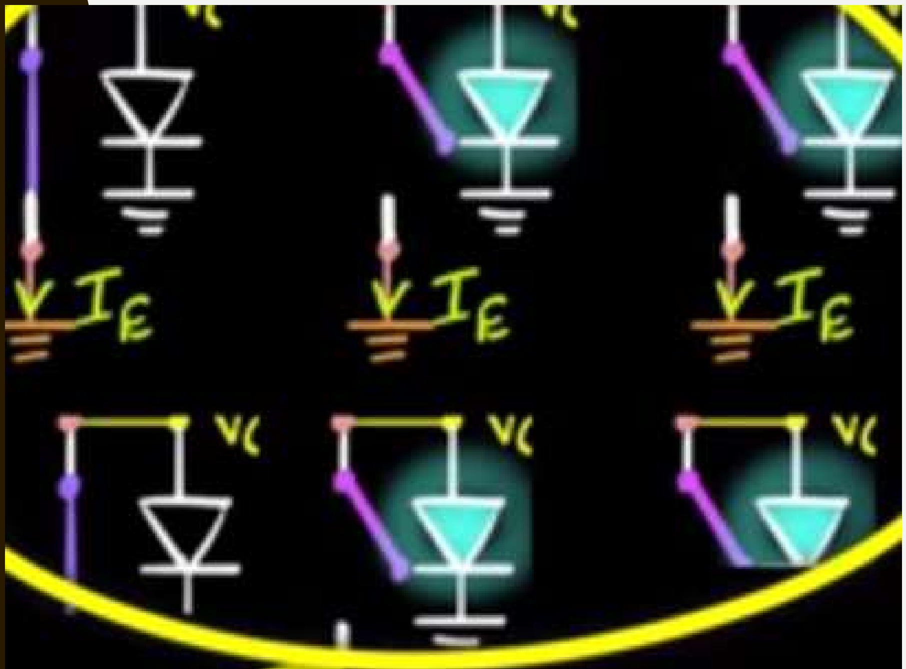
WHY NOT USE A MECHANICAL SWITCH INSTEAD?

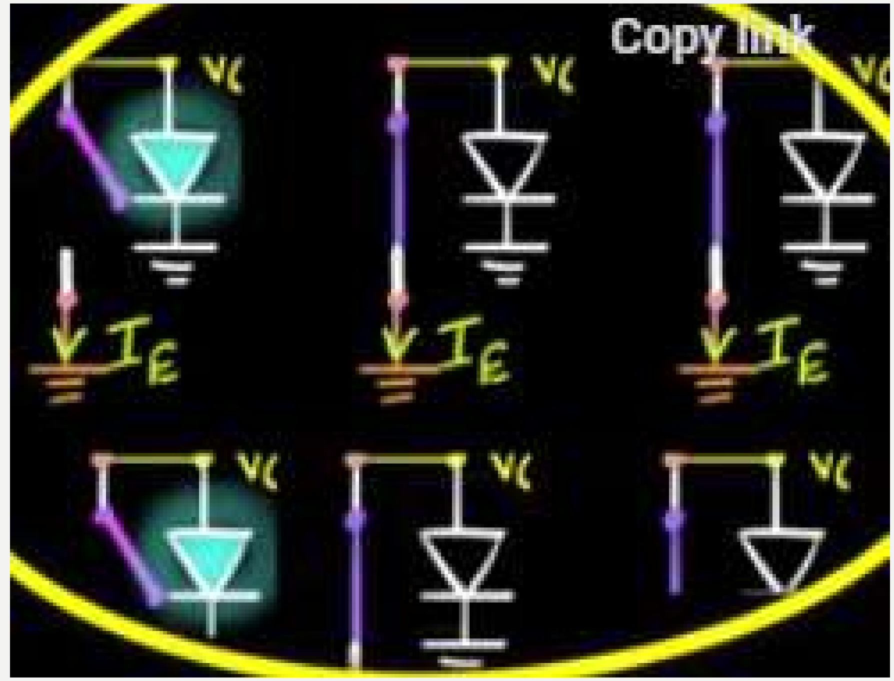
1) It has no moving parts (With moving parts, there is a limit to how fast it is turned on and off), so its switching speed is incredibly high. [EXTREMELY FAST]

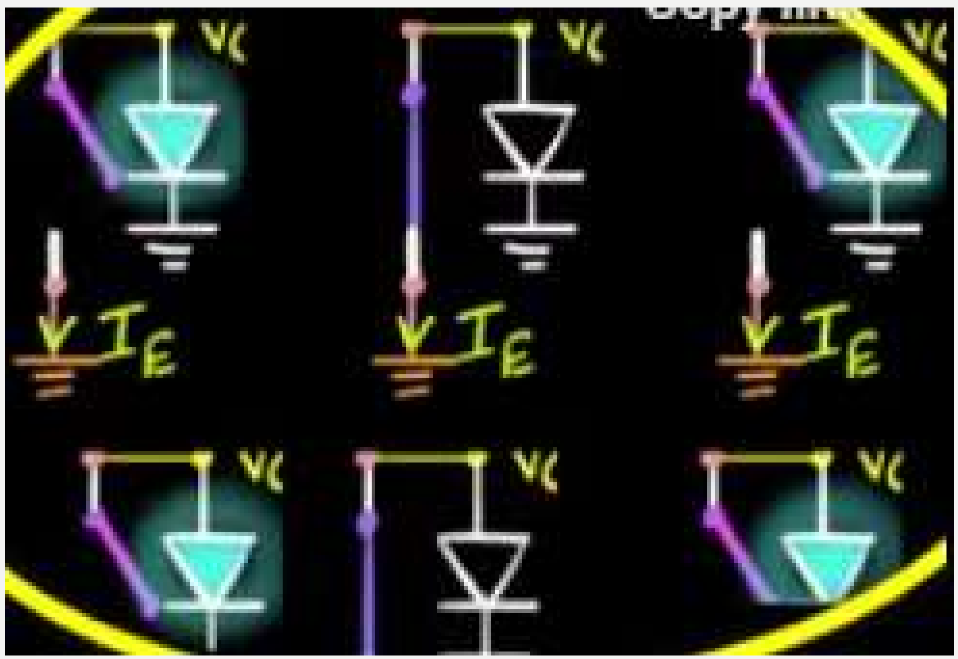
2) Power consumption is very low as it consumes very less electricity, thus it is extremely efficient. [EXTREMELY LOW POWER]

3) Today's transistors can be made extremely tiny, thus a lot of switches can be placed in a very small space. [EXTREMELY TINY]

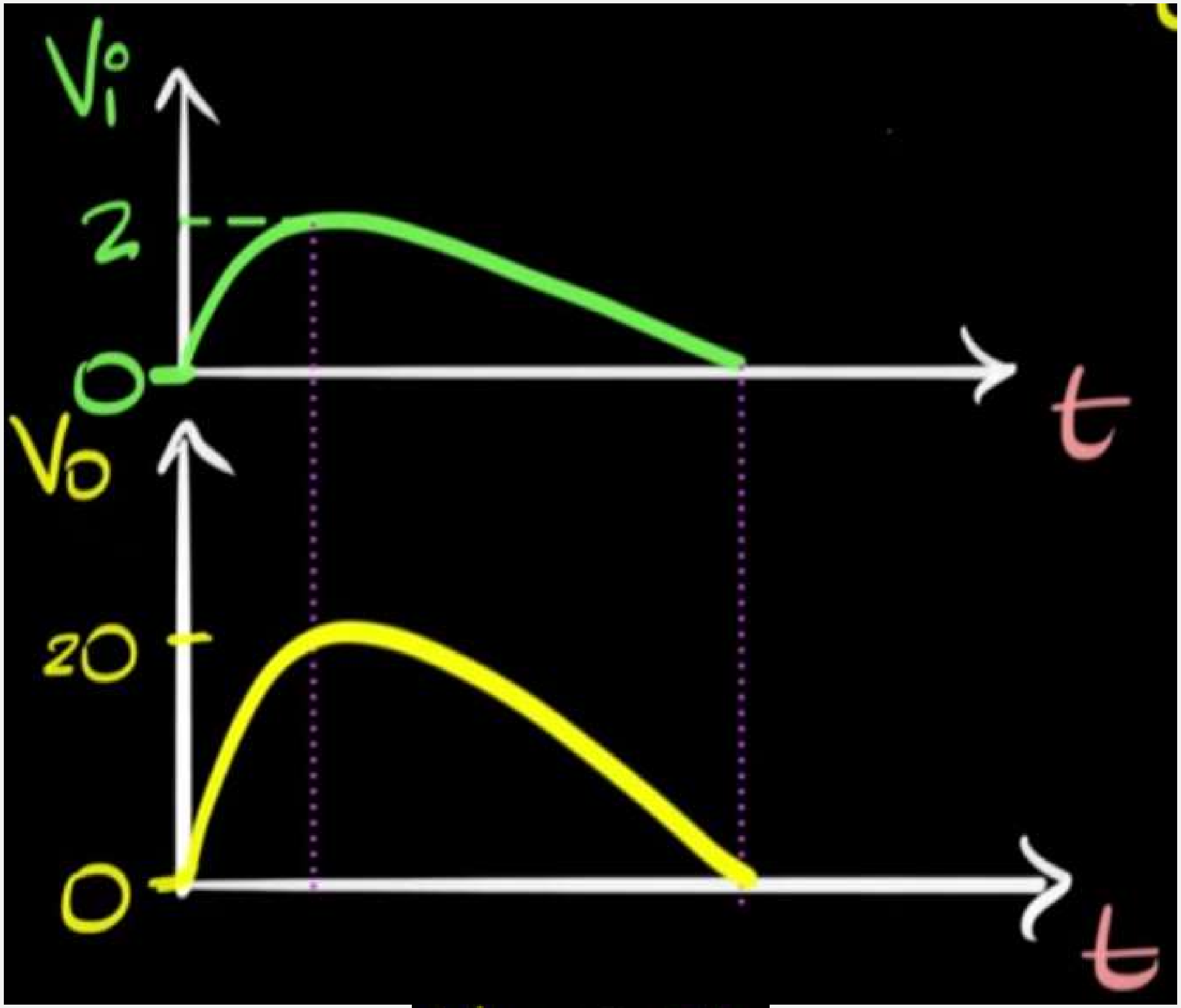
So, by combining these switches together in a great number, we can make operators, we can do addition, subtraction and all the mathematical computing and thus make a computer (because inside it there are lot many switches)


VC
IE

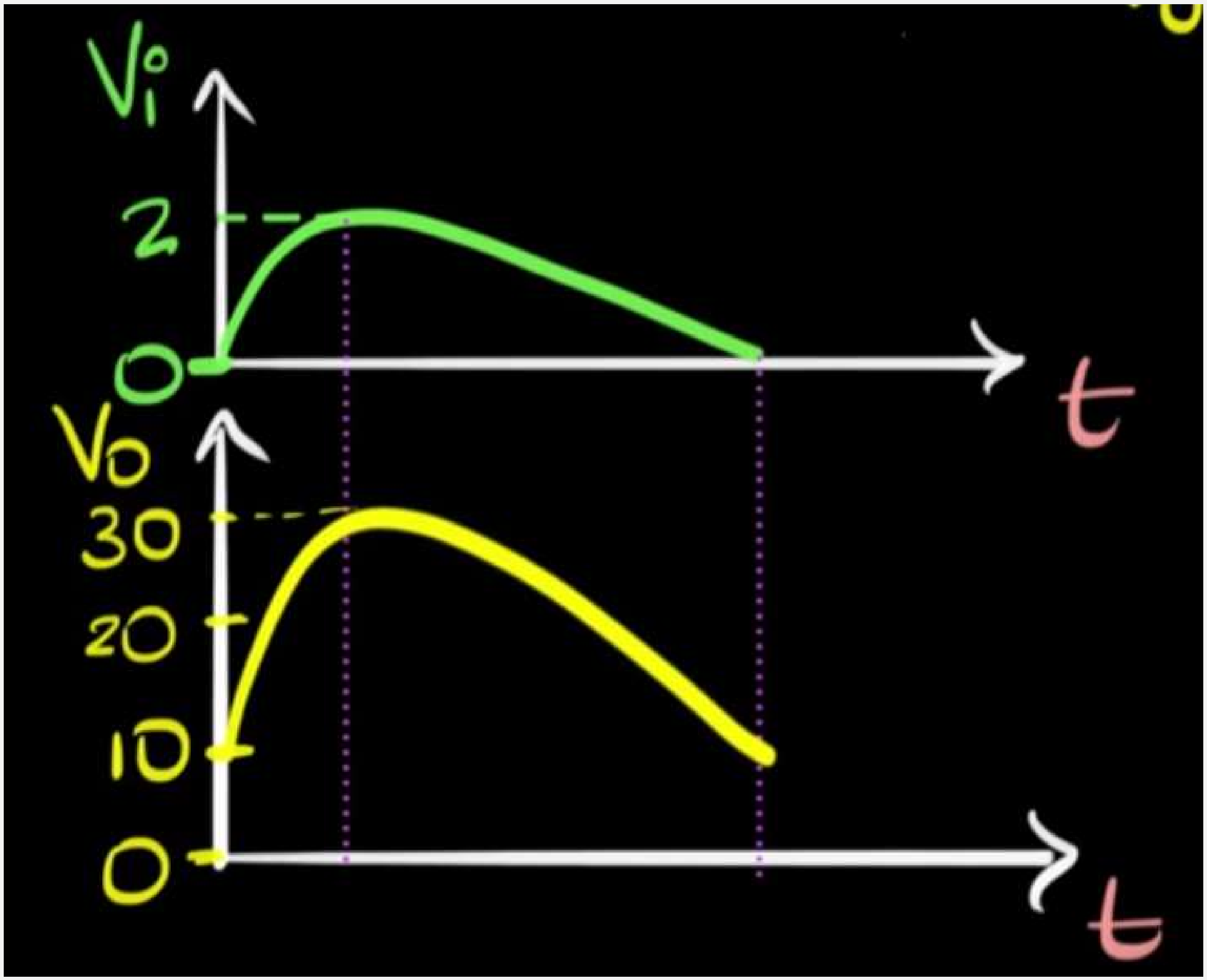

Copy link
VC
IE

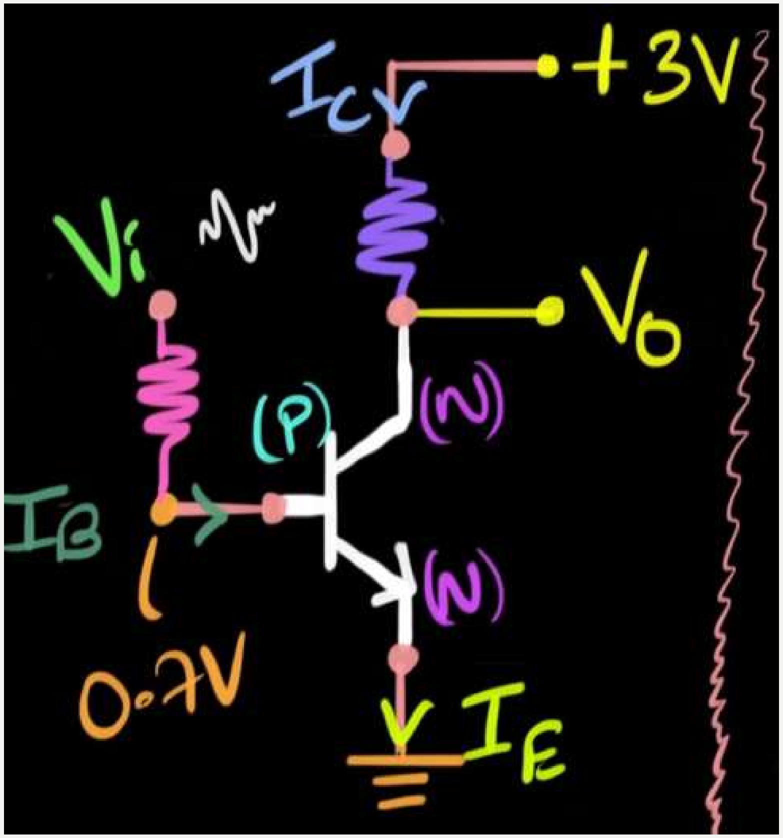

VC
IE

TRANSISTOR AS AN AMPLIFIER



$$\Delta V_0 = 10 \Delta V_i$$





I_C
+3V
V_i
V_o
(P)
(N)
(N)
I_B
0.7V
I_E

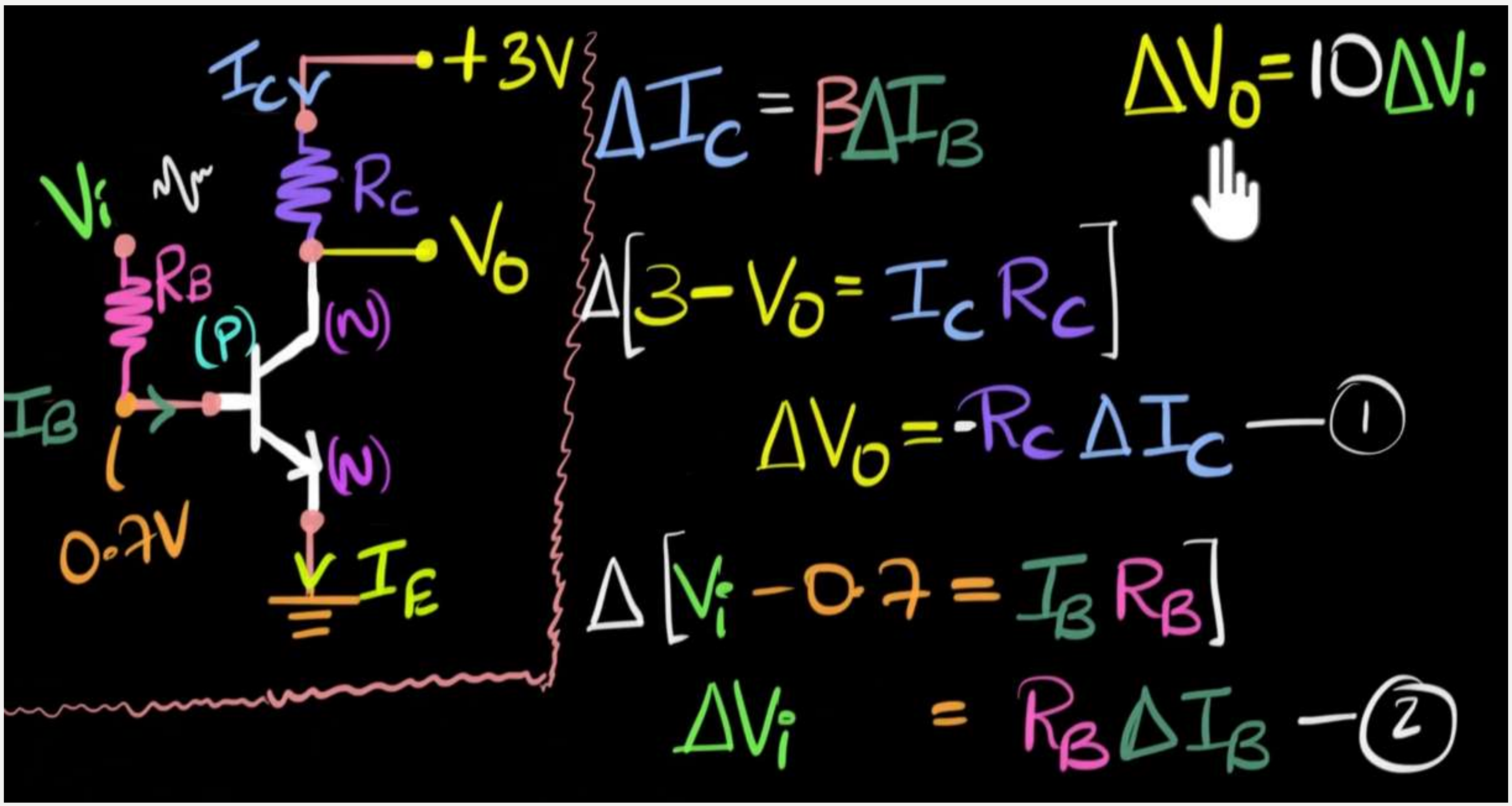
$$\Delta V_0 = 10 \Delta V_i$$

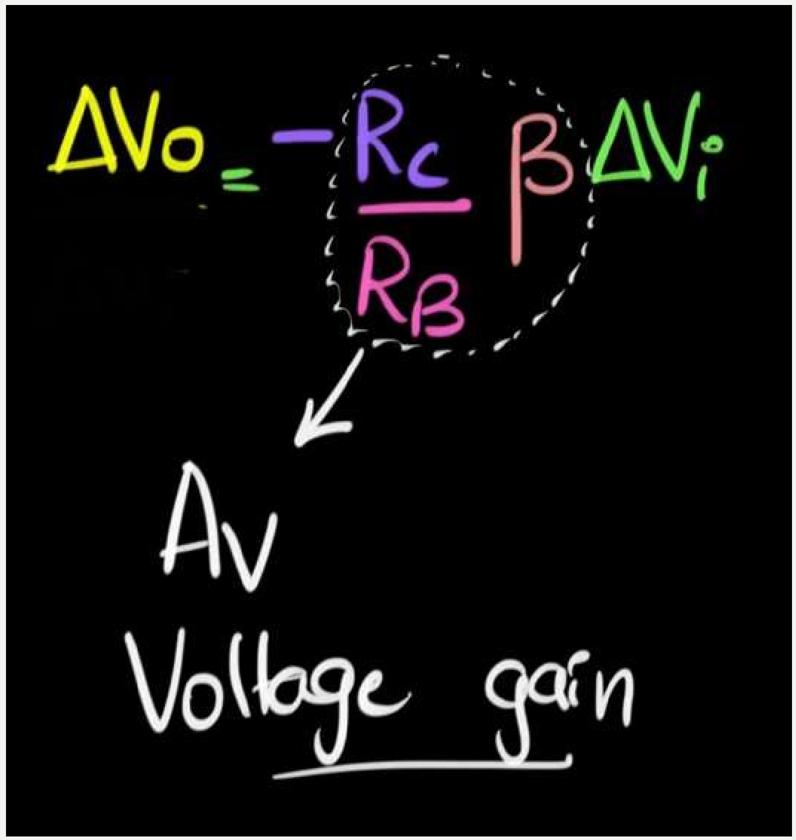
$$\Delta I_C = \beta \Delta I_B$$

$$I_{C_1} = \beta I_{B_1}$$

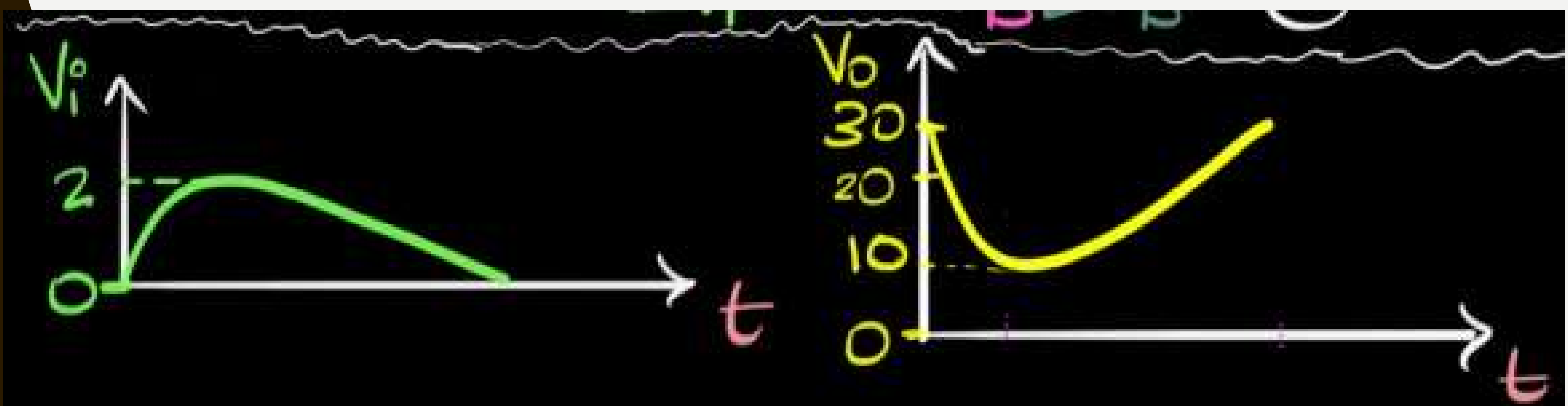
$$I_{C_2} = \beta I_{B_2}$$

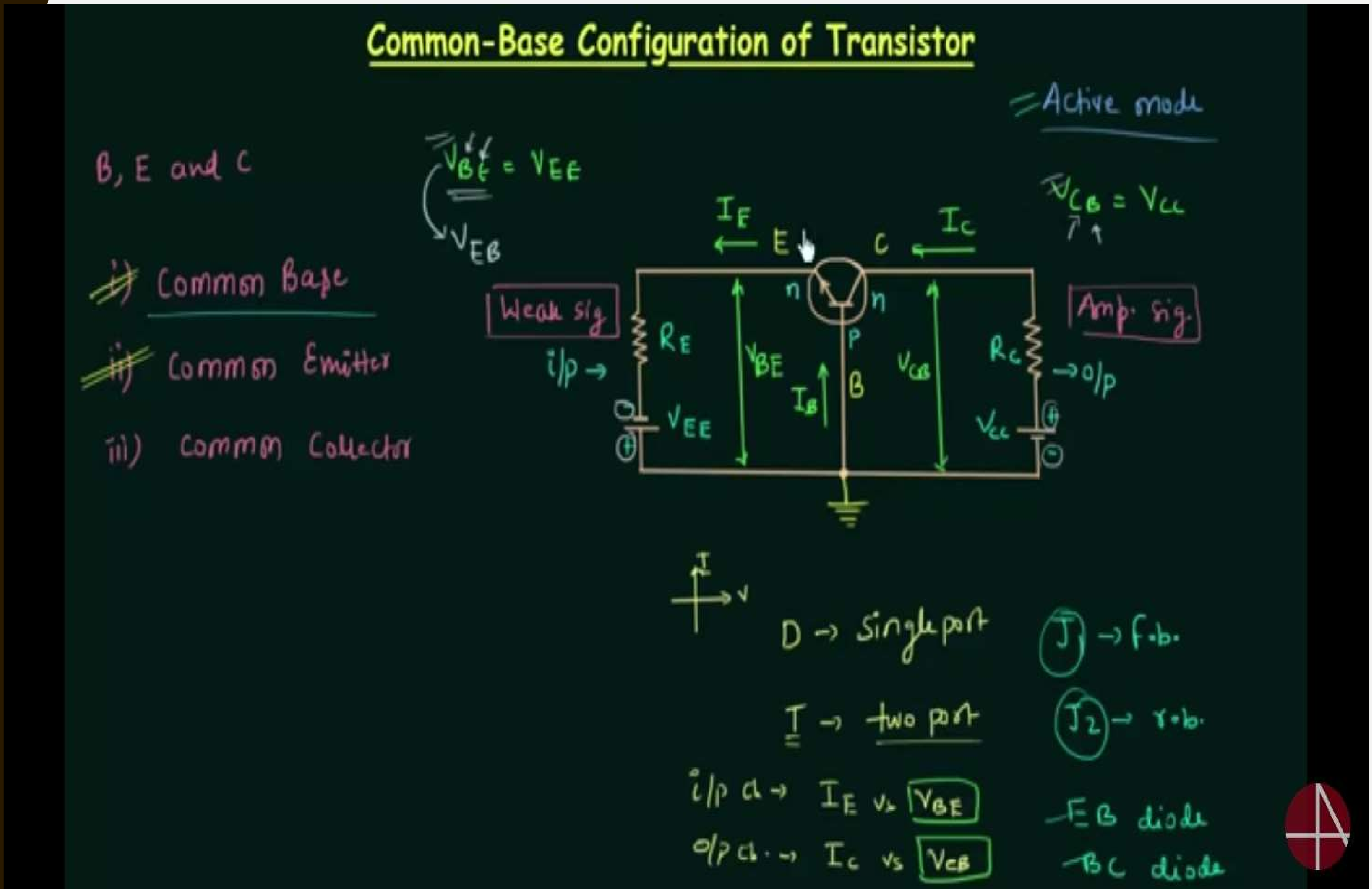
$$I_{C_2} - I_{C_1} = \beta I_{B_2} - \beta I_{B_1}$$


+3V
I_C
R_C
V_i
R_B
V_o
(P)
(N)
(N)
I_B
0.7V
I_E
ΔI_C = βΔI_B
ΔV_o = 10ΔV_i
Δ[3 − V_o = I_C R_C]
ΔV_o = −R_C ΔI_C — 1
Δ[V_i − 0.7 = I_B R_B]
ΔV_i = R_B ΔI_B — 2


$\Delta V_o = -\frac{R_C}{R_B} \beta \Delta V_i$
A_v
Voltage gain

- If input voltage V_i increases, current I_B increases, due to which I_C increases, due to which there is more voltage drop across R_C
- As a result, there is a higher voltage drop at the output.

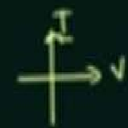



Common-Base Configuration of Transistor
Active mode
B, E and C
i) Common Base
ii) Common Emitter
iii) Common Collector
VBE = VEE
VEB
VCB = VCC
IE
E
C
IC
n
n
P
B
IB
Weak sig
Amp. sig.
RE
RC
i/p →
→ o/p
VBE
VCB
VEE
VCC
I
V
D → Single port
T → two port
J1 → f.b.
J2 → r.b.
i/p ch → IE vs VBE
o/p ch. → IC vs VCB
EB diode
BC diode

KCL:

$$\boxed{I_E = I_B + I_C} \quad \text{— (1)}$$

active mode



D → single port

T → two port

J_1 → f.b.

J_2 → r.b.

i/p ch → I_E vs $\boxed{V_{BE}}$ — EB diode

o/p ch. → I_C vs $\boxed{V_{CB}}$ — BC diode

$$I_C = \alpha I_E + I_{CO}$$

r.s.c.

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

open ckt

$$\text{gain} = \frac{o/p}{i/p}$$

$$I_E >> I_{CBO}$$

$$I_C = \alpha I_E \Rightarrow \boxed{\alpha = \frac{I_C}{I_E}}$$

o/p

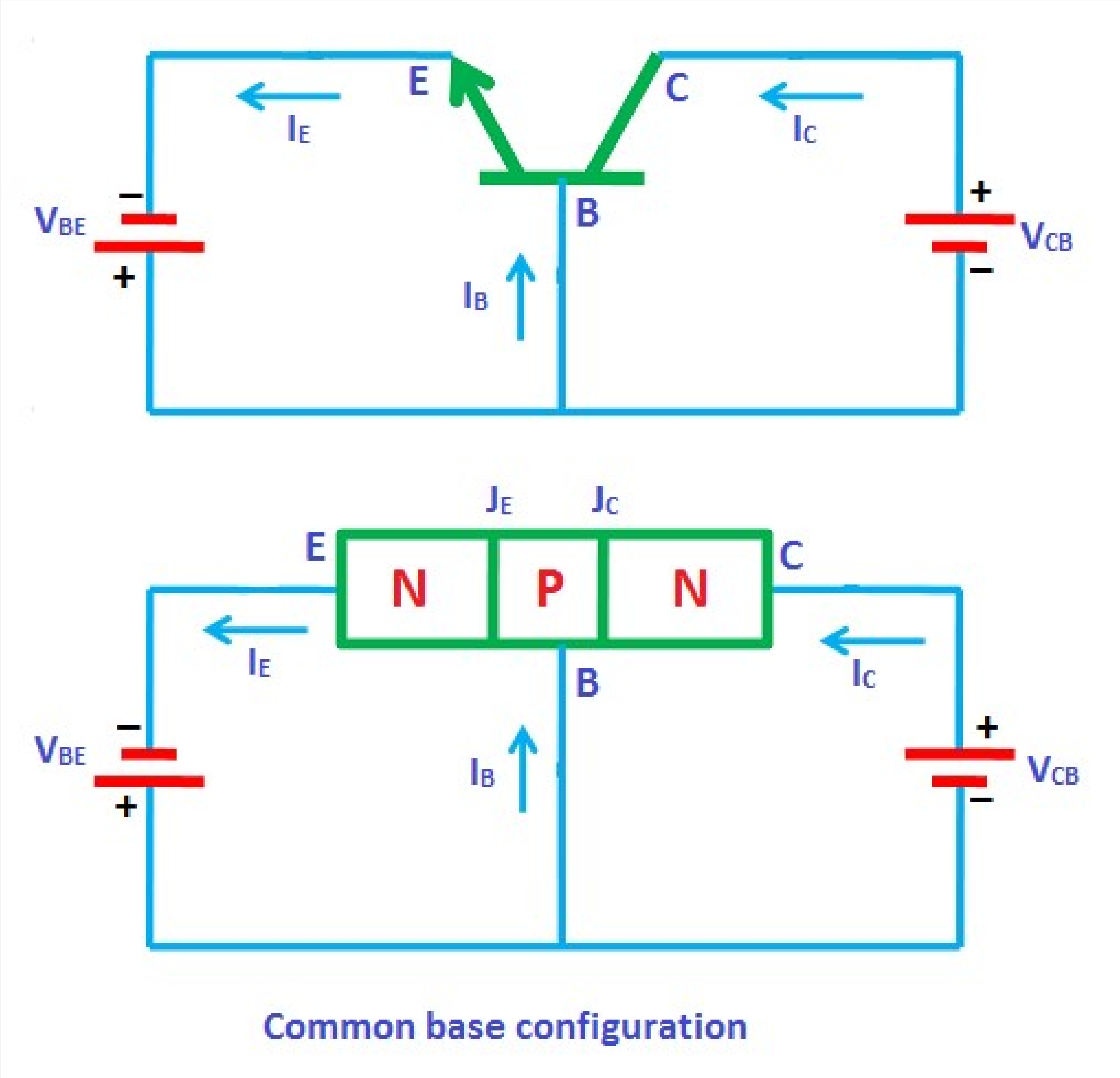
i/p

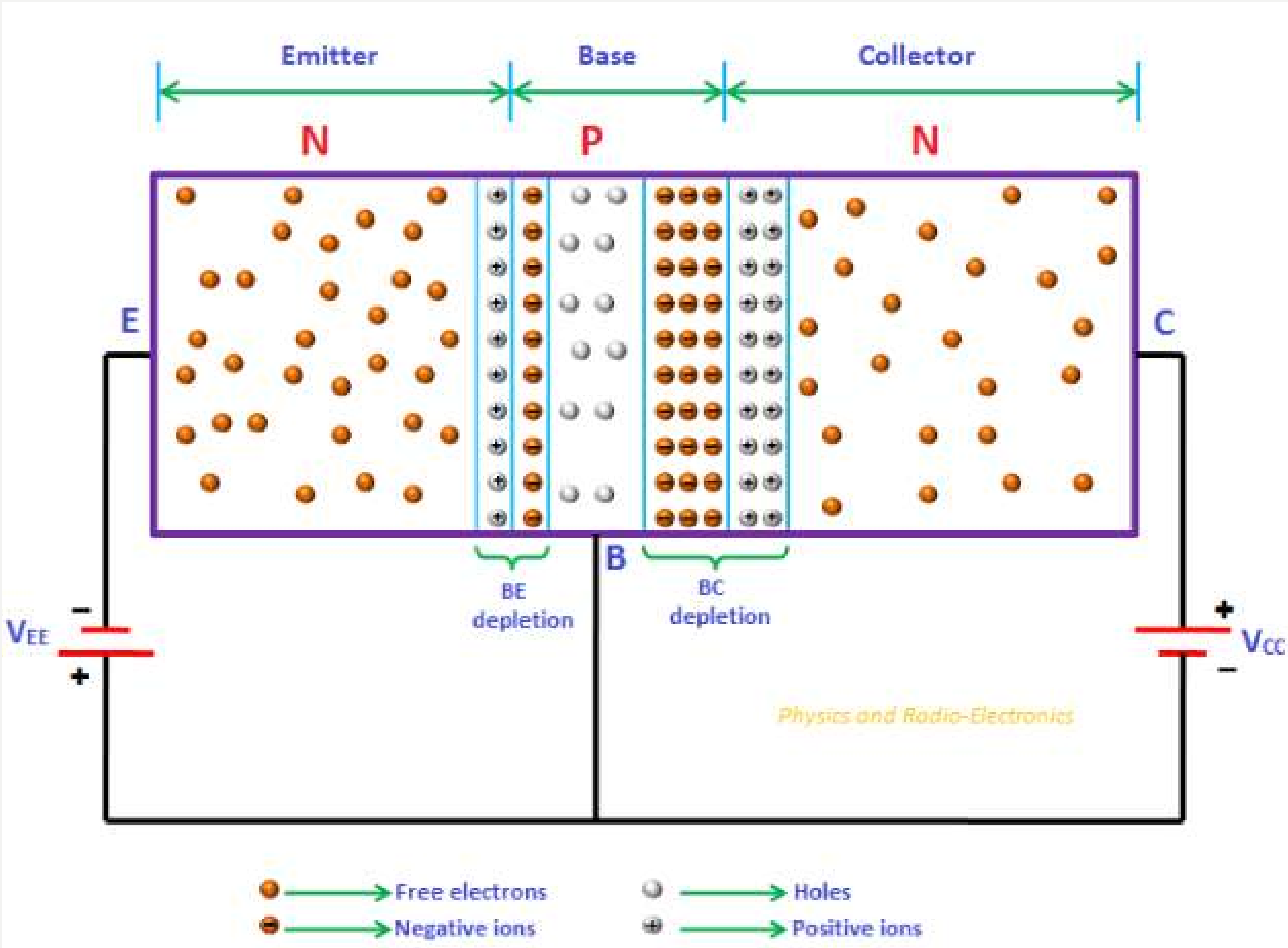
Common base current gain/am. factor

$$\alpha = 0.95 - 0.98 \Rightarrow 95\% \text{ to } 98\%$$

5% 2%

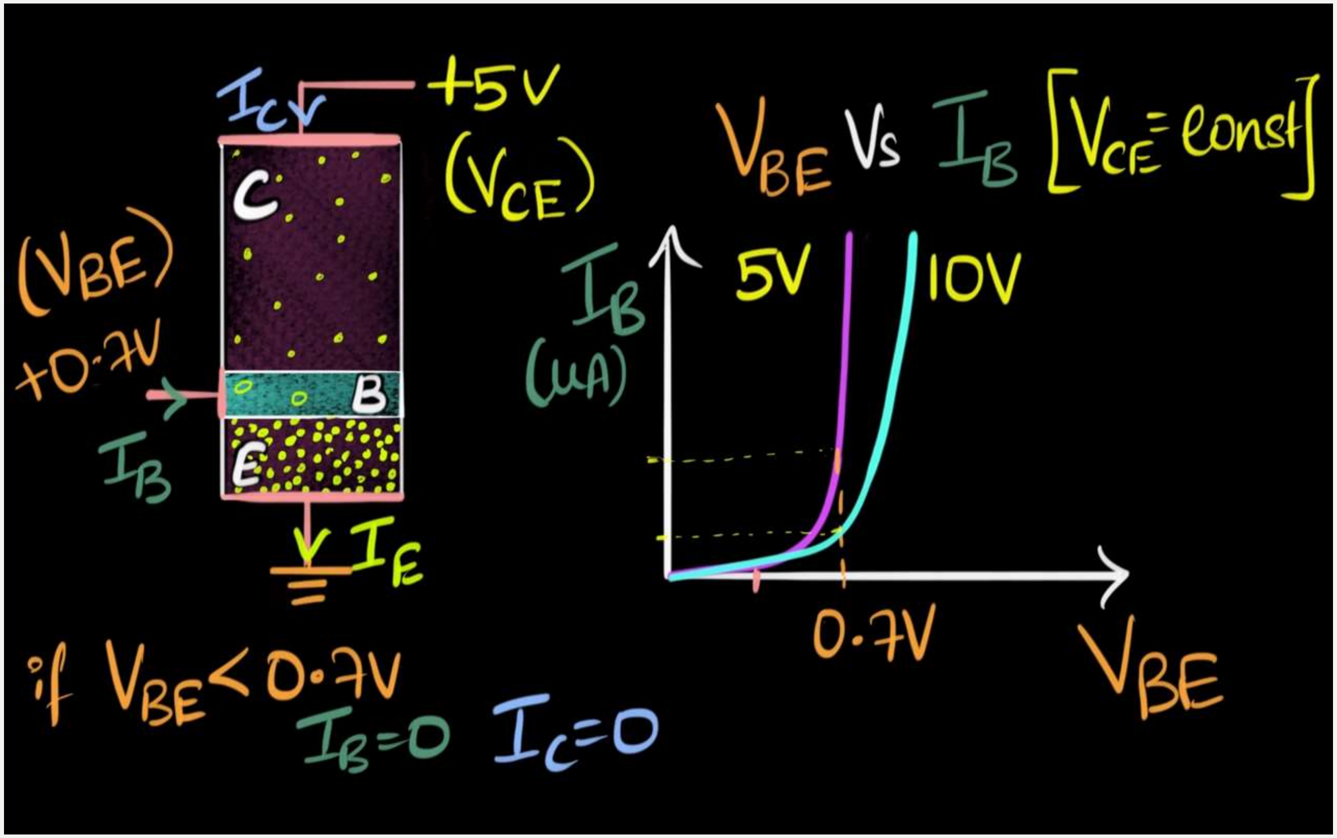
$$I_B = (1-\alpha) I_E$$

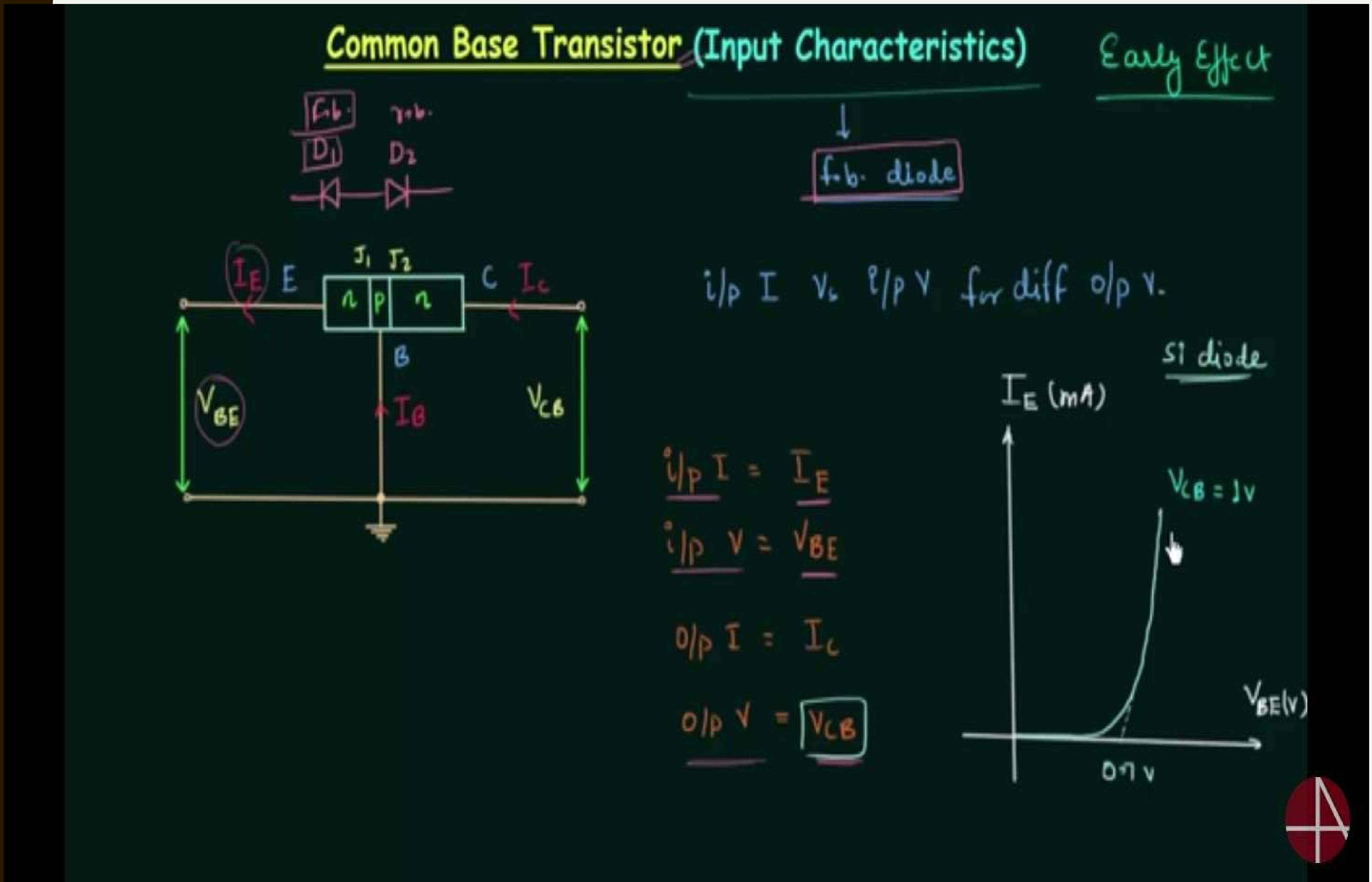

E
C
I_E
I_C
V_{BE}
B
V_{CB}
I_B
J_E
J_C
E
N
P
N
C
I_E
I_C
B
V_{BE}
V_{CB}
I_B
Common base configuration

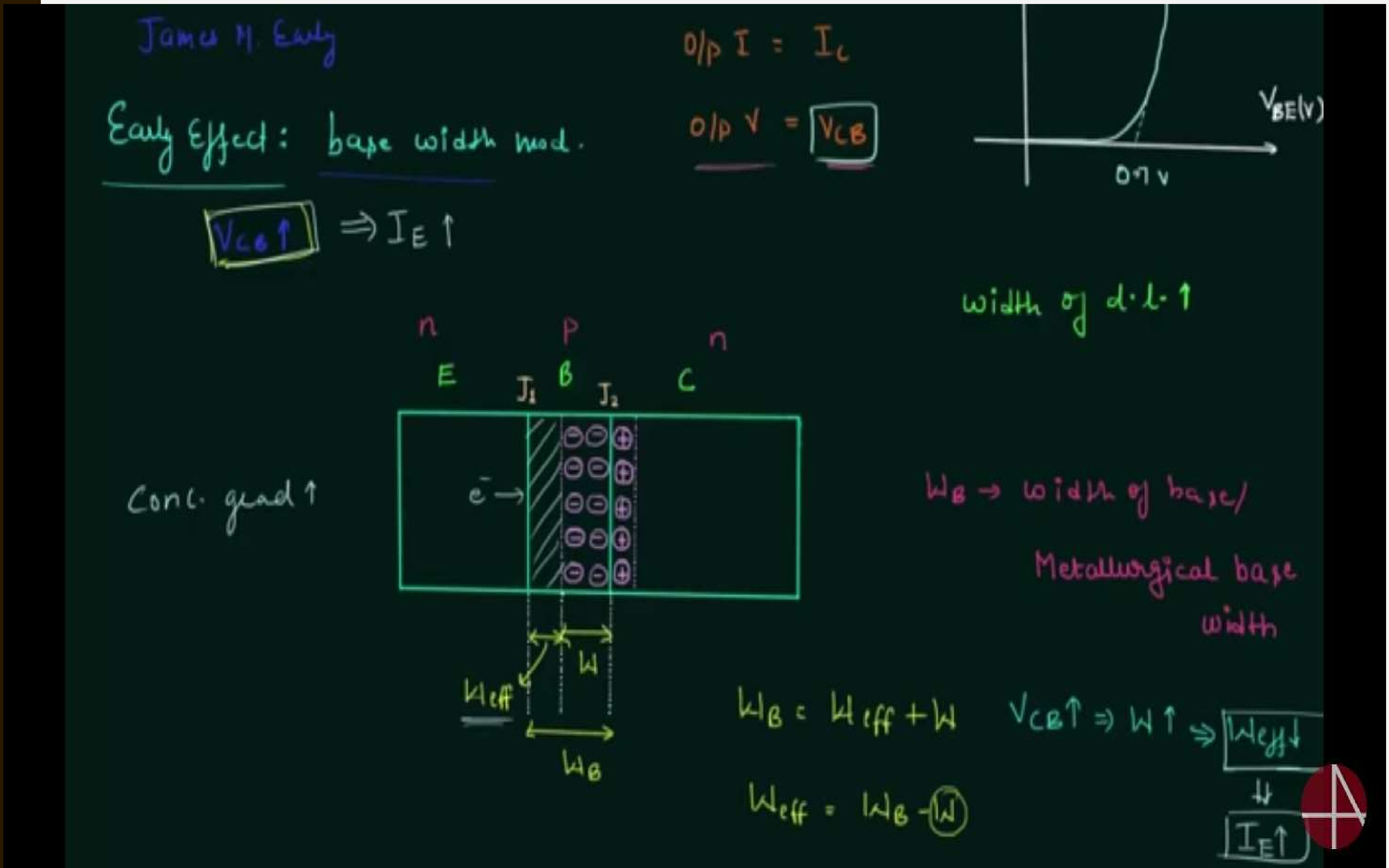


Emitter
Base
Collector
N
P
N
E
C
B
BE depletion
BC depletion
VEE
VCC
Physics and Radio-Electronics
Free electrons
Negative ions
Holes
Positive ions

INPUT CHARACTERISTICS




Common Base Transistor (Input Characteristics)
Early Effect
f.b. diode
f.b.
r.b.
D1
D2
IE
E
J1
J2
n
p
n
C
Ic
B
VBE
IB
VCB
i/p I vs i/p V for diff o/p V.
Si diode
IE (mA)
VCB = 1V
VBE(V)
0.7 V
i/p I = IE
i/p V = VBE
o/p I = Ic
o/p V = VCB


James M. Early
O/P I = I_C
O/P V = V_{CB}
$V_{BE}(V)$
0.7 V
Early Effect: base width mod.
$V_{CB}\uparrow \Rightarrow I_E \uparrow$
width of d.l. ↑
n
p
n
E
J_1
B
J_2
C
Conc. grad ↑
$e^- \rightarrow$
$W_B \rightarrow$ width of base/
Metallurgical base width
W_{eff}
W
W_B
$W_B = W_{eff} + W$
$V_{CB}\uparrow \Rightarrow W\uparrow \Rightarrow W_{eff}\downarrow$
$\Downarrow$
$I_E\uparrow$
$W_{eff} = W_B - W$

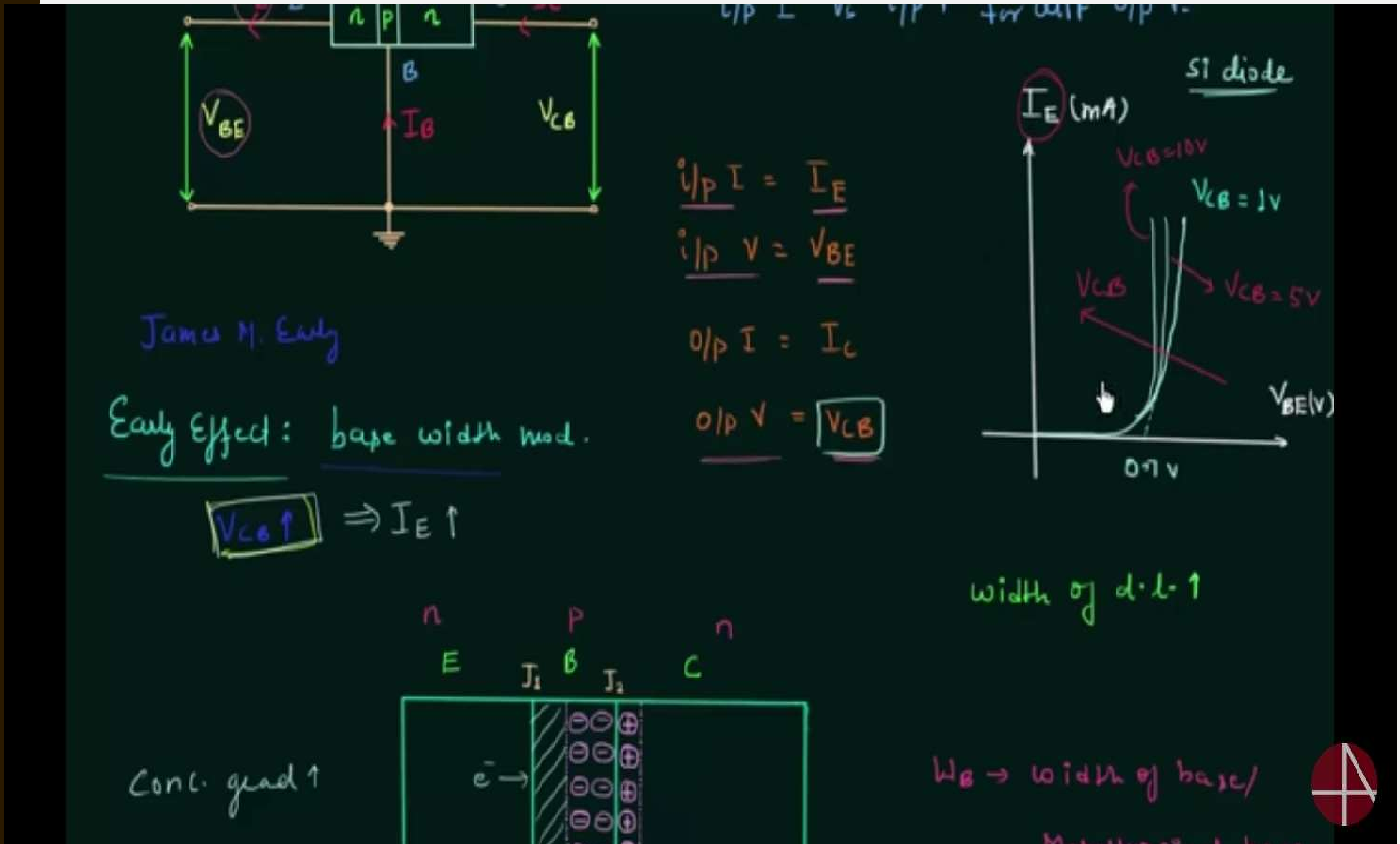
Early effect (or) Base-width modulation:-

In Common Base configuration in the Reverse Bias, As the voltage V_{CC} increases, the space-charge width between collector and base tends to increase, with the result that the effective width of the base decreases. This dependency of Base-width on the Collector to emitter voltage is known as the early effect.

The early effect has three consequences:-

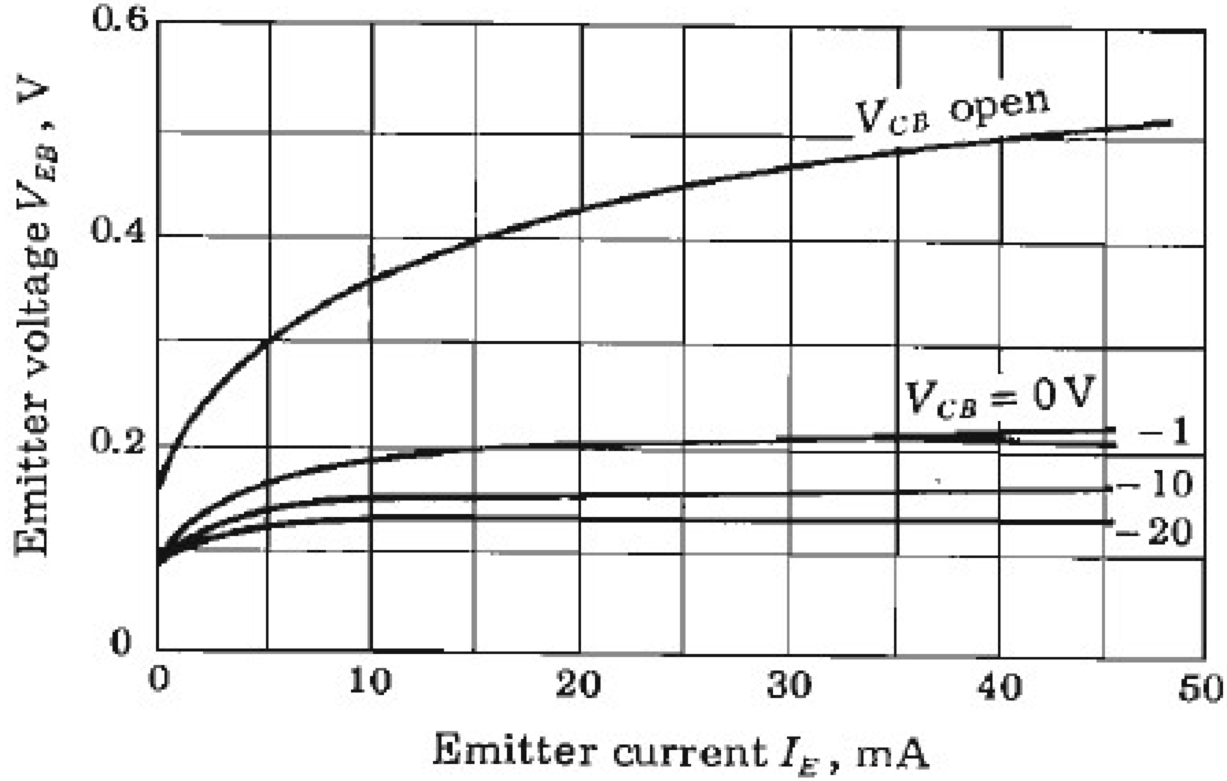
1. There is less chance for recombination with in the base region. Hence α increases with increasing $|V_{CB}|$.
2. The charge gradient is increased with in the base and consequently, the current of minority carriers injected across the emitter junction increases.
3. For extremely large voltages, the effective Base-width may be reduced to zero, causing voltage break-down in the transistor. This phenomenon is called the Punch-through.

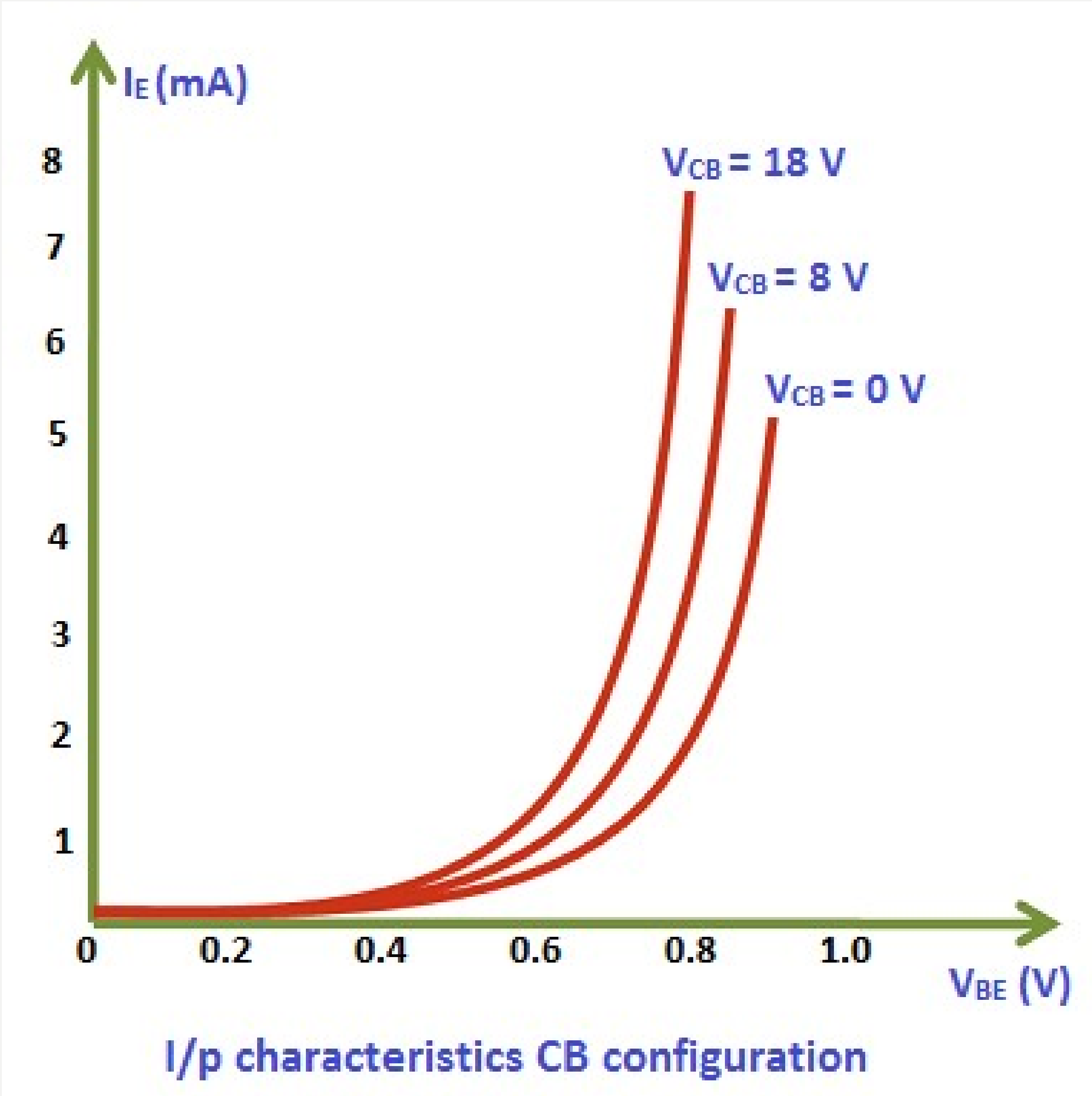
For higher values of V_{CB}, due to early effect the value of α increases, for example α changes say from 0.98 to 0.985. Hence there is a very small positive slope in the CB output characteristics and hence the output resistance is not zero.



n p n
B
V_BE
I_B
V_CB
James M. Early
Early Effect : base width mod.
V_CB ↑ ⇒ I_E ↑
i/p I = I_E
i/p V = V_BE
o/p I = I_C
o/p V = V_CB
Si diode
I_E (mA)
V_CB = 10V
V_CB = 1V
V_CB = 5V
V_CB
V_BE (V)
0.7 V
width of d.l. ↑
n
p
n
E
J1
B
J2
C
Conc. grad ↑
W_B → width of base/

Fig. 5-7 Common-base input characteristics of a typical p-n-p germanium junction transistor.





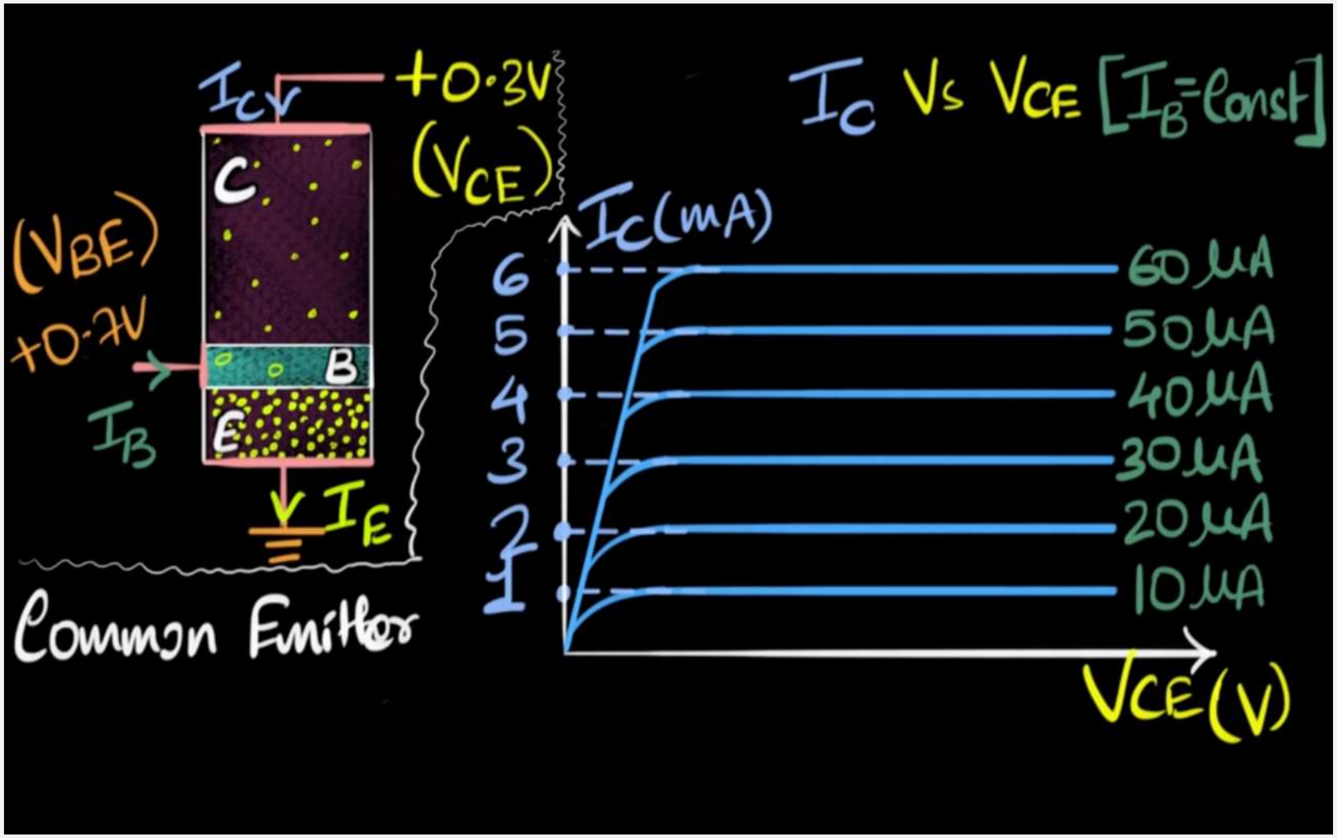
IE (mA)
8
7
6
5
4
3
2
1
0
0.2
0.4
0.6
0.8
1.0
VBE (V)
VCB = 18 V
VCB = 8 V
VCB = 0 V
I/p characteristics CB configuration

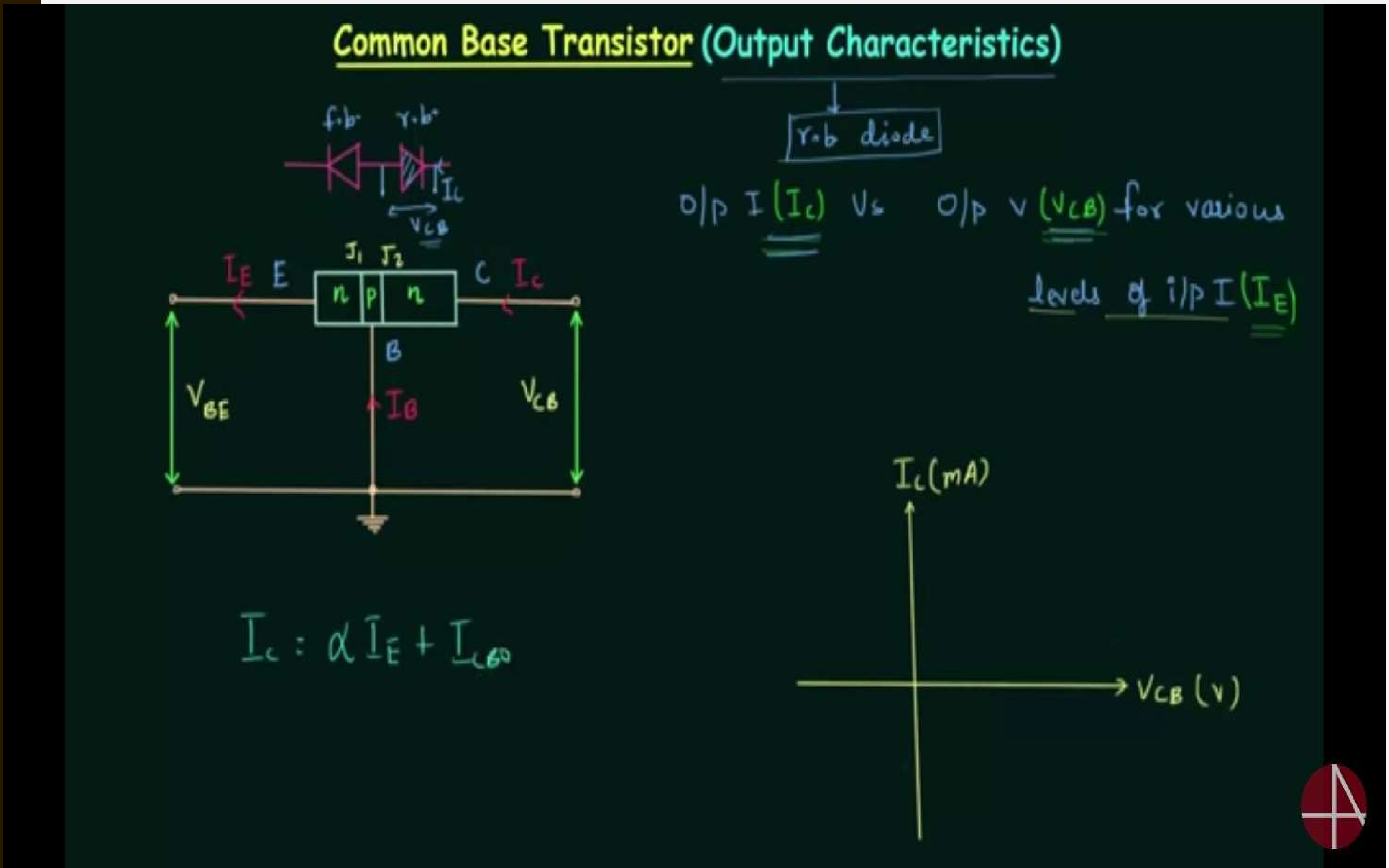
- What is the value of thermal voltage at room temperature?
- (a) 26 V (b) 26 mV (c) 260 mV (d) 0.026 mV

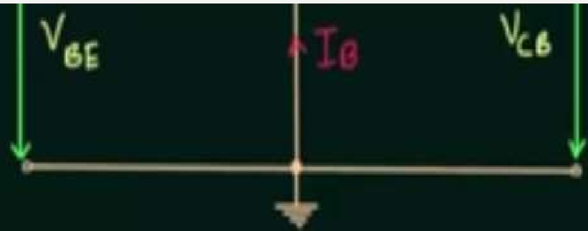
- The Early Effect is also called as
- a) Base-width modulation effect
- b) Base-width amplification effect
- c) Both of the mentioned
- d) None of the mentioned

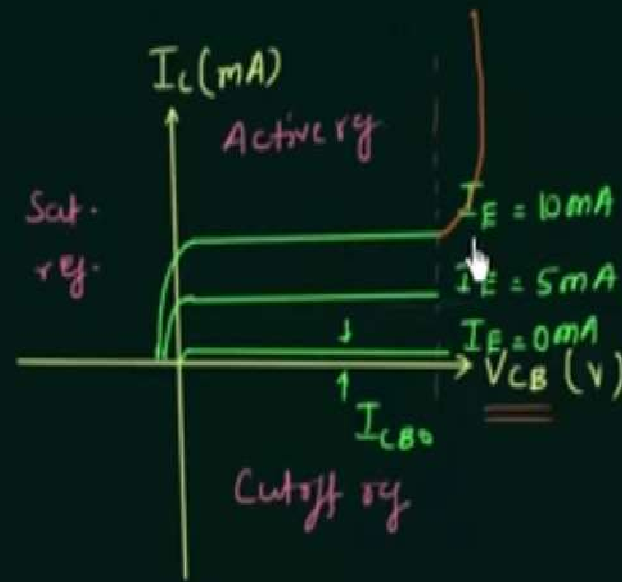
- The value of alpha of a transistor is
- a) more than 1 b) less than 1 c) 1 d) none of the above

OUTPUT CHARACTERISTICS




Common Base Transistor (Output Characteristics)
r.b diode
O/P I (Ic) Vs O/P V (VCB) for various levels of i/p I (IE)
f.b.
r.b.
Ic
VCB
J1 J2
IE E n p n C Ic
B
VBE IB VCB
Ic = α IE + ICBO
Ic(mA)
VCB (V)





$I_C = \alpha I_E + \boxed{I_{CBO}}$ (independent of V_{CB})

$I_C \approx \alpha I_E$

$\boxed{I_C \approx I_E}$ ($\alpha = 0.95 - 0.98$)

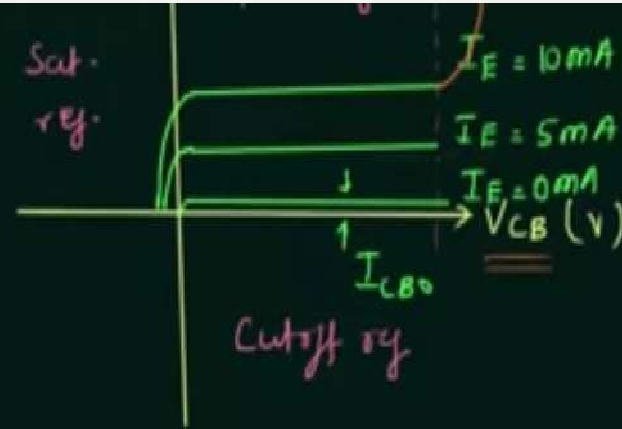
O/P I/P

$I_c = \alpha I_E + \boxed{I_{CBO}}$ (independent of V_{CB})

$I_c \approx \alpha I_E$

$\boxed{I_c \approx I_E}$ ($\alpha = 0.95 - 0.98$)

o/p i/p



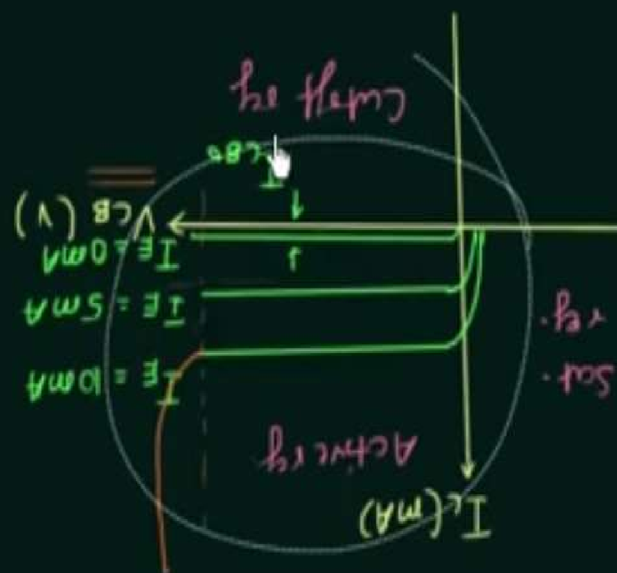
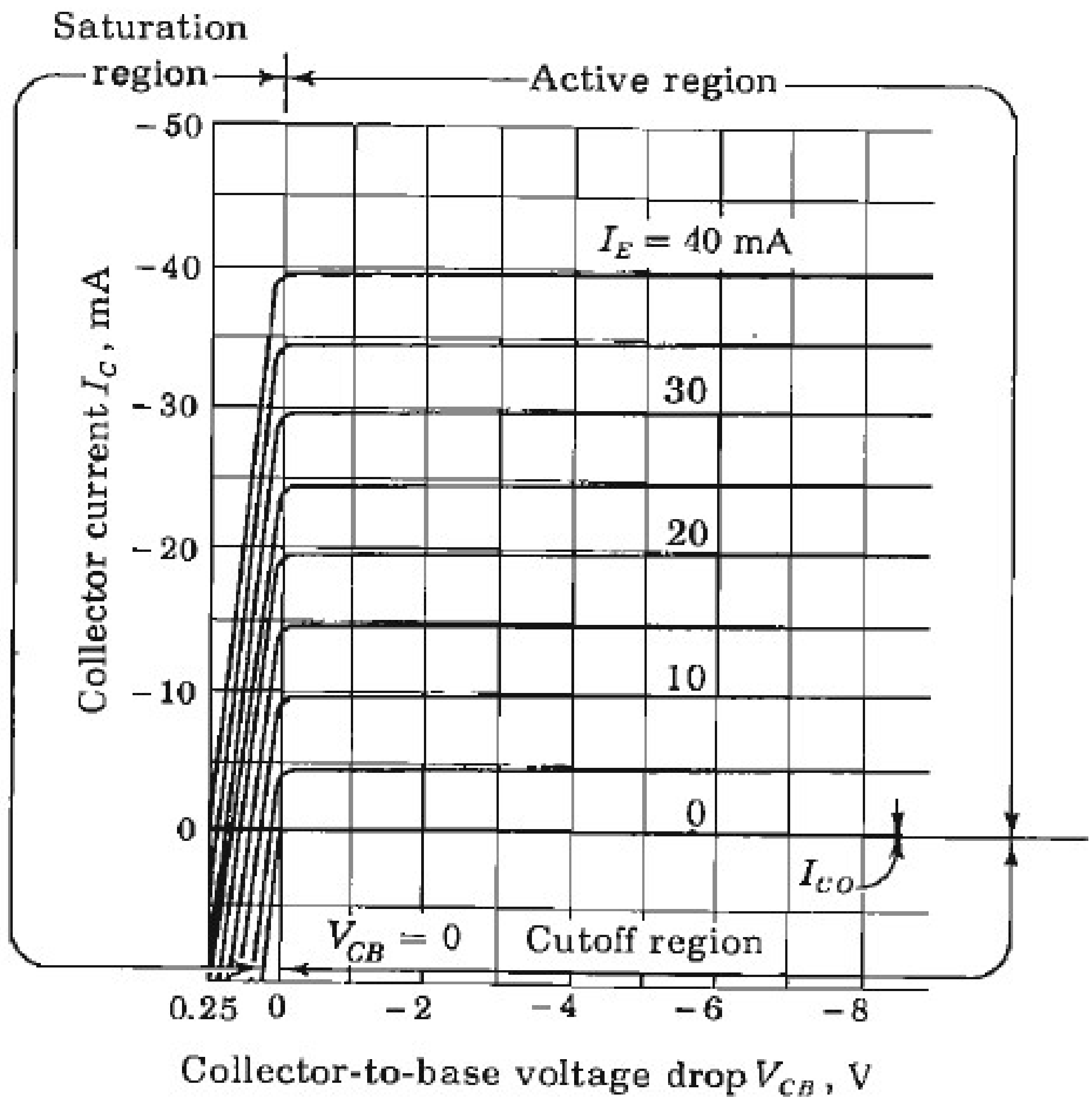
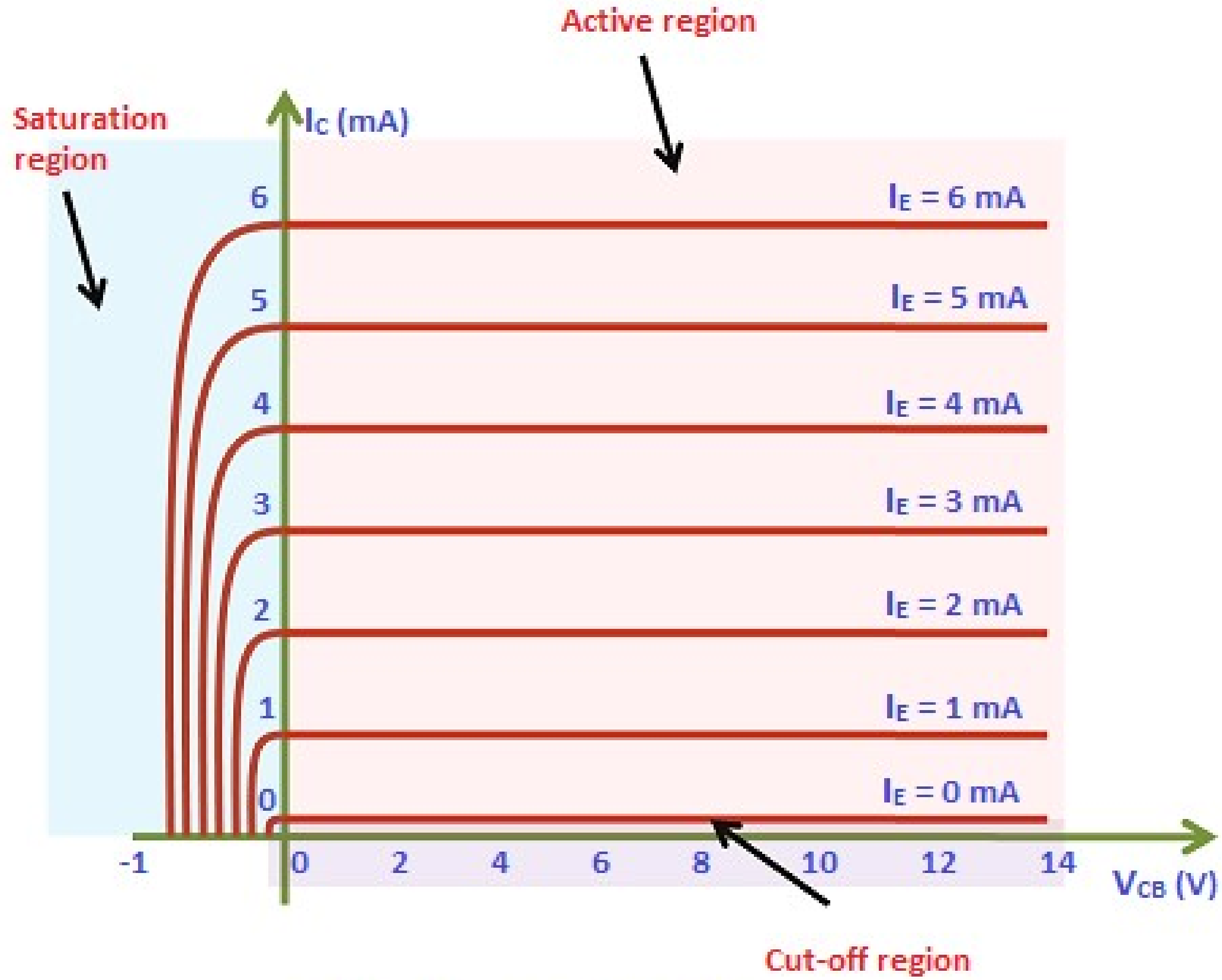
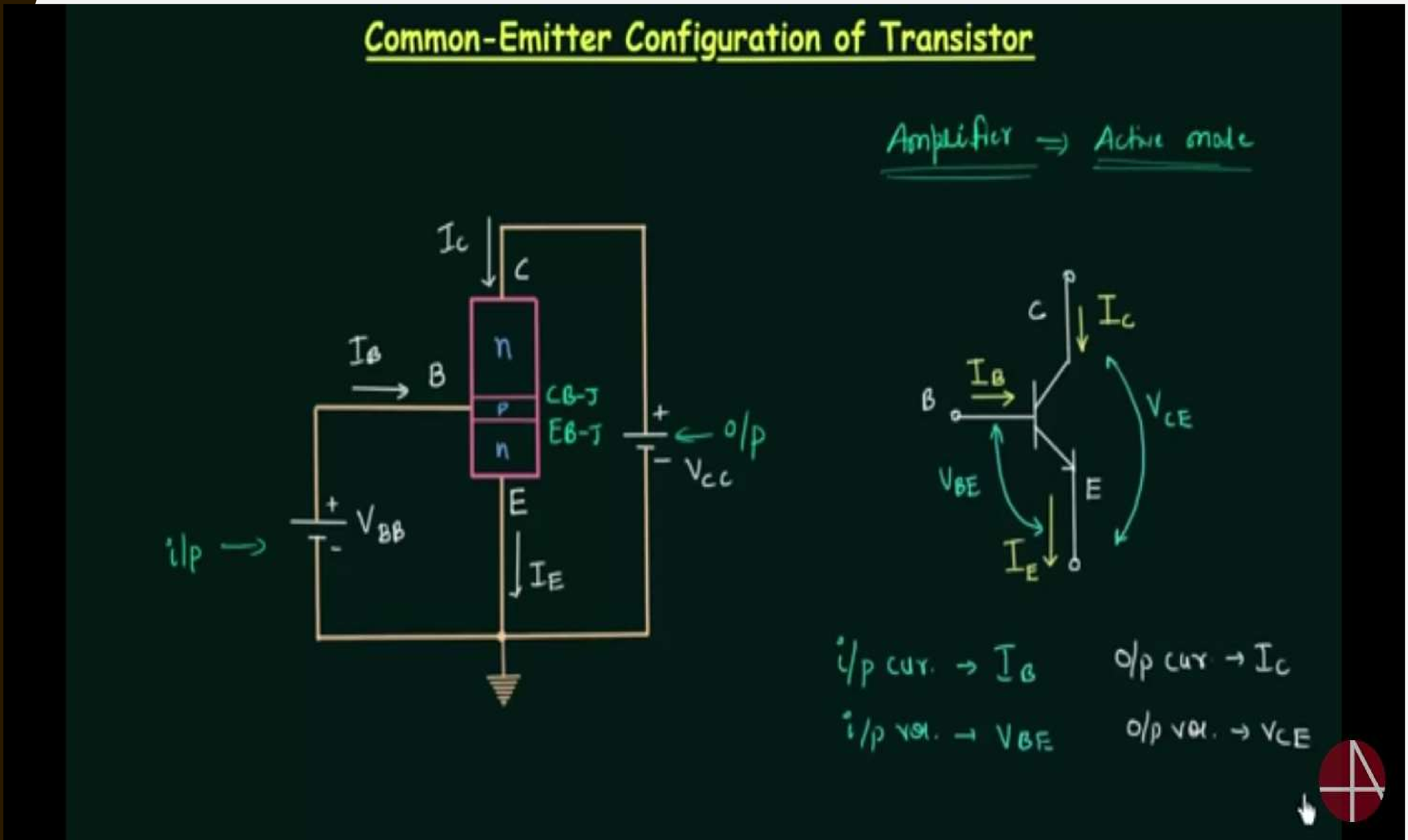


Fig. 5-6 Typical common-base output characteristics of a *p-n-p* transistor. The cutoff, active, and saturation regions are indicated. Note the expanded voltage scale in the saturation region.





O/P characteristics CB configuration



Common-Emitter Configuration of Transistor
Amplifier ⇒ Active mode
I_C
C
I_B
B
n
p
n
CB-J
EB-J
+
−
o/p
V_{CC}
E
+
V_{BB}
i/p
I_E
C
I_C
I_B
B
V_{CE}
V_{BE}
E
I_E
i/p cur. → I_B
o/p cur → I_C
i/p vol. → V_{BE}
o/p vol. → V_{CE}

- Input current in CB configuration?
- A IB
- B Ic
- C IE
- D None of the above

- Input current in CE configuration?

A IB

B Ic

C IE

D None of the above

i/p cur. → I_B o/p cur → I_C

i/p vol. → V_{BE} o/p vol. → V_{CE}

$$I_E = I_C + I_B \quad \text{——— (i)}$$

$$I_C = \alpha I_E + I_{CBO} \quad \text{——— (ii)}$$

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

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

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

$$I_C = \alpha \underline{\underline{I_E}} + I_{CBO} \quad \text{——— (ii)}$$

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

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

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

$$I_C = \underbrace{\frac{\alpha}{1-\alpha}}_{\beta} I_B + \underbrace{\frac{1}{1-\alpha}}_{\beta+1} I_{CBO} \Rightarrow I_C = \beta I_B + (\beta+1) I_{CBO}$$

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

$\rightarrow \alpha < 1$

$\rightarrow \underline{50} \le \beta \le \underline{400}$

Case-I

$$\underline{\alpha} = \underline{0.98}$$

$$\beta = \frac{0.98}{1-0.98} = \underline{49}$$

Case-II

$$\alpha = \underline{0.95}$$

$$\beta = \frac{0.95}{1-0.95} = \underline{19}$$

$1-0.95$

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

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

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

$$\Rightarrow I_C = \beta I_B + \underbrace{(\beta+1) I_{CBO}}_{I_{CEO}}$$

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

$$I_{CEO} << \beta I_B$$

$$I_C = \beta I_B$$

$$\boxed{\beta = \frac{I_C}{I_B}}$$ Current Amp fact

CE conf → C.A.

$$I_B = 1\,mA$$

$$\beta = 100$$

$$I_C = \beta I_B$$

$$I_C = 100\,mA$$

CE Conf → C.A.

$I_B = \underline{1\,mA}$

$\beta = 100$

$I_C = \beta I_B$

$I_C = \underline{100\,mA}$

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

$I_{CEO} << \beta I_B$

$I_C = \beta I_B$

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

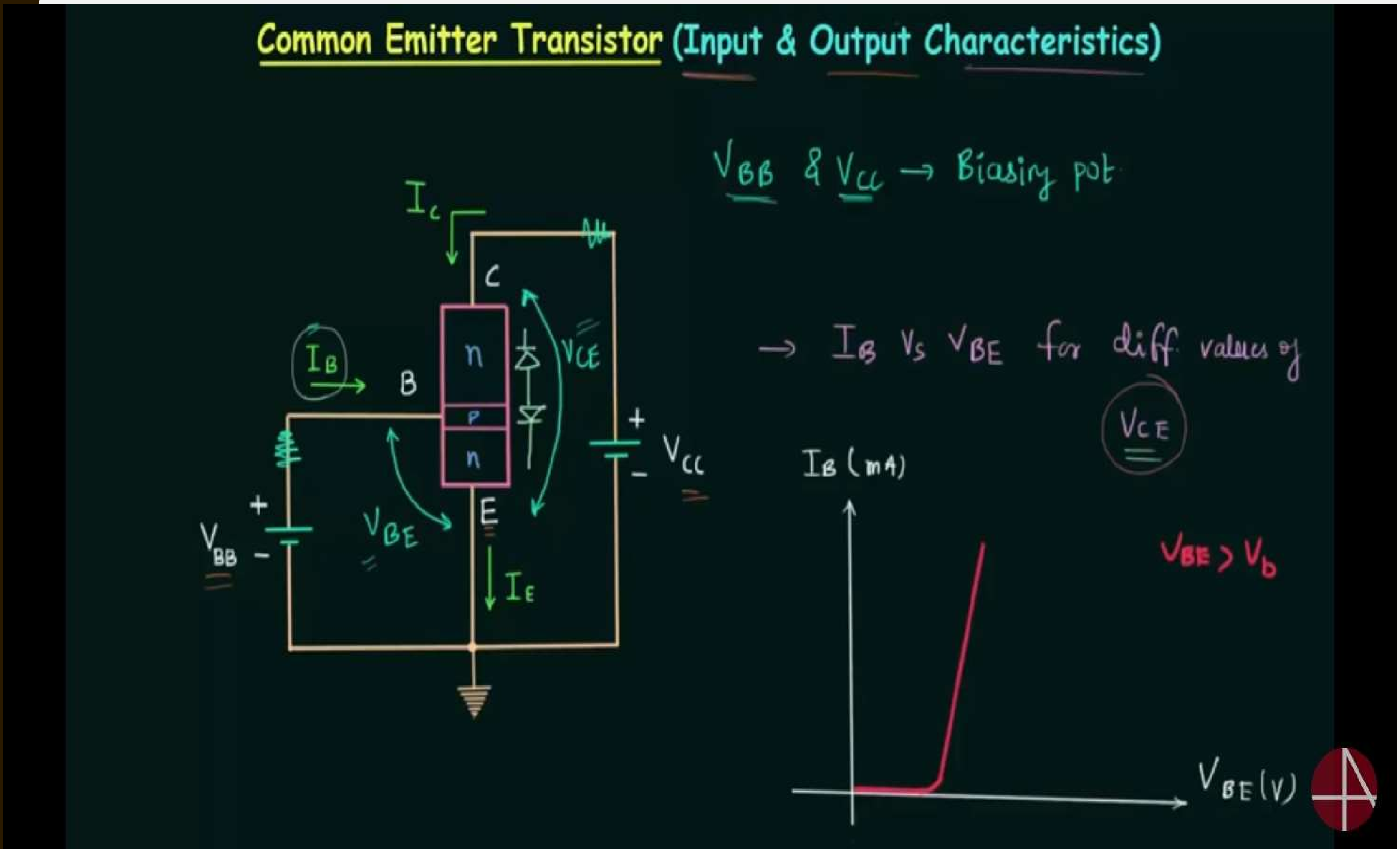
Current Amp fact

CB

NOTE :- $\underbrace{I_C} = \alpha I_E + \underbrace{I_{CBO}}$

CE

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



$$V_{BE} = f_1(V_{CE}, I_B)$$

$$I_C = f_2(V_{CE}, I_B)$$

3. A transistor has a β_{DC} of 250 and a base current, I_B, of 20 μ A. The collector current, I_C, equals:

A. 500 μ A

B. 5 mA

C. 50 mA

D. 5 A

1. Which of the following condition is true for cut-off mode?
a) The collector current Is zero
b) The collector current is proportional to the base current
c) The base current is non zero
d) All of the mentioned

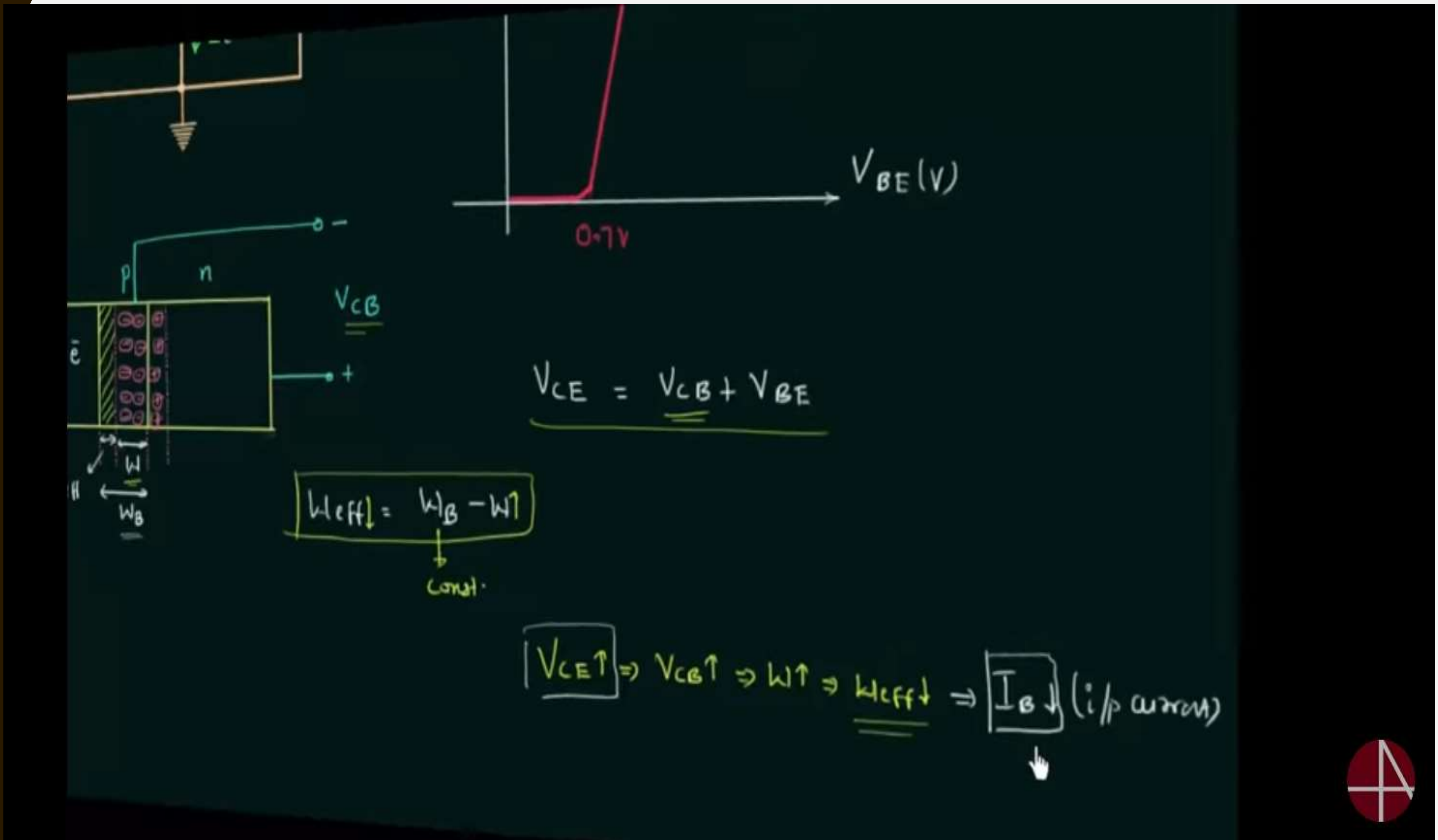
Which of the following is true for a pnp transistor in saturation region?

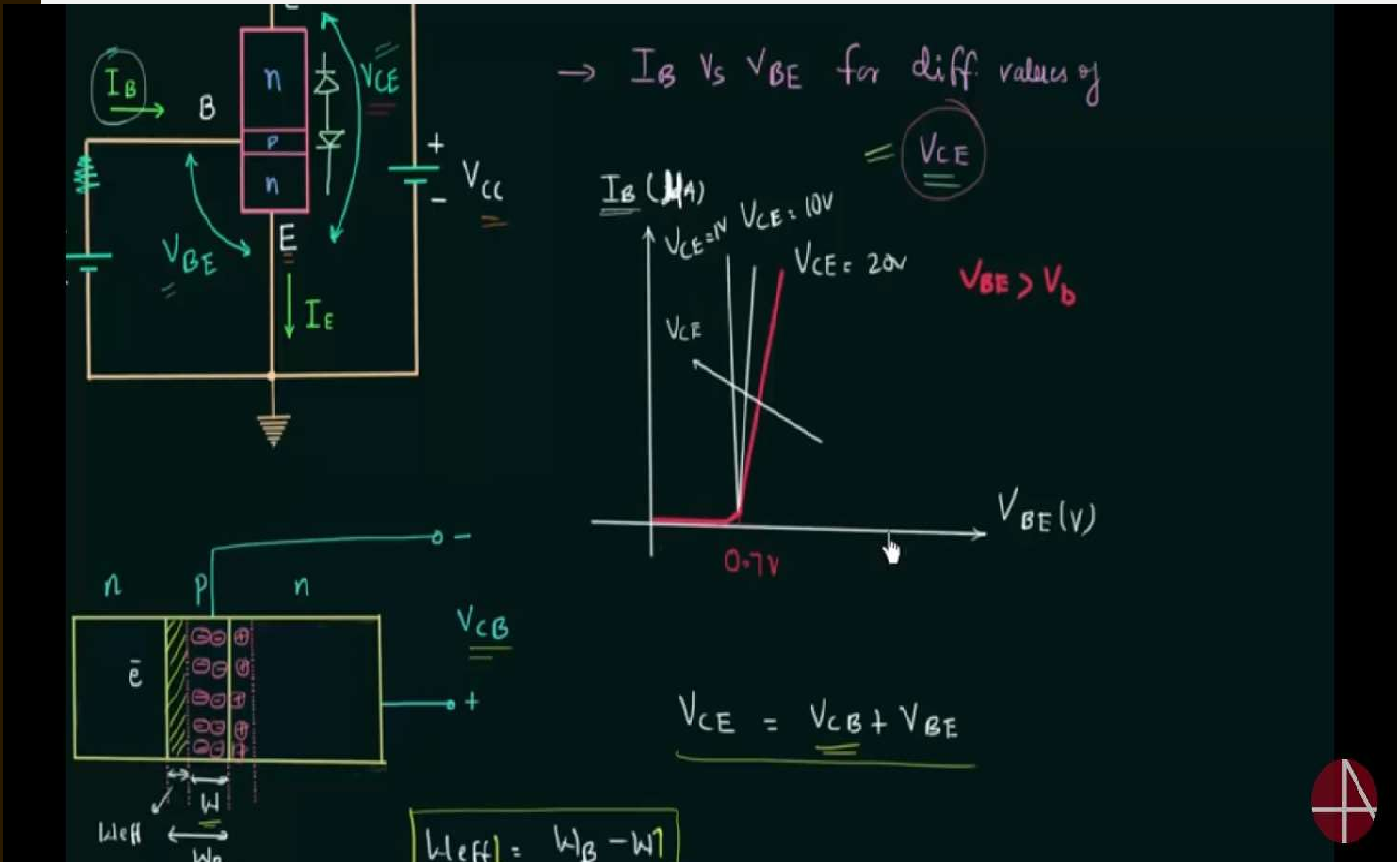
a) CB junction is reversed bias and the EB junction is forward bias

b) CB junction is forward bias and the EB junction is forward bias

c) CB junction is forward bias and the EB junction is reverse bias

d) CB junction is reversed bias and the EB junction is reverse bias


V_BE (V)
0.7V
p
n
V_CB
ē
W
W_B
V_CE = V_CB + V_BE
W_eff↓ = W_B − W↑
const.
V_CE↑ ⇒ V_CB↑ ⇒ W↑ ⇒ W_eff↓ ⇒ I_B↓ (i/p current)



I_B
B
n
p
n
E
V_{CE}
V_{BE}
I_E
+
V_{cc}
−
→ I_B Vs V_{BE} for diff. values of
= V_{CE}
I_B (μA)
V_{CE}=1V
V_{CE} = 10V
V_{CE} = 20V
$V_{BE} > V_b$
V_{CE}
V_{BE}(V)
0.7V
n
p
n
ē
−
+
V_{CB}
W
Weff
W_B
$V_{CE} = V_{CB} + V_{BE}$
$W_{eff}\downarrow = W_B - W\uparrow$

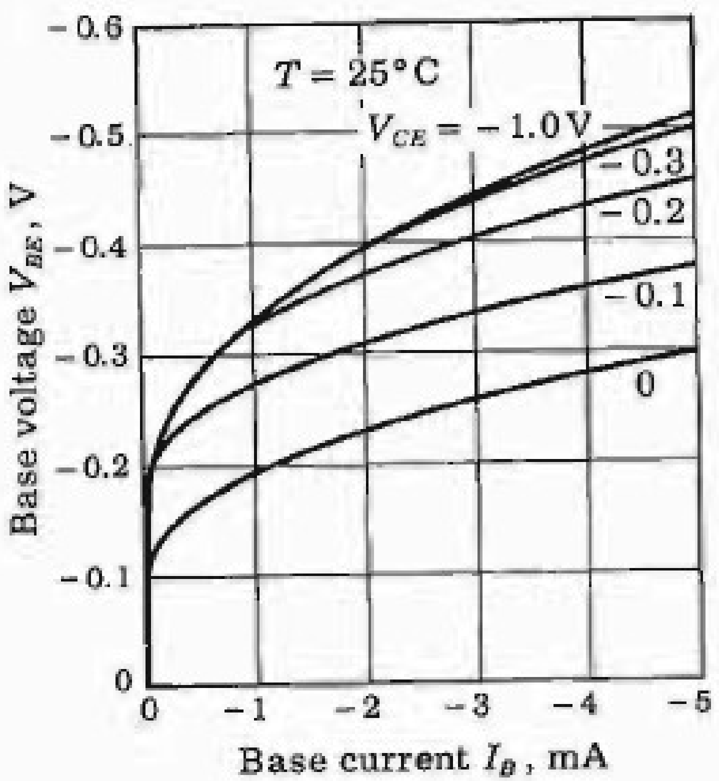


Fig. 5-11 Typical common-emitter input characteristics of the *p-n-p* germanium junction transistor of Fig. 5-10.

I_C vs V_{CE} for diff levels of I_B

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

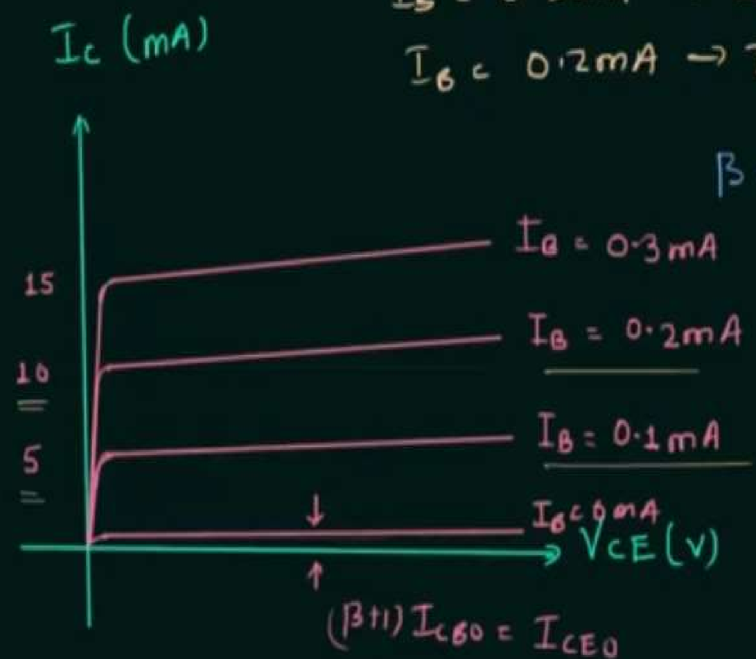
$I_B = 0$

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

$I_B = 0.1\,mA \rightarrow I_C = 5\,mA$

$I_B = 0.2\,mA \rightarrow I_C = 10\,mA$

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



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

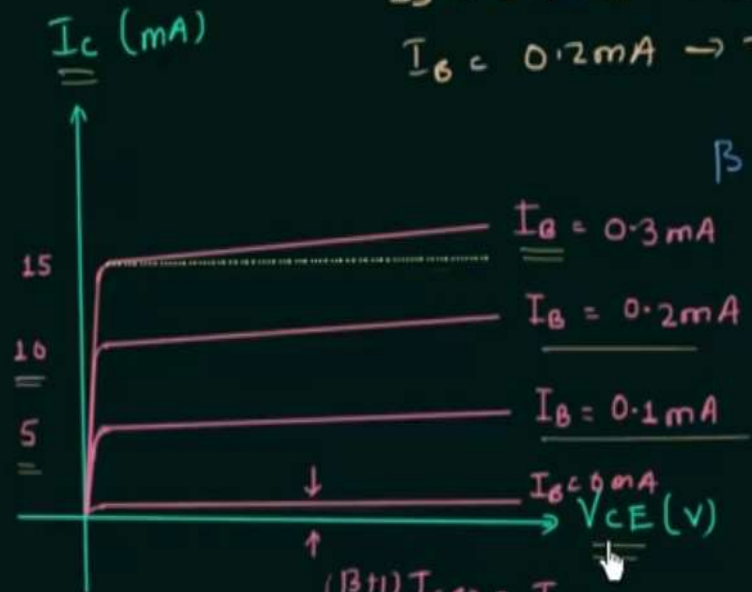
$(\beta+1) I_{CBO}$

$I_B = 0.1\,mA \rightarrow I_C = 5\,mA$

$I_B = 0.2\,mA \rightarrow I_C = 10\,mA$

$\beta = \frac{\Delta I_C}{\Delta I_B} = \frac{10-5}{0.2-0.1}$

$\boxed{\beta = 50}$

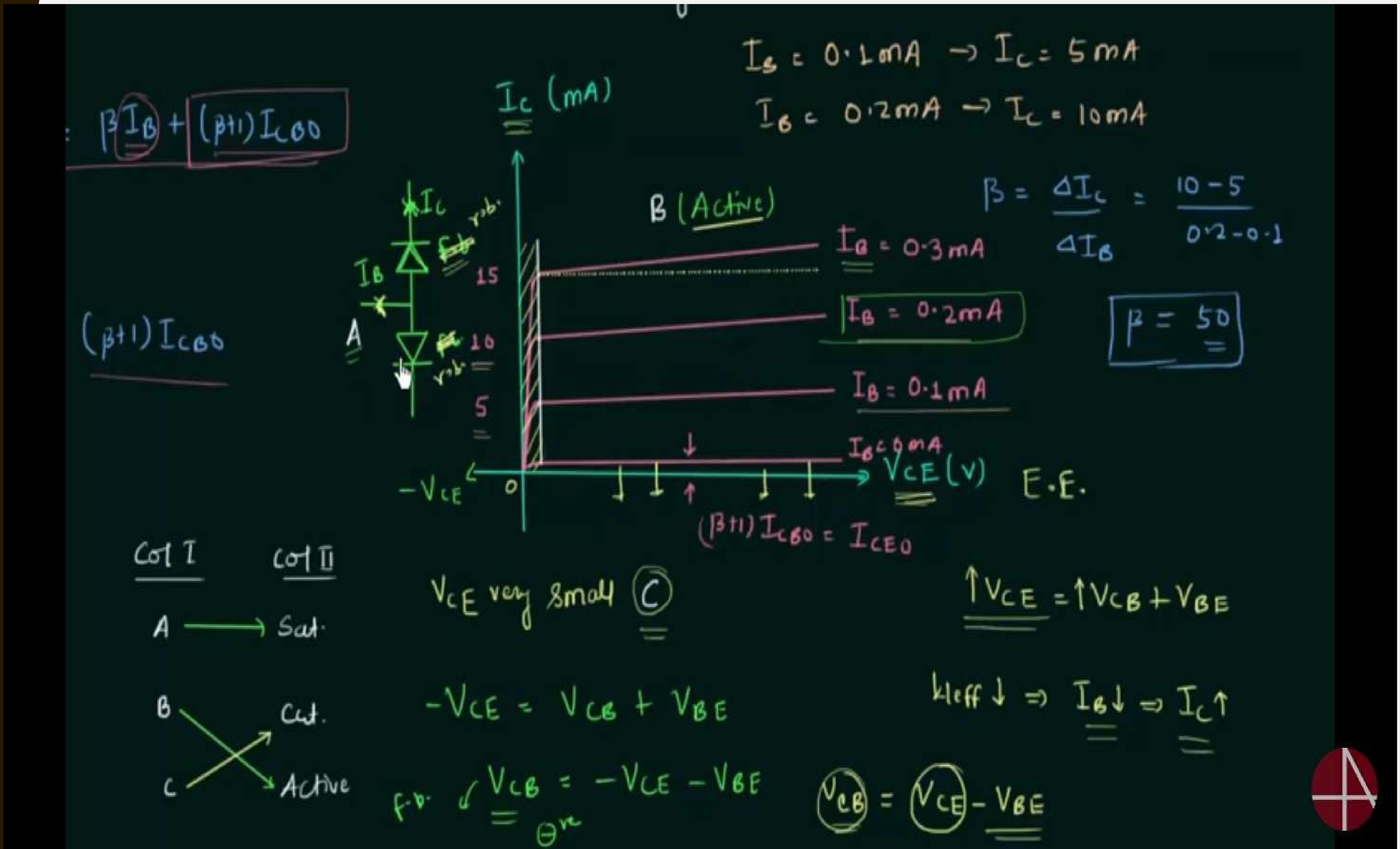


$(\beta+1) I_{CBO} = I_{CEO}$

E.E.

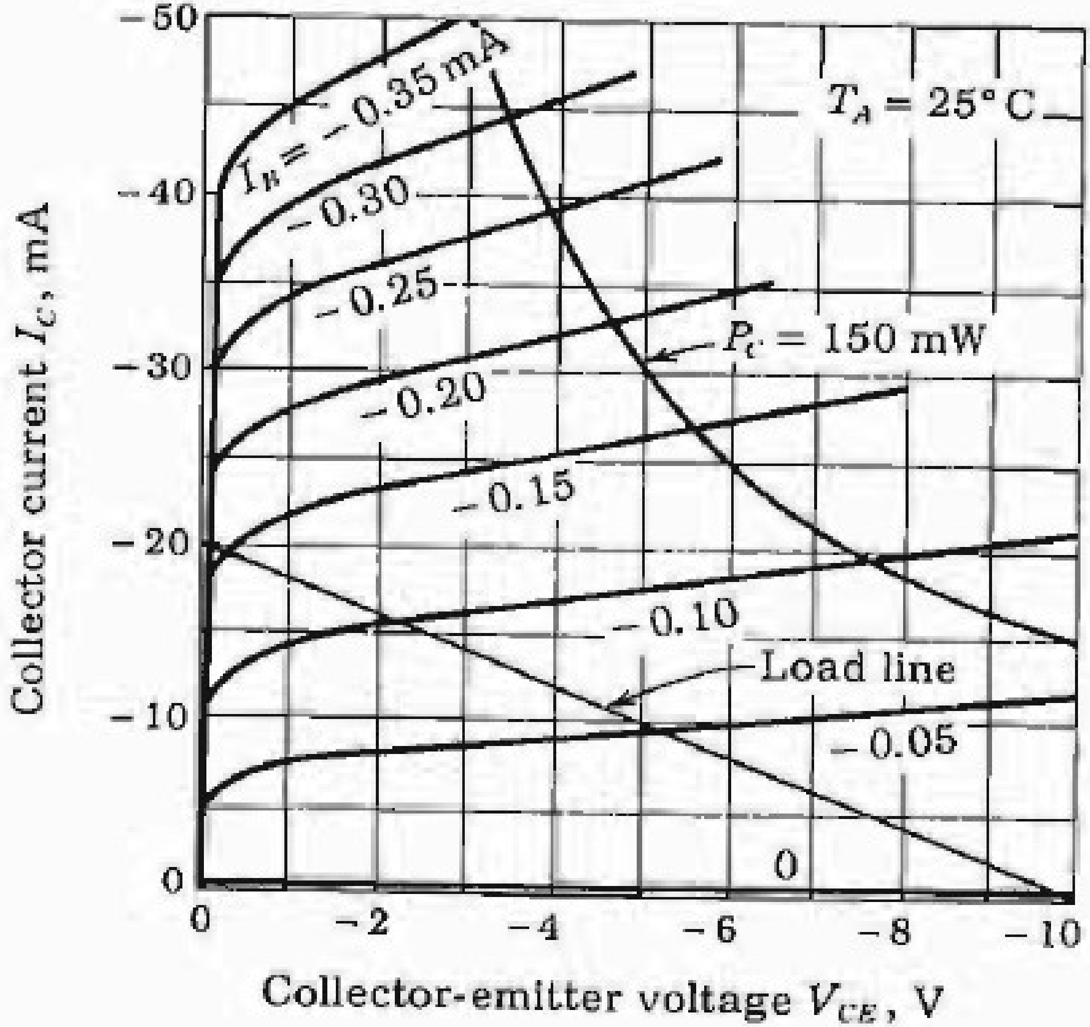
$\uparrow V_{CE} = \uparrow V_{CB} + V_{BE}$

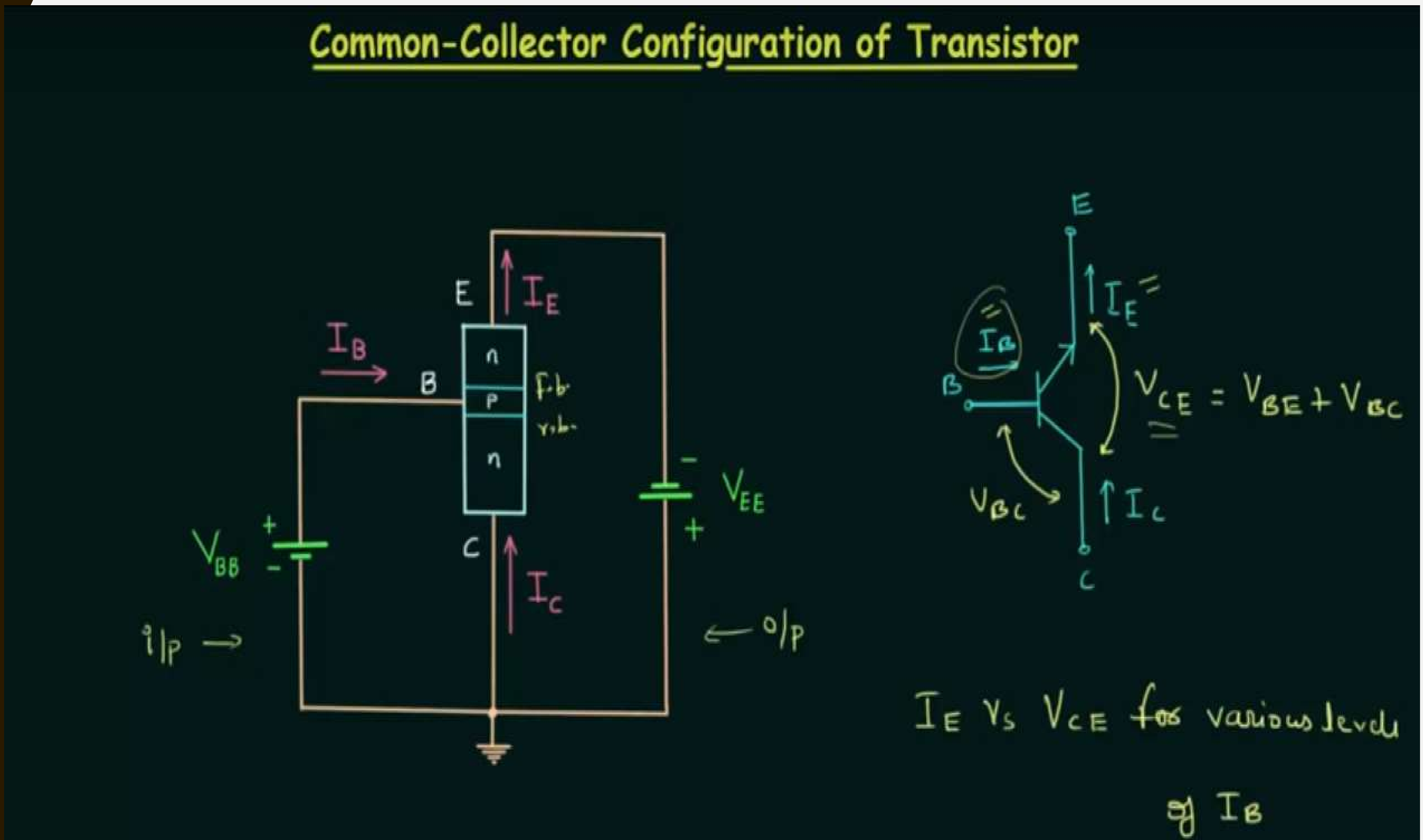
$W_{eff} \downarrow \Rightarrow I_B \downarrow \Rightarrow I_C \uparrow$



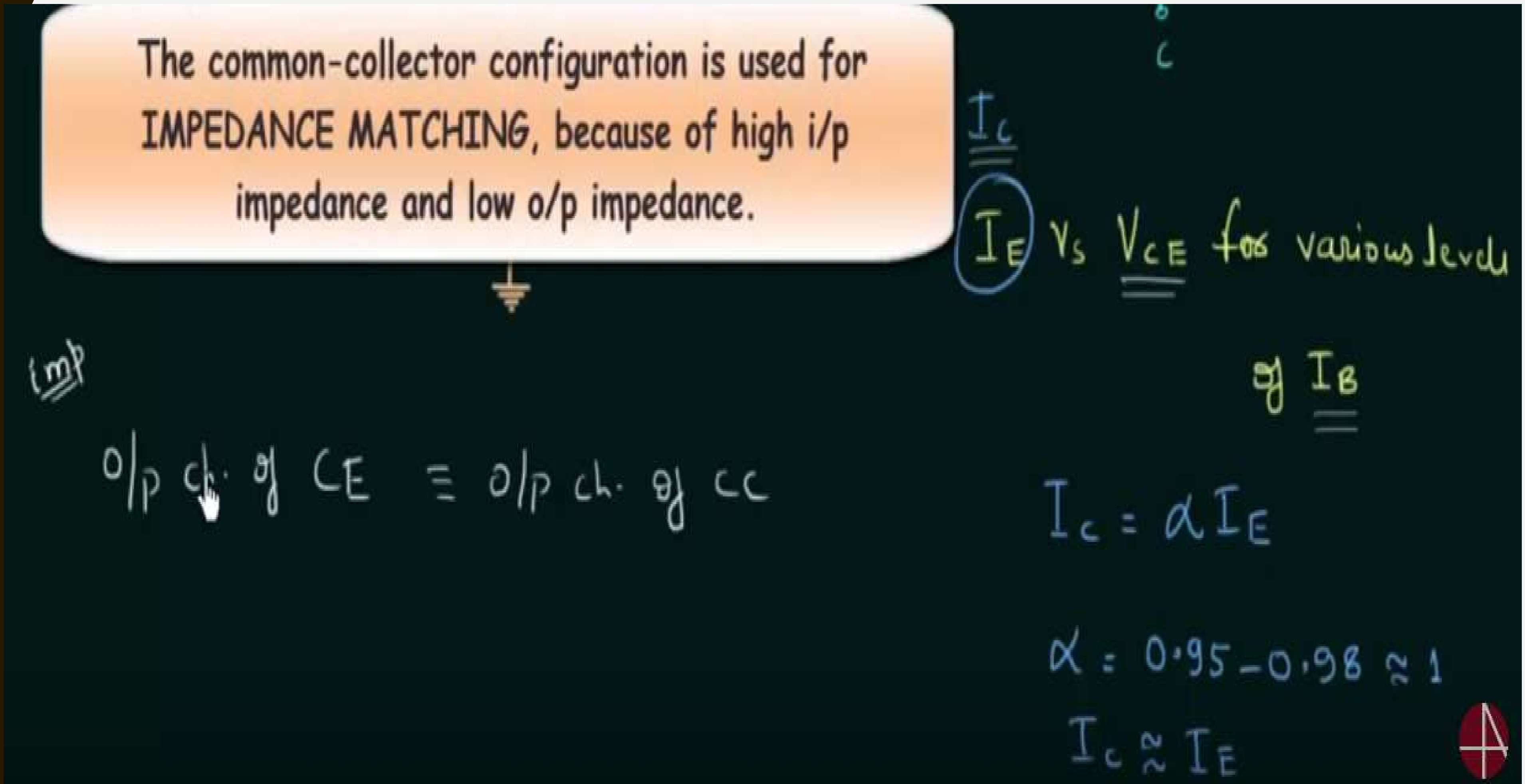
$I_B = 0.1\,mA \rightarrow I_C = 5\,mA$
$I_B = 0.2\,mA \rightarrow I_C = 10\,mA$
$\beta I_B + \boxed{(\beta+1) I_{CBO}}$
I_C (mA)
B (Active)
$\beta = \frac{\Delta I_C}{\Delta I_B} = \frac{10-5}{0.2-0.1}$
$\boxed{\beta = 50}$
$I_B = 0.3\,mA$
$I_B = 0.2\,mA$
$I_B = 0.1\,mA$
$I_B = 0\,mA$
15
10
5
0
$(\beta+1) I_{CBO}$
A
$-V_{CE}$
V_{CE} (V)
E.E.
$(\beta+1) I_{CBO} = I_{CEO}$
Col I
Col II
A → Sat.
B → Cut.
C → Active
V_{CE} very small (C)
$\uparrow V_{CE} = \uparrow V_{CB} + V_{BE}$
$-V_{CE} = V_{CB} + V_{BE}$
$W_{eff} \downarrow \Rightarrow I_B \downarrow \Rightarrow I_C \uparrow$
f.b. $V_{CB} = -V_{CE} - V_{BE}$
$V_{CB} = V_{CE} - V_{BE}$

Fig. 5-10 Typical common-emitter output characteristics of a *p-n-p* germanium junction transistor. A load line corresponding to V_{CC} = 10 V and R_L = 500 Ω is superimposed. (Courtesy of Texas Instruments, Inc.)





Common-Collector Configuration of Transistor
E
I_E
I_B
B
n
p
n
f.b.
r.b.
C
I_C
V_{BB}
V_{EE}
i/p
o/p
E
I_E
I_B
B
$V_{CE} = V_{BE} + V_{BC}$
V_{BC}
I_C
C
I_E Vs V_{CE} for various levels of I_B


The common-collector configuration is used for IMPEDANCE MATCHING, because of high i/p impedance and low o/p impedance.
imp
o/p ch. of CE ≡ o/p ch. of CC
C
I_C
I_E vs V_{CE} for various levels of I_B
$I_C = \alpha I_E$
$\alpha = 0.95 - 0.98 \approx 1$
$I_C \approx I_E$

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

$$I_E = I_C + I_B \quad \text{—— (i)}$$

$$I_C = \alpha I_E + I_{CBO} \quad \text{—— (ii)}$$

I_E

I_B

$$I_E = \alpha I_E + I_{CBO} + I_B$$

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

α, β & γ

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

$$\boxed{I_E = \gamma I_B + \gamma I_{CBO}}$$