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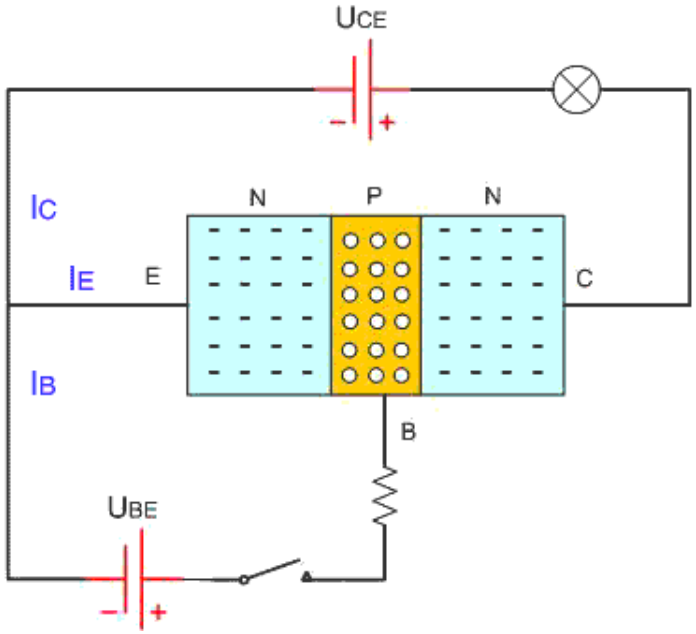
Semiconductors

Lecture - 3

Transistor



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Jayant Nagda

Physics Educator

unacademy.com/@JayantNagda

B.Tech, **IIT Bombay**

IIT-JEE **AIR - 161**

9+ Years of Teaching Experience at

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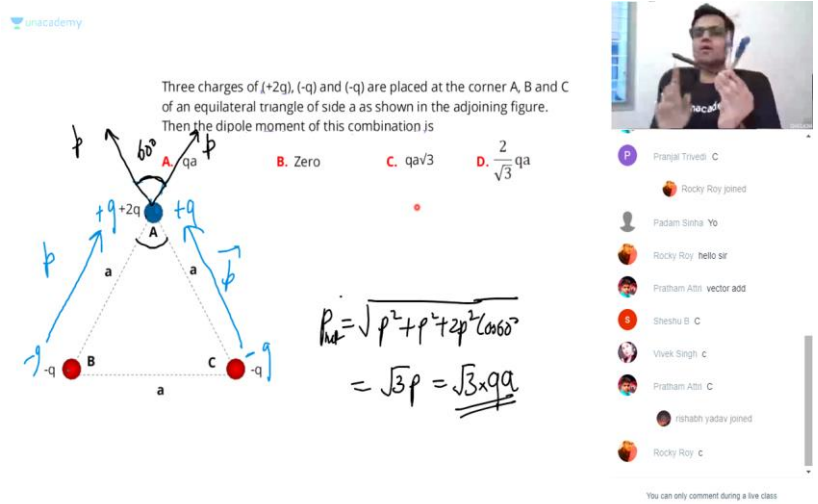

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Lesson 8 • Today, 8:30 PM

Namo Kaul

HINDI BATCHES AND YEAR LONG CO...

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Lesson 32 • Oct 20, 9:00 AM

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EVOLVE for Class 12 (JEE Main/Advanced 2020) October '19

Lesson 31 • Oct 20, 11:00 AM

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EMERGE for Class 11 (JEE Main/Advanced 2021) - October '19

Lesson 36 • Today, 3:15 PM

Megha Khandelwal

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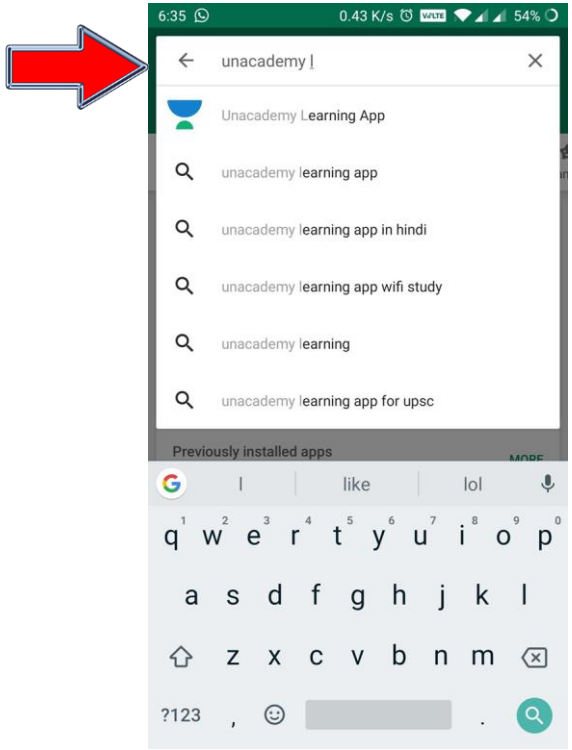
Kailash Sharma

Step 1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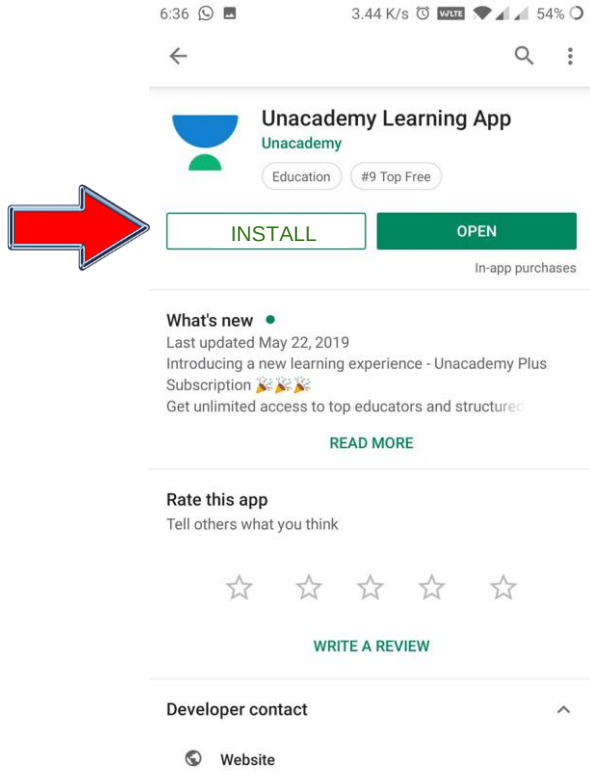
Step 2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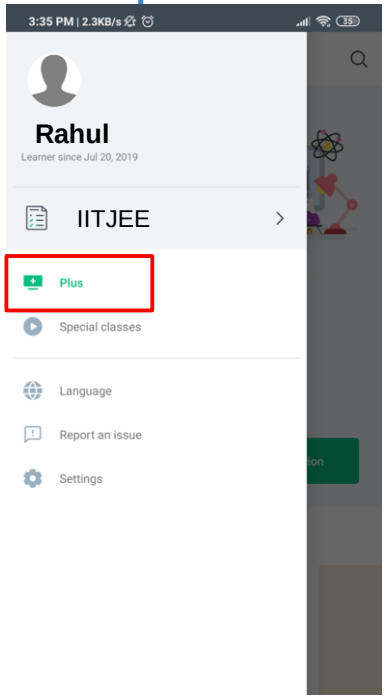
Step **3**



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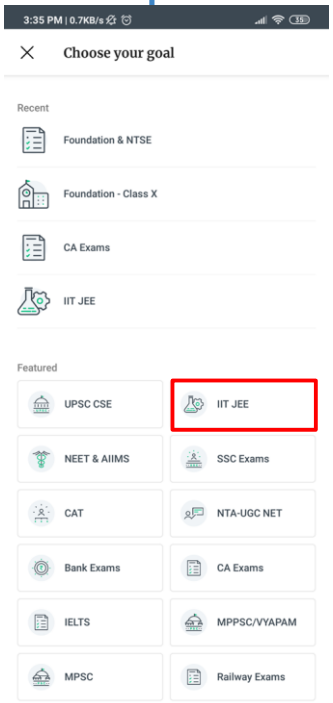

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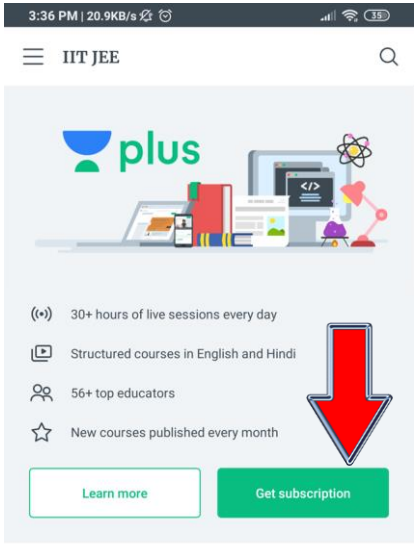
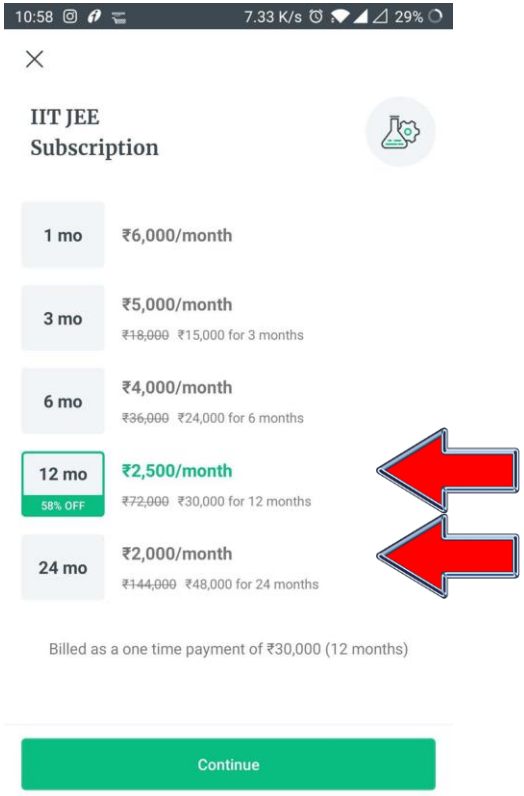


Step 6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Transistor

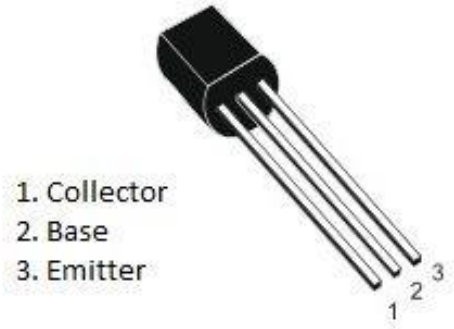
It is a three terminal Semiconductor Device

Transistor: Transfer + Resistor

Current is transferred from Low Resistance to High Resistance circuit

Transistor is used for rectification, amplification, oscillation etc.

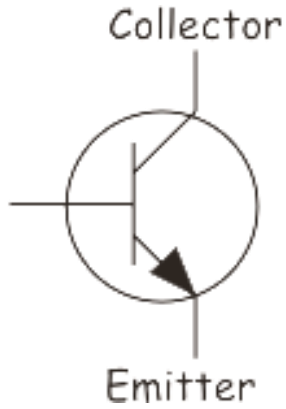
Transistor



1. **Emitter :** Heavily Doped crystal supplies/emits majority charge carriers.
Moderate Size: thinner than collector and thicker than base

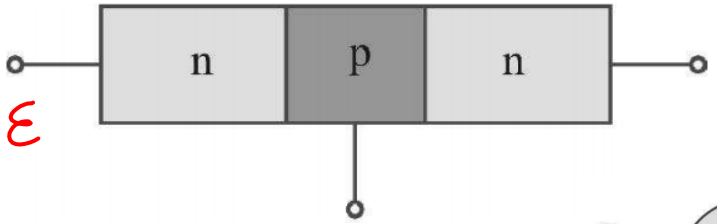
2. **Base :** Lightly Doped crystal and made very thin.
It passes most of the emitter injected charge carriers to the collector.

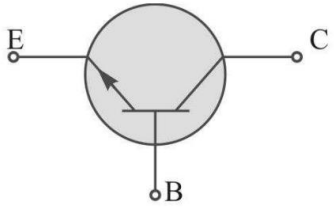
3. **Collector :** Moderately Doped crystal thickest in size.
Collects/removes majority charge carriers coming from emitter.



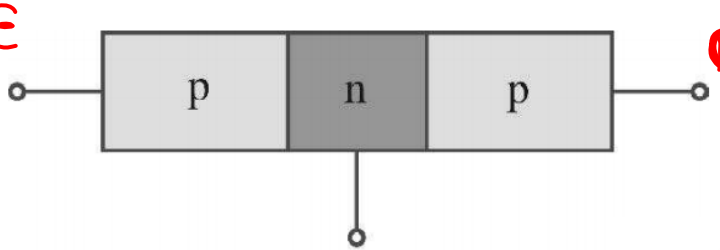
Transistor

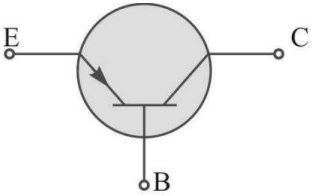
A p-type crystal sandwiching between two n-type crystals





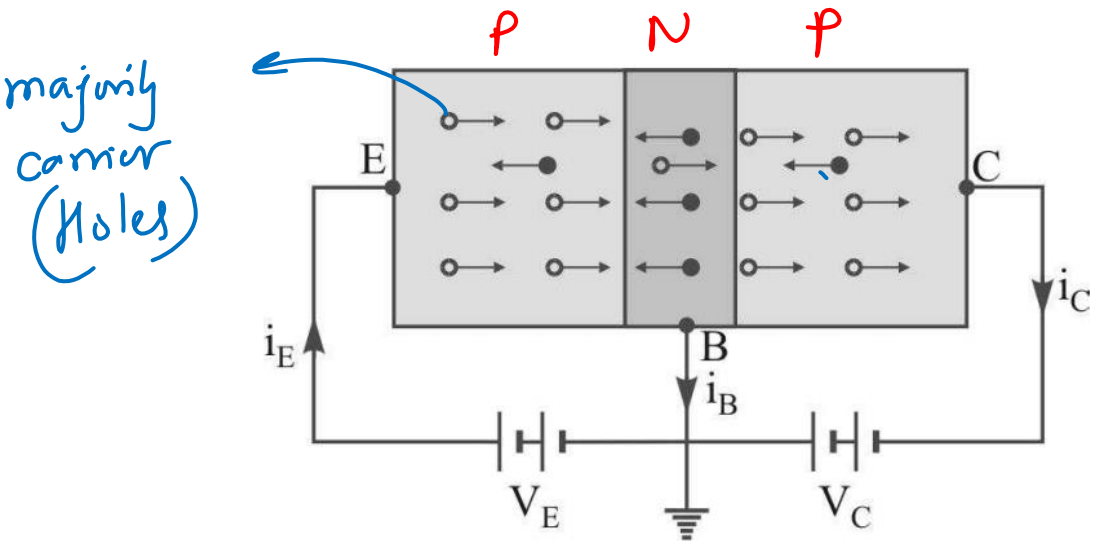
A n-type crystal sandwiching between two p-type crystals





Working of a p-n-p Transistor

Base is common with Emitter and Collector



Emitter-Base junction is given small forward bias

Collector-Base junction is given large reverse bias

Working of a p-n-p Transistor

holes move from emitter towards base

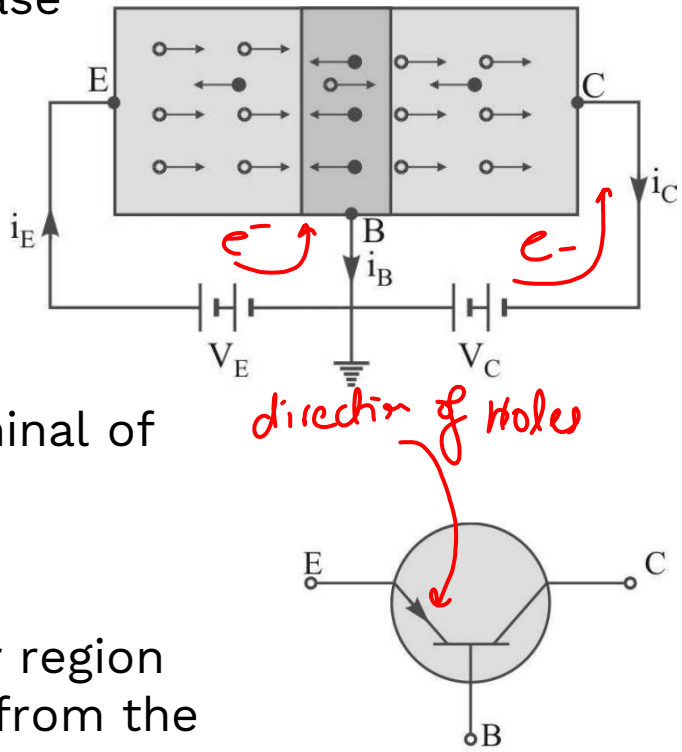
Most of them (nearly 98%) cross base and enter into collector region

while very few (nearly 2%) combine with the electrons in base

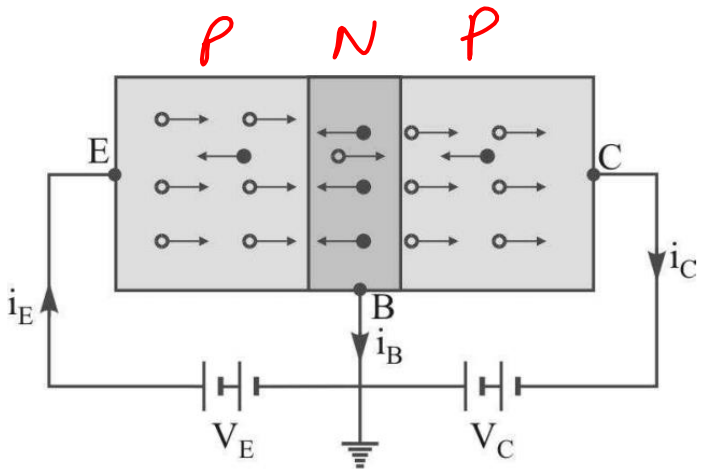
an electron leaves the negative terminal of battery V_E and enters into base.

This causes a small base current I_B

The holes entering into the collector region combine with the electrons coming from the negative terminal of V_C. This causes collector current I_C



Working of a p-n-p Transistor



$$i_E = i_B + i_C$$

(2-10%) of i_E (90-98%) of i_E

1. The base current may be nearly 2 to 10% of the emitter current depending on the doping level. Similarly collector current may be nearly 90 to 98% of the emitter current.
2. The holes are the charge carriers within the transistor while electrons are charge carriers in external circuit.

Example

MCQ type Question [+4 , -1]

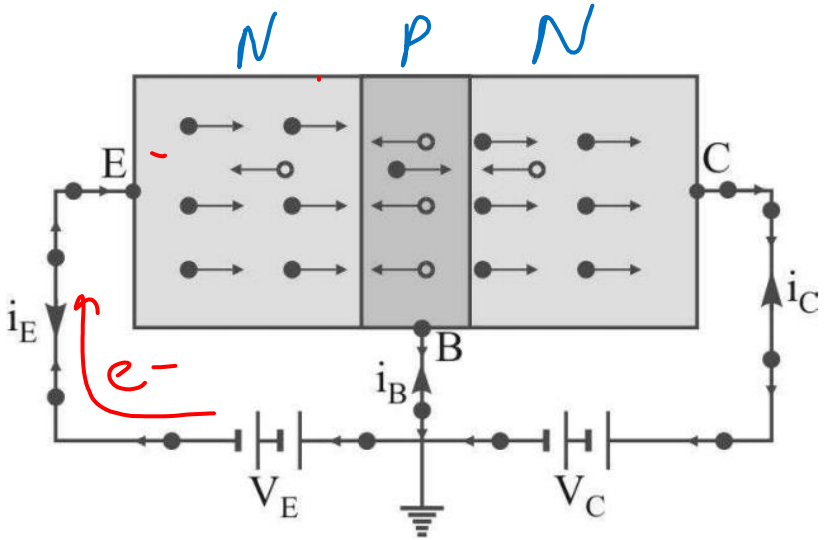
The emitter-base junction of a transistor is .....biased while the collector base junction is .....biased.

A. forward, forward **B.** forward, reverse

C. reverse, forward **D.** reverse, reverse

Working of a n-p-n Transistor

Base is common with Emitter and Collector



Emitter-Base junction is given small forward bias

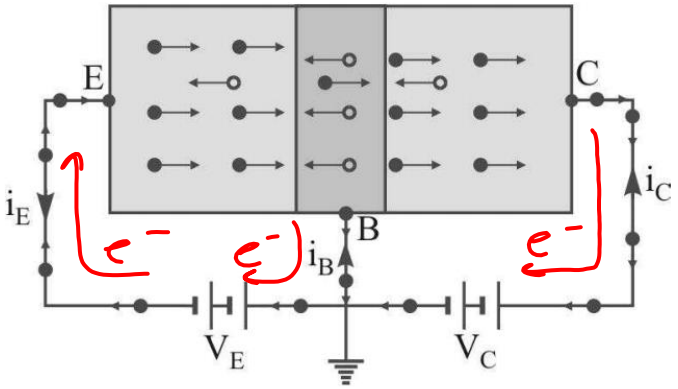
Collector-Base junction is given large reverse bias

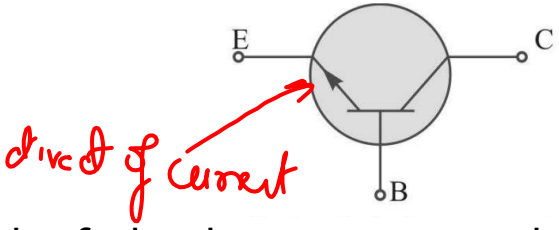
Working of a n-p-n Transistor

forward bias in emitter-base region, electrons from emitter region move towards base.

Most of them (nearly 98%) cross the base and enter into collector region

while very few (nearly 2%) combine with the holes in base

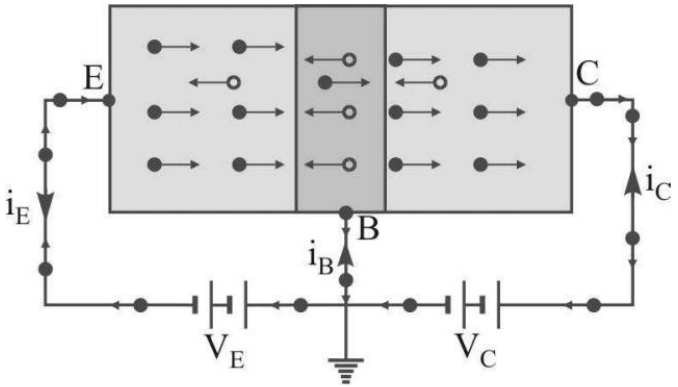




This electron is captured by positive terminal of the battery V_E and send it towards emitter region. This causes a small base current I_B. The electrons entering into collector region are attracted by the positive terminal of V_C. This causes collector current I_C.

Working of a n-p-n Transistor

These two currents combine together constitute emitter current i_E. Thus



$$i_E = i_B + i_C$$

(2-10)% of i_E (90-98)% of i_E

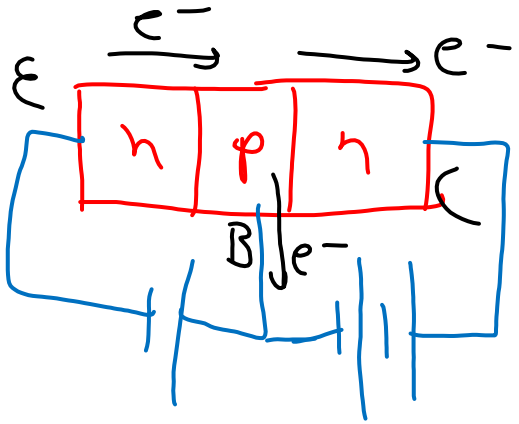
1. The base current may be 2 to 10% of the emitter current depending on the doping level. Similarly collector current may be 90 to 98% of the emitter current.
2. The electrons are the charge carriers within the transistor as well as in external circuit.

Example

MCQ type Question [+4 , -1]

In an n-p-n transistor -

A. holes move from emitter to base.
B. negative charge carrier move from emitter to base.
C. holes move from base to collector.
D. negative charge carrier move from collector to base



Transistor Configurations

A transistor can be connected in the circuit in the following three ways :

1. Common base (CB) connection.
2. Common emitter (CE) connection.
3. Common collector (CC) connection.

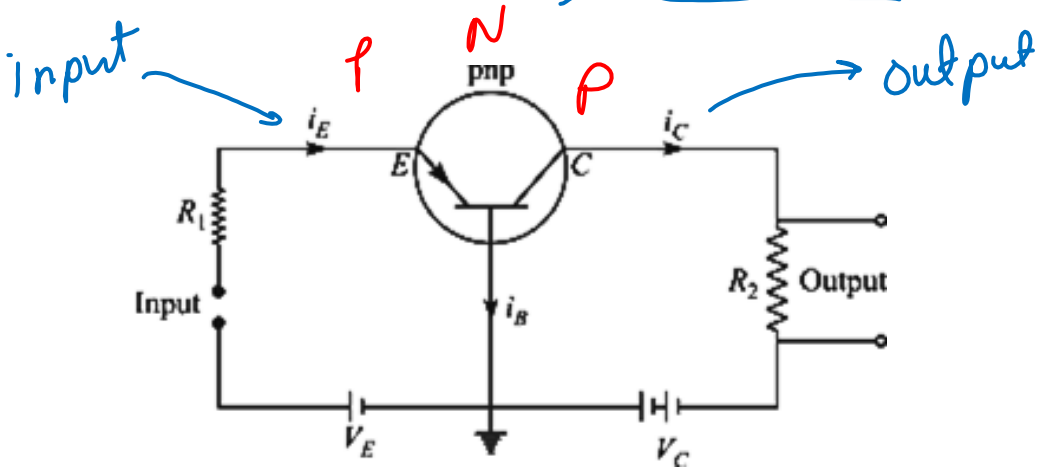
first two are commonly used in practice

Each circuit connection has specific advantage and disadvantage

In all configurations
the emitter is always connected with small forward bias, while the collector always has a large reverse bias

Common Base Connection

The input is applied between emitter and base and output is taken from collector base

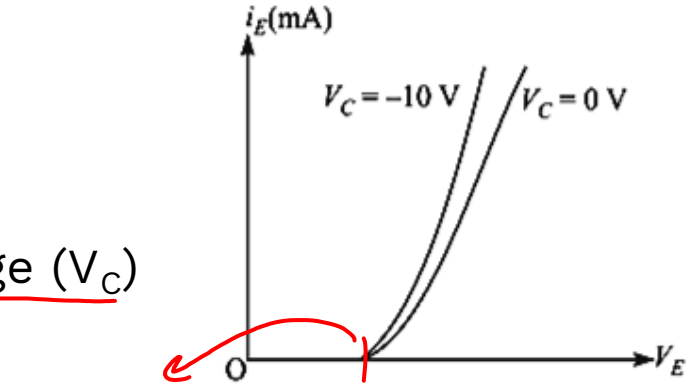


A p-n-p transistor in common base connection

Common Base Connection

Input characteristics

Shows variation of emitter current (i_E) with emitter voltage (V_E) at constant collector voltage (V_C)

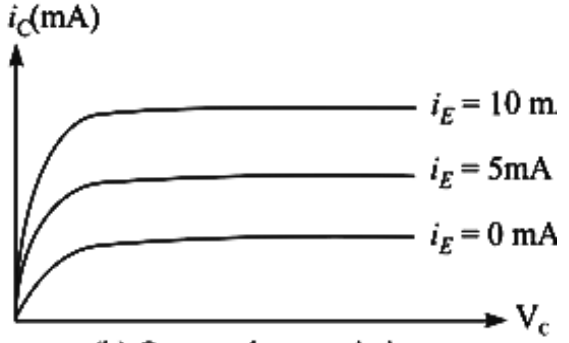


(a) Input characteristics.

cut-in volt

Output characteristics

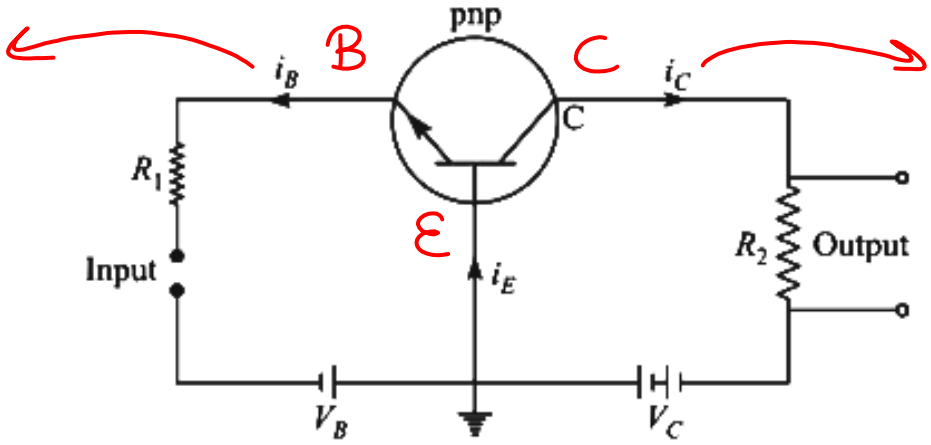
Shows the variation of collector current (i_C) with collector voltage (V_C) at constant emitter current (i_E)



(b) Output characteristics

Common Emitter Connection

The input is applied between base and emitter and output is taken from collector and emitter

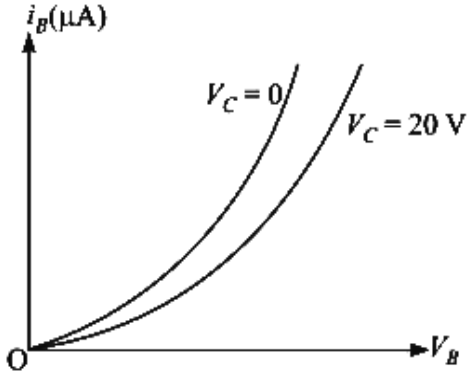


A p-n-p transistor in common emitter connection

Common Emitter Connection

Input characteristics

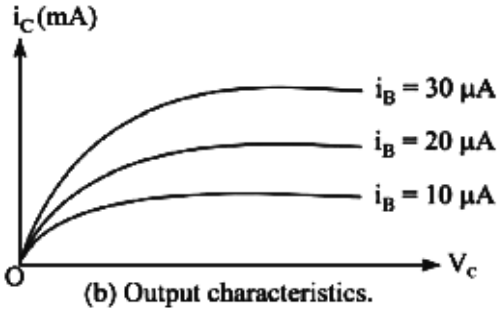
Variation of base current i_B with base voltage V_B at constant collector voltage V_C



(a) Input characteristics.

Output characteristics

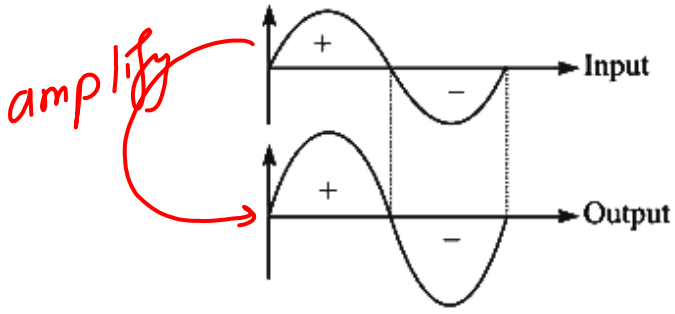
Variation of collector current i_C with collector voltage V_C at constant base current i_B



(b) Output characteristics.

Transistor as an Amplifier

A transistor can be used for amplification in which strength of output signal is more than input signal.

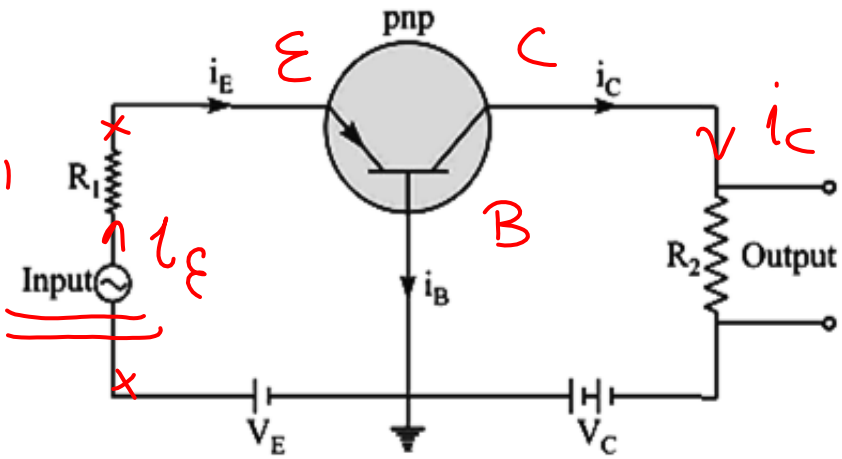


The transistor can be used as an amplifier in the following three configurations

1. CB amplifier
2. CE amplifier
3. CC amplifier

CB Transistor Amplifier

A pnp transistor in common-base-connection



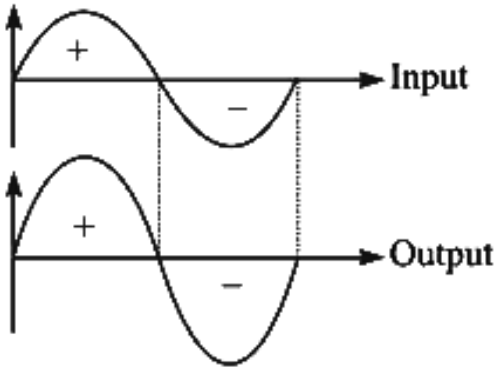
$V_{input} = i_E R_1$

$V_{output} = i_C R_2$

Voltage gain =

Input signal is fed between the emitter and base

CB Transistor Amplifier



(b) Input and output signals.

input voltage = $i_E R_1$

output voltage = $i_C R_2$

$$\text{Voltage gain} = \frac{\text{Output voltage}}{\text{Input voltage}} = \frac{i_C R_2}{i_E R_1}$$

The output signal is in phase with input signal.

CB Transistor Amplifier

The current gain α is defined as :

$$\alpha = \frac{[\text{Change in collector current}]}{[\text{Change in emitter current}]}, \; V_c \text{ Constant}$$

$$\alpha = \frac{\Delta i_C}{\Delta i_E}, \; V_c \text{ Constant}$$

$(i_E = i_C + i_b)$

$i_C < i_E$

The value of α ranges from 0.9 to 0.99.

For dc signal, $\alpha = \frac{i_C}{i_E}$

Example

MCQ type Question [+4 , -1]

In a common base transistor circuit, the current gain is 0.98. On changing emitter current by 5.00 mA, the change in collector current is -

A. 0.196 mA

B. 2.45 mA

C. 4.9 mA

D. 5.1 mA

$\alpha = 0.98$

$\Delta i_E = \Delta i_{input} = 5\ mA$

$\Delta i_C = \Delta i_{output} = ?$

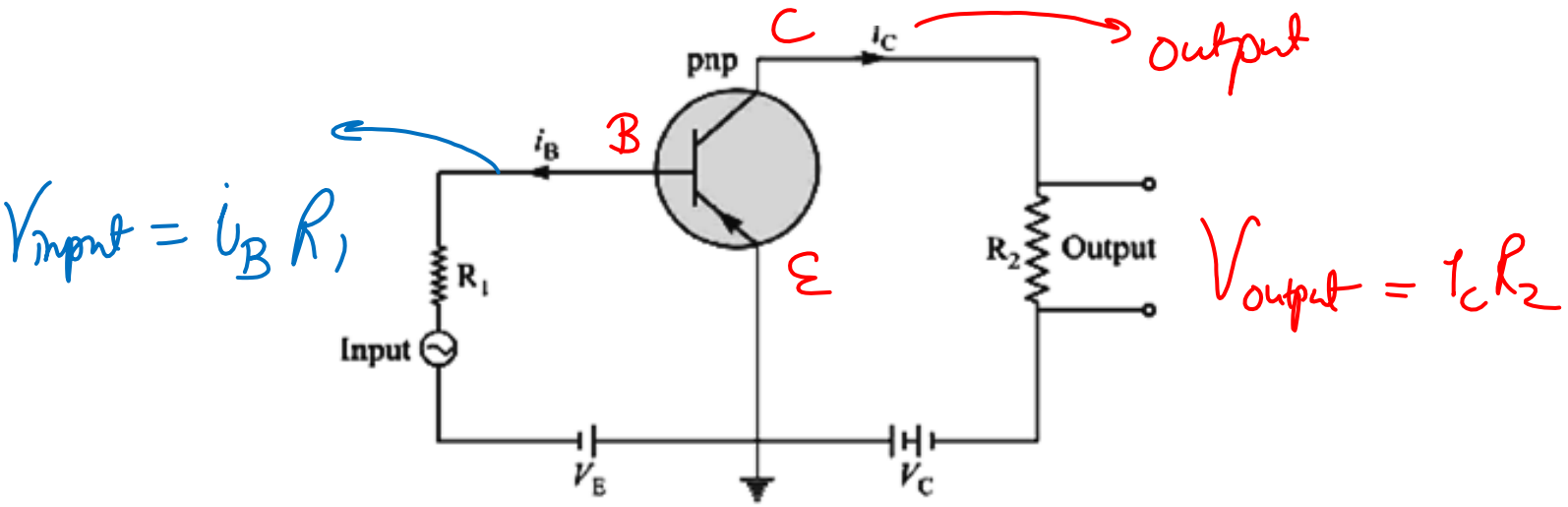
$\alpha = \frac{output}{input}$

$\Delta i_C = \alpha \Delta i_E$

$= 0.98 \times 5\ mA$

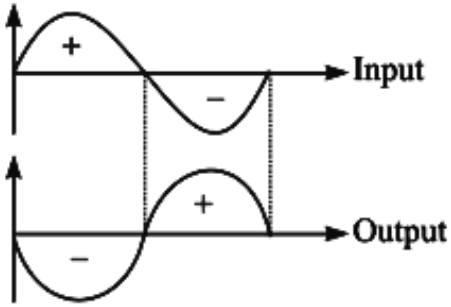
CE Transistor Amplifier

A pnp transistor in common emitter connection



Input signal is fed between the base and emitter

CE Transistor Amplifier



(b) Input and output signals.

Power gain

$= \frac{P_{output}}{P_{input}}$

$= \frac{I_{output} V_{output}}{I_{input} V_{input}}$

input voltage = $i_B R_1$ output voltage = $I_C R_2$

Voltage gain = $V_{output} / V_{input} = i_C R_2 / i_B R_1$

Power gain = Current gain × Voltage gain

The output signal is out of phase with the input signal.

CE Transistor Amplifier

The current gain β is defined as :

$$\beta = \frac{[\text{Change in collector current}]}{[\text{Change in base current}]}$$, V_c Constant

$$\beta = \frac{\Delta i_C}{\Delta i_B}$$ V_c Constant *

$i_E = i_B + i_C$

i_B → Small (2-10-1)

The value of β ranges from 20 to 200

For dc signal,

$$\beta = \frac{i_C}{i_B}$$

Example

MCQ type Question [+4 , -1]

A common emitter transistor amplifier has a current gain of 50. If the load resistance is 4kΩ and input resistance is 500Ω the voltage gain of the amplifier -

A. 160 **B.** 200

C. 400 **D.** None

$R_i = 500\Omega$

$R_{output} = 4000$

$$V_{gain} = \frac{V_o}{V_i} = \left(\frac{i_o}{i_i}\right) \times \frac{R_o}{R_i} = 50 \times \frac{4000}{500} = 400$$

50

Relationship between ∝ and β

$$I_E = I_B + I_C$$

$$\frac{I_E}{I_C} = \frac{I_B}{I_C} + 1$$

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

$$\Rightarrow \frac{1}{\alpha} - 1 = \frac{1}{\beta} \Rightarrow \boxed{\beta = \frac{\alpha}{1-\alpha}} \ *$$

Relationship between $\propto$ and β

$$I_E = I_B + I_C$$

$$\Delta I_E = \Delta I_B + \Delta I_C$$

$$\frac{\Delta i_E}{\Delta i_C} = \frac{\Delta i_B}{\Delta i_C} + 1$$

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

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

Example

MCQ type Question [+4 , -1]

For a transistor, $\alpha = 0.9$, the value of β is -

A. 1

B. 0.09

C. 0.9

D. 9

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.9}{1-0.9}$$

$$= 9$$

Daily Practice Problems

Example

MCQ type Question [+4 , -1]

The part of a transistor which is most heavily doped to produce large number of majority carriers is

[AIEEE 2002]

A. Emitter **B.** Base

C. Collector **D.** Can be any of the above three.

Ans: A

Example

MCQ type Question [+4 , -1]

If I_1, I_2, I_3 are the lengths of the emitter, base and the collector of a transistor, then -

A. $I_1 = I_2 = I_3$

B. $I_1 < I_2 > I_3$

C. $I_1 < I_2 < I_3$

D. $I_1 > I_2 > I_3$

Ans: D

Example

MCQ type Question [+4 , -1]

To use transistor as an amplifier -

A. Emitter-base junction is forward biased and collector base junction is reverse biased.

B. Both junctions are forward biased.

C. Both junctions are reverse biased.

D. It does not matter how the transistor is biased. It always works as an amplifier

Ans: A

Example

MCQ type Question [+4 , -1]

When npn transistor is used as an amplifier

[AIEEE 2003]

A. Electrons move from collector to base
B. Holes move from emitter to base
C. Electrons move from base to collector
D. Holes move from base to emitter

Ans: D

Example

MCQ type Question [+4 , -1]

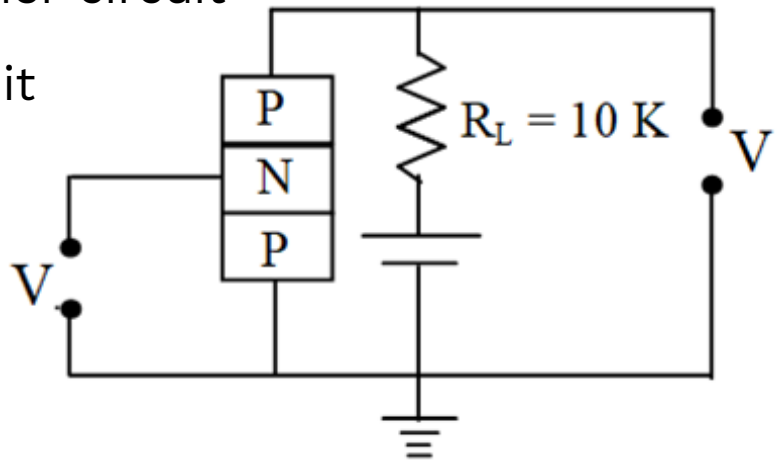
An P-N-P transistor circuit is arranged as shown. It is a –

A. Common base amplifier circuit

B. Common emitter amplifier circuit

C. Common collector circuit

D. None



Ans: C

Example

MCQ type Question [+4 , -1]

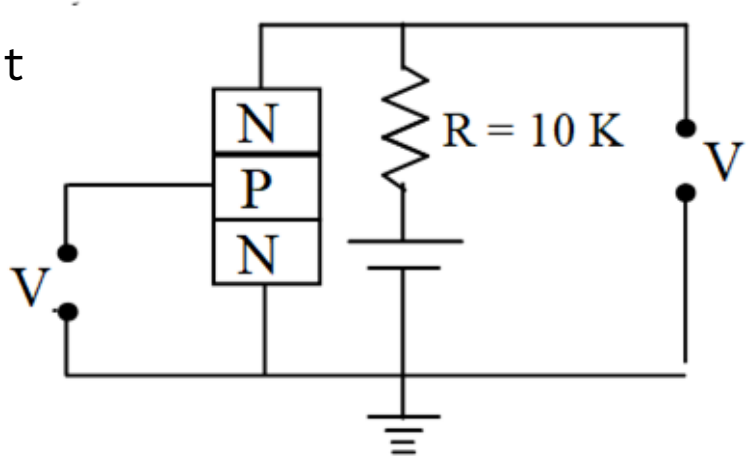
An N-P-N transistor circuit is arranged as shown. It is a –

A. Common base amplifier circuit

B. Common emitter amplifier circuit

C. Common collector circuit

D. None



Ans: B

Example

MCQ type Question [+4 , -1]

In a common base amplifier, the phase difference between the input voltage and output voltage is

[AIEEE 2005]

A. π

B. π/4

C. π/4

D. 0

Ans: D

Example

MCQ type Question [+4 , -1]

For a transistor working as common base amplifier, the emitter current is 7.2 mA. The current gain is 0.96. The collector current is -

A. 0.96 × 7.2 mA

B. 0.96/0.72 mA

C. 0.96 – 7.2 mA

D. 7.2 A – 2 × 0.96 mA

Ans: A

Example

MCQ type Question [+4 , -1]

In a common base mode of a transistor, the collector current is 5.488 mA for an emitter current of 5.60 mA. The value of the base current amplification factor (β) will be

[AIEEE 2006]

A. 49

B. 50

C. 51

D. 48

Ans: A

Example

MCQ type Question [+4 , -1]

An n-p-n transistor circuit has $\propto = 0.985$. If $I_c = 2mA$, then value of I_B is -

A. 0.03 mA **B.** 0.66 mA

C. 0.003 mA **D.** 0.015 mA

Ans: C

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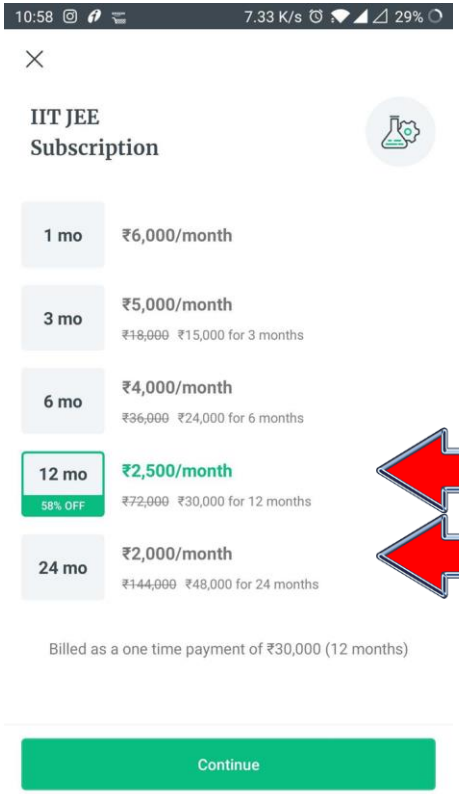
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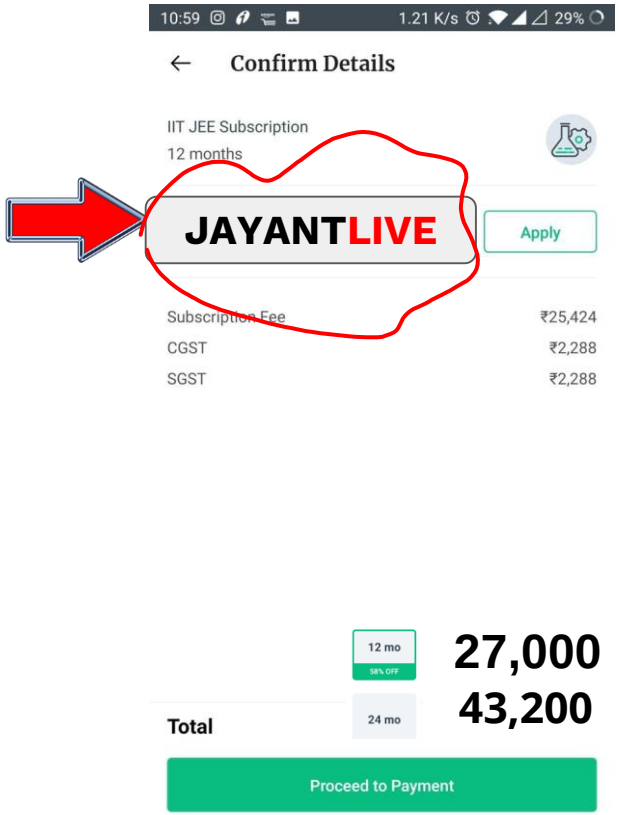
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