The University Of Sheffield.

EEE105 “Electronic Devices”

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Lecture 18

- Bipolar Junction Transistor
- Operation – Bias and Currents
- Current Amplification – Base
- Application as amplifier
- Characteristics, Load Line, Transconductance

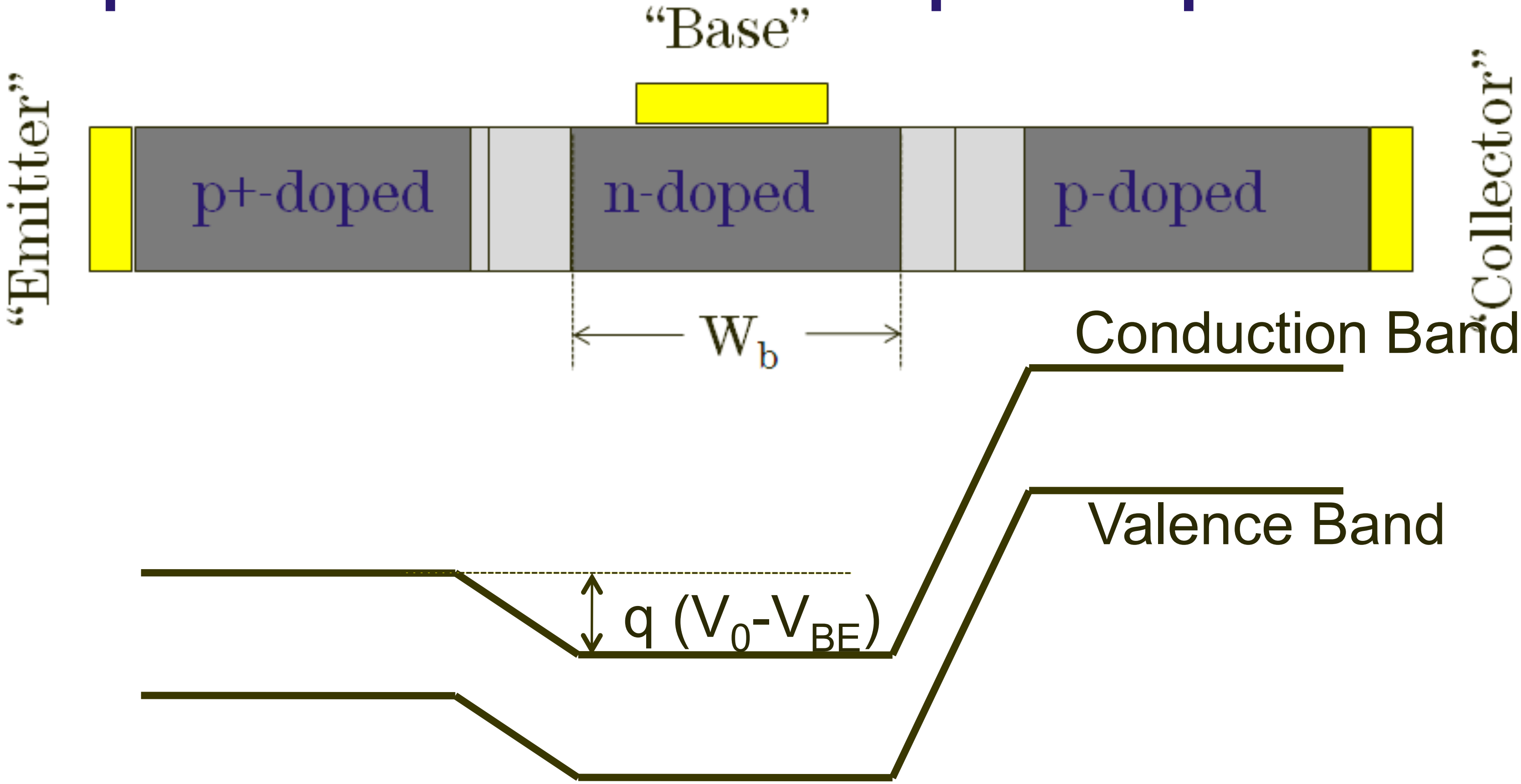
Ingredients for BJT

- Need n^+-p-n or p^+-n-p so that diffusion current is dominated by one carrier
- Need base width to be less than diffusion length of this carrier

n-p-n

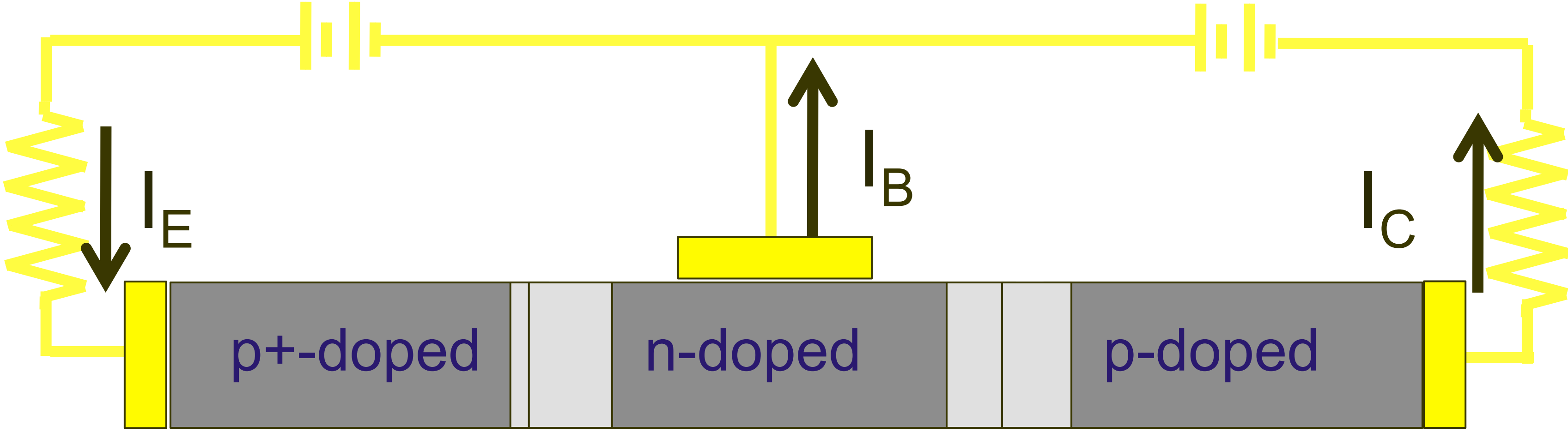
p-n-p

Operational Bias – p+-n-p



V_{BE} determines Emitter and Collector current

Currents

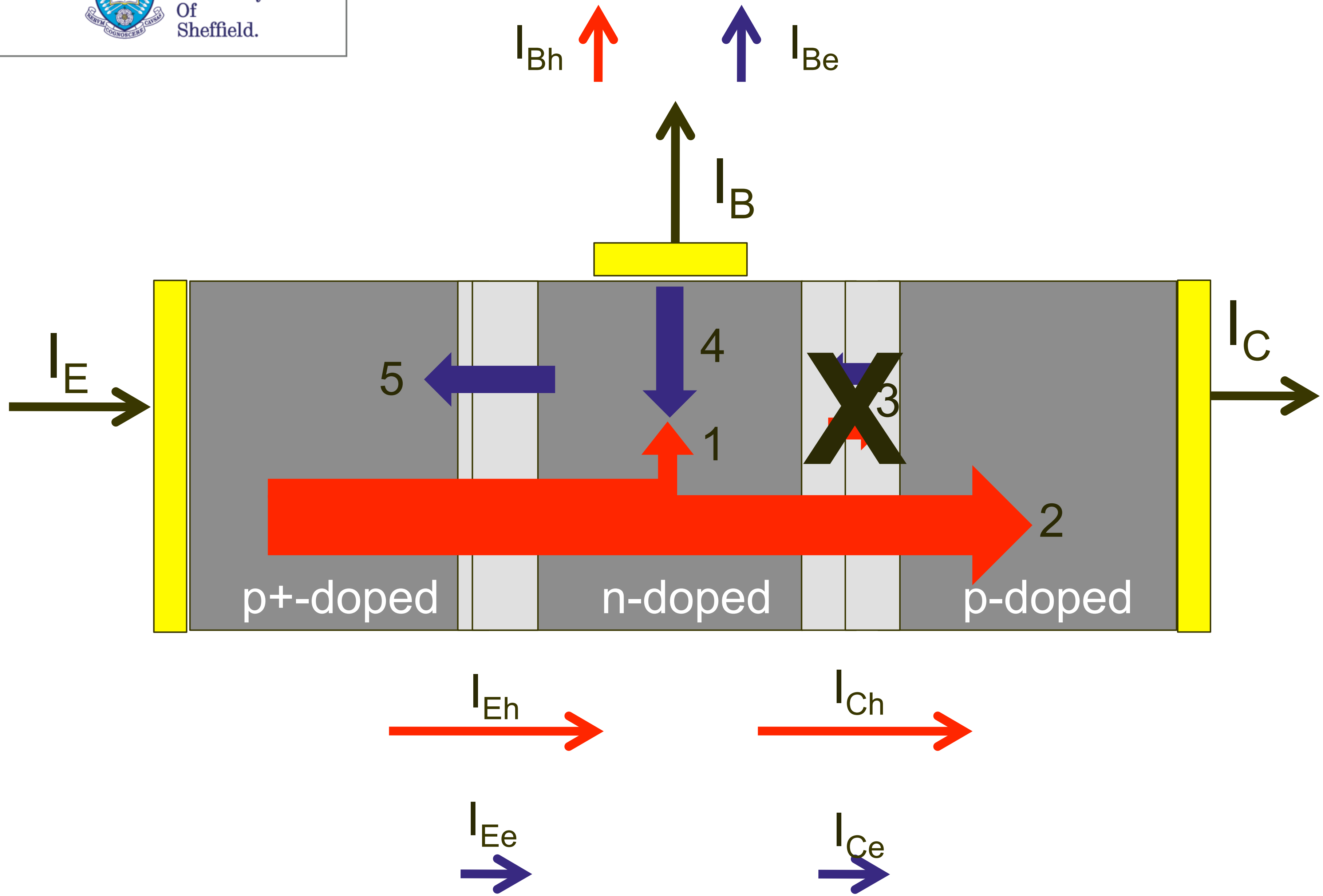


Ideally I_E=I_C and I_B is small.

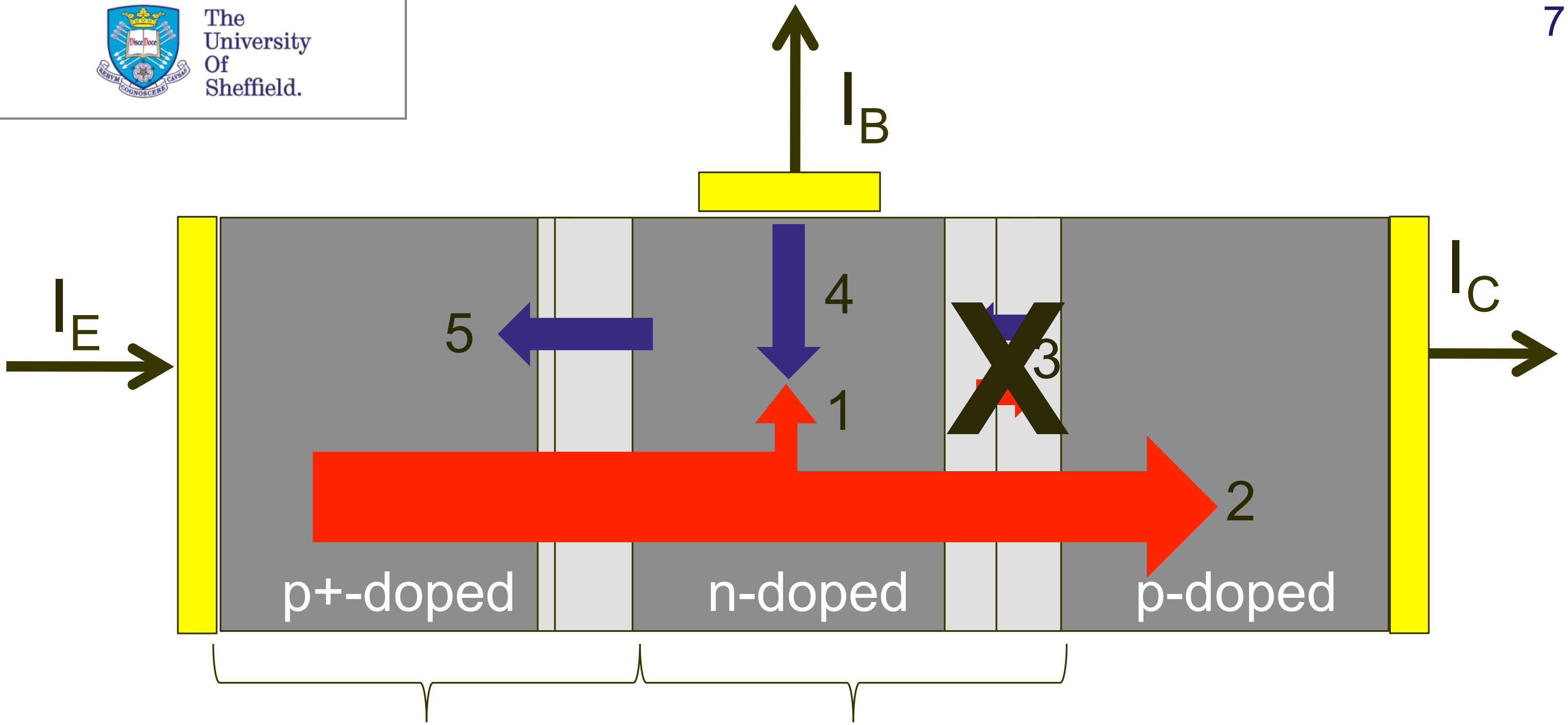
No current amplification using I_E and I_C

Best chance for amplification is from I_B to I_E or I_C

Derive relationships for ratios of these three currents



I_{Bh}
I_{Be}
I_B
I_E
I_C
5
4
3
X
1
2
p+-doped
n-doped
p-doped
I_{Eh}
I_{Ch}
I_{Ee}
I_{Ce}



Have emitter efficiency

$$\gamma = \frac{i_{Eh}}{i_{Ee} + i_{Eh}}$$

$I_C = \mathit{B} I_{Eh}$

B - "Base transport factor"

Ideally both are very close to 1

Currents Contd. (2)

Ratio of I_E and I_C

$$\frac{i_C}{i_E} = \frac{Bi_{Eh}}{i_{Ee} + i_{Eh}} = B\gamma = \alpha \approx 1$$

α is the “current transfer ratio” and is slightly less than 1 between the emitter and collector i.e. ~0.99

Base current

$$i_B = i_{Ee} + (1 - B)i_{Eh}$$

Ratio of I_B and I_C

$$\frac{i_C}{i_B} = \frac{Bi_{Eh}}{i_{Ee} + (1 - B)i_{Eh}}$$

Try to put in terms of B and γ

Expand and divide top and bottom by total emitter current

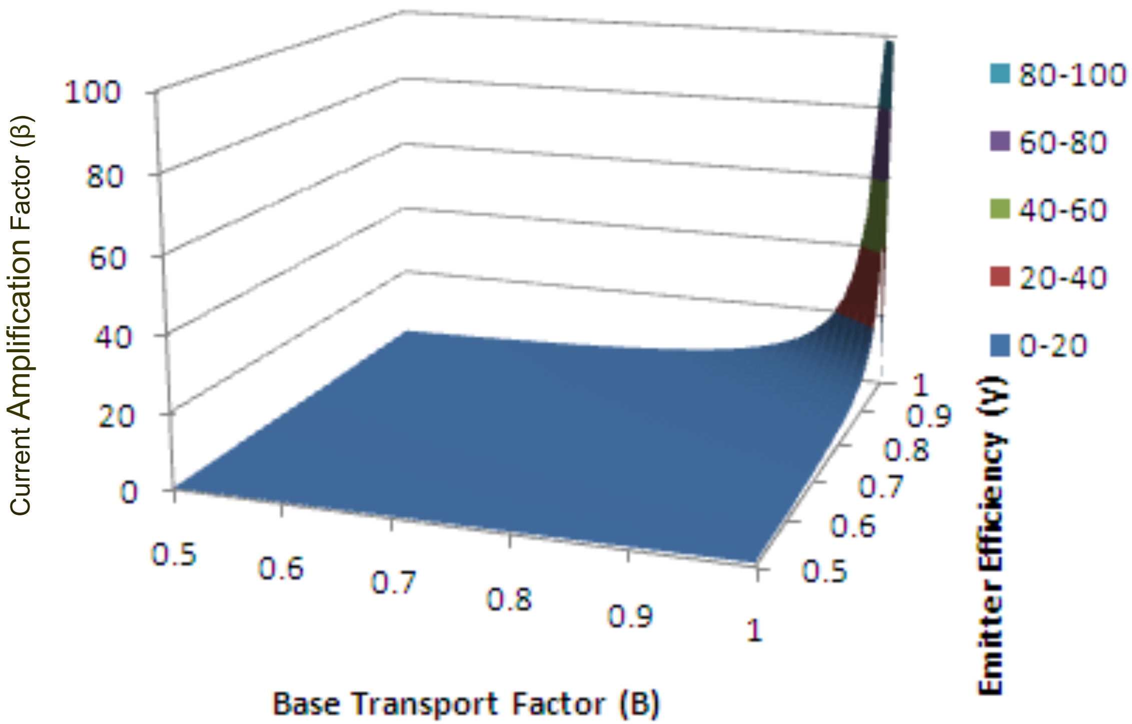
$$\frac{i_C}{i_B} = \frac{B i_{Eh}}{i_{Ee} + (1 - B) i_{Eh}} = \frac{B\left(i_{Eh} / i_{Ee} + i_{Eh}\right)}{\left(i_{Ee} / i_{Ee} + i_{Eh}\right) + (1 - B)\left(i_{Eh} / i_{Ee} + i_{Eh}\right)}$$

Cancel and substitute for γ

$$\frac{i_C}{i_B} = \frac{B\left[i_{Eh} \big/ i_{Ee} + i_{Eh} \right]}{1 - B\left[i_{Eh} \big/ i_{Ee} + i_{Eh} \right]} = \frac{B\gamma}{1 - B\gamma} = \frac{\alpha}{1-\alpha} \equiv \beta$$

Current amplification factor β

Current Amplification Factor



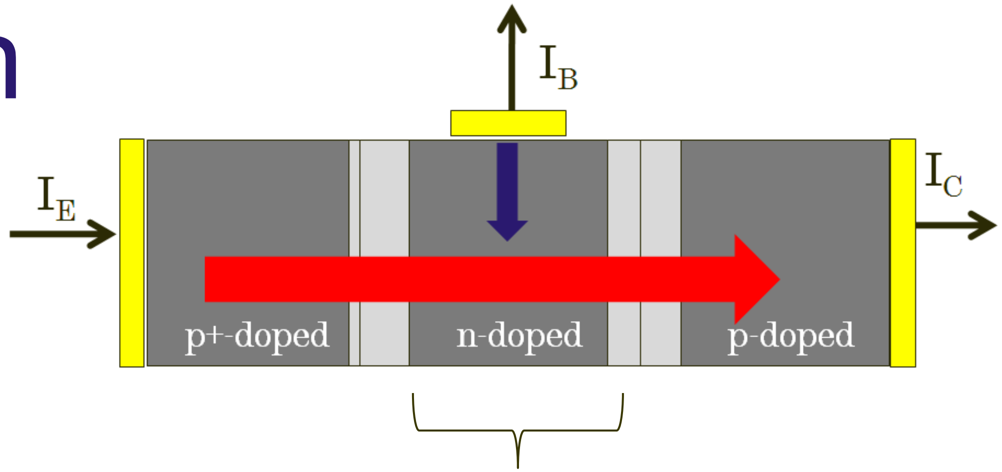
For current amplification

Need B and γ ~0.9

-Single minority carrier injection (γ~1)
-High base transport factor (B~1)

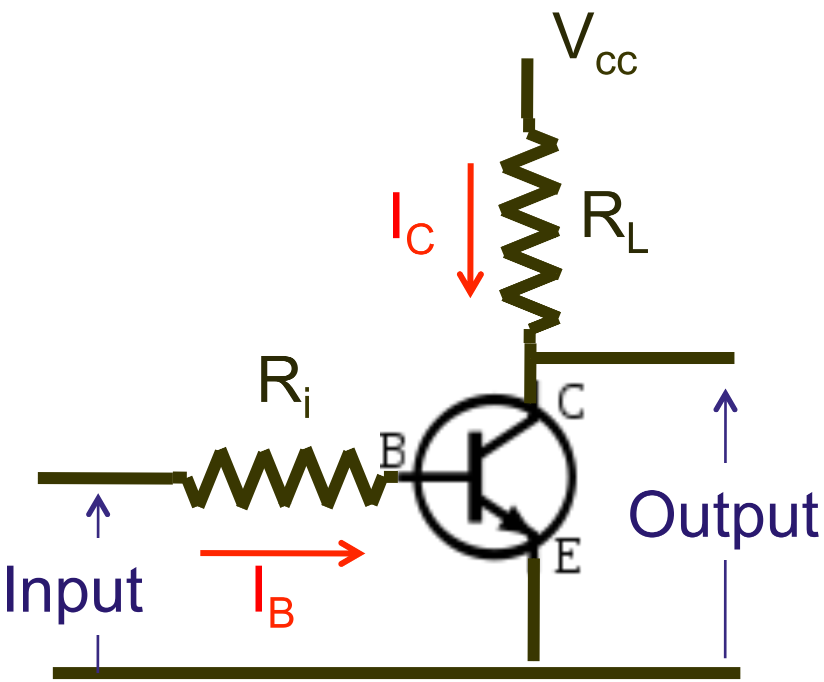
Much higher curent amplification if both are very close to 1

Origin of Gain



- The base must remain neutral – same free carrier density as donor atom dopant density
- Excess holes in base spend a short time there – they are transitting the base in time τ_t
- Average excess eletrons injected have lifetime much longer than this they live for ~ hole minority carrier lifetime τ_p
- For each electron entering the base τ_p / τ_t =β holes pass from emitter to collector to balance the charge

Common Emitter Amplifier



The base emitter is in ~forward bias so gives $V_{BE} \sim V_0$

Input voltage varies I_B

$\Delta I_C = \beta \Delta I_B$

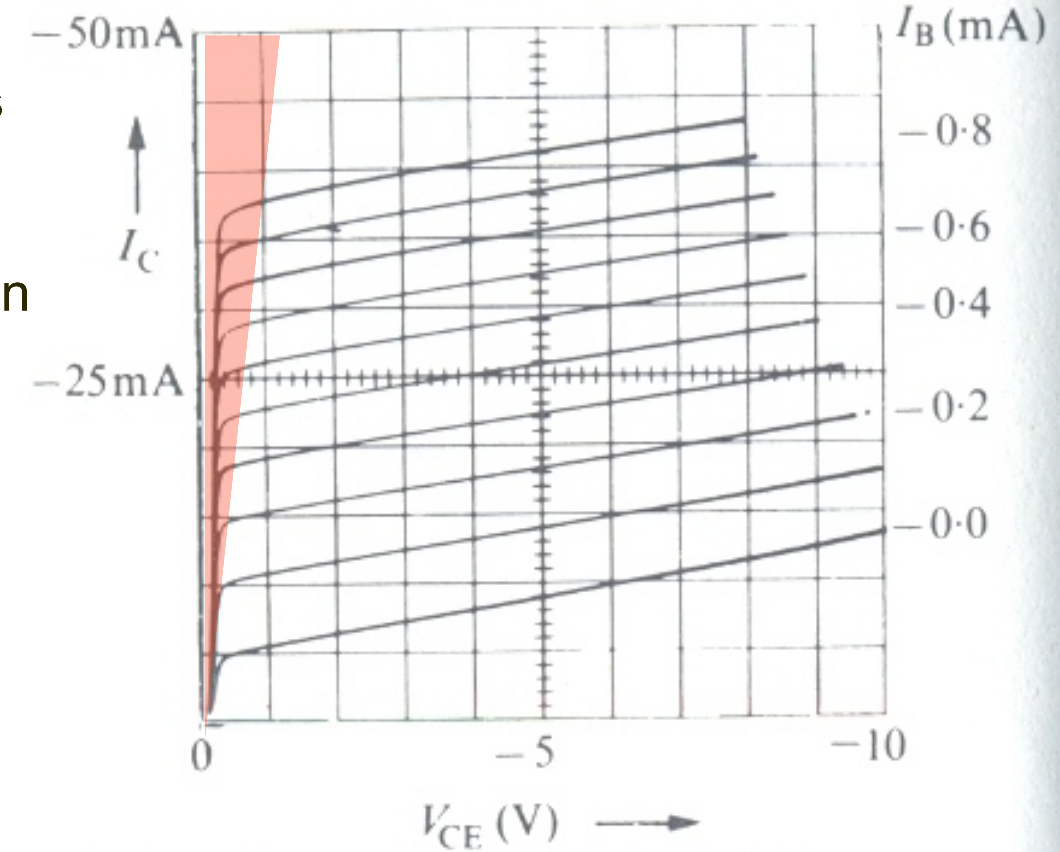
For using the device – important characteristics are V_{CE} , I_C , and I_B

Characteristics

Saturation region – both junctions in forward bias
Conducts electricity freely
(n.b. Don't confuse with saturation current!)

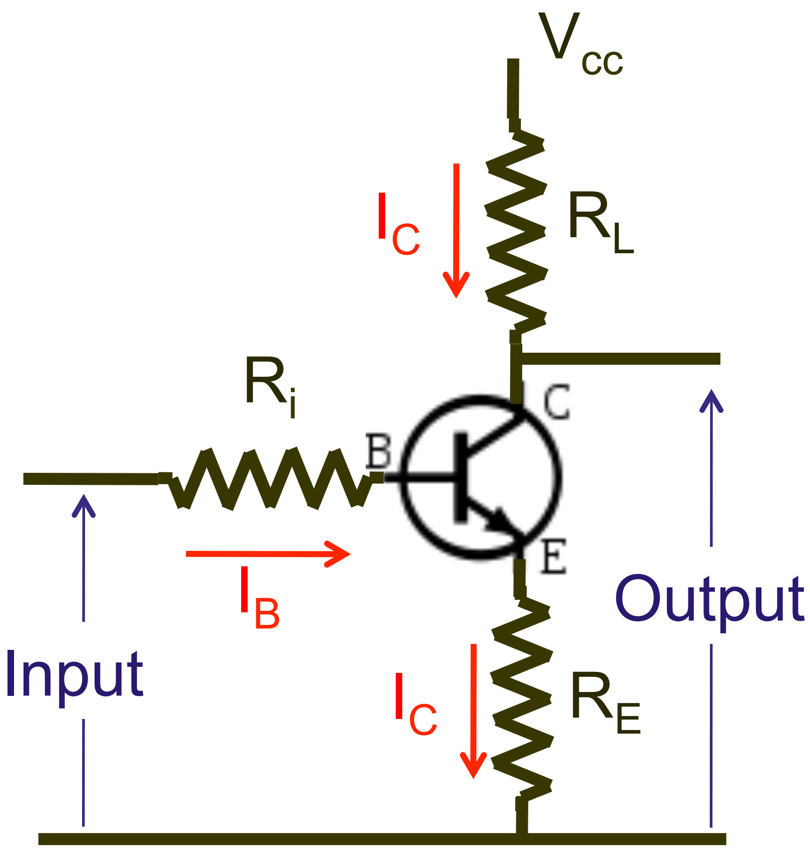
Remainder is "normal operation"
Emitter-base forward biased
Base-collector reverse biased
$\Delta I_C = \beta \Delta I_B$

For this device $\beta \sim 30$
n.b. More linear when I_B is not close to zero (cut off region)



(b) Ge p n p bipolar transistor OC72

Common Emitter Amplifier (2)



$$V_{CC} = I_c(R_L + R_E) + V_{CE}$$

What are extremes?

$I_C = 0 \rightarrow V_{CE} = V_{CC}$

and $V_{CE} = 0 \rightarrow I_c = \dfrac{V_{CC}}{(R_C + R_E)}$

Load Line

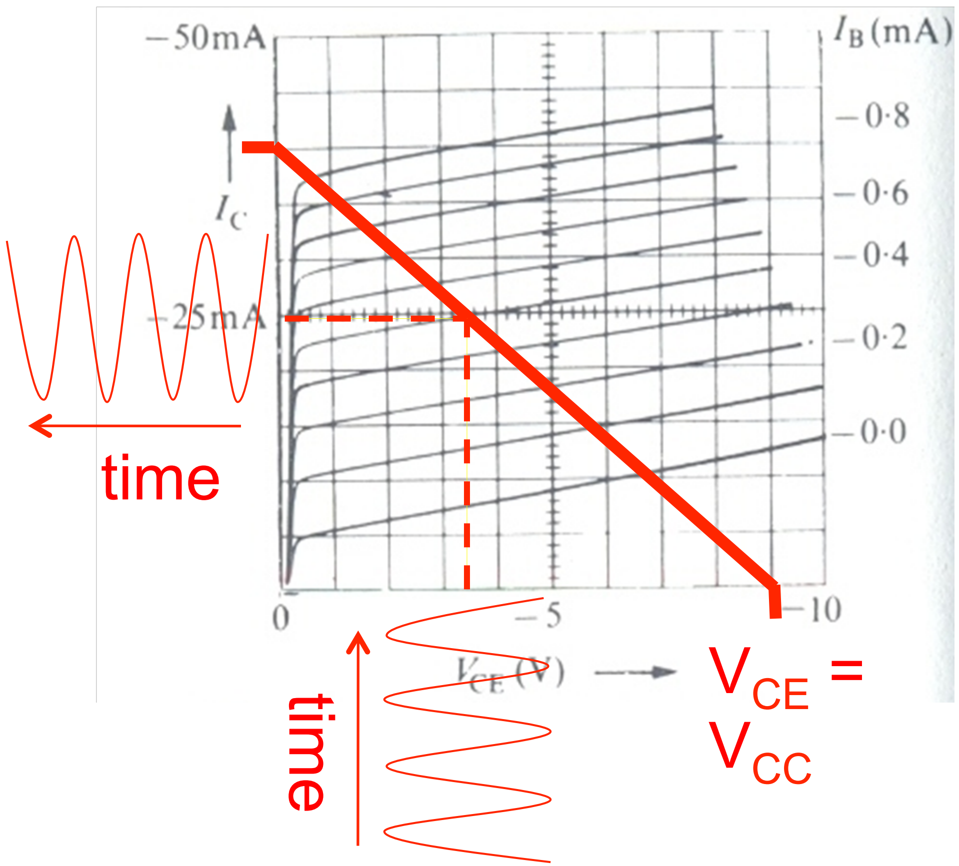
$$I_c = \frac{V_{CC}}{(R_C + R_E)}$$

D.C. Quiescent point
-deviations about this
point carry signals

Determined by
R_C and R_E

Transconductance

$$g_m = \frac{\Delta I_{out}}{\Delta V_{in}}$$



Summary

A bipolar transistor is analysed in terms of the bias required and currents present under operation

Analysis of the currents indicates current gain is possible

Described common emitter configuration of a BJT, biasing requirements and the load line, and introduced the transconductance

