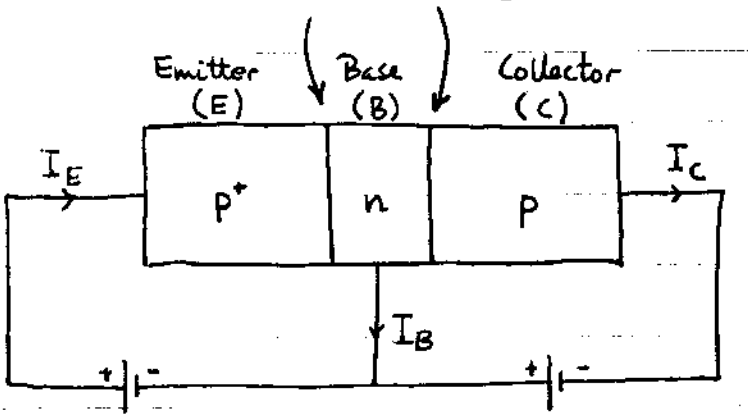
2.4.03 **Transistor** (**Transfer resistor**)

Bell Labs, New Jersey 1947 : Bardeen, Brattain, Shockley

↑

også BCS-teorien for superledning
(Nobelpris, fysikk 1956 og 1972)

pnp-transistor : 2 pn-overganger



$V_{EB} > 0$ $V_{BC} > 0$

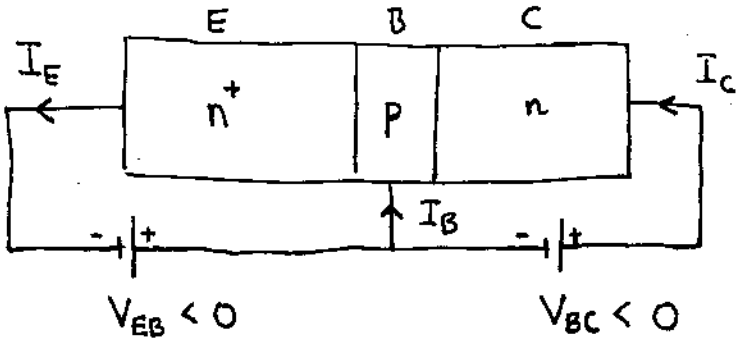
Kirchhoff

↓

$I_B = I_E - I_C$

Dopemengder : $p_E^+ > n_B > p_C$

npn-transistor :

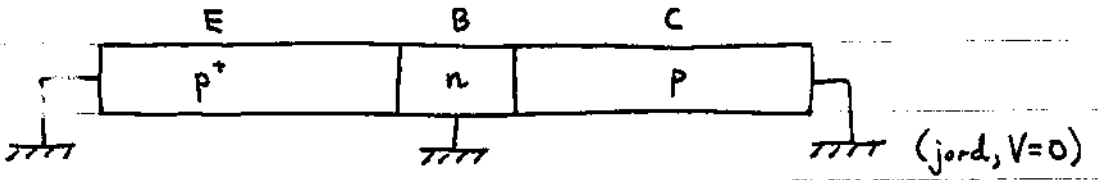


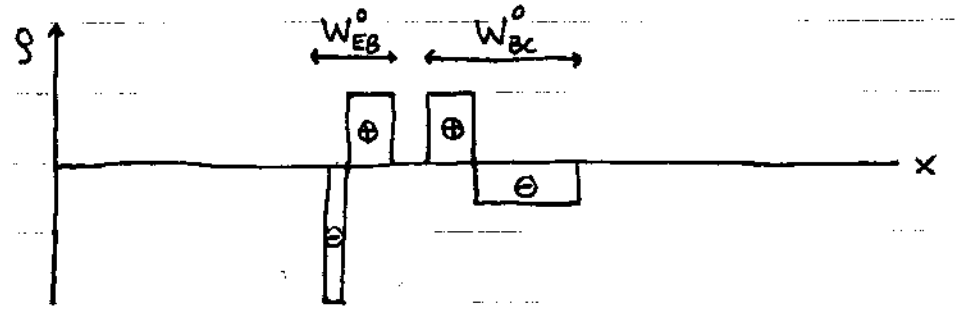
$V_{EB} < 0$ $V_{BC} < 0$

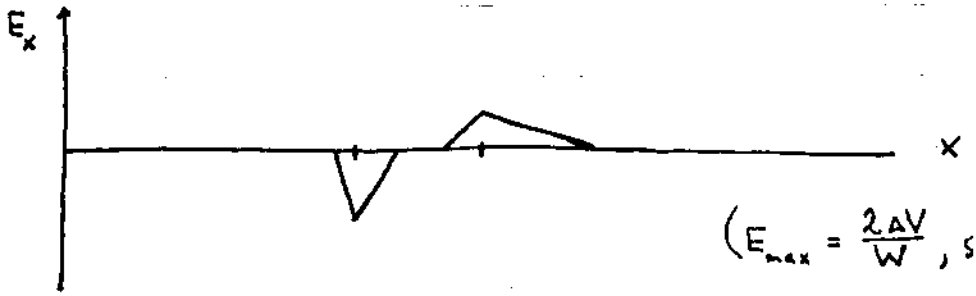
$I_B = I_E - I_C$

$n^+ > p > n$

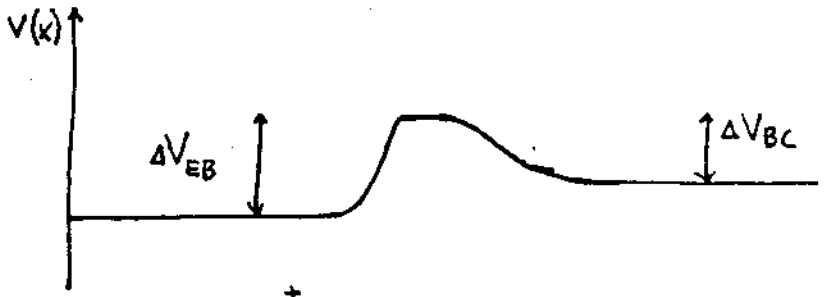
I likevekt:







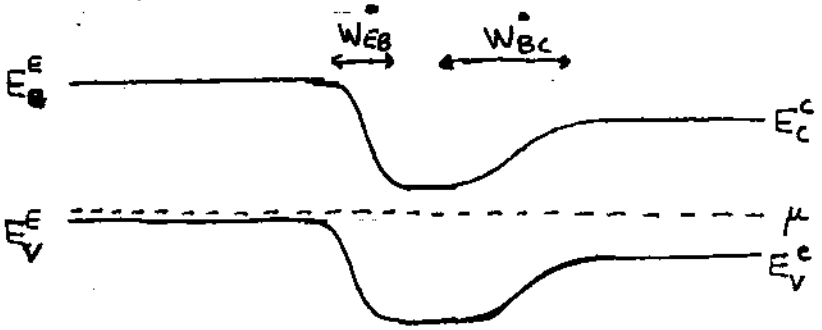
$\left(E_{max} = \frac{2\Delta V}{W}\right.$, se øving 10)



$\updownarrow \Delta V_{EC}$
$= \Delta V_{EB} - \Delta V_{BC}$

$\left(\Delta V_{EB} = \frac{k_B T}{e} \ln \frac{p^+ \cdot n}{n_i^2}\right.$, se øving 10)

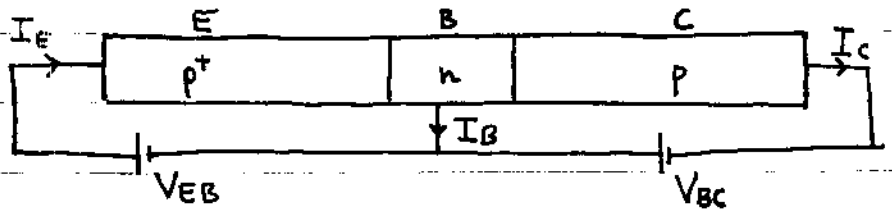
Energibåndene blir:



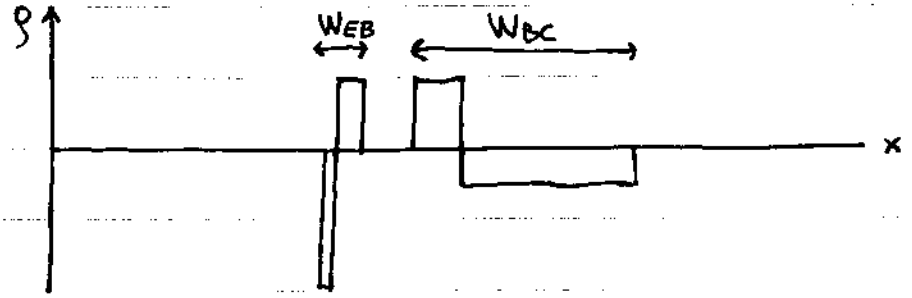
(konstant i likevekt)

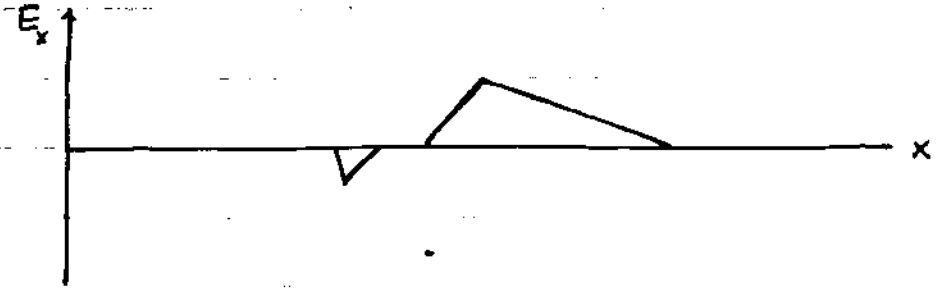
Aktiv modus: $V_{EB} > 0 \quad \Rightarrow W_{EB} < W_{EB}^{\circ}$

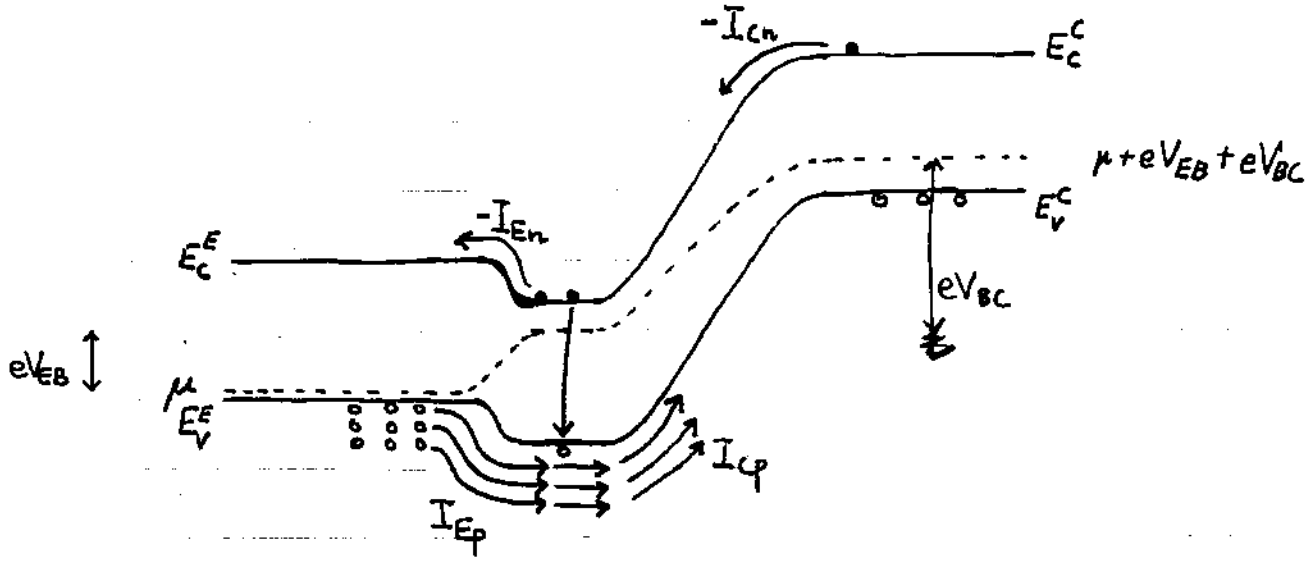
$V_{CB} < 0 \quad \Rightarrow W_{BC} > W_{BC}^{\circ}$



(Felles base konfigurasjon)







Med smal base : $I_{Cp} \lesssim I_{Ep}$

Dvs: Stor strøm I_C over pn-overgang med $V_{CB} < 0$

(Husk: $I(V) = I_0\left(e^{eV/k_BT} - 1\right) \approx -I_0$ liten for en enkelt pn-overgang)

Dvs: Transistor-virkning!

(Bred base ⇒ "emitterte" hull fra E rekombinerer i stor grad med elektroner i B, dvs hullene "collect"-es ikke av C
⇒ I_C blir liten
⇒ oppførsel som to separate pn-overganger)

Strøm-relasjoner :

$$I_E = I_{Ep} + I_{En}$$
$$I_C = I_{Cp} + I_{Cn}$$
$$I_B = I_E - I_C = I_{En} + (I_{Ep} - I_{Cp}) - I_{Cn} \quad \text{(se fig. s 57)}$$

Felles base "strømfaktor" : $\alpha_0 \equiv I_{Cp}/I_E \lesssim 1$

$$\alpha_0 = \frac{I_{Cp}}{I_{Ep}+I_{En}} = \underbrace{\frac{I_{Ep}}{I_{Ep}+I_{En}}}_{\gamma} \cdot \underbrace{\frac{I_{Cp}}{I_{Ep}}}_{\alpha_T}$$

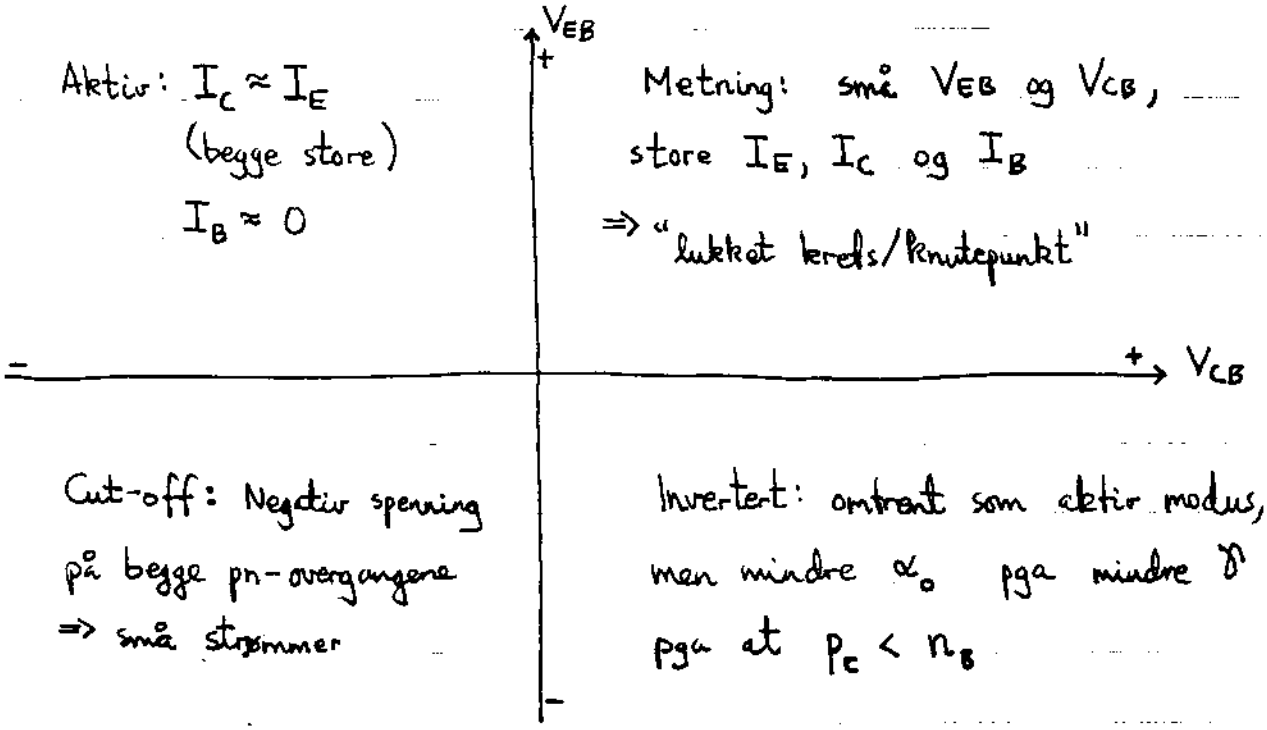
Emitter-effektivitet: $\gamma \equiv \frac{I_{Ep}}{I_E} \lesssim 1$

Base transportfaktor: $\alpha_T \equiv I_{Cp}/I_{Ep} \lesssim 1$

$$I_C = I_{Cp} + I_{Cn}$$
$$= \alpha I_E + I_{Cn}$$
$$= \alpha_0 I_E + I_{CBO}$$

I_{CBO} = Collector - Base (lekkasje-)strøm med åpen ("Open") emitter (dvs når $I_E = 0$)

Kan ha V_{EB} og V_{CB} positiv og negativ
⇒ 4 ulike "operasjonsmodi"



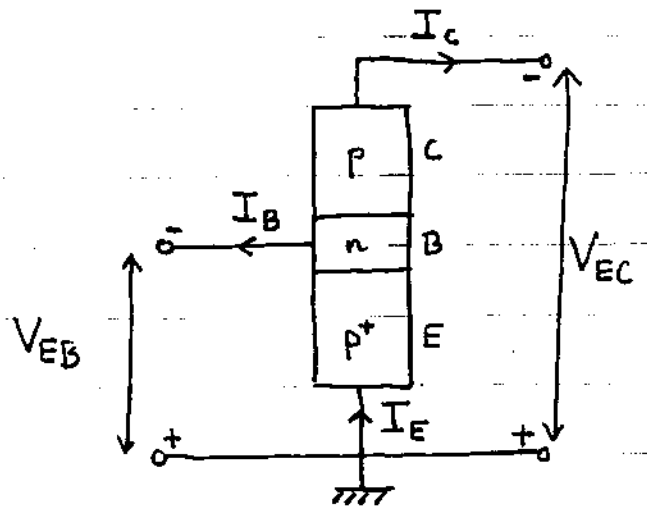
Aktiv: $I_C \approx I_E$ (begge store)
$I_B \approx 0$

Metning: små V_{EB} og V_{CB}, store I_E, I_C og I_B
⇒ "lukket krets/knutepunkt"

Cut-off: Negativ spenning på begge pn-overgangene
⇒ små strømmer

Invertert: omtrent som aktiv modus, men mindre α_0 pga mindre δ pga at $p_E < n_B$

Vanligst i krets-anvendelser: Felles emitter konfigurasjon



$$I_C = \alpha_0 I_E + I_{CBO}$$
$$= \alpha_0 (I_B + I_C) + I_{CBO}$$

$$\Rightarrow I_C (1-\alpha_0) = \alpha_0 I_B + I_{CBO}$$

$$\Rightarrow I_C = \frac{\alpha_0}{1-\alpha_0} I_B + \frac{I_{CBO}}{1-\alpha_0} = \beta_0 I_B + I_{CEO}$$

Felles emitter strømforsterkning: $\beta_0 \equiv \frac{dI_C}{dI_B} = \frac{\alpha_0}{1-\alpha_0}$

$I_{CEO} \equiv \frac{I_{CBO}}{1-\alpha_0}$ = Collector - Emitter lekkasjestrøm med Open base (dvs $I_B = 0$)

$\alpha_0 \lesssim 1 \Rightarrow \beta_0 \gg 1 \Rightarrow I_C \gg I_B$

$\Rightarrow$ strømforsterkning!

F.eks: $\alpha_0 = 0.99 \Rightarrow \beta_0 = 99$

Hit 2.4.03