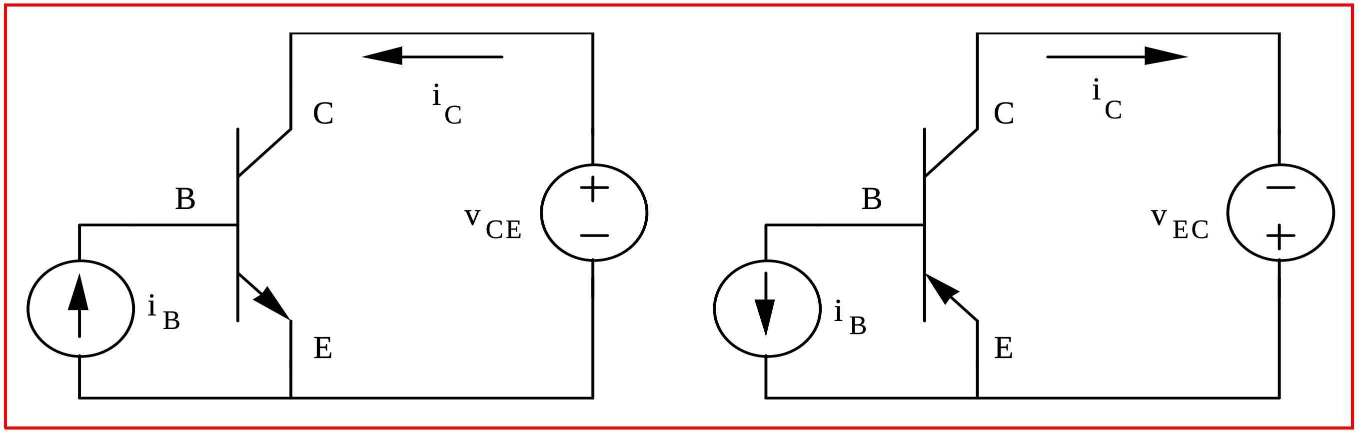
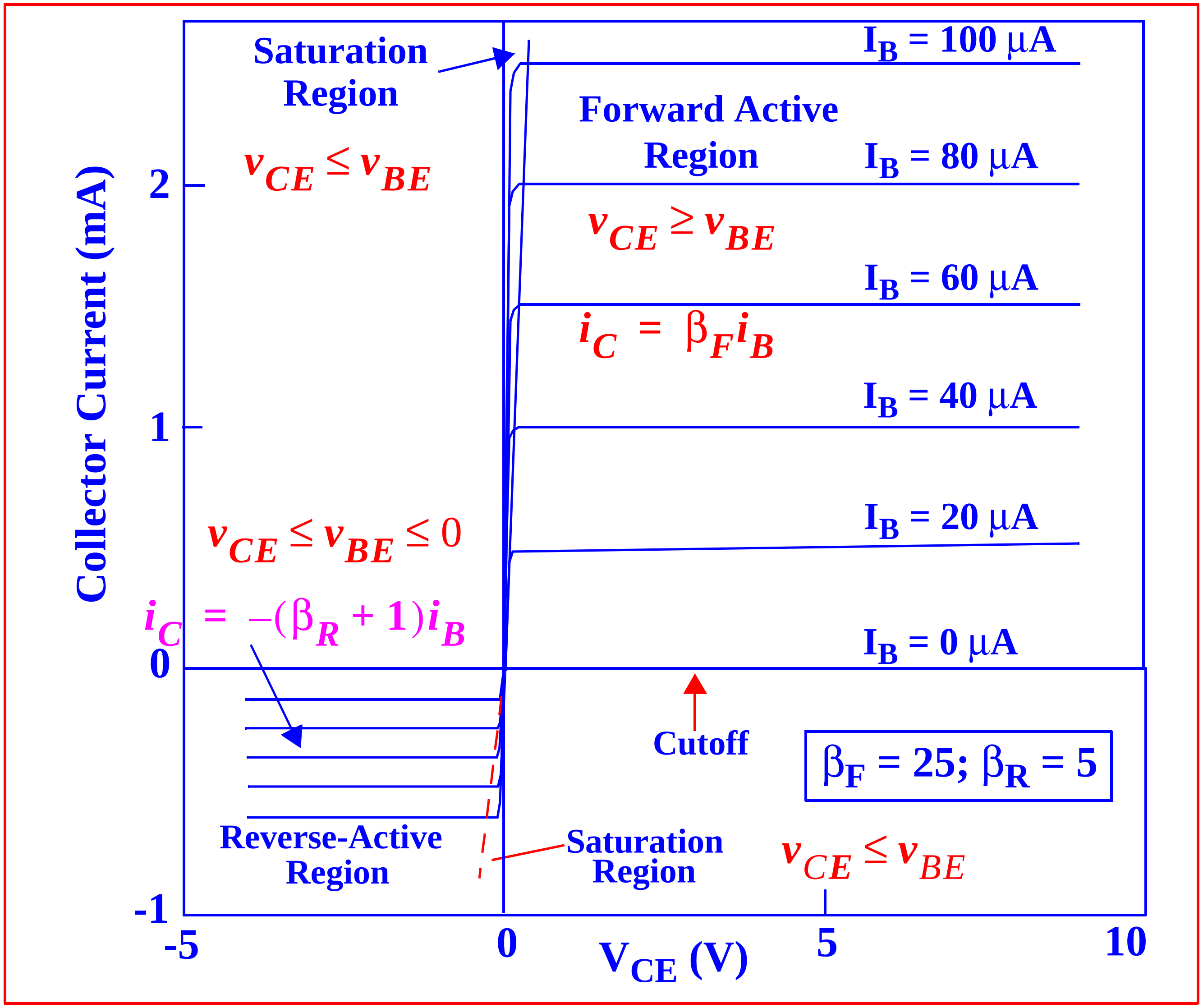
I-V Characteristics of BJT

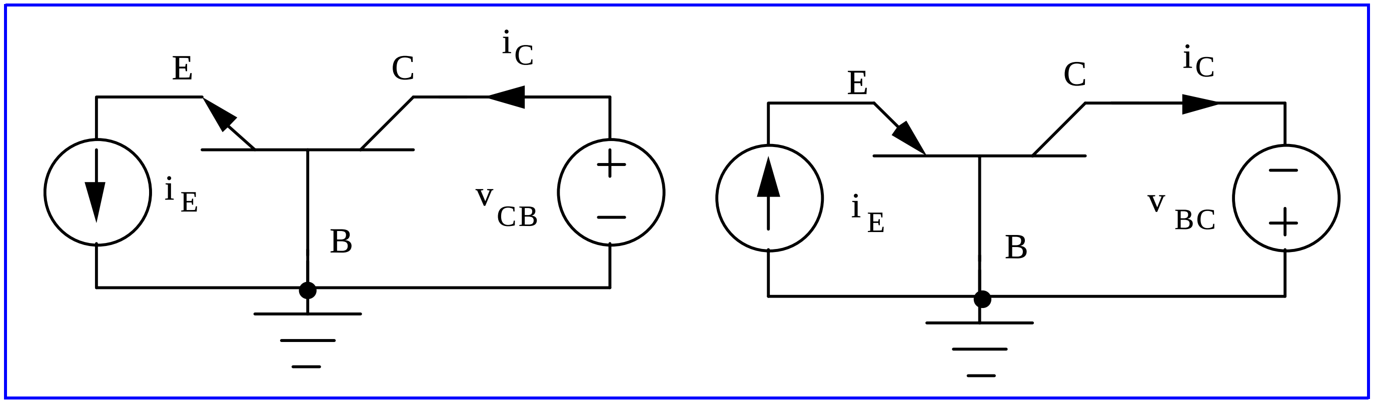
Common-Emitter Output Characteristics

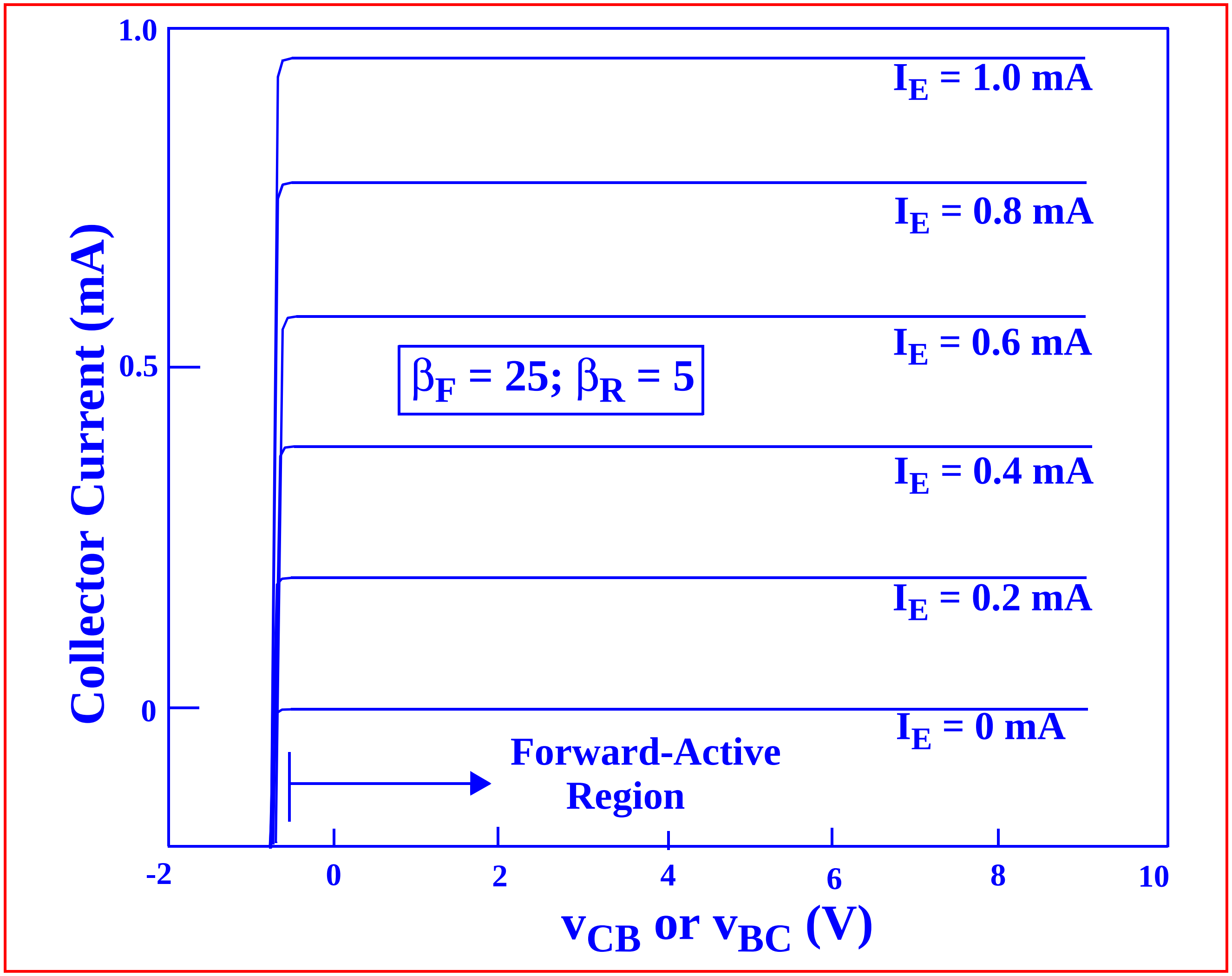


To illustrate the I_C-V_{CE} characteristics, we use an enlarged β_R



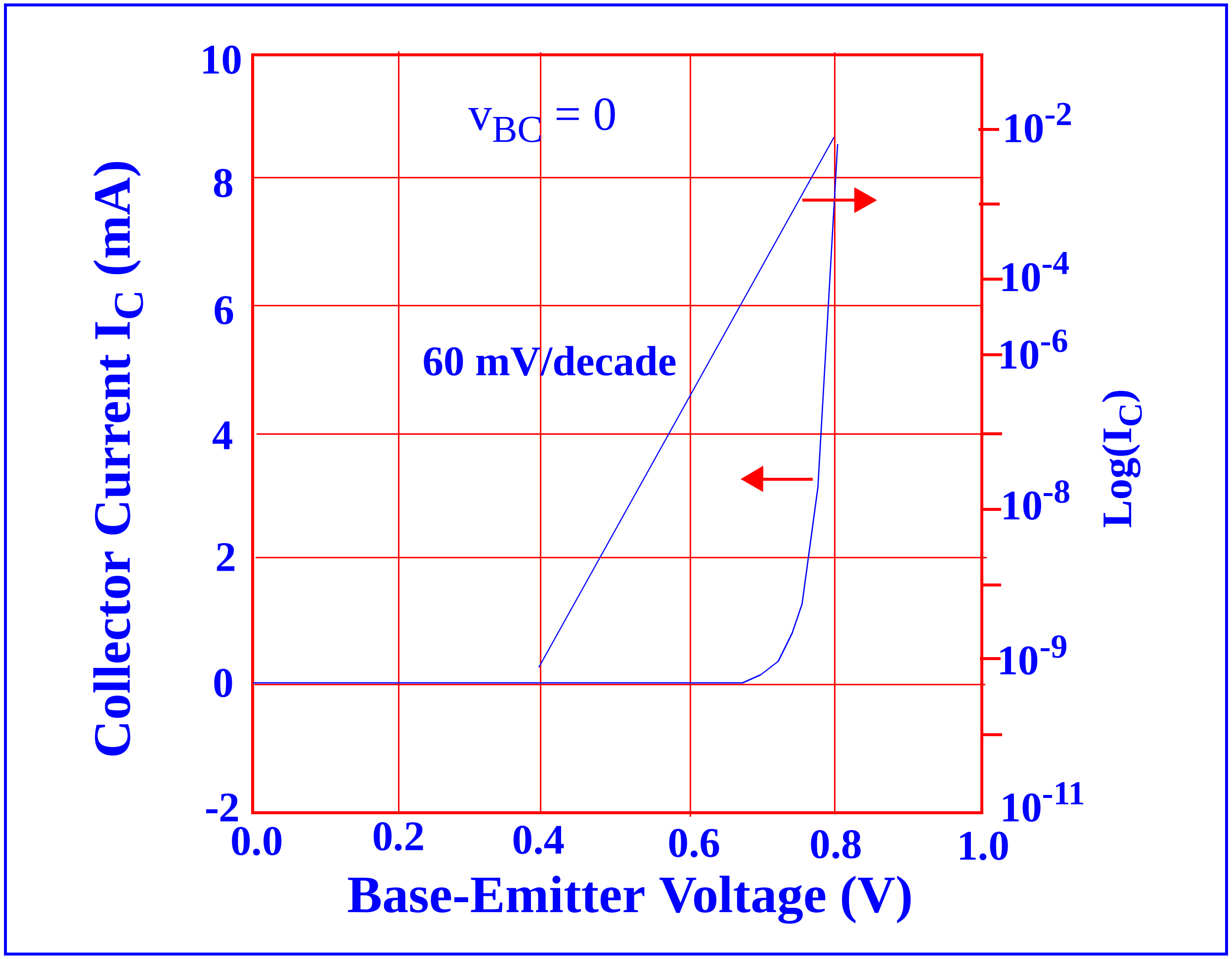
Common Base Output Characteristics




1.0
0.5
0
Collector Current (mA)
I_E = 1.0 mA
I_E = 0.8 mA
I_E = 0.6 mA
I_E = 0.4 mA
I_E = 0.2 mA
I_E = 0 mA
β_F = 25; β_R = 5
Forward-Active Region
-2
0
2
4
6
8
10
v_{CB} or v_{BC} (V)

Common-Emitter Transfer Characteristic i_C - v_{BE}

. BE voltage changes as -1.8 mV/^{O}C - this is its temperature coefficient (recall from diodes).



Common-Emitter Transfer Characteristic i_C - v_{BE} (p. 180)

$$\boxed{I_C = I_S\left\{\exp\left(\frac{v_{BE}}{V_T}\right) - 1\right\}}$$

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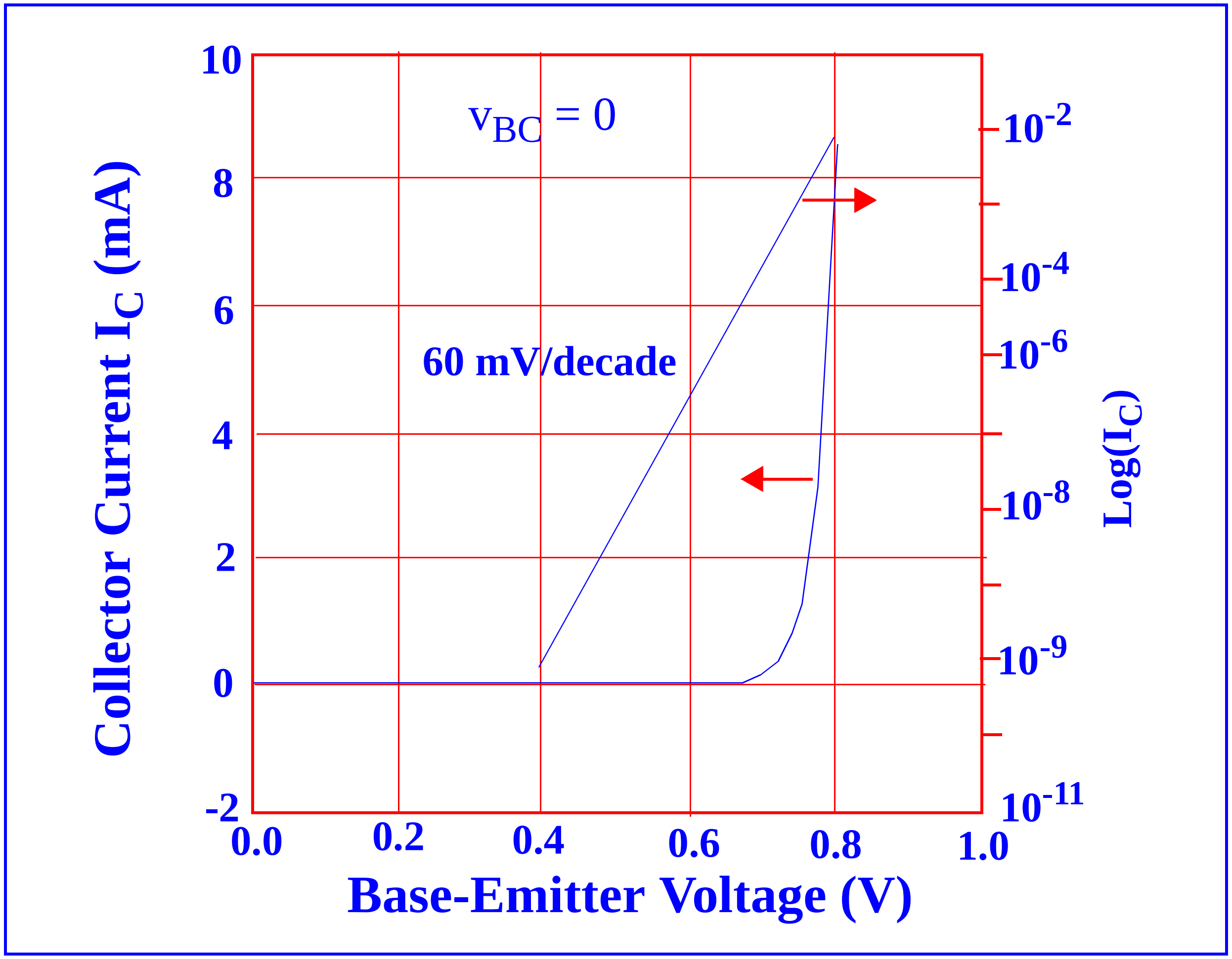

Junction Breakdown - BJT has two diodes back-to-back. Each diode has a breakdown. The diode (BE) with higher doping concentrations has the lower breakdown voltage (5 to 10 V).

In forward active region junction is reverse biased.

In cut-off region, are both reverse biased.

The transistor must withstand these reverse bias voltages.

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In cut-off region, BE and BC are both reverse biased.

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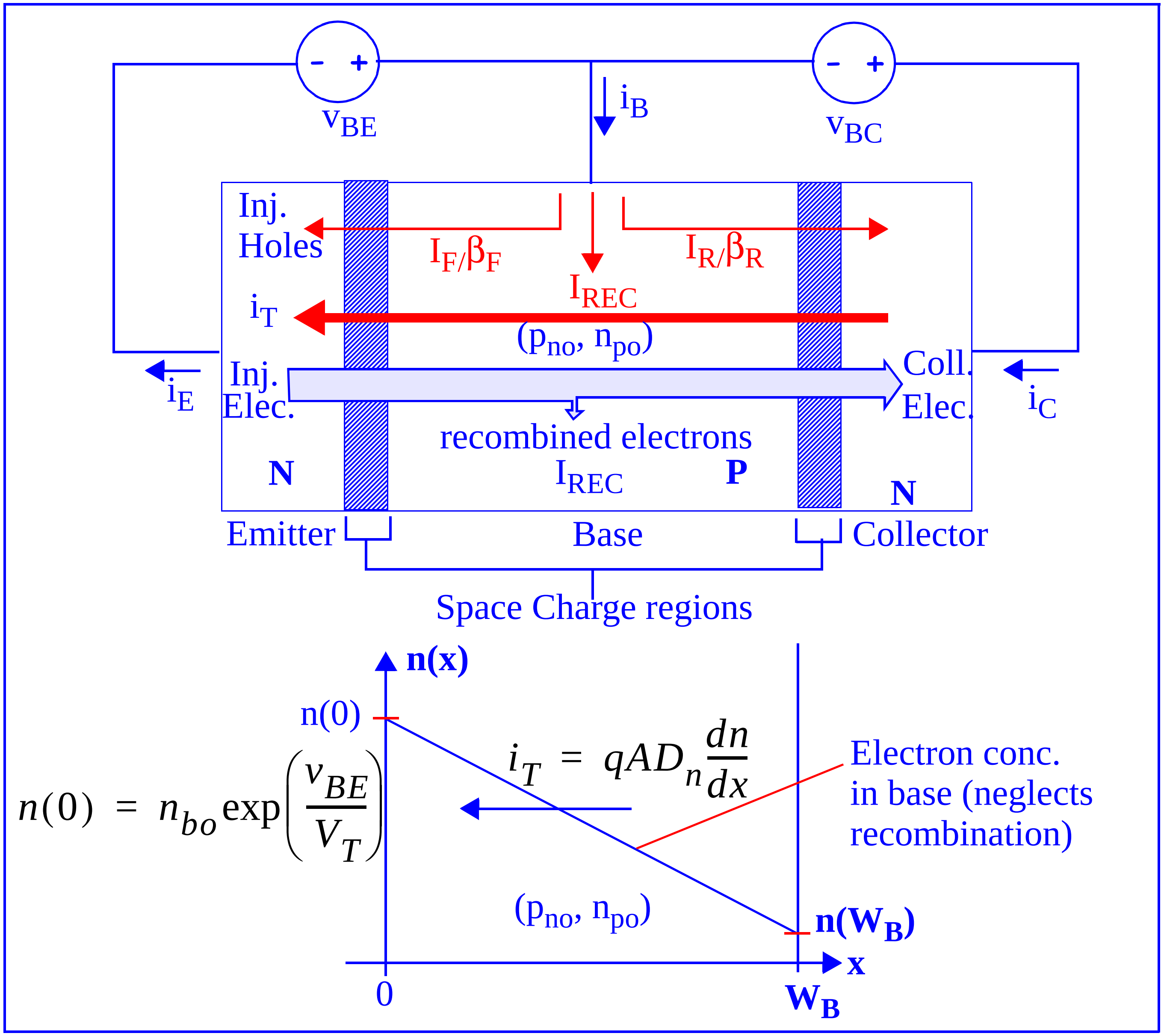
Minority Carrier Transport in Base Region



$$i_T = qAD_n\frac{dn}{dx}$$

$$n(0) = n_{bo}\exp\left(\frac{v_{BE}}{V_T}\right)$$

Transport current i_T results from diffusion of minority carriers (holes in npn) across base region.

Base current i_B is composed of holes injected back into E and C and I_{REC} needed to replenish holes lost to recombination with electrons in B.

The minority carrier concentrations at two ends of base are

and where n_{bo} is the equilibrium electron density in the base region.

The junction voltages establish a minority carrier concentration gradient at ends of base region. For a narrow base, we get

W_B is the B width; A is the cross-sectional area of B region.

The **saturation current** is

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$\boxed{n(0) = n_{bo}\exp\left(\frac{v_{BE}}{V_T}\right)}$ and $\boxed{n(W_B) = n_{bo}\exp\left(\frac{v_{BC}}{V_T}\right)}$ where n_{bo} is the equilibrium electron density in the base region.

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$$\boxed{i_T = \left|qAD_n\frac{dn}{dx}\right| = \left|-qAD_n\frac{n_{bo}}{W_B}\left\{\exp\left(\frac{v_{BE}}{V_T}\right) - \exp\left(\frac{v_{BC}}{V_T}\right)\right\}\right|} .$$

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W_B is the B width; A is the cross-sectional area of B region.

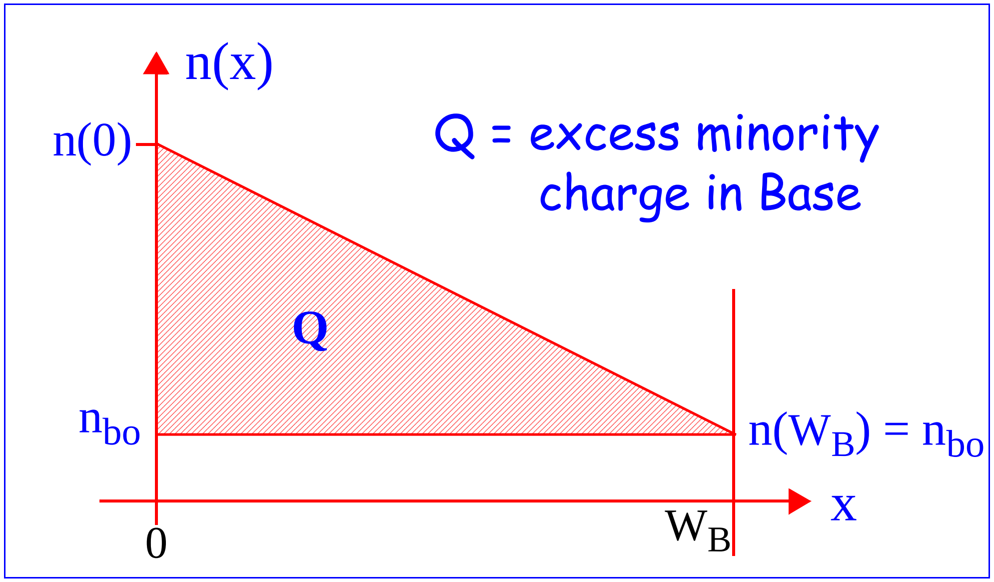
The **saturation current** is $\boxed{I_S = qAD_n\frac{n_{bo}}{W_B} = qAD_n\frac{n_i^2}{N_{AB}W_B}}$.

Base Transit Time

Forward transit time is time associated with storing charge Q in Base region and it is

$\boxed{\tau_F = \frac{Q}{i_T}}$ with $\boxed{Q = qA[n(0) - n_{bo}]\frac{W_B}{2}}$.

Using $\boxed{Q = qAn_{bo}\left\{\exp\left(\frac{v_{BE}}{V_T}\right) - 1\right\}\frac{W_B}{2}}$ we get

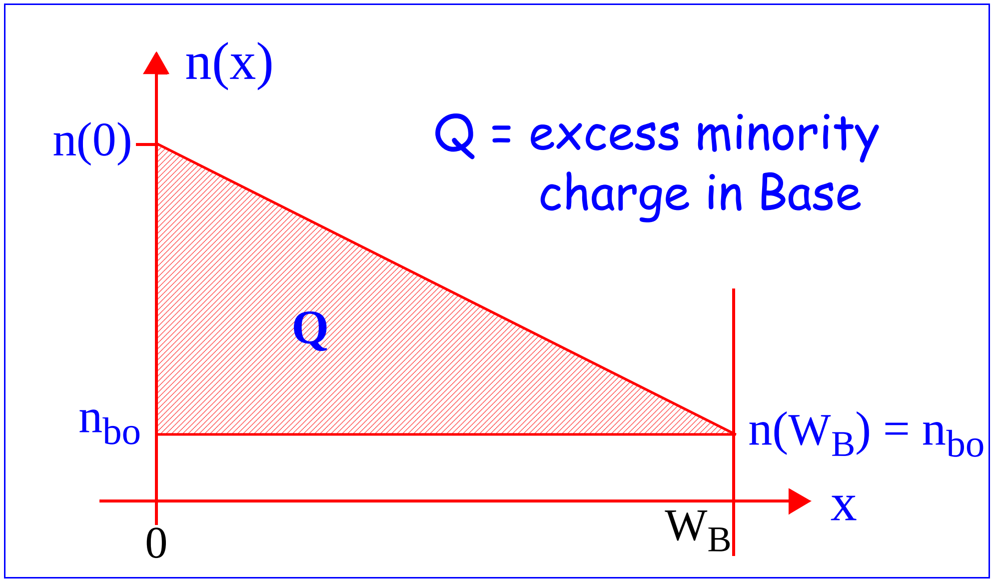


Q = excess minority charge in Base

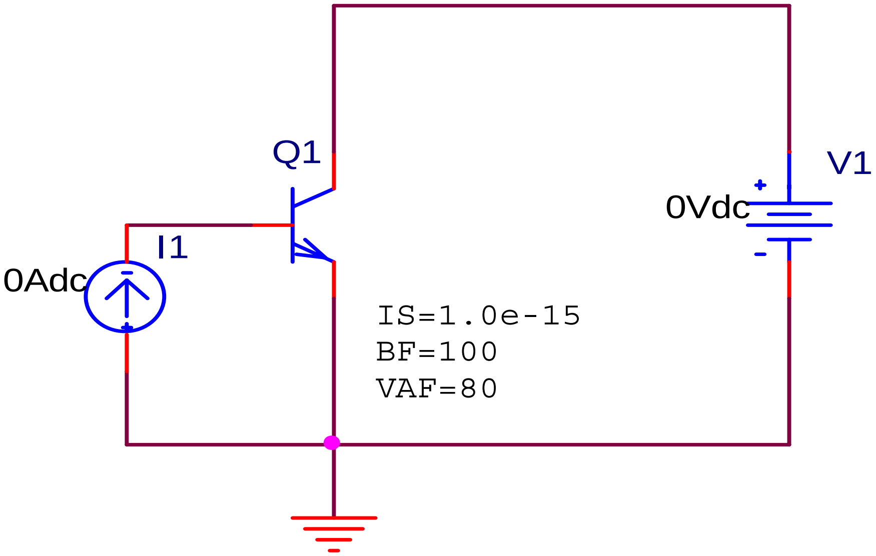
Using $\boxed{Q = qAn_{bo}\left\{\exp\left(\frac{v_{BE}}{V_T}\right) - 1\right\}\frac{W_B}{2}}$ we get

$\boxed{i_T = \frac{qAD_n}{W_B}n_{bo}\left\{\exp\left(\frac{v_{BE}}{V_T}\right) - 1\right\}}$ and $\boxed{\tau_F = \frac{W_B^2}{2D_n} = \frac{W_B^2}{2V_T\mu_n}}$.

This defines an upper limit on frequency $\boxed{f \le \frac{1}{2\pi\tau_F}}$.



PSPICE EXAMPLE



```
*Libraries:
* Local Libraries :
.LIB ".\example10.lib"
* From [PSPICE NETLIST] section of C:\Program Files\OrcadLite\PSpice\PSpice.ini file:
.lib "nom.lib"
*Analysis directives:
.DC LIN V_V1 0 5 0.05
+ LIN I_I1 10u 100u 10u
.PROBE V(*) I(*) W(*) D(*) NOISE(*)
.INC ".\example10-SCHEMATIC1.net"
**** INCLUDING example10-SCHEMATIC1.net ****
* source EXAMPLE10
```

PSPICE EXAMPLE (Cont'd)

```
Q_Q1          N00060 N00159 0 Qbreakn
V_V1          N00060 0 0Vdc
I_I1          0 N00159 DC 0Adc
**** RESUMING example10-SCHEMATIC1-Example10Profile.sim.cir ****
.END
 ****     BJT MODEL PARAMETERS
*************************************************************************************
          Qbreakn
          NPN
          IS     1.000000E-15
          BF   100
          NF     1
         VAF    80
          BR     3
          NR     1
         VAR    30
          CN     2.42
           D      .87
          JOB CONCLUDED
          TOTAL JOB TIME            .21
```

PSPICE EXAMPLE (Cont'd)