NPN BJT Transistor (Fig. 6.1 on page 307):

BJT Cross-section (Fig. 6.7 on page 316):

BJT voltage polarities and current flows when operated in the “active mode” (Fig. 6.13 on page 321):
(a) NPN transistor and (b) PNP transistor

BJT I-V Relationships (Table 6.2 on page 322):

<table>
<thead>
<tr>
<th>Table 6.2</th>
<th>Summary of the BJT Current–Voltage Relationships in the Active Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>$i_C = I_ex^{v_{BE}/v_T}$</td>
<td></td>
</tr>
<tr>
<td>$i_B = \frac{i_C}{\beta} = \left(\frac{I_s}{\beta}\right) e^{v_{BE}/v_T}$</td>
<td></td>
</tr>
<tr>
<td>$i_E = \frac{i_C}{\alpha} = \left(\frac{I_s}{\alpha}\right) e^{v_{BE}/v_T}$</td>
<td></td>
</tr>
</tbody>
</table>

Note: For the pnp transistor, replace $v_{BE}$ with $v_{EB}$.

- $i_C = \alpha i_E$
- $i_B = (1 - \alpha) i_E = \frac{i_E}{\beta + 1}$
- $i_C = \beta i_B$
- $i_E = (\beta + 1) i_B$
- $\beta = \frac{\alpha}{1 - \alpha}$
- $\alpha = \frac{\beta}{\beta + 1}$

$V_r =$ thermal voltage $= \frac{kT}{q} \simeq 25$ mV at room temperature
BJT base-emitter junction $i_C - v_{BE}$ characteristic (Fig. 6.16 on page 326): Note: This is true for silicon BJTs only and curve shown is for an NPN BJT.

![Graph of $i_C - v_{BE}$ characteristic](image)

Section 7.2.2 The BJT Case (pp. 399 to 401):

The $g_m$ of bipolar small-signal transistors varies widely, being proportional to the collector current. It has a typical range of 1 to 400 millisiemens. The input voltage change is applied between the base/emitter and the output is the change in collector current flowing between the collector/emitter with a constant collector/emitter voltage.

The transconductance for the bipolar transistor can be expressed as

$$g_m = I_C / V_T$$

where $I_C$ = DC collector current at the Q-point, and $V_T$ = thermal voltage, typically about 26 mV at room temperature.
BJT common-emitter $i_C - v_{CE}$ characteristic (Fig 6.20 on page 330): Note: Shows saturation, active and cutoff regions of operation.
The Early Effect (pp. 326 to 328):
Figure 6.18 on page 327:

This gives rise to the output resistance $r_o$ of a common-emitter BJT where $r_o = V_A / I_C$, with $V_A$ being the Early voltage as labeled in the figure above.