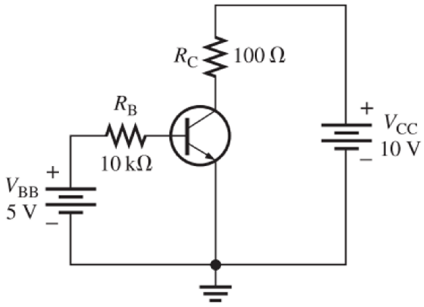
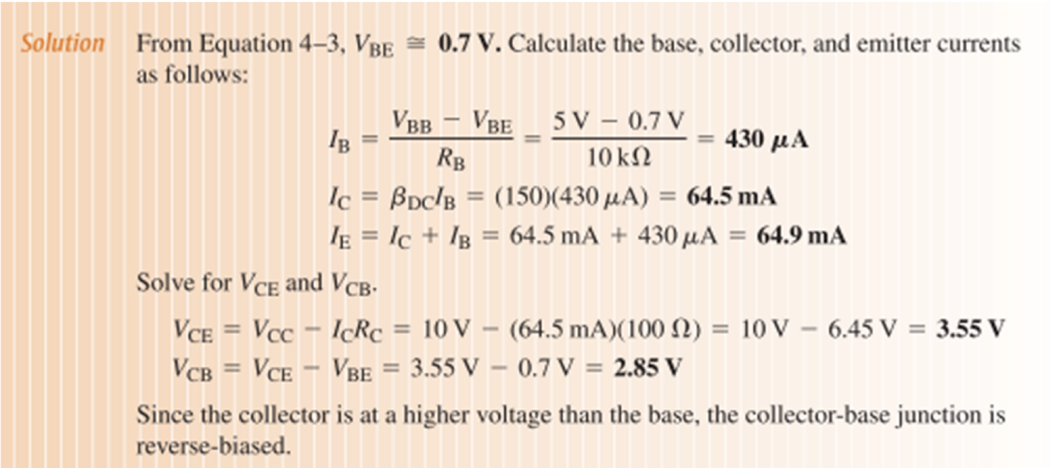
Electronic Engineering

Sheet # 4: Transistors

1- Determine IB, IC, IE, VBE, VCE, and VCB in the below circuit. The transistor has a β_{DC} = 150.





Solution From Equation 4–3, $V_{BE} \cong$ **0.7 V.** Calculate the base, collector, and emitter currents as follows:

$$I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{5\text{ V} - 0.7\text{ V}}{10\text{ k}\Omega} = \mathbf{430\ \mu A}$$

$$I_C = \beta_{DC} I_B = (150)(430\ \mu\text{A}) = \mathbf{64.5\ mA}$$

$$I_E = I_C + I_B = 64.5\text{ mA} + 430\ \mu\text{A} = \mathbf{64.9\ mA}$$

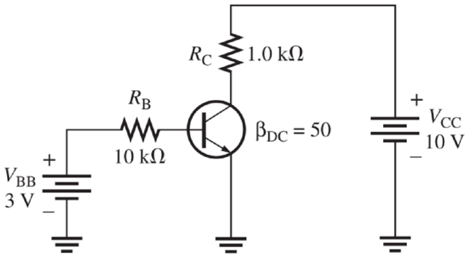
Solve for V_{CE} and V_{CB}.

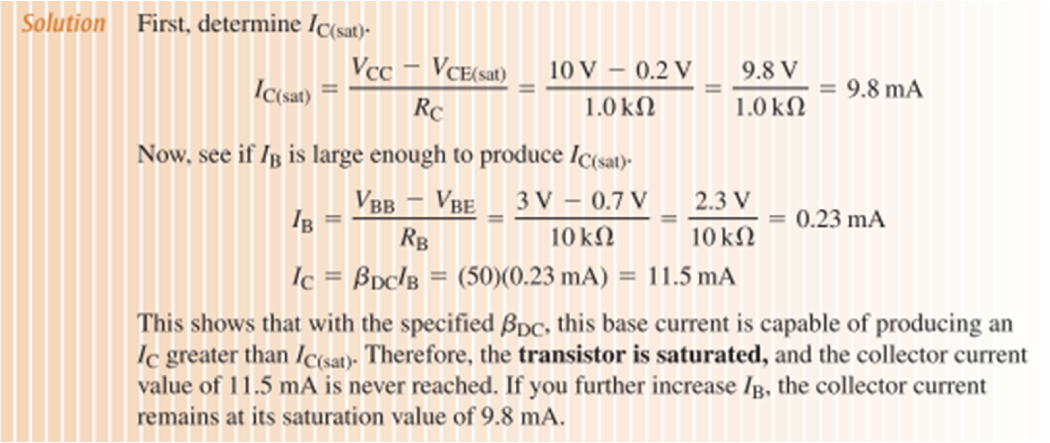
$$V_{CE} = V_{CC} - I_C R_C = 10\text{ V} - (64.5\text{ mA})(100\ \Omega) = 10\text{ V} - 6.45\text{ V} = \mathbf{3.55\ V}$$

$$V_{CB} = V_{CE} - V_{BE} = 3.55\text{ V} - 0.7\text{ V} = \mathbf{2.85\ V}$$

Since the collector is at a higher voltage than the base, the collector-base junction is reverse-biased.

2- Determine whether or not the transistor in the below figure is in saturation. Assume $V_{CE(sat)=}$0.2 V.





Solution First, determine $I_{C(sat)}$.

$$I_{C(sat)} = \frac{V_{CC} - V_{CE(sat)}}{R_C} = \frac{10\text{ V} - 0.2\text{ V}}{1.0\text{ k}\Omega} = \frac{9.8\text{ V}}{1.0\text{ k}\Omega} = 9.8\text{ mA}$$

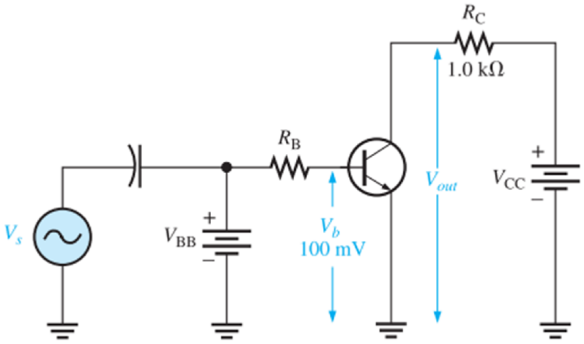
Now, see if I_B is large enough to produce $I_{C(sat)}$.

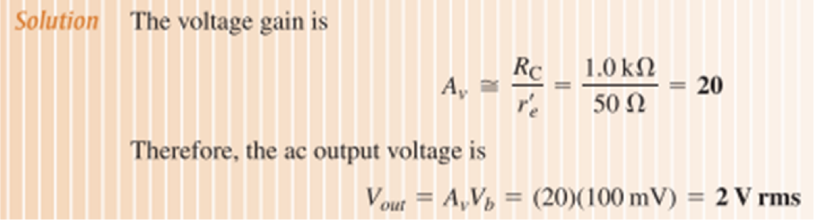
$$I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{3\text{ V} - 0.7\text{ V}}{10\text{ k}\Omega} = \frac{2.3\text{ V}}{10\text{ k}\Omega} = 0.23\text{ mA}$$

$$I_C = \beta_{DC} I_B = (50)(0.23\text{ mA}) = 11.5\text{ mA}$$

This shows that with the specified β_{DC}, this base current is capable of producing an I_C greater than $I_{C(sat)}$. Therefore, the **transistor is saturated,** and the collector current value of 11.5 mA is never reached. If you further increase I_B, the collector current remains at its saturation value of 9.8 mA.

3- Determine the voltage gain and the ac output voltage in the below figure if re’=50 ohm. Sketch the output voltage waveform.





Solution The voltage gain is

$$A_v \cong \frac{R_C}{r'_e} = \frac{1.0\text{ k}\Omega}{50\ \Omega} = \mathbf{20}$$

Therefore, the ac output voltage is

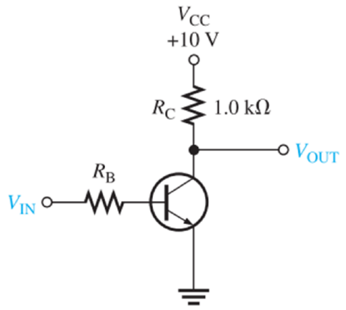
$$V_{out} = A_v V_b = (20)(100\text{ mV}) = \mathbf{2\text{ V rms}}$$

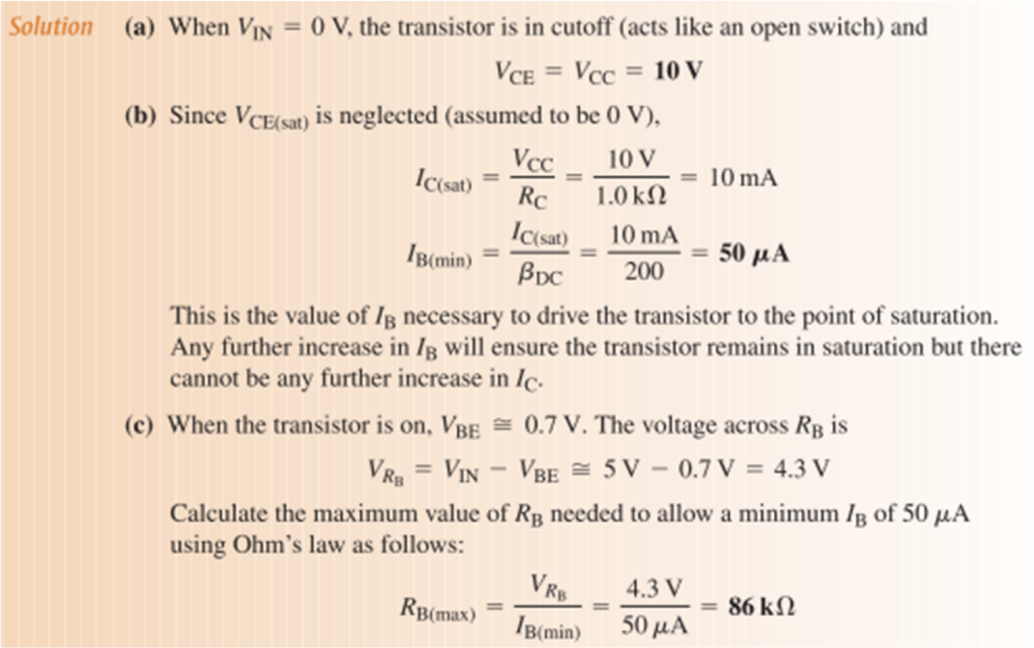
4- For the transistor circuit in the below figure:

a. what is V_{CE} when V_{IN} = 0 V?

b. What minimum value of I_B is required to saturate this transistor if β_{DC} is 200? Neglect $V_{CE(sat)}$.

c. Calculate the maximum value of R_B when V_{IN}= 5 V.





Solution **(a)** When $V_{IN} = 0$ V, the transistor is in cutoff (acts like an open switch) and

$$V_{CE} = V_{CC} = \mathbf{10\ V}$$

(b) Since $V_{CE(sat)}$ is neglected (assumed to be 0 V),

$$I_{C(sat)} = \frac{V_{CC}}{R_C} = \frac{10\ \text{V}}{1.0\ \text{k}\Omega} = 10\ \text{mA}$$

$$I_{B(min)} = \frac{I_{C(sat)}}{\beta_{DC}} = \frac{10\ \text{mA}}{200} = \mathbf{50\ \mu A}$$

This is the value of I_B necessary to drive the transistor to the point of saturation. Any further increase in I_B will ensure the transistor remains in saturation but there cannot be any further increase in I_C.

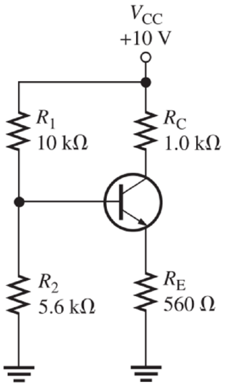
(c) When the transistor is on, $V_{BE} \cong 0.7$ V. The voltage across R_B is

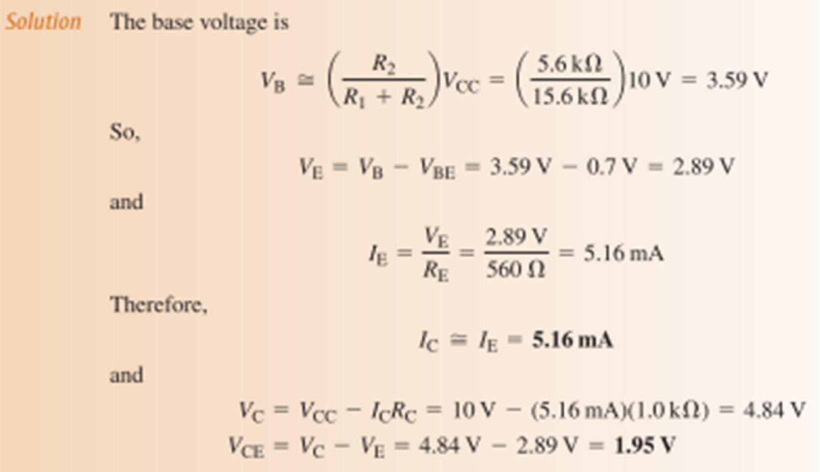
$$V_{R_B} = V_{IN} - V_{BE} \cong 5\ \text{V} - 0.7\ \text{V} = 4.3\ \text{V}$$

Calculate the maximum value of R_B needed to allow a minimum I_B of 50 μA using Ohm's law as follows:

$$R_{B(max)} = \frac{V_{R_B}}{I_{B(min)}} = \frac{4.3\ \text{V}}{50\ \mu\text{A}} = \mathbf{86\ k\Omega}$$

5- Determine VCE and IC in the stiff voltage-divider biased transistor circuit in the below figure if $\beta_{DC} = 100$.





Solution The base voltage is

$$V_B \cong \left(\frac{R_2}{R_1 + R_2}\right)V_{CC} = \left(\frac{5.6\text{ k}\Omega}{15.6\text{ k}\Omega}\right)10\text{ V} = 3.59\text{ V}$$

So,

$$V_E = V_B - V_{BE} = 3.59\text{ V} - 0.7\text{ V} = 2.89\text{ V}$$

and

$$I_E = \frac{V_E}{R_E} = \frac{2.89\text{ V}}{560\ \Omega} = 5.16\text{ mA}$$

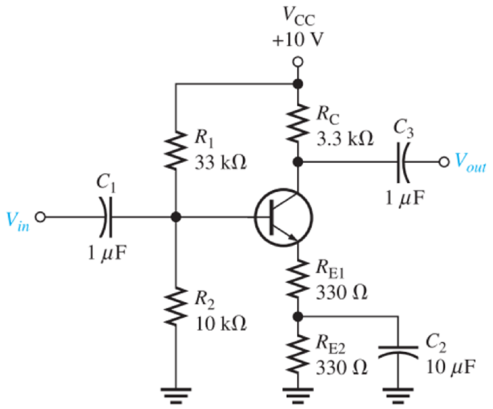
Therefore,

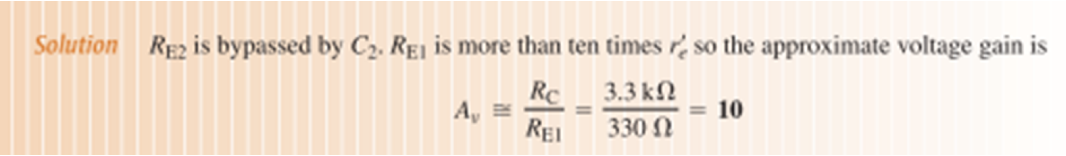
$$I_C \cong I_E = \mathbf{5.16\ mA}$$

and

$$V_C = V_{CC} - I_C R_C = 10\text{ V} - (5.16\text{ mA})(1.0\text{ k}\Omega) = 4.84\text{ V}$$
$$V_{CE} = V_C - V_E = 4.84\text{ V} - 2.89\text{ V} = \mathbf{1.95\ V}$$

6- Determine the voltage gain of the swamped amplifier in the below figure. Assume that the bypass capacitor has a negligible reactance for the frequency at which the amplifier is operated. Assume re'= 20 ohm.

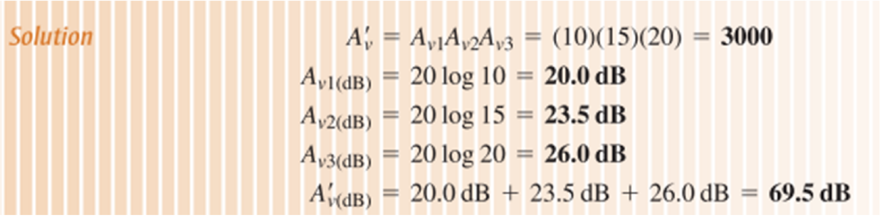




Solution R_{E2} is bypassed by C_2. R_{E1} is more than ten times r'_e so the approximate voltage gain is

$$A_v \cong \frac{R_C}{R_{E1}} = \frac{3.3\text{ k}\Omega}{330\ \Omega} = \mathbf{10}$$

7- A certain cascaded amplifier arrangement has the following voltage gains: A_{v1}=10, A_{v2} = 15, and A_{v3} = 20. What is the overall voltage gain? Also express each gain in decibels (dB) and determine the total voltage gain in dB.



Solution

$$A'_v = A_{v1}A_{v2}A_{v3} = (10)(15)(20) = \mathbf{3000}$$
$$A_{v1(\text{dB})} = 20\log 10 = \mathbf{20.0\ dB}$$
$$A_{v2(\text{dB})} = 20\log 15 = \mathbf{23.5\ dB}$$
$$A_{v3(\text{dB})} = 20\log 20 = \mathbf{26.0\ dB}$$
$$A'_{v(\text{dB})} = 20.0\text{ dB} + 23.5\text{ dB} + 26.0\text{ dB} = \mathbf{69.5\ dB}$$