Transistor Biasing Circuit (Q point and dc load line)

Objective

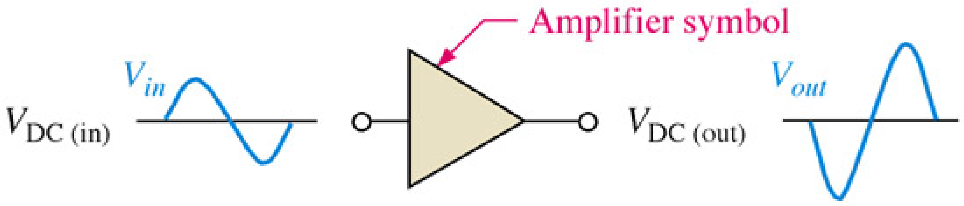
- To understand the concept of dc biasing of a transistor for linear operation.
- To determine Q point and dc load line.

Introduction

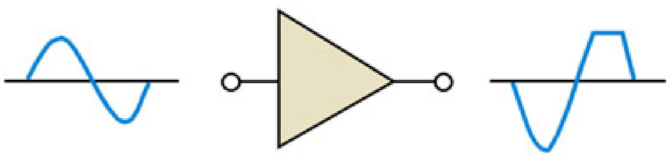
- For the transistor to properly operate it must be biased. There are several methods to establish the DC operating point. We will discuss some of the methods used for biasing transistors as well as troubleshooting methods used for transistor bias circuits.

Amplification

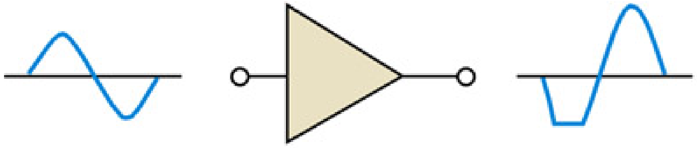
The goal of amplification in most cases is to increase the amplitude of an ac signal without altering it.



(a) Linear operation: larger output has same shape as input except that it is inverted

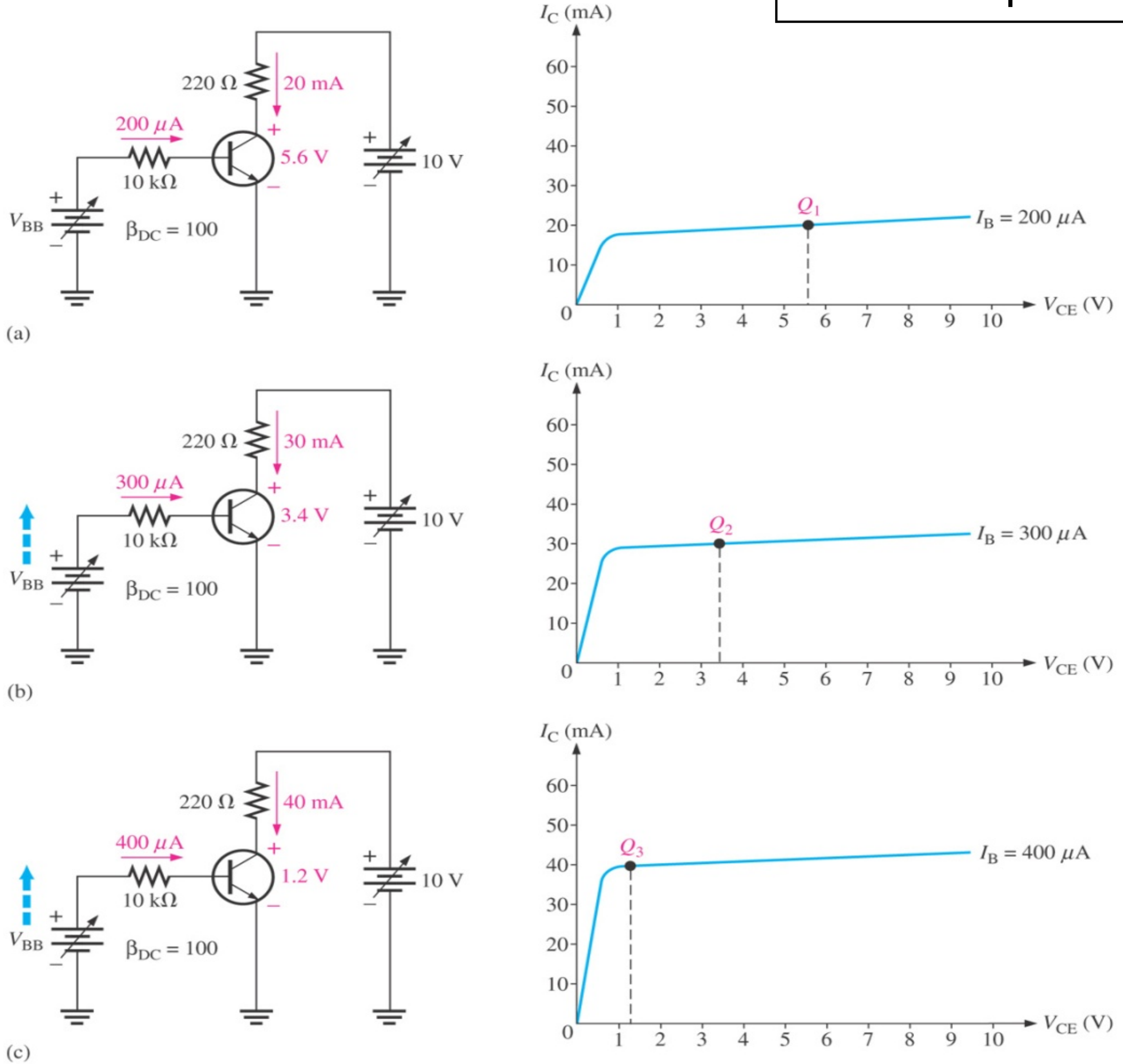


(b) Nonlinear operation: output voltage limited (clipped) by cutoff



(c) Nonlinear operation: output voltage limited (clipped) by saturation

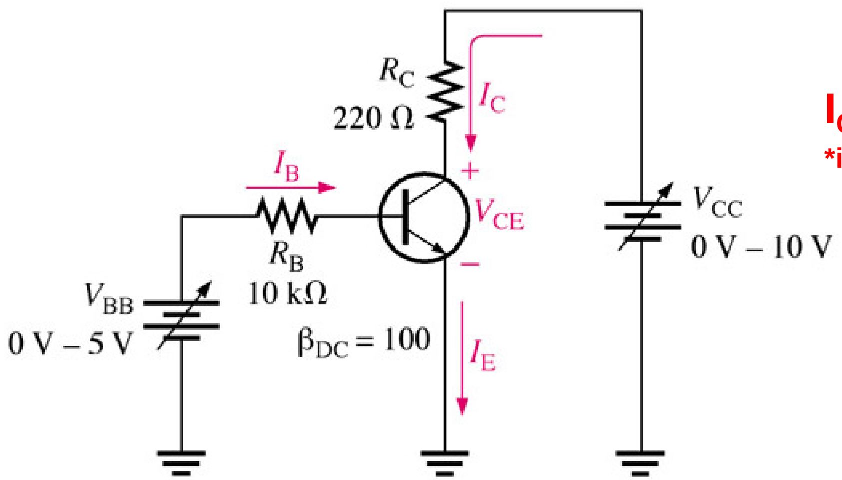
Different operating points



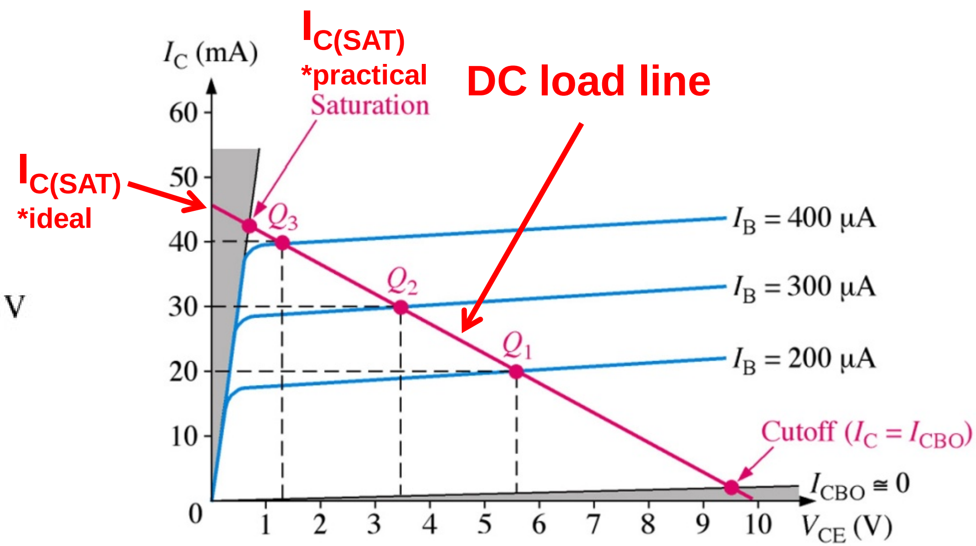
The DC Operating point

For a transistor circuit to amplify it must be properly biased with dc voltages. The dc operating point between saturation and cutoff is called the **Q-point.** The goal is to set the Q-point such that that it does not go into saturation or cutoff when an a ac signal is applied.

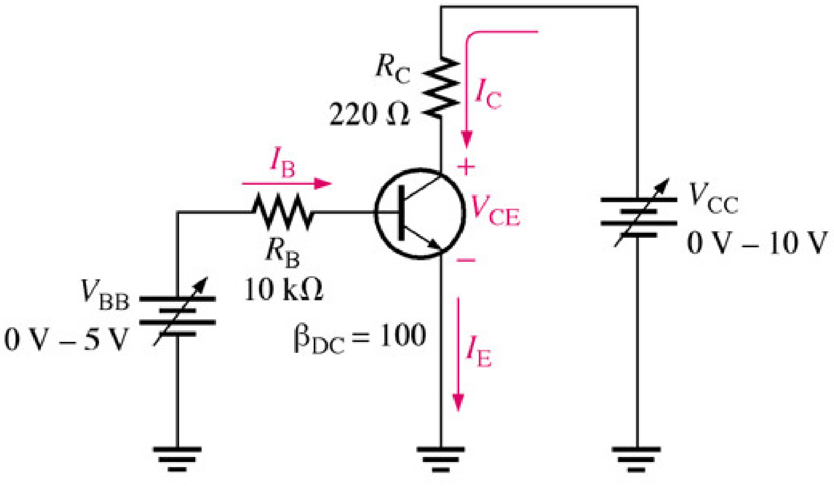
$$I_C = \frac{V_{CC} - V_{CE}}{R_C} = -\left(\frac{1}{R_C}\right)V_{CE} + \frac{V_{CC}}{R_C}$$



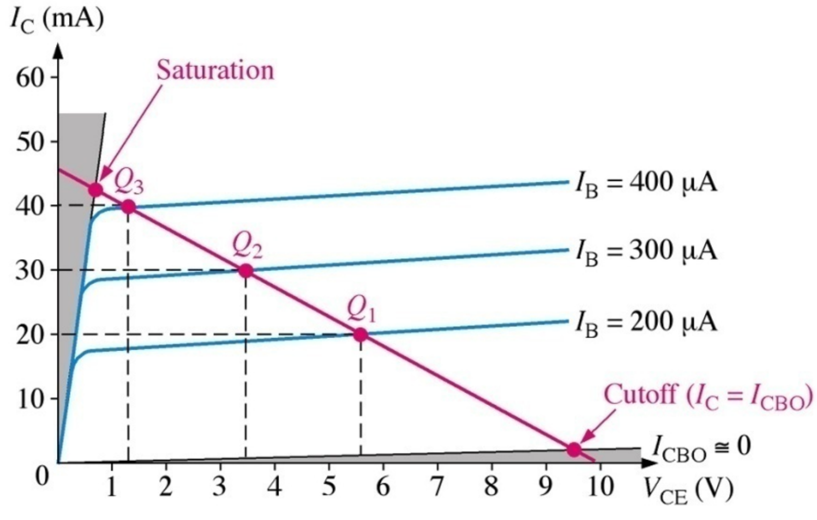
(a) DC biased circuit



Recall that the collector characteristic curves graphically show the relationship of collector current and V_{CE} for different base currents. With the **dc load line** superimposed across the collector curves for this particular transistor we see that 30 mA of collector current is best for maximum amplification, giving equal amount above and below the Q-point. Note that this is three different scenarios of collector current being viewed simultaneously.

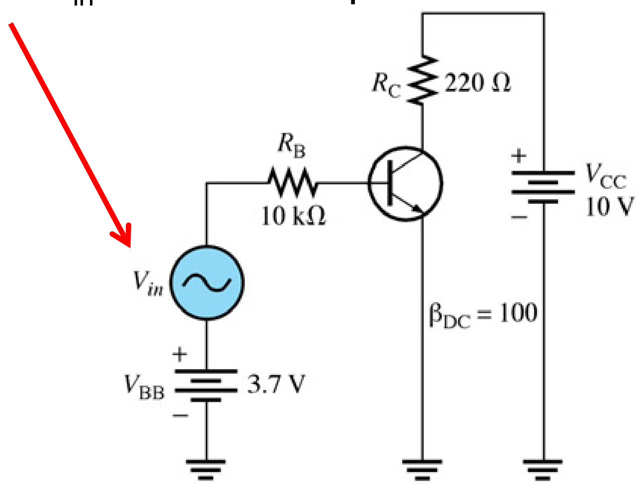


(a) DC biased circuit



With a good Q-point established, let's look at the effect a superimposed ac voltage has on the circuit. Note the collector current swings do not exceed the limits of operation(saturation and cutoff). However, as you might already know, applying too much ac voltage to the base would result in driving the collector current into saturation or cutoff resulting in a distorted or clipped waveform.

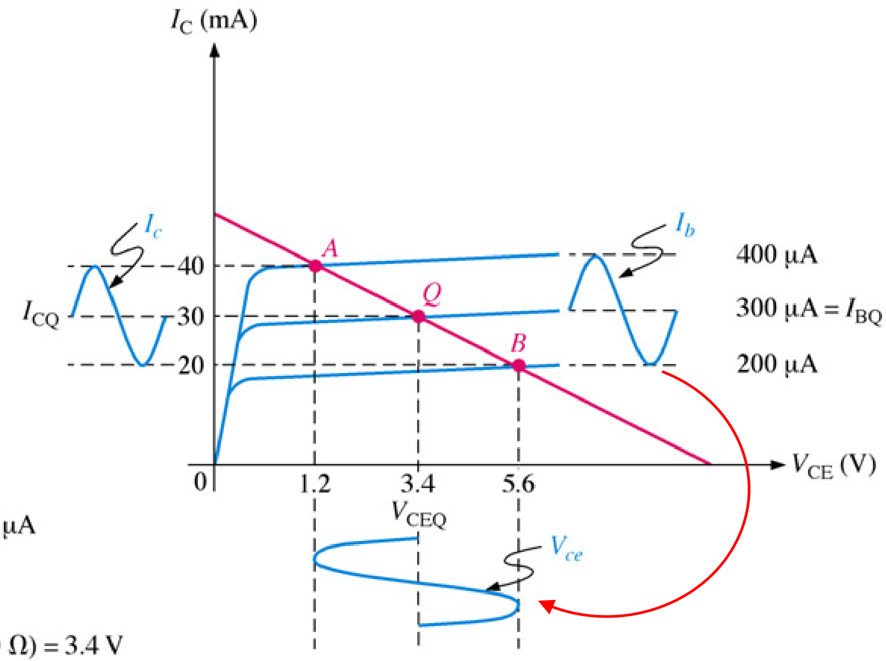
Assume V_{in} causes 100 µA variation

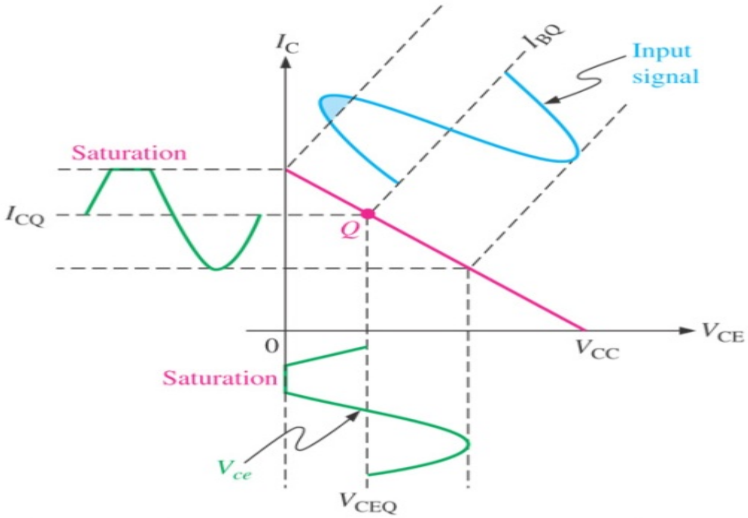


$$I_{BQ} = \frac{V_{BB} - 0.7\text{ V}}{R_B} = \frac{3.7\text{ V} - 0.7\text{ V}}{10\text{ k}\Omega} = 300\ \mu\text{A}$$

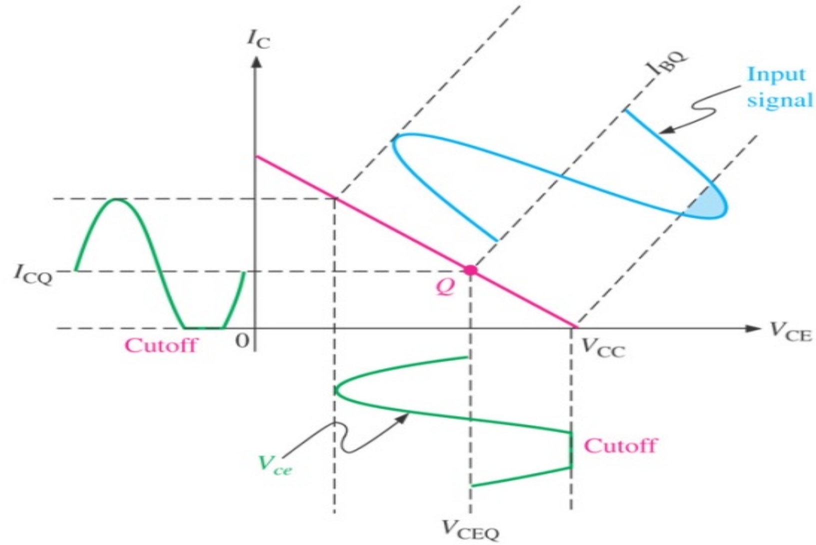
$$I_{CQ} = \beta_{DC} I_{BQ} = (100)(300\ \mu\text{A}) = 30\text{ mA}$$

$$V_{CEQ} = V_{CC} - I_{CQ}R_C = 10\text{ V} - (30\text{ mA})(220\ \Omega) = 3.4\text{ V}$$

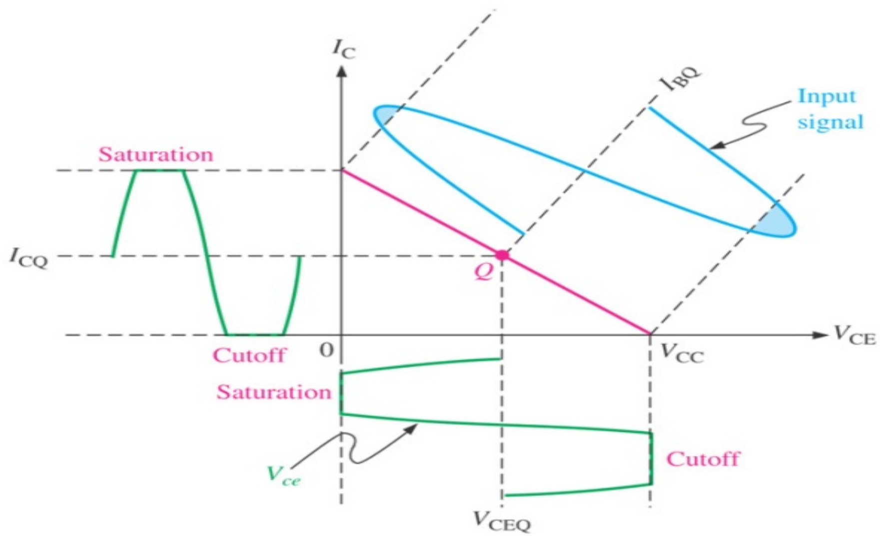




(a) Transistor is driven into saturation because the Q-point is too close to saturation for the given input signal.



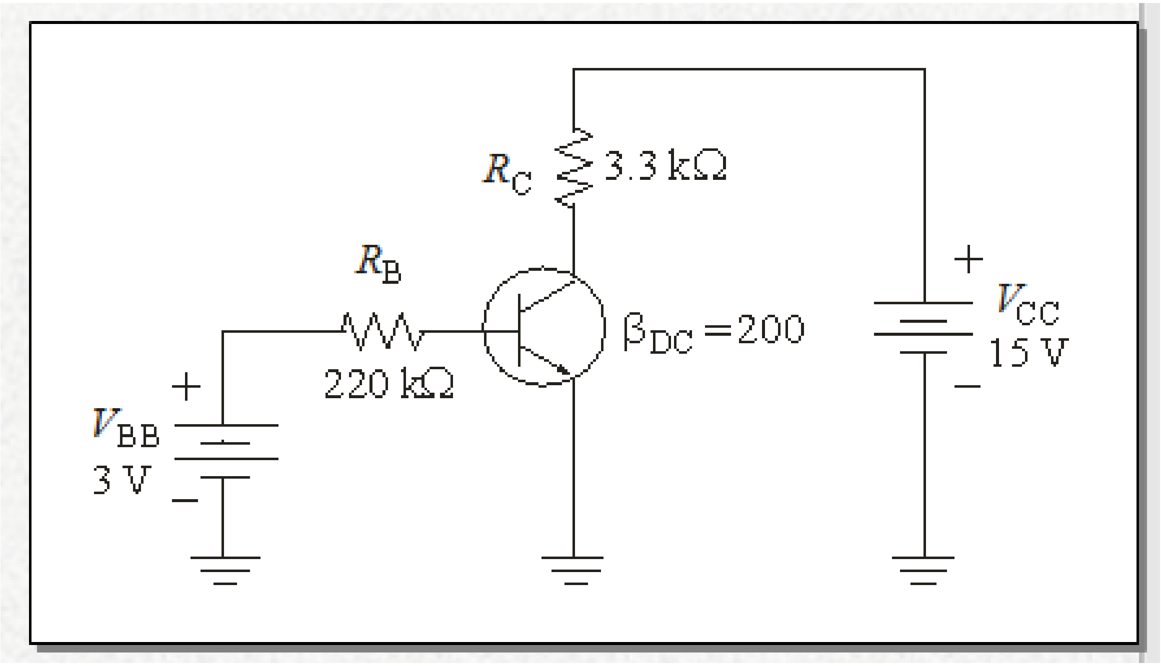
(b) Transistor is driven into cutoff because the Q-point is too close to cutoff for the given input signal.



(c) Transistor is driven into both saturation and cutoff because the input signal is too large.

Example(Review)

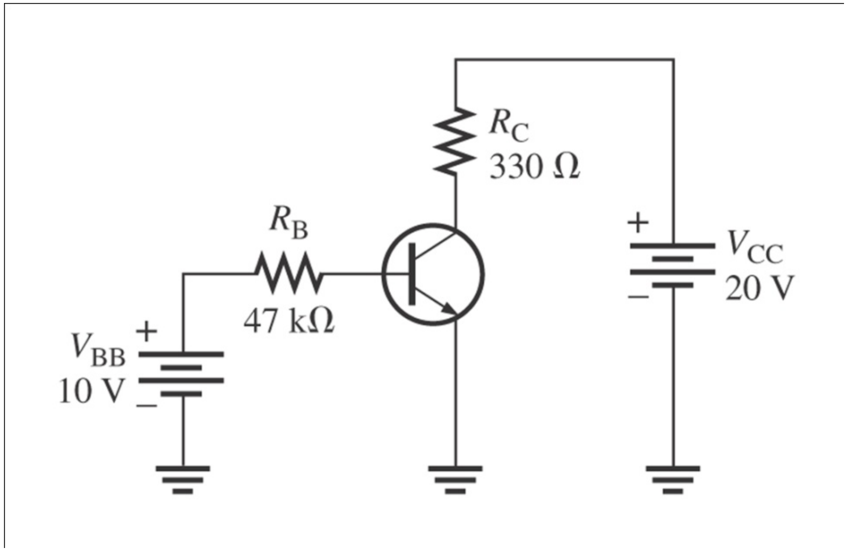
1. What is the saturation current and the cut-off for this circuit? Assume V_{CE}=0.2 V in saturation.
2. Is the transistor saturated?



Solution

Example

- Determine Q point and draw the dc load line. Assume $\beta_{DC} = 200$.
- Determine the maximum peak variation of I_C and I_B for linear operation(no distortion).



Conclusions

- The purpose of biasing is to establish a stable operating point (Q-point).
- The Q-point is the best point for operation of a transistor for a given collector current.
- The dc load line helps to establish the Q-point for a given collector current.
- The linear region of a transistor is the region of operation within saturation and cutoff.