SOLUTION Figure 6-11*b* shows the same circuit with grounds. The base current equals:

$$I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{10\text{ V} - 0.7\text{ V}}{1\text{ M}\Omega} = 9.3\ \mu\text{A}$$

The collector current is:

$$I_C = \beta_{dc} I_B = (300)(9.3\ \mu\text{A}) = 2.79\text{ mA}$$

and the collector-emitter voltage is:

$$V_{CE} = V_{CC} - I_C R_C = 10\text{ V} - (2.79\text{ mA})(2\text{ k}\Omega) = 4.42\text{ V}$$

The collector power dissipation is:

$$P_D = V_{CE} I_C = (4.42\text{ V})(2.79\text{ mA}) = 12.3\text{ mW}$$

Incidentally, when both the base and the collector supply voltages are equal, as in Fig. 6-11*b*, you usually see the circuit drawn in the simpler form of Fig. 6-11*c*.

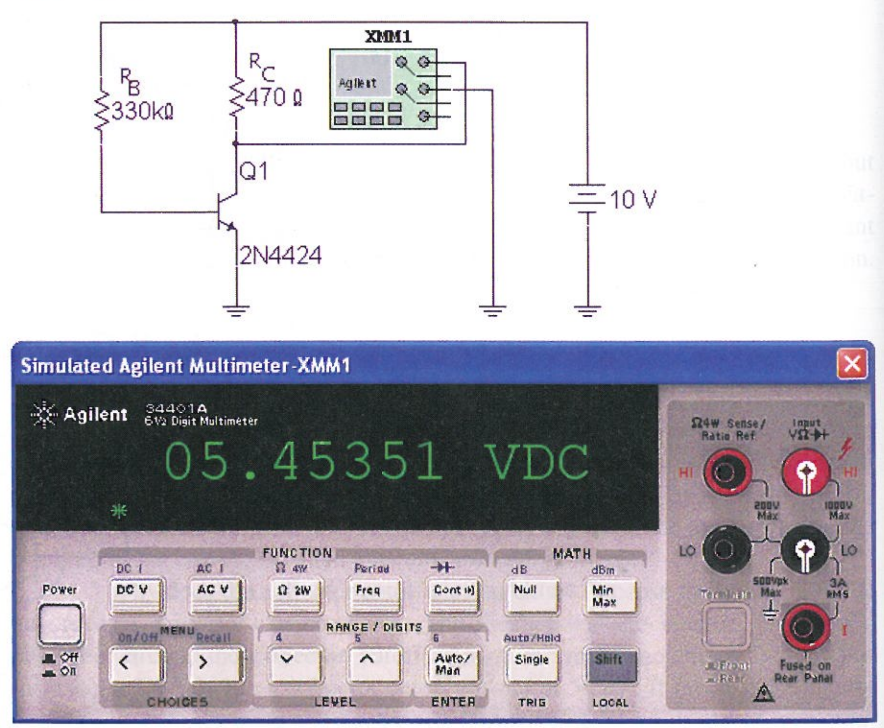
PRACTICE PROBLEM 6-5 Change R_B to 680 kΩ and repeat Example 6-5.

Example 6-6

MultiSim

Figure 6-12 shows a transistor circuit built on a computer screen with MultiSim. Calculate the current gain of the 2N4424.

Figure 6-12 MultiSim circuit for calculating current gain of 2N4424.



SOLUTION First, get the base current as follows:

$$I_B = \frac{10\text{ V} - 0.7\text{ V}}{330\text{ k}\Omega} = 28.2\ \mu\text{A}$$

Next, we need the collector current. Since the multimeter indicates a collector-emitter voltage of 5.45 V (rounded to three places), the voltage across the collector resistor is:

$$V = 10\text{ V} - 5.45\text{ V} = 4.55\text{ V}$$

Since the collector current flows through the collector resistor, we can use Ohm's law to get the collector current:

$$I_C = \frac{4.55\text{ V}}{470\ \Omega} = 9.68\text{ mA}$$

Now, we can calculate the current gain:

$$\beta_{dc} = \frac{9.68\text{ mA}}{28.2\ \mu\text{A}} = 343$$

The 2N4424 is an example of transistor with a high current gain. The typical range of β_{dc} for small-signal transistors is 100 to 300.

PRACTICE PROBLEM 6-6 Using MultiSim, change the base resistor of Fig. 6-12 to 560 kΩ and calculate the current gain of the 2N4424.

6-7 Transistor Approximations

Figure 6-13*a* shows a transistor. A voltage V_{BE} appears across the emitter diode, and a voltage V_{CE} appears across the collector-emitter terminals. What is the equivalent circuit for this transistor?

Ideal Approximation

Figure 6-13*b* shows the ideal approximation of a transistor. We visualize the emitter diode as an ideal diode. In this case, $V_{BE} = 0$. This allows us to calculate base current quickly and easily. This equivalent circuit is often useful for troubleshooting when all we need is a rough approximation of base current.

As shown in Fig. 6-13*b*, the collector side of the transistor acts like a current source that pumps a collector current of $\beta_{dc} I_B$ through the collector resistor. Therefore, after you calculate the base current, you can multiply by the current gain to get the collector current.

GOOD TO KNOW

A bipolar transistor is frequently used as a constant current source.

The Second Approximation

Figure 6-13*c* shows the second approximation of a transistor. This is more commonly used because it may improve the analysis significantly when the base-supply voltage is small.

This time we use the second approximation of a diode when calculating base current. For silicon transistors, this means that $V_{BE} = 0.7$ V. (For germanium transistors, $V_{BE} = 0.3$ V.) With the second approximation, the base and collector currents will be slightly less than their ideal values.