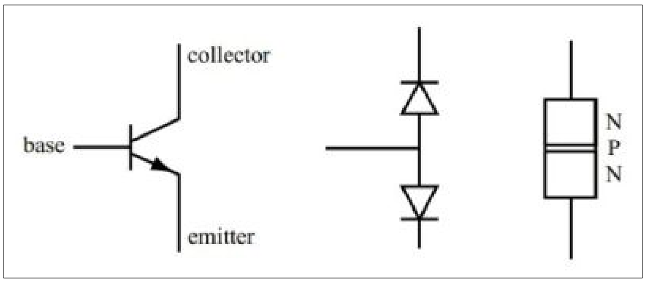
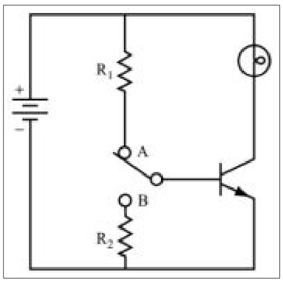
Transistor Switches.

The transistor is one of the most important modern electronic components, playing a major role in all kind of electrical circuits. One of these roles consists in acting similar to a mechanical switch, conducting electric current or not, depending on how it is connected within the circuit and on the value of the current, flowing into (for some transistors out of) the one of its leads, called the **base**. The 2 other leads are respectively called the **collector** and the **emitter**.



The picture shows a NPN bipolar junction transistor (BJT), as all those used in the DCircuits2 program. To get current flow (switch on), base and collector must have positive voltage, the emitter being connected to the minus pole of the battery.

When you connect the base and the collector to the battery, currents flowing through the circuit demonstrate the so called transistor action: if **base current** (I_B) flows in a transistor, **collector current** (I_C) will also flow. It is a property of the transistor that the ratio of collector current to base current is constant. The collector current is always much larger than the base current. The ratio of the two currents is called the **current gain** (β) of the transistor. Typical values of β range from 10 to 300.



The transistor circuits shown in the DCircuits2 program are supposed to produce a given current through a lamp. The resistance of the lamp is referred to as the load and the current, in this case, is called **load current** (I_L). With battery voltage V_S, load current I_L and current gain β of the transistor given, the problem to solve is to determine the base resistance (R_1) needed to produce the load current wanted.

In actual practice, there is a very small voltage drop across the transistor from the collector to the emitter. This is really a saturation voltage and is the smallest voltage drop that can occur across a transistor when it is ON as ‘‘hard’’ as possible. In the DCircuits2 program, this voltage drop is considered to be a negligible value and, therefore, the **collector voltage** is said to be 0V. For a quality switching transistor, this is a safe assumption. Thus, if the load is known as R_L, the load current is given by $I_L = V_S / R_L$ and the collector current may be assumed being equal to the load current: $I_C = I_L$.

The base current is given by $I_B = I_C / \beta$ and the base resistance, we want to determine will be given by $R_1 = V_S / I_B$. This is true if the **base-emitter voltage** drop is ignored (default option in the program); otherwise this voltage has to be subtracted from V_S. If you look at the transistor picture, you see that this voltage is equal to the one dropped on the base-emitter diode, which is a constant value for a given material: 0.7V for silicon, 0.3V for germanium.

If the mechanical switch at the circuit picture is at position B, the base of the transistor is connected via the resistor R_2 to the minus pole of the battery; there is no base current and by this there will be no collector current either (switch off). Suitable values for R_2 to keep the transistor turned off are 1kΩ to 1MΩ, for convenience you often choose $R_2 = R_1$.

The program DCircuits2 includes switch circuit examples with 1, 2 or 3 transistors. In the case of several transistors, the collector current of transistor Q_{n-1} serves as base current for transistor Q_n. Thus, having determined I_{Bn}, you may assume that: $I_{Cn-1} = I_{Bn}$.

Resistors are manufactured with “**standard resistance values**.” The DCircuits2 program includes an option to determine the base resistances as standard values instead of the exact values calculated. This option also applies to the program’s test mode. In this case, you may use the standard resistors table in the “Help” menu to determine the resistance you have to enter: calculate the exact resistance value and then choose the nearest standard value from the table; e.g. 235 kΩ => 240 kΩ, 1.65 MΩ => 1.6 MΩ.

The calculations considered here are only valid if the transistor is in the **saturation region** of its operation. Saturation is the state of a BJT transistor in which the collector current has reached a maximum and becomes independent of the base current; in this case, the equation $I_C = \beta I_B$ is no longer true. The program DCircuits2 actually doesn’t check for this condition, thus if you choose a very small load, the calculation result will be incorrect in the sense that the circuit’s load current would be higher than the transistor’s saturation current and so could never be reached.