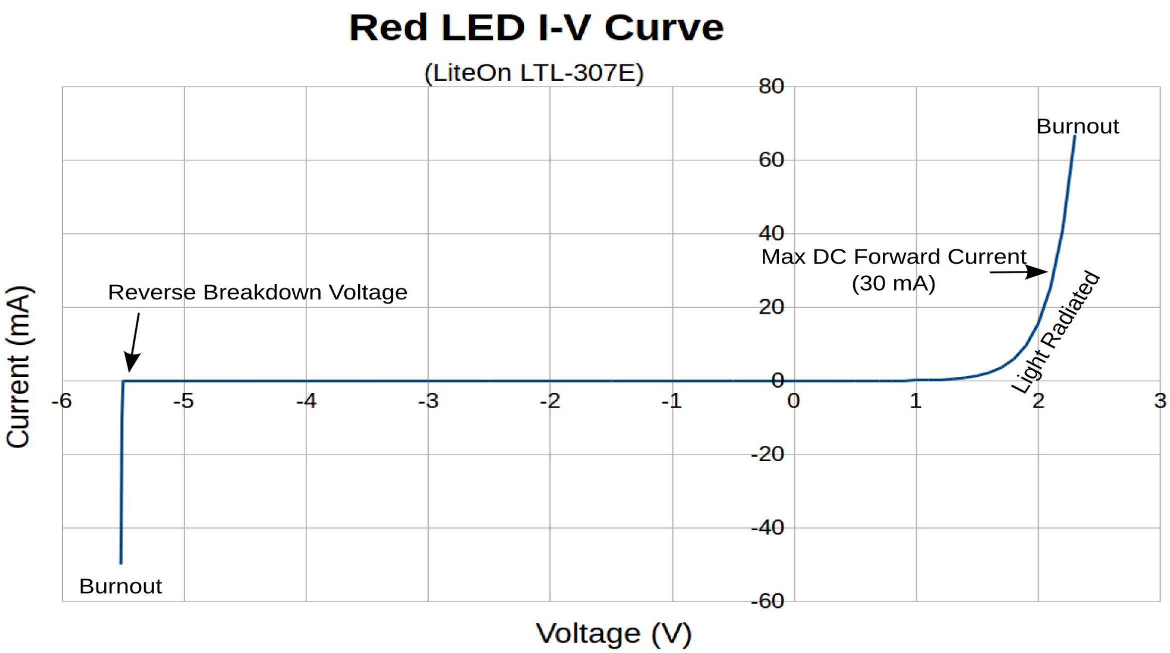
# Using LEDs

Light-emitting diodes are easily burned out because they are highly non-linear devices; a very slight excess in voltage above their nominal operating voltage will cause their current to increase beyond the maximum limit. The following graph shows the current-voltage curve for an LED similar to that supplied with the CanaKit:




In a great simplification, a diode is a one-way valve for electricity; it lets current flow in one direction (forward direction) and not in the opposite direction (reverse direction). In reality, it is more complicated. A voltage applied in the forward direction must exceed a threshold value before the current flows. Beyond that value the current increases very rapidly for small increases in forward voltage. For LEDs that threshold voltage depends on LED color, but is usually around 2 V.

Also, when a reverse voltage is applied, very little current flows until a particular value (the breakdown voltage) is reached. Then suddenly a large current flows, and often the diode burns out.

If the LED with the $I(V)$ curve shown above is directly connected to 3.3 V in its forward direction (its shorter lead toward the positive supply), it will burn out. The current through it will exceed its 30 mA maximum specification. Putting a 220 Ω resistor in series with the LED is a suitable solution. The LED current can be determined by requiring that the voltage across the resistor plus the voltage across the LED equals 3.3 V:

$$I \times (220\,\Omega) + V(I) = 3.3\text{ V}$$

We can solve this non-linear by guessing that $I$=10 mA so that $V(I)$=1.9 V and the left-hand side of the equation becomes 4.1 V. That was a bad guess. Now try $I$=5 mA so the $V(I)$= 1.8 V and the left-hand side is 2.9 V. The answer must be a bit higher than 5 mA, maybe 6.3 mA.

If instead, the 220 Ω resistor were used with the LED and a 5.0 V source, the answer would be about 14 mA.

There is one other thing to check. The resistor is rated at a maximum power of 250 mW. The power lost in the resistor is given by the formula

$$P = I^2 R$$

where $I$ is the current through the resistor. In this case, the power is only

$$(0.014\text{ A})^2 \cdot (220\,\Omega) = 0.043\text{ W} = 43\text{ mW} \quad ,$$

much less than 250 mW, so the resistor will not overheat.