

Working with Temperatures in Mathcad

Unit Systems in Mathcad

Most unit conversions are very easy in Mathcad because the units are direct multiplications into the other unit system.

$$1 \cdot \text{kg} = 2.205 \text{ lb}$$

$$5 \cdot \text{kg} = 11.023 \text{ lb}$$

In the example above, 1 kg equals 2.205 lb, so 5 kg is 5 times the number of equivalent pounds. The same holds true for converting most other units.

Mathcad's default unit system is SI (International System of Units). You can change unit systems in Mathcad through the **Tools** menu, under **Worksheet Options**, and the **Unit Tab**.

To convert units in individual equations, such as in the example above, just click on the unit placeholder, and type in the unit that you want, or if you don't know the unit, use the **Insert > Unit** menu item.

Converting Temperature Units

To convert temperature from one unit system to another, you don't simply multiply by a conversion factor. You must also add or subtract a constant. For example, to convert from Celsius to Fahrenheit, you first add 32 degrees and then multiply by 9/5. These type of units are called affine scaling units, because it combines a linear and a multiplication relationship.

You can write Mathcad functions to do the conversion from Fahrenheit to Celsius:

Fahrenheit to Celsius

$$\text{tempF} := 68$$

$$\text{Cel}(\text{tempF}) := (\text{tempF} - 32) \cdot \frac{5}{9}$$

$$\text{Cel}(\text{tempF}) = 20$$

Celsius to Fahrenheit

$$\text{tempC} := 20$$

$$\text{Far}(\text{tempC}) := (\text{tempC}) \cdot \frac{9}{5} + 32$$

$$\text{Far}(\text{tempC}) = 68$$

Mathcad Custom Characters

An easier way to convert temperatures is to use Mathcad Custom Characters from the **Custom Characters** toolbar.



Because the relationship between Fahrenheit and Celsius degrees is not a direct multiplied relationship, you can't multiply the unit placeholder

$$100 \cdot \text{°C} = \blacksquare$$

Instead enter the degrees Fahrenheit or Celsius directly from the Custom Characters toolbar or **Insert Unit** menu.

$$100 \text{ °C} = 373.15 \text{ K}$$

You get the degrees in Kelvin, which is Mathcad's default unit of temperature. To convert in this instance to Celsius, just click on the units placeholder and enter the degrees Celsius from the toolbar or **Insert Unit** menu.

$$100 \text{ °C} = 212 \text{ °F}$$

$$0 \text{ °C} = 32 \text{ °F}$$

Entering Negative Temperatures

To enter a negative temperature, you must select the *entire* number before inserting the temperature unit. Otherwise, the entire expression is negated.

The entire expression is negated, which is clearly false as the unit conversion shows:

$$-10\text{ }^{\circ}\text{F} = -260.93\text{ K}$$

$$-10\text{ }^{\circ}\text{F} = -929.34\text{ }^{\circ}\text{F}$$

Below the entire temperature is selected before applying the temperature unit. Mathcad automatically adds the parentheses:



$$(-10)\text{ }^{\circ}\text{F} = 249.817\text{ K}$$

$$(-10)\text{ }^{\circ}\text{F} = -10\text{ }^{\circ}\text{F}$$

Note: To type the degree symbol in a math region, press [**Alt**] **017 6** on the **Number** keypad (not the numbers on the main keyboard) with Num Lock on. Another option is to use the new Mathcad UniMath font distributed with Mathcad 14 and search for degree in the Charmap accessories.

Temperature Change Units

Mathcad includes change units for calculating changes in temperature, $\Delta^{\circ}\text{F}$ and $\Delta^{\circ}\text{C}$. You can insert these Delta temperature units from the **Insert Unit** menu by choosing the dimension Temperature. They must be used to calculate changes in temperature.

The unit $\Delta^{\circ}\text{F}$ is equal to

$$\Delta^{\circ}\text{F} = \frac{5}{9} \text{K}$$

Note: On both the Kelvin and Rankine scale 0° is equal to absolute zero. One degree in Rankine is equal to one Fahrenheit degree. One Kelvin degree is equal to one Celsius degree.

$$\Delta^{\circ}\text{F} = 1 \text{R}$$

$$\Delta^{\circ}\text{C} = 1 \text{K}$$

Temperature change units are required to find the change between two temperatures.

Right: $10^{\circ}\text{F} + 10 \cdot \Delta^{\circ}\text{F} = 20^{\circ}\text{F}$

Wrong: $10^{\circ}\text{F} + 10^{\circ}\text{F} = 479.67^{\circ}\text{F}$

Temperature change units are required when you add two temperatures, because doing so implies a change from the current temperature. In the equation below the change is represented on the right-hand side.

Right: $10^{\circ}\text{F} - 10^{\circ}\text{F} = 0 \Delta^{\circ}\text{F}$

Wrong: $10^{\circ}\text{F} - 10^{\circ}\text{F} = -459.67^{\circ}\text{F}$

Temperature change units *can* be used in combination with other units. It's important to distinguish between a temperature change and an absolute temperature when you enter or convert temperature results. For example, calculate the temperature at which an electronic component fails:

$$T_{amb} := 25 \text{ }^\circ\text{C} \quad \text{ambient temperature}$$

$$\theta_{JA} := 10 \cdot \frac{\Delta^\circ\text{C}}{\text{W}} \quad \text{temperature rise per watt}$$

$$P_d := 13 \cdot \text{W} \quad \text{Maximum power rating}$$

The temperature at which the component fails is given by

$$T_{fail} := T_{amb} + \theta_{JA} \cdot P_d$$

$$T_{fail} = 428.15 \text{ K} \quad \text{in degrees Kelvin, or}$$

$$T_{fail} = 155 \text{ }^\circ\text{C} \quad T_{fail} = 311 \text{ }^\circ\text{F}$$

Note that many material properties and component specifications, such as the temperature rise per watt, or the specific heat, and others, are given as change in temperature per quantity or quantity per change in temperature. If you are doing a calculation given in degrees Kelvin, and you wish to convert results into Celsius or Fahrenheit, you may need to use the $\Delta^\circ\text{C}$ and $\Delta^\circ\text{F}$ unit functions.