# FE simulation: Consistent Units

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4. Specifying model data in inconsistent units will yield results that are **not physically meaningful**
5. Inappropriate units may cause numerical problems during solution (round-off errors)

# System of units: the basics

**Fundamental Units: the SI system**

The fundamental units used in the SI system are the following:

- Mass [M], specified in kilograms
- Length [L], specified in meters
- Time [T], specified in seconds
- Temperature [$\Theta$] , specified in degrees Kelvin (or Celsius)
- Electric current [A], specified in amperes

**Derived Units**

These quantities are derived from the fundamental units.
Typical derived units in the SI system are:

- Force (in Newtons) = MassAcceleration = $ML/T^2$
- Density = Mass/Volume = $M/L^3$
- Stress or Pressure (in Pascals) = Force/Area = $(ML/T^2)/L^2 = M/LT^2$
- Work, Energy, or Unit of Heat (in Joules) = ForceLength = $ML^2/T^2$
- Power (in Watts) = Energy/Time = $ML^2/T^3$
- Electrical Charge (in Coulombs) = CurrentTime = $AT$

# Typical consistent set of units

| System: | MKS | mmNS | FPS | IPS |
|---|---|---|---|---|
| Length | m | mm | ft | in |
| Time | sec | sec | sec | sec |
| Mass | Kg | tonne | slug | lbf-sec$^2$ |
| Force | N | N | lbf | lbf |
| Temperature | $^\circ$C | $^\circ$C | $^\circ$F | $^\circ$F |
| Area | m$^2$ | mm$^2$ | ft$^2$ | in$^2$ |
| Volume | m$^3$ | mm$^3$ | ft$^3$ (cu-ft) | in$^3$ (cu-in) |
| Velocity | m/sec | mm/sec | ft/sec | in/sec |
| Acceleration | m/sec$^2$ | mm/sec$^2$ | ft/sec$^2$ | in/sec$^2$ |
| Angle, rotation | rad | rad | rad | rad |
| Angular Velocity | rad/sec$^2$ | rad/sec$^2$ | rad/sec$^2$ | rad/sec$^2$ |
| Mass density | Kg/m$^3$ | Tonne/mm$^3$ | slug/ft$^3$ | lbf-sec$^2$/in$^4$ |
| Moment, torque | N-m | N-mm | ft-lbf | in-lbf |
| Line load | N/m | N/mm | lbf/ft | lbf/in |
| Surface load | N/m$^2$ | N/mm$^2$ | lbf/ft$^2$ | lbf/in$^2$ |
| Stress, pressure | Pa | MPa | | Psi |
| Youngs modulus | Pa | MPa | | Psi |
| Thermal exp. coef. | /$^\circ$C (/K) | /$^\circ$C (/K) | /$^\circ$F (/K) | /$^\circ$F (/K) |
| Beam cross-section inertia $I$ | m$^4$ | mm$^4$ | ft$^4$ | in$^4$ |
| Energy, Work, Heat | J | mJ | ft-lbf | in-lbf |
| Power, heat transfer rate $\dot{Q}$ | W | mW | ft-lbf/sec | in-lbf/sec |
| Temperature gradient | $^\circ$C/m | $^\circ$C/mm | $^\circ$F/ft | $^\circ$F/in |
| Heat flux | W/m$^2$ | mW/mm$^2$ | lbf/ft-sec | lbf/in-sec |
| Therm. conductivity | W/m-$^\circ$C | mW/mm-$^\circ$C | lbf/sec-$^\circ$F | lbf/sec-$^\circ$F |
| Specific heat $C_p$ | J/Kg-$^\circ$C | mJ/tonne-$^\circ$C | ft-lbf/slug-$^\circ$F | in$^2$/sec$^2$-$^\circ$F |

# Unit conversion table 1

## SI to other metric units

| | SI (m, k, s) | Metric (mm, k, s) | Metric (cm, g, s) |
|---|---|---|---|
| Time | second (s) | second (s) | second (s) |
| Length meter | 1 meter (m) | 1000 millimeter (mm) | 100 centimeter (cm) |
| Velocity | 1 m/s | 1000 mm/s | 100 cm/s |
| Acceleration | 1 $m/s^2$ | 1000 $mm/s^2$ | 100 $cm/s^2$ |
| Mass | 1 kilogram (kg) | 1.0e-3 tonnes | 1000 gram (g) |
| Density | 1 kg/m3 | 1.0e-12 $tonnes/mm^3$ | 1.0e-3 $g/cm^3$ |
| Force | 1 Newton (N) | 1 Newton (N) | 1.0e5 dyne (dyn) |
| Moment | 1 $N \cdot m$ | 1000 $N \cdot mm$ | 1.0e7 $dyn \cdot cm$ |
| Stress/Pressure | 1 Pascal (Pa) | 1.0e-6 $N/mm^2$ | 10 $dyn/cm^2$ |
| Energy | 1 Joule (J) | 1000 millijoule (mJ) | 1.0e7 erg |
| Power | 1 Watt (W) | 1000 milliwatt | 1.0e7 erg/s |

# Unit conversion table 2

## SI to English units

| | SI (m, k, s) | English (inch, lbf, s) | English (foot, lbf, s) |
|---|---|---|---|
| Time | second (s) | second (s) | second (s) |
| Length | 1 meter (m) | 39.370 inches (in) | 3.2808 feet (f) |
| Velocity | 1 m/s | 39.370 in/s | 3.2808 f/s |
| Acceleration | 1 $m/s^2$ | 39.370 $in/s^2$ | 3.2808 $f/s^2$ |
| Mass | 1 kilogram (kg) | 5.7100e-3 lbf $s^2/in$ | 6.8522e-2 slugs |
| Density | 1 $kg/m^3$ | 9.3572e-8 lbf $s^2/in^4$ | 1.9403e-3 $slug/ft^3$ |
| Force | 1 Newton (N) | 0.22481 lbf | 0.22481 lbf |
| Moment | 1 N·m | 8.8508 lbf·in | 0.73756 lbf·ft |
| Stress/Pressure | 1 Pascal (Pa) | 1.4504e-4 $lbf/in^2$ | 2.0885e-2 $lbf/ft^2$ |
| Energy | 1 Joule (J) | 8.8507 lbf·in | 0.73756 lbf·ft |

Note: lbf = pound force

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4. In Abaqus: use Tool $\Rightarrow$ Query $\Rightarrow$ Distance to verify the units