ThermophysicalData

Maple 2021 enhances the ThermophysicalData package with reference atmosphere models. These describe how air pressure, temperature, density, and molecular weight typically change with altitude.

```
> restart :
  with(ThermophysicalData)
```

[*Atmosphere*, *Chemicals*, *CoolProp*, *PHTChart*, *Property*, *PsychrometricChart*, *TemperatureEntropyChart*] **(1)**

Two models are available—the 1976 US Standard Atmosphere (the default), and the International Standard Atmosphere.Both are similar but are valid between different altitude limits.

Altitude can be specified as geopotential (the default) or geometric. Geopotential altitude adjusts for the variation in gravity with altitude.

```
> Atmosphere(3 km, all, altitudetype = geopotential)
```

$268.6500\ \mathrm{K},\ 70108.52215\ \mathrm{Pa},\ 0.9091219586\ \frac{\mathrm{kg}}{\mathrm{m}^3},\ 328.5779005\ \frac{\mathrm{m}}{\mathrm{s}},\ 0.00001693718731\ \mathrm{Pa\ s}$ **(2)**

```
> Atmosphere(3 km, all, altitudetype = geometric)
```

$268.6591984\ \mathrm{K},\ 70121.13970\ \mathrm{Pa},\ 0.9092544424\ \frac{\mathrm{kg}}{\mathrm{m}^3},\ 328.5835256\ \frac{\mathrm{m}}{\mathrm{s}},\ 0.00001693764616\ \mathrm{Pa\ s}$ **(3)**

Altitude is assumed to be in meters if no units are provided.

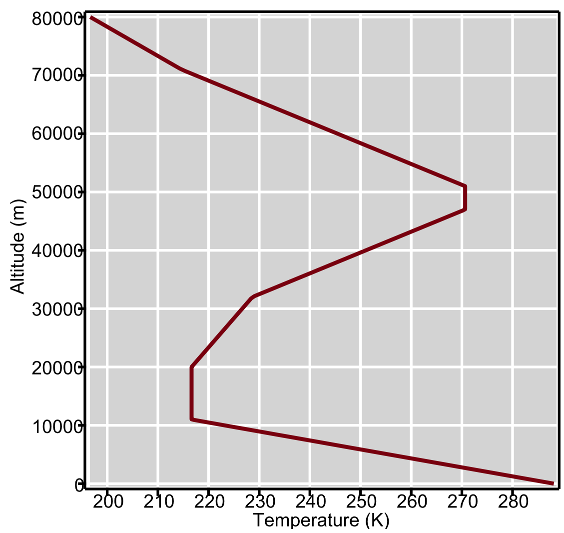
```
> Atmosphere(3000, all, altitudetype = geometric)
```

268.6591984, 70121.13970, 0.9092544424, 328.5835256, 0.00001693764616 **(4)**

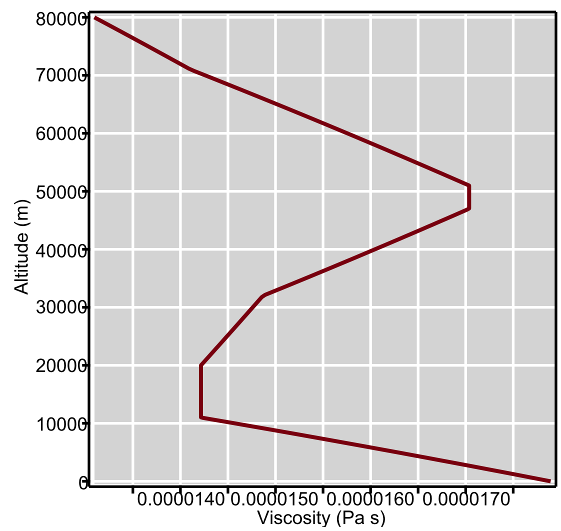
Here we plot air temperature, viscosity, density, pressure, and speed of sound as functions of altitude.

```
> plotOpts := size = [400, 400], background = "LightGrey", axis = [gridlines = [10, color
      = white]], titlefont = [Arial, 16], axesfont = [Arial], labelfont = [Arial, 12], axes = boxed,
      labeldirections = [horizontal, vertical] :
```

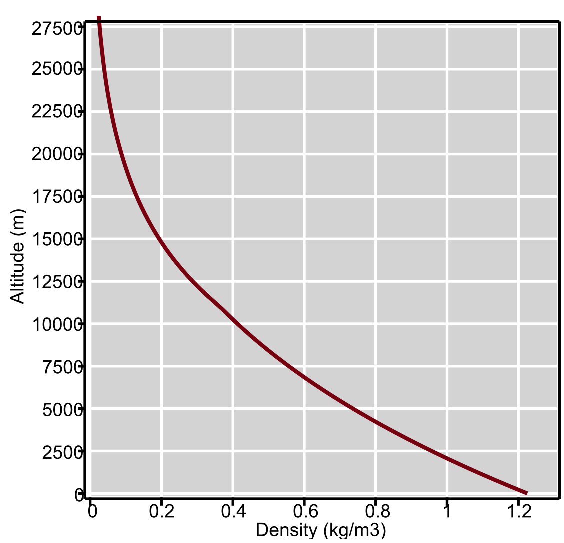
> *plot*([*Atmosphere*(*x*, "temperature"), *x*, *x* = 0 ..80000], *labels* = ["Temperature (K)", "Altitude (m)"], *plotOpts*)



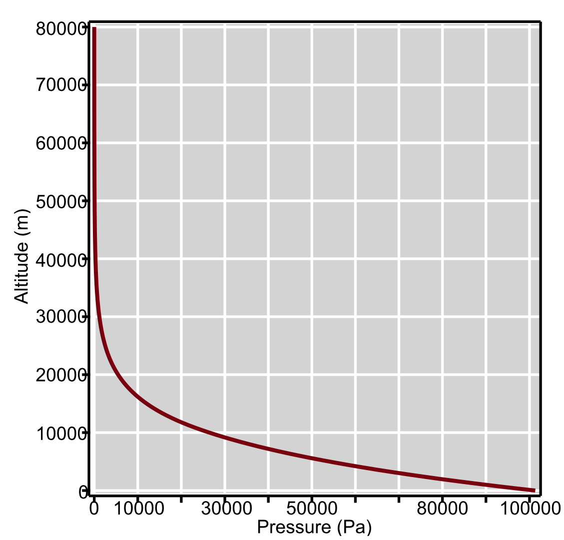
> *plot*([*Atmosphere*(*x*, "viscosity"), *x*, *x* = 0 ..80000], *labels* = ["Viscosity (Pa s)", "Altitude (m)"], *plotOpts*)



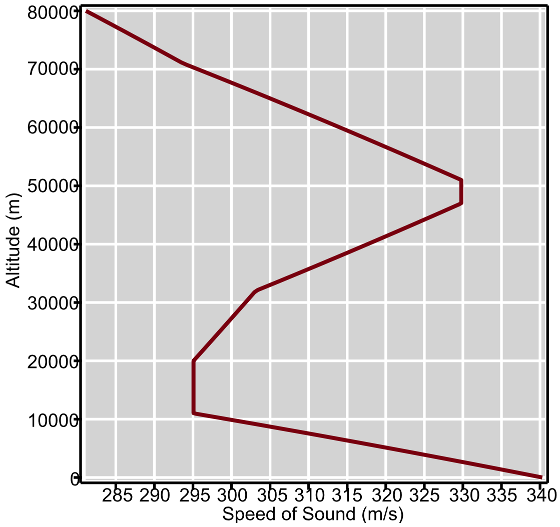
> *plot*([*Atmosphere*(*x*, "density"), *x*, *x* = 0 ..80000], *labels* = ["Density (kg/m3)", "Altitude (m)"], *plotOpts*)



> *plot*([*Atmosphere*(*x*, "pressure"), *x*, *x* = 0 ..80000], *labels* = ["Pressure (Pa)", "Altitude (m)"], *plotOpts*)



> *plot*([*Atmosphere*(*x*, "speedofsound"), *x*, *x* = 0 ..80000], *labels* = ["Speed of Sound (m/s)", "Altitude (m)"], *plotOpts*)



A skydiver free-falls through the atmosphere. The descent is modeled by this differential equation.

> $de := m \frac{d^2}{dt^2} y(t) = -m \cdot g + \frac{1}{2} A \cdot Cd \cdot \rho(t) \cdot vel(t)^2, vel(t) = -\frac{d}{dt} y(t) :$

where

- m is mass
- g is gravity
- Cd is the drag coefficient
- ρ(t) is the air density

Air density ρ varies with altitude.

> $\rho := t \rightarrow Atmosphere\text{:-}Property(\text{"density"}, y(t)) :$

Define the other parameters:

> $A := 1 : m := 85 : Cd := 0.58 : g := 9.8 :$

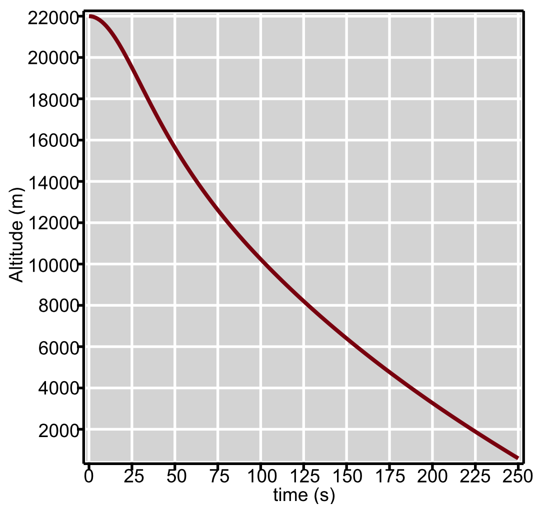
vNumerically solve the differential equation.

> $sol := dsolve(\{de, vel(0) = 0, y(0) = 22000, \mathrm{D}(y)(0) = 0\}, numeric, known = \{Atmosphere{:-}Property\}, range = 0..250)$

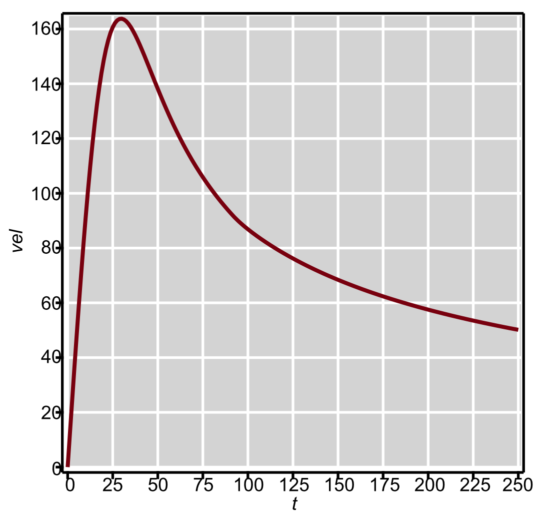
$$sol := \mathbf{proc}(x\_rkf45\_dae)\ \ldots\ \mathbf{end\ proc} \tag{5}$$

Plot the altitude vs. time, velocity vs. time, and velocity vs. altitude.

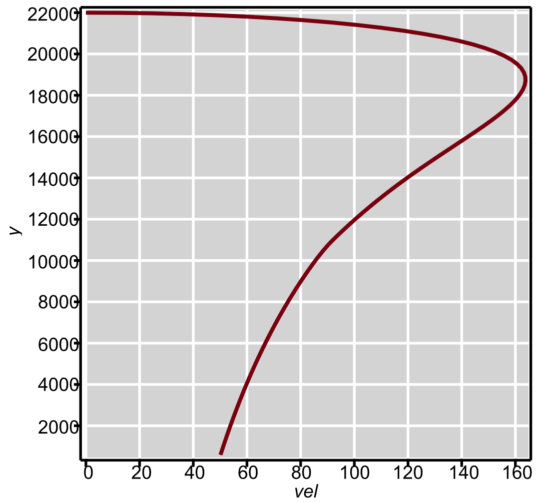
> $plots{:-}odeplot(sol, [t, y(t)], t = 0..250, labels = [\text{"time (s)"}, \text{"Altitude (m)"}], plotOpts)$



> $plots{:-}odeplot(sol, [t, vel(t)], t = 0..250, plotOpts)$



> $plots{:-}odeplot(sol, [vel(t), y(t)], t = 0..250, plotOpts)$



22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
y
0
20
40
60
80
100
120
140
160
vel