Simulating a Rocket Launch

Fluxion Example Description

1 Physical Background

This example simulates the start of a rocket launch until all the fuel is consumed. First, we must consider all the forces acting on the rocket.
The physically interesting thing about a rocket is that it is an object with a mass that varies over time. Therefore, Newton's Second Law does not simplify to its usual form:

$$F = m \cdot a \tag{1}$$

Because in general:

$$F = \dot{p} = m \cdot a + \dot{m} \cdot v \tag{2}$$

Two forces act on the rocket altogether. Of course, one is the weight:

$$F_g = -m \cdot \hat{g} \tag{3}$$

and the thrust:

$$F_s = \Delta mT \cdot u \tag{4}$$

which is given as a momentum change resulting from the ejected fuel (u is the ejection speed of the fuel relative to the rocket). The net force is then given by the sum of the two forces.

As previously noted, the mass of the rocket changes over time (fuel is constantly being ejected). We take this fact into account through the following equation:

$$mT' = -\Delta mT \tag{5}$$

Where ΔmT is the rocket's fuel consumption rate, i.e. dmT/dt.

2 Simulation

In the simulation, in addition to the relationships described above, the total mass of the rocket is calculated. In addition, variable parameters for the mass of the rocket m_R, the mass of the initial fuel m_{T_0}, the fuel flow rate ΔmT and the ejection speed u are introduced. The termination condition is set as whenever m_T <0, i.e. the simulation ends when the tank is empty.

To make sure that the mass of the remaining fuel does not become negative (in case a different termination condition is chosen), we use a Conditional Variable, mTH, which is equal to the current fuel quantity if it is greater than zero, and otherwise equals zero.

Since there is an analogous problem with the thrust force, we use a second conditional variable. The thrust force FsH is equal to the real thrust force F_s, provided that the remaining mass is greater than zero, otherwise it is equal to zero.

The plots show by default the altitude h of the rocket and the amount of remaining fuel mTH as a function of time.

If the termination condition $m_T < 0$ is omitted, then you can watch the rocket fall back to the ground and "crash" ;)