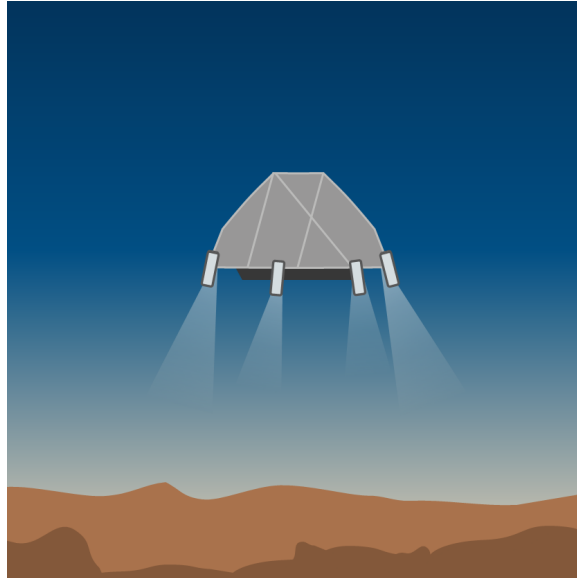


# Mars Rover Landing



In the final stages of a landing on Mars, the rover descends under retrothrust of its descent engine to a height of 5 m above the Martian surface where it has a downward speed of 2 m/s. Compute the impact speed  $v$  of the rover with the surface if the engine is immediately shut down at this point. Assume gravity on Mars is 0.38 times Earth's gravity and take  $g_{\text{earth}} = 10 \text{ m/s}^2$ .

*Using known expressions:*

$$a = \frac{dv}{dt} \Rightarrow dv = a dt \quad (1)$$

$$\int_{v_0}^v dv = a \int_0^t dt \quad (2)$$

$$v(t) = a \cdot t + v_0 \quad (3)$$

$$v = \frac{ds}{dt} \Rightarrow ds = v dt = (v_0 + at) dt \quad (4)$$

$$\int_{s_0}^s ds = \int_0^t (v_0 + at) dt \quad (5)$$

$$s(t) = \frac{1}{2} a \cdot t^2 + v_0 \cdot t + s_0 \quad (6)$$

*Given:*

Gravitational acceleration on Earth:  $g = 10m/s^2$

Gravitational acceleration on Mars:  $g_{mars} = 0.38 \cdot g = 3.8m/s^2$

Initial downward velocity:  $v_0 = -2m/s$

Distance above surface:  $h = s_0 = 5m$

The time it takes to reach the surface can be calculated using Equation 6, with  $g_{mars}$  is pointing downward, and take the origin of the coordinate system at the ground (hence  $s(t_{end}) = 0m$ ).

$$s(t) = \frac{1}{2}a \cdot t^2 + v_0 \cdot t + s_0 \Rightarrow \frac{1}{2} \cdot -3.8 \cdot t^2 + -2 \cdot t + 5 = 0 \quad (7)$$

From this  $t$  can be calculated using:

$$t = \frac{2 \pm \sqrt{(-2)^2 - 4 \cdot \frac{-3.8}{2} \cdot 5}}{-3.8} = -2.23s \quad \vee \quad 1.18s \quad (8)$$

Inserting  $t = 1.18s$  in Equation 3 gives the velocity at the surface.

$$v(t) = a \cdot t + v_0 \Rightarrow v(1.18) = -3.8 \cdot 1.18 - 2 = -6.48m/s \quad (9)$$

Thus the impact speed at the surface is  $v = 6.48m/s$  pointing in the downward direction.