Chapter 4 Problem 54 †

Given
$v_0 = 5.0\ m/s$
$\theta = 20°$
$a_y = -g_{moon} = -1.60\ m/s^2$

Solution
How long will the rover be 'airborne' after hitting the bump?

First convert the speed into scalar components using unit vectors.

$$\vec{v}_0 = v_0 \cos\theta\ \hat{\imath} + v_0 \sin\theta\ \hat{\jmath}$$

$$\vec{v}_0 = (5.0\ m/s)\cos(20°)\ \hat{\imath} + (5.0\ m/s)\sin(20°)\ \hat{\jmath} = \{4.70\ \hat{\imath} + 1.71\ \hat{\jmath}\}\ m/s$$

Since we are only interested in the time where the rover is not in contact with the lunar surface, we only need to focus on the y-direction. Assuming the landing point is at the same elevation as the launch point, we know that $y_0 = 0\ m$ and $y_f = 0\ m$. Now use the third kinematic equation

$$y_f = y_0 + v_{y0}t + \tfrac{1}{2}a_y t^2$$

$$0 = 0 + v_{y0}t - \tfrac{1}{2}g_{moon}t^2$$

$$0 = v_{y0}t - \tfrac{1}{2}g_{moon}t^2$$

Notice that we can factor t out of each term.

$$0 = t\left(v_{y0} - \tfrac{1}{2}g_{moon}t\right)$$

For the equation to be true, each term must equal zero. This gives two solutions.

$$0 = t$$

$$0 = v_{y0} - \tfrac{1}{2}g_{moon}t$$

$$\tfrac{1}{2}g_{moon}t = v_{y0}$$

$$t = \frac{2v_{y0}}{g_{moon}}$$

Substituting in the initial vertical velocity of the rover and the acceration due to gravity on the moon gives

$$t = \frac{2(1.71\ m/s)}{1.60\ m/s^2}$$

$$t = 2.14\ s$$

The first solution, $t = 0\ s$, is when the rover leaves the surface. The second solution, $t = 2.1\ s$ is when it lands again.

Although it was not asked in this problem, we can easily find the horizontal distance traveled while the rover is not in contact with the surface. Since there is no acceleration in the x-direction, the distance equals

$$x = x_0 + v_{x0}t = 0 + (4.70\ m/s)(2.14\ s) = 10.0\ m$$

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†Problem from University Physics by Ling, Sanny and Moebs (OpenStax)