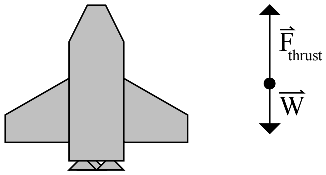
Chapter 4 Problem 33 †



Given

$m = 630\ Mg = 630 \times 10^6\ g = 6.30 \times 10^5\ kg$
$v_0 = 0\ m/s$
$v_f = 7200\ km/h$
$\Delta t = 2.0\ min = 120\ s$

Solution

a) Find the thrust of the Ares I engine.

Find convert the final velocity into m/s.

$$v_f = \frac{7200\ km}{hr}\left(\frac{1\ hr}{3600\ s}\right)\left(\frac{1000\ m}{1\ km}\right) = 2000\ m/s$$

Next calculate the average acceleration of the rocket

$$a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{\Delta t} = \frac{2000\ m/s - 0\ m/s}{120\ s} = 16.67\ m/s^2$$

The two forces acting on the rocket are the thrust and the weight. From Newton's 2nd law

$$\Sigma \vec{F} = \vec{F}_{thrust} + \vec{W} = m\vec{a}$$

Solving for thrust gives

$$\vec{F}_{thrust} = m\vec{a} - \vec{W}$$

The weight vector is

$$\vec{W} = -mg\hat{j}$$

and the acceleration upward at $16.67\ m/s^2$ is represented as the vector

$$\vec{a} = 16.67\ m/s^2\hat{j}$$

This makes the force of thrust

$$\vec{F}_{thrust} = m\vec{a} - \vec{W} = ma\hat{j} - (-mg\hat{j})$$
$$\vec{F}_{thrust} = ma\hat{j} + mg\hat{j} = m(a+g)\hat{j} \tag{1}$$
$$\vec{F}_{thrust} = (6.30 \times 10^5\ kg)(16.67\ m/s^2 + 9.80\ m/s^2)\hat{j}$$
$$\vec{F}_{thrust} = (6.30 \times 10^5\ kg)(26.47\ m/s^2)\hat{j} = 1.67 \times 10^7\ \hat{j}\ N$$

b) Find the force on an astronaut with a mass of $75\ kg$.

The astronaut is accelerating at the same rate as the shuttle, so formula (1) is still applicable except with a mass of $75\ kg$.

$$\vec{F}_{astronaut} = (75\ kg)(16.67\ m/s^2 + 9.80\ m/s^2)\hat{j}$$
$$\vec{F}_{astronaut} = (75\ kg)(26.47\ m/s^2)\hat{j} = 1.98 \times 10^3\ \hat{j}\ N$$

†Problem from Essential University Physics, Wolfson