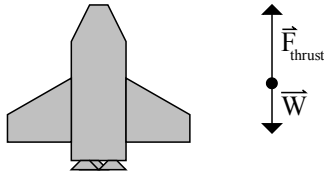


Chapter 4 Problem 31 †



Given

$$m = 630 \text{ Mg} = 630 \times 10^6 \text{ g} = 6.30 \times 10^5 \text{ kg}$$

$$v_0 = 0 \text{ m/s}$$

$$v_f = 7200 \text{ km/h}$$

$$\Delta t = 2.0 \text{ min} = 120 \text{ s}$$

Solution

a) Find the thrust of the Ares I engine.

Find convert the final velocity into m/s .

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

Next calculate the average acceleration of the rocket

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

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

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

Solving for thrust gives

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

The weight vector is

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

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

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

This makes the force of thrust

$$\vec{F}_{\text{thrust}} = m\vec{a} - \vec{W} = ma\hat{j} - (-mg\hat{j})$$

$$\vec{F}_{\text{thrust}} = ma\hat{j} + mg\hat{j} = m(a + g)\hat{j}$$

$$\vec{F}_{\text{thrust}} = (6.30 \times 10^5 \text{ kg})(16.67 \text{ m/s}^2 + 9.80 \text{ m/s}^2)\hat{j}$$

$$\vec{F}_{\text{thrust}} = (6.30 \times 10^5 \text{ kg})(26.47 \text{ m/s}^2)\hat{j} = 1.67 \times 10^7 \hat{j} \text{ N}$$

(1)

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 .

$$\vec{F}_{\text{astronaut}} = (75 \text{ kg})(16.67 \text{ m/s}^2 + 9.80 \text{ m/s}^2)\hat{j}$$

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

†Problem from Essential University Physics, Wolfson