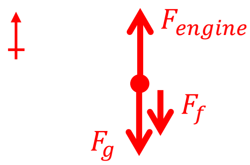
Problems

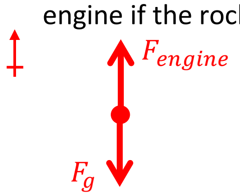
1. A model rocket of mass 4.80 x 10^2 g accelerates vertically upward at 34.0 m/s^2 during launch, overcoming both gravity and air resistance.
   a) Draw a free-body diagram of the rocket during launch.



   b) Calculate the magnitude of the thrust force applied by the rocket engine during launch if the air resistance acting on the rocket is 2.40 N.

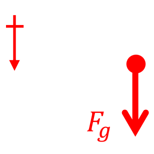
$$\sum F_y = F_{engine} - F_g - F_f = ma$$
$$F_{engine} = ma + F_g + F_f$$
$$F_{engine} = ma + mg + F_f$$
$$F_{engine} = m(a + g) + F_f$$
$$F_{engine} = (0.480\ kg)(34.0\ m/s^2 + 9.8\ m/s^2) + (2.40\ N)$$
$$F_{engine} = (0.480\ kg)(43.8\ m/s^2) + (2.40\ N)$$
$$F_{engine} = 21.024\ N + (2.40\ N)$$
$$F_{engine} = 23.424\ N$$
$$F_{engine} = 23\ N$$

2. A tiny model rocket of mass 8.40 g is fired directly upward inside an evacuated chamber (no air resistance).
   a) Draw an FBD and determine the magnitude of the upward force that must be supplied by its engine if the rocket is to accelerate at 3.8 m/s^2.



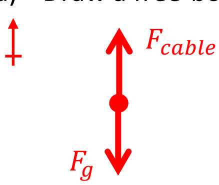
$$\sum F_y = F_{engine} - F_g = ma$$
$$F_{engine} = ma + F_g$$
$$F_{engine} = m(a + g)$$
$$F_{engine} = (0.0084\ kg)(3.8\ m/s^2 + 9.8\ m/s^2)$$
$$F_{engine} = 0.11424\ N$$
$$F_{engine} = 0.11\ N$$

   b) If the engines suddenly stopped functioning, draw a new FBD and determine the acceleration of the rocket.



$$\sum F_y = F_g = ma$$
$$ma = F_g$$
$$a = g$$
$$a = 9.8\ m/s^2 \qquad a = 9.8\ m/s^2[\downarrow]$$

3. An elevator and its contents have a combined mass of 6500 kg. It is suspended by a single cable.
   a) Draw a free-body diagram of the elevator.



b) What force must the cable exert on the elevator when it is at rest?

$$\sum F_y = F_{cable} - F_g = ma$$
$$F_{cable} - F_g = 0\ m/s^2$$
$$F_{cable} = F_g$$
$$F_{cable} = mg$$
$$F_{cable} = (6500\ kg)(9.8\ m/s^2)$$
$$F_{cable} = 63700\ N$$
$$F_{cable} = 6.8 \times 10^4\ N[\uparrow]$$

c) What force must the cable exert on the elevator when it is moving upward at 2.0 m/s^2?

$$\sum F_y = F_{cable} - F_g = ma$$
$$F_{cable} = ma + F_g$$
$$F_{cable} = ma + mg$$
$$F_{cable} = (6500\ kg)(2.0\ m/s^2 + 9.8\ m/s^2)$$
$$F_{cable} = 76700\ N$$
$$F_{cable} = 7.7 \times 10^4\ N[\uparrow]$$

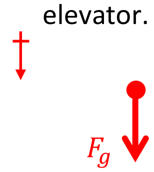
d) What force must the cable exert on the elevator when it is moving downward at 2.0 m/s?

$$\sum F_y = F_{cable} - F_g = ma$$
$$F_{cable} - F_g = 0\ m/s^2$$
$$F_{cable} = F_g$$
$$F_{cable} = mg$$
$$F_{cable} = (6500\ kg)(9.8\ m/s^2)$$
$$F_{cable} = 63700\ N$$
$$F_{cable} = 6.8 \times 10^4\ N[\uparrow]$$

e) What force must the cable exert on the elevator when it is moving downward at 2.0 m/s^2?

$$\sum F_y = F_{cable} - F_g = -ma$$
$$F_{cable} = -ma + F_g$$
$$F_{cable} = -ma + mg$$
$$F_{cable} = (6500\ kg)(-2.0\ m/s^2 + 9.8\ m/s^2)$$
$$F_{cable} = 50700\ N$$
$$F_{cable} = 5.1 \times 10^4\ N[\uparrow]$$

f) If the cable snapped, draw a new free-body diagram and determine the acceleration of the elevator.



$$\sum F_y = F_g = ma$$
$$ma = F_g$$
$$a = g$$
$$a = 9.8\ m/s^2 \qquad a = 9.8\ m/s^2[\downarrow]$$

4. A bowling ball of mass 2.0 kg strikes a stationary pin of mass 5.00 x 10^2 g. The collision lasts for 0.45 s after which the pin moves off with a velocity of 12.8 m/s [W]. Ignoring friction between the pin and the floor, calculate

a) the acceleration of the pin during the collision

$\vec{v}_1 = 0\ m/s\ [W]$ $\qquad$ $\vec{a} = ?$

$\vec{v}_2 = 12.8\ m/s\ [W]$ $\qquad$ $\Delta\vec{d} = ?$

$\Delta t = 0.45\ s$

$\vec{v}_2 = \vec{v}_1 + \vec{a}\Delta t$

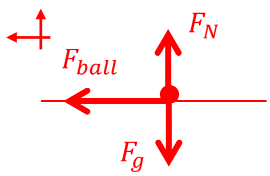
$\vec{a} = \frac{\vec{v}_2 - \vec{v}_1}{\Delta t}$

$\vec{a} = \frac{12.8\ m/s - 0\ m/s}{0.45\ s}$

$\vec{a} = 28.44444\ m/s^2$

$\vec{a} = 28\ m/s^2\ [W]$

b) the force exerted by the bowling ball on the pin (include a FBD)



$\sum F_x = F_{ball} = ma$

$F_{ball} = ma$

$F_{ball} = (0.500\ kg)(28\ m/s^2)$

$F_{ball} = 14\ N$ $\qquad F_{ball} = 14\ N[W]$

c) the acceleration of the bowling ball during the collision

$F_{pin\ on\ ball} = -F_{ball\ on\ pin}$

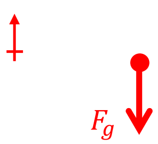
$\vec{a}_{ball} = \frac{-F_{ball\ on\ pin}}{m_{ball}}$

$\vec{a}_{ball} = \frac{-14\ N[W]}{2.0\ kg}$

$\vec{a}_{ball} = 7.0\ m/s^2\ [E]$

5. A person throws a 2.4 kg object vertically upward and it reaches a maximum position 4.1 m above the point of release.

a) What speed must the object have had upon release? Include a FBD of the object *after* release.



$\Delta\vec{d} = 4.1\ m$

$\vec{a} = -9.8\ m/s^2$

$\vec{v}_2 = 0\ m/s$

$\vec{v}_1 = ?$

$v_2^2 = v_1^2 + 2a\Delta d$

$v_1 = (v_2^2 - 2a\Delta d)^{1/2}$

$v_1 = \left((0\ m/s)^2 - 2(-9.8\ m/s^2)\ (4.1\ m)\right)^{1/2}$

$v_1 = 8.9644\ m/s$

$\vec{v}_1 = 9.0\ m/s\ [\uparrow]$

b) If throwing the object vertically took 0.823 s (from rest until release), what was the acceleration of the object?

$\Delta t = 0.823\ s$

$\vec{a} = ?$

$\vec{v}_2 = 9.0\ m/s$

$\vec{v}_1 = 0\ m/s$

$\vec{v}_2 = \vec{v}_1 + \vec{a}\Delta t$

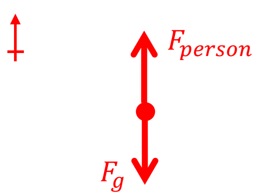
$\vec{a} = \frac{\vec{v}_2 - \vec{v}_1}{\Delta t}$

$\vec{a} = \frac{9.0\ m/s - 0\ m/s}{0.823\ s}$

$\vec{a} = 10.9364\ m/s^2$

$\vec{a} = 11\ m/s^2\ [\uparrow]$

c) What force must the person have exerted during the throw to reach the determined height? Provide a new FBD of the object *before* release.



$\sum F_y = F_{person} - F_g = ma$

$F_{person} = ma + F_g$

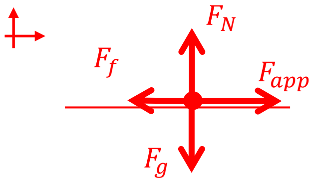
$F_{person} = m(a + g)$

$F_{person} = (2.4\ kg)(11\ m/s^2 + 9.8\ m/s^2)$

$F_{person} = 49.92\ N$

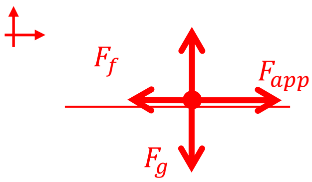
$F_{person} = 5.0 \times 10^1\ N[\uparrow]$

6. A wagon of mass 2.4 kg is pushed along the ground at 1.2 m/s² [→] against a frictional force of 1.22 N. Determine the magnitude and the direction of the applied force.



$$\sum F_x = F_{app} - F_f = ma$$
$$F_{app} = ma + F_f$$
$$F_{app} = (2.4\ kg)(1.2\ m/s^2) + 1.22\ N$$
$$F_{app} = 4.1\ N\ [\rightarrow]$$

7. If a 7.2 N force is required to accelerate a 3.4-kg object along a horizontal surface at a rate of 1.6 m/s² [E], what is the frictional resistance that is acting?

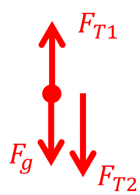


$$\sum F_x = F_{app} - F_f = ma$$
$$F_f = ma - F_{app}$$
$$F_f = (3.4\ kg)(1.6\ m/s^2) - 7.2\ N$$
$$F_f = -1.76\ N\ [E]$$
$$F_f = 1.8\ N\ [W]$$

8. One 3.2-kg paint bucket is hanging by a massless cord from another 3.2 kg paint bucket, also hanging by a massless cord.

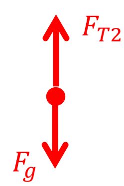
a) If the buckets are at rest, what is the tension in each cord?

Top bucket:



$$\sum F_y = F_{T1} - F_g - F_{T2} = ma$$

Bottom bucket:



$$\sum F_y = F_{T2} - F_g = ma$$

From bottom bucket:

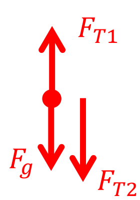
$$F_{T2} - m_B g = 0$$
$$F_{T2} = m_B g$$
$$F_{T2} = (3.2\ kg)(9.8\ m/s^2)$$
$$F_{T2} = 31.36\ N$$
$$F_{T2} = 31\ N$$

From top bucket:

$$F_{T1} - m_T g - F_{T2} = 0$$
$$F_{T1} = m_T g + F_{T2}$$
$$F_{T1} = (3.2\ kg)(9.8\ m/s^2) + 31.36\ N$$
$$F_{T1} = 62.72\ N$$
$$F_{T1} = 63\ N$$

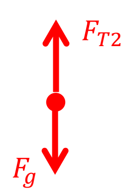
b) If the two buckets are pulled upward with an acceleration of 1.60 m/s² by the upper cord, calculate the tension in each cord.

Top bucket:



$$\sum F_y = F_{T1} - F_g - F_{T2} = ma$$

Bottom bucket:



$$\sum F_y = F_{T2} - F_g = ma$$

From bottom bucket:

$F_{T2} - m_B g = m_B a$

$F_{T2} = m_B a + m_B g$

$F_{T2} = (3.2\ kg)(1.6\ m/s^2 + 9.8\ m/s^2)$

$F_{T2} = 36.48\ N$

$F_{T2} = 36\ N$

From top bucket:

$F_{T1} - m_T g - F_{T2} = m_T a$

$F_{T1} = m_T a + m_T g + F_{T2}$

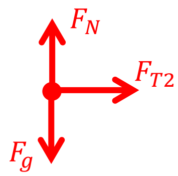
$F_{T1} = (3.2\ kg)(1.6\ m/s^2 + 9.8\ m/s^2) + 36.48\ N$

$F_{T1} = 72.96\ N$

$F_{T1} = 73\ N$

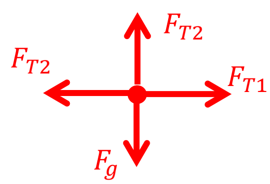
9. A train is pulling two cars of the same mass behind it. Determine the ratio of the tension in the coupling between the locomotive and the first car (***F**$_{T1}$*), to that between the first car and the second car (***F**$_{T2}$*), for any non-zero acceleration of the train (assume no friction between the cars and the track).

car 2:



$\sum F_x = F_{T2} = m_2 a$

car 1:



$\sum F_x = F_{T1} - F_{T2} = m_1 a$

Since both masses are the same, and both cars will accelerate at the same rate,

$m_2 a = m_1 a$

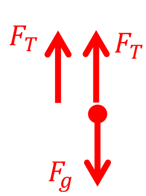
$F_{T2} = F_{T1} - F_{T2}$

$2F_{T2} = F_{T1}$

$\frac{F_{T1}}{F_{T2}} = 2$

10. A window washer pulls herself upward using a bucket-pulley apparatus. The combined mass of the bucket and washer is 65 kg.

a) How hard must she pull downward to raise herself slowly at a constant speed?



$\sum F_y = F_T + F_T - F_g = ma$

$2F_T - F_g = 0$

$F_T = \frac{F_g}{2}$

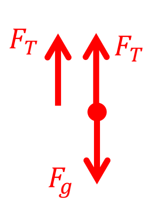
$F_T = \frac{(65\ kg)(9.8\ m/s^2)}{2}$

$F_T = 318.5\ N$

$F_T = 320\ N$

Since the tension in the rope is determined by how hard the window washer pulls, she needs to pull downwards with 320 N of force to raise herself at a constant speed.

b) If she increases this force by 15%, what will her acceleration be?



$\sum F_y = F_T + F_T - F_g = ma$

$a = \frac{2F_T - F_g}{m}$

$a = \frac{2(1.15 \times 320\ N) - (65\ kg)(9.8\ m/s^2)}{65\ kg}$

$a = 1.5231\ m/s^2$

$a = 1.5\ m/s^2$ [↑]