

Chapter 4

1. A 20 kg box rests on the table. A) What is the weight and the normal force acting on it? b) A 10 kg box is placed on top of 20 kg box. Determine the normal force that the table acts on the 29 kg box and the normal force that 20 kg box exerts on 10 kg box.

- (a) The weight of the box depends on the value of g :

$$F_G = m_2g = (20.0 \text{ kg})(9.80 \text{ m/s}^2) = 196 \text{ N.}$$

We find the normal force from

$$F_y = ma_y;$$

$$F_N - m_2g = 0, \text{ which gives } F_N = m_2g = 196 \text{ N.}$$

- (b) We select both blocks as the object and apply Newton's second law:

$$F_y = ma_y;$$

$$F_{N2} - m_1g - m_2g = 0, \text{ which gives}$$

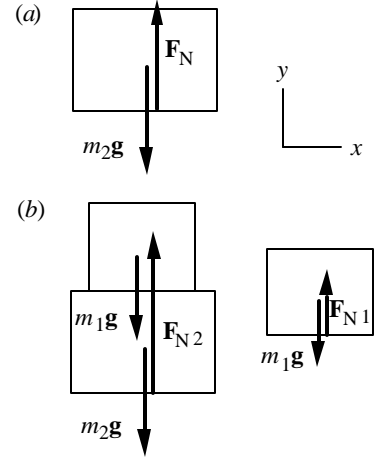
$$F_{N2} = (m_1 + m_2)g = (10.0 \text{ kg} + 20.0 \text{ kg})(9.80 \text{ m/s}^2) = 294 \text{ N.}$$

If we select the top block as the object, we have

$$F_y = ma_y;$$

$$F_{N1} - m_1g = 0, \text{ which gives}$$

$$F_{N1} = m_1g = (10.0 \text{ kg})(9.80 \text{ m/s}^2) = 98.0 \text{ N.}$$



2. A fisherman yanks a fish out of the water with the acceleration 4.5 m/s^2 using very light fishing line that has a "test" value of 22 N. The fisherman unfortunately loses the fish as the line snaps. What is the mass of the fish?

Because the line snapped, the tension $F_T > 22 \text{ N}$.

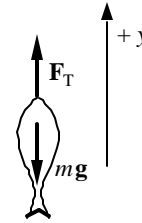
We write $\mathbf{F} = m\mathbf{a}$ from the force diagram for the fish:

$$y\text{-component: } F_T - mg = ma, \text{ or } F_T = m(a + g).$$

We find the minimum mass from the minimum tension:

$$22 \text{ N} = m_{\min}(4.5 \text{ m/s}^2 + 9.80 \text{ m/s}^2), \text{ which gives } m_{\min} = 1.5 \text{ kg.}$$

Thus we can say



- The cable supporting a 2100 kg elevator has a maximum strength of 21,750 N. What maximum upward acceleration can it give the elevator without breaking?

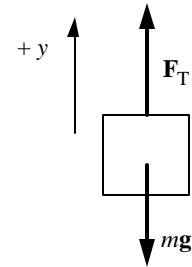
The maximum tension will be exerted by the motor when the elevator has the maximum acceleration.

We write $\mathbf{F} = m\mathbf{a}$ from the force diagram for the elevator:

$$y\text{-component: } F_{T\max} - mg = ma_{\max};$$

$$21,750 \text{ N} - (2100 \text{ kg})(9.80 \text{ m/s}^2) = (2100 \text{ kg})a_{\max},$$

$$\text{which gives } a_{\max} = 0.557 \text{ m/s}^2.$$



3. A train is pulling two cars of the same mass behind it. Show that the tension in the coupling between the train and the first car is twice that between the first car and the second car for any nonzero acceleration of the train.

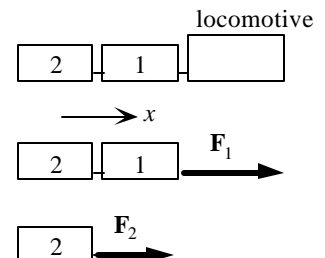
If we select the first and second cars as the system, the only horizontal force is the tension in the coupling between the locomotive and the first car. From the force diagram, we have

$$F_x = (m_1 + m_2)a_x, \text{ or } F_1 = (m + m)a = 2ma.$$

If we select the second car as the system, the only horizontal force is the tension in the coupling between the first car and the second car. From the force diagram, we have

$$F_x = m_2a_x, \text{ or } F_2 = ma.$$

Thus we have $F_1/F_2 = 2ma/ma = 2$, for any nonzero acceleration.



4. The two masses $m_1=2.2$ kg and $m_2=3.2$ kg shown in the figure are both initially 1.8 m above the ground and massless and frictionless pulley is 4.8 m above the ground. What maximum height does the lighter object reach after the system is released? [Hint: First determine the acceleration of the lighter mass and then the velocity at the moment the heavier hits the ground.]

Forces are drawn for each of the blocks. Because the string doesn't stretch, the tension is the same at each end of the string, and the accelerations of the blocks have the same magnitude. Note that we take the positive direction in the direction of the acceleration for each block.

We write $\mathbf{F} = m\mathbf{a}$ from the force diagram for each block:

$$y\text{-component (block 1): } F_T - m_1g = m_1a;$$

$$y\text{-component (block 2): } m_2g - F_T = m_2a.$$

By adding the equations, we find the acceleration:

$$\begin{aligned} a &= (m_2 - m_1)g / (m_1 + m_2) \\ &= (3.2 \text{ kg} - 2.2 \text{ kg})(9.80 \text{ m/s}^2) / (3.2 \text{ kg} + 2.2 \text{ kg}) \\ &= 1.81 \text{ m/s}^2 \text{ for both blocks.} \end{aligned}$$

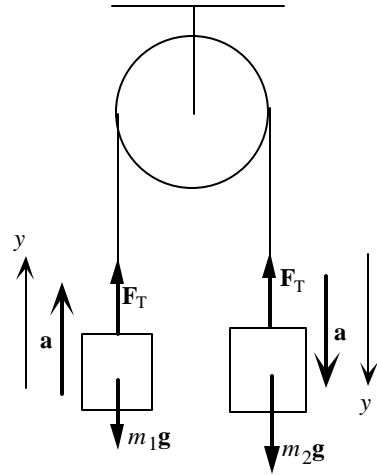
For the motion of block 1 we take the origin at the ground and up positive. Until block 2 hits the ground, we have

$$\begin{aligned} v_1^2 &= v_{01}^2 + 2a(y_1 - y_{01}) \\ &= 0 + 2(1.81 \text{ m/s}^2)(3.60 \text{ m} - 1.80 \text{ m}), \text{ which gives} \\ v_1 &= 2.56 \text{ m/s.} \end{aligned}$$

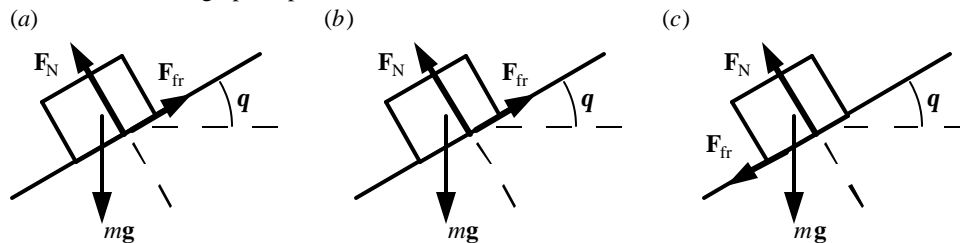
Once block 2 hits the floor, $F_T \rightarrow 0$ and block 1 will have the downward acceleration of g .

For this motion of block 1 up to the highest point reached, we have

$$\begin{aligned} v^2 &= v_1^2 + 2a(h - y_1) \\ 0 &= (2.56 \text{ m/s})^2 + 2(-9.80 \text{ m/s}^2)(h - 3.60 \text{ m}), \text{ which gives } \quad h = 3.93 \text{ m.} \end{aligned}$$



5. a) A box sits at rest on a rough 30 degree inclined plane. Draw free body diagram, showing all the forces acting on the box. b) How the diagram change if the box were sliding down the plane? c) How the diagram change if the box were sliding up the plane?



In (a) the friction is static and opposes the impending motion down the plane.

In (b) the friction is kinetic and opposes the motion down the plane.

In (c) the friction is kinetic and opposes the motion up the plane.

6. A box given a push so that it slides across the floor. How far it will go given that the coefficient of kinetic friction $\mu_k = 0.20$ and push imparts an initial speed of 4 m/s?

The kinetic friction force provides the acceleration. For $\mathbf{F} = m\mathbf{a}$ we have

$$x\text{-component: } -\mu_k F_N = ma;$$

$$y\text{-component: } F_N - mg = 0.$$

Thus we see that

$$a = -\mu_k g = -(0.20)(9.80 \text{ m/s}^2) = -1.96 \text{ m/s}^2.$$

We can find the distance from the motion data:

$$v^2 = v_0^2 + 2a(x - x_0);$$

$$0 = (4.0 \text{ m/s})^2 + 2(-1.96 \text{ m/s}^2)(x - 0), \text{ which gives } x = 4.1 \text{ m.}$$

7. A vector \mathbf{V} is 8.8 units long and points along the negative x axes. Vector \mathbf{V} is 4.51 units and points at 45.0 angle to the positive x axis. A) What are the x and y components of each vector? B) Determine the sum of two vectors (magnitude and angle)

$$(a) \quad V_{1x} = -8.08, \quad V_{1y} = 0;$$

$$V_{2x} = V_2 \cos 45^\circ = 4.51 \cos 45^\circ = 3.19,$$

$$V_{2y} = V_2 \sin 45^\circ = 4.51 \sin 45^\circ = 3.19.$$

- (b) For the components of the resultant we have
 $R_x = V_{1x} + V_{2x} = -8.08 + 3.19 = -4.89;$
 $R_y = V_{1y} + V_{2y} = 0 + 3.19 = 3.19.$

We find the resultant from

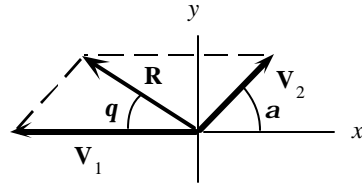
$$R = (R_x^2 + R_y^2)^{1/2} = [(-4.89)^2 + (3.19)^2]^{1/2}$$

$$= 5.84;$$

$$\tan q = R_y/R_x = (3.19)/(-4.89) = 0.652, \text{ which gives}$$

$$q = 33.1^\circ \text{ above } -x\text{-axis.}$$

Note that we have used the magnitude of R_x for the angle indicated on the diagram.



8. A tiger leaps horizontally from a 7.5 m high rock with speed of 4.5 m/s. How far from the base of the rock she will land?

We choose a coordinate system with the origin at the takeoff point, with x horizontal and y vertical, with the positive direction down.

We find the time for the tiger to reach the ground from its vertical motion:

$$y = y_0 + v_{0y}t + \frac{1}{2}a_y t^2;$$

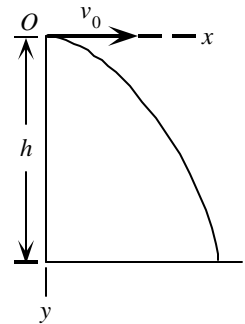
$$7.5 \text{ m} = 0 + 0 + \frac{1}{2}(9.80 \text{ m/s}^2)t^2, \text{ which gives } t = 1.24 \text{ s.}$$

The horizontal motion will have constant velocity.

We find the distance from the base of the rock from

$$x = x_0 + v_{0x}t;$$

$$x = 0 + (4.5 \text{ m/s})(1.24 \text{ s}) = 5.6 \text{ m.}$$



9. A projectile is shot from the edge of a cliff 125 m above the ground level with initial speed of 105 m/s at the angle of 37.0° with horizontal, as shown in figure. a) Determine the elapsed time before projectile hits the ground at point P. b) Determine the range X measured from the base of the cliff. c) The vertical and horizontal components of velocity. d) the magnitude of velocity and e) the angle made by velocity vector with the horizontal.

- (a) We choose a coordinate system with the origin at the base of the cliff, with x horizontal and y vertical, with the positive direction up.

We find the time required for the fall from the vertical motion:

$$y = y_0 + v_{0y}t + \frac{1}{2}a_y t^2;$$

$$0 = 125 \text{ m} + (105 \text{ m/s})(\sin 37.0^\circ)t + \frac{1}{2}(-9.80 \text{ m/s}^2)t^2,$$

which gives $t = -1.74, 14.6 \text{ s}.$

Because the projectile starts at $t = 0$, we have $t = 14.6 \text{ s}.$

- (b) We find the range from the horizontal motion:

$$X = v_{0x}t = (105 \text{ m/s})(\cos 37.0^\circ)(14.6 \text{ s})$$

$$= 1.22 \times 10^3 \text{ m} = 1.22 \text{ km.}$$

- (c) For the velocity components, we have

$$v_x = v_{0x} = (105 \text{ m/s}) \cos 37.0^\circ = 83.9 \text{ m/s.}$$

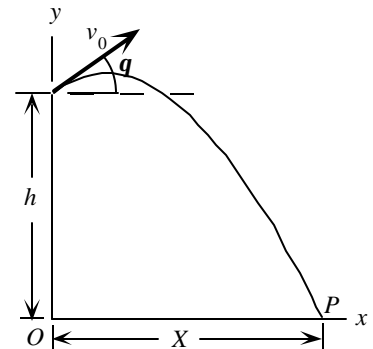
$$v_y = v_{0y} + a_y t = (105 \text{ m/s}) \sin 37.0^\circ + (-9.80 \text{ m/s}^2)(14.6 \text{ s}) = -79.9 \text{ m/s.}$$

- (d) When we combine these components, we get

$$v = (v_x^2 + v_y^2)^{1/2} = [(83.9 \text{ m/s})^2 + (-79.9 \text{ m/s})^2]^{1/2} = 116 \text{ m/s.}$$

- (e) We find the angle from

$$\tan q = v_y/v_x = (79.9 \text{ m/s})/(83.9 \text{ m/s}) = 0.952, \text{ which gives } q = 43.6^\circ \text{ below the horizontal.}$$



Chapter 5

Problems from Giambattista textbook

$$15.(a) \Delta q = \omega \Delta t = \frac{2\pi}{T} \Delta t = \frac{2\pi}{365.25 \text{ d}} (1 \text{ d}) = \boxed{1.72 \times 10^{-2} \text{ rad}}$$

(b) For a small Δq , $|\Delta \bar{v}| = v \Delta q = \frac{2pr}{T} \Delta q = \frac{2p(1.50 \times 10^{11} \text{ m})}{(365.25 \text{ d}) \left(\frac{86,400 \text{ s}}{\text{d}} \right)} (1.72 \times 10^{-2} \text{ rad}) = 514 \text{ m/s}$.

$\Delta \bar{v}$ is perpendicular to the average velocity, so $\Delta \bar{v} = \boxed{514 \text{ m/s perpendicular to the average velocity}}$.

(c) $a_{\text{av}} = \frac{|\Delta \bar{v}|}{\Delta t} = \frac{2pr \Delta q}{T \Delta t} = \frac{2p(1.50 \times 10^{11} \text{ m})(1.72 \times 10^{-2} \text{ rad})}{(365.25 \text{ d})(1 \text{ d}) \left(\frac{86,400 \text{ s}}{\text{d}} \right)^2} = 0.00595 \text{ m/s}^2$

So, $\bar{a}_{\text{av}} = \frac{\Delta \bar{v}}{\Delta t} = \boxed{0.00595 \text{ m/s}^2 \text{ perpendicular to the average velocity}}$.

(d) $a_c = \omega^2 r = \frac{4p^2}{T^2} r = \frac{4p^2(1.50 \times 10^{11} \text{ m})}{(365.25 \text{ d})^2 \left(\frac{86,400 \text{ s}}{\text{d}} \right)^2} = 0.00595 \text{ m/s}^2$

$\bar{a}_c = 0.00595 \text{ m/s}^2$ perpendicular to the velocity, which is the same as \bar{a}_{av} within 3 significant figures.

17.(a) Use Newton's second law.

$$\Sigma F_y = T_y - mg = 0, \text{ so}$$

$$T_y = T \cos f = mg, \text{ or } T = \boxed{\frac{mg}{\cos f}}.$$

(b) $\Sigma F_c = T_c = ma_c = m \omega^2 r = m \omega^2 L \sin f = T \sin f$, so $T = m \omega^2 L$.

And, from part (a), $T = \frac{mg}{\cos f}$.

Eliminate T .

$$m \omega^2 L = \frac{mg}{\cos f}$$

$$\omega^2 L = \frac{g}{\cos f}$$

$$\left(\frac{2p}{T} \right)^2 L = \frac{g}{\cos f} \text{ where } T \text{ is now the period, not the tension}$$

$$\frac{1}{T^2} = \frac{g}{(2p)^2 L \cos f}$$

$$T = \boxed{2p \sqrt{\frac{L \cos f}{g}}}$$

18. Let the x -axis point toward the center of curvature and the y -axis point upward. Use Newton's second law.

$$\Sigma F_y = N \cos q - mg = 0$$

$$\Sigma F_x = N \sin q = ma_c = m \frac{v^2}{r}$$

$$\frac{N \sin q}{N \cos q} = \frac{m \frac{v^2}{r}}{mg}$$

$$\tan q = \frac{v^2}{rg}$$

$$q = \tan^{-1} \frac{v^2}{rg}$$

$$= \tan^{-1} \frac{\left(26.8 \frac{\text{m}}{\text{s}} \right)^2}{(122 \text{ m}) \left(9.8 \frac{\text{m}}{\text{s}^2} \right)}$$

$$= \boxed{31^\circ}$$

20. Use Newton's second law.

$$\Sigma F_x = ma_c = m \frac{v^2}{r}$$

$$\Sigma F_y = N - mg = 0, \text{ so } N = mg.$$

The track exerts an upward force of $N = mg$ and a horizontal force of $m \frac{v^2}{r}$. Calculate the magnitude of the total force exerted on the car by the track.

$$F = \sqrt{\left(m \frac{v^2}{r}\right)^2 + (mg)^2} = m \sqrt{\frac{v^4}{r^2} + g^2} = (320 \text{ kg}) \sqrt{\frac{\left(16 \frac{\text{m}}{\text{s}}\right)^4}{(35 \text{ m})^2} + \left(9.8 \frac{\text{m}}{\text{s}^2}\right)^2} = 3900 \text{ N}$$

Find the angle.

$$\mathbf{q} = \tan^{-1} \frac{mg}{m \frac{v^2}{r}} = \tan^{-1} \frac{gr}{v^2} = \tan^{-1} \frac{\left(9.8 \frac{\text{m}}{\text{s}^2}\right)(35 \text{ m})}{\left(16 \frac{\text{m}}{\text{s}}\right)^2} = 53^\circ$$

$$\text{So, } \vec{\mathbf{F}} = \boxed{3900 \text{ N at } 53^\circ \text{ above the horizontal}}.$$

26. (a) Use Newton's second law and law of universal gravitation.

$$\Sigma F_c = G \frac{mM_E}{r^2} = \frac{mv^2}{r}$$

$$\frac{GM_E}{r} = v^2 = \left(\frac{2\pi r}{T}\right)^2 = \frac{4\pi^2 r^2}{T^2}$$

$$\frac{GM_E T^2}{4\pi^2} = r^3$$

$$r = \sqrt[3]{\frac{GM_E T^2}{4\pi^2}}$$

$$h + R_E =$$

$$h = \sqrt[3]{\frac{GM_E T^2}{4\pi^2}} - R_E$$

$$= \sqrt[3]{\frac{\left(6.673 \times 10^{-11} \frac{\text{N}\cdot\text{m}^2}{\text{kg}^2}\right)(5.975 \times 10^{24} \text{ kg})(6.00 \text{ h})^2 \left(\frac{3600 \text{ s}}{\text{h}}\right)^2}{4\pi^2}} - 6.371 \times 10^6 \text{ m}$$

$$= 16,800 \text{ km} - 6,371 \text{ km}$$

$$= \boxed{10,400 \text{ km}}$$

$$(b) a_c = \frac{v^2}{r} = \left(\frac{2\pi r}{T}\right)^2 \frac{1}{r} = \frac{4\pi^2 r}{T^2} = \frac{4\pi^2 (16,800 \times 10^3 \text{ m})}{(6.00 \text{ h})^2 \left(\frac{3600 \text{ s}}{\text{h}}\right)^2} = \boxed{1.42 \text{ m/s}^2}$$

43. The centripetal acceleration must be the same as the acceleration due to gravity on Earth.

$$a_c = g$$

$$\frac{v^2}{r} = g$$

$$v = \sqrt{gr}$$

$$2\pi f = \sqrt{gr}$$

$$f = \frac{\sqrt{gr}}{2\pi r} = \frac{1}{2\pi} \sqrt{\frac{g}{r}} = \frac{1}{2\pi} \sqrt{\frac{9.8 \frac{\text{m}}{\text{s}^2}}{120 \text{ m}}} = \boxed{0.045 \text{ Hz}}$$

44. (a) At the top, $\vec{\mathbf{g}}$ and $\vec{\mathbf{a}}$ are in the same direction.

$$W' = m|\vec{\mathbf{g}} - \vec{\mathbf{a}}| = m(g - a_y) = \boxed{m(g - \omega^2 R)}$$

(b) At the bottom, $\bar{\mathbf{g}}$ and $\bar{\mathbf{a}}$ are opposite.

$$W' = m|\bar{\mathbf{g}} - \bar{\mathbf{a}}| = m(g + a_y) = \boxed{m(g + \mathbf{w}^2 R)}$$