P6.12 (a) The external forces acting on the water are

$\boxed{\text{the gravitational force}}$

and $\boxed{\text{the contact force exerted on the water by the pail}}$.

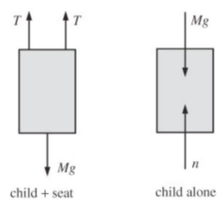
(b) The $\boxed{\text{contact force exerted by the pail}}$ is the most important in causing the water to move in a circle. If the gravitational force acted alone, the water would follow the parabolic path of a projectile.

(c) When the pail is inverted at the top of the circular path, it cannot hold the water up to prevent it from falling out. If the water is not to spill, the pail must be moving fast enough that the required centripetal force is at least as large as the gravitational force. That is, we must have

$$m\frac{v^2}{r} \geq mg \quad \text{or} \quad v \geq \sqrt{rg} = \sqrt{(1.00\,\text{m})(9.80\,\text{m/s}^2)} = \boxed{3.13\ \text{m/s}}$$

(d) If the pail were to suddenly disappear when it is at the top of the circle and moving at 3.13 m/s, $\boxed{\text{the water would follow the parabolic path of a projectile}}$ launched with initial velocity components of $v_{xi} = 3.13$ m/s, $v_{yi} = 0$.

6.14 We first draw a force diagram that shows the forces acting on the child-seat system and apply Newton's second law to solve the problem. The child's path is an arc of a circle, since the top ends of the chains are fixed. Then at the lowest point the child's motion is changing in direction: He moves with centripetal acceleration even as his speed is not changing and his tangential acceleration is zero.



ANS. FIG. P6.14

(a) ANS. FIG. P6.14 shows that the only forces acting on the system of child + seat are the tensions in the two chains and the weight of the boy:

$$\sum F = F_{\text{net}} = 2T - mg = ma = \frac{mv^2}{r}$$

with

$$F_{\text{net}} = 2T - mg = 2(350\ \text{N}) - (40.0\ \text{kg})(9.80\ \text{m/s}^2) = 308\ \text{N}$$

solving for v gives

$$v = \sqrt{\frac{F_{\text{net}}r}{m}} = \sqrt{\frac{(308\ \text{N})(3.00\ \text{m})}{40.0\ \text{kg}}} = \boxed{4.81\ \text{m/s}}$$

(b) The normal force from the seat on the child accelerates the child in the same way that the total tension in the chain accelerates the child-seat system. Therefore, $n = 2T = \boxed{700\ \text{N}}$.

P6.15 See the forces acting on seat (child) in ANS. FIG. P6.14.

(a) $\sum F = 2T - Mg = \dfrac{Mv^2}{R}$

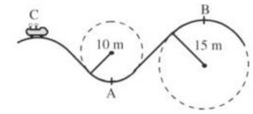
$$v^2 = (2T - Mg)\left(\frac{R}{M}\right)$$

$$\boxed{v = \sqrt{(2T - Mg)\left(\frac{R}{M}\right)}}$$

(b) $n - Mg = F = \dfrac{Mv^2}{R}$

$$\boxed{n = Mg + \frac{Mv^2}{R}}$$

P6.16 (a) We apply Newton's second law at point A, with $v = 20.0$ m/s, n = force of track on roller coaster, and $R = 10.0$ m:



ANS. FIG. P6.16

$$\sum F = \frac{Mv^2}{R} = n - Mg$$

From this we find

$$n = Mg + \frac{Mv^2}{R} = (500\ \text{kg})(9.80\ \text{m/s}^2) + \frac{(500\ \text{kg})(20.0\ \text{m/s}^2)}{10.0\ \text{m}}$$

$$n = 4\,900\ \text{N} + 20\,000\ \text{N} = \boxed{2.49 \times 10^4\ \text{N}}$$

(b) At point B, the centripetal acceleration is now downward, and Newton's second law now gives

$$\sum F = n - Mg = -\frac{Mv^2}{R}$$

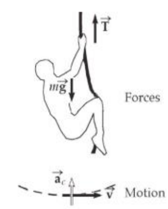
The maximum speed at B corresponds to the case where the rollercoaster begins to fly off the track, or when $n = 0$. Then,

$$-Mg = -\frac{Mv_{\max}^2}{R}$$

which gives

$$v_{\max} = \sqrt{Rg} = \sqrt{(15.0\ \text{m})(9.80\ \text{m/s}^2)} = \boxed{12.1\ \text{m/s}}$$

P6.19 Let the tension at the lowest point be T. From Newton's second law, $\sum F = ma$ and



ANS. FIG. P6.19

$$T - mg = ma_c = \frac{mv^2}{r}$$

$$T = m\left(g + \frac{v^2}{r}\right)$$

$$T = (85.0\ \text{kg})\left[9.80\ \text{m/s}^2 + \frac{(8.00\ \text{m/s})^2}{10.0\ \text{m}}\right]$$

$$= 1.38\ \text{kN} > 1\,000\ \text{N}$$

$\boxed{\text{He doesn't make it across the river because the vine breaks.}}$

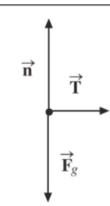
P6.20 (a) From $\sum F_x = Ma$, we obtain

$$a = \frac{T}{M} = \frac{18.0\ \text{N}}{5.00\ \text{kg}} = \boxed{3.60\ \text{m/s}^2} \text{ to the right}$$

(b) If v = const, $a = 0$, so $\boxed{T = 0}$. (This is also an equilibrium situation.)

(c) $\boxed{\text{Someone in the car (noninertial observer) claims that the forces on the mass along } x \text{ are } T \text{ and a fictitious force } (-Ma).}$

(d) $\boxed{\text{Someone at rest outside the car (inertial observer) claims that } T \text{ is the only force on } M \text{ in the } x \text{ direction.}}$



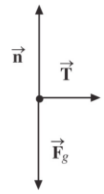
ANS. FIG. P6.20

P6.21 The only forces acting on the suspended object are the force of gravity $m\vec{\mathbf{g}}$ and the force of tension T forward and upward at angle θ with the vertical, as shown in the free-body diagram in ANS. FIG. P6.21. Applying Newton's second law in the x and y directions,

$$\sum F_x = T\sin\theta = ma \qquad \textbf{[1]}$$

$$\sum F_y = T\cos\theta - mg = 0$$

or $$T\cos\theta = mg \qquad \textbf{[2]}$$



ANS. FIG. P6.21

(a) Dividing equation [1] by [2] gives

$$\tan\theta = \frac{a}{g} = \frac{3.00\ \text{m/s}^2}{9.80\ \text{m/s}^2} = 0.306$$

Solving for θ, $\theta = \boxed{17.0°}$

(b) From equation [1],

$$T = \frac{ma}{\sin\theta} = \frac{(0.500\ \text{kg})(3.00\ \text{m/s}^2)}{\sin(17.0°)} = \boxed{5.12\ \text{N}}$$

P6.23 The scale reads the upward normal force exerted by the floor on the passenger. The maximum force occurs during upward acceleration (when starting an upward trip or ending a downward trip). The minimum normal force occurs with downward acceleration. For each respective situation,

$$\sum F_y = ma_y \quad \text{becomes for starting} \quad +591\ \text{N} - mg = +ma$$

$$\text{and for stopping} \quad +391\ \text{N} - mg = -ma$$

where a represents the magnitude of the acceleration.

(a) These two simultaneous equations can be added to eliminate a and solve for mg:

$$+591\ \text{N} - mg + 391\ \text{N} - mg = 0$$

or $$982\ \text{N} - 2mg = 0$$

$$F_g = mg = \frac{982\ \text{N}}{2} = \boxed{491\ \text{N}}$$

(b) From the definition of weight, $m = \dfrac{F_g}{g} = \dfrac{491\ \text{N}}{9.80\ \text{m/s}^2} = \boxed{50.1\ \text{kg}}$

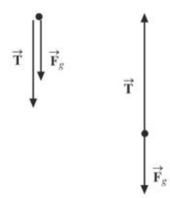
(c) Substituting back gives $+591\ \text{N} - 491\ \text{N} = (50.1\ \text{kg})a$, or

$$a = \frac{100\ \text{N}}{50.1\ \text{kg}} = \boxed{2.00\ \text{m/s}^2}$$

P6.45 (a) At each point on the vertical circular path, two forces are acting on the ball (see ANS. FIG. P6.45):

(1) $\boxed{\text{The downward gravitational force}}$ with constant magnitude $F_g = mg$

(2) $\boxed{\text{The tension force in the string, always directed toward the center of the path}}$



ANS. FIG. P6.45

(b) ANS. FIG. P6.45 shows the forces acting on the ball when it is at the highest point on the path (left-hand diagram) and when it is at the bottom of the circular path (right-hand diagram). Note that the gravitational force has the same magnitude and direction at each point on the circular path. The tension force varies in magnitude at different points and is always directed toward the center of the path.

(c) At the top of the circle, $F_c = mv^2/r = T + F_g$, or

$$T = \frac{mv^2}{r} - F_g = \frac{mv^2}{r} - mg = m\left(\frac{v^2}{r} - g\right)$$

$$= (0.275\ \text{kg})\left[\frac{(5.20\ \text{m/s})^2}{0.850\ \text{m}} - 9.80\ \text{m/s}^2\right] = \boxed{6.05\ \text{N}}$$

(d) At the bottom of the circle, $F_c = mv^2/r = T - F_g = T - mg$, and solving for the speed gives

$$v^2 = \frac{r}{m}(T - mg) = r\left(\frac{T}{m} - g\right) \quad \text{and} \quad v = \sqrt{r\left(\frac{T}{m} - g\right)}$$

If the string is at the breaking point at the bottom of the circle, then $T = 22.5$ N, and the speed of the object at this point must be

$$v = \sqrt{(0.850\ \text{m})\left(\frac{22.5\ \text{N}}{0.275\ \text{kg}} - 9.80\ \text{m/s}^2\right)} = \boxed{7.82\ \text{m/s}}$$