Answers to Circular Motion Problems #1

Horizontal Circular Motion

1. (*a*) Find the centripetal acceleration from Eq. 5-1.

$$a_R = v^2/r = (1.25\,\text{m/s})^2/1.10\text{ m} = \boxed{1.42\,\text{m/s}^2}$$

(*b*) The net horizontal force is causing the centripetal motion, and so will be the centripetal force.

$$F_R = ma_R = (25.0\text{ kg})(1.42\,\text{m/s}^2) = \boxed{35.5\text{ N}}$$

2. The speed can be found from the centripetal force and centripetal acceleration.

$$F_R = ma_R = mv^2/r \quad \rightarrow \quad v = \sqrt{\frac{F_R r}{m}} = \sqrt{\frac{(210\text{ N})(0.90\text{ m})}{2.0\text{ kg}}} = \boxed{9.7\,\text{m/s}}$$

6. Since the motion is all in a horizontal circle, gravity has no influence on the analysis. Set the
general expression for centripetal force equal to the stated force in the problem.

$$F_R = mv^2/r = 7.85W = 7.85mg \quad \rightarrow \quad v = \sqrt{7.85rg} = \sqrt{7.85(12.0\text{m})(9.8\,\text{m/s}^2)} = \boxed{30.4\,\text{m/s}}$$

$$(30.4\,\text{m/s})\left(\frac{1\text{ rev}}{2\pi(12.0\text{ m})}\right) = \boxed{0.403\,\text{rev/s}}$$

<u>Vertical Circular Motion</u>

Concepts

Vertical Circular Motion Problem Drill – Ans

<u>Concepts</u>

1. (II) A bucket of water can be whirled in a vertical circle without the water spilling out, even at the top of the circle when the bucket is upside down. Explain.

For the water to remain in the bucket, there must be a centripetal force forcing the water to move in a circle along with the bucket. That centripetal force gets larger with the tangential velocity of the water, since $F_R = mv^2/r$. The centripetal force at the top of the motion comes from a combination of the downward force of gravity and the downward normal force of the bucket on the water. If the bucket is moving faster than some minimum speed, the water will stay in the bucket. If the bucket is moving too slow, there is insufficient force to keep the water moving in the circular path, and it spills out.

2. A child on a sled comes flying over the crest of a small hill, as shown in Fig. 5–31. His sled does not leave the ground (he does not achieve "air"), but he feels the normal force between his chest and the sled decrease as he goes over the hill. Explain this decrease using Newton's second law.

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When the child is on a level surface, the normal force between his chest and the sled is equal to the child's weight, and thus he has no vertical acceleration. When he goes over the hill, the normal force on him will be reduced. Since the child is moving on a curved path, there must be a net centripetal force towards the center of the path, and so the normal force does not completely support the weight. Write Newton's 2nd law for the radial direction, with inward as positive.

$$\sum F_R = mg - F_N = mv^2/r \quad \rightarrow \quad F_N = mg - mv^2/r$$

We see that the normal force is reduced from *mg* by the centripetal force.

3. Why do bicycle riders lean inward when rounding a curve at high speed?

When a bicycle rider leans inward, the bike tire pushes down on the ground at an angle. The road surface then pushes back on the tire both vertically (to provide the normal force which counteracts gravity) and horizontally toward the center of the curve (to provide the centripetal frictional force, enabling them to turn).