Questions

7.5/5

7. Before the string breaks in question 6, is there a net force acting upon the ball? If so, what is it's direction? Explain.

When you spin an object in a circle, it is not in equilibrium. You can tell because the velocity is changing (at least in its direction) so it must be accelerating and so it must have a net force.

The net force is centripetal (inward).

12.5/10

12. If a ball is whirled in a vertical circle with a constant speed, at what point in the circle, if any, is the tension in the string the greatest? Explain. (Hint: Compare this situation to the Ferris wheel described in section 5.2.)

When you spin an object in a vertical circle, you need a centripetal (inward) force. At the top of the circle, the gravitational force happens to point inwards and helps you keep it moving in a circle (so the tension can be smaller). At the bottom of the circle, the gravitational force happens to point outwards and hinders you from keeping it moving in a circle (so the tension must be larger).

The tension in the string is greatest at the bottom of the circle.

23.5/15

23. Does the sun exert a larger force on the Earth than that exerted on the sun by the Earth? Explain.

No. Newton's third law says that the force on the Earth by the sun is **equal** and opposite to the force exerted on the sun by the Earth. (Aside: The reason the Earth moves and the sun "doesn't" is that the Earth is much less massive than the Sun.)

24.5/20

24. Is there a net force acting on the planet Earth? Explain.

Since the Earth is in orbit around the sun, it is moving in (essentially) a circle (actually an ellipse) and its velocity is continually changing. Since the velocity is changing, there is an acceleration and (by Newton's second law) there is a net force. Objects moving in circles are not in equilibrium.

35.0/20

35. Why is there a high tide, rather than a low tide, when the moon is on the opposite side of the Earth from the ocean and the gravitational pull of the moon on the water is the weakest? Explain. (See everyday phenomenon box 5.2.)

Let's consider three places on the Earth: (1) the side of the Earth closest to the moon, (2) the center of the Earth, which is mid-way between the closest and furthest points, and (3) the side of the Earth furthest from the moon. (1) The side that is closest is pulled the hardest. (2) The middle is still pulled by not as hard. (3) The side that is furthest is pulled the weakest. In the same way that (1) is pulled away from (2), (2 is pulled away from (3), leaving (3) behind. Since we are connected to the Earth itself, we experience our being pulled away from (3) as if (3) is pulled away from us: a bulge outwards.

Exercise

2.5/25

2. A car rounds a curve with a radius of 35 m at a speed of 20 $\mathrm{m/s}$. What is the centripetal acceleration of the car?

$$a_c = \frac{v^2}{r} = \frac{(20\ \mathrm{m/s})^2}{35\,\mathrm{m}} = \frac{(400\ \mathrm{m^2/s^2})}{35\,\mathrm{m}} = 11.4\ \mathrm{m/s^2}$$

6.5/30

6. A car with mass 1300 kg is moving around a curve with a radius of 35 m at a constant speed of 15 $\mathrm{m/s}$ (about 60 $\mathrm{mi/hr}$).

   (a) What is the centripetal acceleration of the car?

   (b) What is the magnitude of the force required (the centripetal force) to produce this centripetal acceleration?

(a)

$$a_c = \frac{v^2}{r} = \frac{(15\ \mathrm{m/s})^2}{35\,\mathrm{m}} = \frac{(225\ \mathrm{m^2/s^2})}{35\,\mathrm{m}} = 6.4\ \mathrm{m/s^2}$$

(b)

$$F_c = m\frac{v^2}{r} = (1300\,\mathrm{kg})(6.4\ \mathrm{m/s^2}) = 8357.1\,\mathrm{N} \ = \ 8.4\times 10^3\,\mathrm{N}$$

12.5/35

12. Two 600 kg masses (1323 lbs) are separated by a distance of 64 m. Using Newton's law of gravitation, find the magnitude of the gravitational force exerted by one mass on the other.

$$\begin{aligned}
F = G\frac{m_1 m_2}{r^2} &= (6.67\times10^{-11}\ {}^{\mathrm{N\cdot m^2}}\!/_{\mathrm{kg^2}})\frac{(600\,\mathrm{kg})(600\,\mathrm{kg})}{(64\,\mathrm{m})^2} \\
&= (6.67\times10^{-11}\ {}^{\mathrm{N\cdot m^2}}\!/_{\mathrm{kg^2}})\frac{(360000\,\mathrm{kg^2})}{(4096\,\mathrm{m^2})} \\
&= (6.67\times10^{-11}\ {}^{\mathrm{N\cdot m^2}}\!/_{\mathrm{kg^2}})(87.89\ {}^{\mathrm{kg^2}}\!/_{\mathrm{m^2}}) \\
&= 5.86\times10^{-9}\,\mathrm{N}
\end{aligned}$$

Problems

2. A Ferris wheel with a radius of 14 m makes one complete rotation every 9 s. 2.10/45
   (a) Using the fact that the distance traveled by a rider in one rotation is $2\pi r$, the circumference of the wheel, find the speed with which the riders are moving.
   (b) What is the magnitude of their centripetal acceleration?
   (c) For a rider with a mass of 35 kg, what is the magnitude of the centripetal force required to keep that rider moving in a circle? Is the weight of the rider larger enough to provide this centripetal force at the top of the cycle?
   (d) What is the magnitude of the normal force exerted by the seat on the rider at the top of the cycle?
   (e) What will happen if the Ferris wheel is going so fast that the weight of the rider is not sufficient to provide this centripetal force at the top of the cycle?

(a)

$$v = \frac{2\pi r}{t} = \frac{2\pi(14\,\mathrm{m})}{9\,\mathrm{s}} = \frac{87.96\,\mathrm{m}}{9\,\mathrm{s}} = 9.77\ \mathrm{m/s}$$

(b)

$$a_c = \frac{v^2}{r} = \frac{(9.77\ \mathrm{m/s})^2}{14\,\mathrm{m}} = \frac{(95.5\ \mathrm{m^2/s^2})}{14\,\mathrm{m}} = 6.82\ \mathrm{m/s^2}$$

(c)

$$F_c = m\frac{v^2}{r} = (35\,\mathrm{kg})(6.82\ \mathrm{m/s^2}) = 239\,\mathrm{N}$$

This is surely less than the weight. Let's check!

$$F_g = mg = (35\,\mathrm{kg})(10\ \mathrm{m/s^2}) = 350\,\mathrm{N}$$

Oh, yes, this centripetal force is definitely smaller than the person's weight!

(d) At the top, I have a weight (downwards) and a normal force (upwards) such that the net force is 239 N (centripetal, or downwards). The math is

$$\begin{aligned} \vec{F}_{\text{net}} &= \vec{F}_g + \vec{F}_N \\ (-239\,\mathrm{N}) &= (-350\,\mathrm{N}) + F_N \\ (+111\,\mathrm{N}) &= F_N \end{aligned}$$

(e) If your weight is not sufficient to provide the centripetal force, then you will leave the circular motion and start following a parabolic path. (That's bad.)

Home Experiment

1. Spin an object in a circle, horizontally and vertically. Note what happens. 1.10/55

   Awesome fun!
