Questions

4. A car travels the same distance at constant speed around two curves, one with twice the radius of curvature of the other. For which of these curves is the change in velocity of the car greater? Explain.

Since the car is traveling at a constant speed, we know that this is not asking about speeding up or slowing down; rather we are talking about changing direction. So, this question is asking about which curve produces more of a change in direction of the car.Intuitively, I hope you can see that the curve with the smaller radius of curvature (the tighter curve) should turn you by a larger amount (for the same distance travelled, which is also the same amount of time spent in the curve because the velocity is the same).

We can also note the mathematics. The centripetal (inward) acceleration is $a_c = \frac{v^2}{r}$. Since the speed is the same, the smaller r gives a larger a (and the larger r gives the smaller a). [The technical words are "a and r are inversely proportional".] Since the acceleration is larger for the tighter curve and acceleration also is related to the change in velocity $\left(a = \frac{\Delta v}{\Delta t}\right)$, a larger a produces a larger Δv. *Your intuition is correct!*

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14. Which safety measure, seat belts or air bags, offers the most protection in head-on collisions? Explain. (See everyday phenomenon box 5.1.)

Without either seat belts or air bags, when your car stops due to a head-on collision, your body is stopped *very suddenly* by the steering wheel and windshield. The suddenness of this change in velocity means that the time to stop is small. Since $a = \frac{\delta v}{\Delta t}$, a large Δv corresponds to a large a, **and** a small Δt corresponds to a large a. Both of these increase the acceleration (and therefore the net force acting on your body.

When you wear a seat belt, your Δv is the same as before (from moving at full speed to completely stopped), but since you are in contact with the seat belt as soon as the car is hit (instead of an instant as you move from the seat to the steering wheel), the time it takes to slow down is slightly increased and so the acceleration (and net force) is slightly smaller. One large advantage of seat belts is that they grab you in structurally firm locations (your hips and rib cage) rather than stopping you with your belly (bottom of the steering wheel) or your face (windshield).

When you have an air bag, your Δv is the same as before (from moving at full speed to completely stopped), but since the airbag catches you and allows you to be slowing down for a longer period of time than it takes the car to come to rest, your acceleration (and the net force) is *even smaller*. In addition the force of the airbag is spread across your entire torso, which is less painful than being stopped by a force concentrated across a smaller area (like the seat belt). However, you are still likely to get black eyes and a bruised torso.

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25. There are equal masses located as shown in the diagram in the book. What is the direction of the net force acting upon m_2?

The equation for the gravitational force between m_1 and m_2 is $F_G = G\frac{m_1 m_2}{r_{12}^2}$, where G is a constant and r_{12} is the smaller distance between these two masses. Since the distance is small, the force is large. Since gravity always pulls, this force on m_2 is towards m_1 or, in this case, to the left.

The equation for the gravitational force between m_2 and m_3 is $F_G = G\frac{m_2 m_3}{r_{12}^2}$, where G is a constant and r_{23} is the larger distance between these two masses. Since the distance is large, the force is small. Since gravity always pulls, this force on m_2 is towards m_3 or, in this case, to the right.

Combining a larger force to the left with a small force to the right, results in a smallish force to the left.

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34. Since the Earth rotates on its axis once every 24 hrs, why don't high tides occur exactly twice every 24 hrs? Explain.

This question is asking why the high tides are every 12 hrs 25 min (or twice in 24 hrs 50 min) rather than every 12 hrs 0 min (or twice in 24 hrs 0 min). The question is not asking why there are two high tides in a day.

The reason it take longer than 12 hr for the tides to occur is that the moon is moving across the sky. (The moon is in orbit around the Earth.) That is, the tidal bulges are lined up with the moon and the Earth spins through those bulges. The orbit of the moon means that the bulges follow the orbit of the moon so that the Earth needs an extra 25 min to catch up to the tidal bulge.

Exercise

1. A ball is traveling at a constant speed of 6 $\mathrm{m/s}$ in a circle with a radius of 08. m. What is the centripetal acceleration of the ball?

$$a_c = \frac{v^2}{r} = \frac{(6\ \mathrm{m/s})^2}{0.8\,\mathrm{m}} = \frac{(36\ \mathrm{m^2/s^2})}{0.8\,\mathrm{m}} = 45\ \mathrm{m/s^2}$$

If you knew the mass, you could find the centripetal force from the formula $F_c = ma_c$.

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8. A Ferris wheel at a carnival has a radius of 10 m and turns so that the speed of the riders is 8 $\mathrm{m/s}$.
   (a) What is the magnitude of the centripetal acceleration of the riders?
   (b) What is the magnitude of the net force required (the centripetal force) to produce this centripetal acceleration for a rider with a mass of 60 kg?

Before we do this I would like to point out (because it will help you do SP2) that the speed, distance, and time are related by $d = vt$ when it moves at a constant speed. In this problem, I know the distance is the circumference of the circle $d = 2\pi r = 2\pi(10\,\mathrm{m}) = 62.8\,\mathrm{m}$ and I know the speed, so I can find the time. In SP2, you are given the radius (and can find the distance/circumference) and the time. You can use that information to find the speed.

(a)

$$a_c = \frac{v^2}{r} = \frac{(8\,\mathrm{m/s})^2}{10\,\mathrm{m}} = \frac{(64\,\mathrm{m^2/s^2})}{10\,\mathrm{m}} = 6.4\,\mathrm{m/s^2}$$

(b)

$$F_c = m\frac{v^2}{r} = (60\,\mathrm{kg})(6.4\,\mathrm{m/s^2}) = 384\,\mathrm{N}$$

As further help for SP2, notice that the person's weight is $mg = (60\,\mathrm{kg})(10\,\mathrm{m/s^2}) = 600\,\mathrm{N}$. So your weight is more than sufficient to hold you in the circular motion. You have to be moving at a pretty high speed for this to not be true, as can be seen in the movies when the car "gets some air" as it drive over a slight hill in the road.

In this problem, if the person weighs 600 N (downward force) and only needs a net force of 384 N (downwards) to stay in the circle, then there must be an upwards 216 N force upwards that slightly cancels some of the weight. This is the normal force. Since you "feel lighter" as you go over the top, the normal does not need to support your full weight.

Problems

1. A 0.20 kg ball is twirled at the end of a string in a horizontal circle with a radius of 0.60 m. The ball travels with a constant speed of 4.0 $^{\text{m}}\!/\!_{\text{s}}$.
   (a) What is the centripetal acceleration of the ball?
   (b) What is the magnitude of the horizontal component of the tension in the string required (the centripetal force) to produce this centripetal acceleration?
   (c) What is the magnitude of the vertical component of the tension in the string required to support the weight of the ball?
   (d) Draw to scale a vector diagram showing these two components of the tension and estimate the magnitude of the total tension.

(a)

$$a_c = \frac{v^2}{r} = \frac{(4.0\ ^{\text{m}}\!/\!_{\text{s}})^2}{0.60\,\text{m}} = \frac{(16\ ^{\text{m}^2}\!/\!_{\text{s}^2})}{0.60\,\text{m}} = 26.7\ ^{\text{m}}\!/\!_{\text{s}^2}$$

(b)

$$F_c = m\frac{v^2}{r} = (0.20\,\text{kg})(26.7\ ^{\text{m}}\!/\!_{\text{s}^2}) = 5.33\,\text{N}$$

(c)

$$F_g = mg = (0.20\,\text{kg})(10\ ^{\text{m}}\!/\!_{\text{s}^2}) = 2.0\,\text{N}$$

(d) We have not discussed how to do this, but the answer is that you should use the Pythagorean theorem

$$F_T = \sqrt{(5.33\,\text{N})^2 + (2.0\,\text{N})^2} = \sqrt{(28.4\,\text{N}^2) + (4.0\,\text{N}^2)} = \sqrt{32.4\,\text{N}^2} = 5.7\,\text{N}$$