Chapter 5

(Q1) 8 points  
**Suppose that the speed of a ball moving in a horizontal circle is increasing at a steady rate. Is this increase in speed produced by the centripetal acceleration? Explain.**

The centripetal acceleration of a ball moving in a horizontal circle always points towards the center of the circle. Since this acceleration is always perpendicular to the ball’s velocity, it can not change the magnitude of the ball’s velocity (speed). Instead, it is only responsible for a change in the direction of the ball’s velocity. As a result, if the speed of a ball moving a horizontal circle is increasing at a steady rate, we can conclude that this increase in speed is not produced by the centripetal acceleration.

(Q3) 10 points  
**Two cars travel around the same curve, one at twice the speed of the other. After traveling the same distance, which car, if either, has experienced the larger change in velocity? Explain.**

The faster car experiences a larger (centripetal) acceleration and, as a result, also experiences a larger change in velocity.

(Q8) 8 points  
**For a ball being twirled in a horizontal circle at the end of a string, does the vertical component of the force exerted by the string produce the centripetal acceleration of the ball? Explain.**

For a ball twirled in a horizontal circle at the end of a string, the vertical component of the force exerted by the string balances the downward gravitational force exerted on the ball. However, neither force is directed toward the center of the circle so, as a result, neither force produces the centripetal acceleration of the ball. Instead, it is the horizontal component of the force exerted by the string on the ball that produces the centripetal acceleration of the ball.

(Q10) 10 points  
**Is there a maximum speed at which the car in question 9 will be able to negotiate the curve? If so, what factors determine this maximum speed? Explain.**

There is a maximum speed at which the car in question 9 will be able to negotiate the curve. When a car travels around a nonbanked curve, it is the frictional force exerted by the ground on the tires of the car that produces the necessary centripetal acceleration. Furthermore, for a given speed, changing the radius of the curve will change the necessary centripetal acceleration. Therefore, the factors that determine how fast a car can negotiate a curve are (1) the frictional force between the tires and the ground and (2) the radius of the curve.

(Q19) 6 points  
**Does a planet moving in an elliptical orbit about the sun move faster when it is farthest from the sun or when it is nearest the sun? Explain by referring to one of Kepler's laws.**

A planet moving in an elliptical orbit about the sun moves faster when it is nearest the sun (Kepler’s second law).

(Q22) 8 points  
**Three masses are located as shown in the diagram. What is the direction of the net force acting upon \( m_2 \)? Explain.**

Since \( m_1 \) is closer to \( m_2 \) than \( m_3 \) is, it will exert a greater force on \( m_2 \) than \( m_3 \) will. As a result, the net force acting on \( m_2 \) will be directed toward \( m_1 \) (or, to the left).
Is Kepler’s third law valid for artificial satellites orbiting about the Earth? Explain.

Kepler’s third law states that the square of the period of any planet is proportional to the cube of the semimajor axis of its orbit \( T^2 \propto a^3 \), where the proportionality constant is the same for any planet around the Sun. Unfortunately, the proportionality constant used for the planets orbiting the Sun is not the same as that for an artificial satellite orbiting the Earth. As a result, Kepler’s third law is only valid for planets orbiting the Sun (for other satellites, we must use Newton’s version of Kepler’s third law).

How much larger is the required centripetal acceleration for a car rounding a curve at 60 MPH than for one rounding the same curve at 30 MPH?

Using \( a_c = \frac{v^2}{r} \), we find that doubling the speed of the car (from say 30 MPH to 60 MPH), results in an increase in the required centripetal acceleration by a factor of 4.

A Ferris wheel at a carnival has a radius of 12 m and turns so that the speed of the riders is 8 m/s.

a. What is the magnitude of the centripetal acceleration of the riders?

The magnitude of the centripetal acceleration of the riders is

\[ a_c = \frac{v^2}{r} = \frac{(8 \text{ m/s})^2}{12 \text{ m}} = 5.3 \text{ m/s}^2. \]

What is the magnitude of the net force required to produce this centripetal acceleration for a rider with a mass of 70 kg?

Using Newton’s second law, we find that the magnitude of the net force required to produce this centripetal acceleration is

\[ F = ma_c = (70 \text{ kg})(5.3 \text{ m/s}^2) = 373 \text{ N}. \]

Joe has a weight of 720 N (about 162 lb) when he is standing on the surface of the Earth. What would his weight (the gravitational force due to the Earth) be if he doubled his distance from the center of the Earth by flying in a spacecraft?

The magnitude of the gravitational force exerted on a particle (Joe, in this case) on mass \( m \) by the Earth (which has a mass \( M_E \)) is \( F = \frac{GM_Em}{d^2} \), where \( d \) is the distance between the particle (Joe) and the center of the Earth. By doubling this distance, we find that the gravitational force decreases by a factor of 4. Therefore, while Joe is flying in the spacecraft, his weight will be 180 N.

Two 200-kg masses (440 lb) are separated by a distance of 1 m. Using Newton’s law of gravitation, find the magnitude of the gravitational force exerted by one mass on the other.

Using Newton’s law of gravitation, we find that magnitude of the gravitational force exerted by one mass on the other is

\[ F = \frac{Gm_1 m_2}{d^2} = \frac{(6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2)(200 \text{ kg})(200 \text{ kg})}{(1 \text{ m})^2} = 2.67 \times 10^{-6} \text{ N}. \]