CONCEPTUAL QUESTIONS

10. **REASONING AND SOLUTION**  The mass of an object is a quantitative measure of its inertia. The mass of an object is an intrinsic property of the object and is independent of the location of the object. The weight of an object is the gravitational force exerted on the object by the earth. The gravitational force depends on the distance between the object and the center of the earth. Therefore, when an object is moved from sea level to the top of a mountain, its weight will change, while the mass of the object remains constant.

PROBLEMS

21. **REASONING**  The magnitude of the gravitational force that each part exerts on the other is given by Newton’s law of gravitation as $F = \frac{Gm_1m_2}{r^2}$. To use this expression, we need the masses $m_1$ and $m_2$ of the parts, whereas the problem statement gives the weights $W_1$ and $W_2$. However, the weight is related to the mass by $W = mg$, so that for each part we know that $m = \frac{W}{g}$.

**SOLUTION**  The gravitational force that each part exerts on the other is

$$F = \frac{Gm_1m_2}{r^2} = \frac{G(W_1/g)(W_2/g)}{r^2} = \frac{W_1}{(W_1/g)^2} \frac{W_2}{(W_2/g)^2} = \frac{6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2)(11000 \text{ N})(3400 \text{ N})}{(9.80 \text{ m/s}^2)^2(12 \text{ m})^2} = 1.8 \times 10^{-7} \text{ N}$$

25. **REASONING**  According to Equation 4.4, the weights of an object of mass $m$ on the surfaces of planet A (mass $= M_A$, radius $= R$) and planet B (mass $= M_B$, radius $= R$) are

$$W_A = \frac{GM_A}{R^2} \quad \text{and} \quad W_B = \frac{GM_B}{R^2}$$

The difference between these weights is given in the problem.

**SOLUTION**  The difference in weights is

$$W_A - W_B = \frac{GM_A}{R^2} - \frac{GM_B}{R^2} = \frac{GM}{R^2} (M_A - M_B)$$
Rearranging this result, we find

\[
M_A - M_B = \frac{(W_A - W_B)R^2}{Gm} = \frac{(3620 \text{ N})(1.33 \times 10^7 \text{ m})^2}{(6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2)(5450 \text{ kg})} = 1.76 \times 10^{24} \text{ kg}
\]

26. **REASONING AND SOLUTION** The planet's acceleration due to gravity is

\[
g_p = G \frac{0.1m_e}{(0.5r_e)^2} = 0.4g_e = 3.92 \text{ m/s}^2
\]

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**CHAPTER 5 | DYNAMICS OF UNIFORM CIRCULAR MOTION**

**CONCEPTUAL QUESTIONS**

5. **REASONING AND SOLUTION** When the car is moving at constant speed along the straight segments (i.e., AB and DE), the acceleration is zero. Along the curved segments, the magnitude of the acceleration is given by \(a_c = \frac{v^2}{r}\). Since the speed of the car is constant, the magnitude of the acceleration is largest where the radius \(r\) is smallest. Ranked from smallest to largest the magnitudes of the accelerations in each of the four sections are: AB or DE, CD, BC.

14. **REASONING AND SOLUTION** When the string is whirled in a horizontal circle, the tension in the string, \(F_T\), provides the centripetal force which causes the stone to move in a circle. Since the speed of the stone is constant, \(a=0\) and the tension in the string is constant.

When the string is whirled in a vertical circle, the tension in the string and the weight of the stone both contribute to the centripetal force, depending on where the stone is on the circle. Now, however, the tension increases and decreases as the stone traverses the vertical circle. When the stone is at the lowest point in its swing, the tension in the string pulls the stone upward, while the weight of the stone acts downward. Therefore, the centripetal force is \(F_c = T - mg\). Solving for the tension shows that \(T = F_c + mg\). This tension is larger than in the horizontal case. Therefore, the string has a greater chance of breaking when the stone is whirled in a vertical circle.
PROBLEMS

3. **REASONING AND SOLUTION** The time for one revolution, the period $T$, can be found from

$$T = \frac{2\pi r}{v}$$

Rearranging gives

$$r = \frac{T v}{2\pi} = \frac{(118s)(17m/s)}{2\pi} = 319m$$

10. **REASONING AND SOLUTION** The sample makes one revolution in time, $T$, as given by $T = 2\delta r/v$. The speed is

$$v^2 = ra_c = (5.00 \times 10^{-2} m)(6.25 \times 10^3)(9.80 \text{ m/s}^2)$$

so that $v = 55.3 \text{ m/s}$

The period is

$$T = 2\pi (5.00 \times 10^{-2} m)/(55.3 \text{ m/s}) = 5.68 \times 10^{-3} \text{ s} = 9.47 \times 10^{-5} \text{ min}$$

The number of revolutions per minute = $1/T = \boxed{10 600 \text{ rev/min}}$.

15. **REASONING AND SOLUTION**

a. In terms of the period of the motion, the centripetal force is written as

$$F_c = 4\pi^2mr/T^2 = 4\pi^2 (0.0120 \text{ kg})(0.100 \text{ m})/(0.500 \text{ s})^2 = 0.1895\text{N}$$

b. The centripetal force varies as the square of the speed. Thus, doubling the speed would quadruple the centripetal force.

51. **REASONING** The centripetal acceleration for any point that is a distance $r$ from the center of the disc is, according to Equation 5.2, $a_c = v^2 / r$. From Equation 5.1, we know that $v = 2\pi r / T$ where $T$ is the period of the motion. Combining these two equations, we obtain

$$a_c = \frac{4\pi^2 r}{T^2}$$

**SOLUTION** Using the above expression for $a_c$, the ratio of the centripetal accelerations of the two points in question is

$$\frac{a_1}{a_2} = \frac{4\pi^2 r_1 T_2^2}{4\pi^2 r_2 T_1^2} = \frac{r_1}{r_2} \frac{T_2^2}{T_1^2}$$
Since the disc is rigid, all points on the disc must move with the same period, so $T_1 = T_2$. Making this cancellation and solving for $a_2$, we obtain

$$a_2 = a_1 \frac{r_2}{r_1} = (120 \text{ m/s}^2) \left(\frac{0.050 \text{ m}}{0.030 \text{ m}}\right) = 2.0 \times 10^2 \text{ m/s}^2$$

Note that even though $T_1 = T_2$, it is not true that $v_1 = v_2$. Thus, the simplest way to approach this problem is to express the centripetal acceleration in terms of the period $T$ which cancels in the final step.