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Circular Motion, Gravitation, Simple Harmonic Motion

Upon completion of this unit you should understand:

1. The uniform circular motion of a particle, so you can:
   a) Relate the radius of the circle and the speed or rate of revolution of the particle to the magnitude of the centripetal acceleration.
   b) Describe the direction of the particle’s velocity and acceleration at any instant during the motion.
   c) Determine the components of the velocity and acceleration vectors at any instant, and sketch or identify graphs of these quantities.
   d) Analyze motion in a horizontal circle (e.g. mass on a rotating merry-go-round, or car rounding a banked curve).
   e) Analyze motion in a vertical circle (e.g. mass swinging on the end of a string, cart rolling down a curved track, rider on a Ferris wheel).

2. Newton’s Law of Universal Gravitation so you can:
   a) Determine the force that one spherically symmetrical mass exerts on another.
   b) Determine the strength of the gravitational field at a specified point outside a spherically symmetrical mass.

3. The motion of a body in a circular orbit under the influence of gravitational forces so you can recognize that the motion does not depend on the body’s mass, describe qualitatively how the velocity, period of revolution, and centripetal acceleration depend upon the radius of the orbit, and derive expressions for the velocity and period of revolution in such an orbit.

4. Torque and Rotational Statics so you can:
   a) Calculate the magnitude and sense of the torque associated with a given force.
   b) Calculate the torque on a rigid body due to gravity.
   c) State the conditions for translational and rotational equilibrium of a rigid body.
   d) Apply these conditions in analyzing the equilibrium of a rigid body under the combined influence of a number of coplanar forces applied at different locations.

5. The kinematics of simple harmonic motion so that you can:
   a. Sketch or identify a graph of displacement as a function of time, and determine from such a graph the amplitude, period, and frequency of the motion.
   b. Identify points in the motion where the velocity is zero or achieves its maximum positive or negative value.
   c. State quantitatively the relation between acceleration and displacement in simple harmonic motion.
   d. Identify points in the motion where the acceleration is zero or achieves its greatest positive or negative value.
   e. State and apply the relation between frequency and period for simple harmonic motion.
   f. State how the total energy of an oscillating system depends in the amplitude of the motion, sketch or identify a graph of kinetic or potential energy as a function of time, and identify points in the motion where this energy is all potential or all kinetic.

2. How to apply the knowledge of simple harmonic motion to the case of a mass on a spring, so you can apply the expression for the period of oscillation of a mass on a spring.

3. How to apply the knowledge of simple harmonic motion to the case of a pendulum, so you can:
   a. Apply the expression for the period of a simple pendulum.
   b. State what approximation must be made in deriving the period.
I have not failed. I’ve just found 10,000 ways that won’t work. -- Thomas Edison

1. A uniform 12.0 m long ladder weighing 125 N rests against a smooth vertical wall. The bottom of the ladder makes an angle of 67.0° with the deck. A bucket of paint with a mass of 14.0 kg rests on a rung, 7.00 m from the bottom end of the ladder. What is the frictional force exerted on the bottom of the ladder?

2. A 158 kg monster runs up a hill that has a slope of 18.0° to the horizontal. The loathsome beast travels 1550 m in 105 seconds. (a) How much work did the creature do on itself? (b) How much power did it develop?
3. A drum of chemical waste has a lid with a radius of 35.0 cm. To open the thing, a torque of 367 Nm is required. With what force must you work on the thing?

4. A uniform 325 N beam that is 3.35 m in length sticks out from a vertical wall. A lightweight cable connects the end of the beam to the wall, making an angle of 60.0° between the beam and the cable. A 625 N worker stands on the beam a distance of 1.10 m from the wall. (a) What is the tension in the cable? (b) What is the force exerted on the beam by the wall?

5. Two little kiddies sit on a teeter totter. One kid has a mass of 15.2 kg and is 1.10 m from the point of balance. The other tot has a mass of 17.1 kg. How far away from the pivot is the second child?
<table>
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<th>Problem</th>
<th>Free Body diagram</th>
<th>Centripetal Force</th>
<th>Set up equation</th>
<th>Solve</th>
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<td>The coefficient of friction acting upon a 900-kg car is 0.850. The car is making a turn around a curve with a radius of 35.0m. Determine the maximum speed with which the car can make the turn.</td>
<td>side view</td>
<td></td>
<td></td>
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<tr>
<td>What is the acceleration of gravity on an astronaut 10000m above the Earth's surface?</td>
<td>side view</td>
<td></td>
<td></td>
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<tr>
<td>( r_{\text{earth}} = 6.38 \times 10^6 \text{ m} \quad \text{m}_{\text{earth}} = 5.97 \times 10^{24} \text{ kg} )</td>
<td></td>
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<tr>
<td>3 kg of water is swung in a vertical circle of radius 0.75 m. If the net force at the top of the swing is 35 N, what is the tangential speed of the water?</td>
<td>head-on view</td>
<td></td>
<td></td>
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<tr>
<td>The Gravitron: If the diameter of the cylinder is 4 m and the rotational period is 2 seconds, find the minimum coefficient of friction needed for the people not to slide down.</td>
<td>side view</td>
<td></td>
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<tr>
<td>Capt. Chip must remain in a holding pattern above the airport. If he flies with a radius of 50000 once every 30 min, what centripetal force must the air exert on the wings of the 50000 kg plane?</td>
<td>birds-eye view</td>
<td></td>
<td></td>
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\[
F_c = ma_c \quad \text{a}_c = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2} = 4\pi^2 rf^2 \quad F_f = \mu F_n \quad mg = F_g = G \frac{m_1 m_2}{r^2} \quad G = 6.67 \times 10^{-11} \text{Nm}^2/\text{kg}^2
\]
AP Physics – Don’t get me Torqued lab

Green Eggs and Hamlet - Would you kill him in his bed? Thrust a dagger through his head? I would not, could not, kill the king. I could not do that evil thing. I would not wed this girl, you see. Now get her to a nunnery.
-- Washington Post’s “Style Invitational”

Here's the deal. In a stationary system, one that is not rotating, the sum of the torques must equal zero. Remember?

Okay, your mission. . . . prove it.

Craft you a lab that will prove that the sum of the torques of a non rotating system is zero.

Remember, a good lab has multiple trials.

Write the lab so another student can follow along and perform the lab.

May the torque be with you.
AP Physics
Centripetal Force Lab

Purpose: a) To determine the relationship between centripetal force and frequency, and
b) verify the equation \( F_c = m \frac{4\pi^2 r}{T^2} \).

Other useful equations.

\[
F_c = ma_c \\
a_c = \frac{v^2}{r} \quad \text{or} \quad a_c = \frac{4\pi^2 r}{T^2} \\
F_c = m \frac{v^2}{r} \\
T = \frac{1}{f}
\]

| Table (1) |

| Mass of stopper (kg): | Average mass of 1 washer (kg): | Mass of Alligator Clip (kg): |

<table>
<thead>
<tr>
<th># of Washers</th>
<th>Mass of Washers + Clip (kg)</th>
<th>Time for 10 revolutions (s)</th>
<th>Period (s)</th>
<th>Frequency (Hz)</th>
<th>Radius (m)</th>
<th>Centrip. Acceleration (m/s²)</th>
<th>Exp. Centrip. Force (N)</th>
<th>Theo. Centrip. Force (N)</th>
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Get 5 trials

1) Satisfy purpose (a) by making a graph using Logger Pro 3.3.
2) Calculate a new column of data to straighten out the graph above. Please enter the data in the space provided on Table (1), and graph the new data points.

3) How are centripetal frequency and force related? How can you prove this?

4) Satisfy purpose (b)? \((100\% \times (T-E)/T)\)
   Which trial gave you the largest percent difference? Why?

5) Given the bird’s eye view of the stopper: at point A, draw the direction of the centripetal force; at point B, draw the direction of the linear velocity of the stopper; at point C, draw the direction of the stopper’s acceleration. The stopper is traveling counterclockwise.


6) If the string attached to the stopper suddenly broke, which way would the stopper go? Explain why this occurs using one of Newton’s Laws.
7) Was the stopper rotating or revolving?

8) What would the period of your stopper be if \( m = 80 \text{ kg} \) was hanging from the string instead of the washers? Assume your stopper's radius was 0.8m.

9) Complete the AP Free Response below.

1. A 0.10-kilogram solid rubber ball is attached to the end of an 0.80-meter length of light thread. The ball is swung in a vertical circle, as shown in the diagram above. Point \( P \), the lowest point of the circle, is 0.20 meter above the floor. The speed of the ball at the top of the circle is 6.0 meters per second, and the total energy of the ball is kept constant.

   (a) Determine the total energy of the ball, using the floor as the zero point for gravitational potential energy.

   (b) Determine the speed of the ball at point \( P \), the lowest point of the circle.

   (c) Determine the tension in the thread at
      i. the top of the circle;
      ii. the bottom of the circle.

   The ball only reaches the top of the circle once before the thread breaks when the ball is at the lowest point of the circle.

   (d) Determine the horizontal distance that the ball travels before hitting the floor.
7.4 Centripetal Acceleration

We have uniform circular motion when there is an acceleration of constant magnitude continually occurs in a direction that is perpendicular to the velocity. This acceleration is called centripetal acceleration since it always points towards the center of the circle. It is along the radius of the circular motion it produces, but oppositely directed. It’s magnitude is given by

\[ a_c = \frac{v^2}{r} = \frac{(r\omega)^2}{r} = r\omega^2 \quad (n.m) \]

If there is also tangential acceleration present the motion may still be circular but it is no longer uniform. The tangential and centripetal accelerations are vectors perpendicular to each other so the magnitude of the resultant acceleration may be obtained from the Pythagorean theorem:

\[ a = \sqrt{a_t^2 + a_c^2} \quad (n.m) \]

7.5 Centripetal Force

If a particle of mass \( m \) is undergoing centripetal acceleration, there must be a net force causing it and the force is called centripetal force. It is parallel to the acceleration and, therefore, along \(-r\).

\[ F_c = ma_c = \frac{mv^2}{r} = mr\omega^2 \quad (n.m) \]

7.6 Describing Motion of a Rotating System

In order to remain in circular motion there must be centripetal accelerations present. Thus an observer in a rotating reference frame is in an accelerated reference frame. Newton’s laws as he gave them to us apply only to inertial (non-accelerating) reference frames. To pretend one is in an inertial frame when actually in a rotating one, requires that one introduces fictional forces to explain the motion of objects. Some of the fictitious forces are the “reaction” forces to the centripetal forces. These non-real forces, called centrifugal, seem real as long as the observer fails to recognize he is in a rotating frame of reference. The surface of the earth rotates about an axis through the poles. Therefore, we observe small centrifugal forces. The measured weight on a spring scale is a little less than it would be if the earth were not rotating.

7.7 Newton’s Universal Law of Gravitation

Newton published his theory of gravitation in 1687 which states: Every particle in the Universe attracts every other particle with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

We have previously described the magnitude of this force as being “weight”. The magnitude of the gravitational acceleration was \( g \) so \( w = mg \). The gravitational acceleration depends on the mass of the object and the distance from it so

\[ g = \frac{Gm_2}{r^2} \quad \text{so that} \quad F_g = \frac{Gm_1m_2}{r^2} = m_1g \quad (n.m) \]

where \( G \) is the universal gravitational constant, with the value \( G = 6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2 \). When \( r = R_E \), the radius of the Earth, and \( m_2 = M_E \), the mass of the Earth, the value of \( g \) is 9.8 m/s² and \( F_g \) equals the weight of the object at the Earth’s surface.

7.8 Kepler’s Laws

Using the data about the positions of the planets in the sky as measured by Tycho Brahe, Johannes Kepler, an assistant of Brahe, deduced three laws of planetary motion. They are:

1. Every planet moves in an elliptical orbit with the Sun at one of the focal points.

2. The radius vector drawn from the Sun to any planet sweeps out equal areas in equal time intervals.

3. The square of the orbital period of any planet is proportional to the cube of the semimajor axis of the elliptical orbit (the average distance of the planet from the sun as it completes an orbit).

Newton was able to use his three laws of motion along with his law of gravity and derive these three laws of Kepler. Newton was able to derive the constant of proportionality in Kepler’s third law and from this it is possible to get the masses of the moon, sun, planets and various satellites. This was done as follows.

KEPLER’S THIRD LAW

By equating the gravitational force of the sun on a planet to the centripetal force (assuming a circular orbit) and setting \( v = 2\pi r/T \) (\( T \) is the period of revolution) one readily derives Kepler’s third law and obtains a value for Kepler’s proportionality constant from which the mass of the sun can be calculated.

\[ \frac{GM_1M_2}{r^2} = \frac{M_2v^2}{r} \quad \text{so} \quad \frac{GM}{r^2} = \left( \frac{4\pi^2}{GM} \right)^3 = K_r^3 \], where

the value of \( K_r \) is, \( K_r = 2.97 \times 10^{-19} \text{ s}^2/\text{m}^3 \).

These equations also apply to planets with a somewhat different value for \( K_r \) since the mass of the planet is different than the sun’s mass. By observing the satellites orbiting a planet, we can use Kepler’s third law to get the mass of the planet.
8
Rotational Equilibrium
and Dynamics

Motion About a
Fixed Axis

Objects at rest or moving at constant velocity are said to be in equilibrium. Buildings, bridges, and biological systems at rest are all examples of the application of equilibrium concepts. From chapter 7 we already have the definitions we need for rotational kinematic equations. From there we can get the dynamical equations, talk about torque (analogous to force), angular momentum (analogous to linear momentum), rotational kinetic energy, etc.

8.1 Torque

The ability of a force to rotate a body about some axis is measured by a quantity called torque, \( \tau \). Torque, like force, is a vector. Its magnitude is

\[
\text{Torque} \quad \tau = Fd \tag{8.1}
\]

\( d \) is the lever arm and is the perpendicular distance from the axis of rotation to a line drawn along the direction of force.

If there are several forces acting on the object then the net torque is obtained by summing the torques produced by each of the forces, thus

\[
\tau_{\text{net}} = \sum \tau = \tau_1 + \tau_2 + \ldots = F_1d_1 + F_2d_2 + \ldots \tag{8.2}
\]

8.2 Torque and the Second Condition for Equilibrium

In section 4.6 we discussed the first condition for equilibrium, namely the sum of all the external forces is zero. With no net forces acting on the object it obeys Newton's first law, i.e., no accelerations and thus no changes in motion. (\( \sum F = 0 \)) The object could still rotate and even change its rate of rotation if the torques don't add to zero.

The second condition for equilibrium, therefore, is that there are no changes in rotation. This happens when the sum of the external torques adds to zero, so we have

\[
\sum \tau = 0 \tag{8.3}
\]

POSITION OF THE AXIS OF ROTATION

If the object is in equilibrium, it does not matter where you put the axis of rotation for calculating the net torque; the location of the axis is completely arbitrary.
Gravitation, and Uniform Circular Motion

CHOOSE THE BEST ANSWER TO THE FOLLOWING MULTIPLE CHOICE QUESTIONS.

1. Which of the following best describes the motion of the tip of the second hand moving around a clock?
   a. accelerated motion
   b. periodic motion
   c. constant speed motion
   d. all of the above

2. If you double the speed of your car as you go around a turn, what happens to the amount of force required to keep the car on the road?
   a. the necessary force doubles
   b. the necessary force quadruples
   c. the necessary force is increased eight times
   d. there is no change in force

3. Which of the following would double the force necessary to keep a ball swinging around in a circle at the end of a string?
   a. double the mass of the ball
   b. double the period for one rotation
   c. double the speed of the ball
   d. quadruple the radius

4. How are the acceleration and velocity vectors arranged for a satellite in a circular orbit around the Earth?
   a. the two vectors are pointing in the same direction
   b. the two vectors point in opposite directions
   c. the velocity vector points 90° away from the acceleration vector
   d. the velocity vector is a real vector; acceleration is imaginary

5. If the sun were to collapse to form a black hole (it is impossible for this to really happen), what would happen to the earth?
   a. It would be drawn directly into the black hole.
   b. It would leave the solar system in the direction of its tangential velocity at the time of the sun's collapse.
   c. It would orbit the black hole just as it orbits the sun now.
   d. It would spiral into the black hole.

6. People in the future may well live inside a rotating space structure that is more than 2 km in diameter. Within this structure, people on the inside edge of the outer edge will experience 1 g while people halfway to the axis will experience
   a. 1/4 g
   b. 1/2 g
   c. 1 g
   d. 2 g
   e. 4 g
7. For the wheelbarrow shown below, what is the weight on the front wheel?
   a. (50 cm/150 cm)(800 N) = 267 N-cm
   b. (50 cm/100 cm)(800 N) = 400 N-cm
   c. (100 cm/150 cm)(800 N) = 533 N-cm
   d. (100 cm/50 cm)(800 N) = 1600 N-cm

8. Which one of the following would be considered an inertial frame of reference?
   a. a car going very slowly around a curve
   b. a space ship cruising at constant velocity of half the speed of light
   c. a slowly oscillating platform that has very large mass
   d. a train braking to a stop

9. An object on a string is moving around the circle as shown below. If the string breaks when the object is at point A, the object will fly off in the direction of which arrow?

10. An object weighing 40 N on the earth's surface would weigh only 10 N when its distance from the center of the earth is
    a. doubled
    b. halved
    c. tripled
    d. quadrupled

11. You weigh 526 N on Earth. Planet X has twice the mass of Earth and twice the radius of Earth. What is your weight in newtons on planet X?
    a. 53 N
    b. 263 N
    c. 526 N
    d. 1040 N

12. An automobile changes its velocity from 12 m/s due east to 12 m/s due north. Its vector change of velocity is:
    a. 24 m/s northeast
    b. 24 m/s northwest
    c. 17 m/s northeast
    d. 17 m/s northwest

13. A planet traveling in an elliptical orbit around the sun moves so that the line from the sun to it:
    a. rotates with constant speed
    b. rotates with constant acceleration
    c. rotates more slowly when the body is further from the sun
    d. rotates so that it sweeps through the same number of degrees each second
14. A satellite of a planet follows an elliptical orbit as shown in the drawing. What is the value of the ratio (speed of satellite at P/speed of satellite at Q)?

15. As air resistance causes an orbiting satellite to spiral in toward the earth, there is a decrease in the satellite's:
   a. orbital speed  b. period  c. weight  d. mass

16. A man standing on a scale at the equator weighs 800 N. If the earth were not rotating, the weight of the man would be:
   a. 800 N  b. more than 800  c. less than 800 N

17. A small test mass is placed on the line joining a mass of 4 kg and a mass of 1 kg at such a point that their combined gravitational attractions on it cancel out. The two masses are 12 meters apart. The position of the test mass is:
   a. midway between the two masses  c. 3 meters from the smaller mass
   b. 4 meters from the smaller mass  d. 2 meters from the smaller mass

18. An object of fixed mass is kept moving in a circular orbit of fixed radius. As the speed of the body changes, the centripetal force acting upon it varies inversely with:
   a. the speed  c. the period
   b. the square of the speed  d. the square of the period

19. The strength of the earth's gravitational field at a point in space at which a mass \( m \) is acted on by a force \( f \) is:
   a. \( mg \)  b. \( f/m \)  c. \( f/mg \)  d. \( m/f \)

20. As the altitude at which a satellite is to be launched in a circular orbit around the earth increases, the velocity that must be given the satellite:
   a. increases  b. decreases  c. remains the same

21. The gravitational field strength at the center of the earth is
   a. great  b. the same as the surface of the earth
   c. smaller than at the center, but greater than zero  d. zero
For Questions 22 – 23:

The apparatus shown is used for studying centripetal force. The rubber stopper swings around in a horizontal circle at constant speed. $m_g \vec{g}$ is the weight of the stopper, $m_w \vec{g}$ the weight of the washers suspended from the cord, and $\vec{F}$ the tension in the cord.

22. Which choice below gives the correct expression for the centripetal force acting on the stopper?

(A) $m_g \vec{g} - \vec{F}$
(B) $m_w \vec{g} - \vec{F}$
(C) $m_g \vec{g}$
(D) $m_w \vec{g}$
(E) $\vec{F}$

23. With a given value of length $L$, a certain period is obtained when 8 washers are suspended from the cord. If a second stopper, identical to the first, is fastened to the first stopper, how many washers must be suspended from the cord with the same value of $L$ to obtain the same period?

(A) 2  (B) 4  (C) 8  (D) 16  (E) 32

24. A student is riding a constant speed merry-go-round, as shown above. When the student is at point $P$, which set of vectors shows the direction of the student's

I. velocity $\vec{v}$,
II. acceleration $\vec{a}$, and
III. centripetal force $\vec{F}$?

(A) A
(B) B
(C) C
(D) D
(E) E

25. An object is moving at a constant speed of 20 meters/second in a circle with a radius of 10 meters. What is the period of rotation of this object?

(A) $1\pi$ seconds
(B) $2\pi$ seconds
(C) $4\pi$ seconds
(D) 10 seconds
(E) 20 seconds

26. Which equation(s) can be used to describe the motion of an object moving in a horizontal circle with a radius $R$, period $T$ and constant speed $v$?

I. $F = ma$
II. $v = \frac{2\pi R}{T}$
III. $a = \frac{v^2}{R}$

(A) I only
(B) II only
(C) III only
(D) II and III only
(E) I, II, and III
27. A satellite moves with constant speed along a circular path. Which of the following best represents the acceleration $a$ of the satellite when it is at point $P$ on the path?

![Diagram](image)

(A) ![Diagram](image)

(B) ![Diagram](image)

(C) ![Diagram](image)

(D) ![Diagram](image)

(E) ![Diagram](image)

29. An object has a mass of 50 grams. What is the object's approximate weight on the surface of the earth?

(A) 0.50 newton
(B) 5.0 newtons
(C) 20 newtons
(D) 50 newtons
(E) 500 newtons

30. A satellite is in a circular orbit about the Earth. The gravitational force exerted on the satellite by the Earth is

(A) zero
(B) less than the centripetal force exerted on the satellite
(C) independent of the mass of the satellite
(D) equal but opposite to the gravitational force exerted on the Earth by the satellite
(E) less than but opposite to the gravitational force exerted on the Earth by the satellite

31. A stone is moving at constant speed in a horizontal circular path on a frictionless table. If the speed of the stone is doubled without changing the radius of the path, the centripetal force will be

(A) one-fourth as great.
(B) one-half as great.
(C) unchanged.
(D) twice as great.
(E) four times as great.

28. Planet Earth has mass $M$ and radius $R$; planet $X$ has mass $2M$ and radius $3R$. If Janie weighs 450 newtons (N) on the Earth, then her weight on planet $X$ is most nearly

(A) 100 N
(B) 200 N
(C) 300 N
(D) 450 N
(E) 680 N
32. An object with a mass M on the end of a rod is moving in a **vertical** circle with a constant speed. The force exerted by the rod is:
   (A) the same at points I, II, III, and IV.
   (B) largest at point I (top of circle).
   (C) largest at point II.
   (D) largest at point III (bottom of circle).
   (E) largest at point IV.

33. A car is to make a turn without skidding on an unbanked curve with a radius of 90 meters. If the coefficient of friction is 0.64, what is the maximum speed the car can have?
   (A) Less than 5 meters/second.
   (B) Between 5 and 10 meters/second.
   (C) Between 10 and 15 meters/second.
   (D) Between 15 and 20 meters/second.
   (E) More than 20 meters/second.

34. If the distance between the center of the earth and a satellite were halved, the force of gravitation between the earth and the satellite would be about
   (A) one-fourth as great.
   (B) one-half as great.
   (C) the same.
   (D) twice as great.
   (E) four times as great.

35. Two stationary bodies attract each other with a gravitational force of $5.0 \times 10^{-12}$ newtons. What will be the force if the mass of each body is tripled?
   (A) $1.5 \times 10^{-12}$ newtons.
   (B) $3.0 \times 10^{-11}$ newtons.
   (C) $4.5 \times 10^{-11}$ newtons.
   (D) $2.1 \times 10^{-10}$ newtons.
   (E) $4.1 \times 10^{-10}$ newtons.
1. Passengers riding in the Great Six Flags Air Racer are spun around a tall steel tower. At top speed the planes fly at a 56-degree bank approximately 46 m from the tower. In this position the support chains make an angle of 56 degrees with a vertical line.

a) Calculate the speed of the planes.

b) If the mass of the plane and passengers is 1100 kg, what is the magnitude of the force exerted by the chains?
A popular amusement park ride consists of a broad short cylinder arranged so that it rotates around its vertical axis. People stand inside the cylinder with their backs to the outer wall and "feel pushed back" when the cylinder rotates. When the cylinder is rotating fast enough, it is tipped so that its axis is almost horizontal. If the radius of the cylinder is 4.5 m, how fast must it rotate so that the riders do not fall away from the walls at the topmost position?
3. A sign is supported by a beam and chain as shown below. The mass of the beam is 20 kg, and the mass of the sign is 40 kg. The chain makes an angle of 40 degrees with the beam and the beam is $2.0 \text{ m long}$.

a) What is the tension in the chain?

b) What are the vertical and horizontal components of the force from the wall on the beam?
Passengers riding in the Great SIck Flags Air Racer are spun around a tall steel tower. At top speed the planes fly at a 56 degree bank approximately 46 m from the tower. In this position the support chains make an angle of 56 degrees with a vertical line.

a) Calculate the speed of the planes.

\[ F_{net} = mg \tan 56^\circ \]
\[ F_{net} = 1.48 mg \]
\[ F_{net} = \frac{m v^2}{R} \]
\[ 1.48 mg = \frac{m v^2}{R} \]
\[ 1.48 \times 9.8 m/s^2 \times 46 m = v^2 \]
\[ \sqrt{25.9 m^2/s^2} = v \]

b) If the mass of the plane and passengers is 1100 kg, what is the magnitude of the force exerted by the chains?

\[ \cos 56^\circ = \frac{mg}{T} \]
\[ T = mg \cos 56^\circ = \frac{1100 \times 9.8}{0.559} \]
\[ T = 19,300 N \]
A sign is supported by a beam and chain as shown below. The mass of the beam is 20 kg, and the mass of the sign is 40 kg. The chain makes an angle of 40 degrees with the beam and the beam is 2.0 m long.

a) What is the tension in the chain?

b) What are the vertical and horizontal components of the force from the wall on the beam?

\[ \Sigma \text{Torque}_{\text{clockwise}} = \Sigma \text{Torque}_{\text{ccw}} \]

\[ T \sin 40^\circ \times 2m = 392 \times 2m + 196 \times 1m \]

\[ T = \frac{784 + 196}{2 \times 643} \]

\[ T = 762 \text{ N} \]

b) \[ \Sigma F_{\text{up}} = \Sigma F_{\text{down}} \]

\[ 762 \sin 40^\circ + F_v = 392 + 196 \]

\[ 490 + F_v = 588 \text{ N} \]

\[ F_v = 98 \text{ N} \]

\[ F_{\text{left}} = F_{\text{right}} \]

\[ F_H = T \cos 40^\circ \]

\[ = 762 \times 0.766 \]

\[ = 584 \text{ N} \]
A popular amusement park ride consists of a broad short cylinder arranged so that it rotates around its vertical axis. People stand inside the cylinder with their backs to the outer wall and "feel pushed back" when the cylinder rotates. When the cylinder is rotating fast enough, it is tipped so that its axis is almost horizontal. If the radius of the cylinder is 4.5 m, how fast must it rotate so that the riders do not fall away from the walls at the topmost position?

\[ F_{\text{net}} = \frac{mv^2}{R} \]

\[ mg = \frac{mv^2}{R} \]

\[ \sqrt{gR} = v \]

\[ \sqrt{9.8 \text{ m/s}^2 \times 4.5 \text{ m}} = v \]

\[ 6.6 \text{ m/s} = v \]
1. Cindy Lou has run up a staircase very quickly indeed. Cindy's mass is 35.2 kg. It took her 6.75 s to get to the top. If she developed 0.875 hp on the vertical trip, how high was the staircase?

2. A 255 g mass is hooked up to a spring \((k = 175 \text{ N/m})\) and moves back and forth on your basic frictionless surface. If the mass is released from rest at \(x = 0.200 \text{ m}\), (a) find the force acting on the mass, (b) the max acceleration, (c) it’s acceleration at \(x = 0 \text{ m}\), (d) its energy, and (e) its period.
3. The drawing shows the harmonic motion of a mass on a spring at the extremes of its motion. The middle drawing shows the midpoint of travel. Indicate on the drawing (a) the points of greatest and least velocity, (b) the points of greatest and least acceleration, (c) the points of greatest and least potential E and kinetic E.

4. Using this graph of position vs time for the simple harmonic motion of a weight on a string, find (a) the amplitude of the motion, (b) the period of the motion, (c) the frequency of the motion (d) place on the graph where the velocity is zero, (e) places on the graph where the acceleration is max and min, (f) places on the graph where the kinetic energy is max, (g) places on the graph where the potential energy is max.

5. A 355 g mass is attached to a spring \( k = 435 \text{ N/m} \). If the system is allowed to oscillate on a frictionless surface, what is the period and frequency of the motion?

6. You are designing a pendulum clock escapement. You have determined that the pendulum must have a period of 0.500 s. What should be the length of the thing?
7. A 545 g block is pushed into a spring (k = 485 N/m) a distance of 18.0 cm. (a) When the ball is released, what is its velocity? The block slides across a smooth surface once it leaves the spring and then up a ramp. It travels up the ramp a distance of 275 cm. (b) What is the elevation angle of the ramp?

8. A new planet (mass of $7.50 \times 10^{23}$ kg, radius of $3.50 \times 10^7$ m) is discovered circling the sun (it’s the famous planet X). Anyway, the period for the thing is 67.0 years. So what is the average distance for the planet from the sun? Sun’s mass is $1.99 \times 10^{30}$ kg.
9. A 345 g ball is placed on a ramp as shown in the drawing. The ball rolls downward a distance of 50.0 cm and then goes into a vertical loop deal (like on a roly coaster) and then ends up at the bottom going from point C to point D. Determine the following: (a) the speed of the ball at the bottom of the ramp, point C. (b) the speed of the ball at point A. (c) Draw a FBD for the ball at point A. (d) The force exerted on the ball by the track at point A. (e) The speed of the ball at point B. (f) Draw a FBD for the ball at point B. (g) The speed of the ball at point D. (h) Draw a FBD for the ball at point D.