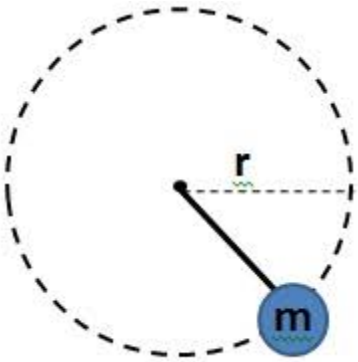
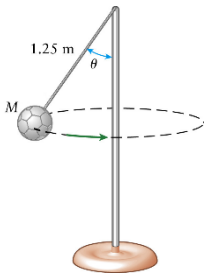
AP Physics – Unit 3 – Circular Motion

Wkst – Circular motion Packet

1. Label the following variables for the object below that has uniform circular motion
    a. The tangential velocity for this object
    b. Centripetal acceleration vector (a_c)
    c. Label the Centripetal Force (Centripetal force is the *NET force*, but not a force, therefor Fc should NEVER appear on FBD)
    d. Predict the motion of the object if the string is cut at the position shown

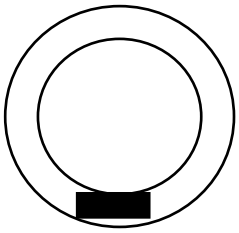


2. Jason hits a tetherball around a pole. In what direction is the acceleration for the ball and what direction is the force?



3. Zack is driving a 2,400 kg race car and is traveling around a circular track that has a radius of 35 meters. If it takes him 23.2 seconds to complete on lap,
    a. What is the speed with which Zack and the car make it around the track?
    b. What is the acceleration?
    c. What is the centripetal force?

d. On the diagram below, label the vector to indicate the centripetal acceleration of the car at the time shown, and label the vector to indicate the velocity of the car at the time shown. The car is traveling in a clockwise direction.

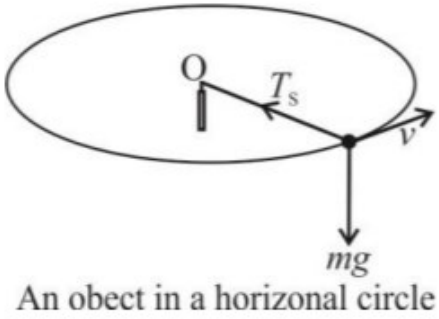


4. Maddy is riding on a merry-go-round and is moving with a speed of 1.00 m/s when she is 1.08m from the center of the merry-go-round.
    a. Calculate Maddy's centripetal acceleration
    b. Calculate the net horizontal force exerted on Maddy (mass 40.0 kg)
    c. Calculate the frequency of revolution Maddy has on the merry-go-round.

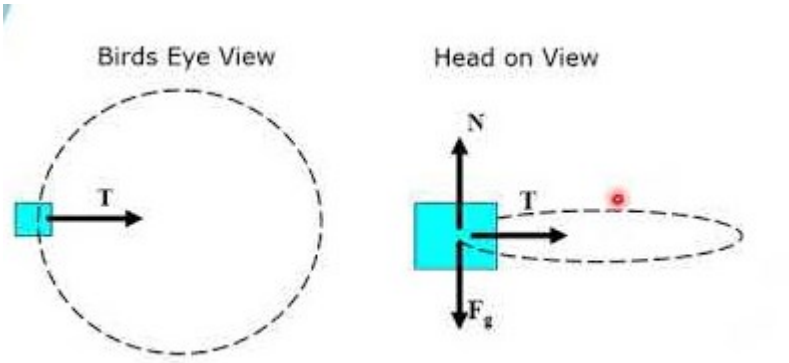
5. Jake has tied a 1.8 kg stone to one end of a string and whirls it at a constant speed of 2.5 m/s along a horizonal circle of radius 1.3m, Determine:
    a. The time period for the circular motion
    b. The frequency of the circular motion
    c. The centripetal acceleration
    d. The tension in the string

6. What would happen to centripetal force if:
    a. The mass of the object is tripled?
    b. The radius of the object was doubled?
    c. The mass was halved and the radius was quadrupled?
    d. The period of object was doubled?

Horizontal Circular motion



An obect in a horizonal circle



Steps

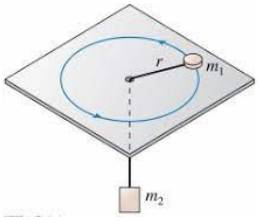
- Make a Free body diagram
- Choose coordinate system
    - One positive axis should be toward the center (acceleration)
    - Remember circular motion a and F_{net} are always TOWARD the center
- Customize $F_{net} = ma$
    - Centripetal force is the *NET force*, but not a force, therefor Fc should NEVER appear on FBD

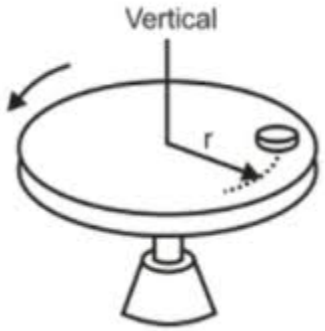
7. Alex is driving his car and is traveling on a 20.0 m radius turn. If the coefficient of static friction between the tires and the surface of the road is 0.600, determine the maximum possible safe speed Alex can travel to avoid slipping.

8. What is the maximum speed with which a 1180 kg car can round a turn of radius 80.0 m on a flat road if the coefficient of friction between the tires and road is 0.80?
    a. Is this result independent of the mass of car?

9. How large must the coefficient of static friction be between the tires and the road if a car is to round a level curve of radius 76 m at a speed of 90. Km/h?

10. A string passing through a hole in a table carries a mass m_1 at one end and a mass m_2 at the other end. Mass m_1 is placed on a horizontal frictionless table and a mass m_2 is hanging freely. The length of the string from the hole to the mass m_1 is r. Determine the frequency with which the mass m_1 must move in a circle of radius r so that the mass m_2 stays at rest.



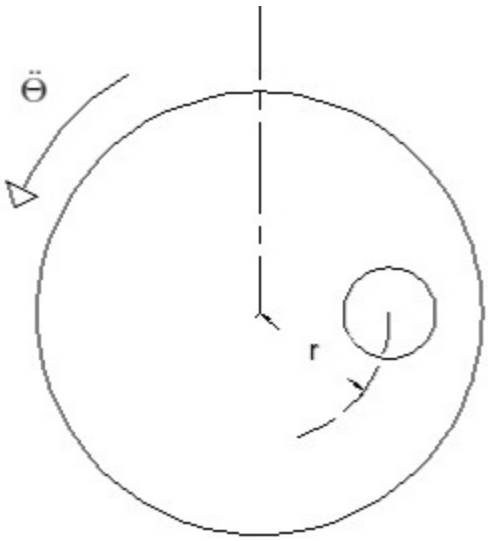


11. A coin C of mass 0.0050 kg is placed on a horizontal disk at a distance of 0.14 m from the center, as shown above. The disk rotates at a constant rate in a counterclockwise direction. The coin does not slip, and the time it takes for the coin to make a complete revolution in 1.5 secs.
    a. The figure below shows the disk and coin as viewed from above. Draw and label vectors on the figure below to show the instantaneous acceleration and linear velocity vectors for the coin when it is at the position shown.

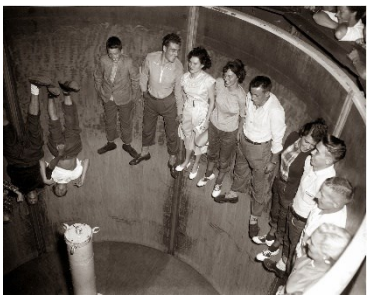
    b. Determine the linear sped of the coin.

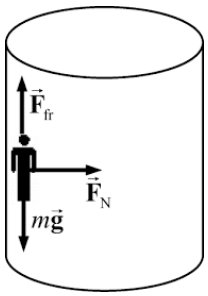
    c. The rate of rotation of the disk is gradually increased. The coefficient of static friction between the coin and the disk is 0.50. Determine the linear speed of the coin when it just begins to slip.

    d. If the experiment in part c were repeated with a second, identical coin glued to the top of the fist coin, how would this affect the answer to part c? Explain your reasoning.



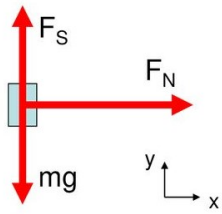
Rotor Circular Motion





Sketch a free-body diagram for the rider.

He's blurry because he is going so fast!



Axis of rotation

Apply Newton's Second Law, once for each direction.

y direction: $F_S - mg = ma_y = 0$ (he hopes)

x direction: $F_N = ma_x = m\,(v^2/r)$

12. In a "Rotor-ride" (also called Gravitron) at a carnival, people pay money to be rotated in a vertical cylindrically walled "room".
    a. If the room radius is 4.7m, and the rotation frequency is 0.70 revolutions per second when the floor drops out, what is the minimum coefficient of static friction so that people will not slip down?

    b. People describe this ride by saying they are being "pressed against the wall". Is this true? Is there really and outward force pressing them against the wall?

13. Troy straps himself into a 5.0m radius Gravitron ride at the local fair. At what frequency does the Gravitron have to be spinning, in order for a 80.0 kg Troy to stay suspended (at rest) during the duration of the ride. The coefficient of friction between Troy and the ride is 0.40.

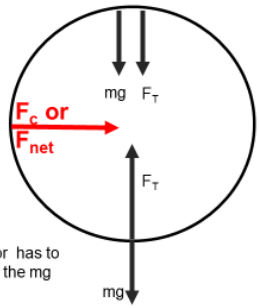
Vertical Circular Motion Problems

Vertical Circular Motion – Ball on String

- Uniform circular motion, ball on string, but what happens to Tension on string Top vs Bottom

$F_c = ma_c = m\frac{V_t^2}{r}$

Fc = Net forces
Fc = forces toward center – forces away from center



Tension vector has to be great than the mg vector

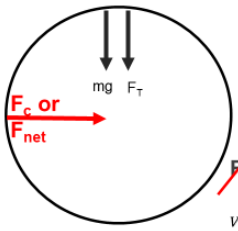
$m\frac{V_t^2}{r} = F_T + mg$ **Lower Tension**

$F_T = m\frac{V_t^2}{r} - mg$

$m\frac{V_t^2}{r} = F_T - mg$ **Higher Tension**

$F_T = m\frac{V_t^2}{r} + mg$

Vertical Circular Motion – Ball on String



$m\frac{V_t^2}{r} = F_T + mg$ **Lower Tension**

$F_T = m\frac{V_t^2}{r} - mg$

0

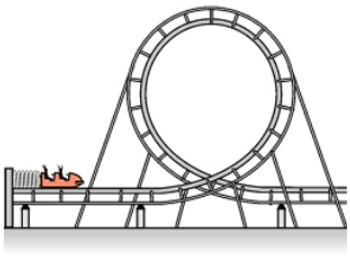
$F_T = m\frac{V_t^2}{r} - mg$

$\frac{V_t^2}{r} = g$

$V_{min} = \sqrt{rg}$

Special Case: To maintain circular motion, the tension on the string at the top of the path must be at least zero. Solving for the velocity when the tension is zero yields the minimum speed for the object at stay on a circular pat at the top.

14. At what minimum speed must a roller coaster be traveling when upside down at the top of a circle if the passengers are not to fall out? Assume a radius of curvature of 8.4m

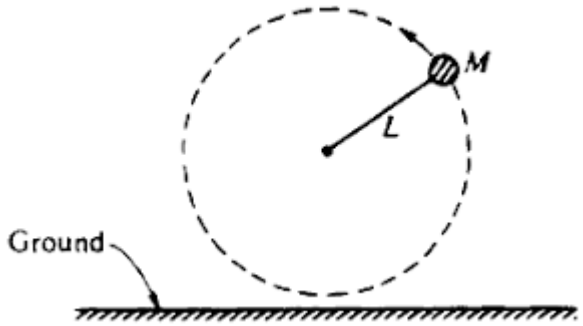


15. A loop de loop roller coaster has a radius of 30.0 m. Determine the apparent weight of a 500. N person will feel at the bottom of the loop, traveling at 25 m/s and at the top of the loop, traveling at a speed of 20. m/s.

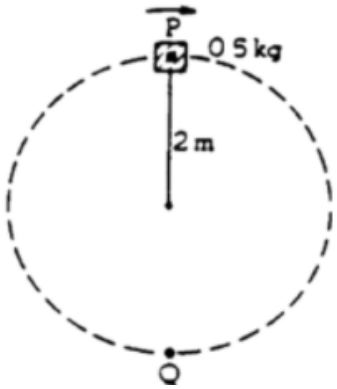
16. A loop-de-loop roller coaster has a radius of 25m. Determine the apparent weight a 600. N rider would feel:

    a. Traveling at a speed of 30. m/s at the bottom of the vertical arc
    b. Traveling at a speed of 10. m/s at the top of vertical arc.

Vertical Circular Motion Problems - Sample AP problems

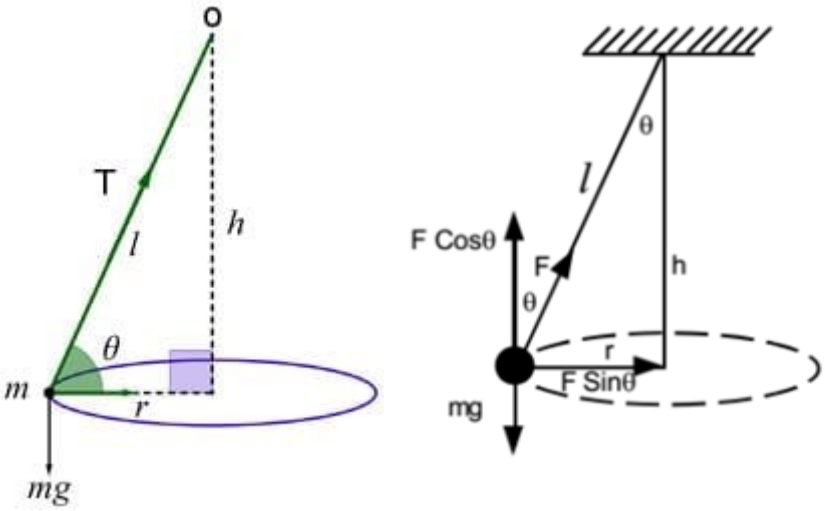


17. A ball of mass M is attached to a string of length L, moves in a circle in a vertical plane as shown above. At the top of the circular path, the tension in the string is twice the weight of the ball. At the bottom, the ball just clears the ground. Air resistance is negligible. Express all answers in terms of M, L, and g.
    a. Determine the magnitude and direction of the net force on the ball when it is at the top.
    b. Determine the speed, v, of the ball at the top
    c. Determine the time it takes the ball to reach the ground
    d. Determine the horizontal distance the ball travels before hitting the ground



18. A 0.50 kg object rotates freely in a vertical circle at the end of a string of length 2.0 m as shown above. As the object passes through point P at the top of the circular path, the tension in the string is 20. N. Assume g =10 m/s2 .
    a. Draw a free body diagram of the object and clearly label all significant forces on the object when it is at point P.
    b. Calculate the speed of the object at point P.
    c. Calculate the tension in the string as the object passes through point Q, assuming the speed doesn't change.

Conical Pendulum Problems

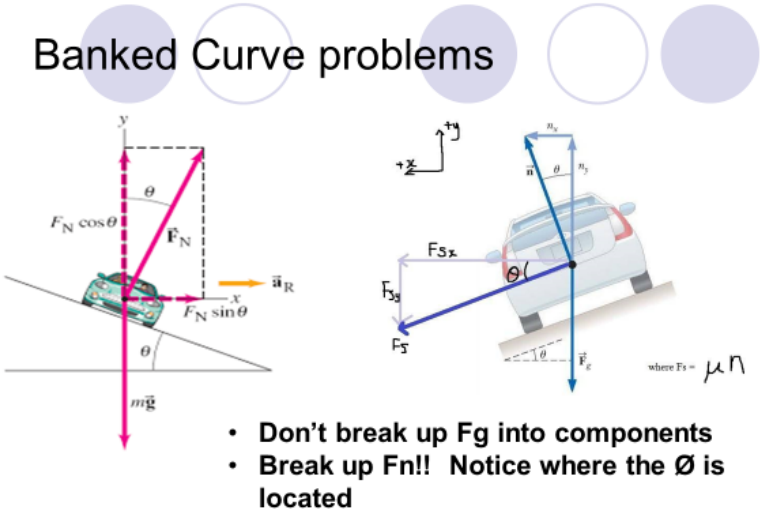


- Solve for radius if given L
  - Sin Ø = $\frac{r}{l}$
- Break up F_T into components

19. A conical pendulum has a string of length 1.8 m at an angle of 30.º from the vertical. The bob has a mass of 0.30 kg. Determine:
    a. The tension in the string
    b. The linear speed of the bob
    c. The period of this conical pendulum

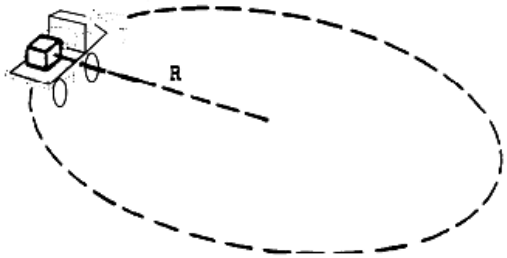
20. A conical pendulum has a bob of mass 0.10 kg and a string length 1.25 m. It's time period is 2.00 s. Determine:
    a. The angle made by the string with the vertical direction
    b. The tension in the string

Banked curve Problems



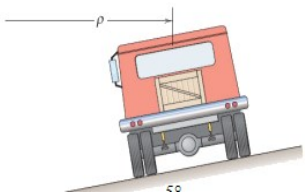
21. Tom like to drive very quickly (at a velocity of V) around the Village of Tulley in the rain. To protect its inhabitants, at what angle should Tully bank its curves around the village of radius r, so that even without friction, Tom makes it safely around the village?

Banked Curve Sample AP Problem



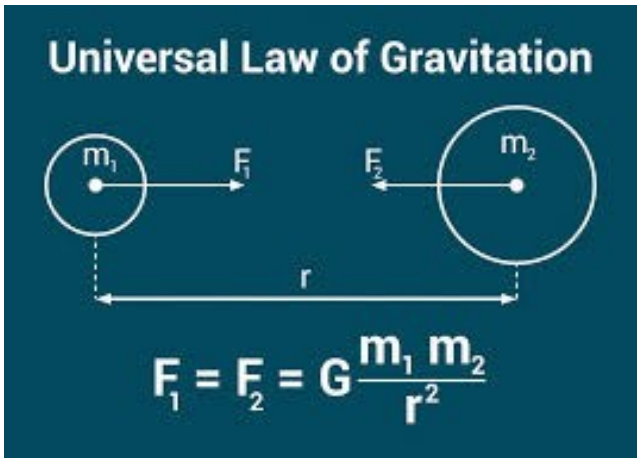
22. A box of mass M, held in place by friction, rides on the flatbed of a truck, which is traveling with constant speed v. The truck is on an unbanked circular roadway having radius of curvature R.

    a. Make a diagram indicating and clearly label all the force vectors on the box.
    b. Find what condition must be satisfied by the coefficient of static friction μ_s between the box and the truck bed.
    c. On the diagram below, (make your own), indicate and clearly label the two forces action on the box under these conditions.



    d. Which, if either, of the two forces acting on the box is greater in magnitude? Explain

Orbital and Universal Gravitational Problems



23. What is the orbital period of a shoe lost by a careless astronaut that is located 350 km above the Earth's surface? Radius of the Earth is 6.4×10^6 m., Mass of Earth 6×10^{24} kg.

24. A group of astronauts in a spaceship are attempting to land on Mars. As they approach the planet, they begin to plan their descent to the surface.

    a. Before the spaceship can land on Mars, it must enter a stable "parking orbit" above the planet. Derive an equation to find the orbital speed of the of mass, *m*, at a height, *h,* above the surface of Mars (with a mass, *M,* and a radius, *R*)

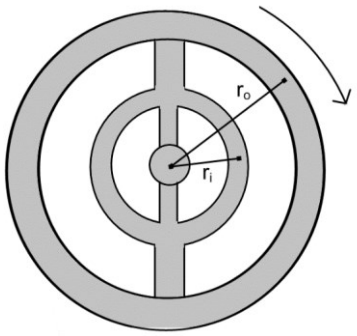
    b. Two of the astronauts are trying to determine *g* at height, *h,* above Mars. Astronaut A says that *g* depends only on the mass of the spaceship, while Astronaut B argues that it depends only on the orbital radius, $r = R + h$.

        i. Which aspects of each astronaut's reasoning are correct? Explain your reasoning.

        ii. Which aspects of each astronaut's reasoning are incorrect? Explain your reasoning.

    c. There's a malfunction in the spaceship and the astronauts can no longer determine how fast they are orbiting Mars but they know that their distance from the center of Mars is not changing. One of the astronauts looks out the window and has an idea for how to determine their orbital velocity using her digital watch. Describe a procedure that the astronauts can use to estimate the spaceship's orbital speed.

25. The design for a rotating spacecraft consists of two rings. The outer ring with a radius, r_o, holds the living quarters and mimics the surface gravity of Earth, g. The inner ring is designed to help the astronauts become accustomed to the surface gravity of a new planet, $g/2$.



a. Derive an equation for the speed of the outer ring, v_o, in terms of r_o and g.

b. Derive an equation for the spacecraft's period of rotation in terms of r_o and g.

c. Determine the radius of the inner ring, r_i, relative to the radius of the outer ring, r_o.

d. The spacecraft was originally put into rotational motion by thrusters. After the thrusters are turned off, what will happen to the spacecraft's rotational speed?

_____ increase _____ decrease _____ stays the same

Justify your answer.

26.