The Flying Pig

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Topic: Centripetal Force

Purpose

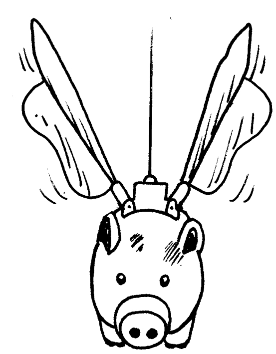
To show that the net force for a conical pendulum is mv^2/r.

Equipment and Supplies

Flying Pig and pivot (or equivalent)
stopwatch
meterstick
vertical and horizontal rod and table clamp (not required if pivot is attached to the ceiling)

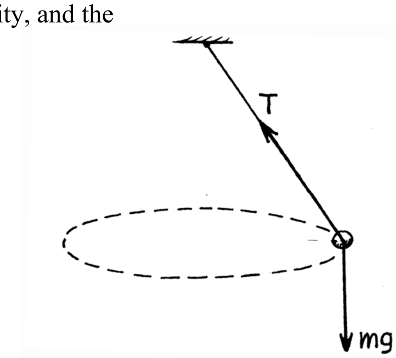
Discussion

When an object travels at constant speed along a circular path, we say it has uniform circular motion (if its speed were changing, then its motion would not be uniform). Any object moving in uniform circular motion is accelerated toward the center of its circular path. This acceleration is called *centripetal acceleration*, and equals v^2/r, where v is the speed, and r the radius of the circular path. Although the net force on any object equals ma, during uniform circular motion the net force, called *centripetal force,* equals mv^2/r and is directed *toward the center*. When an object suspended by a string moves in a circular path the centripetal force creates a *conical pendulum*. The string of a conical pendulum sweeps out a right-circular cone. In this experiment you will measure the speed of an object that produces a conical pendulum and show that the net force is mv^2/r.



Pre-Lab Analysis

Step 1: Draw the force vectors (a free-body diagram) that act on a conical pendulum. Ignoring air resistance, note there are only two forces that act on the pendulum bob—in this case, the pig. One is mg, the force due to gravity, and the other is string tension, T.



Step 2: Resolve the tension into horizontal and vertical components. Represent the tension T with a solid line and its components with dashed lines. Also label the angle θ, between the tension T and the vertical.

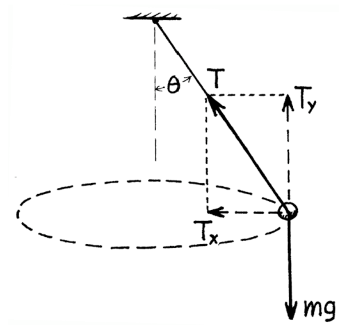
Step 3: Does the pig accelerate in the *vertical* direction? What does this tell you about the magnitude of the vertical component of T and mg?

T_y = ____

Step 4: Does the pig accelerate in the horizontal (radial) direction? Knowing that the net force in the radial direction for any object in uniform circular motion is the centripetal force, what does this tell you about the magnitude of the horizontal component of *T* and mv^2/r?

T_x = ____

Step 5: Write an equation that shows how the horizontal and vertical components of *T* are related to the weight and the centripetal force.



Hint: $\tan\theta = \dfrac{\text{opposite}}{\text{adjacent}} = \dfrac{Tx}{Ty} =$

Step 6: Algebraically solve for the tangential speed of the pendulum from your equation in Step 5. Show your work.

v = __________

Procedure

Your teacher may assist you setting up the *Flying Pig*. (Note: Anything that "flies" in a circle works here—whether it be toy airplane, a toy *Flying Pig* or *Flying Cow*, etc.) It is essential to use the pivot that comes with the pig; the pivot enables the pig to fly in a circle of constant radius. For best results, attach the pivot *securely* to the ceiling. If this is not practical, the pivot can be mounted to a horizontal rod attached to a vertical rod with fine wire and/or masking tape. Be careful not to damage their delicate wings as you click them into their fixed-wing position. Ask your instructor to check your pivot *before* switching on to battery power. Carefully hold the pig by its body and give it a *slight* shove about 30° from the vertical, just enough so that the pig "flies" in a circle. The goal is to launch the pig *tangent* to the circle of flight. It's better to launch it too easy than too hard. If the pig does not fly in a stable circle in 10 seconds or so, carefully grab it and try launching it again.

Step 7: Once the pig is up and flying in a circle of constant radius, measure the radius of the circle as accurately as you can. Express your answer in meters.

r = __________

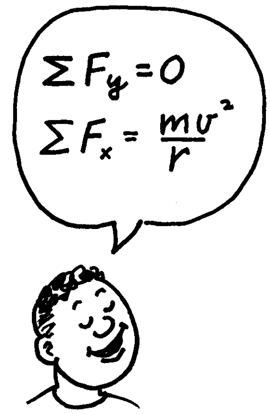
Step 8: There are several ways to determine the angle the string makes with the vertical, *θ*. Using a protractor may not be as practical as other methods you may devise. Describe your method and then record your value for *θ*. Include a sketch.

Method: ____

____

$\theta =$ ________

Step 9: Using the values for r and θ you determined in Steps 7 and 8, compute the theoretical speed of the pig using the formula you derived for the speed in Steps 5 and 6. (Remember, this speed is based on $F_{net} = mv^2/r$.)



$v =$ ________

Step 10: In Step 9 you calculated the *theoretical* speed of the pig. Now, actually *measure* the speed of the pig and see how these two values for the speed compare. Since the pig flies in a circle, the speed is the circumference ($2\pi r$) divided by the time t for one complete revolution. To make your measurements of t more precise, measure the time it takes the pig to make 10 revolutions—then divide by 10.

$10t =$ ________ s (for ten revolutions)

So for one revolution, $t =$ ________ s

Step 11: Using your measurement of r, compute the speed of the pig:

$v = d/t = 2\pi r/t =$ __________ m/s

Step 12: Compute the percent difference between the value for the speed you computed in Step 9 and measured in Step 11. (Use the calculated speed as the known.)

% difference = _________

Post-Lab Analysis

1. What techniques for measuring r and θ would you recommend for best results?

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2. What do you conclude about the magnitude of the string tension compared with the weight of the pig? For uniform circular motion, the tension will always be (less than) (the same as) (greater than) the weight.

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3. What do you conclude about the direction of the net force that keeps the flying pig in uniform circular motion?

4. For uniform circular motion, the centripetal force will always be (less than) (the same as) (greater than) the tension in the string.

5. How does the pig overcome air friction?

6. List sources of error.