Rotational Motion Lab

PHYSICS 221: CLASSICAL PHYSICS I

NAME: ____

LAB DATE: ___________________________ **DUE DATE:** ______________________________

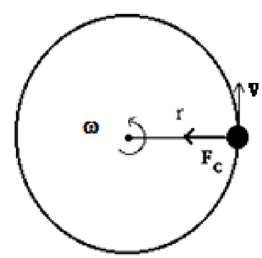
LAB PARTNER(S): ____

Introduction

A penny sits on a turntable; the turntable is spinning faster and faster. Suddenly, the penny flies off the turntable. What exactly happened and why?

The natural motion for the penny is to move in a straight line. The surface under the penny is moving in a circle. Friction prevents the penny from moving in a straight line that would require the penny to slide across the surface. Static friction provides the force which bends the penny's path into a circle

To bend an object of mass *m* into a circular path of radius *r* traveled at speed *v* requires a force directed toward a center $F_c = \frac{mv^2}{r} = mr\omega^2$



where ω is angular velocity $\omega = \frac{v}{r}$

Here, friction is supplying the force that bends the trajectory into a circle.

$$f = F_c$$

Sometimes such a force is called a “centripetal force”; that’s an unfortunate and imprecise jargon!

There is a maximum amount of force friction can exert, given by

$$f = \mu N \ ,$$

where μ is the coefficient of static friction, N is the normal force. For a plain surface, and no acceleration in the vertical direction,

$$N = mg \ .$$

The penny flies off the turntable when the needed force $F_c = \frac{mv^2}{r} = mr\omega^2$ exceeds the maximal force of friction $f = \mu N$. Then, the penny breaks away from the surface and travels in its desired straight-line path (not exactly straight because of kinetic friction while the penny slides across the turntable).

The penny breaks free when

$$\mu mg = mr\omega^2$$

Solving this for ω gives

$$\omega = \sqrt{\frac{\mu g}{r}} \qquad (1)$$

If we know μ and r, this formula predicts at what angular speed ω the penny should come loose. Note that (i) ω has units of rad/sec and that (ii) the formula is independent of mass *m*!

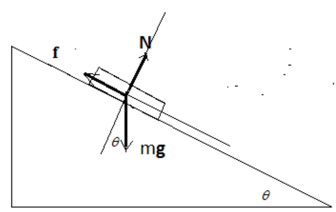
Measuring the coefficient of static friction μ

A flat plane is slowly inclined at one end. A penny on the inclined plane eventually slips, let

θ = angle of the plane when the penny slips .

The penny slips when static friction reaches its maximum value $f = \mu N$ and the frictional force up the slope can no longer counter the force acting down the slope.

The forces acting on the penny are shown on a free body diagram.



In our case, $N = mgcos\theta$ always because there is no acceleration in the direction perpendicular to the incline. When the penny is on the verge of slipping, its acceleration along the plane is still zero, and, therefore, from second Newton's law we have $f = mgsin\theta$. But the force of friction is now maximal: $f = \mu N = \mu mgcos\theta$.

From this, solving for μ we get

$$\mu = \frac{sin\theta}{cos\theta} = tan\theta$$

We conclude that the coefficient of static friction between two surfaces μ can be simply obtained by taking the tangent of the inclination angle θ at which the object just starts sliding.

The experiment

1. Measure the coefficient of static friction μ between the penny (or any other object of your chose) and the surface of the turntable disk. Repeat the measurement two more times and average your results. Your instructor may give you hints as to how to perform the experiment in the best manner.

2. Place the turntable disk in the position to be rotated, put the penny on the turntable. Measure and record the distance *r* from the center of the turntable to the center of the penny. Calculate the expected angular velocity ω at which the penny should become loose using equation (1)
3. Attach a motor drive to the apparatus and affix one radian sector to the turntable. Position a photogate timer to measure the passage time of the one radian sector. The angular velocity can be calculated by dividing the one-radian angle by the time Δt for the sector to pass through the photogate. Increase the motor speed until the penny comes loose.
4. Determine the angular rotation speed at which this occurs. Repeat it two times more. Average the values and compare to the previously calculated value.
5. Repeat the experiment putting the penny at the different distance *r* from the center of the turntable.
6. Repeat again using the same surfaces but *different mass* (like two stacked pennies).

Data and Calculations

Position r (m)	t_1 (s)	ω_1(rad/s)	t_2 (s)	ω_2 (rad/s)	t_3 (s)	ω_3 (rad/s)	ω_{av}(rad/s)	$\omega_{theor(}$rad/s)

Questions

1. How does the angular speed depend on the position of an object relative to the axis of rotation?

2. What is the “centrifugal” force? Is it real or fictitious? **Hint:** See 6.3 in Chapter 6.