

Name \_\_\_\_\_ Date \_\_\_\_\_

Partners \_\_\_\_\_

### **Inertia Wheel: Mechanics Lab #4**

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**Objective:** To investigate the conversion of gravitational energy into rotational kinetic energy, and to see if energy is conserved in this system. This apparatus is also designed to study angular acceleration and the moment of inertia of a rotating disk.

#### **Equipment**

**Sketch, diagram, or photo (with distances clearly labeled)**

#### **Procedure:**

##### 1. Getting started

Attach the string from the mass hanger to the nail on the dark hub and wind it up carefully in a single layer around the hub. Set the mass hanger holding 20 grams on the little platform. Pull the release cord and use the stopwatches to time how long it takes for the mass to hit the floor. Take all measurements at least three times and average them. Make whatever other measurements you need to calculate gravitational potential energy. Remember to convert everything into mks units.

2. Time the falling of two other masses between 25 grams and 105 g. Record your data in a well-organized team spreadsheet.

##### 3. Predictions

Predict the falling time for a different mass in the range between 25 grams and 105 grams.

Explain how you made this estimate. Record this in your team's report (text) document.

Try this mass and report how close your interpolation came.

Then predict the falling time for a mass of 155 grams (beyond your experiments so far).

Explain how you made this estimate.

Try the falling of this mass and report how close your extrapolation came.

Add these data to your team's spreadsheet.

Discuss which is more accurate, interpolation or extrapolation, and why this might be so.

##### 4. Acceleration

What is the equation for the distance  $y(t)$  of a body starting from rest at constant acceleration?

For each of the five cases you have measured of a different falling mass calculate the acceleration, assuming it is constant.

### 5. Final velocity

Calculate the average velocity for the whole interval from the raw data.

Calculate the final velocity as twice the average velocity, since the initial velocity was zero.

Calculate the final velocity from the acceleration \* time. Do they agree? Should they?

### 6. Angular velocity

For each case, we will want to calculate  $\omega$  (the final angular velocity of the disk combination). What are the units for  $\omega$ ?

How is the linear velocity at the outside edge of the hub related to the velocity of the mass on the hanger? Why?

The angular velocity  $\omega$  is this velocity/radius of the hub.

Calculate these values for the final time, just when the mass hits the floor.

### 7. Moment of inertia

Next we want to calculate  $I$ , the moment of inertia of the whole rotating apparatus.

The mass,  $m$ , of the dark hub is only 70 grams. The mass of the combination of both disks is written on the hub and is \_\_\_\_\_ (about 4 kg). The mass,  $M$ , of the big metal disk is then the difference of these two masses, \_\_\_\_\_.

Use these masses and the measurements of the radii ( $R$ ,  $r$ ) of the disks from your sketch to calculate  $I$ , the moment of inertia of each disk, using:

$$I (\text{metal disk}) = (1/2) M R^2$$

$$I (\text{dark hub}) = (1/2) m r^2$$

Calculate  $I$  (metal disk),  $I$  (dark hub), and then  $I$  (sum total).

### 8. Energy In

The energy input to this system is the gravitational potential energy of the falling mass.

What is the equation for the gravitational energy of a body of mass  $m$  at height  $h$  above the floor on Earth?

Calculate this quantity for each case.

### 9. Energy out

The energy output from this system is the kinetic energy of the falling mass just as it hits the floor plus the kinetic energy of rotation of the disk combination.

What is the equation for the kinetic energy of a body of mass  $m$  moving at velocity  $v$ ?

$$KE (\text{disk rotation}) = (1/2) I (\text{sum total}) * \omega^2$$

Add these kinetic energies together to get the total energy output for each case.

#### 10. Conservation of energy

Plot Energy (Out) vs. Energy (In).

Fit a linear trendline to these data.

Does the line go through (0, 0)?

Explain why the line should not go through (0, 0).

Calculate the equivalent mass for (0, 0) and try it on the apparatus.

Report what happened.

#### 11. Calculate the percent energy lost, and plot this percent vs. Energy (In).

Discuss.

**Team Report:** Write a team report of your experience. Include a list of equipment, a sketch of the setup, handwritten raw data, Excel spreadsheet with appropriate graphs, a sample of each calculation, experimental errors, estimate of errors at each step, suggested improvements, and application of these methods to other situations.

The team report is due next week, signed by everyone in the team.