

SAN DIEGO MESA COLLEGE

Name: _____

PHYSICS 195 LAB REPORT

Date: _____ Time: _____

TITLE: Conservation of Mechanical Energy

Partners: _____

Objective:

To predict the range of a ball rolled down a curved launch tube by applying the principle of energy conservation, and to investigate the distribution of the initial energy of the system.

Theory:

$$E_o - E_{\text{lost due to friction}} + W_{\text{other non-conservative}} = E_F$$

$$U_g = m g h$$

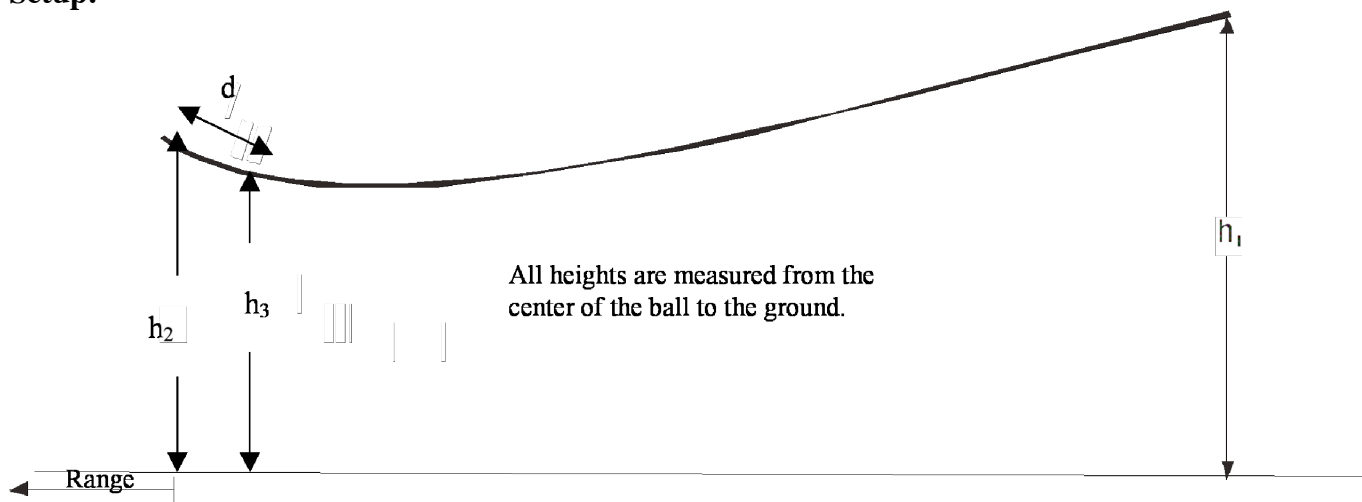
$$K_{\text{trans}} = \frac{1}{2} m v^2 \quad K_{\text{rot, solid ball}} = \frac{1}{5} m v_{\text{cm}}^2$$

Equipment:

Launch tube apparatus with ball
 Table Rod clamps
 2 kg mass
 2-meter sticks

Plumb bob
 Carbon paper
 Masking tape
 Vernier calipers

Setup:



Procedure:

Adjust the height of the tube such that the ball, when released from rest, stops before leaving the launch end of the tube. *Do not record any data at this time.*

Now raise the ball-release end of the tube about 10 centimeters with the elevating screw and record on the data table the measurements h_1 , h_2 , h_3 , and d . Record these values to the nearest 0.0005 m in SI units. It is important that these measurements be as accurate as possible. The small holes in the back of the tube define the center of the ball at the three positions h_1 , h_2 , h_3). Measure and record the diameter D of the ball several times using the Vernier Calipers.

Data:

Mass of ball; $M =$ _____

Diameter of ball; $D =$ _____

$D =$ _____

$D =$ _____

Average Diameter; $D_{\text{avg}} =$ _____

Ball radius; $r =$ _____

$h_1 =$ _____

$h_2 =$ _____

$h_3 =$ _____

$d =$ _____

RANGE* = _____

*MEASURED FROM PAGE 4

Analysis: Part I: System Energies

Assume that mechanical energy is conserved, so that $U_{g1} + K_1 = U_{g2} + K_2$ while the ball is in the tube.

Derive the following expressions using the symbols m , g , v , h_1 , and h_2 .

What is the initial potential energy U_{g1} of the ball? _____

What is the final potential energy U_{g2} of the ball? _____

What is the initial kinetic energy K_1 of the ball? _____

What is the final kinetic energy, K_2 of the ball? _____

Use these symbolic expressions and the assumptions about energy conservation to calculate a symbolic value for the speed at which the ball leaves the tube.

$V_{\text{launch}} =$ _____

Now use the mass of the ball and the other measured data to calculate the following energy values in Joules. Show each calculation with units.

The initial potential energy U_{g1} of the ball:

The final potential energy U_{g2} of the ball:

The initial kinetic energy K_1 of the ball:

The final kinetic energy, K_2 of the ball:

Use the appropriate measurements to determine the angle at which the ball leaves the tube. Show your work with units.

$$\theta = \underline{\hspace{2cm}}$$

What is the **velocity** of the ball when it leaves the tube?

$$\vec{v}_{launch} = \underline{\hspace{2cm}}$$

Use the analysis of projectile motion to calculate the range of the ball. Note that h_2 defines the **center** of the ball at the instant of launch; therefore the vertical displacement of the ball will be need to be adjusted by the radius of the ball.

$$\text{Calculated range} = \underline{\hspace{2cm}}$$

Now launch the ball several times, record the data and calculate the average range.

Measured range_{avg} = _____

Calculate the percent error between the measured and predicted values:

$$\% \text{ Error} = \frac{|X_{meas} - X_{pred}|}{X_{meas}} * 100$$

Percent Error = _____

Analysis: Part II: Correction for Friction

You probably anticipated the large percent difference between the measured and predicted range. The tube is obviously not frictionless, and some amount of the initial potential energy U_g is dissipated instead of being transferred to kinetic energy K . We can easily modify the theoretical calculation to include friction, but the experimental problem is to find out how much energy is dissipated by the friction force, and then to apply the correction factor to the measurements of the initial system.

Since the mechanical energy of the ball actually was not conserved, the analysis of Part I must be corrected. Use the expression $E_f = E_o - E_{\text{lost due to friction}} + W_{\text{other non-conservative}}$ to write the *symbolic* equation which better describes what happens to the potential energy U_g that the ball initially had at the top of the tube in Part I.

Solve this equation symbolically for the corrected final speed of the ball when it leaves the launch tube:

Symbolic $v_2 =$ _____

Data:

Now, lower the tube with the elevation screw and determine exactly the elevation of the tube such that the ball rolls just to the edge of the exit end of the tube but does not launch.

$h_{1fr} =$ _____ $h_{2fr} =$ _____ ,
where the subscript '*fr*' stands for friction.

Now call the amount of potential energy lost by the ball ΔU_g , where $(U_{g2fr} - U_{g1fr})$. Use your data to calculate this quantity in Joules.

ΔU_g : _____

What happens to this ΔU_g as the ball traverses the tube? Where does it go?

Therefore the mechanical energy lost due to friction (E_{lost}) is = _____

Next, use your data to calculate a numerical value for the corrected launch speed of the ball

Numerical v_2 = _____

Use the analysis of projectile motion to predict the range of the ball, using this corrected speed. Please note that a different launch speed will give a different time of flight. Compare your new prediction with your measured value in the same manner as in Part I.

Measured range_{avg} (from part I) = _____

Calculated range = _____

Calculate the percent error between the measured and predicted values:

$$\% \text{ Error} = \frac{|X_{meas} - X_{pred}|}{X_{meas}} * 100$$

Percent Error (corrected for friction) = _____

Analysis: Part III: Correction for Rotation

It should be apparent from the results of Part II that there is still some energy loss that is unaccounted for. A portion of the potential energy available at the start goes into the rotational kinetic energy of the ball as it rolls down the tube. The rotational kinetic energy of the ball as it exits the tube is given by $K_{rot, solid ball} = \frac{1}{5} m v_{cm}^2$, where v_{cm} is the same speed associated with the translational kinetic energy of the ball when it exits the tube from Part II. Use $E_f = E_o - E_{lost\ due\ to\ friction} + W_{other\ non-conservative}$ to write the symbolic equation which better describes what happens to the initial U_g of the ball.

Solve this equation symbolically for the corrected final speed of the ball when it leaves the launch tube:

$$\text{Symbolic } v_3 = \underline{\hspace{4cm}}$$

Next, use your data to calculate a numerical value for the corrected launch speed of the ball

$$\text{Numerical } v_3 = \underline{\hspace{4cm}}$$

Use the analysis of projectile motion to predict the range of the ball, using this corrected speed. Compare your new prediction with your measured value in the same manner as in Part I.

$$\text{Measured range}_{avg} \text{ (from part I)} = \underline{\hspace{4cm}}$$

$$\text{Calculated range} = \underline{\hspace{4cm}}$$

Calculate the percent error between the measured and predicted values:

$$\% \text{ Error} = \frac{|X_{meas} - X_{pred}|}{X_{meas}} * 100$$

$$\text{Percent Error (corrected for rotation)} = \underline{\hspace{4cm}}$$

You have seen how the predicted range of the ball becomes progressively closer to the measured range as correction factors are added to the original assumption, or first approximation. This is a common technique in the study of physical behavior, limited only by the time, effort, cost and validity of the correction.

Part I:	Part II:	Part III:
$v_{\text{launch,I}} =$	$v_{\text{launch,II}} =$	$v_{\text{launch,III}} =$
Measured Range =		
Range_I =	Range_{II} =	Range_{III} =

I: % error when energy conservation is assumed: _____

II: % error when friction is included and rotational kinetic energy is ignored: _____

III: % error when friction and rotational kinetic energy are included: _____

Use the ideas of energy conservation to predict the speed of the ball when it hits the floor. Include a carefully drawn and labeled diagram.

Conclusion and Summary of Results:

Write a brief conclusion, including a brief discussion of the physics involved in this experiment, including possible sources of error, and indicate whether your results give support or validate the purpose of the lab exercise.