Name: ________________________________

Handout 5.1.1.1.1: Introduction to Angular Quantities
Part 1: Rotational Motion Investigations

Directions: Complete the following two investigations with your group.

Part I – Paper Towel

Description: Determine the relationship between circumference (arc length) and the linear displacement of a rolling object.

A. Measure the circumference of the paper towel in two ways using the tools provided.
   1. Method 1:

   2. Method 2:

B. Draw a line from the point where the last piece of paper towel touches the center of the roll.
C. Tape the end of the roll to the table and roll the paper towel until it has completed 1 revolution.
D. Measure the distance the roll has traveled.
   1. What distance did you find?

E. What relationship do you notice between (A) and (D).

F. Do you think this relationship is *always* true? Explain.

Part II – Constant Velocity Vehicle

Description: Determine the relationship between the linear speed of the axis (center of the wheel) and the tangential speed of a point on the edge of the wheel.

A. With tape mark a point on the edge of one wheel.
B. Determine the circumference of the wheel.
   1. Circumference of wheel:

C. With a timer ready, release the car at a constant speed. Let the car travel until the marked wheel undergoes a certain number of rotations of your choice. Measure the linear distance and record the time it took to go that distance.
   1. Number of Rotations

   2. Linear Distance

   3. Travel Time

D. With the circumference you already found and the number of rotations, calculate the distance at the point at the end of the wheel traveled (arc length).

E. Calculate the linear speed of the car

F. Calculate the tangential speed of the point at the outside of the wheel

G. What relationship do you notice?

H. Do you think this relationship is *always* true? Explain.

Name: ______________________________

Handout 5.1.1.1.2: Introduction to Angular Quantities
Part 2: Rotational and Linear Motion Analogies

Fill in the table below with its units and description

Linear Motion			Rotational Motion		
Quantity	Units	Description	Quantity	Units	Description
d					
v					
a					

Additional Formulas

Tangential Quantities

Displacement for constant acceleration

Linear Motion	Rotational Motion

Name: ______________________________

Handout 5.1.1.2: Ladybug PhET Investigation

Learning Goals: Students will be able to:

- Explain some of the variables for rotational motion by describing the motion of a bug on a turning platform.
- Describe how the bug's position on the turning platform affects these variables.

Directions: In this activity, you must include values that you measure and show sample calculations to support your answers to the questions. Include examples that use both bugs in different locations.

1. Write a story about the bugs rotating on the turntable. In your story, include how to find the distance the bug travels, the arc length and angular displacement.

2. Suppose you were given the statement "All points on a rigid object have the same angular acceleration and angular speed."
   - How could you use the bugs in *Ladybug Revolution* to test this idea?
   - Is the angular displacement also the same or does it differ? Explain your reasoning.

Loeblein,Trish, PhET Program, Ladybug Revolution Activity: Exploring Rotational Motion. [Student Directions]. CU-Bolder.

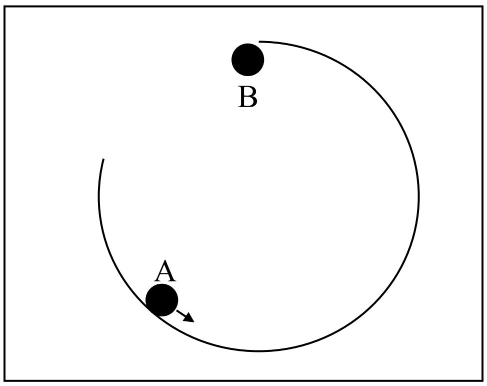
3. How is tangential speed represented in *Ladybug Revolution?* Explain how you know.

4. In class, we discussed angular acceleration and tangential acceleration. Describe how the simulation can be used to find each for the bugs in *Ladybug Revolution.*

Loeblein,Trish, PhET Program, Ladybug Revolution Activity: Exploring Rotational Motion. [Student Directions]. CU-Bolder.

Handout 5.1.1.3: Centripetal Acceleration and Problem Solving

1) For the diagram below, you are looking down from above at a puck sliding on a frictionless tabletop. The puck is sliding at a constant speed along a circular fence and just leaves contact with the fence at position B. The fence and puck are also frictionless.



a) On the top drawing draw vectors and label them for any forces acting parallel to the table top on the puck at positions A and B.

b) On the side views below, draw vectors and label them for any forces acting perpendicular to the tabletop.

side view at A side view at B

c) Which of the forces above are inward forces?

____

d) Which of the forces above are outward forces?

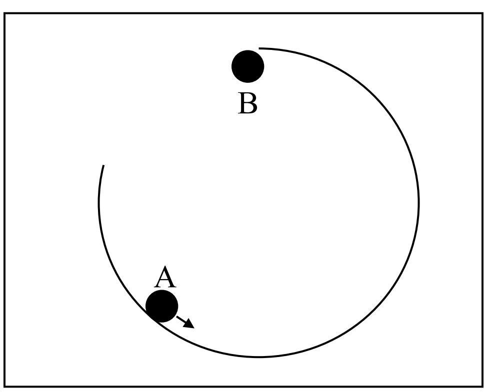
____

e) What would be the equation for the net force on the puck?

____

f) On the top drawing at position B draw a line at least an inch long showing the path the puck will travel after point B. How do you know?

____



g) On the bottom drawing, draw and label a velocity and an acceleration vector on the puck at positions A and B.

h) At position A is the net force on the puck zero? How do you know?

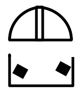
____

i) At position B is the net force on the puck zero? How do you know?

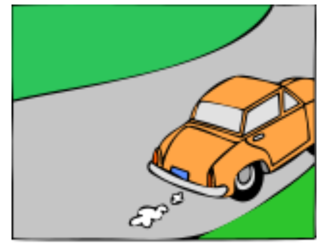
____

 Unit VIII ws2 v3.0

2) The car to the right is traveling around a curve at a constant speed.



rear view of car



a) Draw vectors and label them for each force acting on the car.

b) Which of the forces are acting inward?

____

c) Which of the forces are acting outward?

____

d) What is the direction car's acceleration?

____

e) What is the equation for the net force acting on the car?

____

3) A woman flying aerobatics executes a maneuver as illustrated in Figure below:

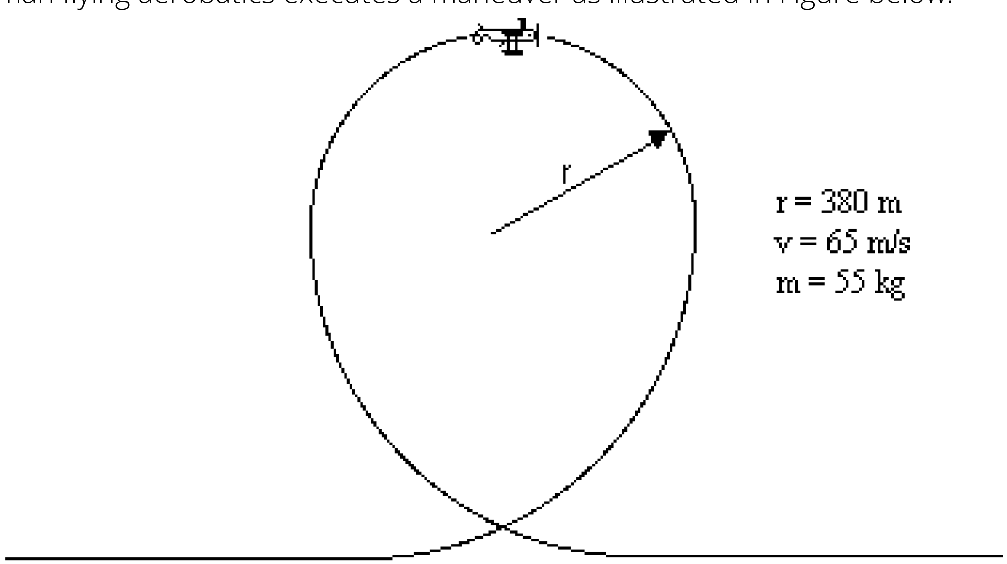


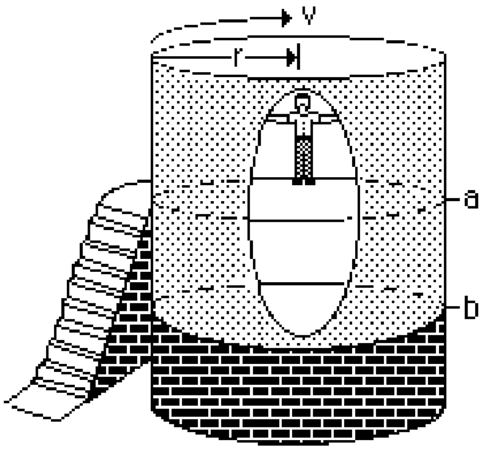
Figure 1

a. Determine the value of the centripetal force acting on the woman flying the airplane when at the top of the loop, as indicated in Figure 1.

b. Construct a quantitative diagram of all relevant forces acting on the woman.

c. Does the woman feel lighter or heavier than normal at this position? Explain.

4) A popular amusement park ride operates as follows: riders enter the cylindrical structure when it is stationary with the floor at the point marked "a". They then stand against the wall as the cylinder then begins to rotate. When it is up to speed, the floor is lowered to the position marked "b", leaving the riders "suspended" against the wall high above the floor.



$r = 1.5$ m
$\mu = 0.50$
$m = 73$ kg

Figure 2

What is the maximum period of rotation necessary to keep the riders from sliding down the wall when the floor is lowered from point "a" to point "b"? (Show all of your work and explain your reasoning.)

Handout 5.1.2.1: Newtonian Gravitation PhET Activity

Today, you will use the Gravity Force Lab PhET Simulation to investigate what the gravitational force between two objects depends on and experimentally determine the Universal Gravitational constant, G.

PreActivity and Beginning Observations

1) Write the formula for the force of gravity (Law of Universal Gravitation). Label each variable and constant and include its units.

2) Open the Gravity Force PhET Simulation. What can you change about the simulation?

Part 1 – Qualitative Observations

3) Look at the formula above. What three things can you change in the formula that you can also change in the simulation?

4) Change each variable and record what happens to the gravitational force as you change it. Be specific with your language (i.e. use terms like increase, decrease, remains constant).

Part 2 – Quantitative Measurements

In this section of the activity, you will develop your own method for determining the gravitational constant, G in the formula for gravity using the simulation and Excel. Consider what variables you can change in the simulation as you develop your procedure.

You will turn in your procedure, data, graph and value for G.

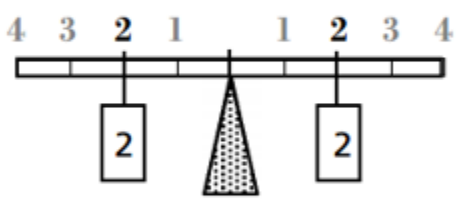
Handout 5.2.1.1: Introduction to Torque and Center of Gravity

1. Describe a scenario when an object is in *static* equilibrium. Draw a picture of this scenario.

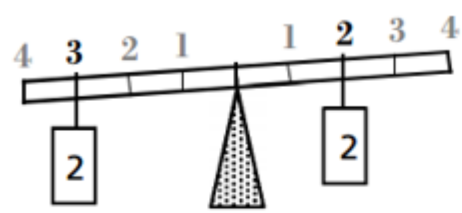
2. Describe a scenario when an object is in *dynamic* equilibrium. Draw a picture of this scenario.

3. What are the similarities between *static* and *dynamic* equilibrium?

4. Construct the scenario below with your meter stick and supplies -



Scenario A



Scenario B

a) What was the same with scenario A and B?

b) What was different with scenario A and B?

Name: ______________________________

Center of Gravity Practice

1. When visiting some countries, you may see a person balancing a load on their head. Explain why the center of mass of the load needs to be directly above the person's neck vertebrae. *It might be helpful to draw a picture of this scenario*

2. Place a chair against a wall so it cannot be slid back. Have one student sit in the chair with their feet flat in front of the chair. Place your thumb on their forehead and ask them to stand up. Why does the student struggle to stand?

Quantitative Practice –

3. A flat dance floor has dimensions $l_x = 17$ m by $l_y = 19$ m and has a mass of $M = 1400$ kg. Use the bottom left corner of the dance floor as the origin. Three dance couples, each of mass $m = 110$ kg start in the top left, top right, and bottom left corners.
   a. What is the initial y coordinate of the center of gravity of the dance floor and three couples?

   b. The couple in the bottom left corner moves 7.6 m to the right. What is the new x coordinate of the center of gravity?

Name: ______________________________

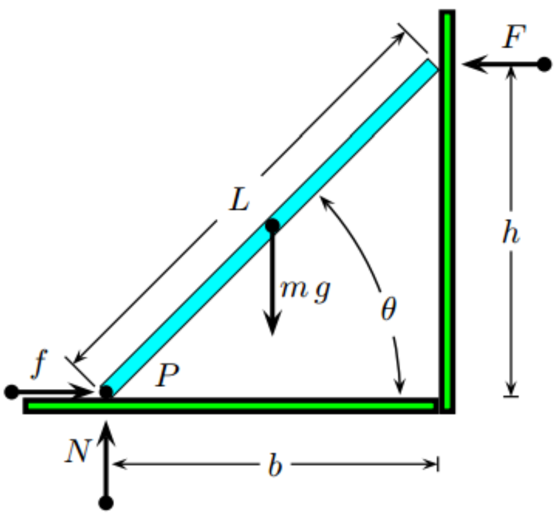
Extension –

4. Open the Balancing Act PhET simulation. Test your understanding of these concepts by playing the Balancing Act game.
   a. Explain your strategies for winning the game.

   b. What difficulties did you encounter?

Handout 5.2.1.4: Complex Torque Practice

1. A uniform ladder is leaning against a smooth wall and resting on a rough floor with a coefficient of static friction μ.

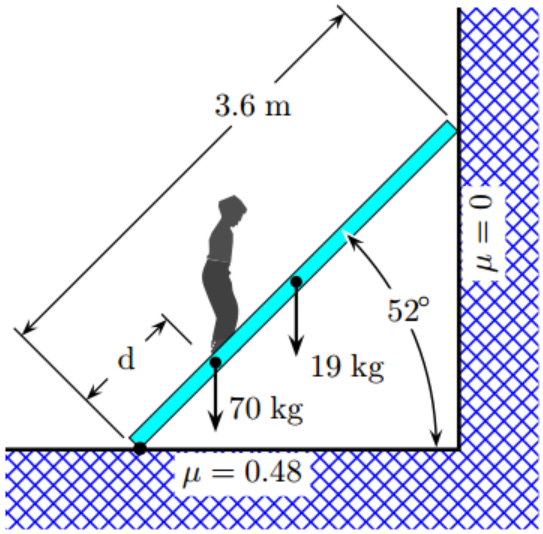


a) What is the equilibrium condition of the sum of the torques about the point P?

b) Find the "critical force" F (which the wall exerts on the ladder) above which the ladder will slip.

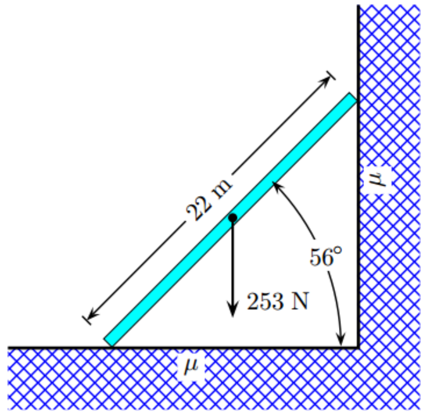
c) If the coefficient of static friction is 0.753, the length of the ladder is 9.9 m, and its mass is 39 kg, find the minimum height h below which the ladder will slip.

2. A 70 kg person climbs up a uniform 19 kg ladder. The ladder is 3.6 m long; its lower end rests on a rough horizontal floor (static friction coefficient 0.48) while its upper end rests against a frictionless vertical wall. The angle between the ladder and the horizontal is 52 degrees.



Let d denote the climbing person's distance from the bottom of the ladder (see the above diagram). When the person climbs too far up ($d > d_{max}$), the ladder slips and falls down. Calculate the maximal distance d_{max} the person will reach before the ladder slips. The acceleration of gravity is 9.8 m/s^2.

3. A uniform ladder weighing 253 N is leaning against a wall. The ladder slips when its angle between the horizontal and the wall is 56 degrees.



Assuming the coefficients of static friction at the wall and the ground are the same, obtain a value μ_s. The acceleration of gravity is 9.8 m/s^2.

Name: ______________________________

Handout 5.2.2.1: Intro to Moment of Inertia and Rotational Kinetic Energy

Hoop	$I = MR^2$	Solid Sphere	$I = \frac{2}{5}MR^2$
Thin Spherical Shell	$I = \frac{2}{3}MR^2$	Solid Cylinder	$I = \frac{1}{2}MR^2$
Thin Rod (Center)	$I = \frac{1}{12}MR^2$	Thin Rod (End)	$I = \frac{1}{3}MR^2$

1. For the items above, assume that M and R remain constant, rank the items in terms of moments of inertia from least to greatest

Least ________ ________ ________ ________ ________ ________ Greatest

2. Consider the following question –

   If a ring, disc and sphere of equal mass and radius all were in a race down a ramp, which item would reach the bottom first? Why?

3. Consider a thin hoop and a uniform cylinder of equal mass and radius competing in a race down a ramp.
   a. Write a general formula for the conservation of energy for both items.

   b. Determine the velocity of the hoop at the bottom of the ramp using energy conservation.

   c. Determine the velocity of the cylinder at the bottom of the ramp using energy conservation.

d. What physical variables are the final velocities independent of? How do you know?

e. How do you think the total energy of the thin hoop and uniform cylinder compare? Why?

f. How do you think the total kinetic energy of the thin hoop and the uniform cylinder compare? Why?

Name: ______________________________

Handout 5.2.2.2: Laws of Rotational Motion Problem Solving

1. A 0.0215 m diameter coin rolls up a 20.0 degree inclined plane. The coin starts with an initial angular speed of 55.2 rad/s and rolls in a straight line without slipping. How much vertical height does it gain before it stops rolling?

2. A figure skater rotating on one spot with both arms and one leg extended has a moment of inertia I_i. She then pulls in her arms and the extended leg, reducing her moment of inertia to 0.75 I_i. What is the ratio of her final to initial kinetic energy?

3. Two astronauts, each having a mass of 74.3 kg are connected by a 13.1 m rope of negligible mass. They are isolated in space, orbiting their center of mass at speeds of 5.65 m/s.
   a. Calculate the magnitude of the initial angular momentum of the system by treating the astronauts as particles.

   b. Calculate the rotational energy of the system.

   c. By pulling the rope, the astronauts shorten the distance between them to 5.99 m. What is the new angular velocity of the astronauts?