40-100 61elsh's Angular Acceleration Apparatus

Warranty and Parts:

We replace all defective or missing parts free of charge. Additional replacement parts may be ordered toll-free. We accept MasterCard, Visa, checks and School P.O.s. All products warranted to be free from defect for 90 days. Does not apply to accident, misuse or normal wear and tear. Intended for children 13 years of age and up. This item is not a toy. It may contain small parts that can be choking hazards. Adult supervision is required.

Safety: All participants and all onlookers should wear protective goggles while performing experiments with this apparatus. Adequate space must be given to the individual performing the experiments.

How to Teach with Angular Momentum Apparatus:

Concepts Taught: Center of Gravity; Angular Acceleration; Moment of Inertia; Counterbalance

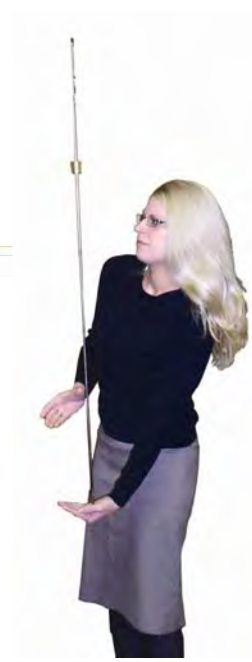
Curriculum Fit: Physics Sequence; Force and Motion. **Grades 6-8 and up.**

Background: **We include three masses on this device to teach 3 key Physics concepts. Use with one mass to teach Center of Gravity and Angular Momentum. Use with two weights to demonstrate Moment of Inertia. Use with three weights to visualize Counterbalance.**

Note: masses cannot be removed from the rod. To simulate removal, please refer to the following experiments.

Experiment 1: Center of Gravity Paradox

Kit components needed: 1 meter aluminum rod with only 1 sliding weight attached. To do this, group the three masses together into one mass.



Procedure:

1) Slide the mass to one end of the rod and hold the heavier mass end of the rod in the palm of your hand.
2) Balance the end of the rod in the palm of your hand, and try to keep the entire rod in a vertical position. This will entail moving your hand to compensate for the rod attempting to fall over.
3) Next, slide the mass to the center of the rod and follow the steps above.

4) Finally, slide the mass to the top of the rod and try to balance the rod upright with the heavy mass up high.

Discussion: As the mass is moved up the rod, it becomes easier and easier to keep the rod in its vertical position. This seems contrary to common sense, which would tell us that we have more control over the system with the heavy mass in our hand. What is happening? The center of mass is far from the fulcrum point in our demonstration. This allows the person balancing the rod more time to make adjustments before the mass gains significant falling velocity. With the mass close to the top, the angular acceleration doesn't accelerate the mass away from the balanced center of mass as quickly.

Experiment 2: Angular Momentum

Kit components needed: 1 meter aluminum rod with two sliding weights attached
stopwatch
stand with clamp

Procedure:

1) Position one of the weights at the top of the rod. Leave it here fore the entire experiment.
2) Tie the other end to a fixed surface (stand with clamp) such that the rod hangs vertically from the string about 5cm from the ground. It should be set up such that the rod will swing back and forth like the weight on a grandfather clock. The string should be tied so it is as short as possible.
3) Slide both weights up to the top of the rod as close to the end as possible.
4) One student will now bring the end of the rod up to horizontal while keeping the string taut (note: the string should be as short as possible).
5) The second student will run the stopwatch and count how many oscillations occur in 30 seconds while the first student merely lets go of the pendulum).
6) Write the results in the graph below. For this experiment, "r" will be the distance from the end of the top of the hanging rod to the bottom of the 2nd (farthest from the string) weight.
7) Slide the lowest weight down the rod to somewhere near the middle.
8) Repeat steps 5-7.
9) Slide the lowest weight all the way to the bottom.
10) Repeat steps 5-7.

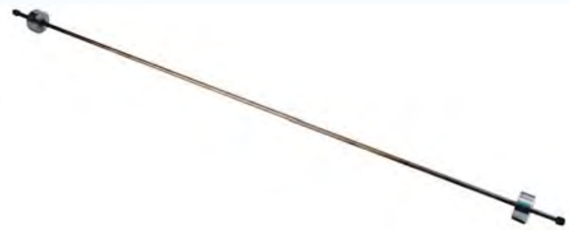
r (meters)	t (sec)	# of oscillations	T (# of oscillations /t)	F=1/T	$I=mr^2$ (use 0.19kg for m)	ω =2ΠF	L=I x ω

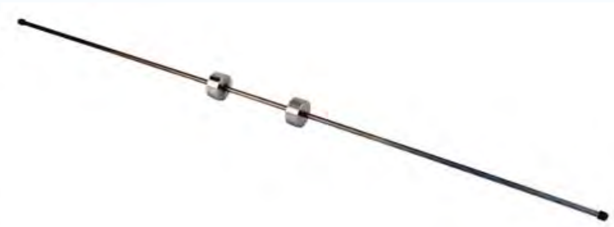
Discussion: Angular Momentum (L)= (Moment of Inertia (I) x Angular Velocity (ω)).

By looking at your results for "L", you will see that with the mass close to the top, the angular acceleration doesn't accelerate the mass away from the balanced center of mass as quickly as when the mass is at the bottom. The conservation of angular momentum holds true for any object in the air or experiencing no external torque. While it is particularly important for sports such as gymnastics, diving, aerial skiing, and figure skating, it is also important in designing helicopters and other types of equipment that have rotational components.

Experiment 3: Moment of Inertia

Kit components needed: 1 meter aluminum rod with 2 sliding weights attached
Stopwatch





Procedure:

1) Position one of the masses in the center of the rod, so that it does not affect the experiment.
2) Slide the two weights to opposite ends so that they are as far apart as possible.
3) Hold two fingers under the rod just inside the weights, one finger by each weight.
4) Slide the two fingers toward each other slowly until they meet. Have your partner place a piece of masking tape on the rod between the two fingers. This is the center point.
5) Measure out 10cm from each side of the centerpoint and place tape marks there.
6) Slide the weights to the tape marks.
7) One student will hold the aluminum rod at the center point and swing it from horizontal to vertical as many times as they can in 5 seconds (One student checks the time while the other counts the oscillations). A count of 1 means the rod went from horizontal up to vertical and back down to horizontal.
8) Record the data in the table below.
9) Measure out 20cm from each side of the centerpoint and mark with masking tape again.
10) Repeat steps 6-8.
11) Measure out 30cm from each side of the centerpoint and mark with masking tape again.
12) Repeat steps 6-8.
13) Continue measuring out additional 10cm increments from the centerpoint and recording the data until you have reached the ends of the bar.

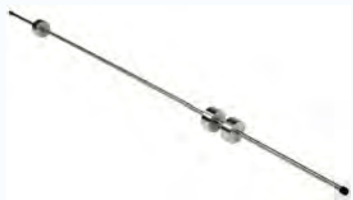
Radius (r)	Time (t)	# of Oscillations	Period of Oscillations (1/# of Oscillations)
10cm	5 seconds		
20cm	5 seconds		
30cm	5 seconds		
40cm	5 seconds		

14) Plot a graph of *Period of Oscillations* vs. *Radius*

Discussion: The moment of inertia is how hard it is to spin an object around a certain axis. In our experiment, we chose the centerpoint of the rod as our axis. We could have chosen any point on the rod. Besides observing the trend in the data, the students can actually feel the change in force as the masses are moved outward. From the graph, the students will see that the trend is quadratic.

Experiment 4: Center of Mass and Counterbalance

Kit components needed: 1 meter aluminum rod with 3 sliding weights attached
Ringstand with clamp



Procedure:

1) If your aluminum rod already has 3 masses, go to step 2. If not, add sliding weights to the rod until there is 3 total. Place the plain rubber cap on end.
2) Lay the rod flat on the table. Slide weight 1 to .01m from the left side.
3) Slide weight 2 to 0.5m from the left side.
4) Slide weight 3 to 0.6m from the left side.
5) Using your finger, try to determine the location where the rod balances perfectly.
6) When found, have another student mark it with tape.
7) The formula for CM (center of mass) with multiple weights is:

$$X_{CM} = \left(\sum_i m_i x_i \right) / \left(\sum_i m_i \right)$$

using the values from our experiment,

CM equals (M*1.0 +M*5.0 + M * 6.0)/ (M +M+M)

which equals 12.0M/3M=4.0m

8) Measure the distance from the left side of the rod to your tape mark. Do they match the above answer?

Discussion: If you wished to move one mass over to the left, but keep the center of mass in the same place that it was, you will have to move one of the other masses over to compensate for this. This concept is called Counterbalance.

Experiment Suggestions:

Move the weights to different positions and compare the math formula answer to the actual experimental position.

Benchmarks and Standards

This investigation provides support for the *Benchmarks for Science Literacy* and *National Science Education Standards* shown in the table below.

Benchmarks for Science Literacy				*National Science Education Standard*
			Grades 5 – 8 **Physical Science Content Standard B.1** – Motions and Forces	"The motion of an object can be described by its position, direction of motion and speed. The motion can be measured and represented on a graph." (p. 154)
Grades 3 – 5 **The Physical Setting**	**4B.1**	"Changes in speed or direction of motion are caused by forces. The greater the force is the greater the change in motion will be."	Grades 5 – 8 **Physical Science Content Standard B.2** – Motions and Forces	"An object that is not being subjected to a force will continue to move at a constant speed and in a straight line." (p. 154)
Grades 6 – 8 **The Physical Setting**	**4B.3**	"An unbalanced force acting on an object changes its speed or direction of motion, or both.	Grades 5 -8 **Physical Science Content Standard B.3** – Motions and Forces	"If more than one force acts on an object along a straight line, then the forces will reinforce or cancel one another, depending on their direction and magnitude. Unbalanced forces will cause changes in speed or direction of an object's motion." (p. 154)
Grades 9 – 12 **The Physical Setting**	**4B.1**	"The change in motion of an object is proportional to the applied force and inversely proportional to the mass."	Grades 9-12 **Physical Science Content Standard B.1** – Motions and Forces	"Objects change their motion only when a net force is applied. Laws of motion are used to calculate precisely the effects of forces on the motion of objects. The magnitude of the change in motion can be calculated using the relationship F = ma, which is independent of the nature of the force. Whenever one object exerts a force on another, a force equal in magnitude and opposite in direction is exerted on the first object." (p. 180)