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| **Lesson Title** | Physical Pendulum Lab (Moment of Inertia) |
| **Length of Lesson** | 1 Day |
| **Created By** | Jed Leggett, William Funderburk, Dustin Spayde |
| **Subject** | Physics |
| **Grade Level** | 11-12 |
| **State Standards** | Physics: 2 a, b; |
| **DOK Level** | DOK 3 |
| **DOK Application** | Explain Phenomena in Terms of Concepts |
| **National Standards** | 9-12: B (physical); |
| **Graduate Research Element** | Use curve fitting to characterize a periodic signal. |

**Student Learning Goal:** Students will investigate the physical implications of changing the axis of rotation a solid disc.

Physics: 2. Develop an understanding of concepts related to forces and motion: (a) Use inquiry to investigate and develop an understanding of the kinematics and dynamics of physical bodies – relations among mass inertia and weight; (b) Analyze, describe, and solve problems by creating and utilizing graphs of one dimensional motion.

National Science Education Standards of Content 9-12
B (Physical): 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 the forces on the motion of objects.

**Materials Needed (supplies, hand-outs, resources):** Rotation sensor (available from several vendors, i.e. Vernier, PASCO), Solid disc with multiple mounting points, String, Masses, Computer with data logging software installed (i.e. LoggerPro, DataStudio).

**Lesson Performance Task/Assessment:** In this lesson, student s will calculate and measure the moment of inertia of a disc when rotating about 2 different axes. Students must use the parallel axis theorem to calculate the moment of inertia about the off-center axis. Students will use different methods to measure the moment of inertia about each axis. For the off-center axis, students will construct a physical pendulum, a system with important real-world applications.

**Lesson Relevance to Performance Task and Students:** This lab provides students with methods to quantitatively describe rotational motion. This lab also introduces the students to the physical pendulum, which is important in understanding more complicated mechanical oscillations.

**Anticipatory Set/Capture Interest:** The teacher will show the students a picture of the Riefler regulator clock, which kept the US time standard from 1909 to 1929. The Riefler clock uses an Invar pendulum kept in a low pressure tank. The Riefler clock is one of the most accurately characterized pendulums ever constructed.

**Guided Practice:** The teacher will demonstrate the lab setup. A rotation sensor with pulley attached is mounted on a lab post. For the measurement of the moment of inertia about the center of the disc, the sensor should be mounted at the top of the post. A string is wrapped around the pulley, and a small mass (~50g) is hung from the string. After data collection is started, the mass is allowed to fall causing a rotational acceleration of the disc. For the measurement of the moment of inertia about a point on the rim, the sensor should be moved down to minimize vibrations in the lab post. The disc is attached at point on the rim and set into oscillation by releasing it from a small angle (<15 deg). Data collection can be started after the disc is oscillating.

**Independent Practice:** Students will set up their apparatus and perform several runs for each type of measurement. For the measurement of the moment of inertia about the center of the disc, students must identify the part of their data that corresponds to the angular acceleration, and fit this data to a quadratic. For the physical pendulum setup, students can fit a portion of their data to a sine cure to find the period. Students should only fit a range of their data that has a nearly constant amplitude (<15 deg).

**Remediation and/or Enrichment:**
R: individual IEP; partner help throughout lesson

E: If students finish early, they can use the rod and point masses to create a seconds pendulum (2 second period). Seconds pendulums were used in older designs of pendulum clocks.

**Check(s) for Understanding:**
What effect does increasing the moment of inertia have on the period of oscillation of a physical pendulum? Does the moment of inertia increase or decrease as the axis of rotation is moved away from the center of mass?

**Closure:**
Students can calculate the percentage error of their experimental measurements using their calculated values as the theoretical values. Students should attempt to identify the sources of the error.

**Possible Alternate Subject Integrations:**
*Math – Curve fitting can be used for this lab, along with along with numerical differentiation to find the angular velocity, and angular acceleration.

**Teacher Notes:**