Using the Arduino with LabVIEW on Moment of Inertia experiment

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Abstract. In this paper, the physical nature of moment of inertia is examined using pulleys, strings, a mass holder and a set of masses for the classical experiment. Another modern experiment is computer-based control to interface Arduino Uno R3 using LabVIEW. The DIY photogate is made with 30mA@5V laser and light diode resistance (LDR) that has two different intensities of light (low and high) as two logical states to measure time interval. An acrylic support is placed on a 12V high torque DC motor. The speed of the motor is controlled by a potentiometer. In the experiment, an aluminum sheet and a cylindrical steel pipe are used as testing objects. The result shows that the moment of inertia of aluminium disk and cylindrical steel pipe (central axis) are 0.000432 and 0.000083 kg·m\textsuperscript{2}. The percentage of error between the theoretical and experimental values for the aluminium disk and cylindrical steel pipe (central axis) are 12.90 and 15.31%, respectively.

1. Introduction
The classical and modern physics experiments are designed to prove the concepts or theories. Modern technologies, which play important roles in the digital world, are also utilized to help improve learning performance of fundamental science knowledge [1,2]. The data processing, data acquisition, data control and visualization are provided based on computer controlled with LabVIEW-Arduino interfacing [3]. Arduino is the most popular microcontroller which is used as a tool to create interactive projects. It is an open-source electronic platform based on easy-to-use hardware and software. It has been used in thousands of projects, from everyday objects to complex scientific instruments [4].

For this purpose, we developed a modern experiment apparatus to explain the physical nature of moment of inertia ($I$). The object is placed on the support which is rotated by motor that produces torque ($\tau$) corresponding to power ($P$). Thus, the power of motor will be directly proportional to angular velocity ($\omega$). The time interval for each turn or period will be measured to calculate the angular velocity that corresponds to the power of motor. The data of frequency and power of motor will be plotted and curve fitted using the Origin8.
2. Theoretical Background

![Figure 1](image-url)

**Figure 1.** The power of motor is defined by a torque and an angular velocity.

In figure 1, consider rotation of a rigid object around the fixed axis at a certain angular velocity ($\omega$) and the torque ($\tau$). The total power of motor ($P$) is defined as

$$ P = \tau \omega $$

(1)

The moment of inertia is quantitatively measure of rotational inertia, known as the angular mass of a rigid body. To determine the moment of inertia ($I$), the torque is needed for a desired angular acceleration ($\alpha$) on a rotational axis [5], according to

$$ \tau = I \alpha = I \omega^2 r $$

(2)

where $\alpha = \omega^2 r$, $r$ is the radius (in this case $r$ is the radius of the acrylic support).

Substitute equation (2) into equation (1), the total power of motor can be written as

$$ P = (I \omega^2 r) \omega = Ir \omega^3 $$

(3)

where $P_0$ is the initial power of motor that can rotate the support and object.

$$ \Delta P = P - P_0 = (Ir)\omega^3 $$

(4)

Then,

$$ P = (Ir)\omega^3 + P_0 = (8\pi^3 Ir) f^3 + P_0 $$

(5)

The relationship between the frequency of the 3rd power and the power of motor is linear. The slope of equation 5 is equal to $8\pi^3 Ir$. The moment of inertia of the object, obtained from the experiment, is equal to the moment of inertia from the support and object, can be described by

$$ I_{exp} = I_{support} + I_{object} $$

(6)

The moments of inertia of rigid objects with simple geometry are relative to calculation, provided the rotation axis that coincides with an axis of symmetry, as shown in the table 1.
Table 1. Moment of inertia for objects

| Object type       | Rotation axis | Moment of inertia |
|-------------------|---------------|-------------------|
| Thin-walled cylinder |               | $I = mR^2$        |
| Disk              |               | $I = \frac{1}{2} mR^2$ |

3. Hardware and Software preparation

3.1. Hardware

The experimental apparatus, as shown in figure 2, includes a microcontroller system (MCS), a motor controller unit (MCU), DIY photogate and objects (Aluminium disk and cylindrical steel pipe). The MCS is a system which consists of a signal detection circuit and Arduino Uno R3 [6]. The signal is connected to analogue input A0 of Arduino board. The MCU is a unit that includes a 12V high torque DC motor, 12V1A switching power supply and a potentiometer. The speed of the motor is controlled and can be adjusted to 9 levels using potentiometer. The acrylic support has a mass of 0.491 kg with the radius of 0.105 m, is designed to place the objects on for observation. The DIY photogate [7] is made of 30mA@5V laser and light diode resistance (LDR). The aluminium disk and cylindrical steel pipe are used as objects. The mass and radius of aluminium disk are 0.155 kg and 0.080 m, respectively. The cylindrical steel pipe has a mass of 0.157 kg with the radius and length of 0.025 m and 0.100 m, respectively.

![Figure 2. The microcontroller system (MCS) unit.](image-url)
3.2. Software
The software has been developed using LINX (LabVIEW MakerHub) for user interface. To communicate the DIY photogate sensor with Arduino Uno R3, an easy to use add-on called LabVIEW VIs is provided by LINX for interfacing with the microcontroller board using common embedded platforms like Arduino. The built in VIs is used to access devices through digital I/O and analog I/O [6]. The built in VI of Analog Read is used to measure the voltage difference which is depended on the light intensity from LDR. Since the laser beam is blocked by a fin that is attached to the acrylic support, the light intensity changes from a high to a low state. Two different intensities of light are used as two logical states (0V@low and 5V@high), like stop watch, to measure time interval in each turn.

![Image](image1)

**Figure 3.** The LabVIEW program is used to measure time interval in each turn (a) front panel and (b) block diagram.

The code to calculate moment of inertia is shown in figure 3. The protocol has a serial port for serial communication between the program and Arduino board during program execution. The default setting number of turn is 10. When the start button is clicked, the program will measure the time interval in each turn or period and the angular velocity will be calculated automatically. In the experiment, only the moment of inertia of the acrylic support is measured. Then, a series of measurements of the moment of inertia of the aluminium disk and cylindrical steel pipe can be obtained later.
4. Experimental results
The raw data of the frequency of the 3\textsuperscript{rd} power and the power of motor is plotted and curve fitted using Origin8. The data of the acrylic support, from figure 4, the slope value is found to be 0.06225, thus the calculated moment of inertia is 0.002390 kg\cdot m\textsuperscript{2}. In the same way, the data of the aluminum disk and cylindrical steel pipe from figure 5(a) and 5(b) show that the moment of inertias of the aluminum disk and cylindrical steel pipe (central axis) are 0.000432 and 0.000083 kg\cdot m\textsuperscript{2}, respectively.

The percentage of error between the theoretical and experimental values of the aluminum disk and cylindrical steel pipe (central axis) are 12.90 and 15.31\%, respectively.

![Figure 4](image_url)

**Figure 4.** Data of the acrylic support shows the relation between the frequency of the 3\textsuperscript{rd} power and the power of motor.

![Figure 5](image_url)

**Figure 5.** The relation between the frequency of the 3\textsuperscript{rd} power and the power of motor (a) data of aluminium disk and (b) data of cylindrical steel pipe (central axis).
5. Conclusions
In order to improve learning performance about the moment of inertia by modern technology, interfacing of LabVIEW and Arduino Uno R3 is used in the experiment with a high torque DC motor. The DIY photogate sensor has a very simple design and useful. An effect of misalignment of the acrylic support must be considered to reduce the percentage of error between the theoretical and experimental values. By the way, the theoretical and experimental values are in good agreement.

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References
[1] McKnight K, O’Malley K, Ruzic R, Horsley M K, Franey J J and Bassett K 2016 Teaching in a digital age: how educators use technology to improve student learning Journal of Research on Technology in Education 48(3) 194
[2] Thepnurat M, Saphet P and Tong-on A 2017 Low cost DIY lenses kit for high school teaching J. Phys. Conf. Ser. 901 012120
[3] Labviewmakerhub Learn (2017, April 19) Retrieved from https://www.labviewmakerhub.com/doku.php?id=learn:libraries:linx:reference:labview:start
[4] Arduino Introduction (2017, April 19) Retrieved from https://arduino.cc/en/Guide/Introduction
[5] Serway R A and Jewett J W 2013 Physics for scientists and engineers with modern physics 9th ed. (Brooks Cole) p 303
[6] Tong-on A, Saphet P, and Thepnurat M 2017 Simple harmonics motion experiment based on LabVIEW interface for Arduino J. Phys. Conf. Ser. 901 012114
[7] Saphet P, Tong-on A, and Thepnurat M 2017 One dimensional two-body collisions experiment based on LabVIEW interface with Arduino J. Phys. Conf. Ser. 901 012115