

Circular Motion

Purpose

Using Arduino accelerometer with “Lab in Your Pocket” app to investigate the equation of circular motion.

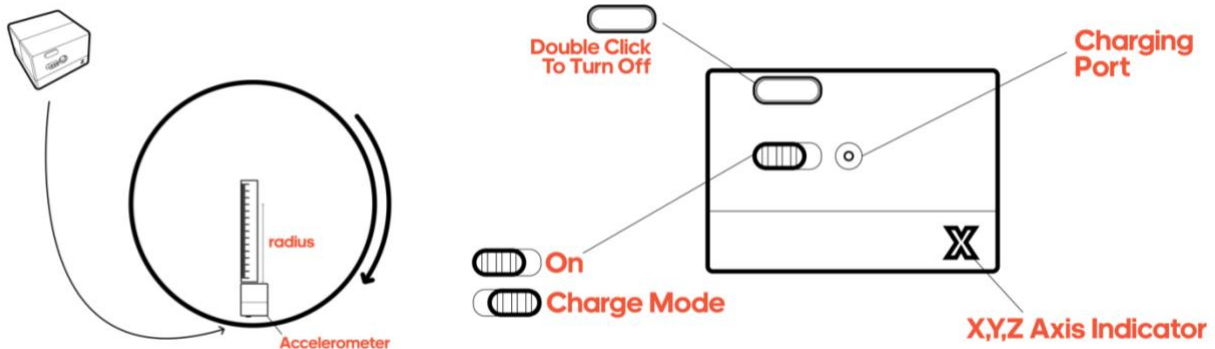
Theory

- Circular motion describes movement along circular path. Object may move in varying angular speeds, or in uniform speed throughout the motion. The latter case is called uniform circular motion. In order to reduce complexity, only uniform circular motion is concerned in this experiment.
- In the study of circular motion, the concept of directions is important. The line along the center and the object is called “radial direction”, while the instantaneous line of the object’s movement (tangent) is called “tangential direction”.
- According to Newton’s Laws, the establishment of circular motion originates from a constant net force in radial direction acting on the object towards the center, as a result of an unchanged speed but change in direction. Applying the basic concepts of mechanics, in other words, the net force constantly changes the object’s velocity but not its speed!
- The parameters involved in circular motion are radius r , centripetal acceleration a and angular speed ω . The formula is given by $a = r\omega^2$.
- The SI unit of radius, centripetal acceleration and angular speed are m, ms^{-2} and rad respectively.
- In the formula $a = r\omega^2$, the centripetal acceleration a is in radial direction, while the angular speed ω is in tangential direction.
- The Arduino accelerometer and Lab in Your Pocket app can display acceleration in 3 axes and the magnitude at a frequency of 20Hz.

Apparatus

- A mobile device with “Lab in Your Pocket” app
- An Arduino accelerometer (provided by PolyU)
- A rotating platform
- A stopwatch

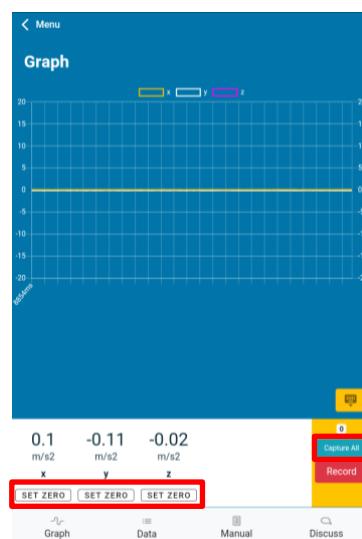
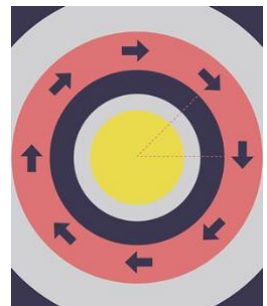
Setup



Procedure

Set up the Experiment

1. Place the accelerometer on a flat surface.
2. Turn on the Arduino accelerometer by pressing the power button once.
3. Open “Lab in Your Pocket” app in the mobile device and choose “Circular Motion”.
4. Register the accelerometer with the address printed on it. Press “Connect” to connect the sensors. When the connection finishes, the app will automatically jump into a real-time graph of the acceleration in different axes.



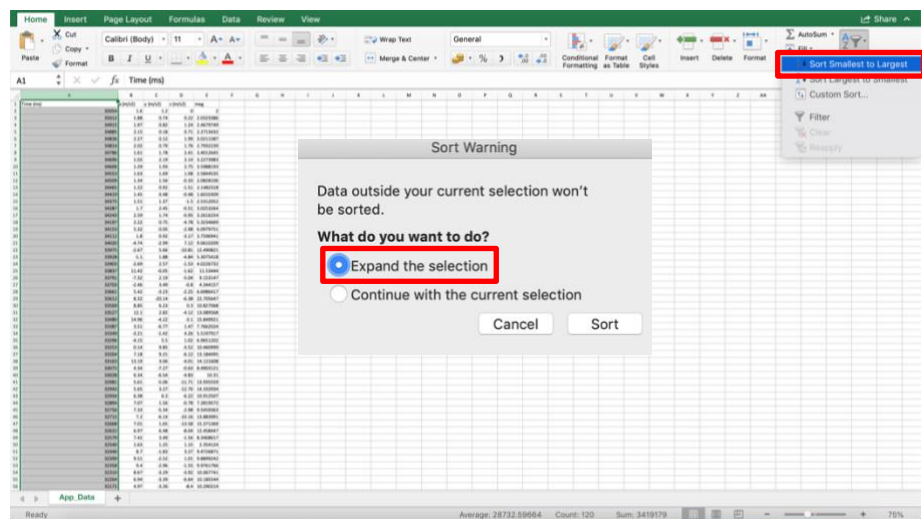
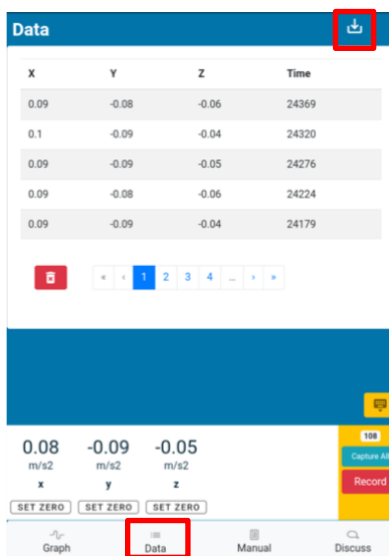
5. If necessary, press “Set Zero” button on the app interface to remove offsets.
6. Find and identify the axes and +/- directions of the accelerometer by moving it in all directions.
7. Place the accelerometer on the rotating platform with proper orientation. Measure the distance between the center of rotation and the accelerometer, i.e. radius of circular motion.

Testing for Rotation

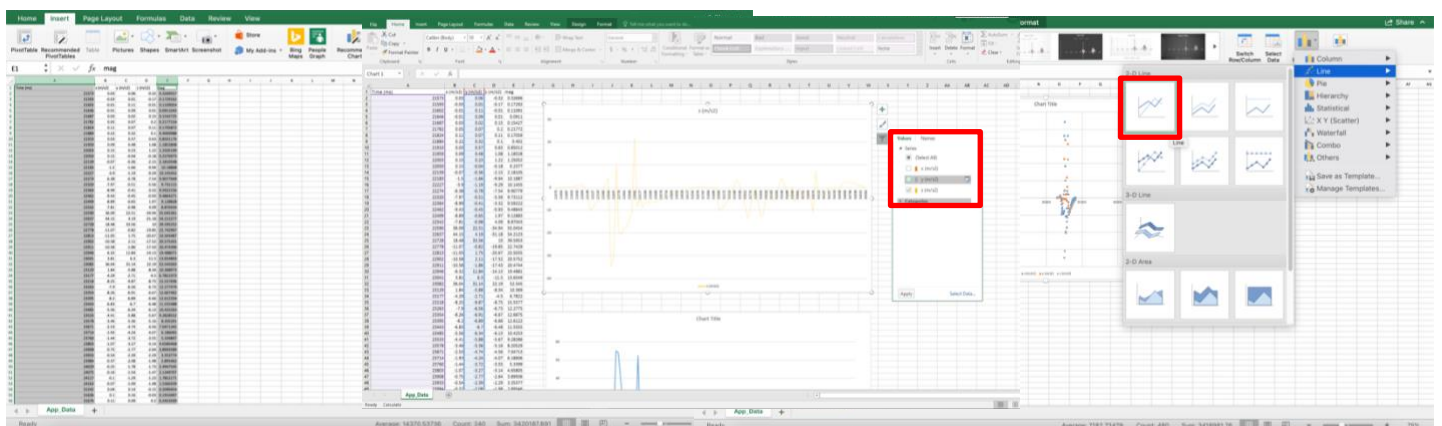
8. Start recording data by pressing “Capture All” in the app. The number above the button shows the data points collected.
9. Start the stopwatch and rotate the rotating platform at a constant angular speed (suggested around π per second) for 10 revolutions then stop the stopwatch. Stop the measurement and export the data as .csv file. The file can be used in MS Excel for further data analysis.
10. Repeat Step 8-9 with different radius and different angular speed.
11. Switch off the accelerometer by pressing the power button twice.

Data Analysis

12. In the data page, read the acceleration of all axes.
13. Press the “export” button to export the data as .csv file. Send the file to a computer.



14. Open the .csv file with Excel. (Change the file format to .csv if necessary.) Reverse the time sequence of the recorded data.
15. Highlight the needed data columns and plot a “scatter” chart with Excel. Connect the data points as line. Then display the desired axis by filtering out the others.



16. From the graph, analyze the rotational motion. Find the average centripetal acceleration.

17. Compare the data and verify the formula $a = r\omega^2$.

DataCentripetal Acceleration with Different Radius

Radius r (m)	Angular Speed ω (rad)	Square of Angular Speed ω^2 (rad ²)	Centripetal Acceleration a (ms ⁻²)

Discussion

1. Which axis is the centripetal acceleration along? Does it obey the Newton's Law of Motion?
2. What is the force that provides the centripetal acceleration? What is expected to happen if the rotating platform spins too fast?
3. What is the relationship of centripetal acceleration and the square of angular speed?
4. What are the possible errors of the experiment? How can we improve to reduce the errors?