Circular Motion

Purpose

Using "AP-Senor" app to investigate the equation of circular motion, particularly the relation between centripetal force and the distance of sensor from the rotational center.

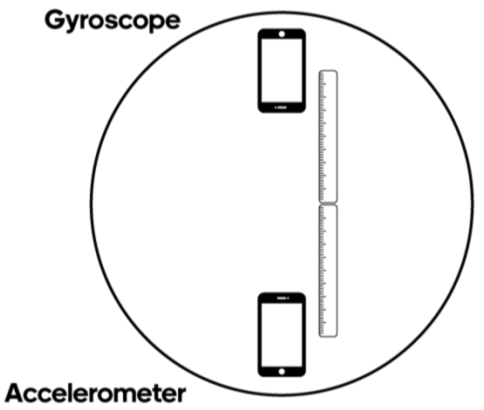
Theory

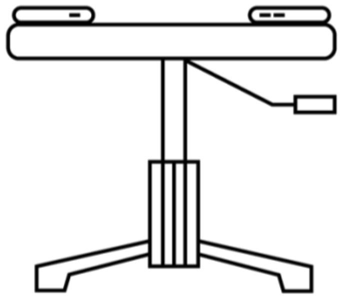
- Circular motion describes movement along circular path. Object may move in varying angular speeds, or in uniform speed throughout the motion. The latter case is called uniform circular motion. In order to reduce complexity, only uniform circular motion is concerned in this experiment.
- In the study 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 $\boxed{a = r\omega^2}$.
- 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 AP-Sensor app comprises accelerometer and gyroscope. The accelerometer will serve the main purpose in this experiment, while gyroscope is an optional component which you may include for your interest in observing the angular velocity during the motion.

Apparatus

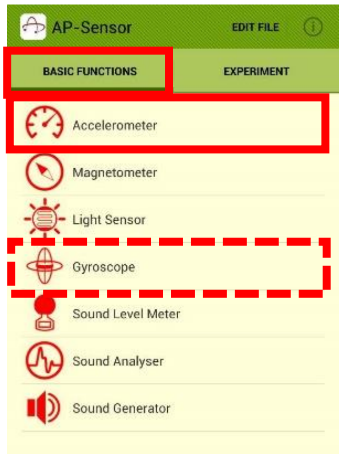
- 1-2 mobile device(s) with "AP-Sensor" app
- A rotating platform
- A stopwatch

Setup





Procedure



Set up the Experiment

1. Open "AP-Sensor" app in the mobile device and choose "Accelerometer".
2. Optional: Open "AP-Sensor" app in another mobile device and choose "Gyroscope".
3. Find and identify the axes and +/- directions of the accelerometer (and gyroscope) by moving it in all directions.
4. Place the accelerometer (and gyroscope) on the rotating platform with proper orientation. Measure the distance between the center of rotation and the accelerometer, i.e. radius of circular motion.

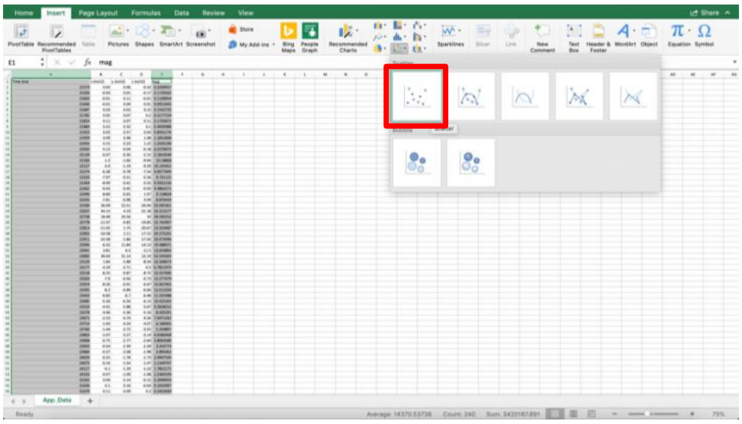
Testing for Rotation

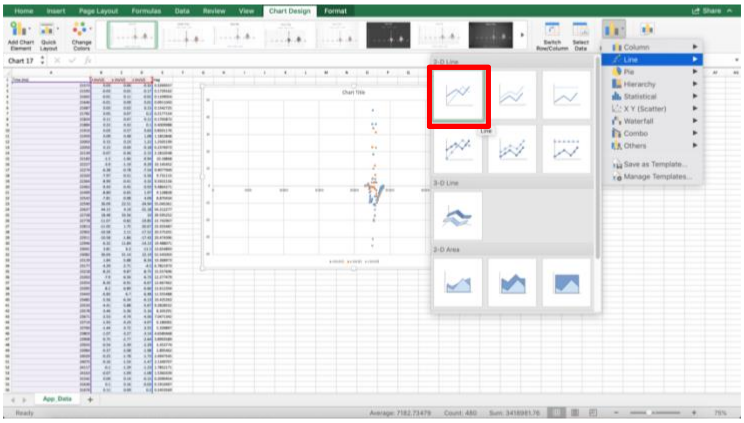
5. Start recording data by pressing "Start" in the app.
6. Start the stopwatch and rotate the rotating platform at as constant as possible angular speed (suggested around **π** per second) for 10 revolutions then stop the stopwatch. Stop the measurement and export the data as .csv file. The file can be used in MS Excel for further data analysis.
7. Repeat Step 6-7 with different radius.

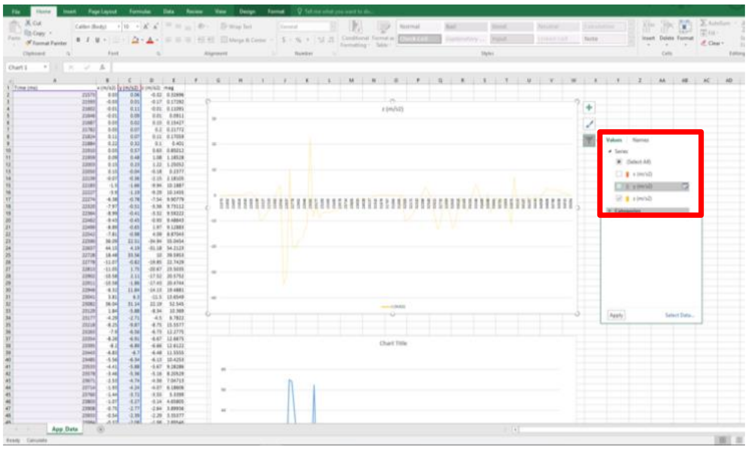
Data Analysis

8. Send the file to a computer.
9. Open the .csv file with Excel. Change the file format to .csv if necessary.

10. 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.







11. From the graph, analyze the rotational motion. Find the average centripetal acceleration.
12. The angular velocity can be obtained by 10 complete circles (20**π** rad) divided by the time taken for the 10 revolutions.
13. If a gyroscope is used, you may try to identify the starting and stopping time from both graphs, then verify the relation by dividing any instantaneous centripetal acceleration by its corresponding instantaneous square angular velocity.
14. Compare the data and verify the formula $a = r\omega^2$.

Data

Centripetal 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?
5. If you have used the gyroscope in the experiment, which approach comes to a more accurate result? The one using average centripetal acceleration and angular velocity, or the one using instantaneous data from the accelerometer and gyroscope?