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| 10/27/2018 |
| Laboratory 2: Accelerometers |
| ELEC 344 |

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| Jessica Morrison  20008084 |

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# Introduction

## 1.1: Theory

The ADXL335 accelerometer is a device used to measure accelerations in a triaxial plane. This product detects changes in acceleration with a minimum full-scale range of ±3 g. It is capable of detecting changes in static acceleration in tilt-sensing situations, as well as dynamic accelerations such as changes in motion, shock or vibration. The device is composed of a polysilicon surface that is suspended over a silicon wafer using polysilicon springs. As the device is accelerated, the structure deflects. This deflection is then measured using a differential capacitor. The capacitor consists of a fixed plate and a motional plate that is attached to a mass. As the structure deflects with applied forces the differential capacitor shifts out of balance altering the output voltage. The structure of the differential capacitor can be seen in Figure 1.

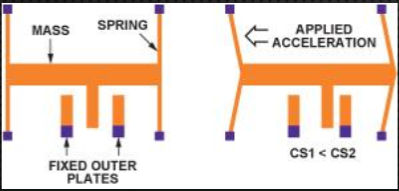


Figure 1: Structure of the differential capacitor used in the ADXL 335 accelerometer [1]

The output voltage that is observed for all three directions is dependant on gravity. Therefore, the relationship between the gravitational acceleration that is applied to the device and the outputted tangential acceleration observed can be seen in Equation (1).

Equation (1)

Where represents tangential acceleration measured in g’s. L represents the length of the pendulum measured in meters, and s is the pendulum’s displacement measured in meters.

Therefore, to properly assess the effectiveness of the devices the output voltage must be converted to g’s using Equation 2.

Equation (2)

Where output voltage is measured in volts, bias level is measured in volts and sensitivity is measured in volts/g. Therefore, the acceleration is dependant on gravity.

Furthermore, in using the accelerometer in tangential applications the relationship of the period observed and the gravity applied to the system can be seen in Equation (3).

Where T represents the period of the pendulum measured in seconds.

## 1.2: Literature Values

The values that were considered during the analysis of the ADXL335 Accelerometer include; the standard operating voltage range, zero gravitational bias level and the sensitivity level. The standard operating voltage range for the accelerometer is 1.8V to 3.6V. However, the supply voltage fed to the device was a 5V source. Due to this change, all other values were assumed to be maxima. Therefore, the zero gravitational bias level was assumed to be 1.65V and 1.8V for the X, Y axis and Z axis respectively. The sensitivity level was determined to equal 0.33V/g. A summary of all additional operating parameters can be found in Appendix A.

## 1.3: Limitations

The limitations of the lab report include equipment issues, spacing constraints and likelihood for human error. In testing the tangential response of the accelerometer, a clamp was used to hold the accelerometer in place. However, this allowed for minimal movement of the device, preventing that ability of the accelerometer to act as pendulum. Therefore, the clamp had to be loosened, which allowed for accelerations to occur in orthogonal planes and increased the risk of human error. Furthermore, a large space should be used to conduct this experiment as a 1m radium is required to conduct the experiment. Constraints with spacing prevented the accelerometer from completing full rotations, skewing the results.

## 1.4 Objectives

The purpose of this experiment was to test and determine the reliability of the ADXL 335 Accelerometer. Several different tests were run on the system, such as rotating the accelerometer around an axis, treating the device as a pendulum and controlling the gravitational acceleration applied to the device by choosing its orientation. By observing the results of these experiments and comparing them to the design specifications, the accuracy of the device will be determined.

# Methods

## 2.1 Materials

The materials used to conduct the experiment are as follows.

* Arduino Uno Microcontroller
* ADXL335 unit (mounted on a printed circuit board)
* Arduino serial monitor
* Protractor
* Meter stick
* Clamp

## 2.2 Electrical Schematic and Setup:

Throughout the experiment the ADXL335 unit was attached to the end of the meter stick. This allowed for greater control of the movements of the accelerometer. This system was then connected to the Arduino Microcontroller using four wires. Three of the wires detected the variances in voltage in the triaxial plane and the forth supplied a 5v supply voltage to the accelerometer. These signals were then observed on the serial monitor. The general layout of the equipment can be seen in Figure 2.

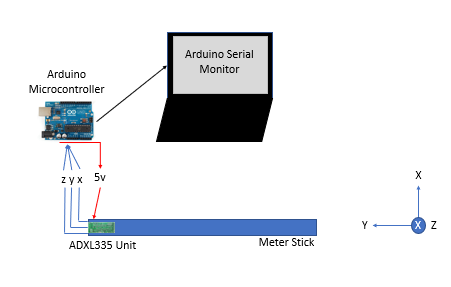


Figure 2: Outline of the equipment setup

## 2.3 Procedure

The laboratory can be divided into three separate experiments and the process followed during the laboratory is outlined below. Diagrams depicting the setup for experiment 2 and 3 can be found in Figure 3 and Figure 4 respectively.

### 2.3.1 Setup

1. Attach the three wires that are connected to the x, y, z ports on the accelerometers to analog inputs on the Arduino microcontroller.
2. Attach the input voltage wire to the 5V voltage source on the Arduino microcontroller.
3. Using the Arduino Serial Monitor, observe the changes in output voltage of the three-axes.

### 2.3.2 Experiment 1

1. Lie the meter stick on a flat surface so that the z axis is pointing to the ground, collect a few seconds of data using the serial monitor.
2. Repeat this procedure twice more with the x axis and the y axis facing the ground.

### Experiment 2

1. Place the meter stick in a vertical position such that the accelerometer is at the bottom of the system
2. Using the protractor as a reference, vary the angle of the meterstick by 15-degrees.
3. Setting the serial monitor to an appropriate delay (100ms), hold the meterstick for five seconds and collect data at this displacement
4. Repeat this procedure, displacing the meterstick another 15 degrees until data has been acquired for 360 degrees of the rotation.

### Experiment 3

1. Place the meter stick in a vertical position such that the accelerometer is at the bottom of the system
2. Clamp the meter stick and the protractor such that the top of the meter stick is placed at the center of the circle. Make sure that the meter stick can rotate.
3. Using the protractor as a reference, displace the meter stick by an angle of 15 degrees.
4. Release the meter stick allowing it to rotate back and forth in a pendulum motion. Take data of the entire motion until the pendulum comes to a stop
5. Repeat the experiment with a displacement of 30 degrees

|  |  |
| --- | --- |
| Figure 3: Diagram depicting the orientation of the accelerometer in experiment 2 | Figure 4: Diagram outlining experiment 3 with a 15-degree displacement |

# Results

The results of the three experiments used to determine the accuracy of the AXDL335 can be found below.

## Experiment 1

The purpose of this experiment was to observe the relationship between output voltage and acceleration when each axis in the triaxial plane experienced 1g of acceleration. A summary of the average output voltages and the standard deviation can be seen in Table 1.

Table 1: The mean output voltage of each axis when its normal vector is parallel to gravity

|  |  |  |  |
| --- | --- | --- | --- |
| Orientation | X-Vout (V) | Y-Vout (V) | Z-Vout (V) |
| X - Axis down | 1.3134 ± 0.0093 | 1.6256 ± 0.0051 | 1.6644 ± 0.0062 |
| Y - Axis down | 1.6494 ± 0.0106 | 1.3033 ± 0.0049 | 1.6222 ± 0.0110 |
| Z - Axis down | 1.6557 ± 0.0065 | 1.6229 ± 0.0047 | 1.3500 ± 0.0104 |

## Experiment 2

The purpose of this procedure was to observe the change in output voltage for each axis when the accelerometer was rotated 360 degree around the x-y axis. Output voltages were recorded for every 15 degrees and then converted to g’s using Equation 2. The gravitational acceleration applied to each axis was then plotted against the degrees of measurement as seen in Figure 5. Refer to Appendix C for calculations and Figure 3 for a visual aid on how the experiment was conducted.

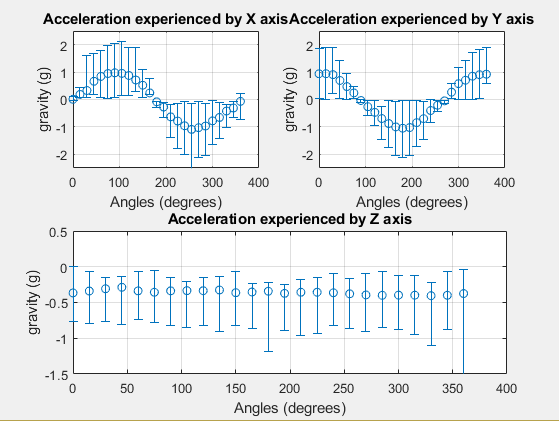


Figure 5: Graphical representation of the acceleration experienced by the X, Y and Z axis for a 360-degree rotation

## Experiment 3

The accelerometer was then treated as a pendulum and the relationship between the period of the swing and the gravitational acceleration applied to each axis was observed. Two trials took place in which the pendulum was displaced by an angle of 15 and 30 degrees. Output voltages for each axis were recorded at intervals of 0.1 seconds for a total length of 8 seconds. This data was then converted to g’s using Equation 2 and plotted against time. The theoretical value for the acceleration was then calculated using Equation 1 and compared to the experimental data. Refer to Appendix C for calculations and Figure 4 for a visual aid on how the experimental was conducted. Graphical representations for the experimental and theoretical accelerations applied to the x, y and z axis can be found in Figure 6, Figure 7, and Figure 8 respectively.

|  |
| --- |
| A close up of a map  Description generated with very high confidence  Figure 6: Tangential acceleration observed in the X axis with a displacement of 15 and 30 degrees |
| A close up of a map  Description generated with high confidence  Figure 7:Tangential acceleration observed in the Y axis with a displacement of 15 and 30 degrees |
| A close up of a map  Description generated with very high confidence  Figure 8: Tangential acceleration observed in the Z axis with a displacement of 15 and 30 degrees |

The theoretical period and the experimental period were then calculated and compared. The experimental period was determined by finding the local maximum and the times in which they occurred, then subtracting the differences between these points and calculating the mean. The theoretical period was calculated using Equation 3. All calculations can be found in Appendix C and a summary of the findings can be found in Table 2.

Table 2: Experimental and Theoretical periods for a pendulum with a displacement of 15 and 30 degrees

|  |  |  |  |
| --- | --- | --- | --- |
| degree | Axis | Experimental period (s) | Theoretical period (s) |
| 15 | x | 0.600 | 0.2908 |
| y | 0.650 | 0.1577 |
| z | 0.425 | 0.2230 |
| 30 | x | 1.650 | 0.3905 |
| y | 0.814 | 0.1302 |
| z | 2.000 | 0.2166 |

# Discussion

In this section, the results that were presented prior will be compared to theoretical values and theories to determine if the ADXL 3353 met specifications.

## Experiment 1

The purpose of this experiment was to determine if 1g of acceleration applied to each axis individually aligned with the theoretical values. These values were calculated by rearranging Equation 2 and can found in Table 3.

Table 3: Theoretical output voltages when 1 g of acceleration is applied to each axis and the zero gravitational bias level

|  |  |  |  |
| --- | --- | --- | --- |
|  | X | Y | Z |
| Vout (V) | 1.98 | 1.98 | 2.13 |
| Zero g (V) | 1.65 | 1.65 | 1.80 |

Comparing these results to the experimental values, the x-axis and the y-axis exhibited output voltages of 1.3041V - 1.3227V, and 1.2984V - 1.3082V respectively. The output voltage observed when 1 g was applied to the z axis equalled 1.336V - 1.364V. Therefore, none of these values correlate with the theoretical values. As per Equation 2 the only variables used to determine the output voltage are the zero gravitational bias level and the sensitivity level. Therefore, to determine where the error occurred both were assessed.

Regarding the zero gravitational bias level, a summary of the theoretical values can be found in Table 3. In comparing these values to the experimental data in Table 1, the x values are within specification however, there are slight discrepancies in the y and z axis. For the y axis there is a difference of 1.2% and the z axis has a difference of 7%. This difference can be attributed to human error, since the accelerometer may not have remained exactly parallel to gravity.

Therefor an error must have occurred from the sensitivity level and the positioning of the accelerometer. This discrepancy most likely occurred because the accelerometer was positioned such that an acceleration of -1g was provided to the system. Therefore the 0.33 sensitivity level was subtracted from the zero gravitational bias level and caused the output voltage to decrease. If the accelerometer had been properly oriented, the correct output voltages would have been displayed.

## 4.2 Experiment 2

In this experiment the accelerometer was rotated 360-degrees around the x-y axis, then the x, y and z accelerations were plotted for every 15 degrees of rotation as seen in Figure 5. The purpose of this experiment was to determine if the output voltages corresponded with the correct acceleration that was applied to each axis throughout the rotation. The relationship between the acceleration applied to the x axis and the angles of rotation can be described by a sin wave. Similarly, the y axis could be represented with a cosine wave. However, the z axis appears to maintain a near zero value of -0.3591 g’s.

This corresponds with the expected result since the position of the accelerometer was initially placed along the y axis, therefore causing the acceleration of gravity to be completely acting the y direction. Subsequently, both x and z axes should have exhibited values of 0g. As the accelerometer rotates, gravity begins to accelerate the x direction as well as the y. This will continue until the accelerometer reaches 90°. At this point gravity is only acting in the x direction and an output of 1g will be produced. The y axis and the z axis will therefore output a value of 0g. This cycle will continue until the accelerometer has finished the rotation. Since the z axis maintains a direction that is orthogonal to the acceleration throughout the rotation, it will continue to output a value that is near zero. This value will have slight variations throughout the experiment due to the cross-axis sensitivity. Per the specifications, ±1% of the acceleration applied to a perpendicular plane will be exhibited in an adjacent plane [2].

## 4.3: Experiment 3

The purpose of this experiment was to treat the accelerometer as a pendulum, and to observe how changes in the period affected the acceleration applied to each axis. It should be noted that the data that was collected did not cover the full pendulum motion as only 8 seconds of data was collected.

The results observed in Figure 6, Figure 7, and Figure 8 show what the theoretical and experimental accelerations are assuming that the experimental data accurately conveyed the relationship. This is because the theoretical acceleration for each axis was calculated using the gravitation array that was produced by the output voltage. This is incorrect because in using this method the theoretical data becomes dependant on the experimental. Therefore, the analysis that should have been performed would make use of a separate gravitational acceleration array. It would be calculated by determining the amount of g that applied to the x and y axis as the pendulum rotated.

Since the pendulum was rotating around the y axis. Gravity will apply 1 g of acceleration on the y axis when the pendulum is at its centre point. It will then decrease in acceleration as it moves towards the extremity of the swing. Alternatively, the acceleration exhibited on the x axis will be centered around an acceleration of zero. As the pendulum moves towards the extremity of the swing the x axis will experience a larger acceleration however one acceleration will be positive, and one will be negative. If this method was conducted the output of the theoretical graph should have looked similar to the results displayed in Figure 9. These theoretical values are assuming that the effect of air resistance is in effect. If this experiment was conducted in a vacuum, the pendulum would swing indefinitely.

A close up of text on a whiteboard

Description generated with high confidence

Figure 9: graphical representation of the true theoretical acceleration applied to each axis

In comparing the x-axis plots exhibited in Figure 9 with the experimental results shown in Figure 6, a similar response between both plots can be seen. Regarding the figure with the 30-degree displacement, both the experimental and the theoretical graphs are centered around 0g’s and they both exhibit a sinusoidal relationship. The plot with the 15-degree displacement does not have a similar shape for the first 3.5 seconds however, after this point it portrays a sinusoidal relationship as expected. This discrepancy can be attributed to an irregular release on the pendulum. If the release added an additional acceleration to the z axis this may have caused the error.

Regarding the y axis, the theoretical data exhibited in Figure 9 had a similar relationship to the experimental data displayed in Figure 7. Again, the plot with the 30-degree displacement more accurately displayed the expected results as it remained below the 1 g and had a sinusoidal shape. The plot for the 15-degree displacement did not show a sinusoidal shape as clearly however, the outputted gravitational accelerations were at the expected level.

Finally, the z axis theoretically should not have had any variance in output values, since it remained orthogonal to the pendulum motion and the affect of gravity throughout the experiment. However, this relationship was not displayed as seen in Figure 8 because the outputted acceleration had non-zero values. This can be attributed to a poor release of the pendulum that caused accelerations in the z axis.

In assessing the experimental and theoretical periods, again, the theoretical period was calculated using the gravitation array that was produced by the output voltage. Therefore, the theoretical period is dependent on the experimental which is an incorrect solution. If you assume that 1 g is applied to the x and y axis throughout the experiment using Equation 2, the period is calculated to equal 1.95s. Since, the z axis remains orthogonal to gravity the period is infinite. In comparing these values to the experimental data displayed in Table 2, there is no overlap between these values. Due to large outliers that was caused by irregular releases of the pendulum, the period that was calculated did not provide insight on the behaviour of the pendulum. The period should not be affected by the displacement of the pendulum.

# 5.0: Conclusion

The ADXL 335 is and accelerometer that measures variances in acceleration in a triaxial field. The accelerometer was placed under a series of tests to determine the reliability of the device.

The accelerometer proved to work well under stationary conditions. Despite issues with orientation, the device was able to accurately detect the affect of -1g of acceleration along each individual axis. Additionally, it accurately maintained the zero gravitational bias level of the axes when the acceleration was being applied to the orthogonal plane.

Furthermore, when the accelerometer was rotated 360 degrees around the x-y axis the device accurately exhibited a sin wave for the relationship along the x axis. A cosine wave for the relationship along the y axis and an acceleration of near zero for the z axis.

However, when testing the accelerometer in motional settings it did not exhibit the correct results. Treating the accelerometer as a pendulum and determining the accelerations applied to the system a sinusoidal wave was expected along the x and y axis and an acceleration of zero was expected along the z axis. Moreover, the period was expected to remain constant regardless of the angle of displacement, for both the x and the y axes. These expectancies were not meet, however, the results did display some regions that were similar to the theoretical values. Therefore, it is assumed that the error was caused by the meterstick that was unable to swing in a motion that resembled a pendulum

In conclusion, this experiment was not a good assessment of the reliability of the accelerometer. However, this is most likely not a cause of the accelerometer, as equipment issues and human error did occur throughout the experiment. In repeating this experiment, attaching the accelerometer to a string may show improved results for the pendulum experiment as it will allow for a more consistent motion.

# 6.0 References

[1] “ELEC344\_Lab2Exercise\_F2018 - ELEC 344 - Sensors and Actuators F18.” [Online]. Available: https://onq.queensu.ca/d2l/le/content/233788/fullscreen/1484120/View. [Accessed: 27-Oct-2018].

[2] “ADXL335\_AccelerometerDatasheet - ELEC 344 - Sensors and Actuators F18.” [Online]. Available: https://onq.queensu.ca/d2l/le/content/233788/fullscreen/1436977/View. [Accessed: 27-Oct-2018].

# Appendix A: Constant Values

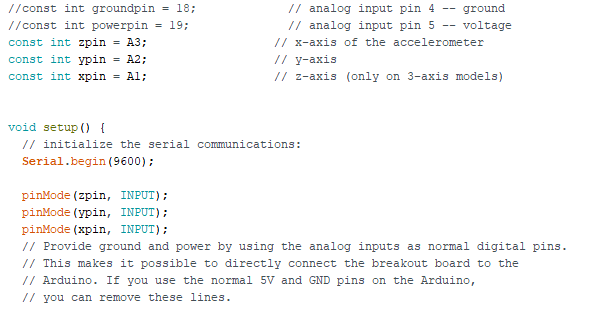
A summary of all the specifications of the ADXL335 can be found in Table 3.

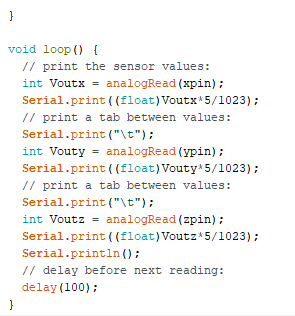
Table 4: ADXL 335 specifications

|  |  |  |
| --- | --- | --- |
| Specification | Value | Unit |
| Measurement Range (minimum) | ±3.0 | g |
| Measurement Range (typical) | ±3.6 | g |
| Non-Linearity | ±0.3 | % |
| Cross-axis sensitivity | ±1 | % |
| Measurement Sensitivity (minimum) | 0.27 | V/g |
| Measurement Sensitivity (typical) | 0.3 | V/g |
| Measurement Sensitivity (maximum) | 0.33 | V/g |
| 0 g voltage (minimum) | X, Y - 1.35 | V |
| Z - 1.2 |
| 0 g voltage (typical) | 1.5 | V |
| 0 g voltage (maximum) | X, Y - 1.65 | V |
| Z - 1.8 |
| Operating temperature range | -40 to +85 | °C |
| Absolute maximum acceleration | 10,000 | g |

# Appendix B: Arduino Code

This code was used to output the x, y and z voltages on the serial monitor.





# Appendix C: MATLAB Code

This code was used to perform all the analysis conducted in this experiment.

## Start of Code

clc

clear all

%Jessica Morrison

%20008084

%LAB2 - ELEC 344

## Assign Variables and Import Data

%Note: Using Max Parameters due to input voltage of 5v

%Zero G Bias Level

X\_Vbias = 1.65; %Volts

Y\_Vbias = 1.65; %Volts

Z\_Vbias = 1.8; %Volts

%Sensitivity

sens = 0.330; %Volts/Gravity

%Theta

angle = [0 15 30 45 60 75 90 105 120 135 150 165 180 195 210 225 240 255 270 285 300 315 330 345 360]; %degrees

%Time

time = 0.1:0.1:7.7; %seconds

%Import Data - Part A

x\_ydown = xlsread('Lab2\_data.xlsx', 'Part A', 'A23:A40');

y\_ydown = xlsread('Lab2\_data.xlsx', 'Part A', 'B23:B40');

z\_ydown = xlsread('Lab2\_data.xlsx', 'Part A', 'C23:C40');

x\_xdown = xlsread('Lab2\_data.xlsx', 'Part A', 'A43:A60');

y\_xdown = xlsread('Lab2\_data.xlsx', 'Part A', 'B43:B60');

z\_xdown = xlsread('Lab2\_data.xlsx', 'Part A', 'C43:C60');

x\_zdown = xlsread('Lab2\_data.xlsx', 'Part A', 'A63:A76');

y\_zdown = xlsread('Lab2\_data.xlsx', 'Part A', 'B63:B76');

z\_zdown = xlsread('Lab2\_data.xlsx', 'Part A', 'C63:C76');

%Import Data - Part B

data\_B = xlsread('Lab2\_data.xlsx', 'Part B', 'A3:BW41');

x\_data = data\_B(:,1:3:75);

y\_data = data\_B(:,2:3:75);

z\_data = data\_B(:,3:3:75);

%Import Data - Part C

data\_C = xlsread('Lab2\_data.xlsx', 'Part C', 'A3:F79');

x\_15 = data\_C(:,1);

y\_15 = data\_C(:,2);

z\_15 = data\_C(:,3);

x\_30 = data\_C(:,4);

y\_30 = data\_C(:,5);

z\_30 = data\_C(:,6);

## Part A

%Output voltages when X axis is parallel to gravity

xXdownavg = mean(x\_xdown);

yXdownavg = mean(y\_xdown);

zXdownavg = mean(z\_xdown);

xXdownstd = std(x\_xdown);

yXdownstd = std(y\_xdown);

zXdownstd = std(z\_xdown);

%Output voltages when Y axis is parallel to gravity

xYdownavg = mean(x\_ydown);

yYdownavg = mean(y\_ydown);

zYdownavg = mean(z\_ydown);

xYdownstd = std(x\_ydown);

yYdownstd = std(y\_ydown);

zYdownstd = std(z\_ydown);

%Output voltages when Z axis is parallel to gravity

xZdownavg = mean(x\_zdown);

yZdownavg = mean(y\_zdown);

zZdownavg = mean(z\_zdown);

xZdownstd = std(x\_zdown);

yZdownstd = std(y\_zdown);

zZdownstd = std(z\_zdown);

## Part B

%converting the input data into g's

x\_g = (x\_data-X\_Vbias)/sens;

y\_g = (y\_data-Y\_Vbias)/sens;

z\_g = (z\_data-Z\_Vbias)/sens;

%Determine the mean values for each degree of rotation for all three

%axes

meanX = mean(x\_g);

meanY = mean(y\_g);

meanZ = mean(z\_g);

%Determine the max values for each degree of rotation for all three axes

maxX = max(x\_g);

maxY = max(y\_g);

maxZ = max(z\_g);

%Determine the min values for each degree of rotation for all three axes

minX = min(x\_g);

minY = min(y\_g);

minZ = min(z\_g);

%Plot the X values for acceleration applied

figure(1)

subplot(2,2,1)

errorbar(angle,meanX,minX,maxX,'o')

xlabel('Angles (degrees)');

ylabel('gravity (g)');

title('Acceleration experienced by X axis');

grid on

ylim([-2.5,2.5])

%Plot the Y values for acceleration applied

figure(1)

subplot(2,2,2)

errorbar(angle,meanY,minY,maxY,'o')

xlabel('Angles (degrees)');

ylabel('gravity (g)');

title('Acceleration experienced by Y axis');

grid on

ylim([-2.5,2.5])

%Plot the Z values for acceleration applied

figure(1)

subplot(2,2,[3,4])

errorbar(angle,meanZ,minZ,maxZ,'o')

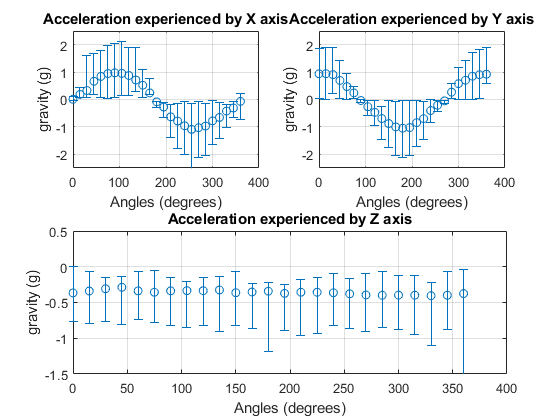
xlabel('Angles (degrees)');

ylabel('gravity (g)');

title('Acceleration experienced by Z axis');

grid on

ylim([-1.5,0.5])



## Part C

%Experimental Data

%converting the voltages into units of g

x\_pd15 = (x\_15 - X\_Vbias)/sens;

y\_pd15 = (y\_15 - Y\_Vbias)/sens;

z\_pd15 = (z\_15 - Z\_Vbias)/sens;

x\_pd30 = (x\_30 - X\_Vbias)/sens;

y\_pd30 = (y\_30 - Y\_Vbias)/sens;

z\_pd30 = (z\_30 - Z\_Vbias)/sens;

%Theoretical Data

l = 0.95; %In meters

s\_15 = 0.25\*sin(7.5); %In meters

s\_30 = 0.50\*sin(15); %In meters

%Theoretical Accelerations

ax\_pd15 = ((-(x\_pd15)/l)\*s\_15);

ay\_pd15 = ((-(y\_pd15)/l)\*s\_15);

az\_pd15 = ((-(z\_pd15)/l)\*s\_15);

ax\_pd30 = ((-(x\_pd30)/l)\*s\_30);

ay\_pd30 = ((-(y\_pd30)/l)\*s\_30);

az\_pd30 = ((-(z\_pd30)/l)\*s\_30);

%find the period of experimental data

%This step is finding the max values and the times in which they occur and

%the average difference between the points

%for a 15-degree displacement

[pks\_x15,locs\_x15] = findpeaks(x\_pd15);

periodX\_15 = mean(diff(locs\_x15\*0.1));

[pks\_y15,locs\_y15] = findpeaks(y\_pd15);

periodY\_15 = mean(diff(locs\_y15\*0.1));

[pks\_z15,locs\_z15] = findpeaks(z\_pd15);

periodZ\_15 = mean(diff(locs\_z15\*0.1));

%for a 30-degree displacement

[pks\_x30,locs\_x30] = findpeaks(x\_pd30);

periodX\_30 = mean(diff(locs\_x30\*0.1));

[pks\_y30,locs\_y30] = findpeaks(y\_pd30);

periodY\_30 = mean(diff(locs\_y30\*0.1));

[pks\_z30,locs\_z30] = findpeaks(z\_pd30);

periodZ\_30 = mean(diff(locs\_z30\*0.1));

%Finding the experimental Period

T15x = mean(2\*pi\*(sqrt(abs(l/ax\_pd15))));

T15y = mean(2\*pi\*(sqrt(abs(l/ay\_pd15))));

T15z = mean(2\*pi\*(sqrt(abs(l/az\_pd15))));

T30x = mean(2\*pi\*(sqrt(abs(l/ax\_pd30))));

T30y = mean(2\*pi\*(sqrt(abs(l/ay\_pd30))));

T30z = mean(2\*pi\*(sqrt(abs(l/az\_pd30))));

%Plot the acceleration experienced by X with a displacement of 15 deg

figure(2)

subplot(2,1,1)

plot(time,x\_pd15,time,ax\_pd15)

xlabel('Time (seconds)');

ylabel('gravity (g)');

title('Pendulum Acceleration experienced by X axis (displacement of 15 deg)');

grid on

legend('experimental','theoretical');

%Plot the acceleration experienced by Y with a displacement of 15 deg

figure (3)

subplot(2,1,1)

plot(time,y\_pd15,time,ay\_pd15)

xlabel('Time (seconds)');

ylabel('gravity (g)');

title('Pendulum Acceleration experienced by Y axis (displacement of 15 deg)');

grid on

legend('experimental','theoretical');

%Plot the acceleration experienced by Z with a displacement of 15 deg

figure(4)

subplot(2,1,1)

plot(time,z\_pd15,time,az\_pd15)

xlabel('Time (seconds)');

ylabel('gravity (g)');

title('Pendulum Acceleration experienced by Z axis (displacement of 15 deg)');

grid on

legend('experimental','theoretical');

%Plot the acceleration experienced by X with a displacement of 30 deg

figure(2)

subplot(2,1,2)

plot(time,x\_pd30,time,ax\_pd30)

xlabel('Time (seconds)');

ylabel('gravity (g)');

title('Pendulum Acceleration experienced by X axis (displacement of 30 deg)');

grid on

legend('experimental','theoretical');

%Plot the acceleration experienced by Y with a displacement of 30 deg

figure(3)

subplot(2,1,2)

plot(time,y\_pd30,time,ay\_pd30)

xlabel('Time (seconds)');

ylabel('gravity (g)');

title('Pendulum Acceleration experienced by Y axis (displacement of 30 deg)');

grid on

legend('experimental','theoretical');

%Plot the acceleration experienced by Z with a displacement of 30 deg

figure(4)

subplot(2,1,2)

plot(time,z\_pd30,time,az\_pd30)

xlabel('Time (seconds)');

ylabel('gravity (g)');

title('Pendulum Acceleration experienced by Z axis (displacement of 30 deg)');

grid on

legend('experimental','theoretical');

