Adam Bennett
1657389

Experiment AM1.2A – Centrifugal Force

Date of experiment – 25/10/2016

Lab Group – F1

Executive Summary

The aim of these experiments was to investigate the centrifugal force and to determine how variations in different variables affect the magnitude of the centrifugal force. This consisted of three experiments, involving two rotating arms that could hold a mass. In the three experiments, we varied one of either the radius, the mass or the angular velocity whilst keeping the other two variables constant. By varying the independent variable over a range of 6 readings, it allowed us to plot a graph and determine a line of best fit with a gradient. We hence plotted three graphs, one for each variable but we squared the angular velocity beforehand to make it proportional to the force, and found that each line of best fit resulted in a positive linear correlation. This tells us that each factor is directly proportional to the centrifugal force.

Introduction and Background

The purpose of this experiment was to increase our understanding of the concept of the centrifugal force and how it can be affected by different independent variables. A body twice as great will affect the fame body twice as much (Emerson, 1769) meaning that mass is proportional to the centrifugal force. The experiment was primarily based on the equation **F=mw^2r**, and we wanted to investigate how each variable can affect the centrifugal force. We conducted three experiments, each time changing one variable of the equation (m, w or r) and keeping the other two constant to try and prove that the variables were proportional or directly proportional to the centrifugal force.

The centrifugal force is the force acting towards the centre of the rotation when a system or object is rotating to stop it flying off in a random direction and to keep it moving in a circular path. The centrifugal force is fundamentally important and is used in many aspects of engineering, from the motion of a propeller to its uses within an automatic clutch. It is also important to understand that an unbalanced centrifugal force can be destructive, so in our experiments we will be ensuring an equal mass will be placed either side of the centre of rotation.

Aims and Objectives

The overall aim of this experiment is to investigate the centrifugal force and to understand how the different variables can affect the magnitude of this force. The aims are to collect a range of data throughout the experiment and to plot 3 graphs with calculated gradients so we can compare our theoretical and experiment values.

Methods

Three experiments were performed in total to investigate the centrifugal force. The equation which our experiments were based on is:

F = mw^2r (equation 1)

Where **F** is the centrifugal force in Newtons, **m** is the mass in kg, **w^2** is the angular velocity squared in (rad/s)^2 and **r** is the radius in meters.

The first experiment involved placing two masses, of 0.1 kg each, at 0.1m from the centre of rotation. With the mass and radius of the system being constant, we varied the angular velocity in steps of 5 rad/s between 0 rad/s and 30 rad/s and recorded the results in a table. The system displayed the centrifugal force in Newtons and hence we could calculate the theoretical force using the equation 1. From our results, we plotted a graph of centrifugal force in Newtons against w^2 in (rad/s)^2. We plotted two sets of data, being our theoretical force and our experimental force, which hence allowed us to compare the gradients and to see how similar the two sets of data were and to determine whether the variable was directly proportional to the centrifugal force. The gradient of the theoretical graph is equal to the mass multiplied by the radius and is therefore 0.01. Also in this experiment, we repeated each step but made the system spin in the opposite direction (anti clockwise) to see if this had any effect on the force.

The second experiment involved varying the mass which was placed on the system while keeping the radius and angular velocity constant. The radius was kept at a constant value of 0.1m, meaning all masses placed were positioned 0.1m either side of the centre of rotation. We also kept the angular velocity at a constant value of 30 rad/s. The mass was varied from 0 kg to 0.1 kg in intervals of 0.02 kg. Like the first experiment, the theoretical force could be calculated using equation 1 and the experimental force was given on the system. With this data, we were then able to plot a graph of centrifugal force against mass. The gradient was equal to w^2r, for this particular experiment, the gradient for our theoretical set of data was 90 m(rad/s)^2. As we had data for both the theoretical force and experimental force we could plot them on the same axis to compare how similar the values were.

The third experiment consisted of varying the radius of the system whilst keeping mass and angular velocity the same. We kept the mass as a value of 0.1kg and kept the angular velocity constant at 30 rad/s. We varied the radius from 0 m to 0.1 m in intervals of 0.02 m and recorded the experimental force in an appropriate table. Like the previous experiments, the mass was added either side of the centre of rotation at its respective distances from the centre. Again, the theoretical force was calculated using equation 1 and by subbing in our values for mass, radius and angular velocity. This then allowed us to plot a graph of centrifugal force against radius, with the gradient being equal to mw^2, which for our theoretical set of data will have a value of 90 kg(rad/s)^2.

Results

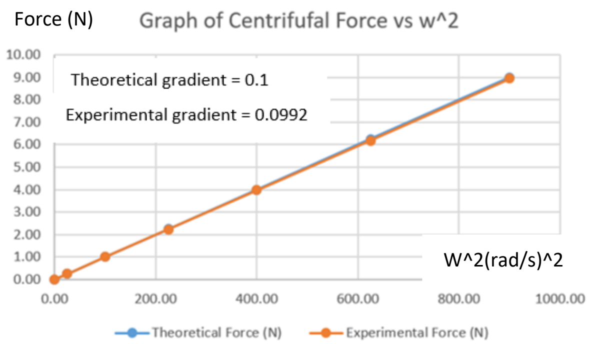

Figure 1: This shows the graph of Centrifugal force(N) against the angular speed squared (rad/s)^2 with the respective gradients.

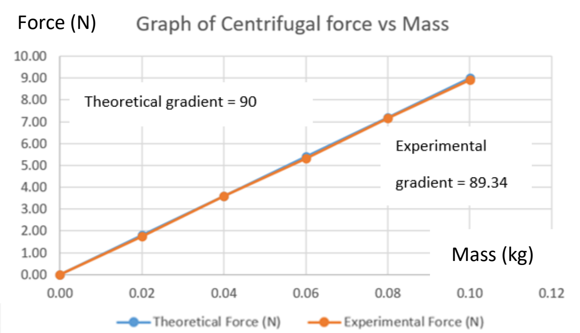

Figure 2: This shows the graph of Centrifugal force (N) against mass (kg) with the respective gradients.

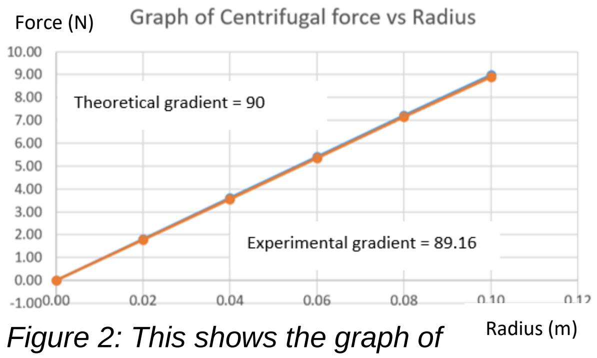

Figure 2: This shows the graph of Centrifugal force (N) against radius (m) with the respective gradients.

Our results showed a very prominent positive linear correlation between each of the variables and the centrifugal force in each independent experiment. The first experiment (figure 1) in which we varied the angular velocity and recorded the centrifugal force gave us a gradient of 0.0992. The gradients were calculated using Microsoft Excel by using linear trendlines to give the most accurate line of best fit and gradient as possible. As our theoretical gradient was 0.1, it shows that the angular velocity squared is directly proportional to the centrifugal force as 0.0992 is very close to 0.1. Similarly, the second experiment (figure 2), with the varying mass, shows the same correlation and the experimental gradient was very close to the theoretical gradient without any anonymous results. Our theoretical gradient was 90 and our experimental gradient was 89.34. This proves that as the mass varies, the centrifugal force will vary at a proportional rate with the constant of proportionality being equal to the radius multiplied by the angular velocity squared. Also, the third experiment (figure 3) shows a similar result where the radius is directly proportional to centrifugal force and hence proves the equation **F=mw^2r**, in our experiments was proven to be correct as each variable was proven to be directly proportional to the centrifugal force.

Discussion

In all three experiments, we saw that the mass, radius and the angular velocity squared was proportional to the centrifugal force. This was as expected when using the equation **F=mw^2r**. William Emerson (1769) stated, “a body twice as great will affect the fame body twice as much”. In all our experiments our experimental gradients were very close to our theoretical gradients and if they were calculated to one significant figure they would have been the same value. While filling in the table there appeared to be no anonymous results as all our experimental values were close to our theoretical values and this is shown on the three graphs (figure 1, figure 2 and figure 3). Also, by analysing the three graphs, they all go through the origin, which shows that the centrifugal force would not exist if there was no radius, no mass or no angular velocity.

However, one way in which our results may have had error was with the difficulty of getting the system to spin at an angular velocity of exactly 30 rad/s, particularly in experiments 2 and 3. We found the angular velocity would fluctuate about 30 and at this velocity, we could not get the system to settle on one specific value. This will then make the centrifugal force change as well which would affect out calculated gradients.

Conclusion

The centrifugal force increases proportionally as the mass, radius or angular velocity squared is increased. Likewise, the centrifugal force is 0 when there is no mass, no angular velocity or the mass is placed on the centre of rotation.

References

1- Emerson, W. (1769) **The laws of centripetal and centrifugal force. Shewing, the motion of bodies in circular orbits, and in the coix sections, and other curves.** London, pp 94.

Appendix

To calculate **w^2**, we squared the value of our angular velocity and hence multiplied the value by itself. For example, when the angular velocity was 10, to find **w^2** we did the calculation of 10x10, which is 100.

To calculate our theoretical force, we used the equation **F=mw^2r** which is a derivation of Newtons 2^{nd} law of **F=ma**. In the given equation, **F** is the centrifugal force, **m** is the mass, **w** is the angular velocity and **r** is the radius. One example of calculating the centrifugal force from the first experiment was when our angular velocity was 25 (rad/s), the mass was 0.1kg and the radius was 0.1 m. By subbing these values into the equation, we are given the theoretical value of centrifugal force as 6.25 N.

When calculating the gradient of the theoretical values of the first experiment we used the method of comparing our equation **y=mx+c,** where m is the gradient and y and x are on their respective axis. We plotted the centrifugal force on the y axis and the angular velocity squared on the x axis, hence by comparing equation 1 and **y=mx+c**, we could see that the gradient was equal to **r*m**. As the radius and mass were kept constant in this experiment at values of 0.1m and 0.1kg, we could sub these into the equation for the gradient of this graph and obtain a value of 0.01.

Similarly, we used the same method of rearranging the equation **F=mw^2r** to acquire the equation in the form of **y=mx+c** for the calculation of the gradient of experiment 2. By Rearranging the equation to **F=rw^2m**, we can see that the gradient, when plotting the graph of centrifugal force against mass will be **r*w^2**. Our value for angular speed in this experiment was 30 rad/s and our radius was 0.1m. by subbing these in, we calculated the gradient for our theoretical values as being 30.

For the gradient of theoretical values in our third experiment, we used the same method as the previous two experiments. We found that the gradient will be equal to **m*w^2**, and as our mass was 0.1kg and our angular velocity was 30 rad/s, we calculated the gradient as being 30.