In this lab session you will conduct two different experiments to test Newton's Second Law of Motion, relating the acceleration of an object to it mass and the applied force.

Experiment 1: Motion with a Constant Force

Equipment:
Low Friction Track with stopper and stand and spirit level
Stop watch
Low friction cart, cart masses, and fan attachment with batteries
Motion detector and LabQuest

Introduction
In this experiment you will investigate the relationship between acceleration and mass when the force is fixed. Newton's second law states that acceleration and mass should be inversely proportional: $a=F/m$

Procedure
Set up the low friction track with a stand and stopper at both ends and adjust the legs of the stand so that the track is level. Set up the motion detector at one end so that is can record the motion of the car on the track. Call the other end of the track the start.

1. Place the cart at the start and give the cart a gentle push in the direction of the detector and record its motion. Based on the position *vs* time graph and the velocity *vs* time graph, what type of motion is the cart exhibiting? How fast is its initial velocity? Is the motion consistent with what you'd expect for a cart with little to no friction?

2. Now attached the fan, with batteries inserted, onto the top of the cart near its center. Record the mass.

3. Place the cart at the start and aim the fan so that it tends to blow the cart *away* from the motion detector. While holding the cart steady turn on the fan and then push it toward the motion detector with enough initial velocity so that it move about ¾ down the track before turning around. Practice this first and then record the motion with the motion detector. Make sure you capture both the forward and return journey.

4. Based on the position vs time graph and velocity vs time graph, what type of motion is the cart exhibiting. Is it consistent with uniformly accelerated motion? From the velocity time graph find the acceleration of cart near the point where it is turning around. Based on Newton's second law, what do you think the value of the force provided by the fan is?

5. Now add a mass to the cart. Based on Newton's second law $F=ma$, the new total mass and the force calculated above, estimate the new acceleration.

6. Now place the cart on the track as before and push the cart toward the motion detector with enough force so that it moves ¾ down the track. Record the motion of the cart with the motion detector and calculate the new acceleration. What is the percentage difference between your predicted value and the measured value?

7. Repeat the process of prediction and measurement for one additional mass added.

Experiment 2: Centripetal Acceleration and Force

Equipment:
Rubber Stopper with hole
Thin smooth flexible string.
Hanging masses
glass tubing with rounded edges
Marker pens and scissors
Stop watch

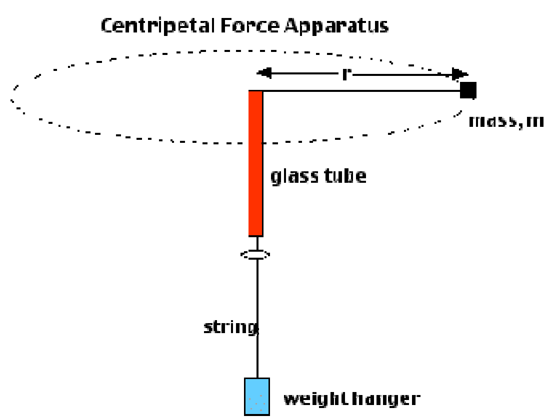
Introduction
In this experiment you will investigate the relationship between acceleration and force for a fixed mass rotating in a horizontal with uniform speed in a circle. According to Newton's 1st law, an object will travel with uniform velocity in a straight line unless acted on by some net external force. From this we can deduce that a net force *is required* to cause a body to move in uniform *circular* motion. This force is called the *centripetal force*, F_c and following Newton's second law

$$F_c = ma_c$$

where a_c is the centripetal acceleration and

$$a_c = \frac{v^2}{r} \text{ and } v = \frac{2\pi \cdot r}{T}$$

Procedure
In this lab the centripetal force is the tension in a string acting on a rubber stopper. The tension is supplied by a hanging weight which is attached to the string at one end. The other ended is threaded through a glass tube and then attached to the stopper. By gripping on to the stopper and rotating the stopper sufficiently fast the hanging weight will not slide down. The faster you rotate the stopper the larger the radius of the rotating circle becomes. A diagram is shown below.



1. Find the mass of your rubber stopper and covert the value to kg.

2. Take a piece of string of at least 1 m and attach it to the stopper at one end. Thread the other end through the glass tube and attached it to the weight hanger.

3. Add a weight attached to this hanger. Record the total mass of the attached weight and the hanger. Write your answer in kg. This weight provides the force necessary for centripetal acceleration, so use this value to calculate the applied force *mg.*

4. Now draw a mark on your string at a distance of about 0.5 meters from the robber stopper.

5. Rotate the stopper fast enough so that this marker is showing just at the top of glass tube. It is useful to let it slide above the top of the glass and then gradually slow the rotations down the mark lines up with the top. Practice a bit before timing. Have your partner time how long it takes for the stopper to rotate 20 times, once you have the radius right. Record this time and then use it to calculate the period *T* and hence the velocity *v.*

6. Repeat the above steps using 4 more weights. Use as large a range of weight values as you can. You should end up with a table with columns where you record the attached weight in kg, the force in Newtons, the time for 20 revolutions, the period *T*, the velocity, and a final column where you calculate the acceleration using $a_c = \frac{v^2}{r}$. Your table will have 5 rows, one for each weight you used.

7. Newton's second law predicts that $F_c = ma_c$, So, plot F_c versus a_c.

8. If Newton's law is valid there should be a linear relationship between force and acceleration. Do the points line up in a straight line that heads toward the origin? Is the slope approximately equal to the mass of the stopper? Check this and discuss any discrepancies.