Experiment 4.1: Going around in circles

Background

An unbalanced force must act on an object if that object is to accelerate.

$$a = \frac{F}{m}$$

Acceleration is the rate of change of velocity. Change of velocity can be either change of speed, change of direction, or both. Thus, a driver can make a car accelerate by turning it around a corner just as much as by pushing harder on the accelerator or brake. As it turns it is accelerating. Therefore, a net or unbalanced force is required to make the car go around the corner.

Aim

To study the relationship between some variables for an object moving in a circular path.

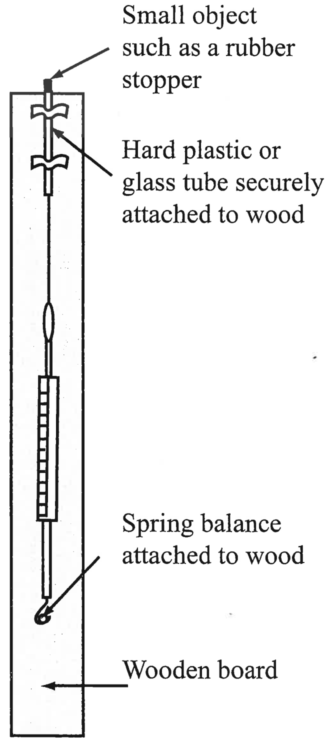
Equipment

- a piece of hollow glass or hard plastic tubing - (150–250 mm)
- large rubber stopper
- fishing line or strong thin cord (1.5 m)
- metre rule
- stop watch
- sticking tape or alligator clip
- spring balance or set of 20 g or 50 g masses

Pre-lab

- Using the equipment shown in the diagram you can investigate the effect on the centripetal force of changes you make to the radius of the circular path, the mass of the object or its speed.
- Note that you can carry out both qualitative (observation-based) and quantitative (measurement-based) investigations using this equipment.
- The glass tubing should be prepared by fire polishing the ends and then wrapping it in cellulose or plastic tape to help prevent it from cutting the line, or cracking and shattering.
- 20 or 50 g masses or large, identical washers and a paper clip can be used instead of a spring balance.
- Be careful. This experiment requires a good deal of space and so should be done outside. It is also advisable to practise whirling the stopper around so that you can control it when you are trying to record your results. Make sure the stopper is securely tied to the fishing line or cord.

Notes



Equipment for Experiment 4.1

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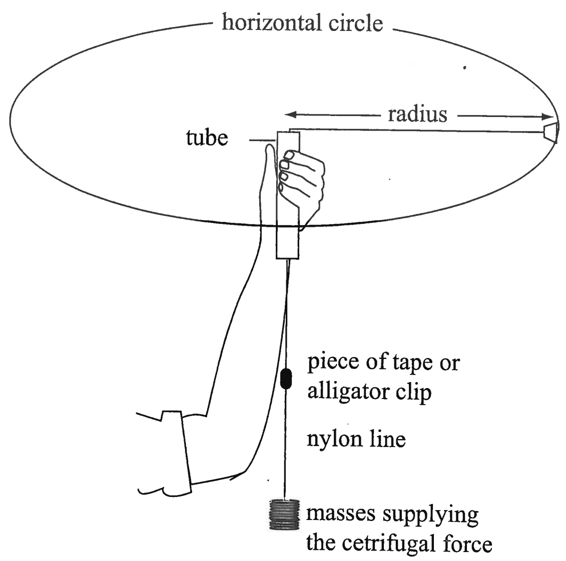
Lab notes

Part A: Variable force with constant radius

- Prepare a data table similar to the one below.

Mass providing centripetal force (kg)	Centripetal force (N)	Time for 20 turns		Average time per turn (s)	Velocity v (m s^{-1})	Velocity^2 v^2 (m^2 s^{-2})
		Trial 1 (s)	Trial 2 (s)			
0.200						

- Measure the mass of the rubber stopper accurately, and record the value.
- If you are using washers and a paper clip instead of slotted masses, measure and record the masses of these as well.
- Use an alligator clip or tape to mark the fishing line below the glass tubing so that you can measure the radius of circle of the revolving rubber stopper. The mark will help you to keep the radius constant.
- Attach a 200 g mass or an appropriate number of washers to the end of the fishing line. *This weight force will provide the centripetal force.*
- Whirl the stopper around so that it is revolving in a horizontal circle of radius 600 mm. You can do this by whirling the stopper with increasing speed until the alligator clip or tape is level with, but not touching, the bottom of the glass tubing.
- Record the time for 20 revolutions in the data table. Repeat to obtain several more results.
- Repeat the experiment with masses of 250 g, 300 g, 400 g and 450 g in the place of the 200 g mass. For each of these, keep the radius of the circular path constant at 600 mm.



Part B: Variable radius with constant force

- Prepare a data table similar to the one below.

Radius (m)	Time for 20 turns		Average time per turn (s)	Velocity v (m s^{-1})	Velocity^2 v^2 (m^2 s^{-2})
	Trial 1 (s)	Trial 2 (s)			
0.20					

- Use the same rubber stopper as in Part A and place a mass of 250 g on the end of the fishing line. You will use this throughout this Part.
- Reset the alligator clip or tape so the radius is 200 mm.
- Whirl the stopper at the speed required for it to revolve at a radius of 200 mm. Record the time for 20 revolutions. Repeat to obtain two sets of data.
- By increasing the speed of revolution, measure the time for 20 revolutions for radii of 400 mm, 600 mm, 800 mm, 1000 mm and 1200 mm. Repeat these measurements to obtain two readings for each radius. In each of these keep the 250 g mass on the end of the fishing line. For each trial, you should reset the alligator clip or tape.

Processing of results

For each set of results calculate the quantities listed in the tables, using $v = \dfrac{2\pi r}{T}$

- For the constant radius set of data, plot
  a) centripetal force vs velocity, and
  b) centripetal force vs velocity squared.

- For the constant force set of data, plot
  a) radius vs velocity, and
  b) radius vs velocity squared.

Post-lab discussion

1. Using the mass of the rubber stopper and any line of data from one of your results tables check the equation for centripetal force,

$$F_c = \frac{mv^2}{r}$$

2. Determine the slope of the graph of centripetal force vs velocity squared. What does this slope represent? Compare it to the value obtained using the mass of the stopper and the radius of revolution.

3. Determine the slope of the graph of radius vs velocity squared. What does this slope represent? Compare it to the value obtained using the mass of the stopper and the centripetal force.

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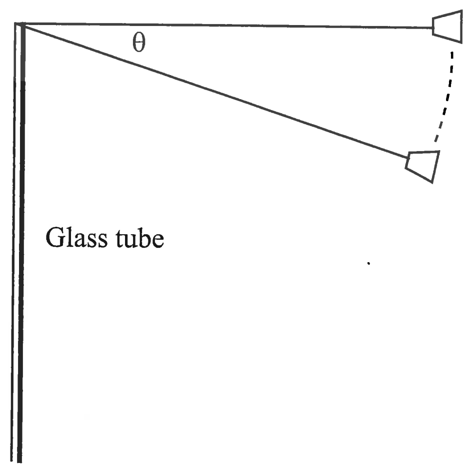
4. Describe the uncertainties in this experiment. Estimate the percentage uncertainty in the expression:

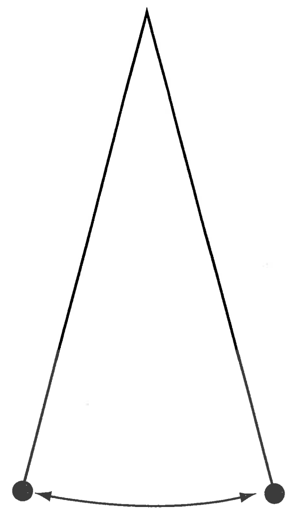
$$\frac{v^2}{r}$$

5. Does the fact that the string holding the stopper is not exactly horizontal affect the relation between F and v? Explain.

6. Determine the relation between F and v in terms of the angle (θ) between the string and the horizontal.



7. The bob of a pendulum swings through a circular arc of constant radius. At what point of the swing does the cord holding the bob exert the greatest centripetal force on the bob? Explain.



Conclusion

State the relationship you have obtained between the variables being investigated in each part of this experiment.