Episode 224: Describing circular motion

In this episode, you will introduce the importance of circular motion and explain the need for a centripetal force to keep an object moving along a circular path.

Motion in a circle is an everyday occurrence and the students should be given time to discuss their experiences of such motion. It is important that they should actually feel the force exerted when an object on a string is whirled round their head.

Summary

Discussion: Observing circular motion. (10 minutes)

Demonstration: Whirling bucket and centripetal force. (15 minutes)

Demonstration: Whirling coin. (5 minutes)

Discussion: Centripetal forces. (15 minutes)

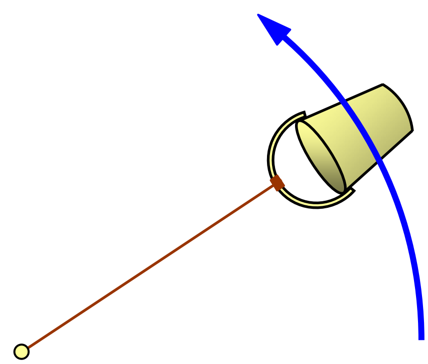
Demonstration: Further demos. (10 minutes)

Discussion:

Observing circular motion

Invite suggestions of objects which move in a circular path:

- The hammer swung by a hammer thrower
- Clothes being dried in a spin drier
- Chemicals being separated in a centrifuge
- Cornering in a car or on a bike
- A stone being whirled round on a string
- A plane looping the loop
- A DVD, CD or record spinning on its turntable
- Satellites moving in orbits around the Earth
- A planet orbiting the Sun (almost circular orbit for many)
- Many fairground rides
- An electron in orbit about a nucleus



Remember that motion in a circle is only a special case of motion in a curve. So why do we study it? It is fairly common and the maths is easier!

Demonstration:

Whirling bucket and centripetal force

The whirling bucket is the classic centripetal force experiment. Put a little water in a bucket - tie a string firmly to the bucket handle and then swing the bucket in a vertical circle. As long as the rate of rotation is great enough the water stays in the bucket! Slowing the rate of rotation can get the water to almost fall out at the top of the path and you can usually hear it slopping around at this critical point.

Make sure that the handles of the bucket do not come off and that the bucket does not hit the floor at the lowest point of the circle, or the ceiling. Many extensions of this are possible such as swinging a tray loaded with beakers by four strings!

This is best done outside; in any case avoid the temptation to stand on anything.

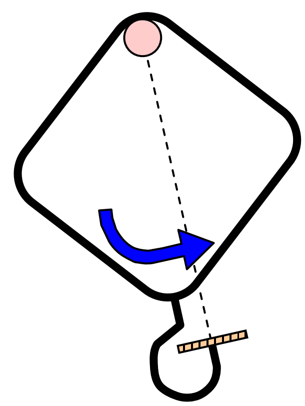
Point out that you are pulling on the string to make the bucket go round. The force with which you are pulling on the string provides the centripetal force needed to keep the bucket orbiting.

Check that your students understand the direction in which this force acts – towards your hand. You can only pull string along its length. Explain the name: “centripetal” means “centre seeking”. *Centripetal* is an adjective describing the force; it is **not** the name of a special type of force, such as tension, gravity, magnetic force etc.

(At the same time, you can feel a force pulling on your hand. This force is the equal and opposite reaction to your pull. Since it acts outwards from the centre of the circle, it can be described as *centrifugal*, or centre-fleeing. However, you may wish to avoid this term, and ask your students to stick to centripetal to describe an inwards force.)

Demonstration:

Whirling coin



Pull open a wire coat hanger so that it forms a square. File the end of the hook flat and then bend the hook until it points towards the opposite corner of the square. Balance a 1p coin on the hook, put one finger in the corner of the square opposite the hook and then spin the coat hanger in a vertical circle – the coin stays in place! This is a very simple but excellent demonstration of centripetal force.

The force of the hook on the penny always acts towards the centre of rotation. Can you beat the record (five 1p pieces stacked on top of each other)? With only one penny balanced and with great care you may be able to bring the coat hanger to rest without the penny falling off.

Discussion:

Centripetal forces

What produces the force to keep the object in a circular path?

The actual way the force is produced depends on the particular example:

Planetary orbits (almost!)	gravitation
Electron orbits	electrostatic force on electron
Centrifuge	contact force (reaction) at the walls
Gramophone needle	the walls of the groove in the record
Car cornering	friction between road and tyres
Car cornering on banked track	component of gravity
Aircraft banking	horizontal component of lift on the wings

So a centripetal force may be a contact force or electrostatic, magnetic, gravitational, etc.

Why must there be an unbalanced force if an object is to follow a circular path? Emphasise Newton's First law. If an object is to move in a circle there must be a force pushing or pulling it out of the straight line path. This force must act towards the centre of the circle and it is this that we call the centripetal force. It is the unbalanced force on the orbiting object.

Imagine whirling a stone on the end of a string, so that it follows a horizontal orbit. If you remove the centripetal force by cutting the string, the stone will move off along a straight line along the tangent to the circle (ignoring gravity for a moment) and not along a radius.

Talk to the students about the following two examples of circular motion in practice:

Sitting in the back seat of a car as it corners: If the car turns to the left, you feel as if you are being thrown to the right. In fact, your bum is in contact with the seat, and gets pulled round to the left (providing there is sufficient friction). The upper half of your body tries to carry on in a straight line. Viewed from a point above the car, your upper half will be seen to be trying to follow a tangential path while the car turns to the left.

Watching a marble roll on the surface of a table in a train as the train corners: again, if the train turns to the left, the marble will appear to drift off to the right. It is following a straight line path, tangential to the curve. There is no friction to pull it to the left, so no centripetal force.

An interesting example is a helium-filled balloon inside a cornering car. The balloon leans in towards the centre of the circle. The air in the car tries to continue in a straight line, so it is slewing to the right inside the car. The balloon is lighter than the air, so it gets pushed towards the lower pressure at the centre of the circle.

Demonstration:

Further demos

Try out a number of other experiments on circular motion.

TAP 224-1: Demonstrations involving circular motion

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Rotating candle - flame bends inwards

Put a candle on a turntable shielded by a glass tube such as a jam jar – the candle must be shorter than the height of the jar. Light the candle and rotate the turntable. Watch the flame! (Diameter of table 30 cm and a rotation rate of about 1 Hz are appropriate)

Back seat of a car

Who falls into whose lap as you go round corners? The person nearest the centre of the curve travels on in a straight line whereas the one on the outside of the curve is pushed round by the side of the car to meet them. So it appears that the person on the inside falls into the other one's lap. This is similar to the effect on the clothes in a spin drier. Notice that if the driver over does it the car will roll outwards - the inner wheels leaving the ground first.

A simple centrifuge by whirling a container on string

A simple centrifuge can be made by whirling a large test tube round your head on a piece of string. Use a mixture of water and sand to show the separation. Experimenting with other liquids such as syrup and wallpaper paste makes an interesting extension to this.

Safety

Eye protection must be worn. The demonstration should be done outside with the class standing at least 10m from the demonstration.

Rotating jelly - circular motion

The effects of centripetal forces on a rotating object can be shown impressively by making a circular jelly about 3 cm deep in an 8cm diameter crystallising dish. When it is set empty it out carefully onto the centre of a saucer which is securely fixed to the centre of the rotating table (use a safety screen all round the table.). Slowly increase the rate of spin of the table. The jelly will flatten.

Further increasing the rate of spin will eventually make the jelly break up - the cohesive forces within it being less than the centripetal forces needed. It can be used to demonstrate why car tyres fly apart when they are spun too fast. It used to be said that if you used some of the old forms of tyre remoulds, you should not travel at more than 60 mph to reduce the risk of the tyres breaking up!

The jelly experiment also shows the shape of the liquid surface while rotating. It is useful to photograph it or take a video for later analysis.

Cress seed and rotating table - g forces

Can we demonstrate the effect of the g force on a cress seed growing on a rotating table? We would have to rotate them for a week – would they grow outwards, inwards or straight up?

Wall of death simulation

Mount a vertical sided glass beaker or crystallising dish on the centre of a rotating table. Set it spinning and carefully place a rubber eraser in it against the wall but not touching the bottom of the dish. The rubber “sticks” to the walls.

External References

This activity is taken from Resourceful Physics http://resourcefulphysics.org/