BALL BEARINGS

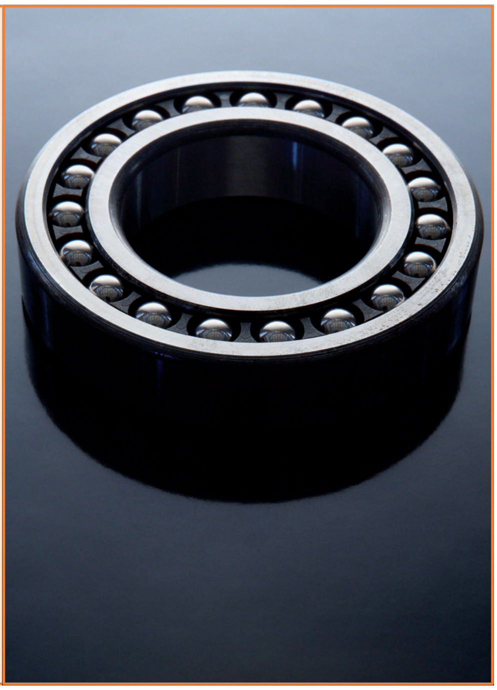
There are lots of moving parts on rides – from giant rollercoasters to small playground swings. And with so many moving parts, friction can be a problem.

Reducing friction saves money by:

- reducing wear and tear
- reducing the energy needed to keep the moving parts moving.

Ball bearings are often used to reduce friction and make things move smoothly.

When we think of ball bearings we may just think of a small metal ball. But, to an engineer, the ball bearing is the whole assembly – the steel balls *and* the casing that holds them.



WHAT YOU HAVE TO DO

You are going to build a simple ball bearing assembly. You will investigate:

- the effect of changing the number of steel balls in the casing
- whether lubricant makes any difference to something that rolls instead of slides.

EQUIPMENT

- 2 metal lids (e.g. from *Golden Syrup* tins), one fastened to a supporting block
- 15 steel ball bearings, approximately 1.5 cm diameter
- 500 g slotted mass
- stopwatch or metronome
- permanent marker pen
- pencil or large nail
- *Blu-Tack* or double sided tape
- lubricants such as water, different oils and graphite powder (optional)

SAFETY NOTES

Take care not to drop the 500 g mass on fingers or feet. Steel balls can cause a very serious risk of slipping and falling if they roll around on the floor. Take care not to drop any and to pick them up IMMEDIATELY if you do. Wear gloves if using graphite powder. Some lubricants can make the floor very slippery – clean up spills quickly.

METHOD 1: CHANGING THE NUMBER OF STEEL BALLS

1. Build the ball bearing assembly:
   - Place as many steel balls as will fit into the groove in the tin lid fastened to the supporting block.
   - Place the other tin lid upside down on top of the steel balls so that again the steel balls fit into the groove in the lid.
2. Place the 500 g slotted mass on the centre of the top lid. Use *Blu-Tack* or double sided tape to fasten it to the lid so that it can't move when the top lid spins round.
3. Make a mark on the edge of the top tin lid, using the permanent marker. Make sure you can still see the mark when the lid spins round.
4. Place a pencil or large nail in the slot in the slotted mass, as close to the centre of the lid as possible. Use it to spin the lid around. Spin the lid as rapidly as you can.
   - The same person should do this each time, as each person will spin it at a slightly different speed.
   - Place the pencil or nail as close to the centre as you can – it reduces wobbling.

   Note: This is probably the easiest way to spin the lid at a constant speed each time, but you will still need to practise first. Use one of these methods to check your speed:
   - Count (or get someone else to count) quickly and steadily, and turn the lid in time with your counting – musicians are usually better at counting steadily than non musicians. Just count one, one, one.....
   - One person uses a stopwatch or a metronome to help them tap quickly and steadily on the desk. The person spinning the lid turns it in time with the tapping.
5. Once you are sure you can spin the ball bearing at a constant rate, start taking readings. Spin the ball bearing steadily for 30 seconds. Then take away your hand. Measure how far the bearing turns before it stops:
   - either as a number of complete turns
   - or as a number of degrees rounded to the nearest 10^{o}.

   Record your result in a table.
6. Repeat Step 5 four more times so you have a total of five measurements. Record your measurements.
7. Remove one of the steel balls from the ball bearing assembly, taking care to support the slotted mass. Take five measurements of how far the bearing turns with this number of steel balls. Record them in the table.
8. Keep removing steel balls one at a time. Take measurements for each number of steel balls until either:
   - you have only one steel ball left, or
   - you are unable to obtain a measurement.

METHOD 2: CHANGING THE LUBRICANT

1. Look at your results for changing the number of steel balls in your ball bearing assembly. Decide on the optimum number of balls that makes your ball bearing work best.
2. Build a ball bearing assembly using the optimum number of steel balls. Add enough of your first lubricant (placed in the bottom groove of the ball bearing assembly) to lightly coat all the steel balls.
3. Take five measurements of how far the ball bearing turns before it stops. Record these in a table.
4. Thoroughly clean all the parts of the assembly using hot water and, if necessary, detergent. Dry the assembly before using a new lubricant.
5. Repeat Step 3 using a different lubricant. Continue until you have taken measurements for all your lubricants.

RESULTS

Table 1

number of steel balls	how far the ball bearing turns before it stops					average measurement of how far the bearing turns
	1st reading	2nd reading	3rd reading	4th reading	5th reading	

Table 2

type of lubricant used	how far the ball bearing turns before it stops					average measurement of how far the bearing turns
	1st reading	2nd reading	3rd reading	4th reading	5th reading	

1. Plot a bar chart of average measurement of how far the bearing turns against number of steel balls:
   - Plot the *average measurement of how far the ball bearing turns* on the *y*-axis.
   - Plot the *number of steel balls* on the *x*-axis.
2. If you used different lubricants, plot a bar chart of average measurement of how far the bearing turns against type of lubricant used.
3. What, if anything, do your results tell you about the best number of steel balls and the best lubricant to use?

EXPLANATIONS

1. For this investigation, why is it better to plot bar charts than line graphs?
2. Were you able to spin the ball bearing at a speed constant enough for your results to be valid?
   - Don't just give a yes or no answer here. Use your results to justify your answer.
3. You took five readings for each measurement, whereas often you may only take three readings. Was it necessary to take the extra readings?
   - Again, use the results you obtained to justify your answer.
4. Suggest some ways in which you could improve the accuracy or the reliability of this investigation.
   - Divide your suggestions into two groups: changes that you might be able to use in your school laboratory, and changes that a manufacturer of ball bearings might use, requiring more sophisticated equipment than in school.

SOME MORE QUESTIONS

- How much effect did the lubricants have on the ball bearing, compared with what you expected?
- If possible, watch an animation of a ball bearing in use. Describe how the movement of the steel balls reduces friction.
- Most ball bearings are supplied as completely sealed units, protected from particles of dirt getting into them. Hard particles, such as sand crystals, can very quickly stop a bearing working properly. Suggest reasons why.
- Most bearings have a shaped casing that holds each steel ball bearing in a particular position. Why do you think this is so?

Not all ball bearings are made from steel. Some are made using acrylic or ceramic casings and balls.

- If you investigated ceramic or acrylic bearings instead of steel, how much difference might you notice in the results?
- List some advantages and disadvantages that acrylic or ceramic ball bearings would have compared with steel ball bearings.

Ball bearings are probably the most common type of bearing, but there are others.

- Find out about some other types of bearings and where they might be used.
- Find out about some unusual places where bearings are used. Hold a class vote to decide which of the uses is the most unusual.

HEALTH AND SAFETY

A risk assessment must be made before starting any practical work. Ensure students are aware of the risk from ball bearings dropped on the floor. They should both pick up any dropped steel balls immediately and be on the look-out for dropped steel balls on the floor if they need to move around the laboratory. Also look for spilled lubricant: wipe up immediately.

THE INVESTIGATION

At 11-14, students will probably have looked at numerous examples of situations where friction is either a nuisance or useful. They will also have an intuitive feel for the fact that things roll more easily than they slide – though they may well never have expressed this for themselves. A ball bearing is an example of it being easier to roll things than to slide them.

Attempting to demonstrate that it requires less force to make something roll than to make it slide is difficult because of the difficulties of keeping all other factors - such as the area of the object in contact with the surface – constant. It may be better to stick to highlighting students' everyday experience, such as the use of wheeled trolleys rather than sledges, or round objects rolling down slopes when other shaped objects don't.

The website http://en.wikipedia.org/wiki/Bearing_%28mechanical%29 is a good, but relatively complicated, starting point for finding out more about bearings. It also has an animation showing the movement of the steel balls within the casing while the bearing is in use. The site http://science.howstuffworks.com/bearing.htm is a more accessible site with plenty of information about different types of bearings and their uses.

Students make their own bearing because this way it is possible to vary the construction of the bearing. Purchased bearings come as sealed units - designed for optimum performance and protected from dirt – but which are usually extremely difficult to dismantle. They also often have a shaped casing over the steel balls, holding each ball in an exact position relative to the others. If it is possible to show this to students after they have completed their investigation, they should be able to explain it, in the light of what they find out.

RESULTS

Without lubrication, students can expect the ball bearing to rotate for up to a couple of complete revolutions after they stop turning it. At first sight, this does not seem very far but can be put in context by comparing it with how far the 'bearing' will rotate without any ball bearings in it! Students will also find a clearly measurable difference between the amount of rotation with different numbers of steel ball bearings. They will find that the optimum number of steel ball bearings is two or three less than the maximum number the casing can hold. Measurements become progressively and rapidly harder to obtain when the number of steel ball bearings falls below half the maximum number the casing can hold, due to the bearing becoming unstable.

SUGGESTED SEQUENCE

This investigation needs a minimum group size of three: one student is needed to turn the bearing, one to count or tap, using a stopwatch or metronome to check the counting is accurate, and one to observe and measure the amount of rotation. The evaluation and follow up questions can be done either in the same groups as the investigation, in larger groups, or even as whole class activities.

Time required

This is not a long or complicated investigation. You can reasonably expect students to complete it during a single, standard practical session. On the Internet, there is a lot of readily accessible information about different bearings, how they work and what they are used for, so you may wish students to spend more time on this.

Plenary activity

Ask students to imagine they are to design a roundabout for a children's play area. The most basic design consists of a 'seat' large enough for several people, rotating on either a central post or a central platform.

- Ask them to consider what types of bearings they could use, and where, in a basic design for a roundabout. Students may well come up with more than one answer here.
- Ask them to consider how they could use either bearings or springs, or both, to improve the basic design of a roundabout, to give a more exciting ride.

NOTES

The shaped metal lids must have a circular groove around the outer edge of a suitable size to hold steel ball bearings securely – the lids from 907 g tins of *Golden Syrup* are ideal for use with steel balls of approximately 15 mm diameter. Different sized steel ball bearings would require different shaped lids, but the 15 mm diameter steel ball bearings have the advantage of being easy to handle and easy to find if dropped, whilst still being small enough that enough of them can fit in the bearing assembly to give a reasonable range of results.

The lower of the two lids needs to be firmly held in place so that it will not move when the top lid is turned. This can be achieved by screwing or nailing it to a block of wood, for example. A mass placed on the top lid will keep the bearing stable – so the top lid does not tip or slide sideways when the bearing is turned. For the bearing described, a mass of between 200 g and 500 g is suitable – 500 g has been recommended as this is more likely to be available as a single mass. If you do not have a 500 g slotted mass, then the necessary mass can be made by fastening together smaller masses. It is important that the mass stays in a central position on the top lid and does not move whilst the bearing is being rotated.

The method described for turning the ball bearing assembly is adequate for producing results accurate enough to show up differences between using different numbers of steel ball bearings and different lubricants. It has been recommended here because it is much easier to achieve than, for example, using a motor to turn the ball bearing assembly. You may wish students to discuss or try out different methods of rotating the ball bearing at a constant rate – ensure they consider why this is important.

TECHNICIAN EQUIPMENT LIST

per group

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- stopwatch or metronome
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- lubricants such as water, different oils and graphite powder (optional)