Activity E3
Investigating moments: the disc balance: teacher and trainer notes

This exploratory activity enables learners to discover for themselves the importance of the perpendicular distance in moments. It is presented as a whole class discussion but can easily be adapted for small group work.

In whole class discussions, the teacher or trainer must make particular effort to use monitoring strategies that require everyone's participation. For example, the use of mini-whiteboards ensures all learners respond to the tasks or questions.

This activity could be adapted and used in a range of engineering contexts, such as a motor vehicle, to demonstrate the concept of static wheel balancing.

Learning objectives

Learners should be able to:

- understand that a force can produce a turning effect
- identify the perpendicular distance and explain its significance.

Materials required

- unwanted disc
- graph paper
- cork to fit in centre of disc, with a hole drilled **accurately** through its centre
- second, larger cork for clamping
- large pin (or thin rod)
- learner dry-wipe mini-whiteboards (not essential)
- stand and clamp
- four pairs of cylindrical button magnets (provided in the resources pack).

Strong magnets are available from a number of suppliers via the internet. Typing 'super magnets' into a search engine will give a number of options. High strength NdFeB magnets were used in the pilots.

In the pilots, some centres made spigots to replace the cork and thin rod, or used a centre bearing.

- example session plan from CD ROM *Resources*.

Time needed

About 15 to 20 minutes for the whole class discussion.

Starting points

Learners would probably have been introduced to moments as part of GCSE Science. This activity does not require them to be able to recall this knowledge. Learners may be more familiar with the term ‘torque’ and this would present a good route in to introducing new technical terminology and concepts.

Preparation

This resource takes about 15 minutes to construct for the first time and then can be reused.

Refer to Figures E3.1 to E3.3.

1. Draw vertical and horizontal axes on the graph paper, and stick a pin through the origin.
2. Glue the graph paper onto the disc ensuring the pin is in the middle of the hole.
3. Mark four points on the graph paper, W, X, Y and Z, as shown on the diagram.
4. Remove the pin and push the cork through the hole in the centre of the disc.
5. Pass a pin or thin rod through the central hole in the cork so that the disc will rotate freely.
6. Push the pin into the larger second cork that can then be clamped, taking care that the disc is vertical and not tilted.

Pilot centres found that they needed to be resourceful when building the equipment; for example, the disc must rotate freely and may need adjustment. Some centres found that larger discs and magnets made measurements easier as the movement was greater.

The axes labelled A–B and E–F referred to in the tutor's text should be omitted from the disc to avoid confusing the learners.

Fig. E3.1

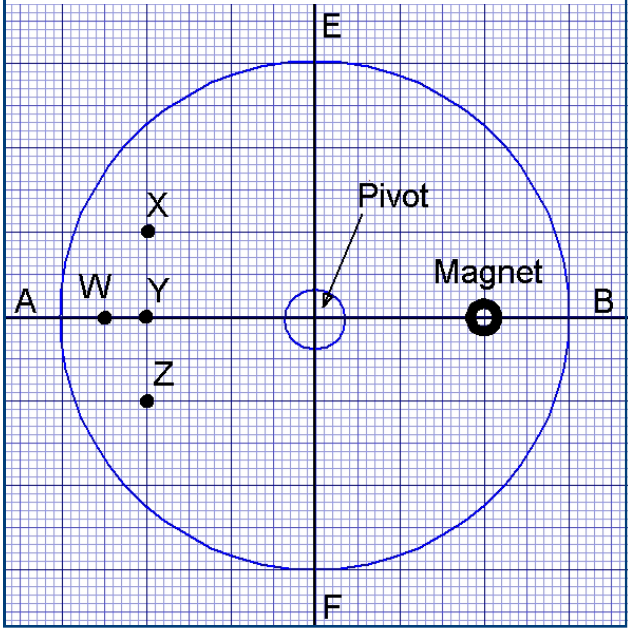


Fig. E3.2

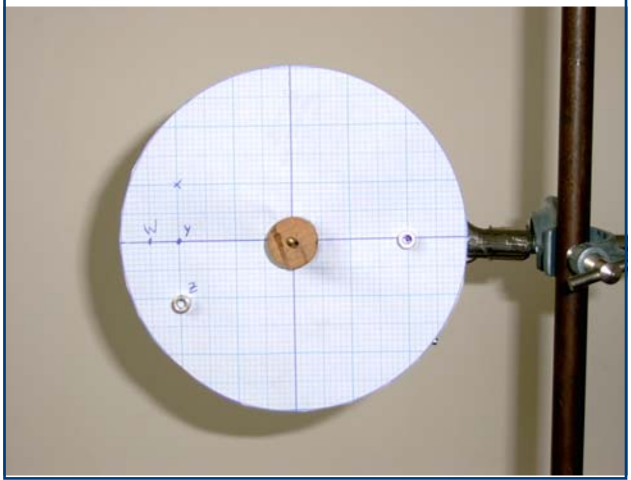
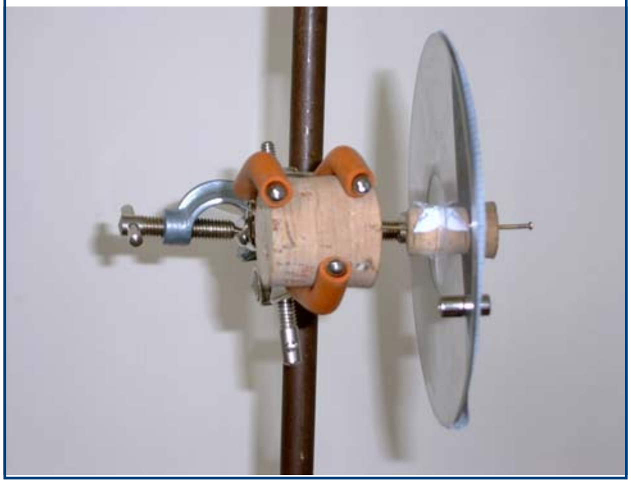


Fig. E3.3



Suggested approach

This activity involves whole class discussions to consider the effect of moments. Discussion forms an important part of "whole class interactive teaching" or "direct instruction", which Hattie[1] has shown to have a significant impact on learning when it is carried out well. This requires a variety of approaches to teaching and learning in theory sessions.

[1] Hattie, J. (2001) *Influences on Student Learning* (www.arts.auckland.ac.nz/staff/ index.cfm?P=5049)

In whole class interactive teaching the challenge to teachers and trainers is to intersperse input with learner interaction, hands on exploratory practise and feedback in order to monitor learning and check understanding. You are in 'control' of direct instruction but learners must be involved in making sense of their ideas and practising their skills through activities and discussion, preferably in small groups. This activity provides a good vehicle for group work and discussion.

Why use a disc?

This activity is to help learners appreciate and understand the role played by the perpendicular distance between the line of action of the force and the pivot, as shown in Figures E3.1 to E3.3.

By placing the magnets in three different positions all the same perpendicular distance from the pivot, learners conclude for themselves that it is the perpendicular distance between the magnet and the pivot that is important, without the need to involve angles and trigonometry. Alternatively, a large wheel or disc could be used, clamping weights to it. Demonstrating this point is not possible with a 'typical' uniform beam.

Beginning the session

To assess learners' prior understanding, ask them to think of some examples of where a force causes a turning effect. Language can be ambiguous and you will want some specific answers from this exploratory activity. There is an interesting example on the DVD CPD Case studies *Revealing and developing understanding: Moments* of what happens when learners misunderstand terminology. You may at this point need to step back to check language use or deepen understanding of fundamental concepts.

Phrase your questions carefully and use language that will give you the information you need. For example:

> "Think of some examples of where force causes a turning effect."
>
> "I'd like you to describe how you're applying the force."
>
> "Where is the rotation coming from?"
>
> "Where is the centre of the rotation?"

It could be useful here to have some physical 'props', other than spanners, for learners to handle to clarify their thoughts. After a few minutes' thinking time, ask the learners to write their ideas on their mini-whiteboards and to hold them up to show you.

Allowing thinking time is always important when you use any questioning technique as it helps learners to register the question and to recall relevant knowledge. It ensures that all learners have a chance to join in. Allow them writing time as well before showing the boards all together.

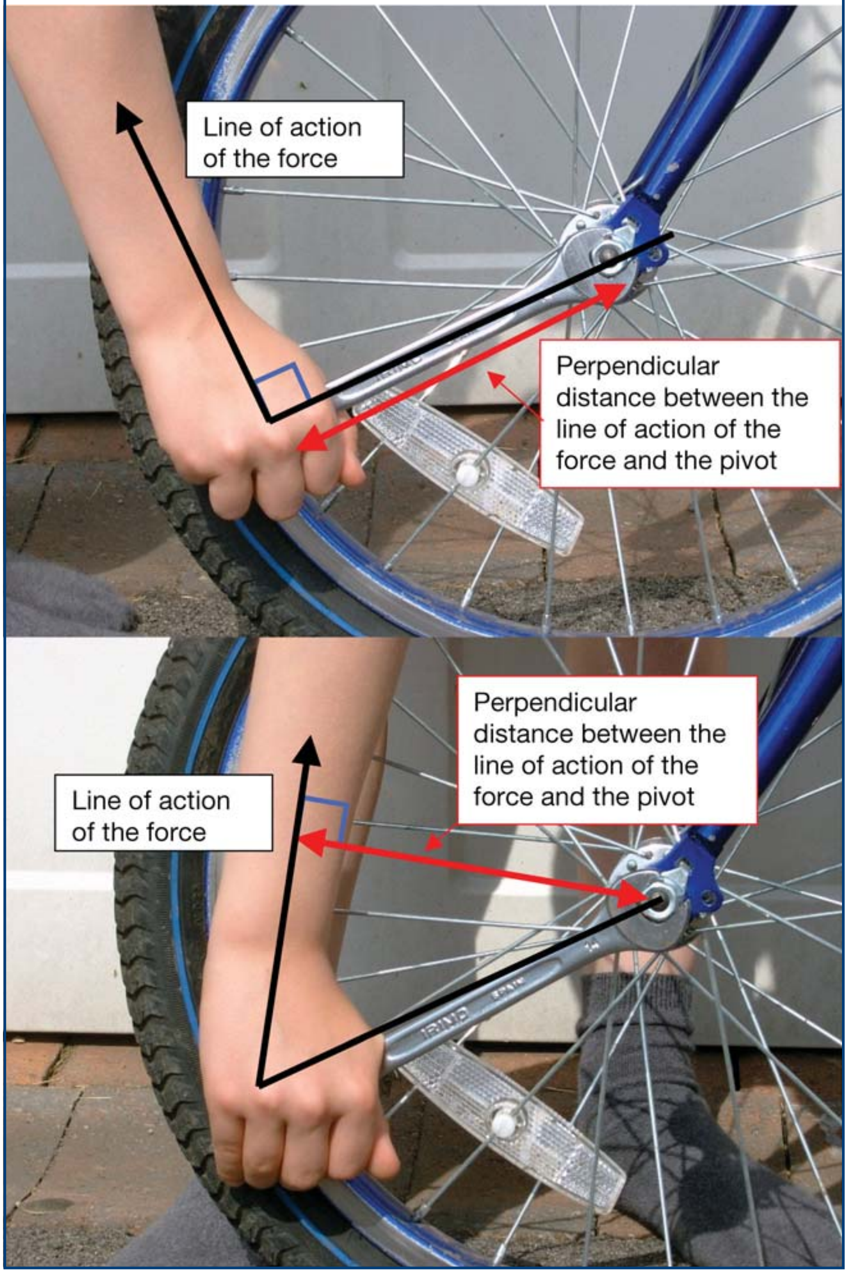
Mini-whiteboards are useful as you get instant feedback on what learners know and they can work at their own level without being put 'on the spot'. This technique is often referred to as 'show me…'.

Record some of the examples on the class whiteboard or flip chart and ask learners if they would like to comment on or try to explain any of the examples. Refer back to the learning objectives for the activity and explain that the challenge now is to use the activity to try to explain the examples on the board.

Learners may be more familiar with the term 'torque' in engineering. To introduce the terminology of moments and to relate it to learners' current understanding, perhaps from real life, this is a good point to explain and introduce the use of technical language in different contexts, engineering and science.

A moment is defined as a force multiplied by the perpendicular distance between the line of action of the force and the pivot.

Fig. E3.4



For the **same** force, the moment will be less as the perpendicular distance has decreased.

Introducing the disc balance

Show the group the disc without any magnets on it.

With the A–B axis horizontal, place a pair of magnets (one either side of the disc) on the horizontal axis 40 mm to the right of the pivot (use the hole in the magnet to position it accurately on the graph paper). Show the learners that this causes the disc to rotate and settle with the magnets directly below the pivot.

Discussion 1:
What is happening? Why?

Now hold the disc with the A–B line horizontal. Ask the group to work in pairs and put in order of preference where a pair of magnets should be added to the left hand side of the pivot in order for the line A–B to remain horizontal. Their response could be written on a mini-whiteboard and then held up. As you accept learners' suggestions, ask them to say why they have chosen the points.

Now place the magnets at each position in turn and observe the effect, so that the learners can assess whether their predictions were correct. Demonstrate clearly that while position W will not produce an equal moment, any position on the line X–Z will produce an equal moment as the perpendicular distance between the magnet and the pivot is equal to that on the right hand side (40mm).

Equal moment means that 'the anticlockwise turning effect is equal to the clockwise turning effect', which means that the object is balanced.

Discussion 2:
What is happening? Why?

Place a double pair of magnets on the line A–B, 20 mm from the origin on the right of the pivot. Ask the group where they would place a single pair of magnets on the left hand side of the pivot for the line A–B to remain horizontal. Again, the learners could answer with a single letter on their whiteboards to ensure that everyone participates. Ask for explanations as you check their responses.

Try out the positions X, Y and Z, demonstrating them to be correct. Then ask the learners why position W must therefore be incorrect, before confirming this by placing the magnets at this position.

Consolidating and checking learning

Ask the learners to draw a horizontal beam on their mini-whiteboards and mark on it the pivot in the centre. Then ask them to draw a weight W, to the right of the pivot hanging on the beam. Next ask them to draw on the left hand side of the pivot the place where a weight 2W would need to be hung in order for the beam to balance.

Once the correct point on the left has been established by all the learners (that is, half the distance between the weight on the right hand side and the pivot), ask them to rub out the hanging weight on the left hand side and add the same value weight back onto the left hand side but in a different place, again so that the beam will balance. Here the learners would be expected to draw the weight resting on top of the beam, although any position on that vertical line would be correct. This demonstrates that they have appreciated the idea of the perpendicular distance.

The whiteboard responses may show misunderstandings. Select one response that is correct and at least one that is incorrect. Copy them onto the whiteboard without revealing the sources. Ask learners to work in pairs or small groups to 'test' each diagram and to explain which are correct and which are incorrect and why. Use assertive questioning to review the explanations from the pairs or groups until you are sure that everyone understands the concept and can explain it in their own words.

Your learners might now find it interesting and relevant to revisit the examples on the class whiteboard or flip chart of where a force causes a turning effect. They could use their new understanding to attempt explanations and implications relating to real life. This could form a summative assessment task.

What learners might do next

Learners could make their own sets of the apparatus and further investigate how the position of the magnets affects the rest position, leading to discussions on the centre of mass.

On a motor vehicle programme, you might stress that the activity has considered static wheel balancing. This could open up an interesting discussion about why dynamic wheel balancing is required.

Learners might place one pair of magnets in four different positions on the right hand side of the axis E–F. For each location balance the disc with the E–F axis vertical by moving two pairs of magnets around on the left hand side of the axis E–F. Write down the horizontal distance of each set of magnets from the vertical axis. Construct a suitable table to enable the clockwise and anti-clockwise moments to be calculated. Take a single pair of magnets to have a weight W, and a double pair to have a weight 2W. This table would verify that for equilibrium the clockwise moments equal the anticlockwise moments.

To further extend the activity for advanced learners, the above could be repeated with the magnets placed so that the A–B line is not horizontal when the disc is at rest. The learner would need to draw onto the graph paper the perpendicular distance between the magnet and the pivot and measure it using a ruler, before calculating the moment.