TUNNELWORKS
KS3 SCIENCE LESSON 2 (ESSENTIALS)
TEACHERS' NOTES

About this lesson

This lesson explores the turning moment created when a force acts about a pivot, using the forces on a crane that come from the load and the counterweight. Students consider how the counterweight can balance different loads at different distances from the centre of the crane.

Learning outcomes

Students can:
- Describe a turning moment as the force acting about a pivot.
- Calculate turning moments using the correct units.
- Solve simple problems to find the turning moment, force or distance from the pivot.

Curriculum links

KS3 Science

• Key concepts	1.1a; 1.2a
• Key processes	2.3a
• Range and content	3.1b, 3.4c

What you will need

- KS3 Science Lesson 2 presentation
- Lesson 2 worksheet

Students are likely to need calculators for the worksheet challenges.

Preparation

Review the KS3 Science Lesson 2 presentation and its presenter's notes, and the student worksheet. Decide on which content you will include in your teaching, and adjust the timings below to suit your own lesson length, or to spread the content across two lessons.

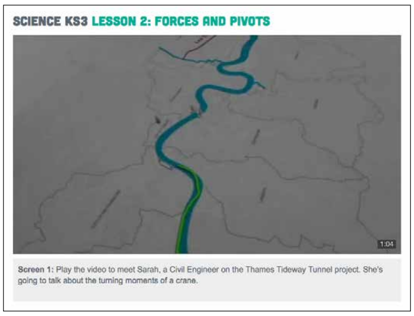
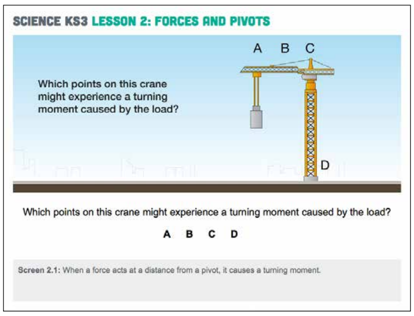
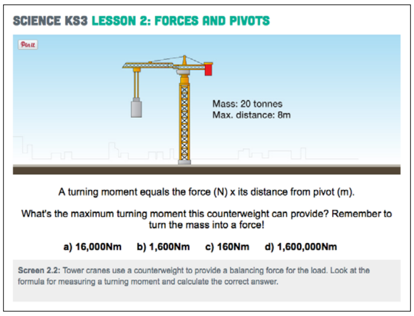
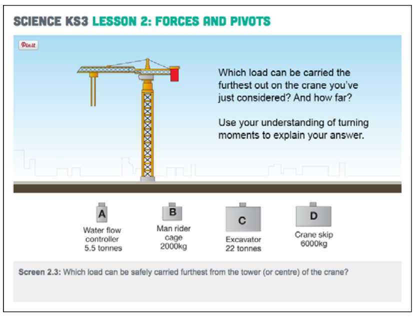
Think of other examples you may wish to use to explore turning moments, such as a lever, see-saw, wheelbarrow and spanner.

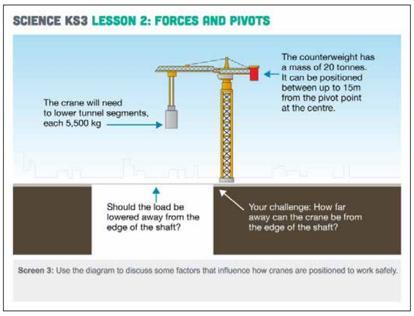
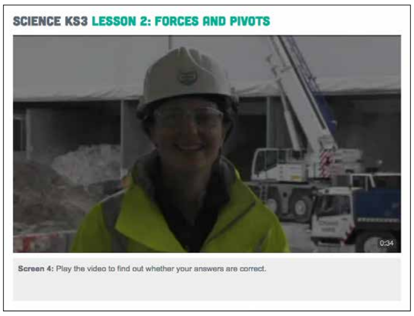
Time (60mins)	Teaching activity	Learning activity	Assessment for learning
5 mins	**Starter:** Use the example of a simple lever to introduce the concept of a force acting at a distance from a pivot.	Students work in pairs or groups to identify as many other examples of levers as they can think of, and share as a class.	Verbal answers, discussion, questioning.
15 mins	**Whole-class:** Optional: Show the intro video and explore the map and site in screens 1.1 and 1.2 of Lesson 1 if you wish. Watch the video in screen 1 and find out what students must do. Work through the interactive in screens 2.1 to 2.3 and answer each question.	Students discuss why the forces on the crane must be balanced about its pivot point at the top. Answer on-screen questions.	Discussion. Verbal answers.
15 mins	**Individuals or pairs:** Read the engineer's note on the worksheet and the first two questions. Students complete challenge 1 on the worksheet, remembering to convert each kg of mass into 10N of force.	Students answer top two questions on worksheet. Discuss as a class. Linking stability to load distance from centre. Students complete the safety table for the crane, remembering that the centre columns (turning moments) must be identical in each row so they can complete both sides.	Discussion, verbal answers. Written work.
20 mins	**Plenary:** Review students' answers and explore the clickable diagram on screen 3. Students complete challenge 2. Watch the answers video on screen 4.	Students work out how far the crane can be from the edge of the shaft, drawing a diagram to help themselves.	Discussion, written work.

Differentiation

Easier	Harder
Explore the example line in the table as a whole class. Write the formula for a moment on the board as a triangle and show how to transpose to find force or distance. Write on the board that the turning moments need to match. Omit challenge 2.	Use challenge 2 while less able students complete challenge 1. Use the ideas in Dig Deeper. Explore (qualitatively) the forces and turning moments on other large and small machines on a construction site, for example: Concrete mixer and load Wheelbarrow Challenge students to consider and add in the forces on the crane from the weight of the load-bearing arm and counterweight arm. If the load arm weighs 15 tonnes and the counterweight arm 10 tonnes, how does this change the answer to challenge 3?

Presentation Notes
Lesson 2

Screen	Notes
1 	Show this short video clip to introduce the challenges in KS3 Science Lesson 2. If you need to set the scene again, quickly show the main introduction video and explore the site map from KS3 Science Lesson 1, as well.
2.1  2.2  2.3 	This simplified diagram introduces turning moments in the context of a tower crane. The crane will experience turning moments about points C and D. For the rest of this exercise the moment about D will be ignored. Assuming that the load hanging from A is the only force acting on the system, what do students think about the result of this? (The force is unbalanced and so will create acceleration. That is, the crane will turn about point C and will fall!) Ensure students are clear that from now on, they must remember the idea of balanced forces in order to solve any problems about the turning moments on the crane. The turning moment is the force x the distance through which it acts around the pivot. Remind students that gravity creates a force of 10N for every kg mass. Here, this force is 20,000kg x 10 = 200,000 N and so the moment is 200,000 x 8 = 1,600,000 Nm (Newton metres) Discuss the idea that the counterweight can change position, moving closer or further away from the centre of the crane. How can this help the crane when it must move loads of different masses? Remember that the counterweight has a mass of 20 tonnes and can be up to 8m from the centre. Calculate each load to see which one is correct. B (the man rider cage, in which people can be lifted in and out of the shaft) can be carried up to 80m from the centre of the crane! This is about as far as a large tower crane can normally reach. C, the excavator, can be held the least far from the centre, just 7.3m.

Screen	Notes
3 	Explore this diagram to help students plan how they will solve the problem in KS3 science lesson 2, and how they will use the information they are given.
4 	Use this video to provide feedback and the answers to the problems at the end of KS3 Science Lesson 2.

TUNNELWORKS
KS3 MATHS
DIG DEEPER

Pressure and forces

Many cranes and other site equipment use hydraulic systems. Challenge students to think about the pressure and forces within a simple system like this, where cylinder A is moved to create movement in cylinder B.

Cross-sectional area in A = 0.3m² **Cross-sectional area in B = 0.6m²**

Start by exploring qualitatively: if the area is 3x larger, what will the force be?

Given that the pressure P must be the same throughout, can students work out the force acting on cylinder B when cylinder A is pressed with a force of 100N using the equation for pressure, where PA (pressure in cylinder A) = PB (pressure in cylinder B)?

e.g. $$\frac{100\text{N}}{0.3} = \frac{?}{0.9}$$

Discuss the idea of a hydraulic system as a force multiplier and compare this to a lever. Why are hydraulic systems so useful for heavy engineering and site work?

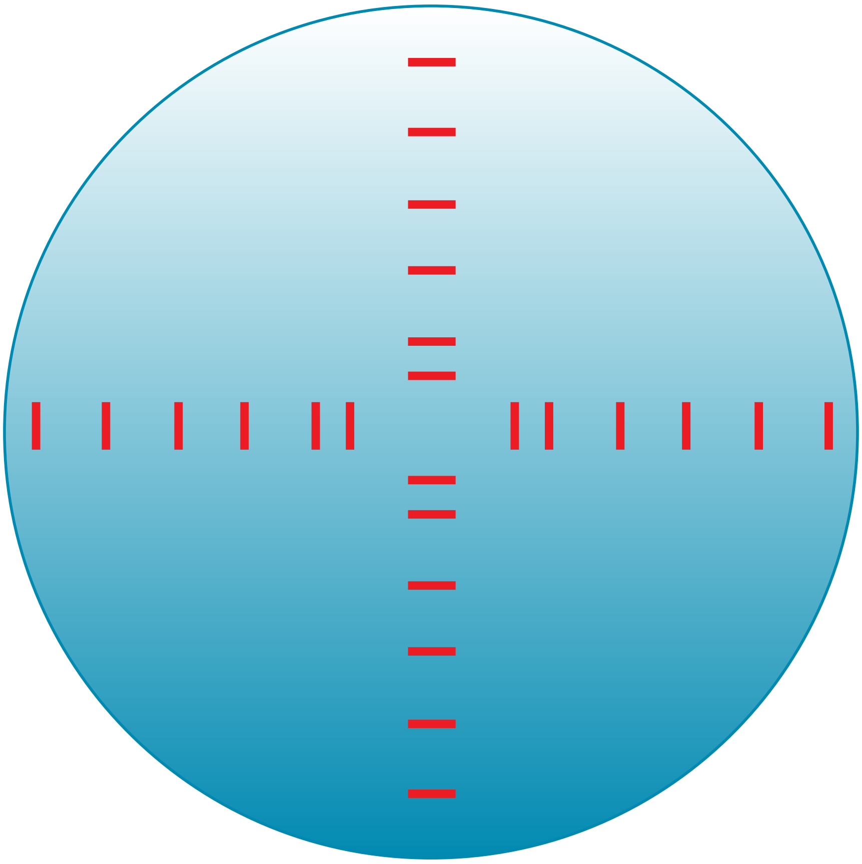
Site equipment, like lorries, has disc brakes for stopping. Can students explain why the driver can stop a heavy piece of site machinery by just pressing his or her foot?

Older and more able students (e.g. if you choose to use this with KS4) could also consider this in terms of the work done as each force moves through a distance (the larger cylinder can exert much more force, but moves through less distance because assuming no losses from friction, the same work is done). Discuss why in the example above, the distance travelled by the driver's foot may be 15 – 20cm while the distance travelled by the brake pads is just a cm or so.

Turning moments

The Tunnel Boring Machine uses a rotating cutting head to break through rocks in the ground. This cutting head is covered in a series of cutters that break off bits of soil as they rotate. How powerful do cutting head motors need to be?

Challenge students to think about the cutter head below. This has four rows of six cutter heads:



In each row, the cutter heads are the following distances from the centre:

0.5m, 1.0m, 1.5m, 2.5m, 3.5m, 4m

To break through the chalk, each cutter head must act with a force of at least 35,000 N.

The torque of the motor (measured in Nm) is the total turning moment that it can produce. Using the information above, and assuming that the TBM is 100% efficient, how much torque does the motor need so every cutter head can act with at least the minimum force to break through the chalk? (Assume each one provides 35,000N)

This ignores the torque needed to rotate the cuter head itself (eg due to its mass) – can students spot this omission?

Simplify this task by considering fewer cutter heads, eg just those at 6.5 and 8m.