TUNNELWORKS
KS4 SCIENCE LESSON 3 (ESSENTIALS)
TEACHERS' NOTES

About this lesson

In this lesson students consider a crane and load to review and apply their understanding of energy changes, forces, work and power. Students review their understanding of key terms before identifying the energy forms and transformations as the crane lifts a load. By identifying the forces acting on the load and the distance it moves up the shaft, students build an equation for the work done to raise the load. Students then complete a table to calculate the work done to lift different loads and can transpose the work equation to find distances and masses moved. In the plenary, students explore power by considering the time taken to raise each load.

Learning outcomes

Students can:

- Identify energy forms and transformations as a load is raised, and the balanced forces acting on the load
- Use the equation for work done to solve simple problems
- Use the equation for power to solve simple problems

Curriculum links

KS4 Science

- Physics: Forces, energy transformations, work and power

What you will need

- KS4 Science shafts lesson three presentation
- Lesson three worksheet

Preparation

Review the lesson plan below and the KS4 Science shafts lesson three presentation. Adapt the content to suit your students' ability.

Time (60mins)	Teaching activity	Learning activity	Assessment for learning
5 mins	**Starter:** Ask students to list forms of energy and energy transformations that might be found on a busy construction site. **Whole-class:** Share ideas. If you wish, create a list on your board.	In pairs, students list forms of energy. They identify possible energy transformations, listing the 'before' and 'after' form and the process or activity behind each transformation. Students share their ideas.	Discussion, questioning. Suggestions.
5 mins	Watch the project intro video on the Tunnelworks KS4 Science landing page if required, and then the cranes video clip on **screen 1**.		
5 mins	**Pairs:** Review the crane diagram on the student worksheet and show **screen 2a**. Ask students to work in pairs and identify the energy forms at each stage as the skip is lifted from the base of the shaft to the surface. **Whole class:** Share ideas and click to reveal the labels on **screen 2b**.	Students write forms of energy in the left-hand boxes on the diagram. Students share their ideas.	Written work.
10 mins	**Pairs:** Show **screen 3a**. Ask students to look again at the diagram. If the skip is at rest or moving upwards at constant speed (i.e. there is no acceleration), what forces are acting on the skip, and what can students say about these forces? Ask students to draw arrows on the skip and label them with the name of each force.	Students identify the downwards force of gravity on the skip, and the upwards force from the cable from which it is suspended. These forces are balanced (they are of the same strength, but act in opposite directions).	Discussion, questions.
5 mins	**Whole class:** Ask students to identify the distance the skip moves, from the base of the shaft to the surface. Ask students to label this distance d.	Students describe distance **d** and can come to the front to indicate this on the slide.	Written work.

15 mins	Explain, if necessary, that work is done when a force moves. Discuss the work equation **w = fd** then click again to reveal the equation on **screen 3b**. Discuss the effect of gravity and help students identify that **f = mg**, where m is the mass of the loaded skip and g is the acceleration due to gravity. **Individuals:** Review task 3 and direct students to complete the table using the work equation. Remind students to convert the mass of each skip into a force, in Newtons. Review answers.	Students identify **w = fd** as the work equation. Students identify the distinction between the mass of the loaded skip in kg and the force acting on it, in Newtons. Students complete the table then share answers.	Discussion, questions. Written work.
15 mins	**Plenary:** Show **screen 4a**. Ask students if the skip rises instantaneously to the surface? Since this is not the case, what can students suggest about a crane that can raise a load faster than one that can raise the same load more slowly? Introduce the idea that power is the rate at which energy is used or transformed (or created). Review the power equation and click to reveal on **screen 4b**. Ask students to complete the table and identify which crane has the most power to raise a load.	Students identify that a crane with more power can raise an identical load more quickly than one of lower power. Students complete the table then share answers.	Discussion, questions. Written work.

Differentiation

Easier	Harder
Energy forms: provide example forms or energy and ask students to name an activity or process that transforms one form into another. Task 3: Students complete A – C. You may wish to omit task 4 or complete one row as a worked class example.	Energy forms: ask students to identify the energy forms and transformations in the crane itself, including any 'lost' energy that is not converted into useful forms. Task 3: Students complete A – E. Task 4: Students complete A – E.

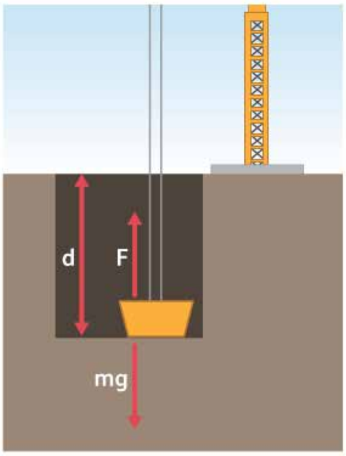
Answers

Answers - Tasks 1 & 2

At the surface:
Gravitational Potential Energy (GPE) (More)

Whilst moving:
GPE + Kinetic Energy

At the bottom:
GPE (Less)



Label the diagram to show the force on the skip and the work done.

The equation for work done is:

$$W = F \times d$$

Answers - Task 3

Location	Shaft depth (m)	Skip mass (kg)	Work done (J)
A	10	5,000	500,000
B	15	4,000	600,000
C	25	3,500	875,000
D	22	4,000	880,000
E	18	5,500	990,000

Answers - Task 4

Location	Time (s)	Power (W)
A	30	16,667
B	40	15,000
C	44	19,886
D	50	17,500
E	45	22,000

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DIG DEEPER

Efficiency
Explain to students that the crane motor is not 100% efficient. Using different values of efficiency, for example 50%, 40%, 30%, ask pupils to calculate the real power required to lift the load at the same rates as in the table for task 4.
e.g. a crane that is 50% efficient will need to have twice the actual power.

Total work done
Students can estimate and calculate the work done to remove all spoil (waste material) from a shaft. Use the following data and a shaft height and skip mass from the table for task 3.

Shaft diameter: 12m

Waste density: 2.6 tonnes (2600kg) per cubic metre

Ask students to 'deconstruct' the shaft into a series of 1m deep sections of shaft, one on top of the other like a pile of coins, each one a cylinder. Students will first need to calculate the volume and therefore mass of a metre-deep cylinder of shaft spoil. Help students identify that they need to raise each cylinder of spoil a different height and will need to calculate how many skips are needed for one cylinder. Ignore the mass of the skip itself, or tell more able students the skip has a mass of 500kg. Remember to use g = 10 and convert from kg to N.

Work done to climb the stairs
If your school has stairs, ask students to calculate the total rise (students could measure the rise for one stair and count the number of stairs, for example). For a sample student of mass 70kg, what work must they do each time they climb these stairs? A digestive biscuit contains about 300kJ (300,000J) energy. How many times can this person climb the stairs using the energy from one digestive? What fraction or percentage of a digestive do they need to provide the energy to climb these stairs once? (Assume they are 100% efficient and remember to use g = 10 and convert from kg to N.)

Model cranes – forces, pressure and turning moments
Students can use syringes, plastic tubing and construction kits like Lego or K'nex to make a simple hydraulic crane or excavator. Students can consider how pistons of different diameters can act as force multipliers, applying their understanding of pressure and force. They can change the distance of one syringe (piston) from the pivot to explore turning moments at a joint, and substitute syringes of different diameters to find out how the force can be increased or decreased. Students can link these changes to the different distances the piston in the syringe moves in each case. Can students identify that the work done in each case is the same, because a large force moves a smaller distance, and vice versa?

Students could also construct a model tower crane and explore how to counterbalance different loads at different lift radii. Some students could develop a simple motor system to rotate the crane, raise and lower the load and move the load closer to or away from the central tower and along the arm.