Canal & River Trust STEM

Canal Crane

Canal Crane Activity Pack

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1. Overview

Historically, our waterways have been used to carry coal, food, steel and other heavy items all over the UK. Engineers have used gear systems to enable dock workers to load and unload heavy goods onto boats. In this activity, we examine the use of gears to provide mechanical advantage and demonstrate that the maths is the same for gears as it is for levers (or pulleys or any other form of mechanism).
There are still many historic canal cranes at wharves and basins all over the country. It may be possible for students to visit an original canal crane like the ones shown.

2. National Curriculum links

- Design and Technology – How mechanical systems enable changes in movement and force (mechanical advantage).
- Science – Mechanisms (gears), recognising that air and water resistance and friction have an effect.
- Maths - Substitution of values into a formula, converting units of measure.

3. Resources and materials

- Leader's activity notes for Canal Crane
- 6 x Gear Kits
- 6 x Crane Kits
- Supporting materials included in box:
    - Experiment Instructions
    - Laminated copy of experiment sheet

Developed with support from

Rolls-Royce

4. Lesson Plan

Learning objectives

- ALL pupils will be able to describe examples of mechanisms we use (in particular where they see gears in use).
- MOST pupils will recognise that some mechanisms allow a smaller force to have a greater effect and will calculate the gear ratio of their model crane (Mechanical Advantage).
- SOME pupils will understand how more advanced mechanical systems (engineering) enable changes in movement and force: Canal Crane – Leader's notes.

Activity objectives

- Explain the objectives of the lesson and the reason for those objectives.
- Identify the group's level of knowledge by showing slide 3 Revision: Asking questions related to mechanical advantage.

What is mechanical advantage?

If the students have already done this, revise mechanical advantage, otherwise skip to slide 5 (gear trains).

Establish that:
a. The work done on either side of the fulcrum is the same.

b. Work = Force x Distance.

c. Mechanical advantage

= Distance moved at the input / Distance moved at the output.

= Force applied at the output / Force applied at the input.

* SI stands for 'International System of Units'

What are the SI units of measure?

Establish that:
• The SI unit of work is the Joule (energy).
• The SI unit of weight is the Newton (force).

Revision: Fulcrum

Explain that levers quickly become too big as the force to be exerted increases.

Demonstration

Use a pre-assembled crane with 3:1 gearing to demonstrate. Lift a weight from the base to the top of the jib, counting the number of turns required.

Then swap the handle to lift without using gears. State that one handle is easier to turn and ask why?

The experiments

Introduce the 'measure the cogs experiment' (2). Allow about half the time for this experiment. Ask the students to experiment by turning the small, medium and large cog wheels. They can measure them and calculate the ratios of the gears - large:small

Confirm students have understood the instructions, and let them start the experiment.

Introduce the 'build a crane' experiment (2). Take a note of the time available, and allocate about half to the exercise. (20 minutes is ideal)

Confirm students have understood the instructions, and let them start the experiment. Check on their progress.

Discuss the results, using the following questions:

What did you find?
Establish that students correctly calculated the gear ratios and that they noticed:
- Turning the medium cog was easier but it took 3 times as many turns to lift the weight as the large cog needed.

What do you think this means?
Steer the discussion to reach the conclusions that:

- Gears are more compact than levers.
- Gears offer continuous motion.
- Mechanical advantage allows us to use a small force to exert a bigger force over a shorter distance.

The formula

NOTE: Some students may know the Joule is a derived unit. It is derived from the units metre (m) and Newton (N). 1J = 1N x 1m.

In this case you could extend knowledge by explaining that the Newton is also a derived unit, and by establishing:

- The formula for calculating force is FORCE = MASS x ACCELERATION
  The acceleration due to gravity is $9.81 m/s^2$.

5. Activity sheets

See Crane Assembly instruction activity sheets for experiment 1 and 2 on the following pages.

6. Background information

Why do this workshop?

Gears are a vital part of everyday life, but are usually hidden inside a box (such as a clock), or as part of a more extensive system (such as a bike). In this activity, we examine the use of gears to provide mechanical advantage and demonstrate that the maths is the same for gears as it is for levers (or pulleys or any other form of mechanism). We have mechanical cranes at the museum that can be used asexamples of the practical application of gears.

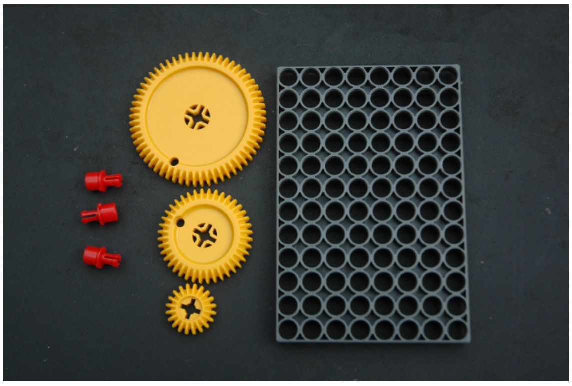
Gear Ratio Activity Sheet

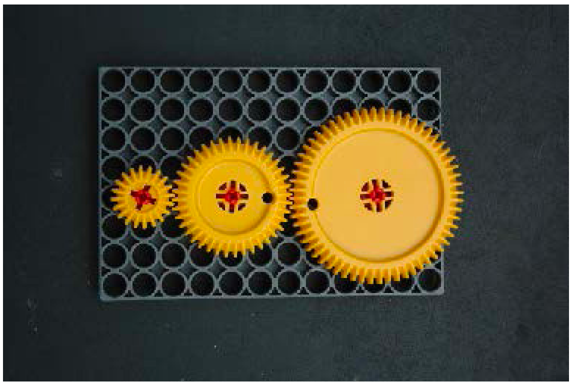
Gear Trains - Experiment 1

1. Collect a gear set.
2. Experiment by turning the medium sized and small cog wheels.
3. Add the large cog wheel.
4. Measure the circumference (in mm) of each gear by putting a piece of string around them or by counting the number of teeth.
5. Write down the number of turns of the small and medium cogs, to a full turn of the large cog.
6. Calculate the large:small, large:medium, medium:small gear ratios.

Cog	Circumference	Number of turns	Gears	Ratio
Large		One full turn	Small	
Medium			Large	
Small			Medium	

What else did you notice?





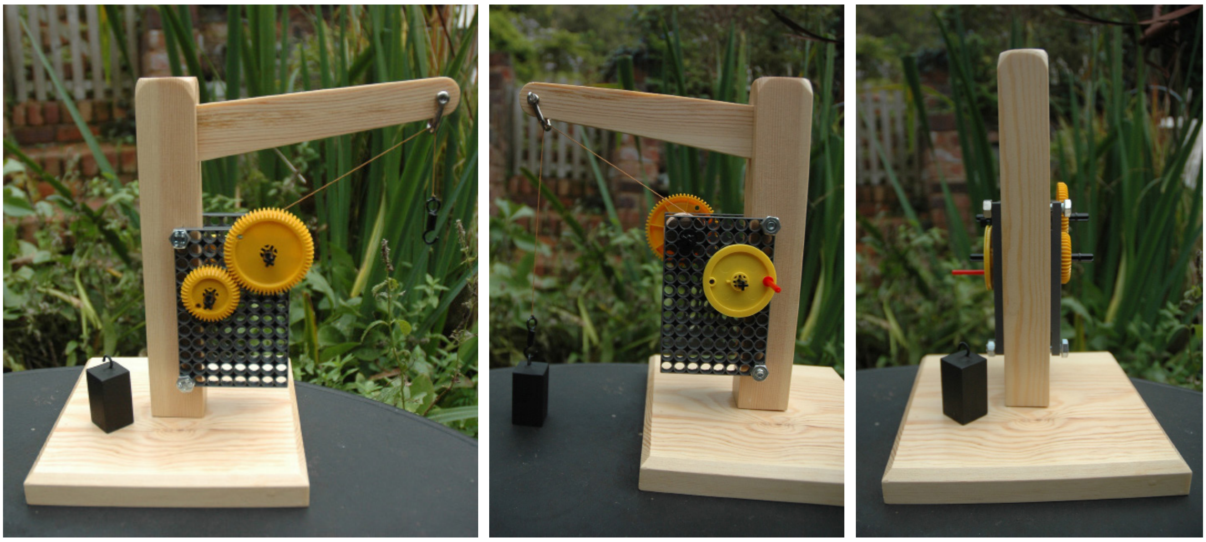
Parts for Experiment 1

Canal Crane

Gear Ratio Activity Sheet

Gear Trains - Experiment 2

Kit of parts to make your crane



Crane seen from sides

Canal Crane

Gear Ratio Activity Sheet

Gear Trains - Experiment 2

1. Collect a crane set and build your crane.
2. Feel the weight of an object to be lifted.
3. Experiment with different combinations of gears to see which will. give you the greatest mechanical advantage (ie: how easy can you make it to lift the object?).
4. Record your findings

Cog	Number of turns to lift object
Biggest cog on its own	
Biggest and smallest cog	

Why do we build a crane like this?

If the centre of gravity of your crane and load is not over the base, the crane will tip over. Real cranes are normally heavier than the load or attached to the ground (cantilevered) to prevent this. In the classroom, you can simulate this by holding the base down.