

Fundamental MECHANICS

Mechanism Fundamentals



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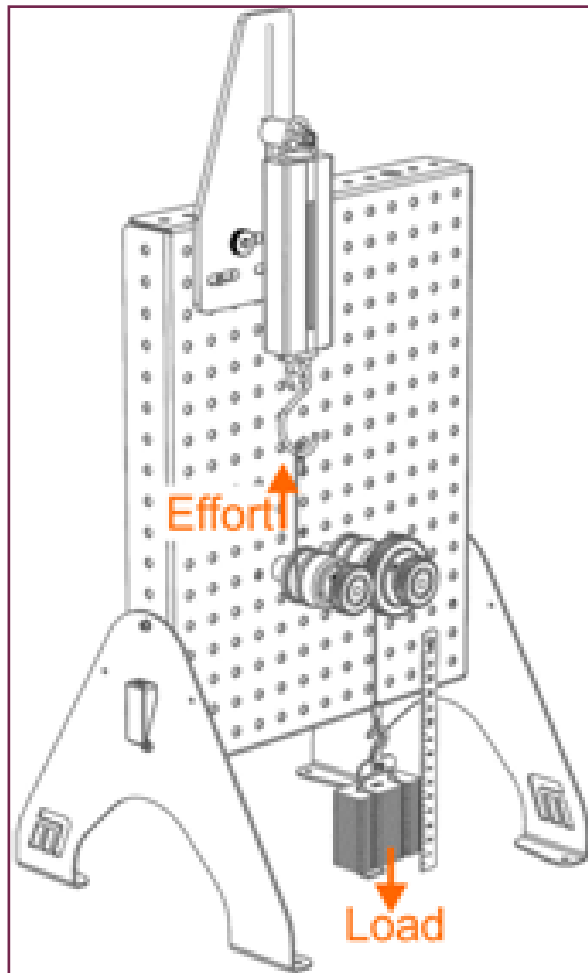
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Worksheet 1

Gear trains - spur gears

A gear train - a number of gear wheels meshed together - can be used:

- to make a shaft rotate faster, or slower, than the driving shaft;
- to lift heavy weights more easily;
- to change the direction of rotation of a shaft.



Worksheet 1

Gear trains - spur gears

System 1 - Simple gears

Over to you:

- Hang a 100g mass (1N weight) from the loop on the larger gear.
This is the **load** you are going to lift.
- Attach a force meter to the loop on the smaller gear to measure the applied **effort**.
- Slide the force meter upwards in the slot until the load starts to move up *at a steady speed*.
- In the table in the Student Handout, record the effort needed to achieve this.
- Next repeat the lift but this time measure how far the load rises, (**'distance moved by load'**) and how far the force meter moves, (**'distance moved by effort'**).
- Record these measurements in the table.
- Repeat this procedure for loads of 200g (2N) and 300g (3N).
- Complete the table by calculating the mechanical advantage, velocity ratio and efficiency for each value of load.

So what:

- Why is the efficiency less than 100%?
- Calculate the gear ratio for this arrangement.
- Compare your value of velocity ratio with this gear ratio.
Comment on the comparison.
- Write your answers in the spaces provided in the Student Handout.

Challenge!

Repeat the experiment using a system like system 1, but having a different gear ratio.
Comment on your findings in the Student Handout.

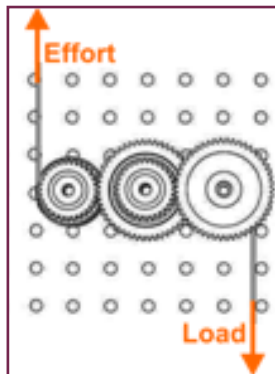
Worksheet 1

Gear trains - spur gears

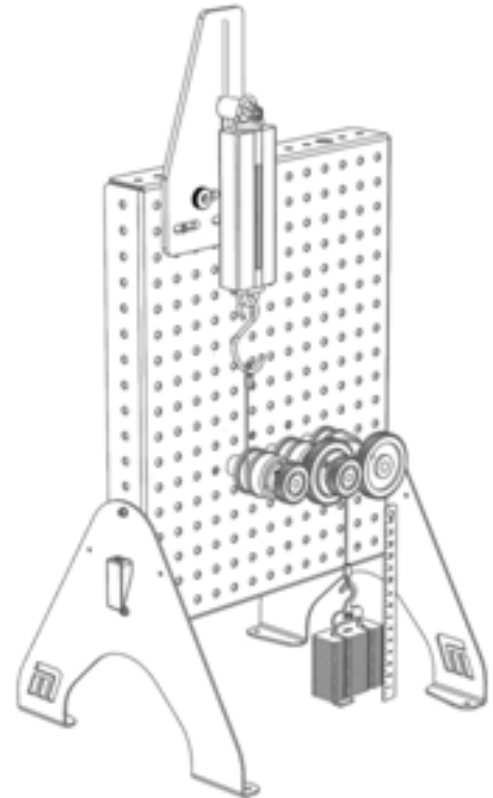
System 2 - Compound gears

The diagram on the right shows the arrangement for the second part of the investigation.

This system uses four spur gear wheels, two with 30 teeth and two with 50 teeth, meshed together as shown below.



As before, looped thread hangs from the winding drums to allow attachment of different loads and the force meter.



Over to you

- Using the same procedure as for system 1, measure the effort needed to lift a load of 3N at a steady speed and the distances that the load and effort move.
- Repeat this procedure for loads of 4N and then 5N.
- Record these measurements in the table.
- Complete the table by calculating the mechanical advantage, velocity ratio and efficiency for each value of load.

So what:

- Calculate the overall gear ratio for this arrangement.
- Explain why the efficiency of system 2 might be less than that for system 1.
- Write your answers in the spaces provided in the Student Handout.

Challenge!

Rearrange the gears to give the system a gear ratio of 9:25 and repeat the experiment. Comment on your findings in the Student Handout.

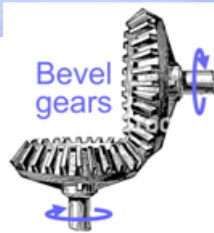
Worksheet 2

Changing the direction of rotation

Often, a gear train is used to change the direction of rotation of the drive shaft.

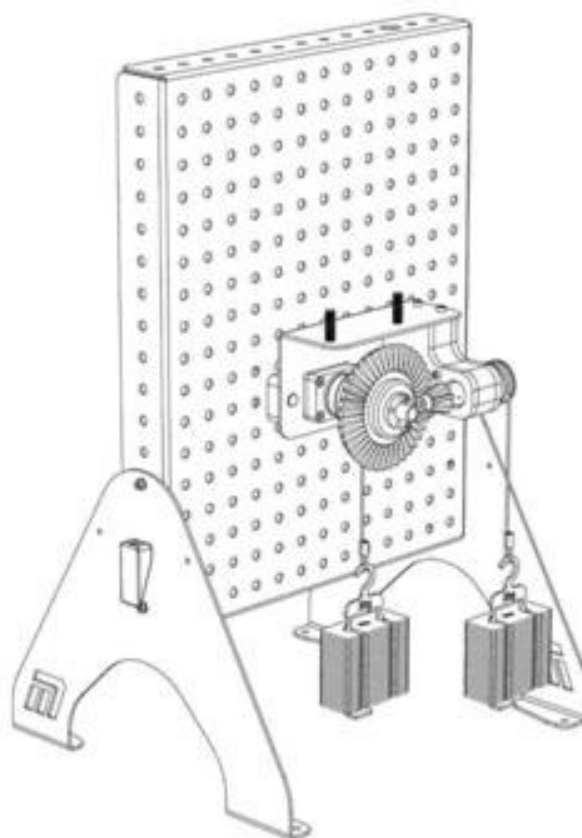


In a helicopter, the drive motor, main rotor and tail rotor all turn in different directions. The transmission gearbox conveys power to the rotors in the required directions.



Bevel gears and worm gears can be used to change the direction of rotation.

System 1 - Bevel gears

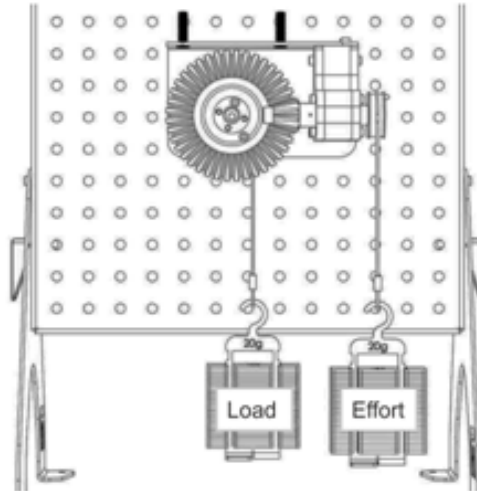


To make it easier to take measurements, this time the effort is applied using a second set of weights. Initially, the load is hung from the larger bevel gear and the effort is applied to the smaller gear. A detailed diagram of the arrangement is shown on the next page.

Worksheet 2

Changing the direction of rotation

System 1 - Bevel gears



Over to you:

- Hang a 100g mass (1N weight) as the load from the thread attached to the drum on the larger gear.
- Add more and more slotted masses to the 'effort' hanger, attached to the smaller gear, until the load starts to rise at a steady speed.
- In the table in the Student Handout, record this value of effort.
- Next repeat the lift but this time measure how far the load rises, (**'distance moved by load'**) and, correspondingly, how far the effort falls, (**'distance moved by effort'**.)
- Record these measurements in the table.
- Repeat this procedure for loads of 200g (2N) and 300g (3N).
- Complete the table by calculating the mechanical advantage, velocity ratio and efficiency for each value of load.
- Calculate the gear ratio for the system.

Challenge!

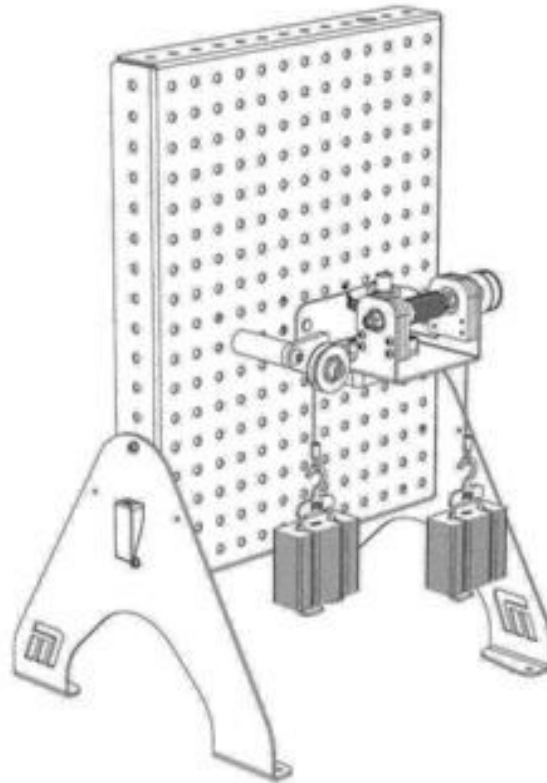
Now repeat the experiment but with the load hanging from the smaller gear and the effort applied to the larger one.

Describe your findings in the Student Handout.

Worksheet 2

Changing the direction of rotation

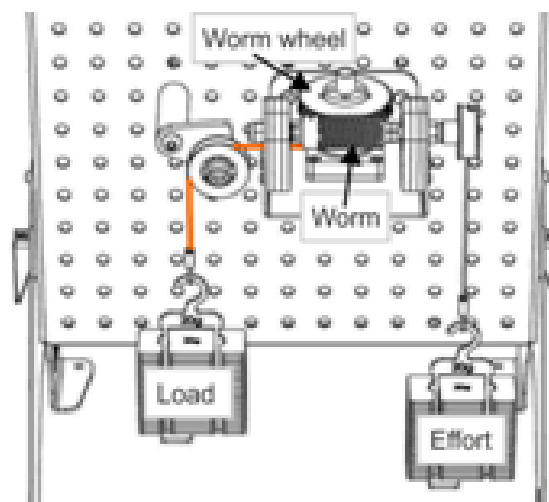
System 2 - Worm gears



Once again, to make it easier to take measurements, the effort is applied using a second set of weights.

The load is hung from the worm wheel and the effort is applied to the worm itself, as shown below.

The diagram also shows how the load is connected to the worm wheel (in orange.)



Worksheet 2

Changing the direction of rotation

System 2 - Worm gears

Over to you:

- Hang a 100g mass (1N weight) as the load from the worm wheel.
- Add more and more slotted masses to the 'effort' hanger, until the load starts to rise at a steady speed.
- In the table in the Student Handout, record this value of effort.
- Next repeat the experiment but this time take measurements that allow you to calculate the velocity ratio of the system. Record these measurements in the table.
- Repeat this procedure for loads of 200g (2N) and 300g (3N).
- Complete the table by calculating the mechanical advantage, velocity ratio and efficiency for each value of load.

So what:

- The worm wheel has 50 teeth.
- The worm itself is a multistart device with 4 'starts'.
- Calculate the overall gear ratio for this arrangement and write your answer in the Student Handout.

Challenge!

Comment on your findings in the Student Handout.

Worksheet 3

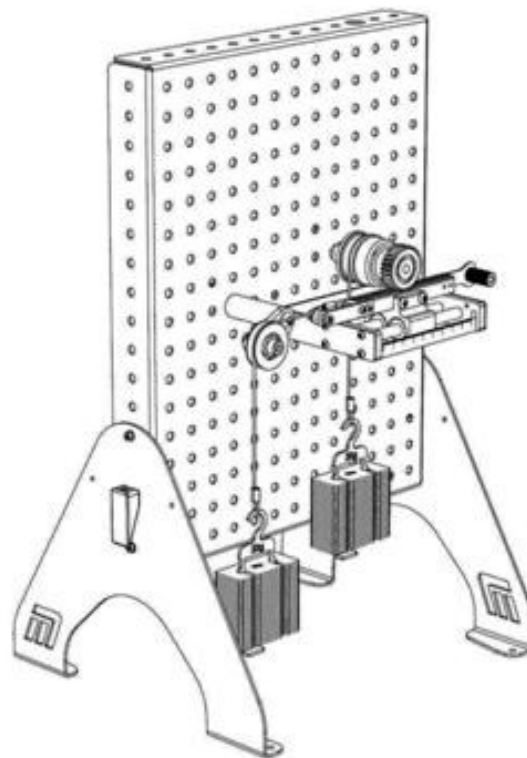
Converting rotary to linear motion

In many systems, the driving force is provided by a rotating electric motor, whereas the desired output is movement in a straight line. The escalator, shown opposite is one example of such a system.

Conversion from rotary to linear motion can be achieved in a number of ways, including use of a rack and pinion system.



Set up the rack and pinion system shown below.



The effort is applied to the pinion gear, making it rotate. As it does so, it lifts the load, i.e. moves it in a linear direction.

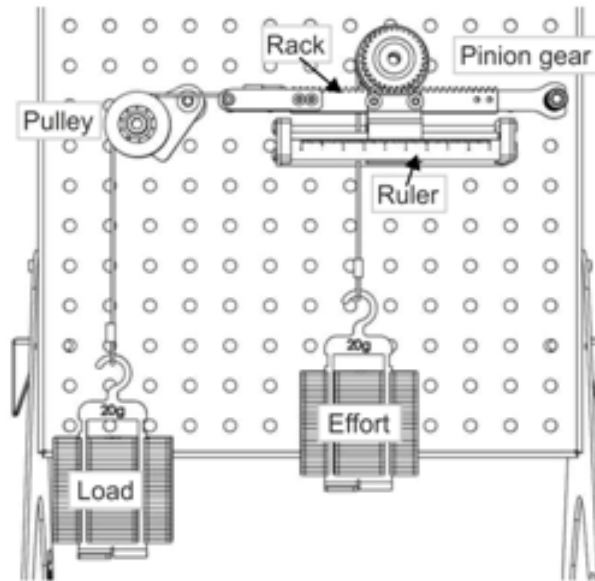
The diagram on the next page shows the arrangement in more detail.

Once again, to make it easier to take measurements, the effort is applied using a second set of weights.

The effort is applied directly to the pinion gear, causing it to rotate. As it does so, the rack moves horizontally, lifting the load.

Worksheet 3

Converting rotary to linear motion



Once again, to make it easier to take measurements, the effort is applied using a second set of weights.

The effort is applied directly to the pinion gear, causing it to rotate. As it does so, the rack moves horizontally, lifting the load.

Over to you:

- Hang a 200g mass to provide a horizontal force of 2N to the rack.
- Add more and more slotted masses to the 'effort' hanger, until the rack and load move at a steady speed.
- In the table in the Student Handout, record this value of effort.
- Repeat this procedure for loads of 300g (3N) and 400g (4N).
- Complete the table by calculating the mechanical advantage for these values of load.

So what:

- The gear ratio for this system is 1:1, suggesting a mechanical advantage of 1. Your findings might differ from this.
- Comment on this difference in the Student Handout.

Challenge!

Design an experiment to measure the velocity ratio of this system. What measurements you need to make? How you would take them? What precautions / measures would you include to improve the accuracy of your result?

Describe your method in the Student Handout.

Worksheet 4

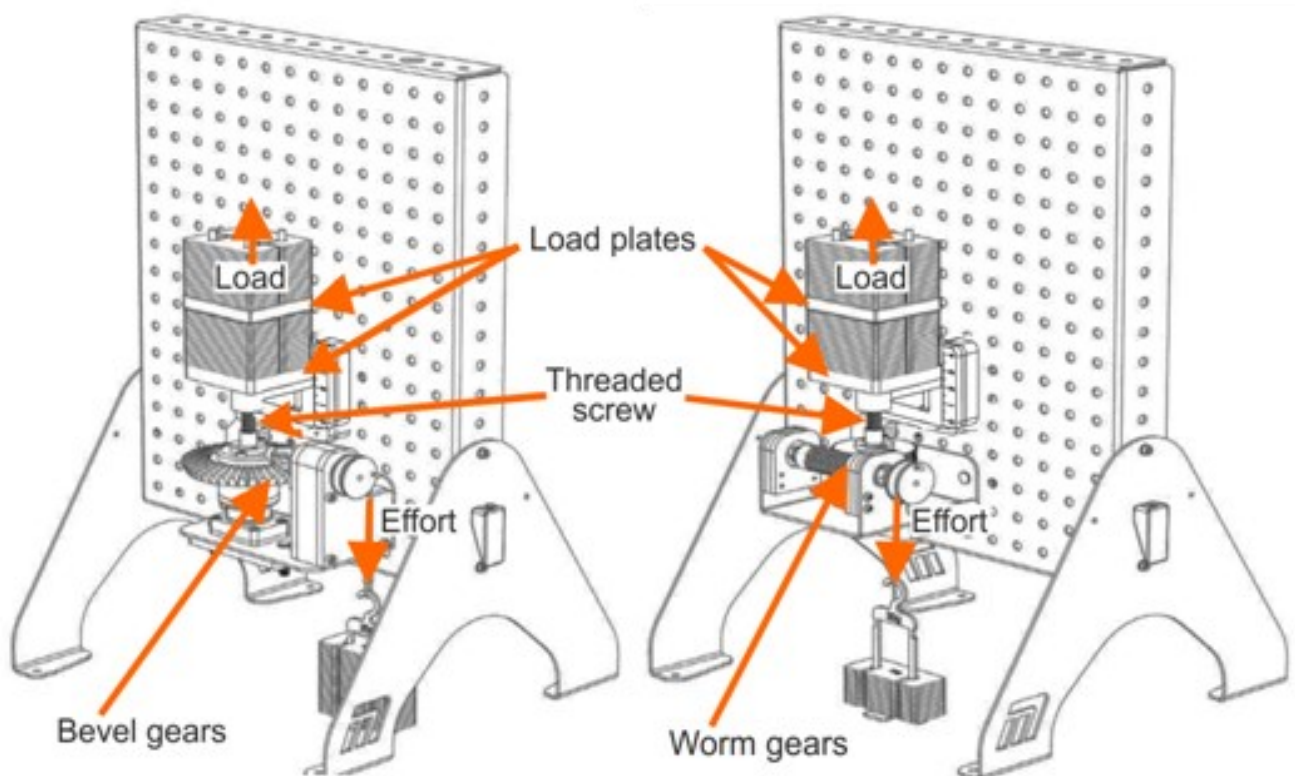
The screw jack

Across engineering, there are many examples of systems in which a driven shaft is used to raise or lower a load.

The picture shows one such example - the car jack. This one is a manual version, where the user turns the screw-threaded shaft, causing the car to rise in the air



We have seen that bevel and worm gear systems can be used to change the direction of rotation. The addition of a threaded shaft can make them move objects in a straight line.



In the system shown on the left in the diagram above, as the effort falls, the horizontal shaft rotates. The bevel gears turn this into a rotation of the vertical threaded shaft. As a result, the load rises.

The system on the right achieves the same result using worm gears.

Worksheet 4

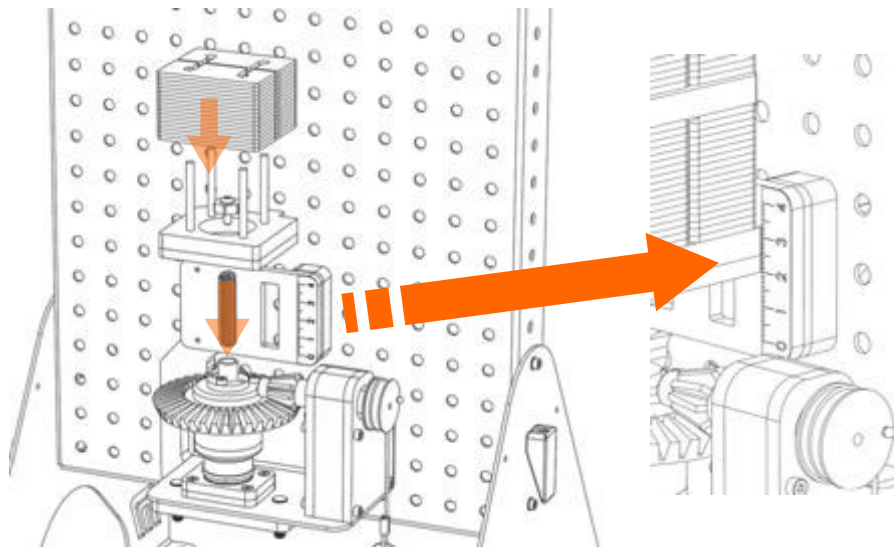
The screw jack

System 1 - Bevel gear jack

Over to you:

- Assemble the bevel gear jack shown in the diagram.
- Screw the threaded rod into the top of the bevel gear.
- Place the first load plate on top of the threaded rod.
- Tighten the first load plate onto the threaded rod using the screw provided.

Caution: Attach the screw jack as low as possible on the back panel to minimise the risk of injury from falling weights.



The load plates have a mass of 58g and 34g .

- Place a load of 200g (2N) on the load plate (giving a total load of 2.58N.)
- Add slotted masses to the 'effort' hanger, until the load rises at a steady speed.
- Record the load and effort in the Student Handout.
- Allow the 'effort' hanger to fall to the bench.
Measure the distance it falls and the corresponding distance the load rises.
- Record these distances in the Student Handout.
- Repeat the same procedure for loads of 3N, 4N and 5N. (Don't forget to add in the weights of the load plate(s)).
- Record all measurements in the table in the Student Handout.
- Calculate experimental values of mechanical advantage, velocity ratio and efficiency for the system.

Worksheet 4

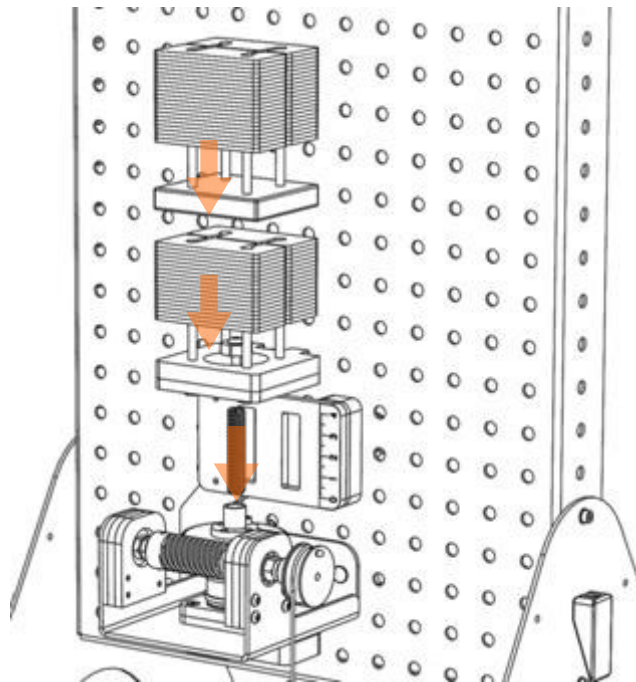
The screw jack

System 2 - Worm gear jack

Over to you:

- Assemble the worm gear jack.
- Screw the threaded rod into the top of the bevel gear.
- Place the first load plate on top of the threaded rod.
- Tighten the first load plate onto the threaded rod using the screw provided.
- Add weights and then the second load plate.

Caution: Again attach the screw jack as low as possible on the back panel to minimise the risk of injury from falling weights.



The procedure is the same as before:

- Place a load of 720g (7.2N) on the load plate (giving a total load of 7.78N with the weight of the load plate).
- Add slotted masses to the 'effort' hanger, until the load rises at a steady speed.
- Allow the 'effort' hanger to fall to the bench.
Measure the distance it falls and the corresponding distance the load rises.
- Record all measurements in the Student Handout.
- Then repeat the same procedure for loads of 11.12N (7.2N on the first plate with 3N on the second plate) and 14.12N (7.2N on the first plate with 6N on the second plate).
- Complete the table in the Student Handout by calculating experimental values for mechanical advantage, velocity ratio and efficiency for the system.

Worksheet 4

The screw jack

Here is some data about components in the two systems:

Winding drums
diameter = 26mm

Threaded rod:
diameter = 8mm
pitch = 2mm
no. of 'starts' = 4

Bevel gears:
number of teeth on larger gear = 40
number of teeth on smaller gear = 10

Worm gears:
gear ratio = $50 / 4 = 12.5$

System 1 - Bevel gear jack

Challenge!

Calculate the theoretical value of velocity ratio for the system.

Given that the gear ratio for the bevel gear system is 4:1, calculate the theoretical value of efficiency for the bevel gear screw jack.

System 2 - Worm gear jack

Challenge!

Calculate the theoretical value of mechanical advantage for the system.

Given that the velocity ratio for the system is 127.6, calculate the theoretical value of efficiency for the worm gear screw jack.

Record all your calculations in the Student Handout.

Worksheet 5

Converting linear to rotary motion

In an internal combustion engine, a crankshaft converts the back-and-forth movement of pistons into rotary motion.

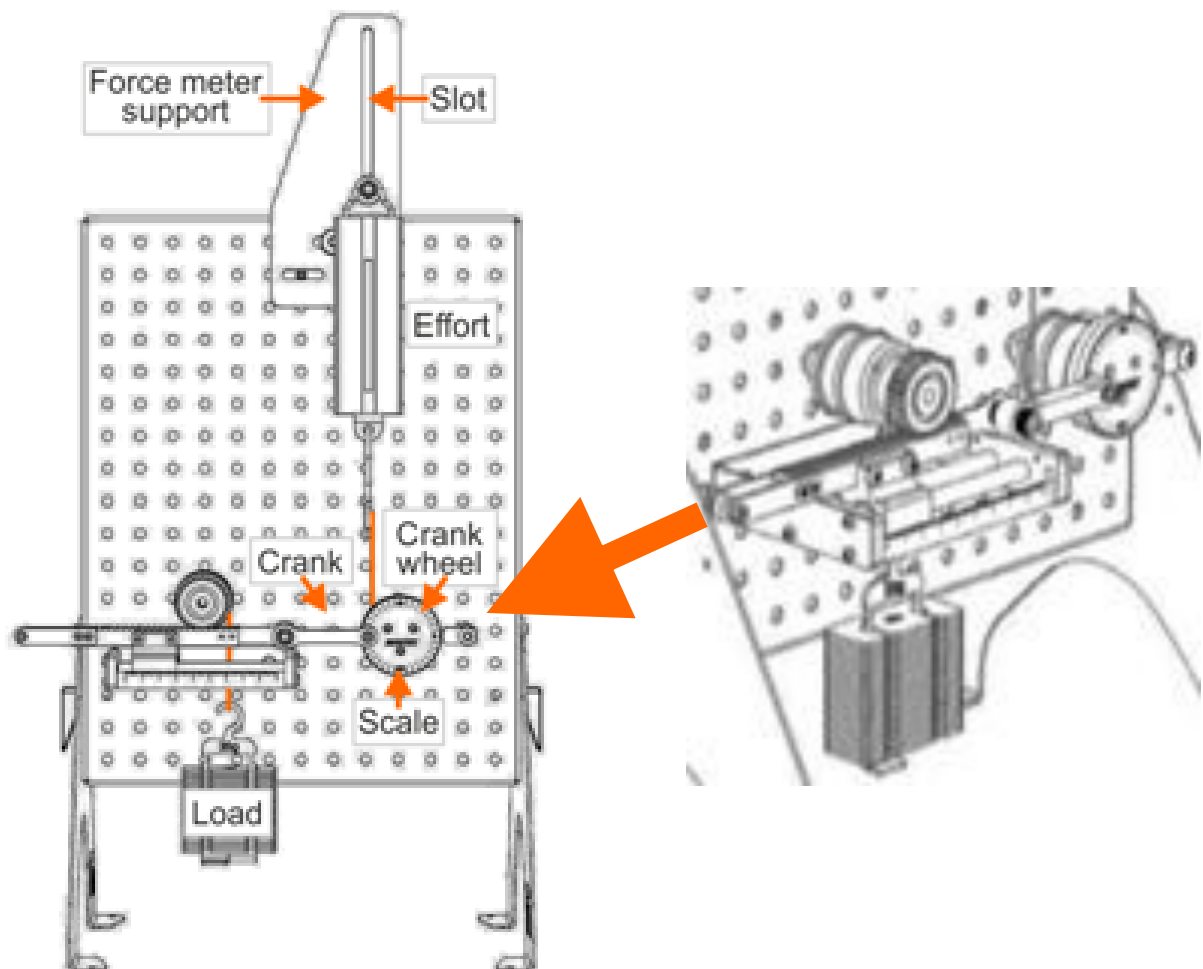
This investigation examines the behaviour of a crank system.



In this experiment, a crank is added to the rack and pinion system. When the crank wheel turns, the rack moves horizontally, rotating the pinion gear and lifting the load.

The effort required to rotate the wheel changes as the crank rotates. The experiment looks at that variation.

The cords attaching the load and the force meter to the rest of the system are highlighted in orange. The smaller diagram shows part of the system in more detail.



Worksheet 5

Converting linear to rotary motion

Over to you:

- Set up the system shown on the previous page.
- Rotate the crank to 0° , shown on the circular scale on the crank wheel.
- Adjust the position of the force meter in the support plate slot until it reads zero.
- Hang a 400g (4N) load on the pinion gear, as shown, so that the load is lifted when the pinion gear rotates in an anticlockwise direction.
- On the force meter, read the value of effort needed to keep the crank at an angle of 0° .
- Slide the force meter upwards in the slot until the crank wheel rotates clockwise to an angle of 10° and maintains that position.
- Read the effort needed to keep the crank at this angle.
- Measure the resulting horizontal displacement of the rack, using the scale attached to it.
- Record all measurements in the table in the Student Handout.
- Increase the crank angle in steps of 10° up to 180° , measuring and recording the effort required and resulting horizontal displacement each time.

So what:

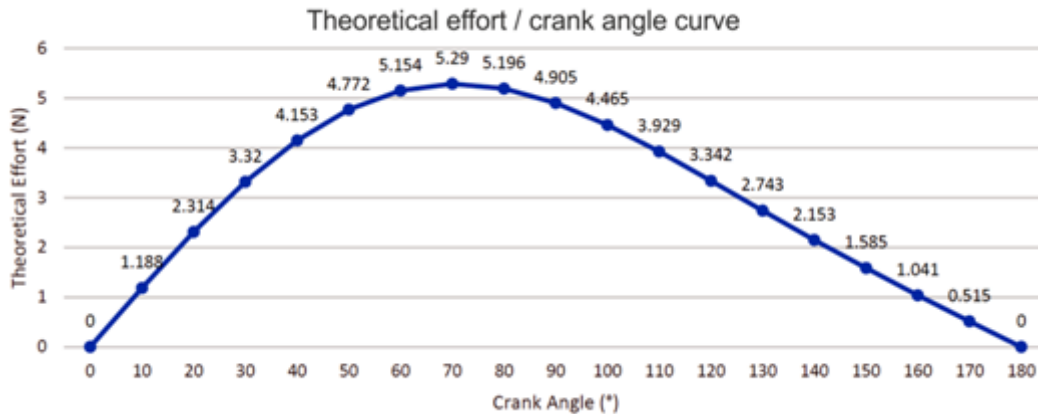
- As the angle approaches 180° the system may “snap” into position, making it difficult to measure the effort required.
- Eventually, the right-hand end of the crank reaches its maximum height and thereafter falls. The force meter must then be lowered in the slot to find the value of effort needed to maintain these angles.

Worksheet 5

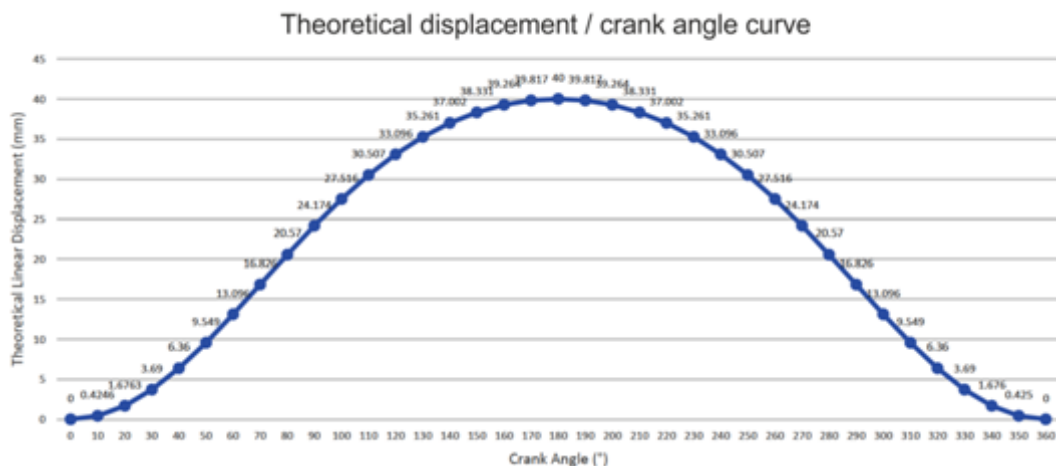
Converting linear to rotary motion

So what

- Using geometry, it can be shown that the effort required to rotate the crank wheel varies with crank angle as shown in the following graph.



- Use your results to plot a graph of effort needed vs crank angle, using this curve as a guide to the shape expected.
- Similarly, it can be shown that the horizontal displacement of the rack varies with the crank angle as shown in the following graph.



- Use your results to plot a graph of horizontal crank displacement vs crank angle using this curve as a guide to the shape expected.

Challenge!

What factors affect the mechanical advantage and velocity ratio of this system?
Comment on your findings in the Student Handout.

Worksheet 6

Exploring cams

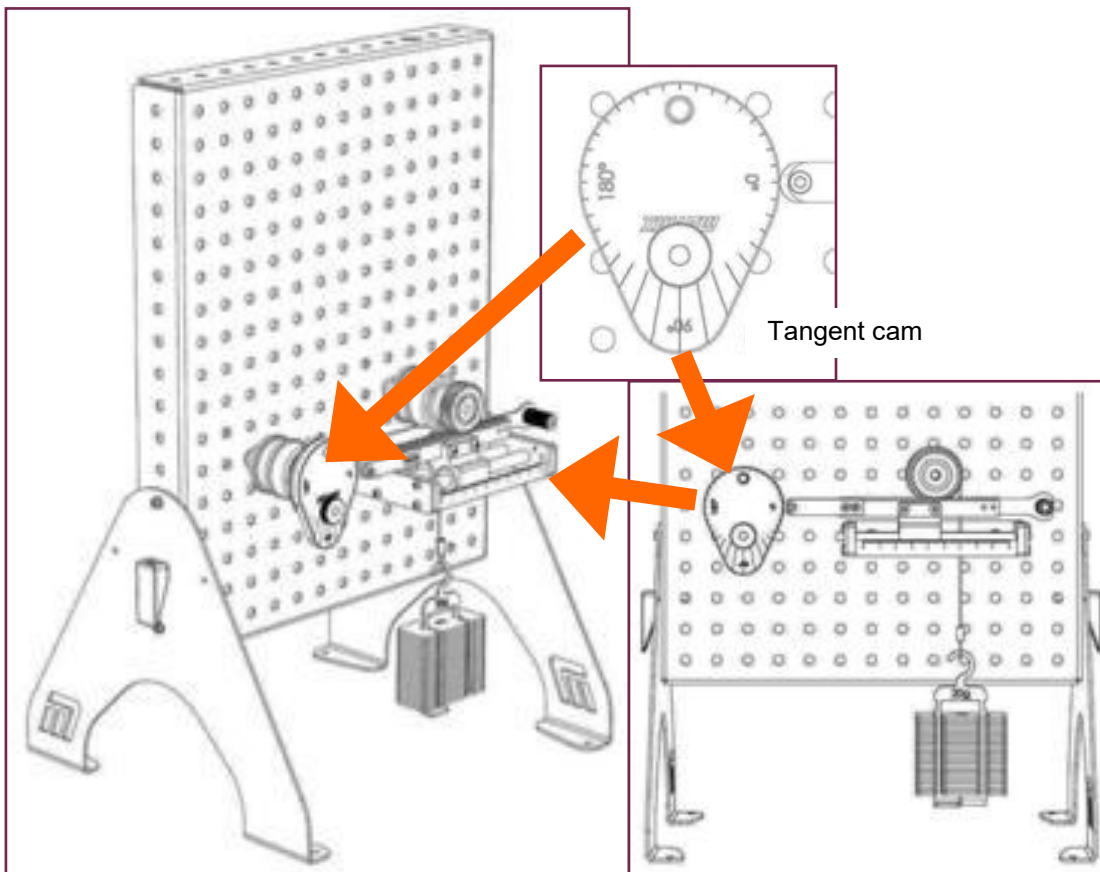
A cam mechanism usually consists of two parts, the cam itself and the cam follower, both mounted on a fixed frame.

Often connected to a camshaft, they convert rotary into reciprocating (linear) motion.

The image shows a camshaft carrying eight cams, used to open and close valves in an internal combustion engine.



In this experiment, a tangent cam (i.e. having straight flanks tangential to the base and nose circles) is in contact with a rack and pinion. As it is rotated, the rack moves horizontally. This displacement is measured for different cam angles.



A scale on the tangent cam indicates the cam angle.

Resulting displacement is read on the linear scale attached to the rack.

The weight suspended from the pinion gear ensures that the rack is kept in contact with the cam as it rotates.

Worksheet 6

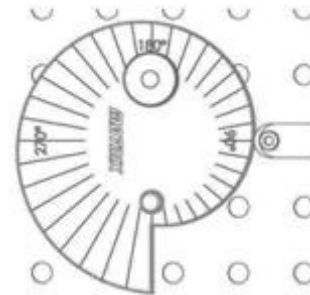
Exploring cams

Over to you:

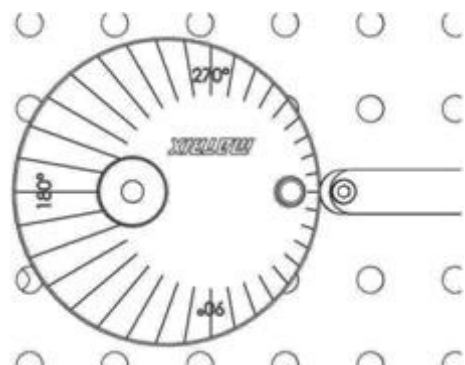
- Set up the system shown on the previous page.
- Hang a 200g (2N) load on the pinion gear, as shown.
- Rotate the cam to 0° , shown on the scale on the cam.
- Note the initial position, shown on the scale attached to the rack.
- Increase the cam angle in steps of 10° up to 180° , measuring the resulting horizontal displacement from the initial position each time.
- Record all measurements in the table in the Student Handout.
- Plot a graph of displacement against cam angle.

So what:

- Now replace the tangent cam with the snail cam.
- Repeat the same experimental procedure, up to a cam angle of 360° .
- Plot a graph of displacement against cam angle.
(For this cam shape, the graph should be linear)



- Finally, do the same thing using the eccentric cam, again up to a cam angle of 360° .
(This time, the graph should be sinusoidal.)



Worksheet 7

Exploring chain and belt drives

Drive systems usually transfer energy using either a chain drive or a belt drive.

Chain drives handle higher loads and can operate at higher temperatures but are heavier and require lubrication.

Belt drives rely on frictional forces between the belt and pulleys and so result in higher frictional losses than chain drives. They are quieter but can suffer from slip whereas chain drives do not.

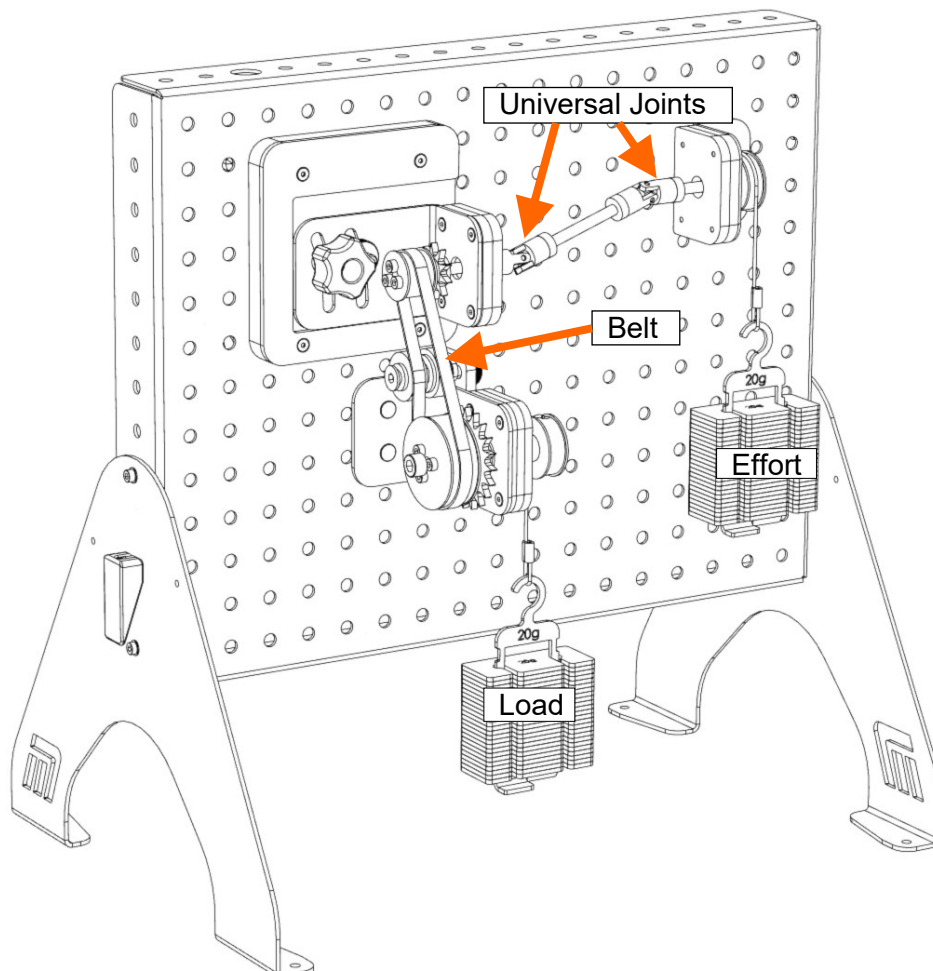


System 1 - Belt drive

In this experiment, a belt drive is used to transfer energy between two sets of weights. A shaft uses two universal joints to create a flexible link between components in the upper part of the system.



A universal joint

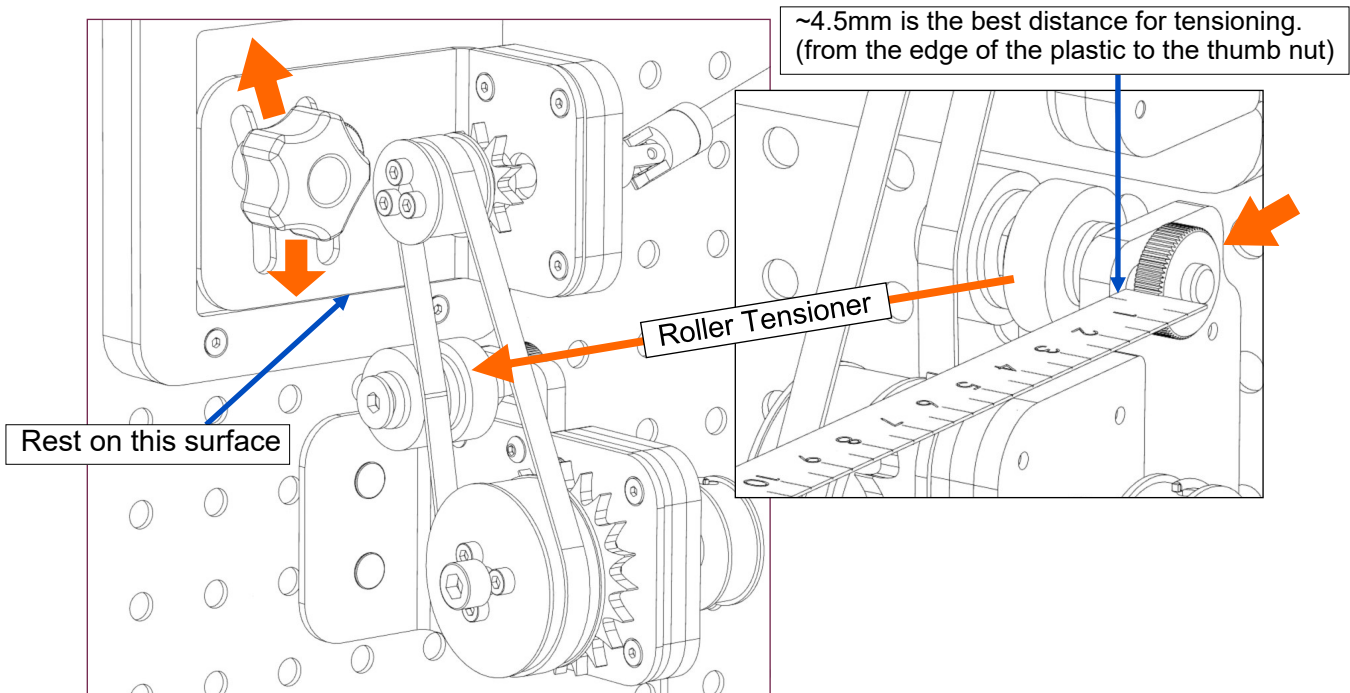


Worksheet 7

Exploring chain and belt drives

Over to you:

- Set up the system shown on the previous page, having a gear ratio of 2:1.
The diagrams below identify adjustments that can be made to belt position and tension.
- The flat surface of the belt should be wrapped around the two wheels.



- Hang a load of 2N (200g mass) from the larger gear wheel.
- Add more and more slotted masses to the 'effort' hanger, until the load rises at a steady speed.
- In the table in the Student Handout, record this value of effort.
- Repeat this procedure for loads of 3N (300g), 4N (400g) and 5N (500g).
- Complete the table by calculating the mechanical advantage for each value of load.

- Next, reverse the system so that it has a gear ratio of 1:2.
- Repeat the above, for loads of 1.0N, 1.2N, 1.4N and 1.6N.
- Calculate the mechanical advantage in each case.

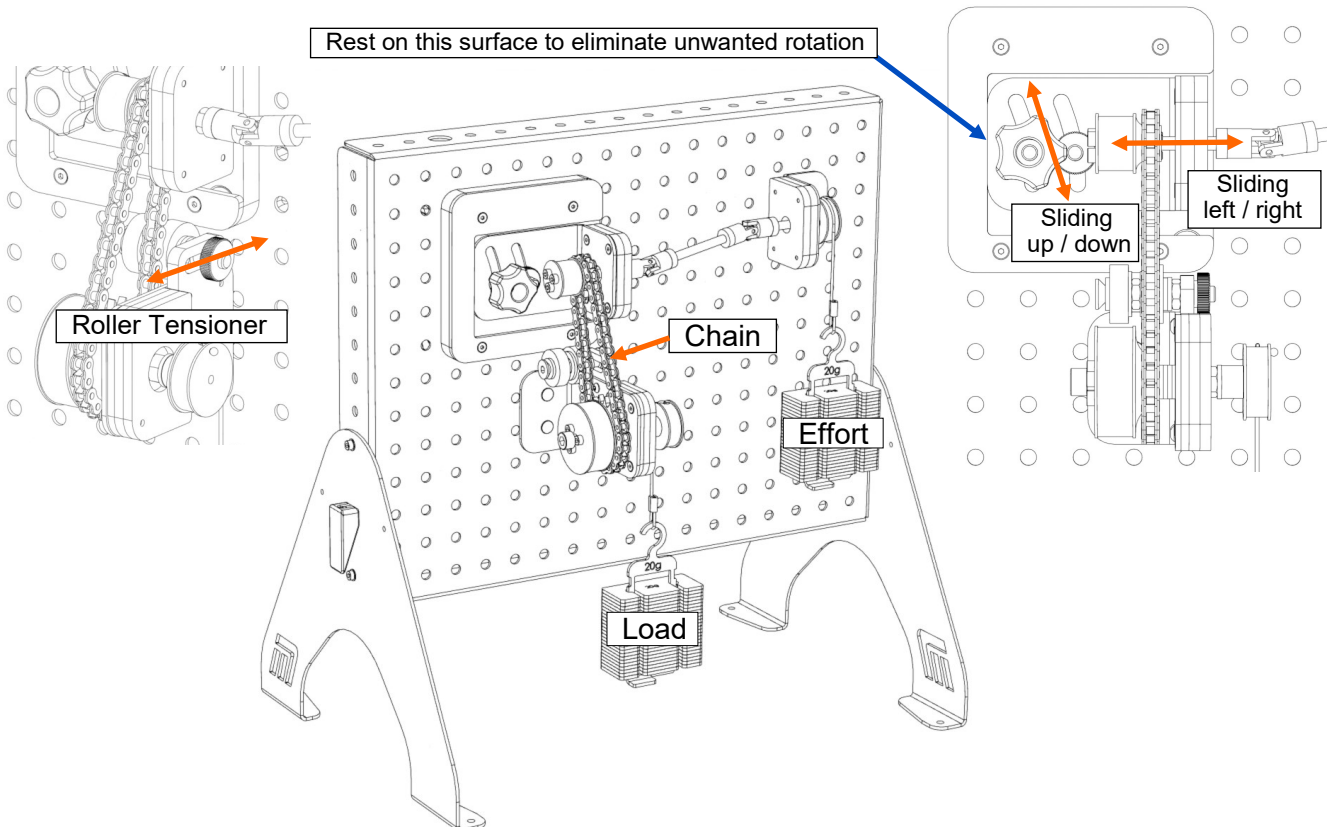
Worksheet 7

Exploring chain and belt drives

System 2 - Chain drive

This system uses a chain drive to transfer energy between the sets of weights. Again, two universal joints create a flexible link between components.

The smaller diagrams show how to adjust the chain alignment:



Over to you:

- Adjust the tension in the chain to take up any slack.
- Adjust the positions of the gear wheels until they are in line (to avoid unsmooth rotation)

Challenge!

In the same way as before, set up the system to have a gear ratio of 2:1.

Then take measurements that allow you to calculate the mechanical advantage of the system for loads of 2N, 3N, 4N and 5N.

Record all your findings in the Student Handout.

Comment on the results for the two types of drive in the Student Handout.

Student Handout

Worksheet 1 - Gear trains - spur gears

System 1 - Simple gears

Load in N	Effort in N	Distance travelled by load in mm	Distance travelled by effort in mm	Mechanical advantage	Velocity ratio	Efficiency %
1						
2						
3						

Gear ratio of system 1 =

Why is the efficiency of this system less than 100%?

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Velocity ratio compared to gear ratio:

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Challenge!

Gear ratio for new system =

Findings:

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Useful formulae:

$$\text{Mechanical advantage} = \text{Load} / \text{Effort}$$

$$\text{Velocity ratio} = \text{distance moved by effort} / \text{distance moved by load}$$

$$\text{Efficiency} = \text{mechanical advantage} / \text{velocity ratio}$$

$$\text{Gear ratio } \mathbf{G} = \text{number of teeth on driven gear} / \text{number of teeth on driving gear}$$

Worksheet 1 - Gear trains - spur gears

System 2 - Compound gears:

Load in N	Effort in N	Distance travelled by load in mm	Distance travelled by effort in mm	Mechanical advantage	Velocity ratio	Efficiency %
3						
4						
5						

So what:

Overall gear ratio for second system =

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Reasons why compound gears might have a lower efficiency than simple gear systems:

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Challenge!

When the gear ratio is 9:25:

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Useful formulae:

- Mechanical advantage = Load / Effort
- Velocity ratio = distance moved by effort / distance moved by load
- Efficiency = mechanical advantage / velocity ratio
- Gear ratio **G** = number of teeth on driven gear / number of teeth on driving gear
- When a gear train has multiple stages: overall gear ratio = **G1** x **G2** x
- where **G1, G2** ... are gear ratios of individual stages.

Worksheet 2 - Changing the direction of rotation

System 1 - Bevel gears

Load in N	Effort in N	Distance travelled by load in mm	Distance travelled by effort in mm	Mechanical advantage	Velocity ratio	Efficiency %
1						
2						
3						

So what:

Overall gear ratio for bevel gear system =

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Challenge!

When the load hangs from the smaller gear and the effort is applied to the larger one:

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Useful formulae:

$$\text{Mechanical advantage} = \text{Load} / \text{Effort}$$

$$\text{Velocity ratio} = \text{distance moved by effort} / \text{distance moved by load}$$

$$\text{Efficiency} = \text{mechanical advantage} / \text{velocity ratio}$$

$$\text{Gear ratio } \mathbf{G} = \text{number of teeth on driven gear} / \text{number of teeth on driving gear}$$

$$\text{When a gear train has multiple stages: overall gear ratio} = \mathbf{G1} \times \mathbf{G2} \times \dots$$

where **G1, G2** ... are gear ratios of individual stages.

Worksheet 2 - Changing the direction of rotation

System 2 - Worm gears

Load in N	Effort in N	Distance travelled by load in mm	Distance travelled by effort in mm	Mechanical advantage	Velocity ratio	Efficiency %
1						
2						
3						

So what:

Overall gear ratio for worm gear system =

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Challenge!

Comment on your findings :

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Useful formulae:

$$\text{Mechanical advantage} = \text{Load} / \text{Effort}$$

$$\text{Velocity ratio} = \text{distance moved by effort} / \text{distance moved by load}$$

$$\text{Efficiency} = \text{mechanical advantage} / \text{velocity ratio}$$

$$\text{Gear ratio } \mathbf{G} = \text{number of teeth on driven gear} / \text{number of teeth on driving gear}$$

$$\text{When a gear train has multiple stages: overall gear ratio} = \mathbf{G1} \times \mathbf{G2} \times \dots$$

where **G1, G2** ... are gear ratios of individual stages.

Student Handout

Worksheet 3 - Converting rotary to linear motion

Load in N	Effort in N	Mechanical advantage
2		
3		
4		

So what:

Theory suggests a mechanical advantage of 1 for this system.

Comment on your findings :

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Challenge!

Describe how you would determine the velocity ratio for this system.

Explain what measurements and what precautions you would take:

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Worksheet 4 - The screw jack

System 1 - Bevel gear jack

Load in N	Effort in N	Distance travelled by load in mm	Distance travelled by effort in mm
2.58			

Experimental value (average) of mechanical advantage:

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Experimental value (average) of velocity ratio:

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Experimental value (average) of efficiency:

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Student Handout

Worksheet 4 - The screw jack

System 2 - Worm gear jack

Load in N	Effort in N	Distance travelled by load in mm	Distance travelled by effort in mm
7.78			

Experimental value (average) of mechanical advantage:

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Experimental value (average) of velocity ratio:

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Experimental value (average) of efficiency:

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Worksheet 4 - The screw jack

Challenge!

System 1 - Bevel gear jack

Theoretical value of velocity ratio:

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Theoretical value of efficiency:

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System 2 - Worm gear jack

Theoretical value of mechanical advantage:

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Theoretical value of efficiency:

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Worksheet 5 - Converting linear to rotary motion

Crank angle in degrees	Effort in N	Horizontal displacement in mm
0		
10		
20		
30		
40		
50		
60		
70		
80		

Crank angle in degrees	Effort in N	Horizontal displacement in mm
90		
100		
110		
120		
130		
140		
150		
160		
170		
180		

So what:

Theory suggests a mechanical advantage of 1 for this system.

Comment on your findings :

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Challenge!

What factors affect the mechanical advantage and velocity ratio of this system?

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Student Handout

Worksheet 6 - Exploring cams

Tangent cam:

Cam angle in degrees	0	10	20	30	40	50	60	70	80	90
Displacement in mm										

Cam angle in degrees	100	110	120	130	140	150	160	170	180	
Displacement in mm										

So what:

Snail cam

Cam angle in degrees	0	10	20	30	40	50	60	70	80	90
Displacement in mm										

Cam angle in degrees	100	110	120	130	140	150	160	170	180	190
Displacement in mm										

Cam angle in degrees	200	210	220	230	240	250	260	270	280	290
Displacement in mm										

Cam angle in degrees	300	310	320	330	340	350	360			
Displacement in mm										

Student Handout

Worksheet 6 - Exploring cams

So what:

Eccentric cam

Cam angle in degrees	0	10	20	30	40	50	60	70	80	90
Displacement in mm										

Cam angle in degrees	100	110	120	130	140	150	160	170	180	190
Displacement in mm										

Cam angle in degrees	200	210	220	230	240	250	260	270	280	290
Displacement in mm										

Cam angle in degrees	300	310	320	330	340	350	360			
Displacement in mm										

Worksheet 7 - Exploring chain and belt drives

System 1 - Belt drive

Gear ratio 2:1

Load in N	Effort in N	Mechanical advantage
2		
3		
4		
5		

Gear ratio 1:2

Load in N	Effort in N	Mechanical advantage
1.0		
1.2		
1.4		
1.6		

Challenge!

System 2 - Chain drive

Load in N	Effort in N	Mechanical advantage
2		
3		
4		
5		

Comparing the results for belt and chain drives:

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Notes for the Instructor

About this course

Introduction

This module allows students to investigate systems using gears, belts and linkages through a structured sequence of practical investigations.

Using the kit, students complete a series of worksheets that focus on a number of topics found in BTEC Higher National and equivalent courses.

Aim

The course teaches students about measuring the performance of mechanical systems that use gears, belts and linkages.

Prior Knowledge

It is expected that students have followed an introductory science course, enabling them to take, record and analyse scientific observations and appreciate the errors inherent in them. Some mathematical capability is required.

Using this course:

It is expected that the Worksheets and Student Handout are printed / photocopied, preferably in colour, for the students' use.

Each worksheet includes:

- an introduction to the topic under investigation;
- step-by-step instructions for the investigation that follows.

The Student Handout is a record of measurements taken in each worksheet and questions relating to them. Students do not need a permanent copy of the worksheets but do require their own copy of the Student Handout

This format encourages self-study, with students working at a rate that suits their ability. It is for the instructor to monitor that their understanding is keeping pace with progress through the worksheets. One way to do this is to 'sign off' each worksheet, as the student completes it, and in the process have a brief chat to assess the student's grasp of the ideas involved in the exercises it contains.

We realise that you as a subject area practitioner take the lead in determining how and what students learn. The worksheets are not meant to supplant this or any other supporting underpinning knowledge you choose to deliver. For subject experts, the 'Notes for the Instructor' are provided simply to reveal the thinking behind the approach taken.

For staff whose core subject knowledge is not in the field covered by the course, these notes can both illuminate and offer guidance.

Time:

It will take students between five and seven hours to complete the worksheets. It is expected that a similar length of time will be needed to support the learning that takes place as a result.

	Notes
<p>Worksheet 1</p> <p>Gear trains - spur gears</p> <p>Timing 45 - 60 mins</p>	<p>Concepts involved: weight mass gravitational field strength mechanical advantage velocity ratio efficiency gear ratio</p> <p>The instructor may need to remind students about the difference between weight and mass and the relationship between them.</p> <p>They need to understand why the load needs to move at a steady speed, rather than accelerate.</p> <p>There could be a discussion about the best way to measure the distances involved, especially the distance moved by the effort. Practice and co-operation may be the essential ingredients for success in this.</p> <p>The factors that limit the efficiency of the systems could form the focus for a group presentation or class discussion.</p> <p>Equally, the instructor could delegate to a group of students the task of creating a presentation on the significance of 'gear ratio'.</p>
<p>Worksheet 2</p> <p>Changing the direction of rotation</p> <p>Timing 45 - 60 mins</p>	<p>Concepts involved: bevel gears worm gear systems calculating the gear ratio of bevel gear and worm gear systems</p> <p>The class could discuss why applying the effort using a second weight hanger, rather than using a force meter, makes it easier to take measurements.</p> <p>Students could be asked to compare and account for differences between the efficiencies of the four systems studied so far.</p> <p>They could explore practical applications of bevel and worm gears.</p>
<p>Worksheet 3</p> <p>Converting rotary to linear motion</p> <p>Timing 30 - 45 mins</p>	<p>Concepts involved: rack and pinion rack pinion gear</p> <p>The instructor could introduce the worksheet by providing practical examples of rack and pinion systems, or task the students with doing so.</p> <p>Once again, we are not looking for a static 'balanced' system. It is important that the load is moving at a steady speed.</p> <p>Students are asked to design an experiment to measure the system's velocity ratio. This could be expanded into a class discussion / presentation.</p>
<p>Worksheet 4</p> <p>The screw jack</p> <p>Timing 45 - 60 mins</p>	<p>Concepts involved: screw jack</p> <p>The screw jack is an obvious example of converting rotational to linear motion. The instructor could task the students with finding and describing others.</p> <p>Once again, it is important that the load is moving at a steady speed.</p> <p>One aim is to contrast the two systems - bevel gear jack and worm gear jack. The results could be presented in a class discussion.</p> <p>Depending on their mathematical ability and experience, students may require assistance from the instructor to complete the challenges.</p> <p>An extension - students could investigate the effects of lubrication.</p>

	Notes
<p>Worksheet 5</p> <p>Converting linear to rotary motion</p> <p>Timing 30 - 45 mins</p>	<p>Concepts involved: crank crankshaft pinion gear</p> <p>Again, the activity could start with the instructor, or students, providing practical examples of crank systems used to convert linear to rotary motion.</p> <p>Measuring the effort needed requires care and practice. We are looking for the force needed to maintain a particular crank angle and overcome frictional forces in the system.</p> <p>The instructor could explore the implications of and factors involved in the shapes of the graphs produced in the investigation.</p> <p>The challenge lends itself to a class discussion of the factors involved.</p>
<p>Worksheet 6</p> <p>Exploring cams</p> <p>Timing 45 - 60 mins</p>	<p>Concepts involved: types of cam reciprocating motion</p> <p>There is scope for an initial presentation on types of cam and their uses. Strictly speaking, this is another example of converting rotary to linear motion. The investigation concentrates on the effect of different cam geometries. The load suspended from the pinion is there only to keep the rack in contact with the cam.</p> <p>For mathematically more able students, the instructor could show how to explore the geometry of the cams and compare theoretical and experimental results.</p>
<p>Worksheet 7</p> <p>Exploring belt and chain drives</p> <p>Timing 45 - 60 mins</p>	<p>Concepts involved: types of belt drive chain drives</p> <p>Running alongside the experimental work, students could be tasked with preparing a comparison of advantages and disadvantages of the two types of drive.</p> <p>The instructor may wish to check that students have set up an appropriate tension in the drives. Too tight and the system may simply lock up. Too loose and the belt may slip. The vertical alignment of the chain drive will also affect the results.</p> <p>The results will show a considerable variation in values for mechanical advantage, both with type of drive used and with the load applied. This could be addressed in a class discussion.</p>