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| Name | |
| Class | |
| Teacher | |

Mechanisms

A Practical Approach

Use this document alongside the VEX IQ Mechanism Kit.



Mechanisms - A Practical Approach

Glossary of Key Words and Terms

Below you will find a table of key words and terms that are used throughout this document. Each key word or term is accompanied by a short description that will help you remember and understand its use.

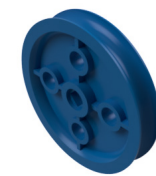
| Key Word / Term | Description |
|----------------------|--|
| Bevel | The inclination that one line or surface makes with another when not at right angles. |
| Compound Gear | A compound gear is a number of gears fixed together and positioned on top of each other. Consequently, they rotate at the same speed. |
| Differential Gearbox | A train of gears designed to permit two or more shafts to rotate at different speeds. |
| Gear Ratio | The ratio of the rotational speeds of the first and final gears in a train of gears or of any two meshing gears. Also known as Velocity Ratio. |
| Idler Gear | A gear placed between a driving and a driven gear to transmit motion between them. |
| Mesh(ed) | To engage, as gear teeth. |
| Output Speed | An equation involving a gear ratio to calculate the "output speed" from a specified "input speed". |
| Revolution | Turning round or rotating, on an axis. |
| Shaft | A rotating straight bar for transmitting motion and torque. |
| Torque | The measured ability of a rotating element, as of a gear or shaft, to overcome turning resistance. |



Bevel Gear



Crown Gear



Pulley Wheel



Rack Gear



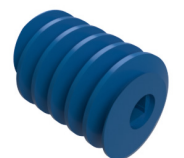
Sprocket



Spur Gear



Universal Joint



Worm Gear



Mechanisms - A Practical Approach

An Introduction to Gears

You will find gears in nearly everything that contains rotating parts. Car engines and gear boxes contain many gears as do clock mechanisms, especially if they have bells or chimes. Engines and motors producing rotational motion will not doubt feature some form of gear configuration. In this section you will learn how different sizes and configurations of gears can be utilised for a wide range of purposes. You will find the formulas below useful when calculating some of the answers.

$$\text{Gear Ratio (Velocity Ratio)} = \frac{\text{Number of teeth on the driven gear}}{\text{Number of teeth on the driver gear}}$$

$$\text{Output Speed} = \frac{\text{Input Speed}}{\text{Gear Ratio}}$$

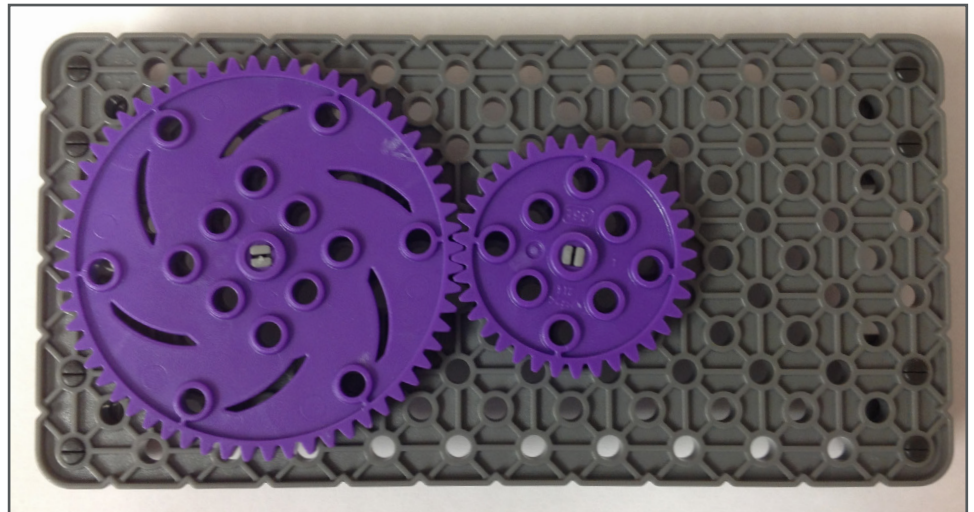
The Simple Gear Train

Sometimes two or more gears mesh with each other to transmit power from one shaft to another. This combination is called a gear train or train of toothed wheels. The nature of the train used depends upon the velocity ratio required and the relative position of the axes of the shafts. A gear train may consist of spur, bevel or spiral gears.

Practical Task

You will need:

- 1 x 6x12 Plate
- 2 x Idler Pins
- 1 x 60 Tooth Spur Gear
- 1 x 36 Tooth Spur Gear
- 1 x 12 Tooth Spur Gear



Questions

1. *What do you notice about the speed and direction of rotation the smaller spur gear when you turn the larger spur gear at a constant speed?*

2. *Calculate the gear ratio and explain what the result means.*

3. *Replace the 60 tooth spur gear with the 12 tooth spur gear - what do you notice now?*





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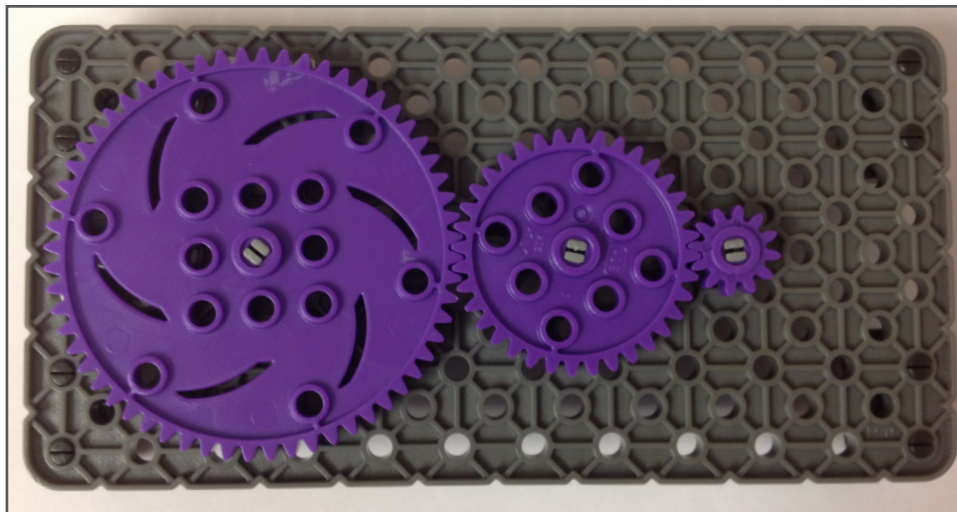
3 Gear Train

As you increase the number of gear wheels in your gear train you will notice that you are able to change the direction of rotation of each gear wheel. Two gear wheels meshed directly to each other will rotate in opposite directions. However if you wanted two shafts to rotate in the same direction you would need to add a third gear wheel. The additional gear wheel is positioned between the two shafts you wish to rotate in the same direction and is known as the idler gear.

Practical Task

You will need:

- 1 x 6x12 Plate
- 3 x Idler Pins
- 1 x 60 Tooth Spur Gear
- 1 x 36 Tooth Spur Gear
- 1 x 12 Tooth Spur Gear



Questions

1. *What do you notice about the rotational direction of all three gear wheels?*
2. *What is the name given to the middle gear wheel and what is its purpose?*
3. *Calculate the output speed when the input speed on the 60 tooth gear wheel is 10rpm.*





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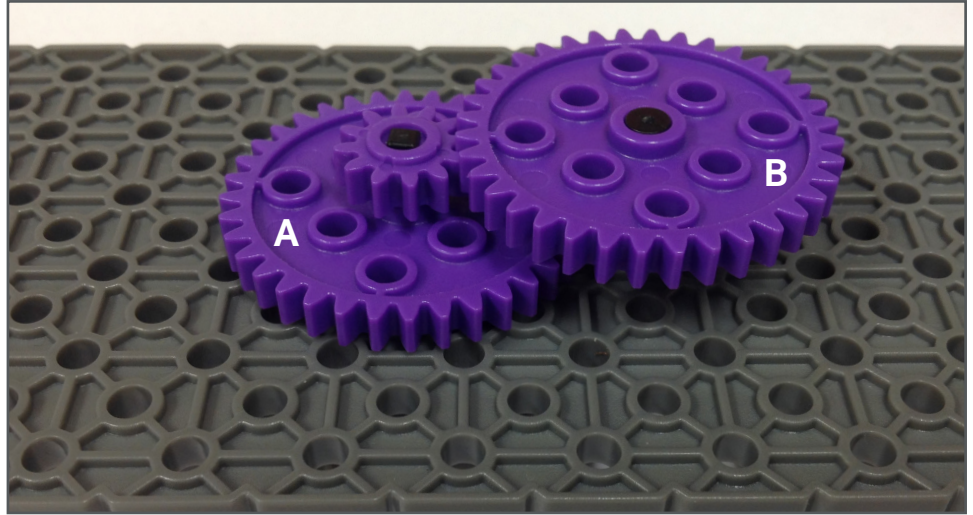
Compound Gear Train

Compound gear trains are great if you need to transfer motion in a tight space. They are often found where space is at a premium and an engineer has been tasked with transferring motion from one shaft to another in a relatively small area.

Practical Task

You will need:

- 1 x 6x12 Plate
- 2 x Axles
- 1 x Spacer
- 2 x 36 Tooth Spur Gear
- 1 x 12 Tooth Spur Gear



Questions

1. *If you turn compound gear (A) through 5 revolutions, how many revolutions will gear (B) complete?*
2. *What is the advantage of a compound gear train over a standard gear train?*
3. *Where do you think you would find this type of gear mechanism and why?*





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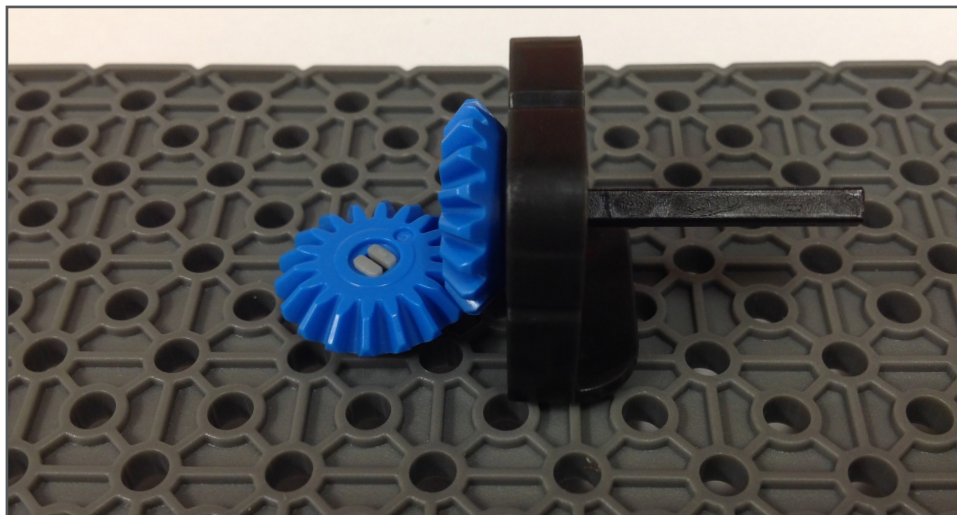
Bevel Gears

Bevel gears have a cone shape which enables them to mesh at various angles except 0 and 180 degrees, that is not to say a single bevel gear can work at multiple angles, the bevel gears must be cut to suit a specific meshing angle. The teeth of a bevel gear can be straight cut, similar to those of a spur gear, or they can be curved along their length with each tooth at an angle (spiral/helical bevel gear).

Practical Task

You will need:

- 1 x 6x12 Plate
- 1 x Axle
- 1 x Idler Pin
- 1 x 2x2 Corner Connector
- 2 x Bevel Gears



Questions

1. *In this configuration, what have the bevel gears allowed you to do?*

2. *What do you notice about the angle of the teeth on the bevel gears?*

3. *Where do you think you would find this type of gear and why?*





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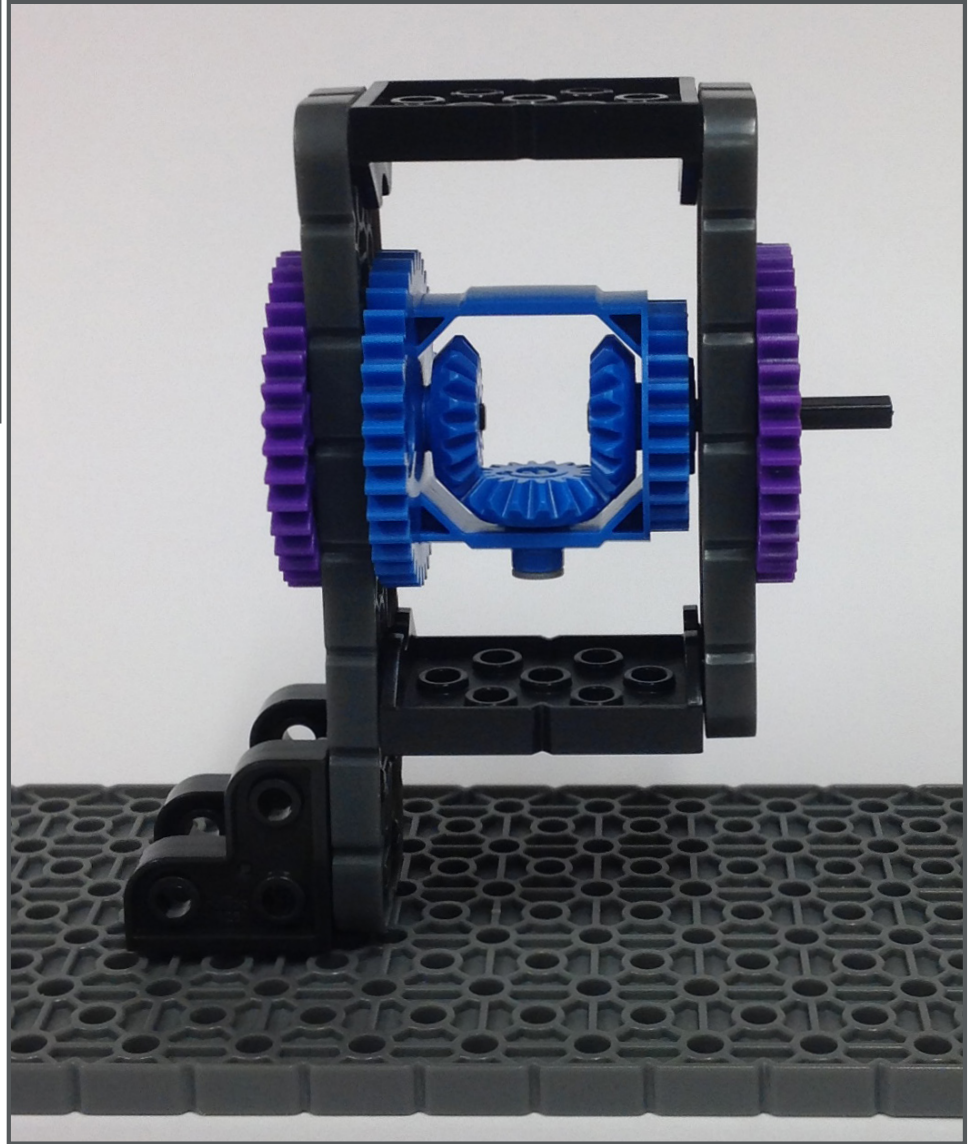
Differential Gears

Try building and experimenting with the differential gearbox shown below. All of the parts you need can be found in the kit.

Practical Task

You will need:

- 1 x 6x12 Plate
- 1 x 8x2 Beam
- 1 x 6x2 Beam
- 2 x Double 2x2 Offset Connectors
- 2 x Axles
- 1 x Idler Pin
- 2 x 1x2 Corner Connector
- 3 x Bevel Gears
- 1 x Differential Gear
- 2 x 36 Tooth Spur Gear



Questions

1. *If you turn the differential gear what happens?*
2. *What happens when you turn the differential gear but hold one outer spur gear?*
3. *Where might you find this system?*





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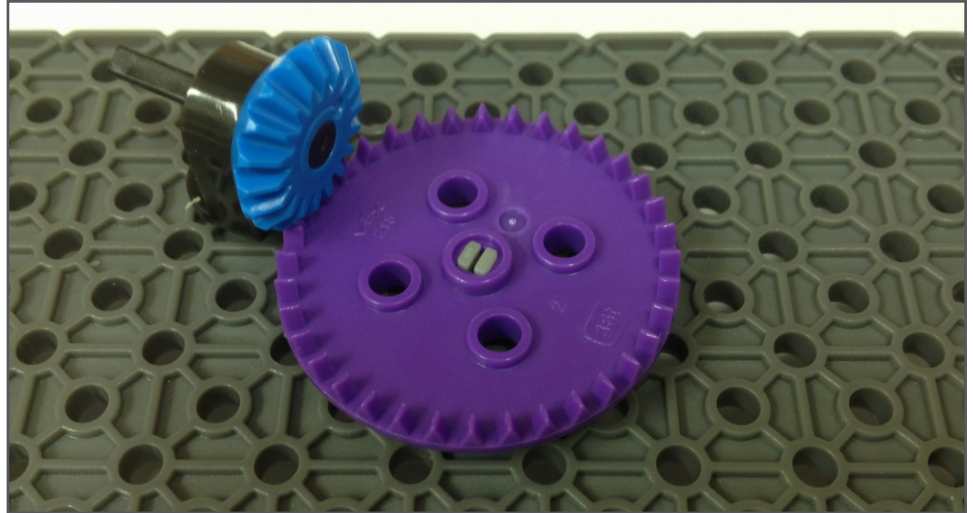
Crown Gears

Crown gears are a form of bevel gear, the teeth of crown gears project at right angles to the plane of the wheel. Crown gears are usually meshed with another bevel gear, but in some instances are meshed with spur gears.

Practical Task

You will need:

- 1 x 6x12 Plate
- 1 x Axle
- 1 x Idler Pin
- 1 x 1x1 Corner Connector
- 1 x Bevel Gear
- 1 x Crown Gear
- 1 x 12 Tooth Spur Gear



Questions

1. *What are the main differences between crown and bevel gears?*
2. *Replace the bevel gear with the 12 tooth spur gear, what do you notice?*
3. *Where do you think you would find this type of gear and why?*





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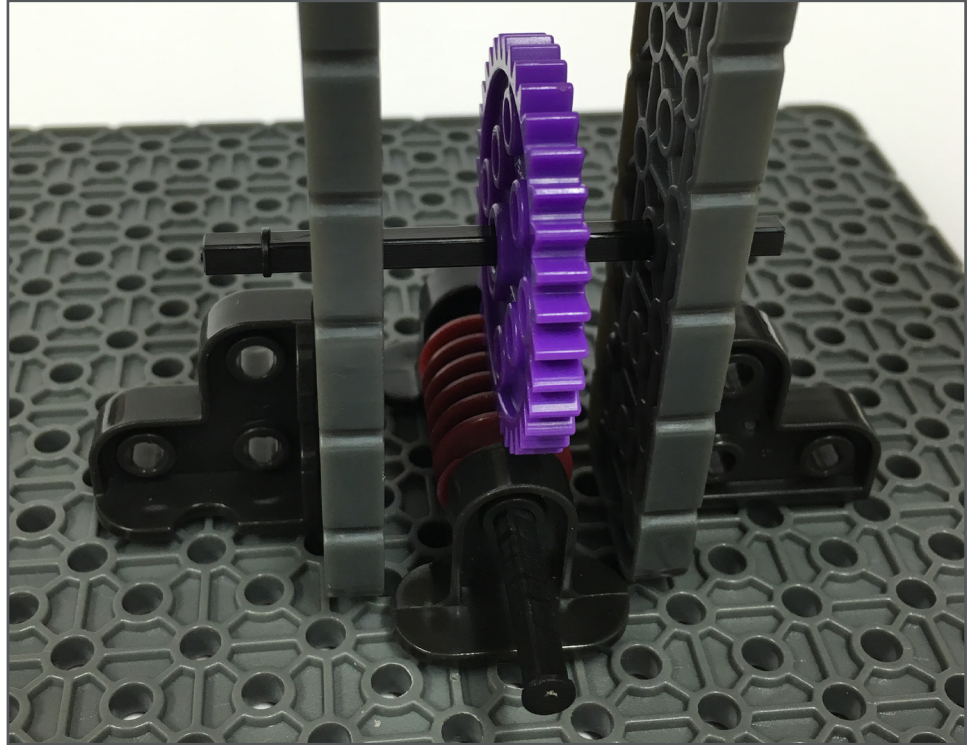
Worm Gears

The worm resembles the thread of a screw and is usually meshed with a worm wheel or a typical spur gear. Worm gears are an excellent way to increase torque output whilst reducing rotational speed. Worm drives have ratios varying from around 10:1 to 500:1. Worm gears do have a slight disadvantage in that they are not very efficient, a lot of energy can be wasted due to the sliding action of the gear teeth. The worm itself can have 1 or more teeth, although 1 tooth that follows around the length of the worm several times can often look like more than one tooth is present. A worm with one tooth is called a single thread or single start, while a worm with more than one tooth is called a multiple thread or multiple start.

Practical Task

You will need:

- 1 x 12x12 Plate
- 1 x 2x8 Beam
- 1 x 2x6 Beam
- 2 x Long Axles
- 2 x 1x1 Offset connector
- 2 x 2x2 Corner Connector
- 1 x Worm Gear
- 1 x 36 Tooth Spur Gear



Questions

1. Turn the axle of the worm gear. What do you notice about the speed and direction of the spur gear?
2. What happens when you turn the spur gear onto the worm gear and why does this happen?
3. Where do you think you would find this type of gear and why?





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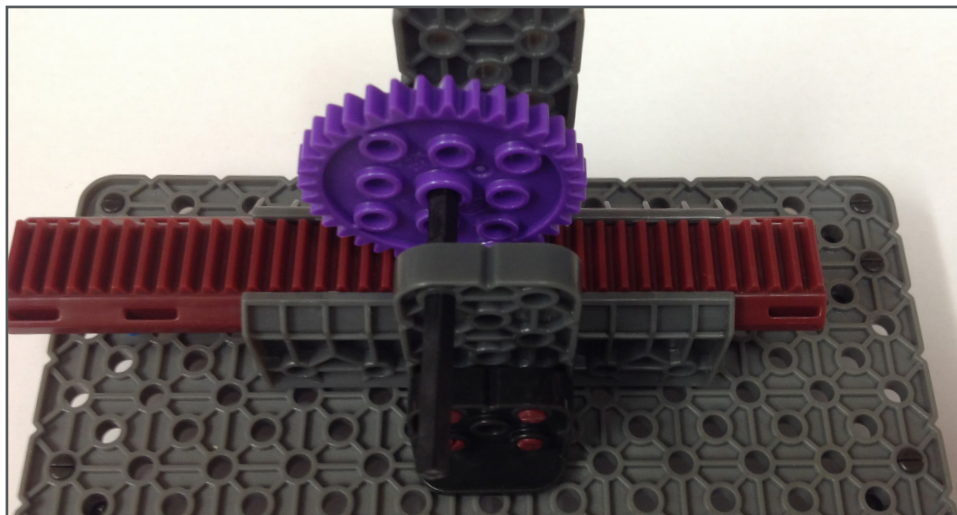
Rack & Pinion

A rack and pinion is a type of linear actuator that utilises a pair of gears which convert rotational motion into linear motion. A circular gear called "the pinion" engages teeth on a linear gear bar called "the rack". Rotational motion applied to the pinion causes the rack to move relative to the pinion, thereby translating the rotational motion of the pinion into linear motion.

Practical Task

You will need:

- 1 x 6x12 Plate
- 8 x 1x1 Connector Pins
- 1 x Axle
- 2 x Rack Guides
- 2 x 2x2 Corner Connector
- 2 x Rack Sections
- 1 x 2x4 Beam
- 1 x 2x6 Beam
- 1 x 36 Tooth Spur Gear



Questions

1. *How could this system be utilised on a traditional railway? Hint: think steep hills.*
2. *Try to think of another application of the rack and pinion system and explain why it is useful for this application. Use sketches and diagrams to help to explain your answer.*





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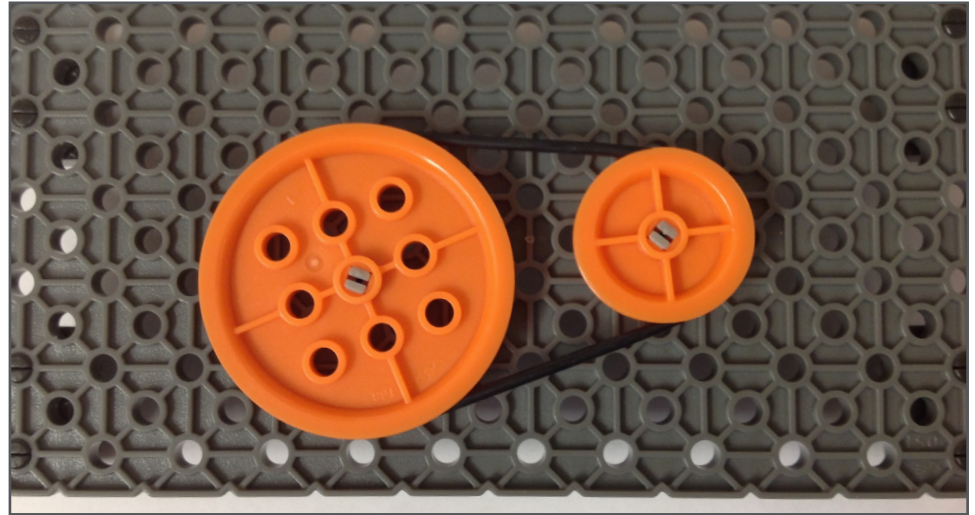
Belt & Pulley

Pulleys can be used to change the speed and direction of rotation, turning force or torque. A pulley system consists of two pulley wheels, each on a shaft and connected by a belt. The belt transmits rotary motion and force from the input or driver shaft, to the output or driven shaft. A belt is a loop of flexible material used to mechanically link two or more rotating shafts which are often parallel. Belts may be used as a source of motion, to transmit power efficiently, or to track relative movement. Belts are looped over pulleys and may have a twist between the pulleys, meaning that the shafts need not be parallel.

Practical Task

You will need:

- 1 x 6x12 Plate
- 2 x Idler Pins
- 1 x $\text{\O}45\text{mm}$ Pulley
- 1 x $\text{\O}25\text{mm}$ Pulley
- 1 x Large Belt



Questions

1. *What are the advantages of a pulley system compared to a gear train?*
2. *Try replacing the belt but this time create a twist in the middle so that it creates a figure 8 between the two pulleys. What do you notice about the direction of rotation of the driven pulley compared to the driver?*
3. *What are the potential disadvantages of a belt and pulley system compared to other systems?*





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Chain & Sprocket

A sprocket or sprocket-wheel is a profiled wheel with teeth, cogs, or even sprockets that mesh with a chain, track or other perforated or indented material. The name 'sprocket' applies generally to any wheel upon which radial projections engage a chain passing over it. It is distinguishable from a gear as sprockets are never meshed together directly. A sprocket differs from a pulley because sprockets have teeth and pulleys are smooth.

Practical Task

You will need:

- 1 x 6x12 Plate
- 2 x Axles
- 1 x 24 Tooth Sprocket
- 1 x 16 Tooth Sprocket
- 1 x Chain



Questions

1. *What are the advantages of a chain and sprocket system compared to the belt and pulley system?*
2. *Where could you typically find this system and why is it used for that application?*
3. *What are the potential disadvantages of this system compared to other systems?*





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Extension Task 1

Create a system capable of converting rotary motion through 90° . Your system must have a ratio of at least 1:4 from the first driver input to the final driven output and must span at least 100mm from input to output.

Parts List

I used:

Affix a picture of your system here.

My Solution

Use this space to explain your solution. Use sketches and diagrams to help explain your reasoning.





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Extension Task 2

Create a system capable of transmitting rotary motion to linear motion. Gear trains are not permitted and the linear motion should fully extend after one full rotation at the input.

Parts List

I used:

Affix a picture of your system here.

My Solution

Use this space to explain your solution. Use sketches and diagrams to help explain your reasoning.





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Extension Task 2

Create a continuous system combining as many different systems as possible. Demonstrate your understanding of the systems that you have learnt and how they can be combined to transfer motion.

Parts List

I used:

Affix a picture of your system here.

My Solution

Use this space to explain your solution. Use sketches and diagrams to help explain your reasoning.

