Gears and Gear Ratios

Introduction to Robotics

Gears – What are they?

Gears are wheels with teeth. Gears mesh together and make things turn. Gears are used to transfer motion or power from one moving part to another.

Gears – The Purpose

Gears are generally used for one of four different reasons:

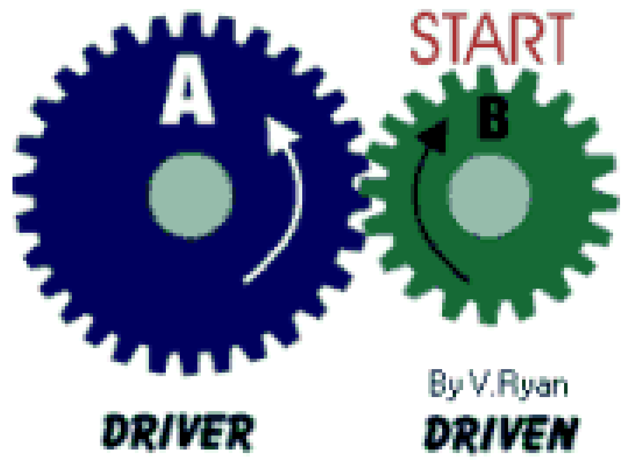
- To reverse the direction of rotation
- To increase or decrease the speed of rotation
- To move rotational motion to a different axis
- To keep the rotation of two axis synchronized

Gears – The Purpose

Sports cars go fast (have speed) but cannot pull any weight. Big trucks can pull heavy loads (have power), but cannot go fast. Gears cause this. Gears increase or decrease the power or speed, but you cannot generally speaking.

Types of Gears

Spur gears are gears in the same plane that move opposite of each other because they are meshed together. Gear ‘A’ is called the ‘driver’ because this is turned by a motor. As gear ‘A’ turns it meshes with gear ‘B’ and it begins to turn as well. Gear ‘B’ is called the ‘driven’ gear.

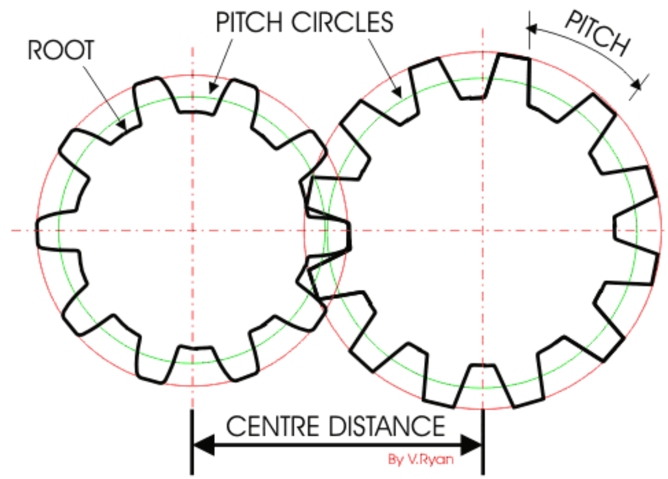


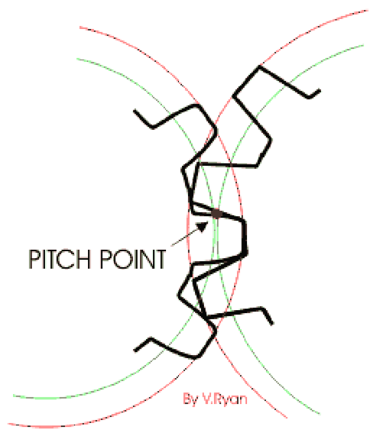
Gear Details(Spur)

The circle marked in red shows the outer limit of the teeth whilst the green circles are known as the pitch circles. The pitch circle of a gear is very important as it is used by engineers to determine the shape of the teeth and the ratio between gears (ratios will be explained later).

The pitch of a gear is the distance between any point on one tooth and the same point on the next tooth.

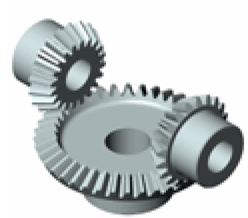
The root is the bottom part of a gear wheel.





The pitch point is the point where gear teeth actually make contact with each other as they rotate.

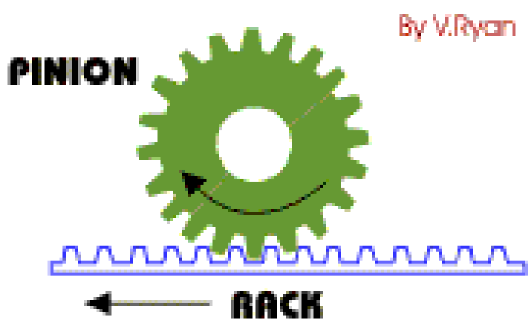
Types of Gears

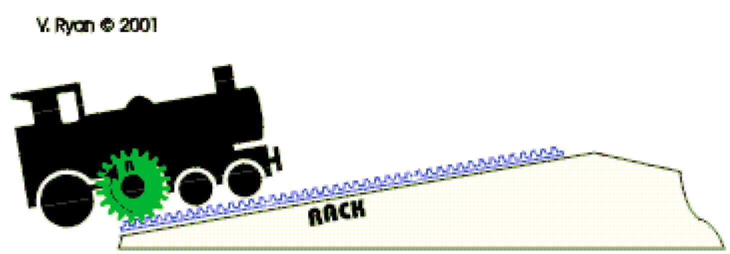


Bevel gears can be used to change the direction of drive in a gear system by 90 degrees. A good example is seen as the main mechanism for a hand drill. As the handle of the drill is turned in a vertical direction, the bevel gears change the rotation of the chuck to a horizontal rotation

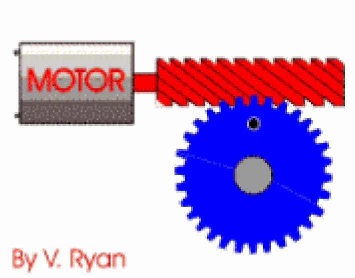
Types of Gears

A ‘rack and pinion’ gears system looks quite unusual. However, it is still composed of two gears. The ‘pinion’ is the normal round gear and the ‘rack’ is straight or flat. The ‘rack’ has teeth cut in it and they mesh with the teeth of the pinion gear.



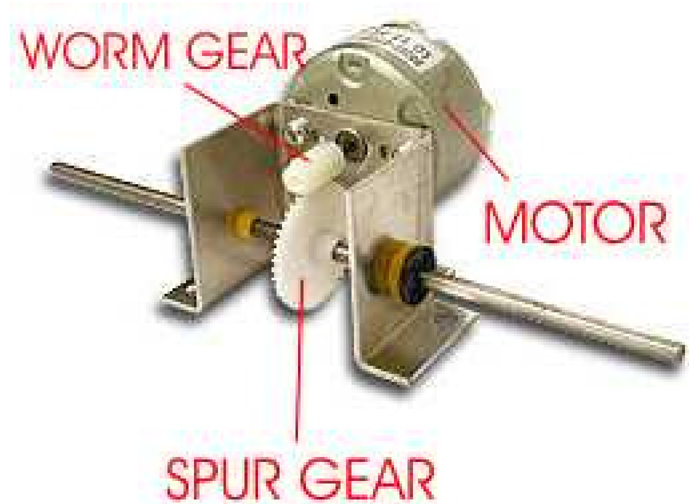


The pinion rotates and moves the rack in a straight line - another way of describing this is to say <u>‘rotary motion’ changes to ‘linear motion’.</u>

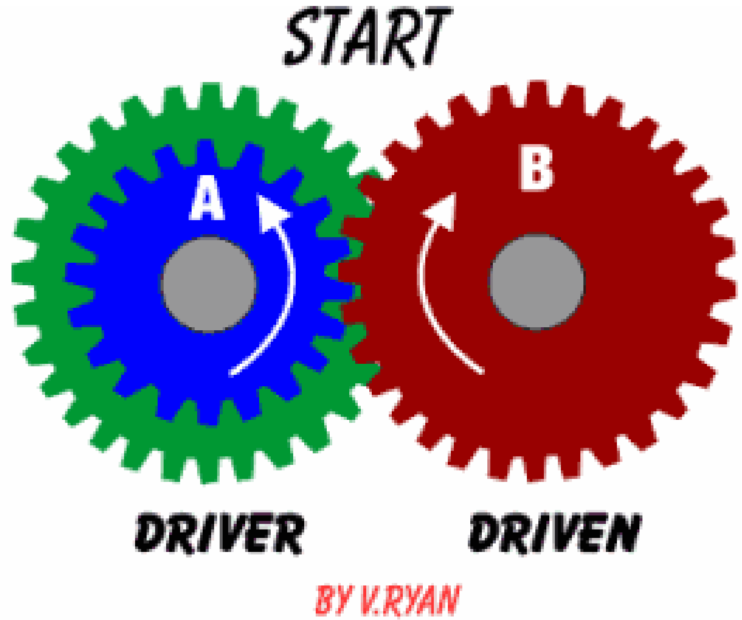


Types of Gears

The arrangement of gears seen is called a *worm* and *wormwheel*. The worm, which in this example is brown in color, only has one tooth but it is like a screw thread. The wormwheel, colored yellow, is like a normal gear wheel or spur gear. The worm always drives the worm wheel round, it is never the opposite way round as the system tends to lock and jam.

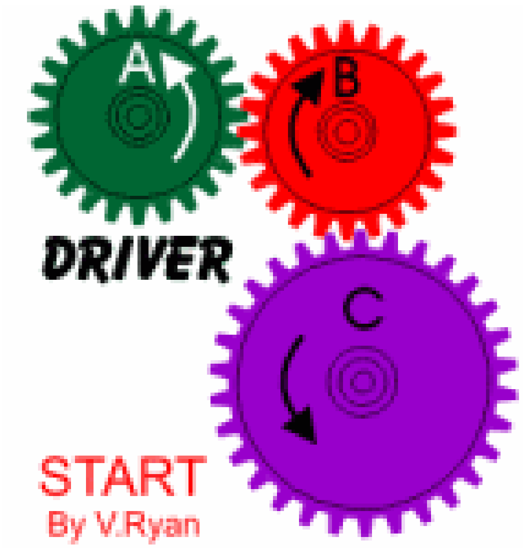


Gear Systems



Compound gears are used in engines, workshop machines and in many other mechanical devices. In the diagram, gear 'A' is actually two gears attached to each other and they rotate around the same centre. Sometimes compound gears are used so that the final gear in a gear train rotates at the correct speed.

Gear Systems



This is a good example of a 'gear train'. A gear train is usually made up of two or more gears. The driver in this example is gear 'A'. If a motor turns gear 'A' in an anticlockwise direction;

Which direction does gear 'B' turn ? Clockwise

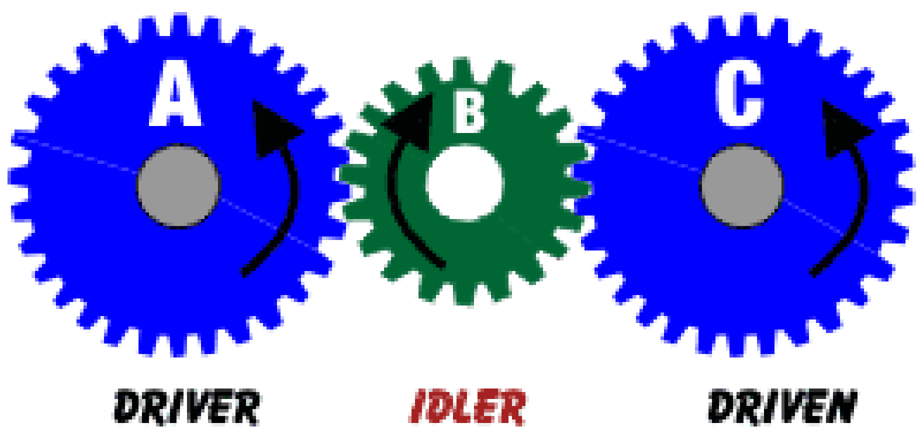
Which direction does gear 'C'' turn ? Counter-Clockwise

Does gear 'C' revolve faster or slower than gear 'A ? - explain your answer.'

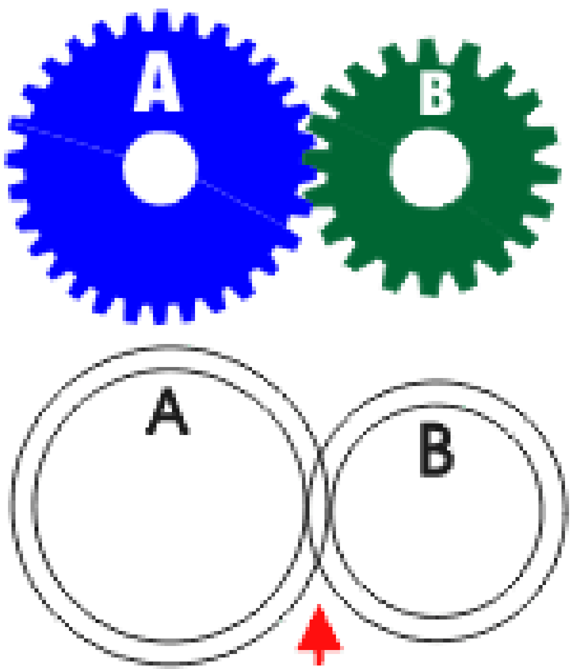
SLOWER – SMALLER GEAR TURNS A LARGER GEAR

Gear Systems

So far you have learned about ‘driver’ gears, ‘’driven’ gears and gear trains. An ‘idler’ gear is another important gear. In the example opposite gear ‘A’ turns in an anticlockwise direction and also gear ‘C’ turns in an anticlockwise direction. The ‘idler’ gear is used so that the rotation of the two important gears is the same.



Drawing Gears

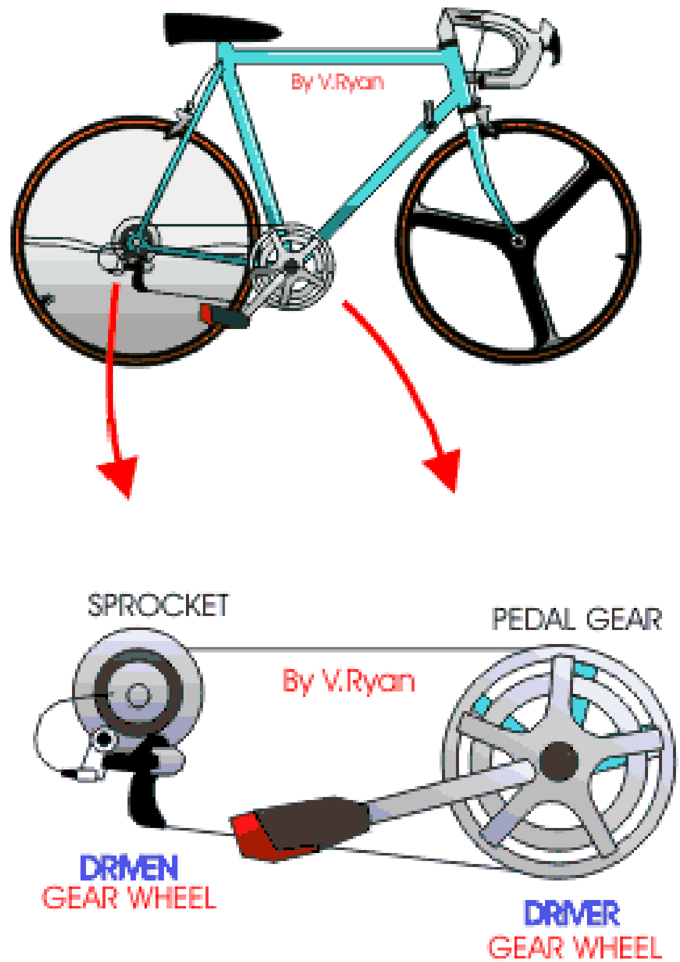


CIRCLES OVERLAP WHERE TEETH MESH

It would be very difficult to draw gears if you had to draw all the teeth every time you wanted to design a gear system. For this reason a gear can be represented by drawing two circles.

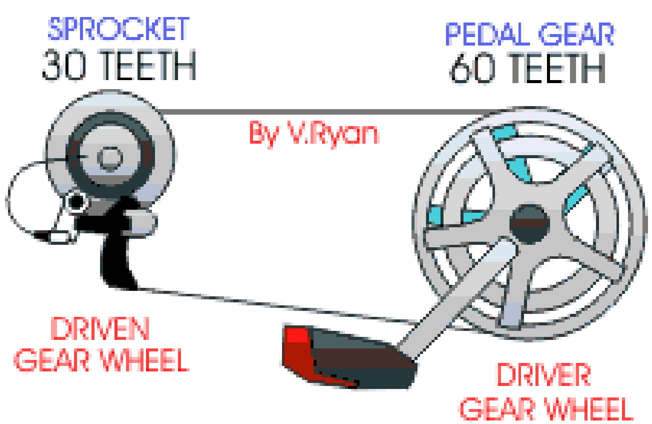
Gear Ratio(Velocity Ratio)

Many machines use gears. A very good example is a bicycle which has gears that make it easier to cycle, especially up hills. Bicycles normally have a large gear wheel which has a pedal attached and a selection of gear wheels of different sizes, on the back wheel. When the pedal is revolved the chain pulls round the gear wheels at the back.



Gear Ratio(Velocity Ratio)

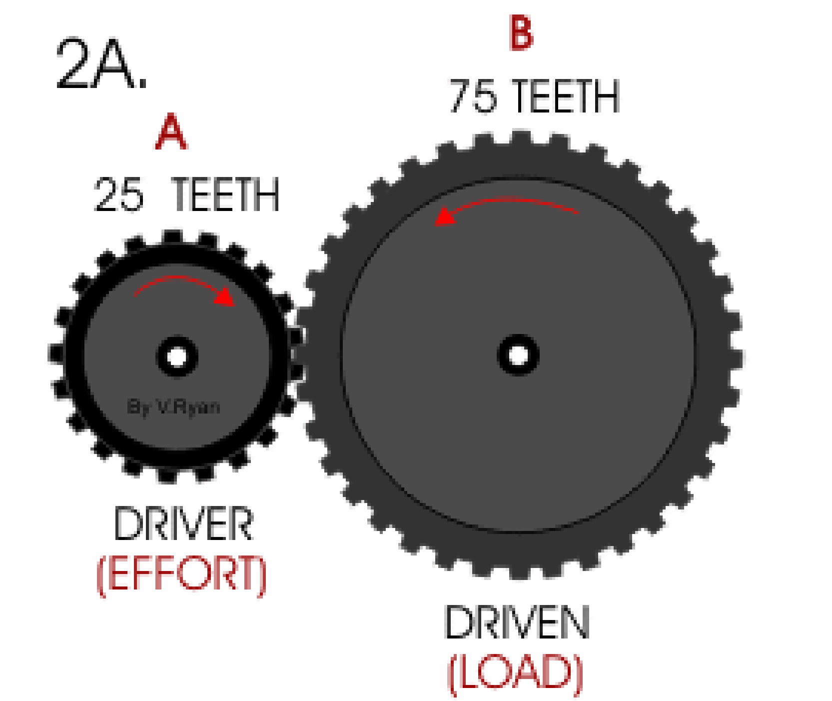
The reason bicycles are easier to cycle up a hill when the gears are changed is due to what is called Gear Ratio (velocity ratio). Gear ratio can be worked out in the form of numbers and examples are shown. Basically, the ratio is determined by the number of teeth on each gear wheel, the chain is ignored and does not enter the equation.



$$\frac{Driven}{Driving} = \frac{30}{60} = \frac{1}{2} \rightarrow 1:2$$

But WHAT does this mean? It means that the DRIVEN gear makes TWO rotations for every ONE rotation of the Driving Gear.

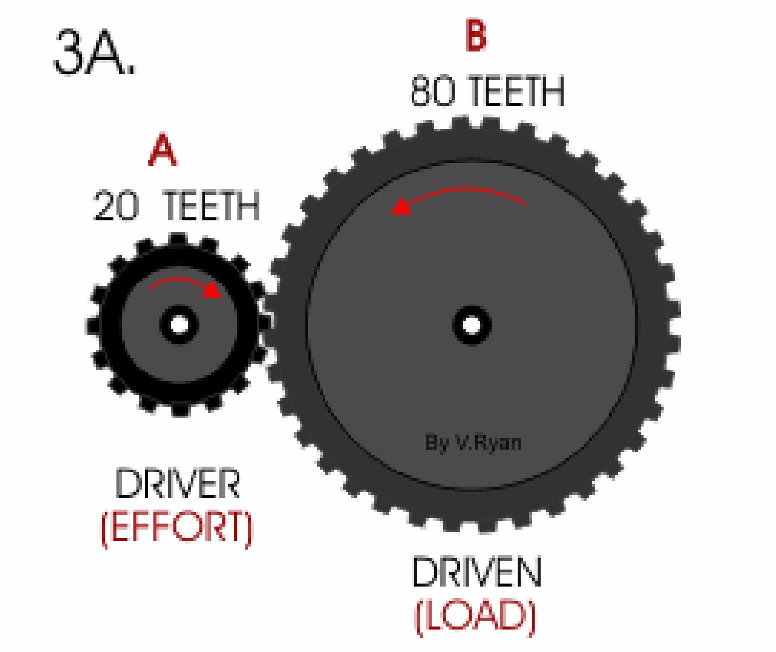
Gear Ratio - Examples



$$\frac{Driven}{Driving} = \frac{75}{25} = \frac{3}{1} \rightarrow 3:1$$

What does this mean? For every 3 rotations of the driving gear, the driven gear makes one rotation.

Gear Ratio - Examples

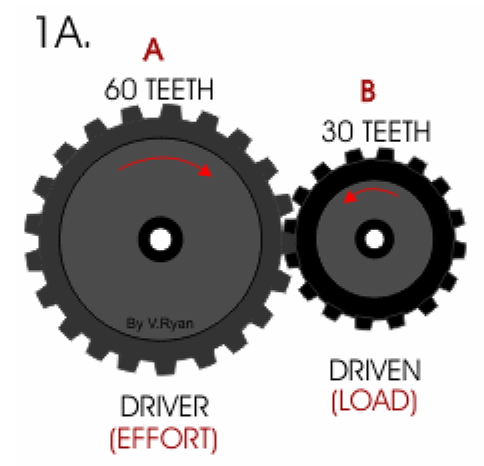


$$\frac{Driven}{Driving} = \frac{80}{20} = \frac{4}{1} \rightarrow 4:1$$

What does this mean? For every 4 rotations of the driving gear, the driven gear makes 1 rotation.

Working out RPMs (revolutions per minute)

In the example shown, the DRIVER gear is larger than the DRIVEN gear. The general rule is - large to small gear means 'multiply' the velocity ratio by the rpm of the first gear. Divide 60 teeth by 30 teeth to find the velocity ratio(1:2). Multiply this number (2) by the rpm (120). This gives an answer of 240rpm



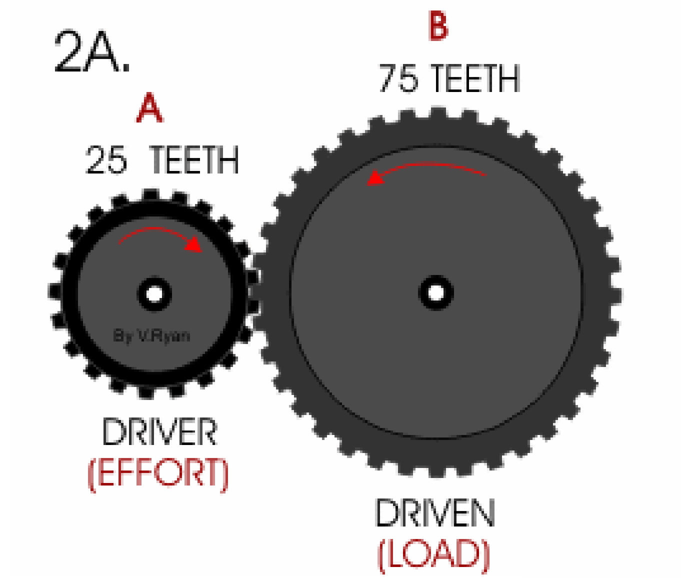
GEAR A	GEAR B
60 teeth	30 teeth
120 rpm	?

$$\frac{60}{30} = 2$$

$$= 120 \text{ X } 2 = 240 \text{ revs/min}$$

Working out RPMs (revolutions per minute)

In the example shown, the DRIVER gear is smaller than the DRIVEN gear. The general rule is - small to large gear means 'divide' the velocity ratio(3:1) by the rpm of the first gear. Divide 75 teeth by 25 teeth to find the velocity ratio. divide the 60rpm by the velocity ration (3). The answer is 20rpm.



GEAR A	GEAR B
25 teeth	75 teeth
60 rpm	?

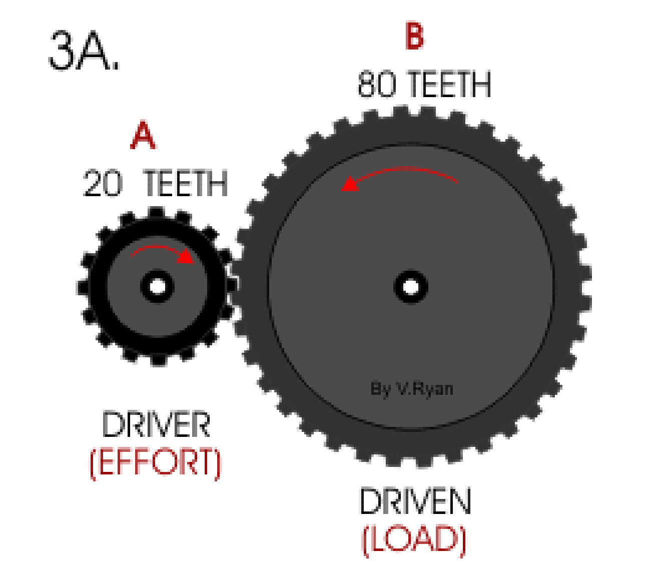
$$\frac{75}{25} = 3$$

$$= \frac{60}{3} = 20 \text{ revs/min}$$

Working out RPMs (revolutions per minute)

If A revolves at 100 revs/min what is B ?

(Remember small gear to large gear decreases revs)



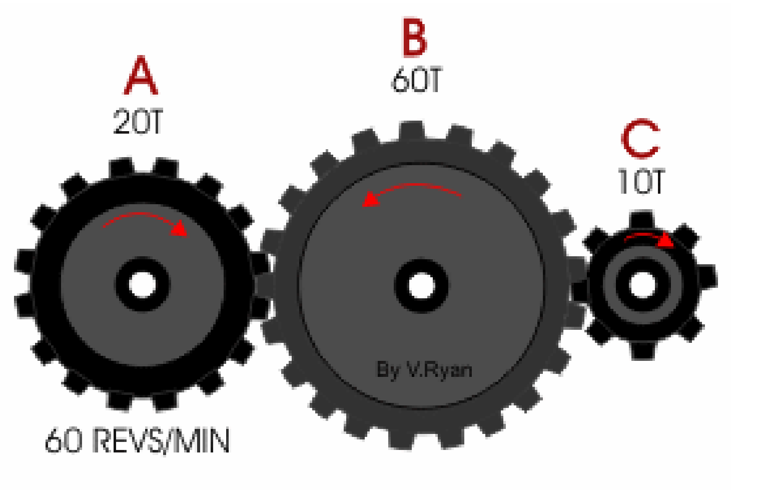
GEAR A	GEAR B
20 teeth	80 teeth
100 rpm	?

$$\frac{80}{20} = 4$$

$$= \frac{100}{4} = 25 \text{ revs/min}$$

Compound Gear Ratios

When faced with three gears the question can be broken down into two parts. First work on Gears *A* and *B*. When this has been solved work on gears *B* and *C*.

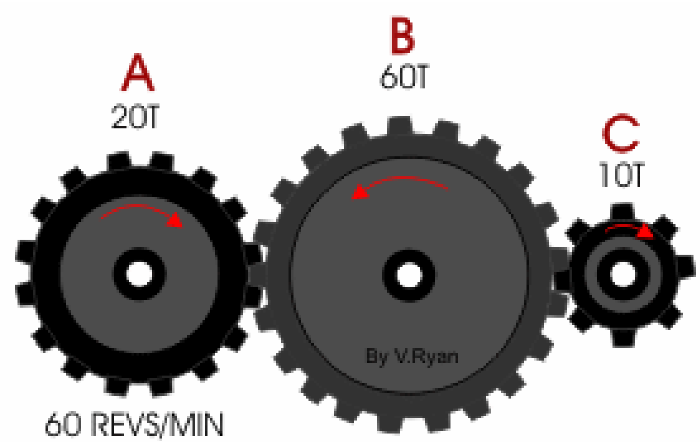


The diagram shows a gear train composed of three gears. Gear A revolves at 60 revs/min in a clockwise direction.

What is the output in revolutions per minute at Gear C?

In what direction does Gear C revolve ?

Compound Gear Ratios



GEAR A	GEAR B	GEAR C
20 teeth	60 teeth	10 teeth

$$\frac{Driven}{Driving} = \frac{60}{20} = \frac{3}{1} \rightarrow 3:1$$

This means that for every THREE revolutions of GEAR A, Gear B travels once. Since we are going from a SMALLER gear to a LARGER gear we DIVIDE the Rpms.

$$\frac{60\ rev/\min}{3} = 20\ rev/\min$$

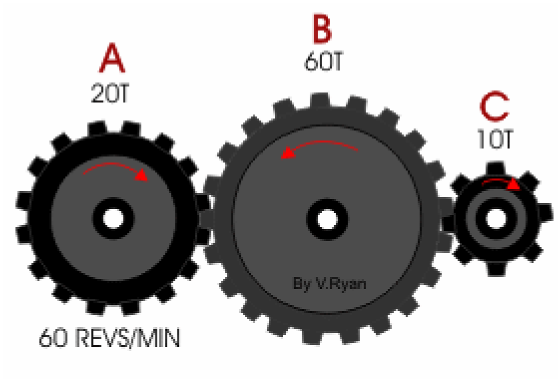
Now find the gear ratio for B & C.

$$\frac{Driven}{Driving} = \frac{10}{60} = \frac{1}{6} \rightarrow 1:6$$

This means for every ONE rotation of gear B, gear C makes SIX rotations.

$$20\ rev/\min \bullet 6 = 120\ rev/\min$$

Is there an easier way?



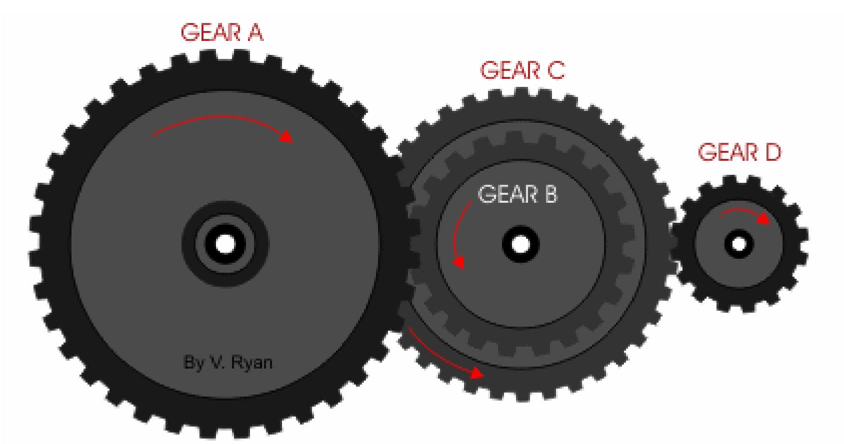
$$\frac{Driven}{Driving} = \frac{60}{20} \bullet \frac{10}{60} = \frac{10}{20} = \frac{1}{2} \rightarrow 1:2$$

You can also multiply the two gear ratios together to get the TOTAL gear ratio. In the above figure we see that gear C will make TWO rotations for every one rotation of gear A. And since gear C is smaller than gear A we multiply.

$$60\,rev/\min \bullet 2 = 120\,rev/\min$$

Compound Gear Ratios

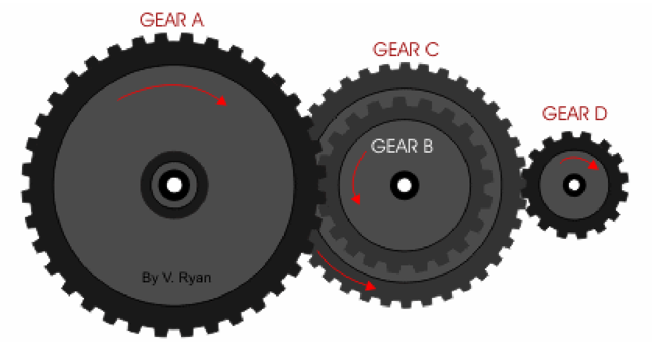
Below is a question regarding '*compound gears*'. Gears C and B represent a compound gear as they appear 'fixed' together. When drawn with a compass they have the same centre. Two gears 'fixed' together in this way rotate together and at the same RPM. When answering a question like this split it into two parts. Treat gears **A** and **B** as one question *AND* **C** and **D** as the second part**.**



What is the output in revs/min at D and what is the direction of rotation if Gear A rotates in a clockwise direction at 30 revs/min?

Compound Gear Ratios

Gear A	Gear B	Gear C	Gear D
120 teeth	40 teeth	80 teeth	20 teeth



$$\frac{Driven}{Driving} = \frac{40}{120} = \frac{1}{3}$$

$$\frac{Driven}{Driving} = \frac{20}{80} = \frac{1}{4}$$

Considering that Gear B is smaller than Gear A we can conclude that the RPMs for gear B is 30*3 = 90 rev/min

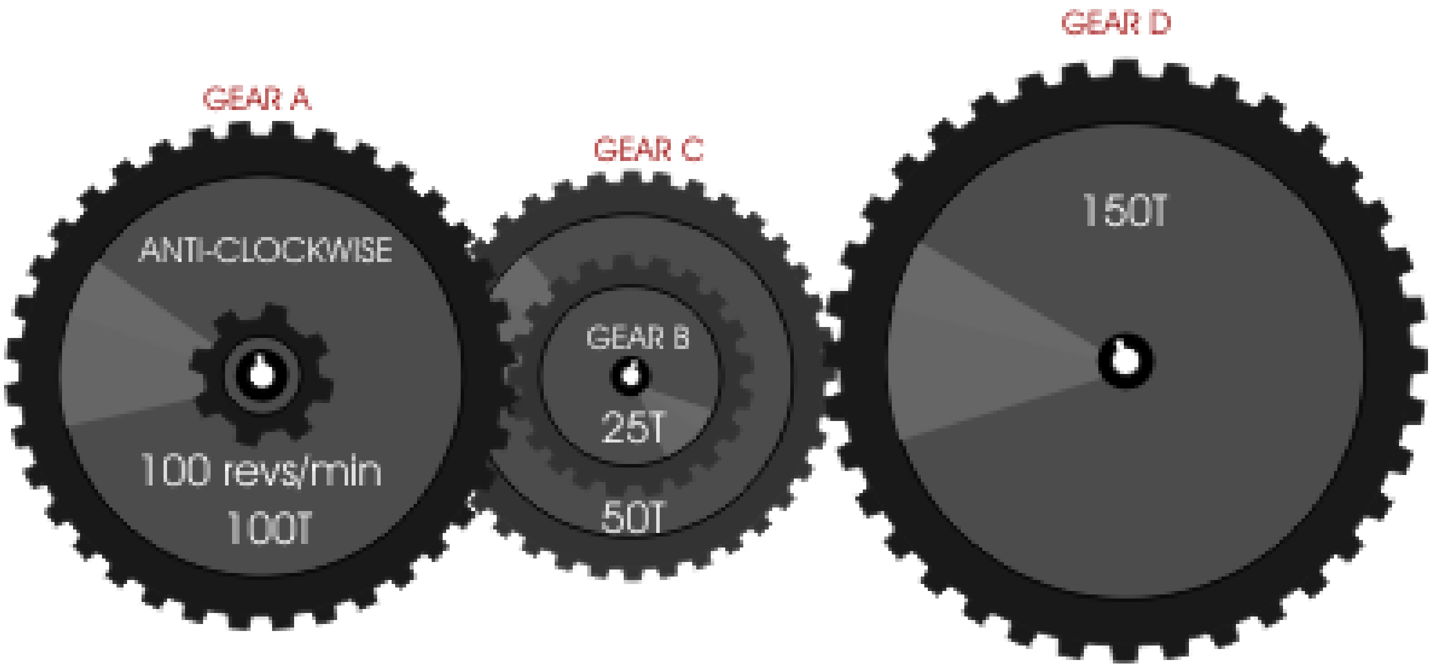
Since Gear B is at 90rev/min and has the SAME rotational speed as gear C Multiply by 4 to get Gear D's speed. Thus, Gear D moves at 90*4 = 360 rev/min

OR

$$\frac{1}{3} \bullet \frac{1}{4} = \frac{1}{12}$$

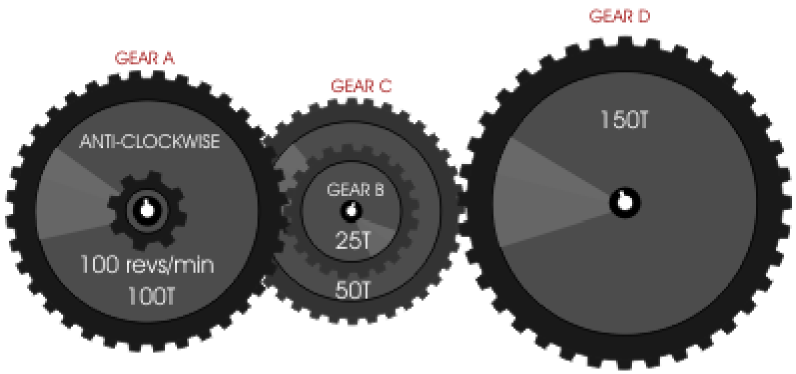
Since Gear A moves at 30rpms and Gear D is SMALLER. We multiply by 12. 30*12 = 360 rev/min

Try this one



What is the revs/min at gear D and what is its direction?

Answer



What is the revs/min at gear D and what is its direction?

Gear A	Gear B	Gear C	Gear D
100T	25T	50T	150T
100 rpm			

$$\frac{Driven}{Driving} = \frac{25}{100} = \frac{1}{4} \rightarrow 1:4$$

$$100 \bullet 4 = 400rpm = gear\ b$$

$$\frac{Driven}{Driving} = \frac{150}{50} = \frac{3}{1} \rightarrow 3:1$$

$$\frac{400}{3} = 133.3rpm = gear\ D$$

If Gear A turns CCW, then gear B turns CW along with gear C as they are a compound gear. Therefore, **Gear D rotates CCW.**