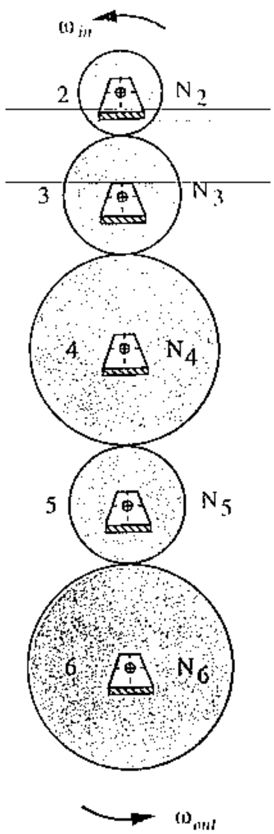
Gear Trains

Simple Trains—Gear axes are parallel



What is the gear ratio of this train?

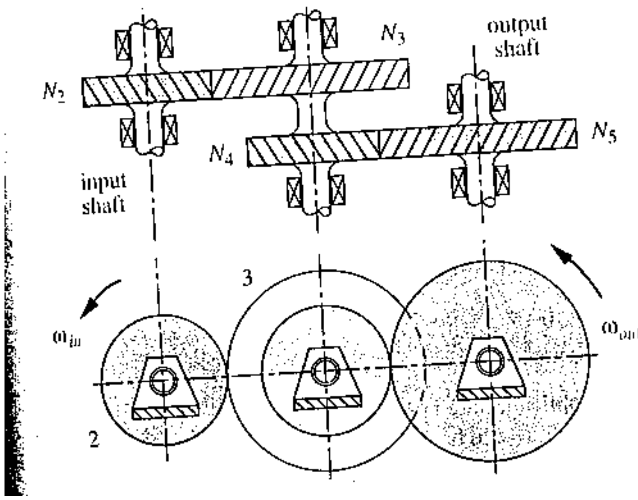
$$\frac{w_{out}}{w_{in}} = \frac{-N_2}{N_3}\frac{-N_3}{N_4}\frac{-N_4}{N_5}\frac{-N_5}{N_6}$$

$$\frac{w_{out}}{w_{in}} = \frac{N_2}{N_6}$$

What is the negative sign all about?

What is an idler gear and why would an engineer use an idler in a train?

Compound Trains



At least one shaft carries more than one gear.

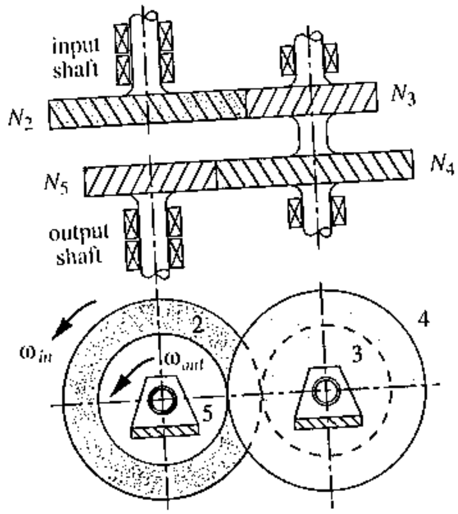
What is the gear ratio of this train?

$$\frac{w_{out}}{w_{in}} = \frac{-N_2}{N_3}\frac{-N_4}{N_5}$$

$$\frac{w_{out}}{w_{in}} = \frac{N_2 N_4}{N_3 N_5}$$

Why would an engineer use a compound train over a simple train?

Reverted Trains



Input and output shafts are coincident—lined up on the same axis.
This is a two stage reverted train—note that the center distance of stage 1 must be equal to the center distance of stage 2

What is the gear ratio of this train?

$$\frac{w_{out}}{w_{in}} = \frac{-N_2}{N_3}\frac{-N_4}{N_5}$$

$$\frac{w_{out}}{w_{in}} = \frac{N_2 N_4}{N_3 N_5}$$

Sample problem:

Design a gear train that is composed of spur gears that has a gear ratio of 29:1. The train must be compound. Gears are cut to exhibit a 25° pressure angle and the module must be 3 mm throughout the train. No gear can have fewer than 12 teeth.

How do we get started on this problem?

Lets assume we can get the 29:1 speed increase in two stages. This means gear 1 on set 1 drives gear 2 on set 2. Gear 2 on set 2 is on the same shaft with gear 3. Gear 3 meshes with gear 4 on set 1. Gears 4 and 1 are in line, and gears 2 and 3 are on the same shaft. The train will end up being reverted (gear 1 and 3 will be in line and gear 2 and 3 will be in line).

$$\frac{w_{out}}{w_{in}} = \frac{-N_1}{N_2}\frac{-N_3}{N_4}$$

$$\frac{w_{out}}{w_{in}} = \frac{N_1 N_3}{N_2 N_4}$$

The reduction of 29:1 occurs in two stages; therefore

$$\frac{w_{out}}{w_{in}} = \frac{-N_1}{N_2}\frac{-N_3}{N_4}$$

$$\sqrt{29} = 5.385$$

Also, we know that the number of teeth on each gear must be an integer. The minimum number of teeth is 12. Let's start with 12 and see how close we can come to a second number that is an integer

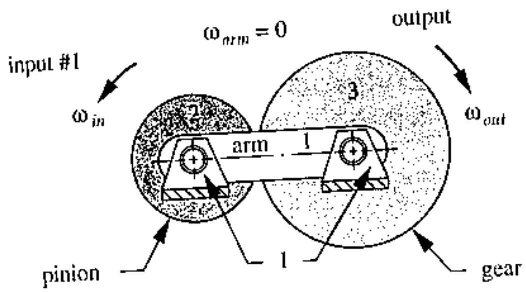
12*5.385 = 64.622
13*5.385 = 70.007
14*5.385 = 75.392

Use 13 and 70

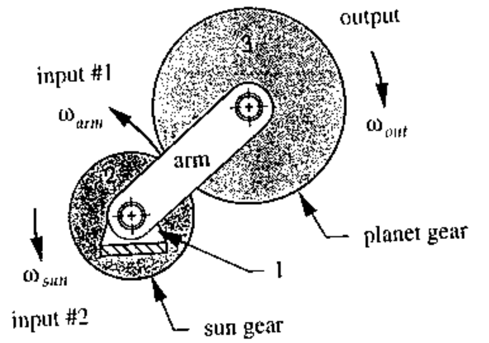
N 1 = 70
N 2 = 13
N 3 = 70
N 4 = 13

(70/13)*(70/13) = 28.99

Epicyclic Trains



(a) Conventional gearset



(b) Planetary or epicyclic gearset

Epicyclic trains give the engineer an opportunity to produce huge speed reductions (or increases) in a relatively small space. Epicyclic trains are also called "planet gears"; one gear, the planet, orbits around a "sun."

They are more difficult to analyze because they are a **two degree of freedom system**.

What is meant by a degree of freedom?

How many degrees of freedom does a 3D object possess?

In analyzing epicyclic trains, we need to use relative velocity equations.

$$w_{gear} = w_{arm} + w_{gear/arm}$$

We will still find the gear ratio, by dividing velocities, but we have to do it like this:

$$w_{first\ gear} = w_{arm} + w_{firstgear/arm}$$

$$w_{last\ gear} = w_{arm} + w_{last\ gear/arm}$$

$$\frac{w_L}{w_F} = \frac{w_{arm} - w_{L/arm}}{w_{arm} - w_{F/arm}}$$

$$\pm \frac{product\ \#\ teeth\, drivers}{product\ \#\ teeth\, driven} = \frac{w_L - w_{arm}}{w_F - w_{arm}}$$

Example

Determine the train ratio for the epicyclic train shown below. The ring gear is stationary and the arm rotates at 1 RPM.

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$$\frac{-40}{20}\frac{20}{80}=\frac{w_L - w_A}{w_F - w_A}=\frac{0-1}{w_F - 1}$$
$$w_F = 3$$