GEAR TRAINS

NILESH PANCHOLI
B.E. (Mech.), M.E. (Mech.), Ph. D.
Email: *nhpancholi@gmail.com*
www.nileshpancholi.com

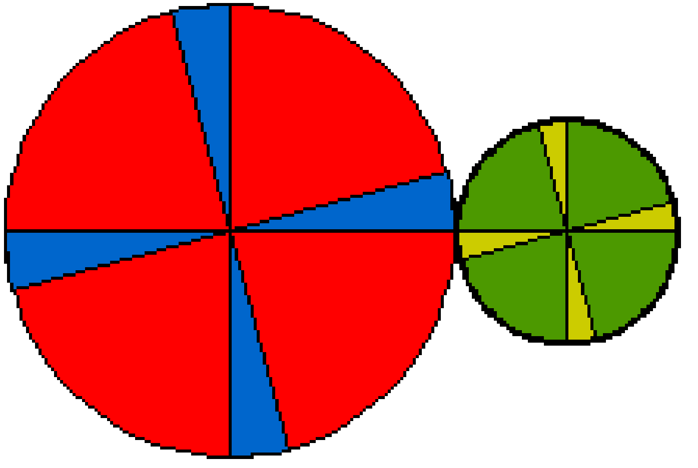
Gear Trains

A gear train is two or more gear working together by meshing their teeth and turning each other in a system to generate power and speed. It reduces speed and increases torque. To create large gear ratio, gears are connected together to form gear trains. They often consist of multiple gears in the train.

The most common of the gear train is the gear pair connecting parallel shafts. The teeth of this type can be spur, helical or herringbone. The angular velocity is simply the reverse of the tooth ratio.

Gear Trains

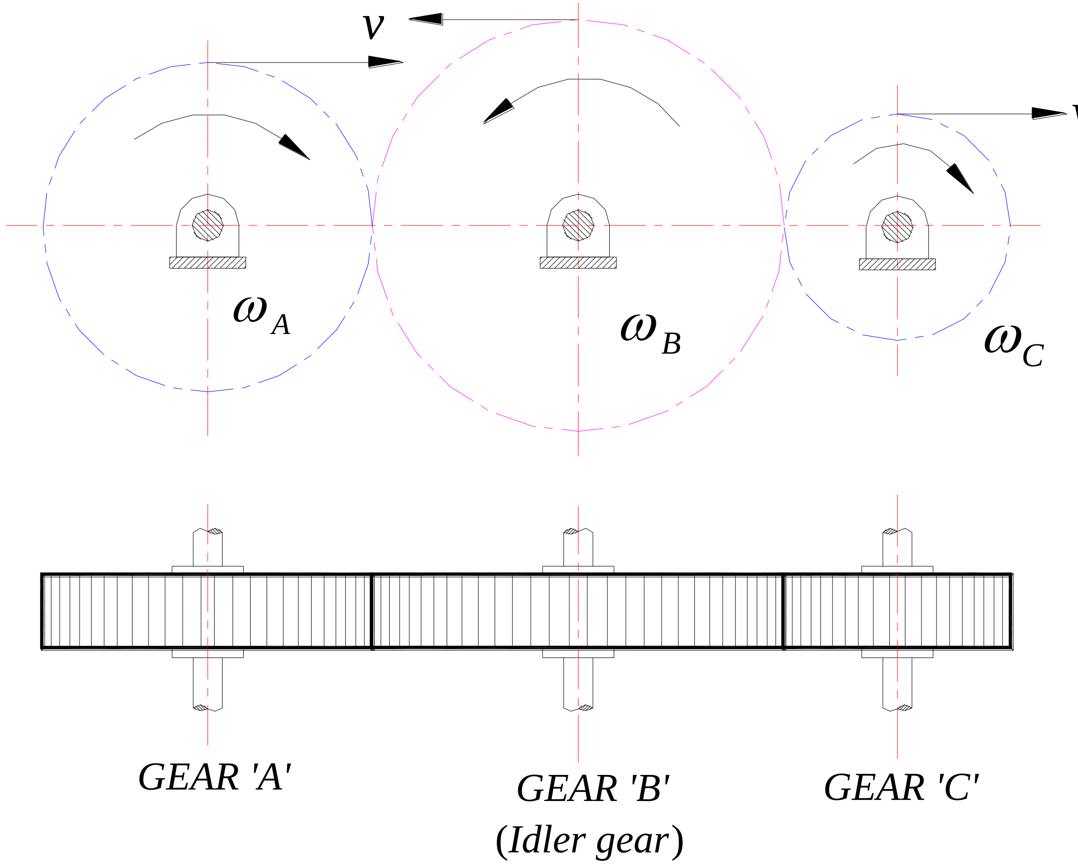
Any combination of gear wheels employed to transmit motion from one shaft to the other is called a gear train. The meshing of two gears may be idealized as two smooth discs with their edges touching and no slip between them. This ideal diameter is called the Pitch Circle Diameter (PCD) of the gear.



Copyright 1998 by Marshall Brain

Simple Gear Trains

Simple Gear Trains



Simple Gear Trains

The typical spur gears as shown in diagram. The direction of rotation is reversed from one gear to another.

The only function of the idler gear is to change the direction of rotation.

It has no affect on the gear ratio. The teeth on the gears must all be the same size so if gear A advances one tooth, so does B and C.

Simple Gear Trains

t = *number of teeth on the gear,*

D = *Pitch circle diameter,* N = *speed in rpm*

$$m = \text{module} = \frac{D}{t}$$

and

module *must be the same for all*

gears otherwise they would not mesh.

Simple Gear Trains

$$m = \frac{D_A}{t_A} = \frac{D_B}{t_B} = \frac{D_C}{t_C}$$

$$D_A = m\,t_A; \qquad D_B = m\,t_B \qquad and \qquad D_C = m\,t_C$$

$$\omega = angular\ velocity.$$

$$v = linear\ velocity\ on\ the\ circle.\ v = \omega \frac{D}{2} = \omega\, r$$

The velocity v of any point on the circle must be the same for all the gears, otherwise they would be slipping.

Simple Gear Trains

$$v = \omega_A \frac{D_A}{2} = \omega_B \frac{D_B}{2} = \omega_C \frac{D_C}{2}$$

$$\omega_A D_A = \omega_B D_B = \omega_C D_C$$

$$\omega_A m \, t_A = \omega_B m \, t_B = \omega_C m \, t_C$$

$$\omega_A \, t_A = \omega_B \, t_B = \omega_C \, t_C$$

$$or \; in \; terms \; of \; rev/\mathrm{min}$$

$$N_A \, t_A = N_B \, t_B = N_C \, t_C$$

Simple Gear Trains

$$\text{The gear ratio is defined as } GR = \frac{Input\ speed}{Output\ speed}$$

If gear A is the input and gear C is the output;

$$\mathrm{GR} = \frac{N_A}{N_C} = \frac{t_C}{t_A} \text{ also called as } Speed\ ratio/Speed\ value$$

$$If\ \frac{N_C}{N_A} = \frac{Speed\ of\ driven\ gear}{Speed\ of\ driver\ gear} \text{ is called the } Train\ value$$

Simple Gear Trains

***Application**:*

a) to connect gears where a large center distance is required

b) to obtain desired direction of motion of the driven gear (CW or CCW)

c) to obtain high speed ratio

Torque & Efficiency

The power transmitted by a torque T N-m applied to a shaft rotating at N rev/min is given by:

$$P = \frac{2\pi N T}{60}$$

In an ideal gear box, the input and output powers are the same so;

$$P = \frac{2\pi N_1 T_1}{60} = \frac{2\pi N_2 T_2}{60}$$

$$N_1 T_1 = N_2 T_2 \quad \Rightarrow \quad \frac{T_2}{T_1} = \frac{N_1}{N_2} = GR$$

Torque & Efficiency

It follows that if the speed is reduced, the torque is increased and vice versa. In a real gear box, power is lost through friction and the power output is smaller than the power input. The efficiency is defined as:

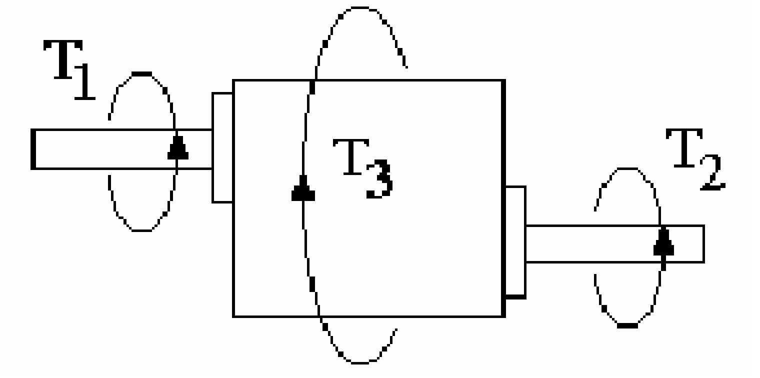
$$\eta = \frac{Power\ out}{Power\ In} = \frac{2\pi \times N_2\, T_2 \times 60}{2\pi \times N_1\, T_1 \times 60} = \frac{N_2\, T_2}{N_1\, T_1}$$

Because the torque in and out is different, a gear box has to be clamped in order to stop the case or body rotating. A holding torque T3 must be applied to the body through the clamps.

Torque & Efficiency

The total torque must add up to zero.

$$T_1 + T_2 + T_3 = 0$$



If we use a convention that anti-clockwise is positive and clockwise is negative we can determine the holding torque. The direction of rotation of the output shaft depends on the design of the gear box.

Problem 1

A gear box has an input speed of 1500 rev/min clockwise and an output speed of 300 rev/min anticlockwise. The input power is 20 kW and the efficiency is 70%. Determine the following.

i. The gear ratio; ii. The input torque.; iii. The output power.; iv. The output torque; v. The holding torque.

Solution:

$$G.R \text{ or } VR = \frac{Input\ speed}{Output\ speed} = \frac{N_1}{N_2} = \frac{1500}{300} = 5$$

$$Input\ Power = \frac{2\pi \times N_1 T_1}{60} \quad \Rightarrow \quad T_1 = \frac{60 \times Input\ Power}{2\pi \times N_1}$$

Problem 1

$$\therefore\ Input\ torque = T_1 = \frac{60\times 20000}{2\pi\times 1500} = 127.3\,N\,m$$

$$(Negative - clockwise)$$

$$\eta = 0.7 = \frac{Output\ \ power}{Inpu\ \ power}$$

$$Power\ \ Output = 0.7\times 20 = 14kW$$

$$\therefore\ Output\ torque = T_2 = \frac{60\times 14000}{2\pi\times 300} = 445.6\,N\,m$$

$$(Positive - unticlockwise)$$

Problem 1

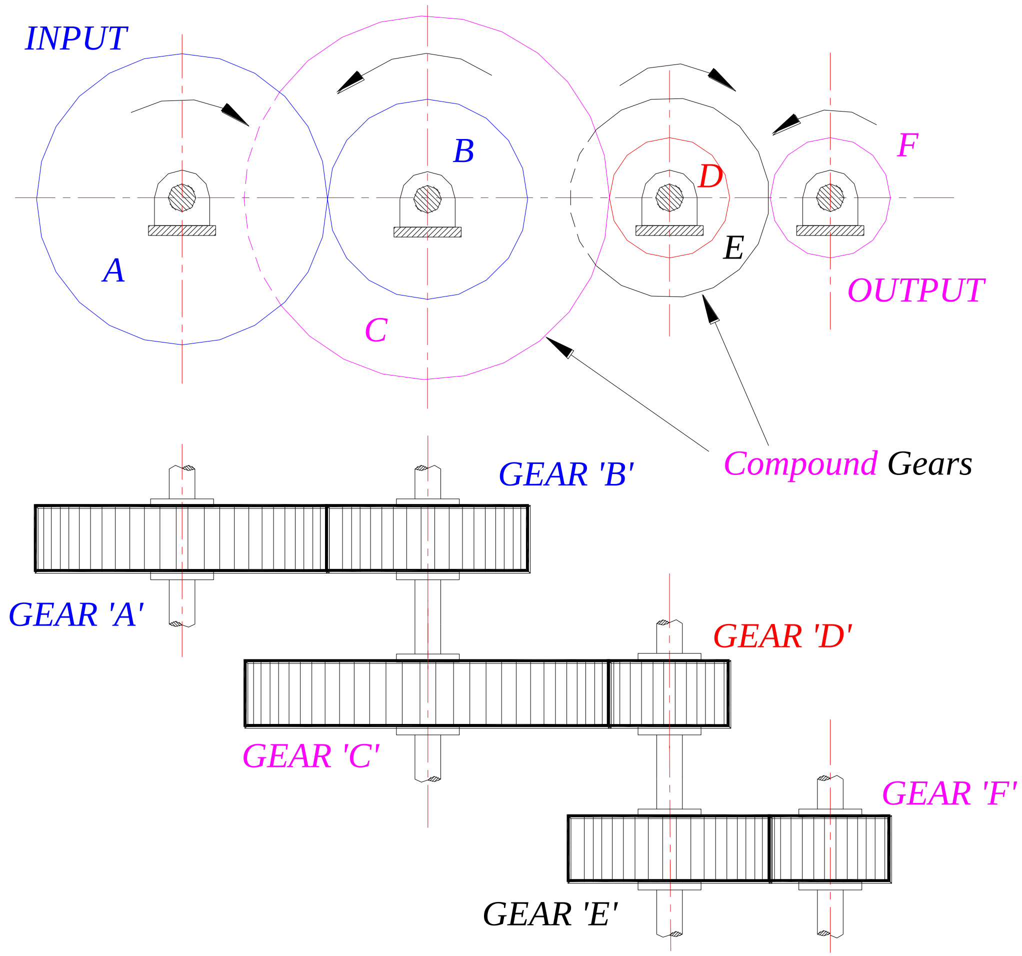
$$\Rightarrow \qquad T_1 + T_2 + T_3 = 0$$

$$-127.3 + 445.6 + T_3 = 0$$

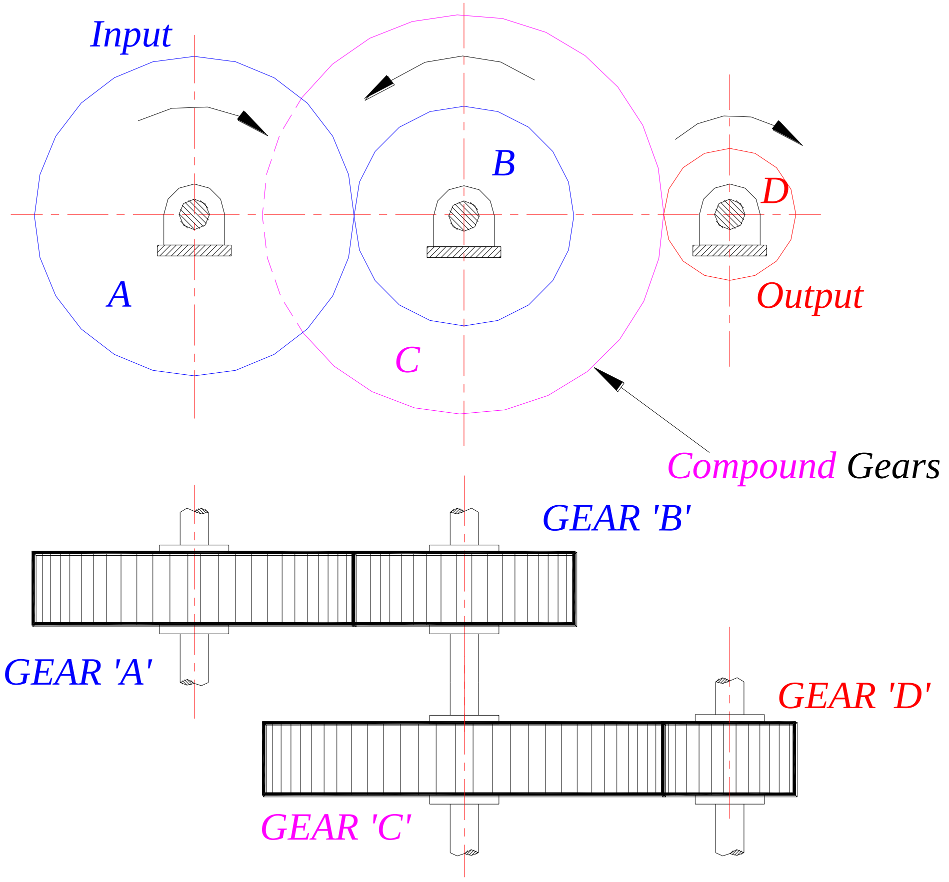
$$T_3 = 127.3 - 445.6 = -318.3\, N\, m$$

$$-Clockwise$$

Compound Gear train



Compound Gear train



Compound Gear train

The velocity of each tooth on A and B are the same so:

$\omega_A t_A = \omega_B t_B$
-as they are simple gears.

Likewise for C and D,
$\omega_C t_C = \omega_D t_D$.

Compound gears are simply a chain of simple gear trains with the input of the second being the output of the first. A chain of two pairs is shown below. Gear B is the output of the first pair and gear C is the input of the second pair. Gears B and C are locked to the same shaft and revolve at the same speed.

For large velocities ratios, compound gear train arrangement is preferred.

Compound Gear train

$$\frac{\omega_A}{t_B} = \frac{\omega_B}{t_A} \quad and \quad \frac{\omega_C}{t_D} = \frac{\omega_D}{t_C}$$

$$\omega_A = \frac{t_B \times \omega_B}{t_A} \quad and \quad \omega_C = \frac{t_D \times \omega_D}{T_C}$$

$$\omega_A \times \omega_C = \frac{t_B \times \omega_B}{t_A} \times \frac{t_D \times \omega_D}{t_C}$$

$$\frac{\omega_A \times \omega_C}{\omega_B \times \omega_D} = \frac{t_B}{t_A} \times \frac{t_D}{t_C}$$

Compound Gear train

$$Since\ gear\ B\ and\ C\ are\ on\ the\ same\ shaft$$

$$\omega_B = \omega_C$$

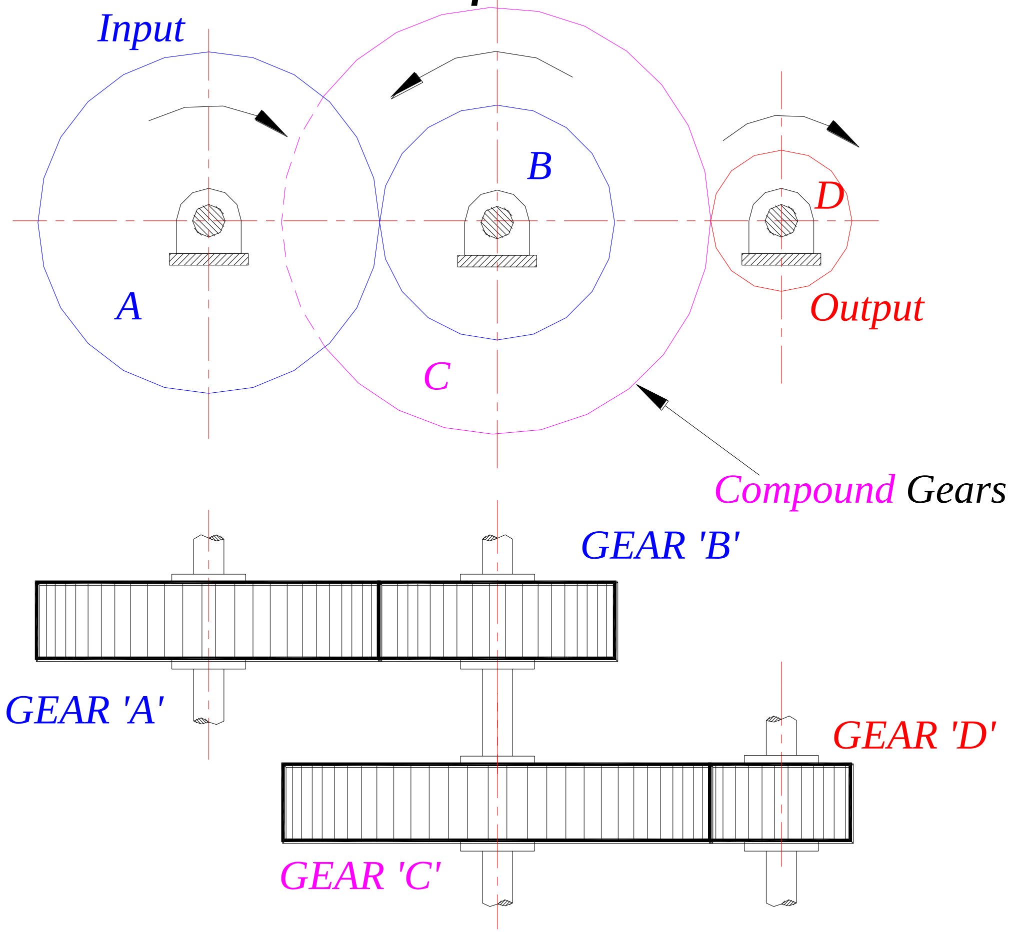
$$\frac{\omega_A}{\omega_D} = \frac{t_B}{t_A} \times \frac{t_D}{t_C} = GR$$

$$Since\ \omega = 2 \times \pi \times N$$

$$The\ gear\ ratio\ may\ be$$

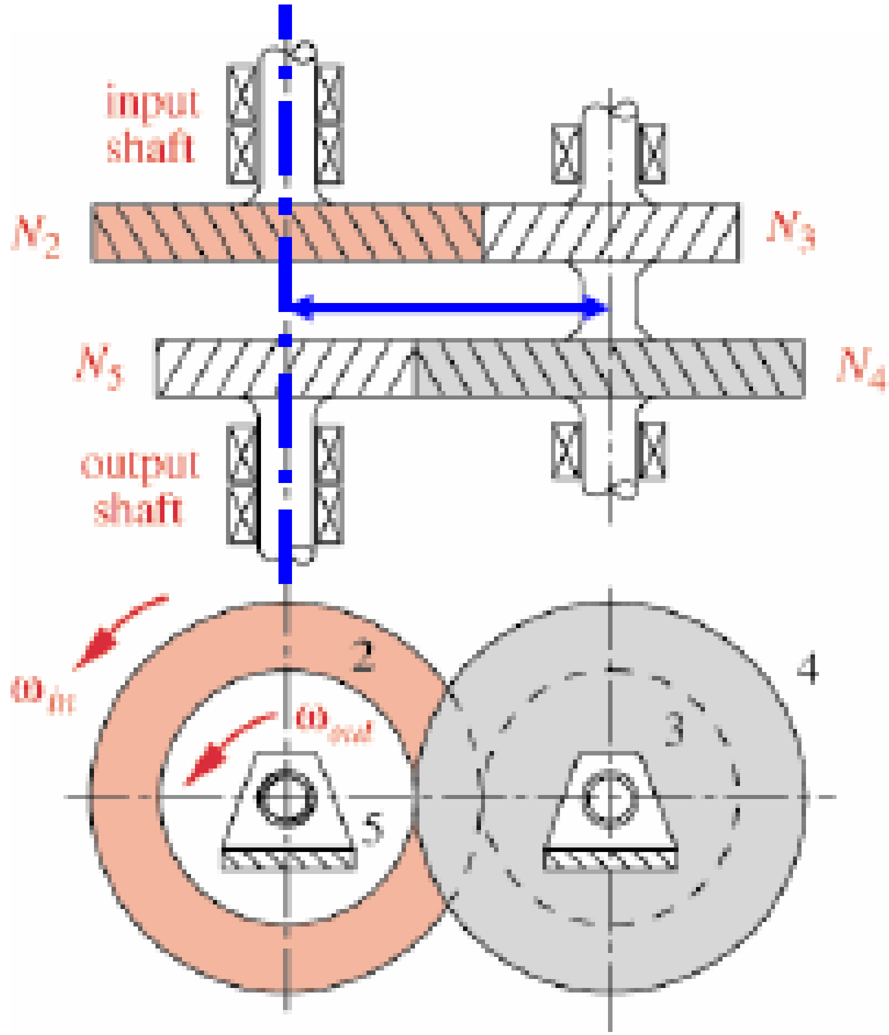
$$written\ as:$$

$$\frac{N(In)}{N(Out)} = \frac{t_B}{t_A} \times \frac{t_D}{t_C} = GR$$



Reverted Gear train

Concentric input & output shafts



Reverted Gear train

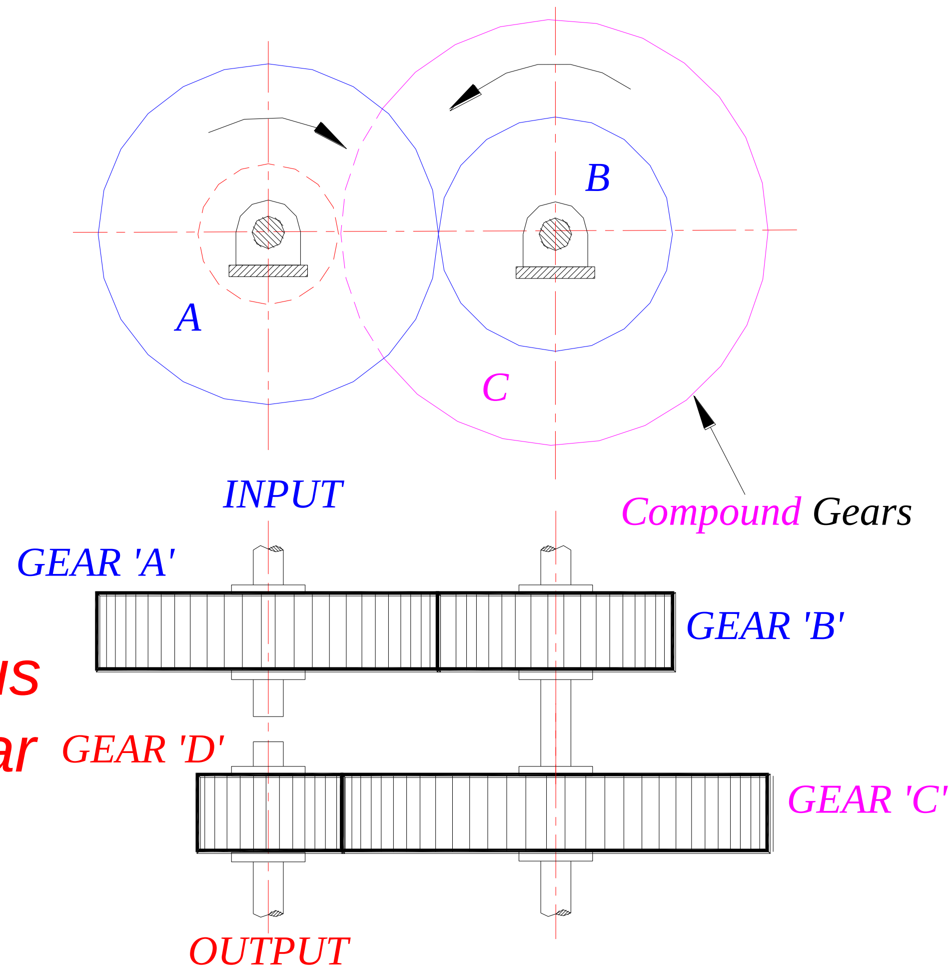
The driver and driven axes lies on the same line. These are used in speed reducers, clocks and machine tools.

$$GR = \frac{N_A}{N_D} = \frac{t_B \times t_D}{t_A \times t_C}$$

If R and T=Pitch circle radius & number of teeth of the gear

$$R_A + R_B = R_C + R_D$$

and $\quad t_A + t_B = t_C + t_D$



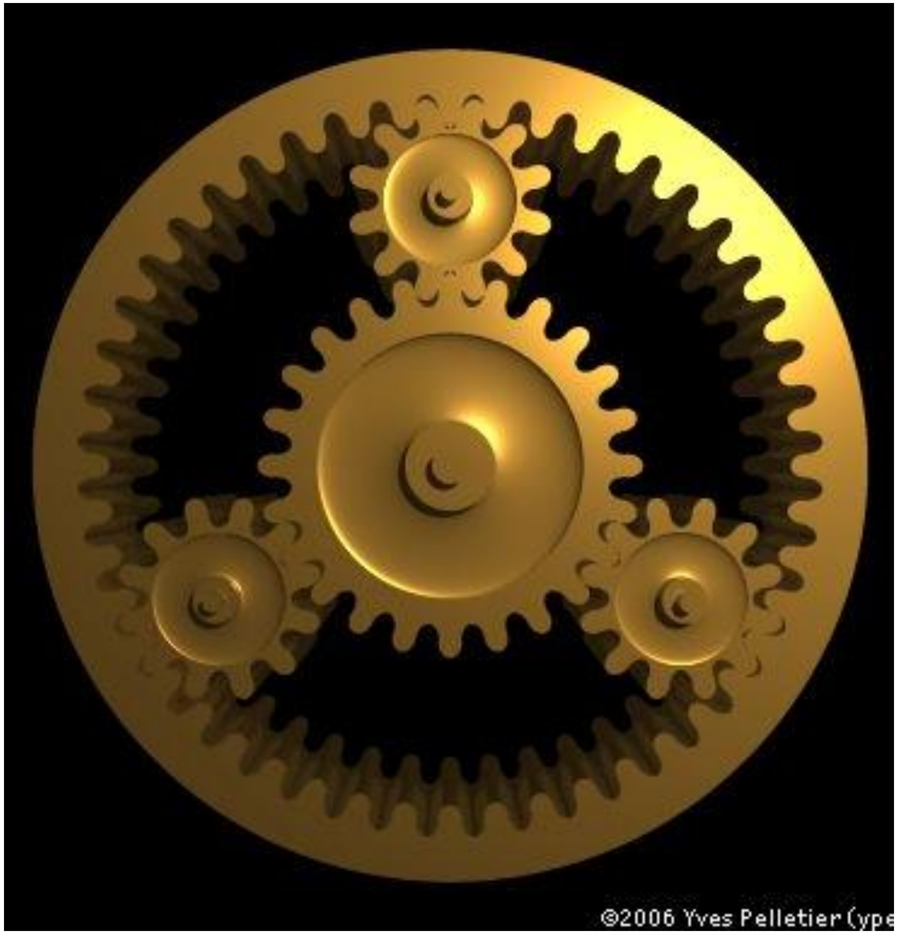
Epicyclic Gear train

Epicyclic means one gear revolving upon and around another. The design involves planet and sun gears as one orbits the other like a planet around the sun. Here is a picture of a typical gear box.

This design can produce large gear ratios in a small space and are used on a wide range of applications from marine gearboxes to electric screw drivers.

Epicyclic Gear train

A small gear at the center called the sun, several medium sized gears called the planets and a large external gear called the ring gear.



Epicyclic Gear train

Planetary gear trains have several advantages. They have higher gear ratios. They are popular for automatic transmissions in automobiles. They are also used in bicycles for controlling power of pedaling automatically or manually. They are also used for power train between internal combustion engine and an electric motor.

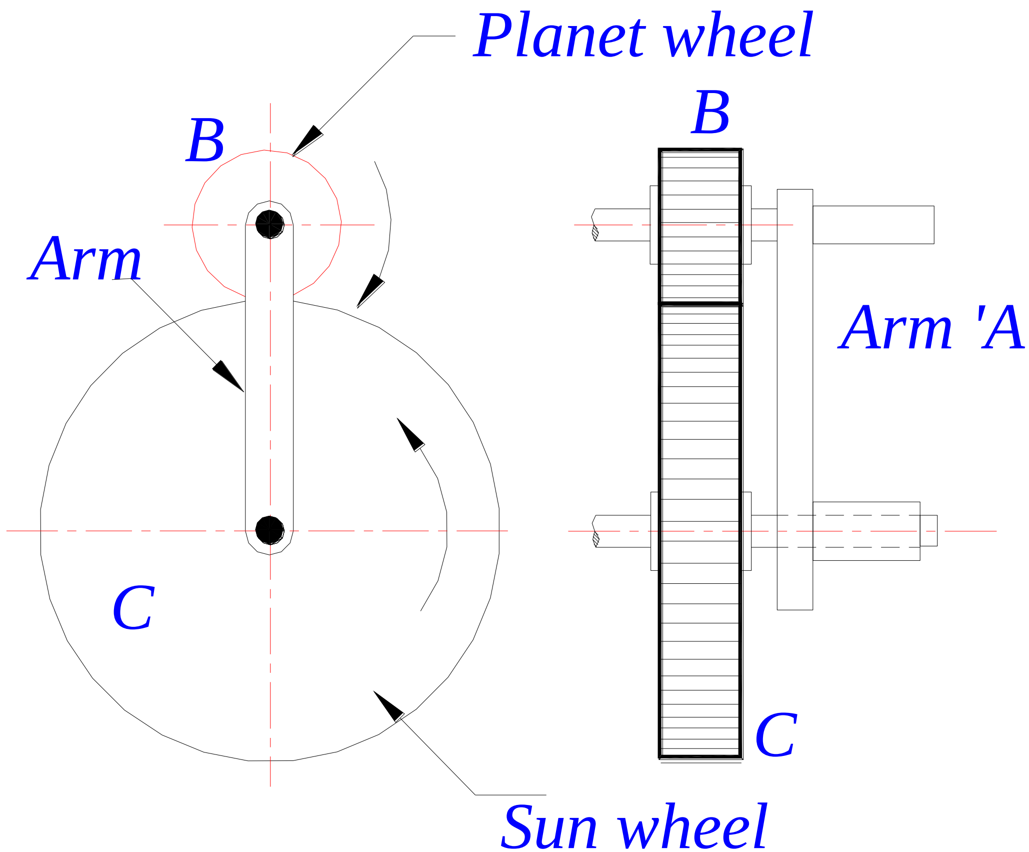
Epicyclic Gear train

It is the system of epicyclic gears in which at least one wheel axis itself revolves around another fixed axis.

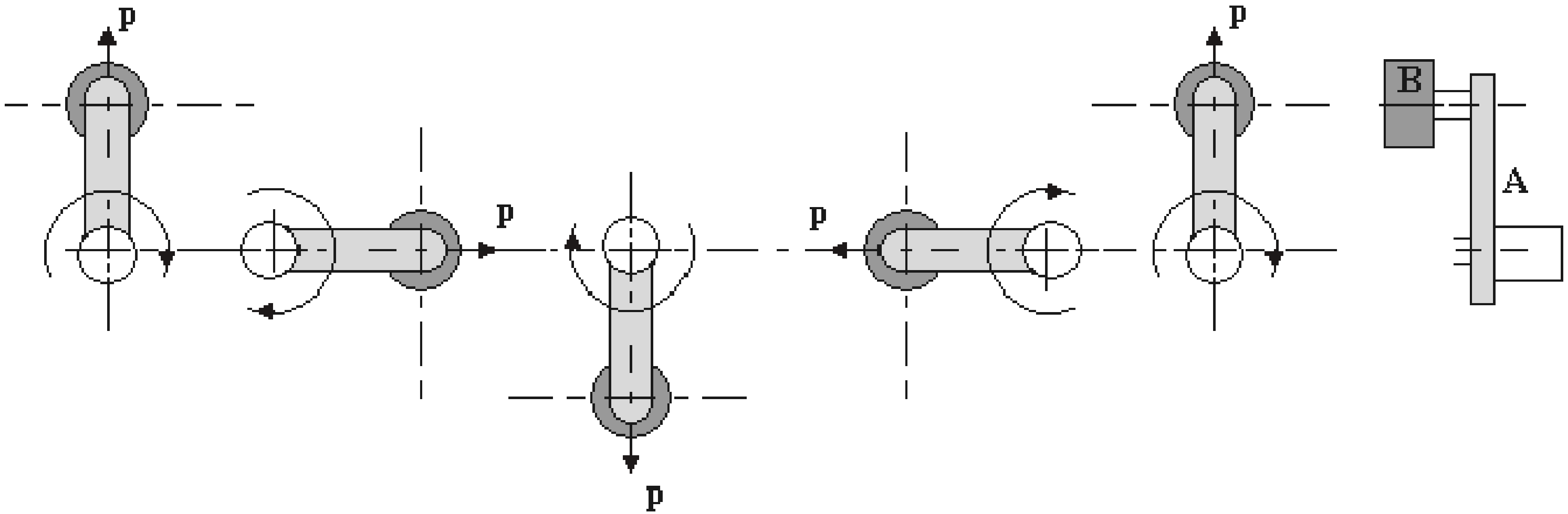
Epicyclic Gear train

Basic Theory

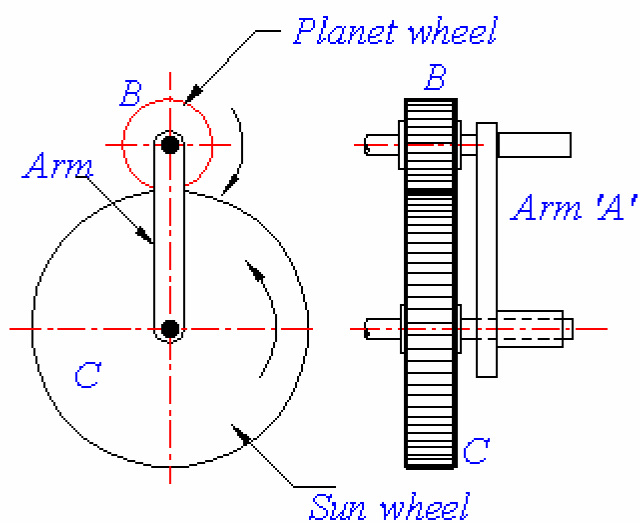
The diagram shows a gear B on the end of an arm. Gear B meshes with gear C and revolves around it when the arm is rotated. B is called the planet gear and C the sun.



Epicyclic Gear train



Observe point p and you will see that gear B also revolves once on its own axis. Any object orbiting around a center must rotate once. Now consider that B is free to rotate on its shaft and meshes with C.



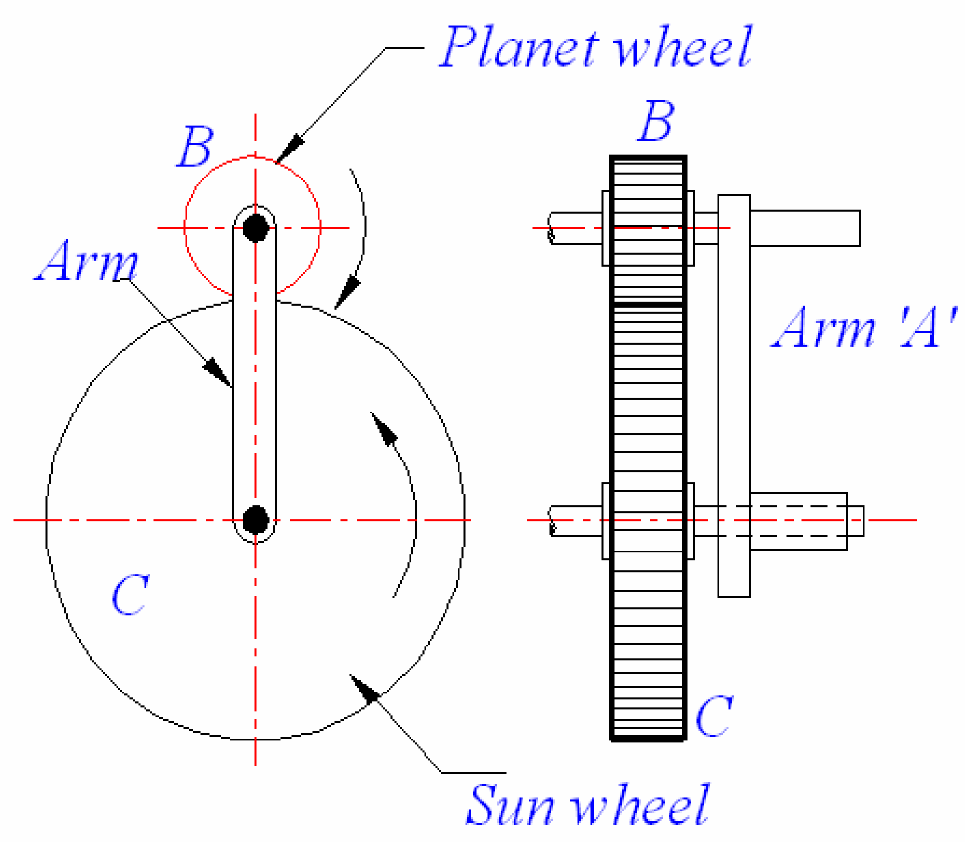
Epicyclic Gear train

Basic Theory

Suppose the arm is held stationary and gear C is rotated once. B spins about its own center and the number of revolutions it makes is the ratio:

$$\frac{t_C}{t_B}$$

B will rotate by this number for every complete revolution of C.

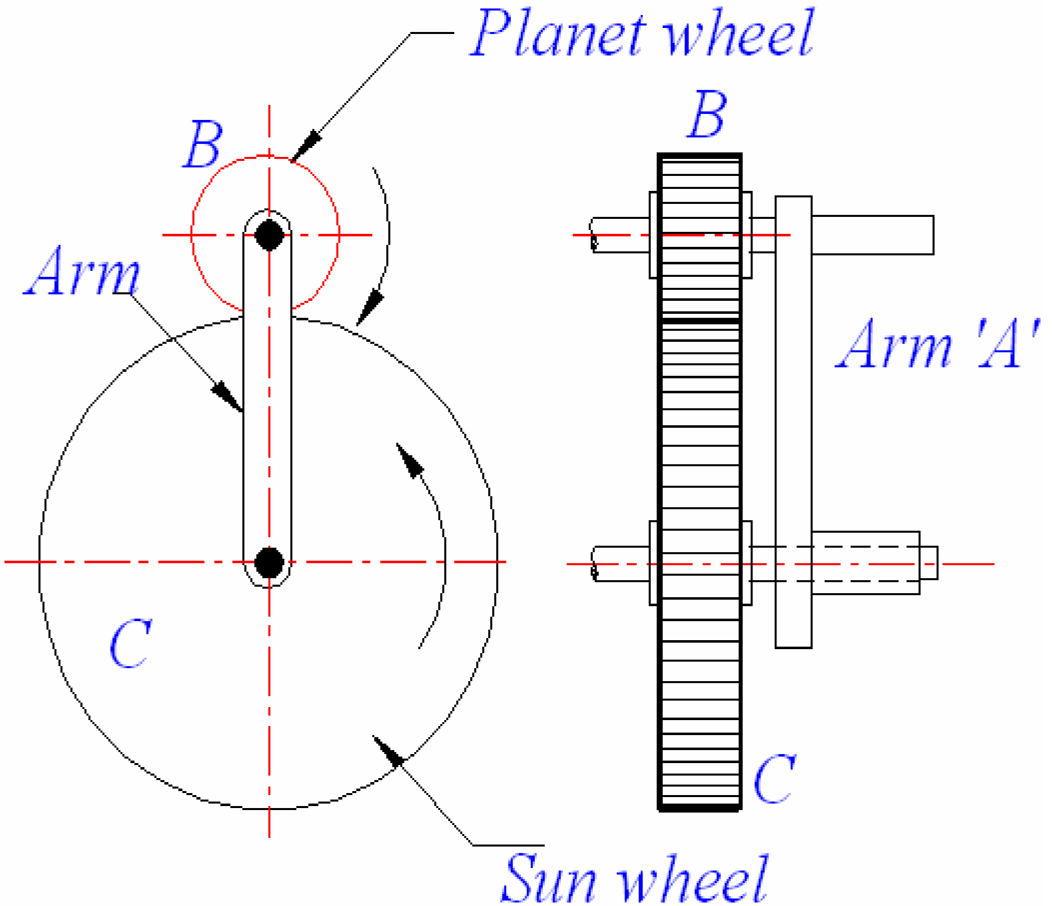


Epicyclic Gear train

Now consider the sun gear C is restricted to rotate and the arm A is revolved once. Gear B will revolve

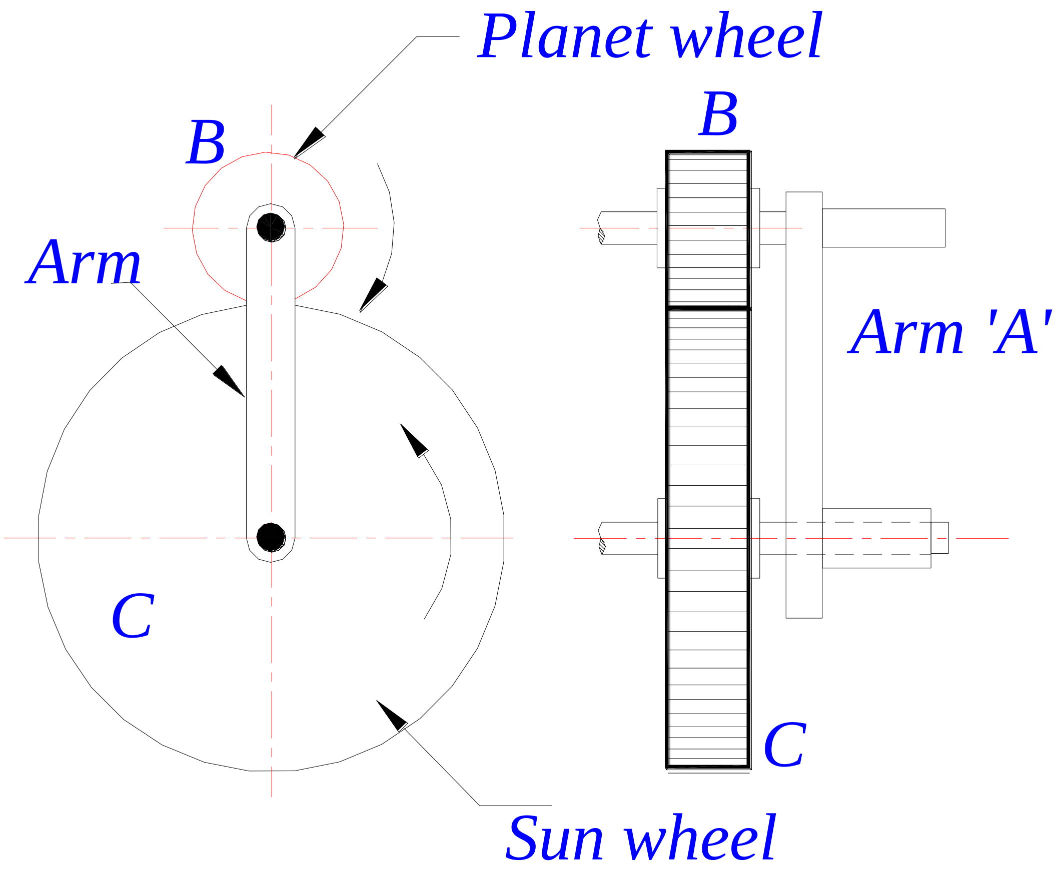
$$1 + \frac{t_C}{t_B}$$

because of the orbit. It is this extra rotation that causes confusion. One way to get round this is to imagine that the whole system is revolved once.



Epicyclic Gear train

Then identify the gear that is fixed and revolve it back one revolution. Work out the revolutions of the other gears and add them up. The following tabular method makes it easy.



Epicyclic Gear train

Basic Theory

Suppose gear C is fixed and the arm A makes one revolution. Determine how many revolutions the planet gear B makes.

Step 1: Arm Fixed – Gear B makes + 1 Rev.

Step 2: Arm Fixed – Gear B makes + x Rev.

Step 3: Add + y Rev. to all as arm A makes + y revolutions

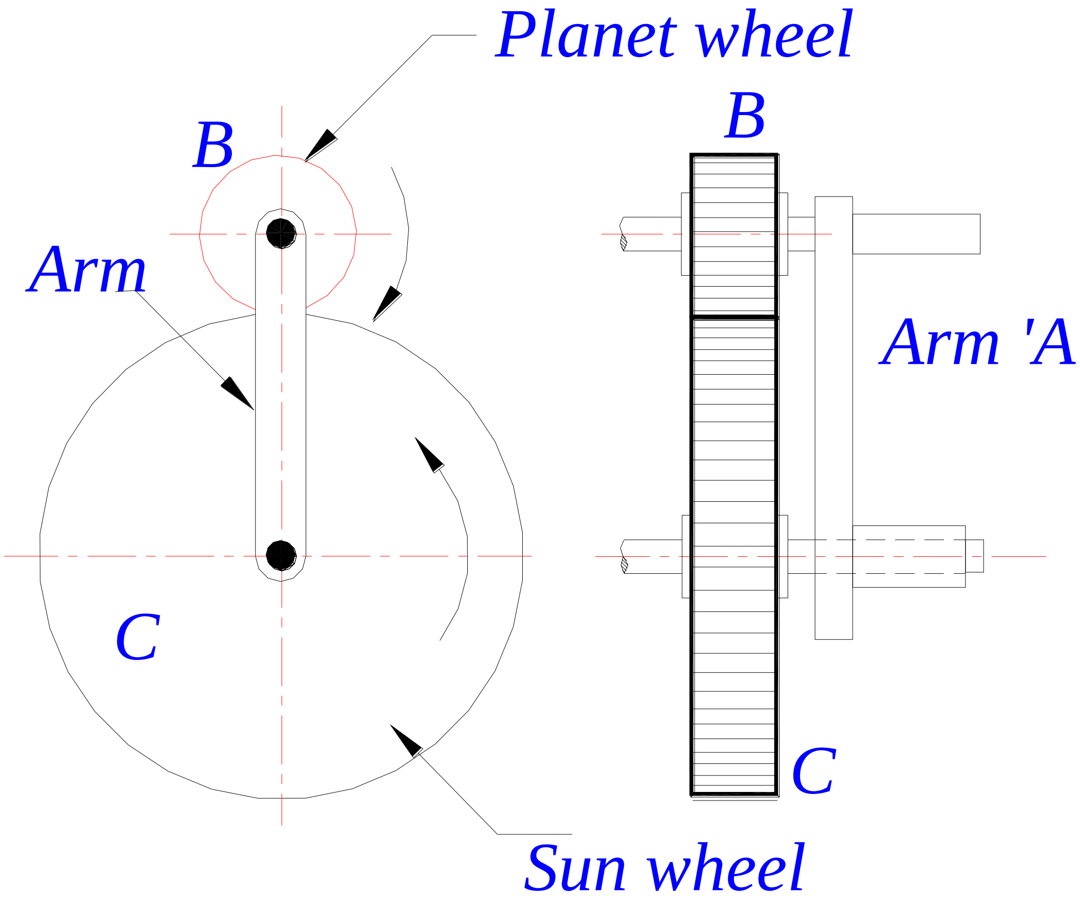
Epicyclic Gear train

TABULAR METHOD

Step	Action	Arm A	Gear B	Gear C
1	Arm Fixed – Gear A makes + 1 Rev.	0	+ 1	- tb/tc
2	Arm Fixed – Gear A makes + x Rev.	0	+ x	- x(ta/tb)
3	Add + y Rev. to all (TOTAL MOTION)	+ y	x + y	y-x(ta/tb)

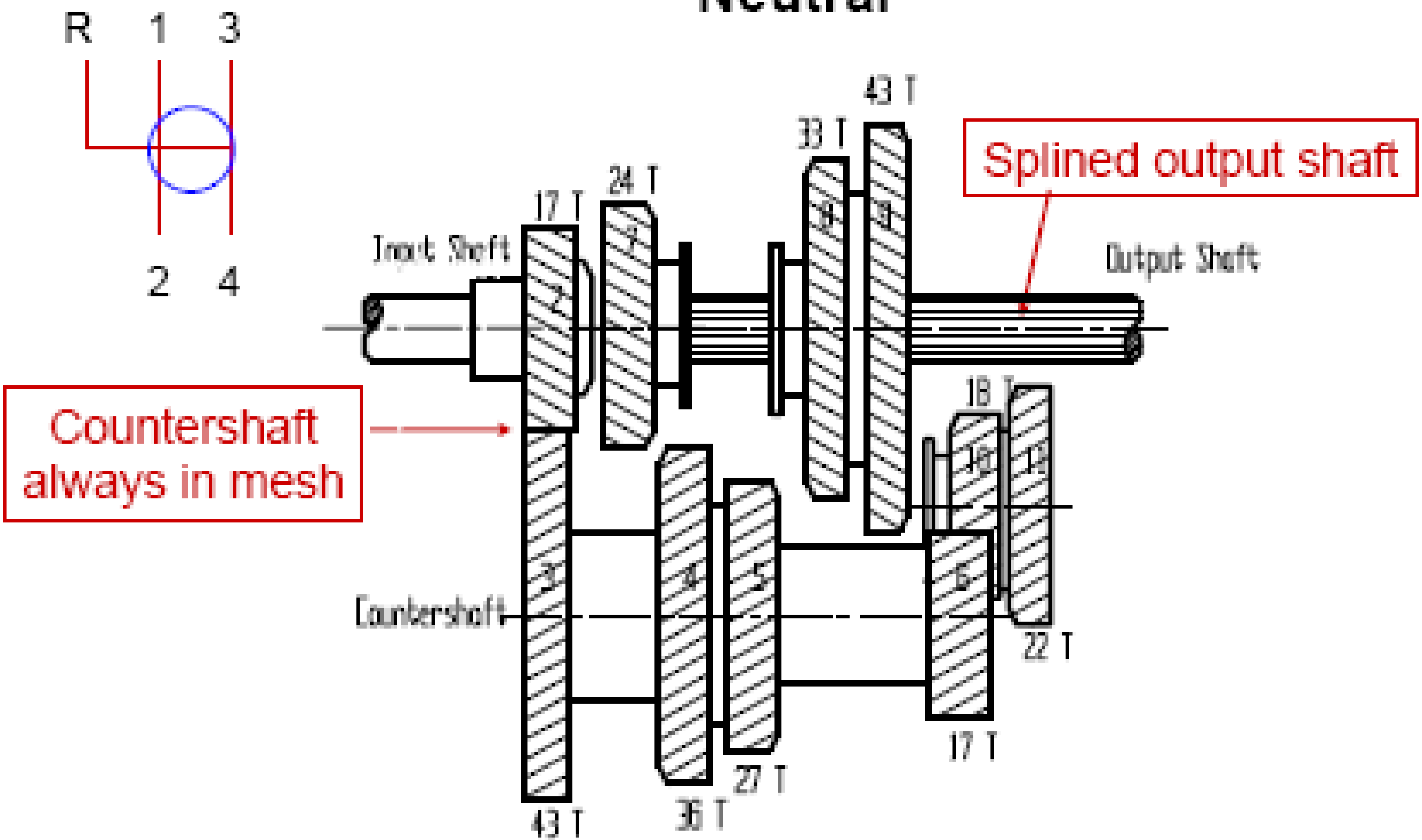
Example 1

A simple epicyclic gear has a fixed sun gear with 100 teeth and a planet gear with 50 teeth. If the arm is revolved once, how many times does the planet gear revolve?

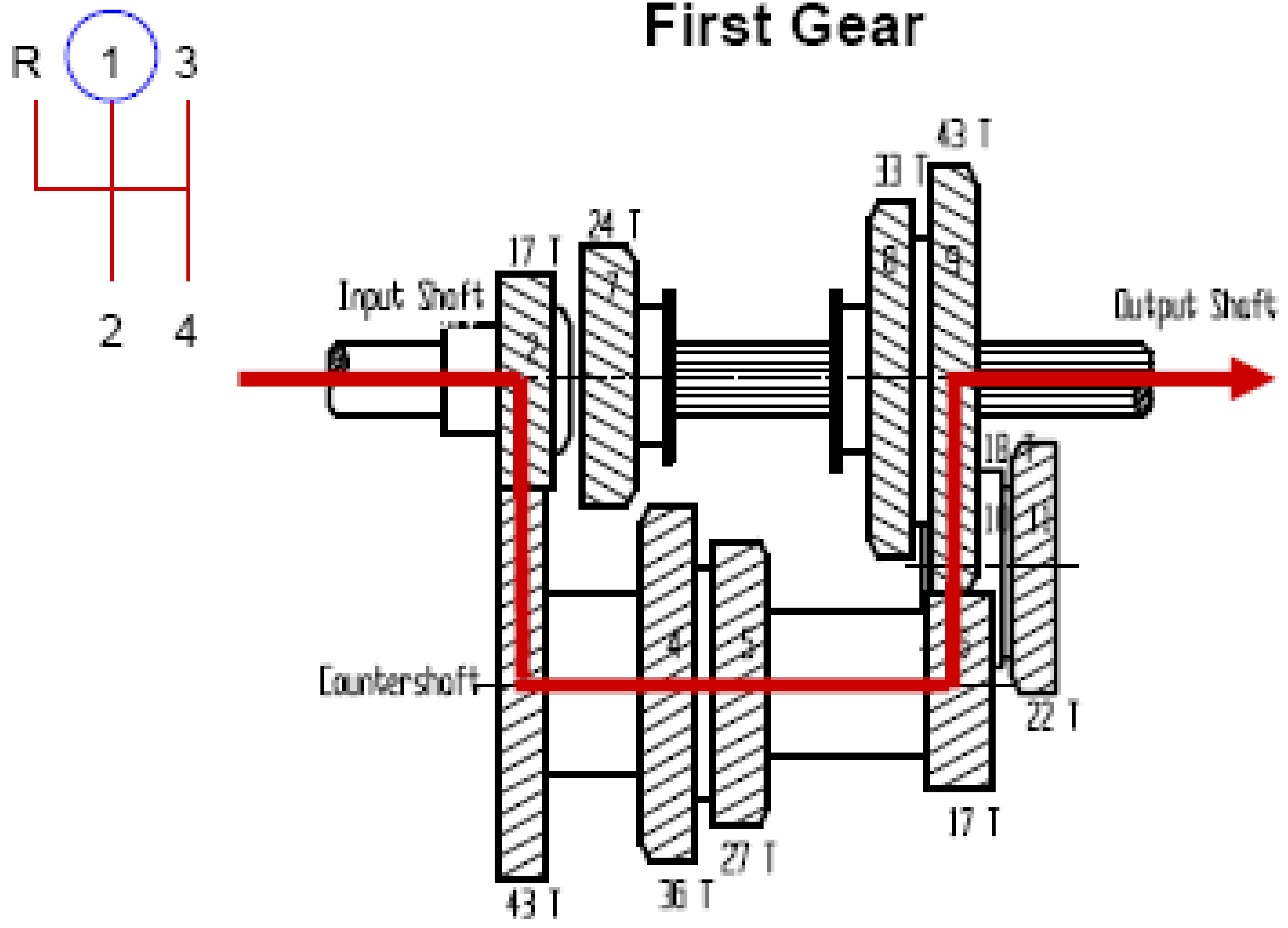


To be continued…

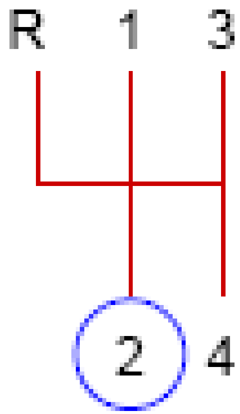
Neutral

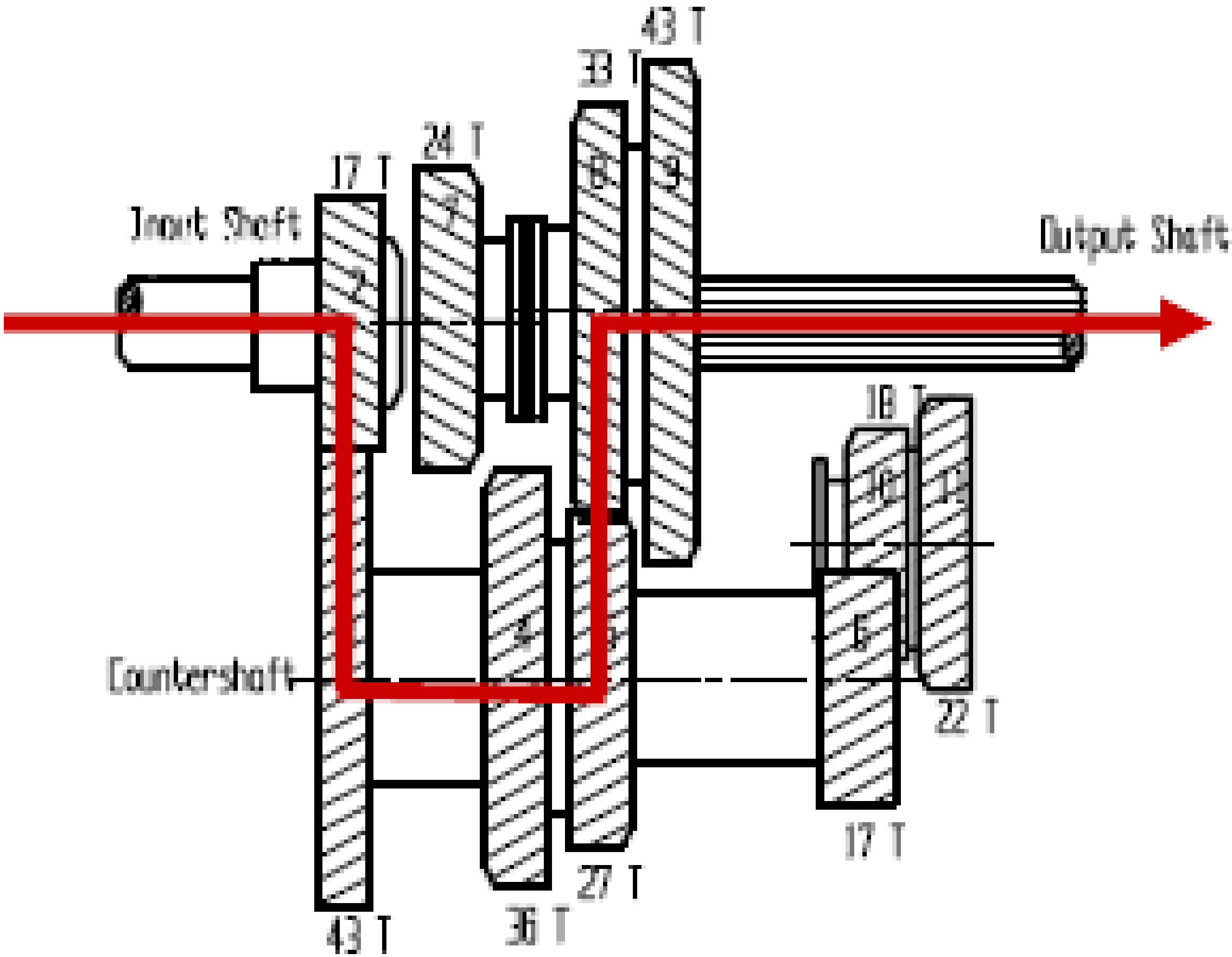

R
1
3
2
4
Splined output shaft
Countershaft always in mesh
Input Shaft
Output Shaft
Countershaft
17 T
24 T
33 T
43 T
18 T
22 T
17 T
27 T
36 T
43 T
2
7
3
4
5
6

First Gear

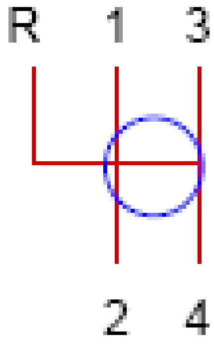

R
1
3
2
4
Input Shaft
Output Shaft
Countershaft
17 T
24 T
33 T
43 T
18 T
22 T
17 T
27 T
36 T
43 T

Second Gear

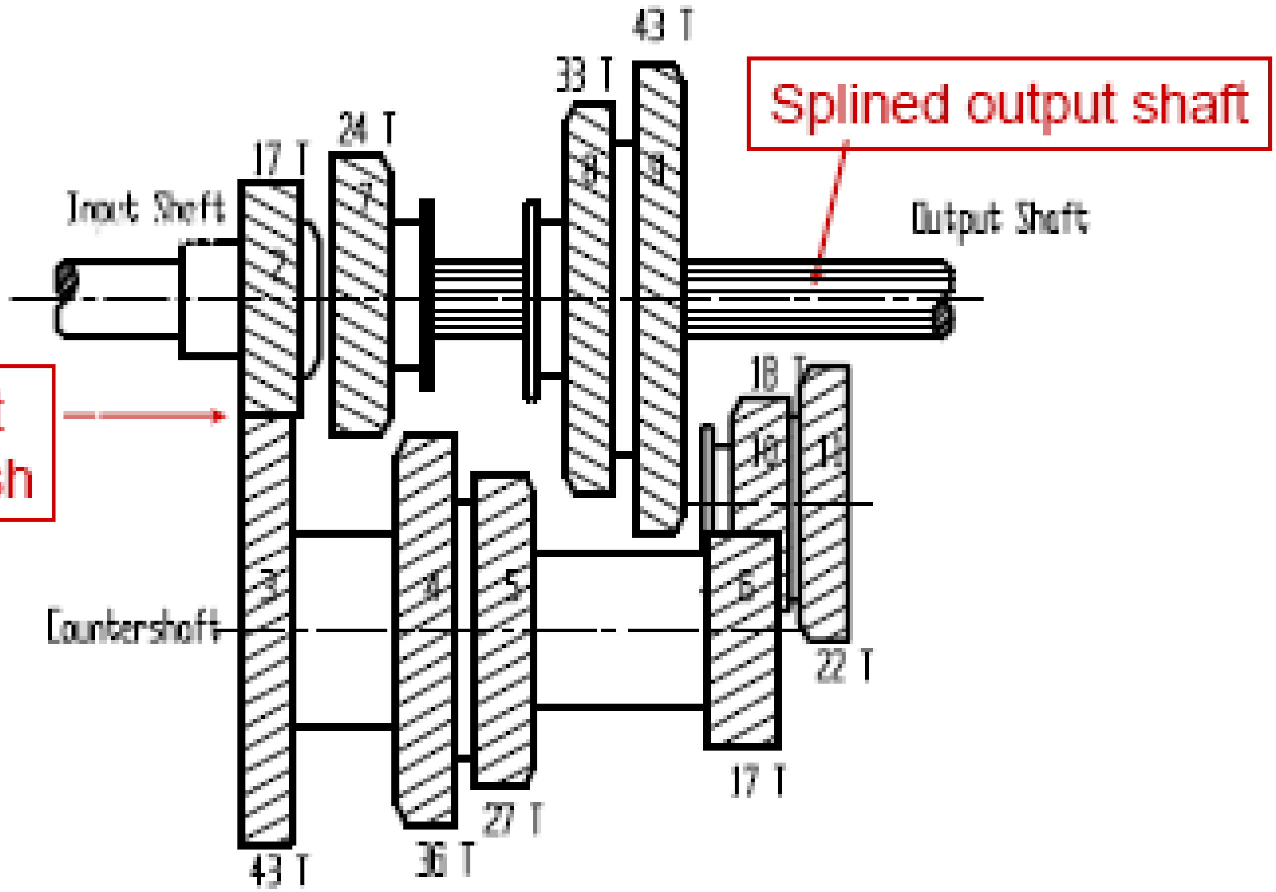

R
1
3
2
4


43 T
33 T
24 T
17 T
Input Shaft
Output Shaft
18 T
22 T
Countershaft
17 T
27 T
36 T
43 T

Neutral

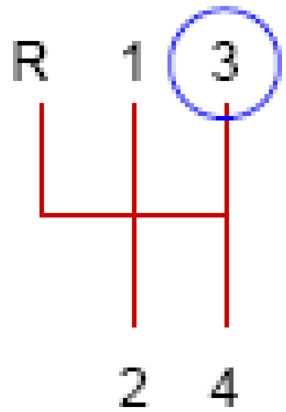


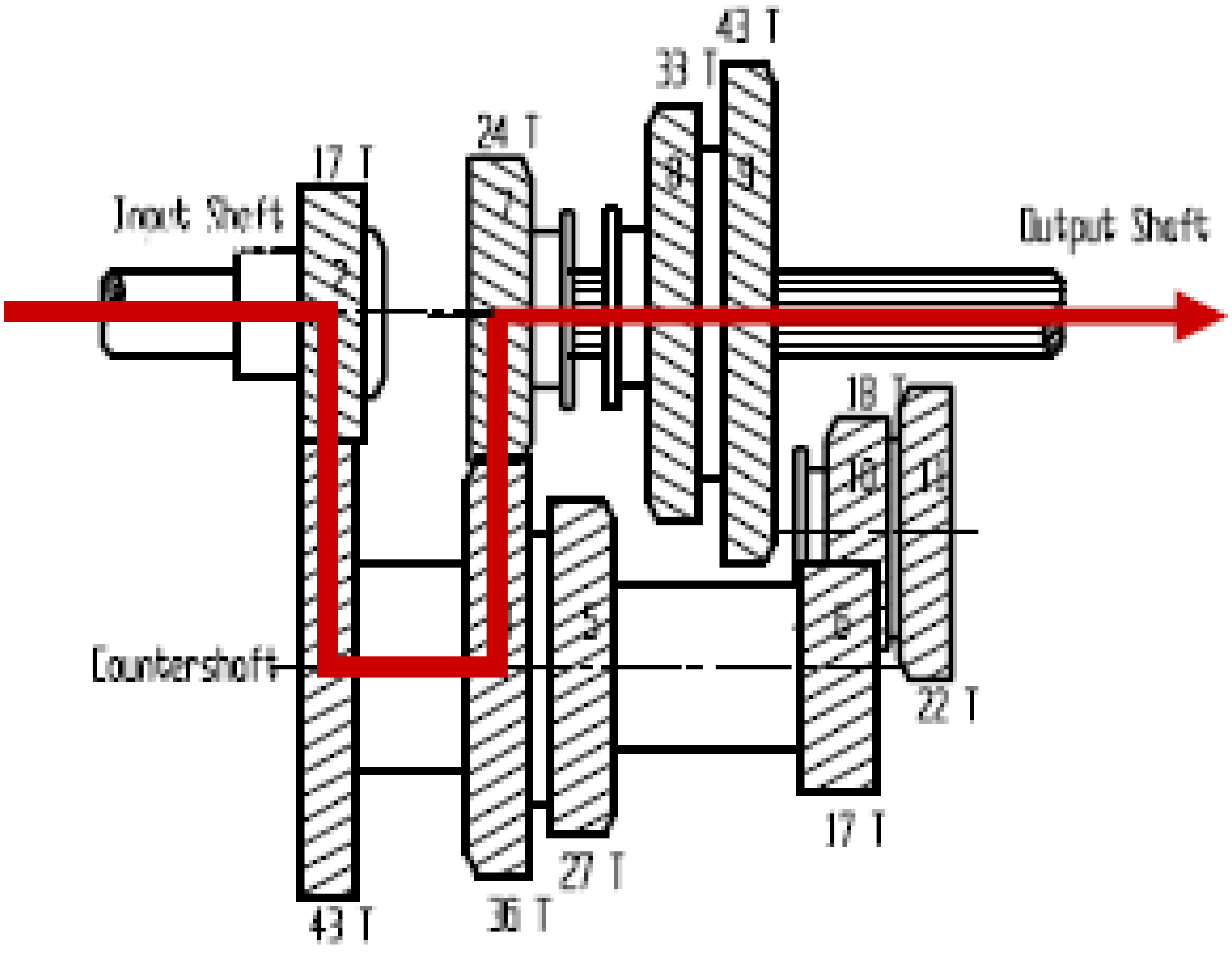
R
1
3
2
4



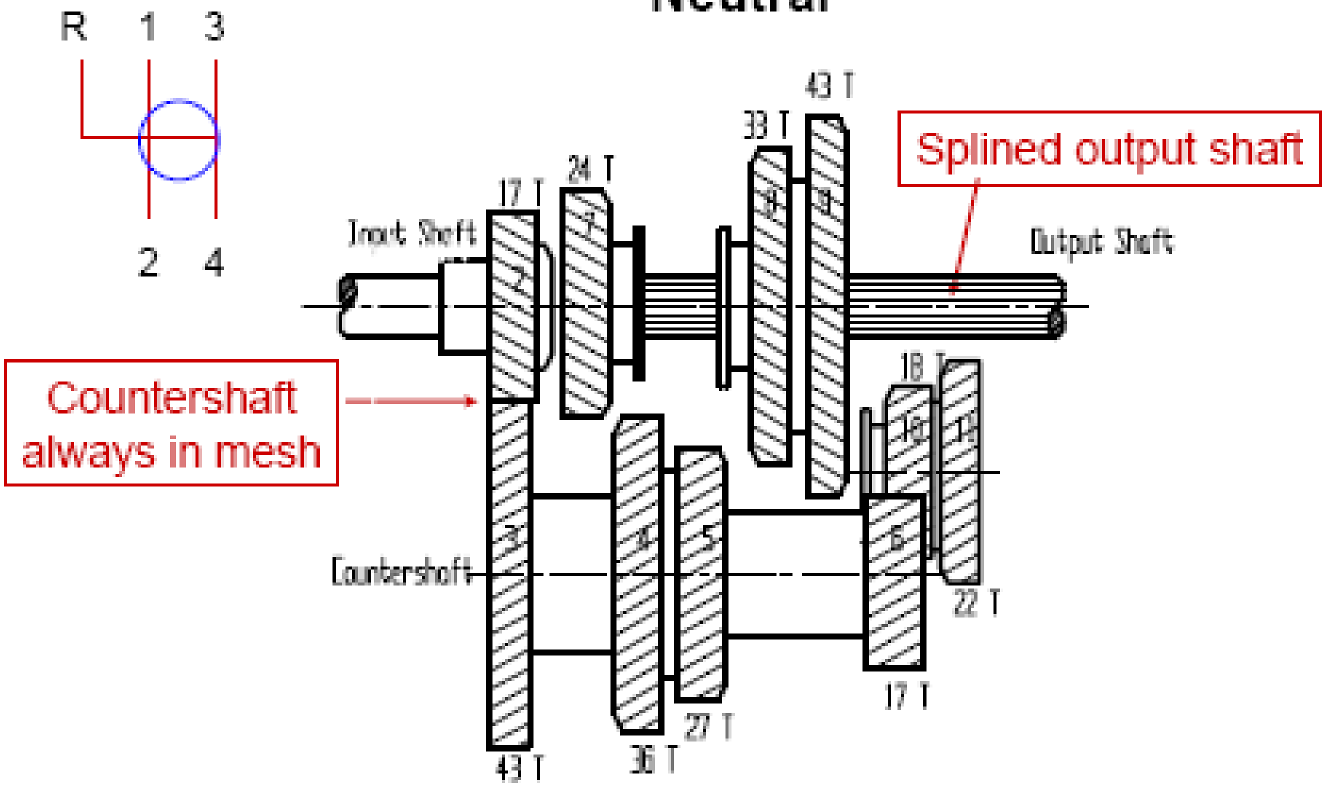
Splined output shaft
Countershaft always in mesh
Input Shaft
Output Shaft
Countershaft
17 T
24 T
33 T
43 T
18 T
22 T
17 T
27 T
36 T
43 T

Third Gear

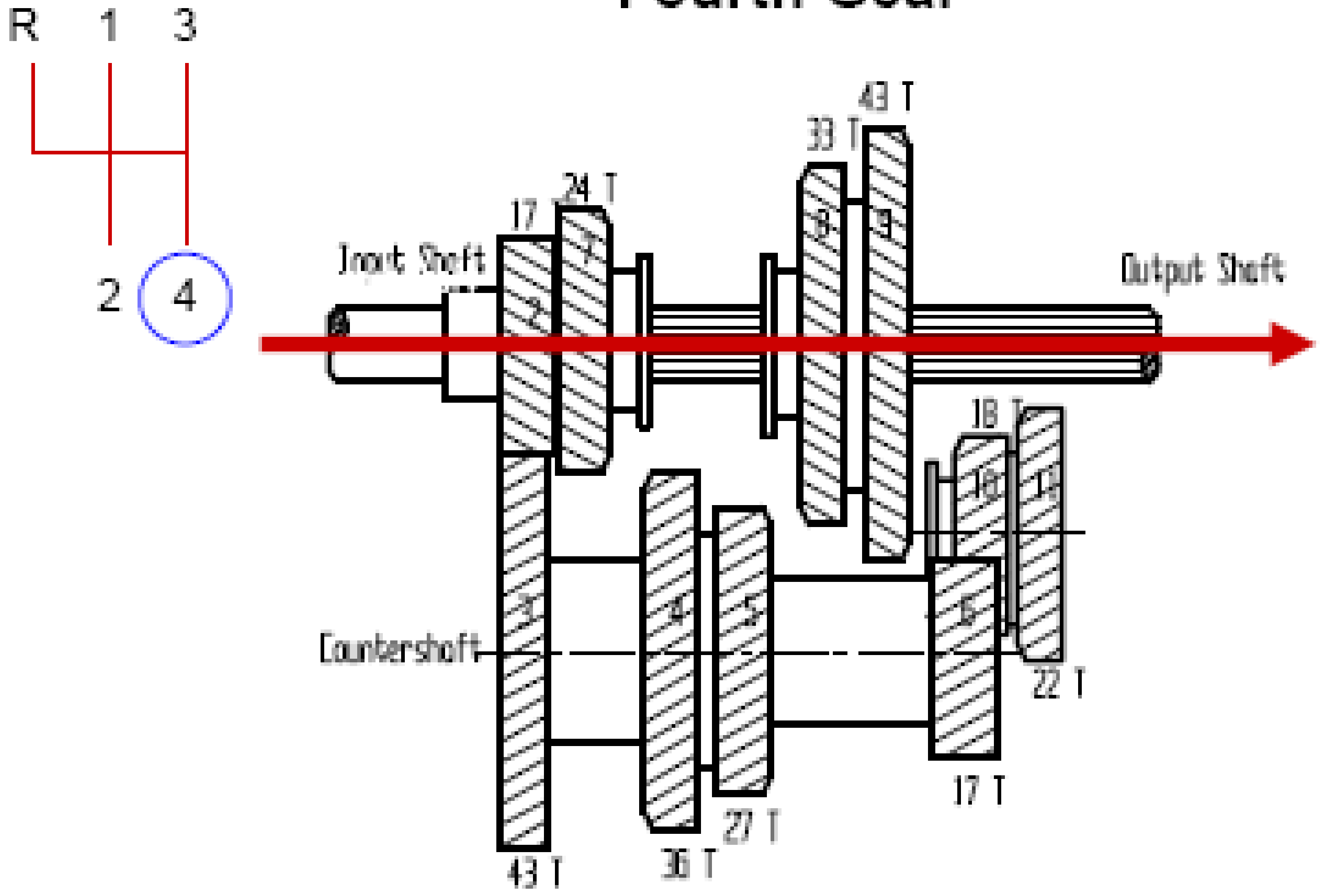

R
1
3
2
4


43 T
33 T
24 T
17 T
Input Shaft
Output Shaft
18 T
Countershaft
22 T
17 T
27 T
36 T
43 T

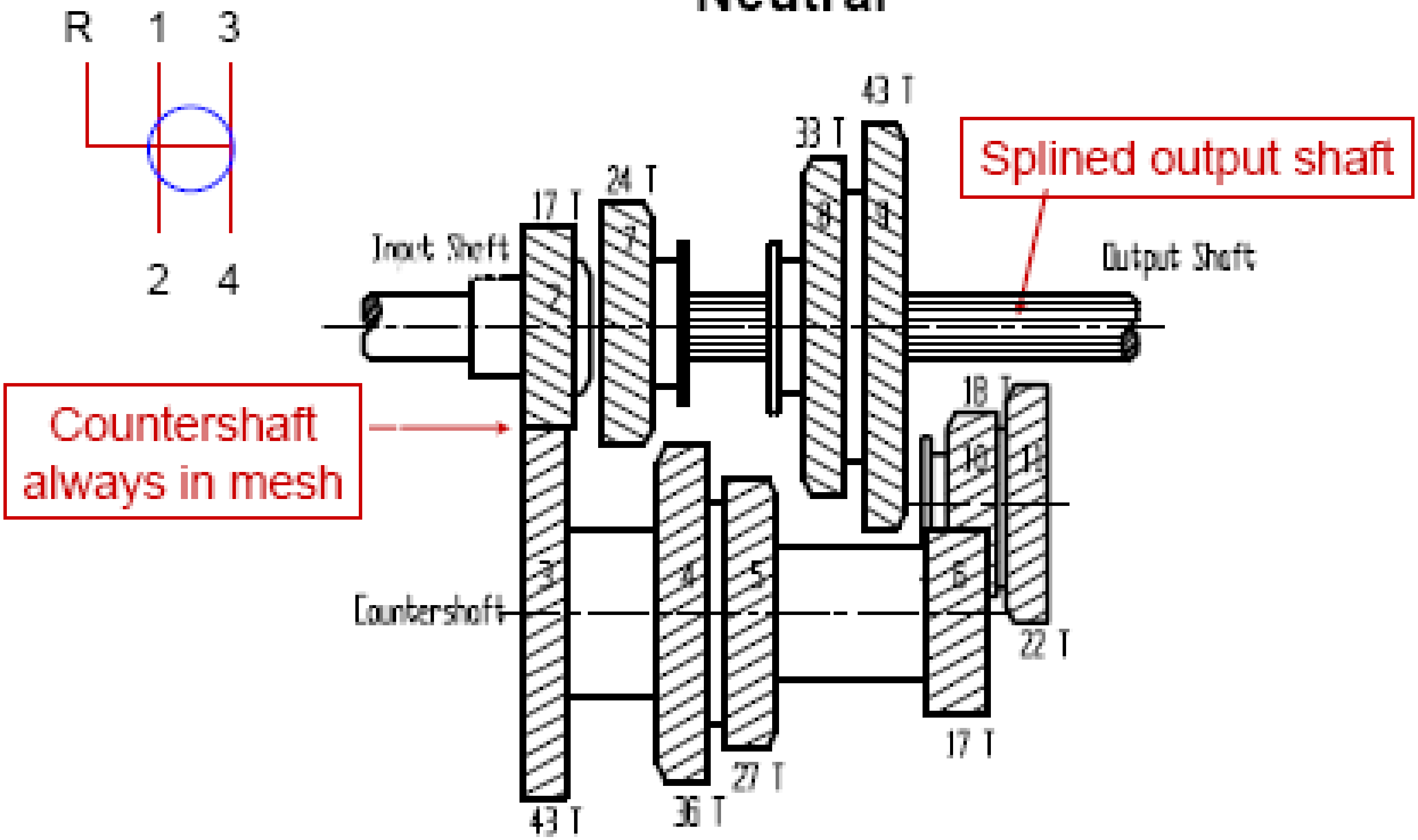
Neutral


R
1
3
2
4
Countershaft always in mesh
Splined output shaft
Input Shaft
Output Shaft
Countershaft
17 T
24 T
33 T
43 T
18 T
22 T
17 T
27 T
36 T
43 T

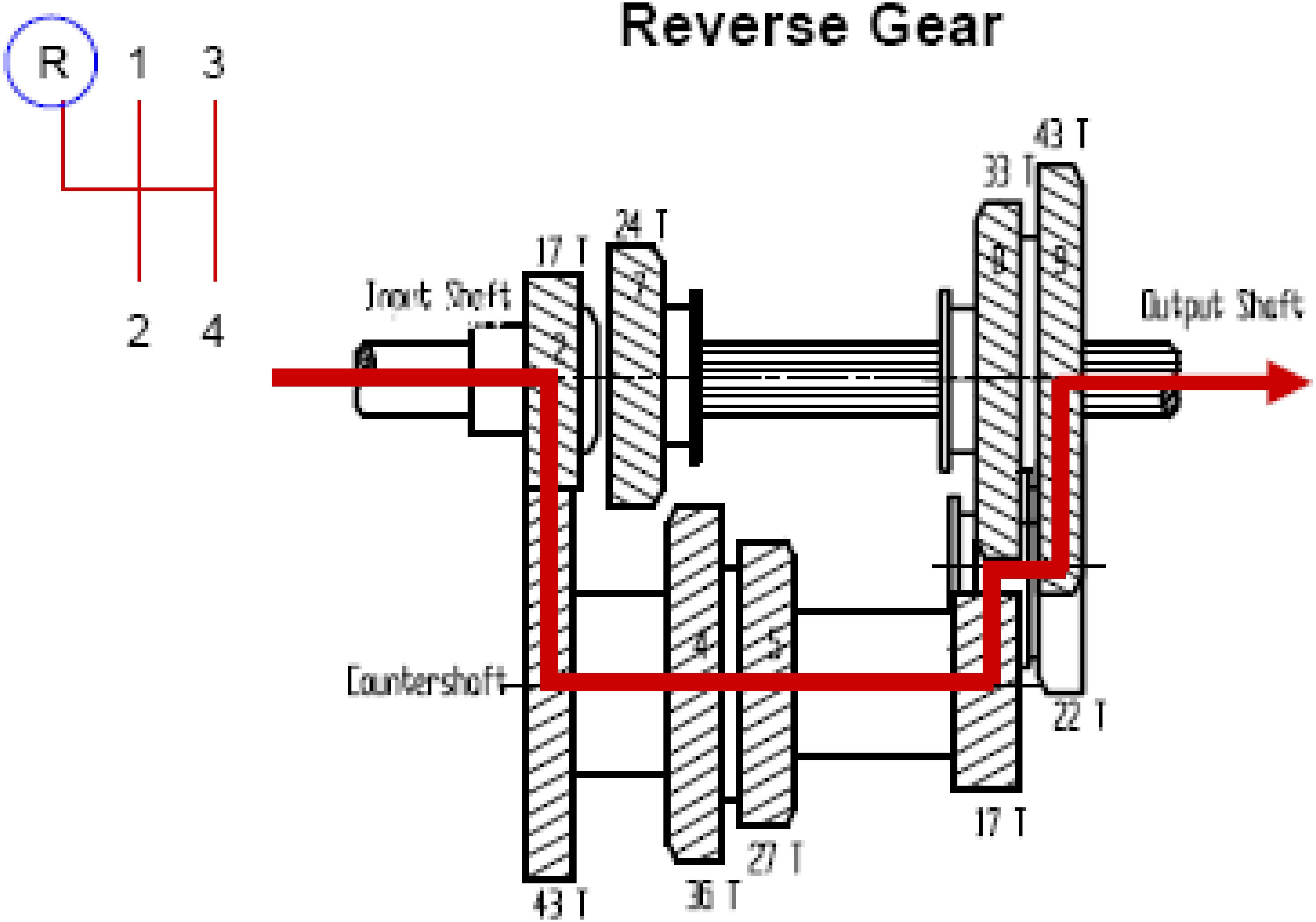
Fourth Gear

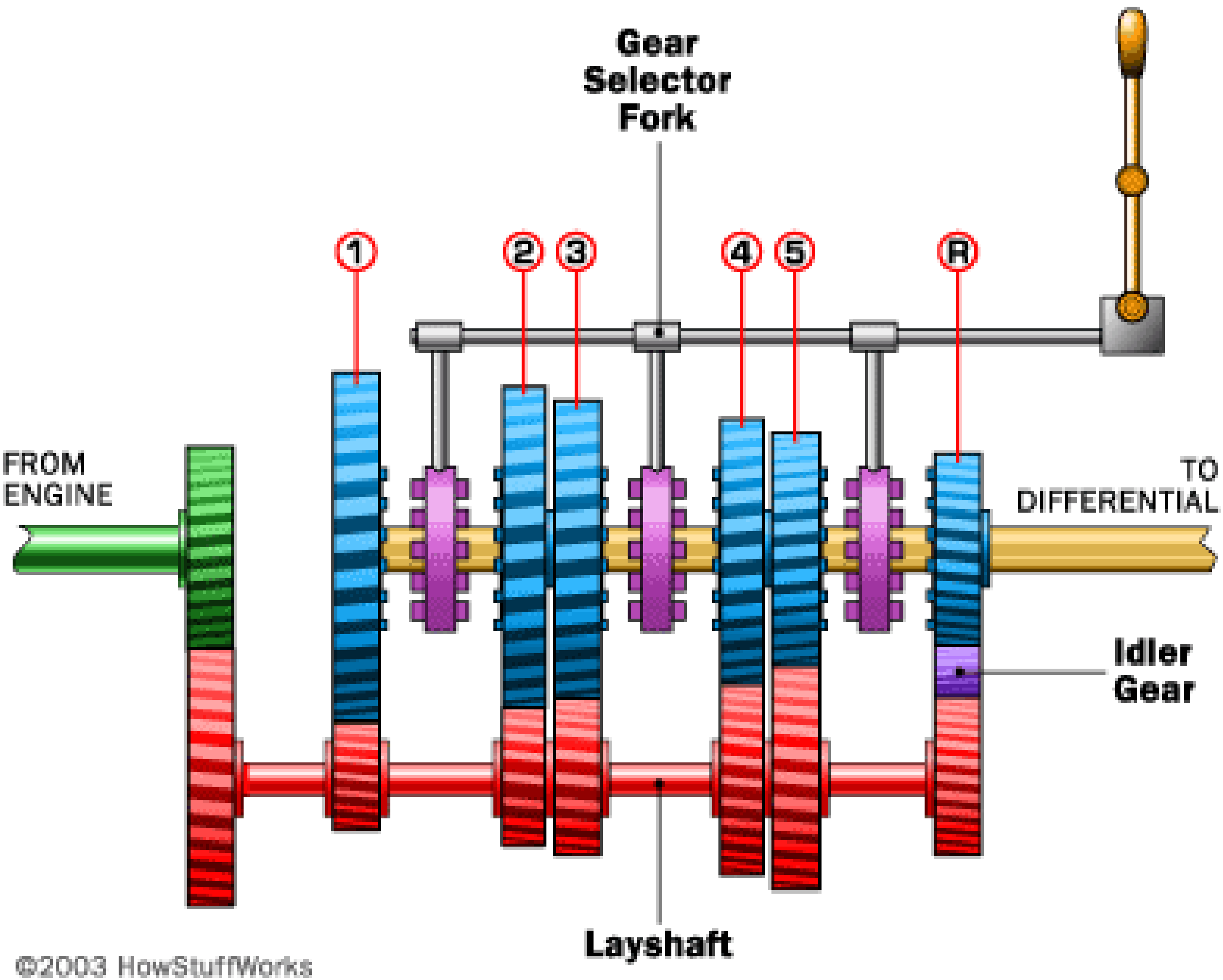

R
1
3
2
4
Input Shaft
Output Shaft
Countershaft
17
24 T
33 T
43 T
18 T
22 T
17 T
27 T
36 T
43 T

Neutral

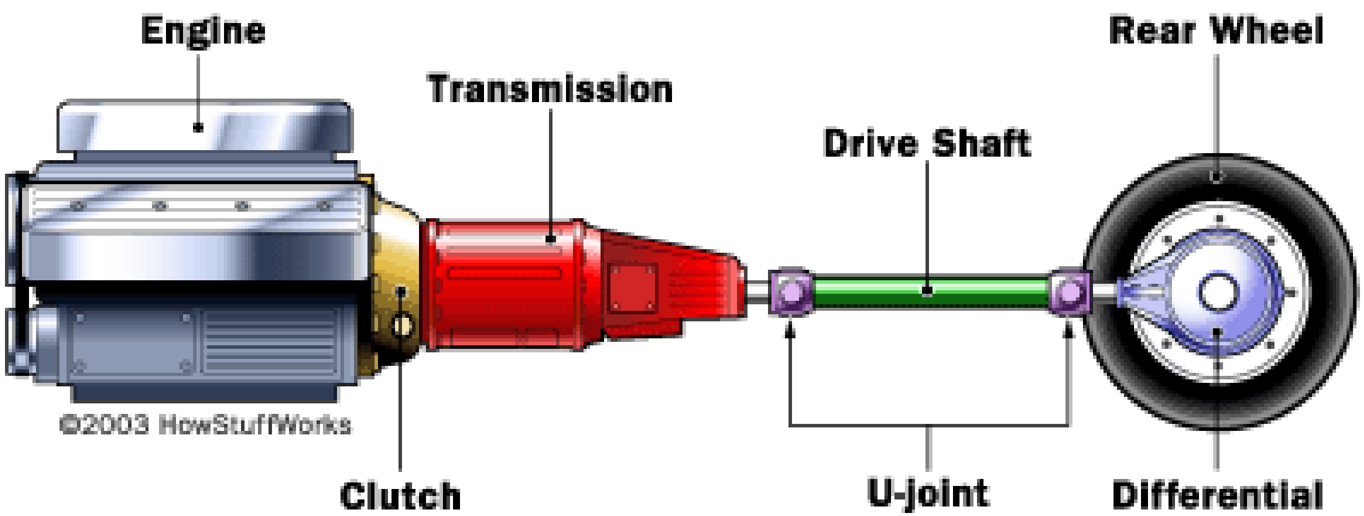

R
1
3
2
4
Splined output shaft
Countershaft always in mesh
Input Shaft
Output Shaft
Countershaft
17 T
24 T
33 T
43 T
18 T
22 T
17 T
27 T
36 T
43 T

Reverse Gear

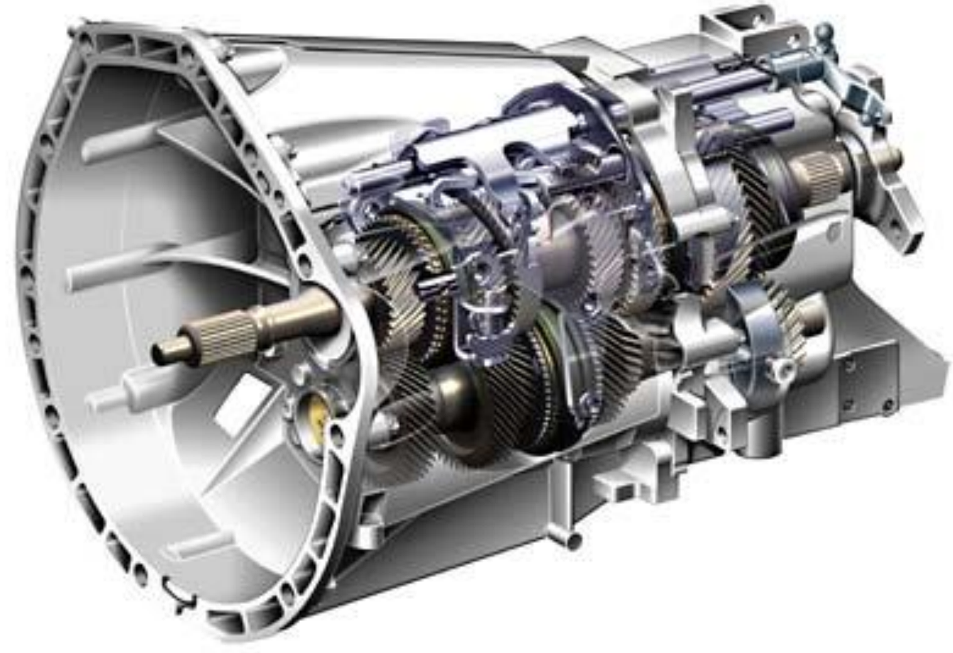


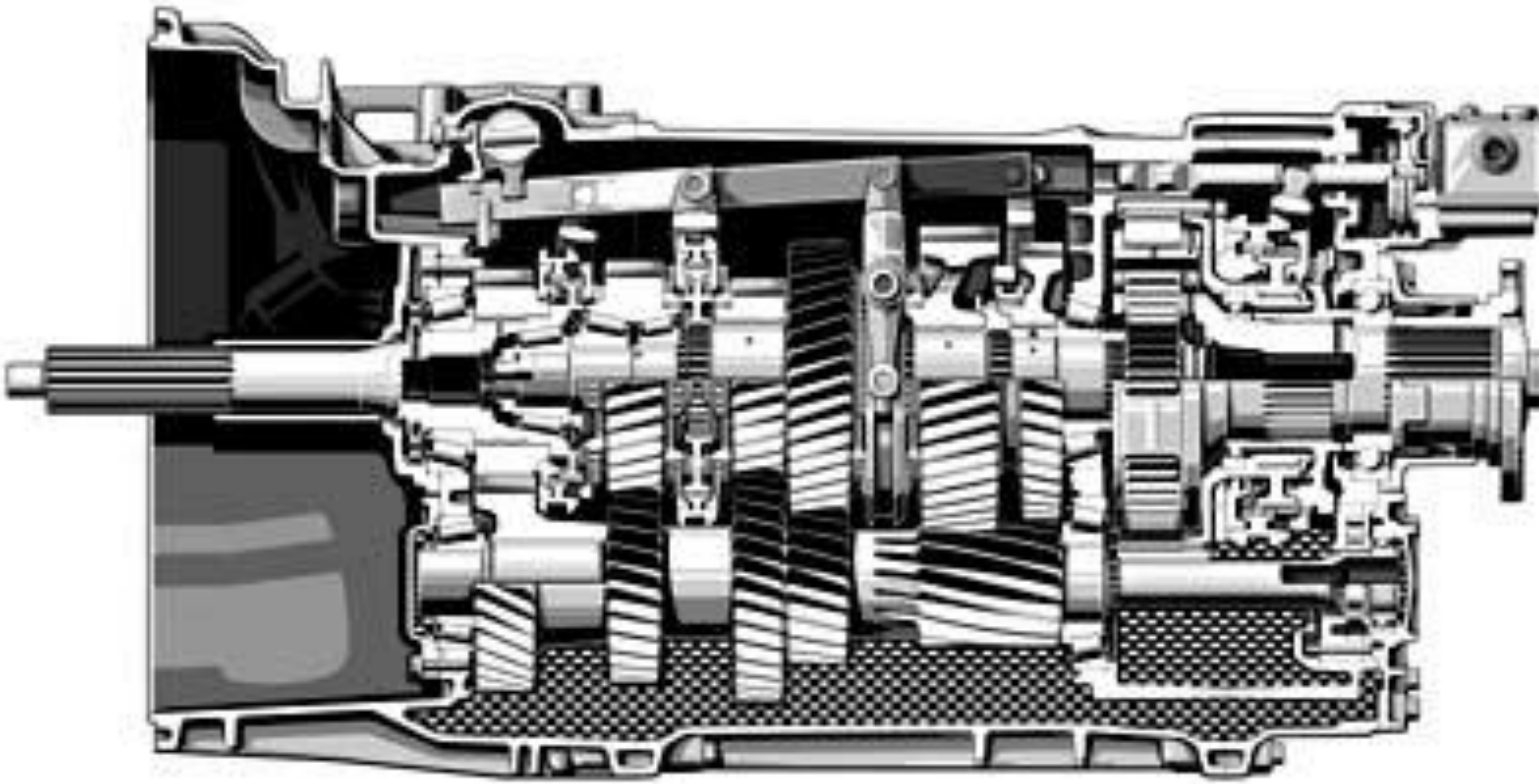

Gear
Selector
Fork
1
2
3
4
5
R
FROM
ENGINE
TO
DIFFERENTIAL
Idler
Gear
Layshaft
©2003 HowStuffWorks

Automotive Gears: *Gears play an important role in trucks, car, buses, motor bikes and even geared cycles. These gears control speed and include gears like ring and pinion, spiral gear, hypoid gear, hydraulic gears, reduction gearbox.*



Depending on the size of the vehicles, the size of the gears also varies. There are low gears covering a shorter distance and are useful when speed is low. There are high gears also with larger number of teeth.





Conveyor Systems:
Conveyor is a mechanical apparatus for carrying bulk material from place to place at a controlled rate; for example an endless moving belt or a chain of receptacles. There are various types of conveyors that are used for different material handling needs.

***Agro Industry**: All agro machinery consists of different types of gears depending upon their function and property. Different gears are used differently in the industry.*

***Wind Turbine:** When the rotor rotates, the load on the main shaft is very heavy. It runs with approximate 22 revolutions per minute but generator has to go a lot faster. It cannot use the turning force to increase the number of revolutions and that is why wind turbine uses gear to increase the speed.*

[Helical gears](#) *- Are used to minimise noise and power losses.*
[Bevel gears](#) *- Used to change the axis of rotational motion.*
[Spur gears](#) *- Passes power from idler gears to the wheels.*
[Planetary gears](#) *- Used between internal combustion engine and an electric motor to transmit power.*

Marine Gears: *Marine gears meet a wide variety of marine applications in a variety of configurations and installations to meet the most critical applications.*

Specific marine applications include main propulsion, centrifuges, deck machinery such as winches, windlasses, cranes, turning gears, pumps, elevators, and rudder carriers.

Mining Gears: *Mining is a process of extracting ores or minerals from the earth's surface. The gears are used for increasing the torque applied on the tool used for mining. They are used for commercial gold production, and coal mining.*

Differential Gear Box