getting ready for Activity #1:

Gear Ratio

- In order to determine what a gear will do for us, we must quantify it.
- Best measure is the gear ratio.
- Gear Ratio = $\dfrac{\text{number of teeth in follower}}{\text{number of teeth in driver}}$
- G.R.=F_t/D_t e.g. ⅓ or 1:3 (read as 1 to 3)
- Interpret above as one turn of driver will turn the follower 3 times.

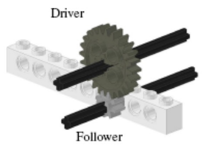
Gear Analysis

- To analyze any gear train you need to:
  - Locate the driver gear (see force applied)
  - Locate the follower gear (see where useful work done)
  - Figure out if it is geared up or geared down (big circle turning small circle – geared up)
  - Calculate the Gear Ratio using Ft/Dt.
  - Use the following 3 rules for gear ratio calculation.

(*)

Rule 1 – Pair up gears

- In the case of 2 gears, it is easy. The driver is the one driven by the motor or applied force. The follower is the one doing work.



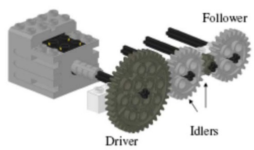
Gear Ratio = $^{8}/_{24}$

= $^{1}/_{3}$

One turn of the 24 tooth will turn the 8 tooth 3 times.

Rule 2 -Long Gear Trains

- For many gears on different axles, driver is one connected to applied force, follower is the last one in the gear train. All others idlers.



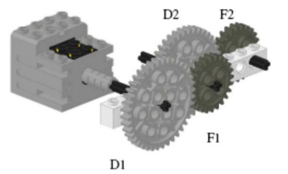
Gear Ratio = $^{24}/_{40}$

= $^{3}/_{5}$

3 turns of the 40 tooth will turn the 24 tooth 5 times.

Rule 3 – Compound Gears

- Pair up as many drivers and followers and label them D1, F1, D2, F2, etc. as needed. Note every time you follow an axle and it has a second gear attached, start a new driver. Multiply the gear ratios of all pairs of driver-follower.



Gear Ratio

$= {}^{24}/_{40} \times {}^{24}/_{40}$

$= {}^{3}/_{5} \times {}^{3}/_{5}$

$= {}^{9}/_{25}$

Real World Gear Types

- Spur gears 1
- Helical gears 2
- Bevel gears 3
- Differential gears 4
- Worm gears 5
- Planetary Gears 6
- Harmonic Drive gears 7

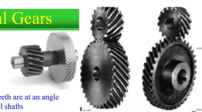
(1)

Spur Gears

- Most common form
- Used for parallel shafts
- Suitable for low to medium speed application
- Relatively high ratios can be achieved (< 7)
- Steel, brass, bronze, cast iron, and plastics
- Can also be made from sheet metal

(2)

Helical Gears



- Helical gears Teeth are at an angle
- Used for parallel shafts
- Teeth engage gradually reducing shocks
- Helix angle 7 to 23 degrees
- More power
- Larger speeds
- More smooth and quiet operation
- Used in automobiles
- Helix angle must be the same for both the mating gears
- Produces axial thrust which is a disadvantage

(3)

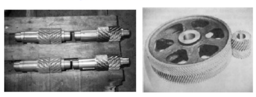
Bevel Gears (Miter Gears)

- They have conical shape
- For one-to-one ratio
- Used to change the direction

type of Helical

Herringbone Gears

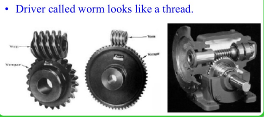
- Two helical gears with opposing helical angles side-by-side
- Axial thrust gets cancelled



(4)

Worm Gears

- For large speed reductions between two perpendicular and non-intersecting shafts
- Driver called worm looks like a thread.

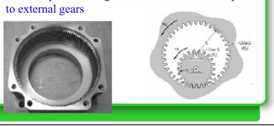


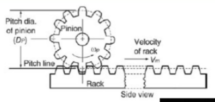
Rack & Pinion

- A rack is a gear whose pitch diameter is infinite, resulting in a straight line pitch circle.
- Involute of a very large base circle approaches a straight line
- Used to convert rotary motion to straight line motion
- Used in machine tools

Internal Spur Gears

- Provides more compact drives compared to external gears
- They provide large contact ratio
- Relatively less sliding and hence less wear compare to external gears





Mechanical System

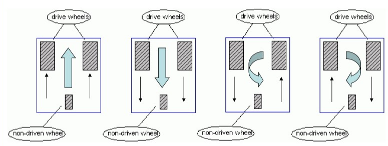
- The most basic and important part of the robot.
- It comprises of chassis, motors, wheels and their placement.
- This system decides the locomotion of the robot.

extras

Differential Drive

- This is the most commonly used form of locomotion system used in robots as it's the simplest and easiest to implement.
- It has free moving wheel(s) in the front accompanied with a left and right wheel. The two wheels are driven by different motors.

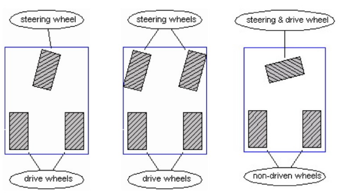
Differential Drive



Car Type Drive

- It is characterized by a pair of driving wheels and a separate pair of steering wheels.
- The translation and rotation are interlinked, hence this system faces severe path planning problem.

Car Type Drive Cont…



Differential Drive: An Analysis

- Simplicity and ease of use makes it the most preferred system by beginners
- Independent drives makes it difficult for straight line motion. The differences in motors and frictional profile of the two wheels cause them to move with slight turning effect
- The above drawback must be countered with appropriate feedback system. Suitable for human controlled remote robots

Wheeled Locomotion System

- Differential drive
- Car type drive
- Skid steer drive
- Synchronous drive
- Pivot drive

Skid Steer Drive

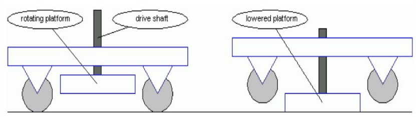
- A close relative of the differential drive system.
- It is mostly used in tracked machines e.g. tanks. Also finds application in some four / six wheeled robots
- The left and right wheels are driven independently.
- Steering is accomplished by actuating each side at a different rate or in a different direction, causing the wheels or tracks to slip, or skid, on the ground.

Synchronous Drive

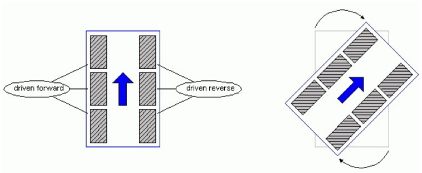
- As the name suggests, it uses synchronous rotation of its wheels to achieve motion & turns
- It is made up of a system of motors. One set of which drive the wheels and the other set turns the wheels in a synchronous fashion
- The two sets can be directly mechanically coupled as they always move in the same direction with same speed

Pivot Drive

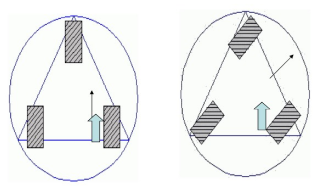
- The most unique type of Locomotion system
- It is composed of a four wheeled chassis and a platform that can be raised or lowered



Skid Steer Drive Cont…



Synchronous Drive



Pivot Drive

- The wheels are driven by a motor for translation motion in a straight line
- For rotation one motor is needed to lower/raise the platform & another to rotate the chassis around the platform
- This system can guarantee perfect straight line motion as well as accurate in – place turns to a desired heading

Example 1

- Gear Ratio = $\dfrac{\text{number of teeth in follower}}{\text{number of teeth in driver}}$

Question:

A gear train consists of a driving gear with 20 teeth and a driven gear with 100 teeth.

follower

a) Calculate the maximum gear ratio when the 100-tooth gear is the output.

b) Calculate the minimum gear ratio when the 20-tooth gear is the output.

a) **Maximum gear ratio** (when 100-tooth gear is the output):

$$\text{Gear Ratio} = \frac{\overset{\text{follower}}{\cancel{\text{Driven Teeth}}}}{\text{Driving Teeth}} = \frac{100}{20} = 5:1$$

(The output rotates 5 times slower than the input.)

b) **Minimum gear ratio** (when 20-tooth gear is the output):

$$\text{Gear Ratio} = \frac{20}{100} = 1:5$$

(The output rotates 5 times faster than the input.)

Example 2

Challenge Question:

You need to design a **gear train** that achieves a gear ratio of **15:1** using at least **two gears** (a simple or compound gear train).

1. **Propose a gear train configuration that meets the ratio requirement.**
2. **Determine the number of teeth for each gear.**
3. **Calculate the output torque if the input torque is 8 Nm.**
4. **Calculate the output speed if the input speed is 1800 RPM.**

Bonus Challenge:

Instead of using a **single stage**, design a **compound gear train** with two stages that still achieves a **15:1** ratio. Show your calculations.

- $\text{Gear Ratio} = \dfrac{\text{number of teeth in follower}}{\text{number of teeth in driver}}$

1 $\text{ratio} = \dfrac{\text{follower}}{\text{driver}} = 15:1$, we want something that if we devide it then the output will be 15

2 follower = 300 teeth
driver = 20 teeth : $\dfrac{300}{20} = 15 = \boxed{15:1}$

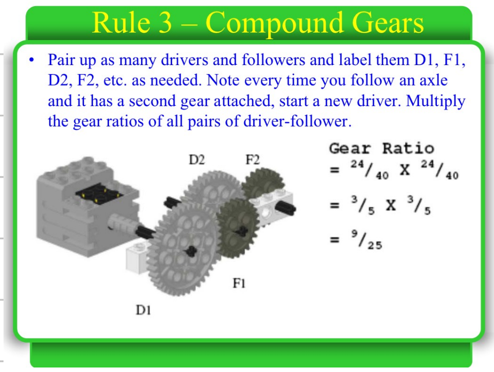
3 output Torque = $T_{out} = T_{in} \times \text{ratio} = 8 \times 15 = 120\,NM$

4 $\text{Speed}_{out} = \dfrac{\text{Speed}_{in}}{\text{ratio}} = \dfrac{1800}{15} = 120\ RPM$

bonus question

Bonus Challenge:

Instead of using a **single stage**, design a **compound gear train** with two stages that still achieves a **15:1** ratio. Show your calculations.



* if asked for compound gears then :
find 2 outputs that if we multiplied them together it will equal 15

1 $\text{ratio} = \dfrac{100}{20} = 5 = 5:1$ follower = 100 teeth
driver = 20 teeth

2 $\text{ratio} = \dfrac{90}{30} = 3 = 3:1$ follower = 90 teeth
driver = 30 teeth

$\boxed{\text{then; } 5 \times 3 = 15}$ this type of gears will be more practical in real-life applications.

Formula might be Needed :

$$\text{Gear Ratio} = \frac{\tau_{out}}{\tau_{in}} = \frac{S_{in}}{S_{out}} = \frac{\text{teeth out (follower)}}{\text{teeth in (driver)}}$$

τ = Torque , S = Speed , number of teeth .

$$\text{efficiency } (\mu) = \frac{P_{out}}{P_{in}} \quad , \quad P = \frac{2\pi N T}{60}$$

P = Power