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A- General Laboratory Safety Rules

Follow Relevant Instructions

Before attempting to install, commission or operate equipment, all relevant suppliers'/manufacturers' instructions and local regulations should be understood and implemented.

- It is irresponsible and dangerous to misuse equipment or ignore instructions, regulations, or warnings.

- Do not exceed specified maximum operating conditions (e.g. temperature, pressure, speed etc.).

Installation/Commissioning

Use lifting table where possible to install heavy equipment. Where manual lifting is necessary beware of strained backs and crushed toes. Get help from an assistant if necessary. Wear safety shoes appropriate.

- Extreme care should be exercised to avoid damage to the equipment during handling and unpacking. When using slings to lift equipment, ensure that the slings are attached to structural framework and do not foul adjacent pipe work, glassware etc.

- Locate heavy equipment at low level.

- Equipment involving inflammable or corrosive liquids should be sited in a containment area or bund with a capacity 50% greater than the maximum equipment contents.

- Ensure that all services are compatible with equipment and that independent isolators are always provided and labeled. Use reliable connections in all instances, do not improvise.

- Ensure that all equipment is reliably grounded and connected to an electrical supply at the correct voltage.

- Potential hazards should always be the first consideration when deciding on a suitable location for equipment. Leave sufficient space between equipment and between walls and equipment.

- Ensure that equipment is commissioned and checked by a competent member of staff permitting students to operate it.

Operation

Ensure the students are fully aware of the potential hazards when operating equipment.

- Students should always be supervised by a competent member of staff when in the laboratory. No one should operate equipment alone. Do not leave equipment running unattended.
- Do not allow students to derive their own experimental procedures unless they are competent to do so.

Maintenance

Badly maintained equipment is a potential hazard. Ensure that a competent member of staff is responsible for organizing maintenance and repairs on a planned basis.

- Do not permit faulty equipment to be operated. Ensure that repairs are carried out competently and checked before students are permitted to operate the equipment.

Electricity

Electricity is the most common cause of accidents in the laboratory. Ensure that all members of staff and students respect it.

- Ensure that the electrical supply has been disconnected from the equipment before attempting repairs or adjustments.
- Water and electricity are not compatible and can cause serious injury if they come into contact. Never operate portable electric appliances adjacent to equipment involving water unless some form of constraint or barrier is incorporated to prevent accidental contact.
- Always disconnect equipment from the electrical supply when not in use.

Avoiding Fires or Explosion

Ensure that the laboratory is provided with adequate fire extinguishers appropriate to the potential hazards.

- Smoking must be forbidden. Notices should be displayed to enforce this.
- Beware since fine powders or dust can spontaneously ignite under certain conditions. Empty vessels having contained inflammable liquid can contain vapor and explode if ignited.
- Bulk quantities of inflammable liquids should be stored outside the laboratory in accordance with local regulations.
- Storage tanks on equipment should not be overfilled. All spillages should be immediately cleaned up, carefully disposing of any contaminated cloths etc. Beware of slippery floors.
- When liquids giving off inflammable vapors are handled in the laboratory, the area should be properly ventilated.
- Students should not be allowed to prepare mixtures for analysis or other purposes without competent supervision.

Handling Poisons, Corrosive or Toxic Materials

Certain liquids essential to the operation of equipment, for example, mercury, are poisonous or can give off poisonous vapors. Wear appropriate protective clothing when handling such substances.

- Do not allow food to be brought into or consumed in the laboratory. Never use chemical beakers as drinking vessels
- Smoking must be forbidden. Notices should be displayed to enforce this.
- Poisons and very toxic materials must be kept in a locked cupboard or store and checked regularly. Use of such substances should be supervised.

Avoid Cuts and Burns

Take care when handling sharp edged components. Do not exert undue force on glass or fragile items.

- Hot surfaces cannot, in most cases, be totally shielded and can produce severe burns even when not visibly hot. Use common sense and think which parts of the equipment are likely to be hot.

Eye/Ear Protection

Goggles must be worn whenever there is risk to the eyes. Risk may arise from powders, liquid splashes, vapors, or splinters. Beware of debris from fast moving air streams.

- Never look directly at a strong source of light such as a laser or Xenon arc lamp. Ensure the equipment using such a source is positioned so that passers-by cannot accidentally view the source or reflected ray.
- Facilities for eye irrigation should always be available.
- Ear protectors must be worn when operating noisy equipment.

Clothing

Suitable clothing should be worn in the laboratory. Loose garments can cause serious injury if caught in rotating machinery. Ties, rings on fingers etc. should be removed in these situations.

- Additional protective clothing should be available for all members of staff and students as appropriate.

Guards and Safety Devices

Guards and safety devices are installed on equipment to protect the operator. The equipment must not be operated with such devices removed.

- Safety valves, cut-outs or other safety devices will have been set to protect the equipment. Interference with these devices may create a potential hazard.
- It is not possible to guard the operator against all contingencies. Use commons sense at all times when in the laboratory.
- Before staring a rotating machine, make sure staff are aware how to stop it in an emergency.
- Ensure that speed control devices are always set to zero before starting equipment.

First Aid

If an accident does occur in the laboratory, it is essential that first aid equipment is available, and that the supervisor knows how to use it.

- A notice giving details of a proficient first aider should be prominently displayed.
- A short list of the antidotes for the chemicals used in the particular laboratory should be prominently displayed.

B-Standard lab safety must be followed in all laboratories

1. First discuss your experiment regarding possible hazards or problems, with your professor, the engineering laboratory demonstrator, or the MIE technical staff.
2. Do not do laboratory work alone. Work with another person in a lab that has running machinery, machine tools, conveyors, hydraulics, lifting equipment, voltage hazards, or where chemicals are in use.
3. Safety glasses must be worn in the vicinity of chemicals, pneumatics, compressed gasses, machine tools, grinders, power saws, and drills. Users of lasers need special safety glasses for the particular wavelength of the laser.
4. No equipment or machine may be operated by anyone unless they have received proper instruction, e.g. machine tools, hydraulics, chemicals, lasers, running machinery, robots. Undergraduate students may not use any machine tool or equipment unless a department technical staff member or an engineering laboratory demonstrator is present. Graduate students are the responsibility of their immediate academic supervisor.
5. All appropriate safety accessories (lab coats, safety glasses, gloves, etc.) must be used when handling chemicals. No open toe shoes are permitted in laboratories.
6. Long term unattended tests must be fail-safe, and information must be posted as if a hazard is present.
7. No eating in laboratories. No food or beverages in laboratories where chemicals are used or stored e.g. wet labs.
8. An incident report must be filled out by the person involved for all accidents and injuries.

C- Introduction

The purpose of the kinematics and dynamics of mechanisms experiments is twofold. First, they are intended to explain the student with machine elements and mechanical systems as well as provide an insight of techniques of Kinematic and dynamic analysis. This is part of the overall design process and it forms an integral part of a good engineering curriculum. Second, they provide a realistic environment within which the student can practice writing technical reports.

The teaching aspect is fulfilled by conducting the experiment and submitting a sample calculation sheet to satisfy the lab instructor that the concepts and methodology of each experiment are thoroughly understood.

These experiments are frequently scheduled to be conducted following the lectures, however, since there is one setup per experiment, it is not uncommon for some groups to start with experiments not yet covered in class. This will give the students the opportunity to prepare for their labs on their own, and discuss with the lab demonstrator if further clarification is essential.

The second objective is slightly challenging and requires hard work on the part of the student. Each group is expected to select one of the experiments performed and submit a formal report on it. In view of the following comments on technical writing, no guidelines shall be given as to how long or detailed the report should be.

D- Four-Bar Linkage Mechanism

1. Definitions

In the range of planar mechanisms, the simplest groups of lower pair mechanisms are four bar linkages. A *four-bar linkage* comprises four bar-shaped links and four turning pairs as shown in Figure 1.

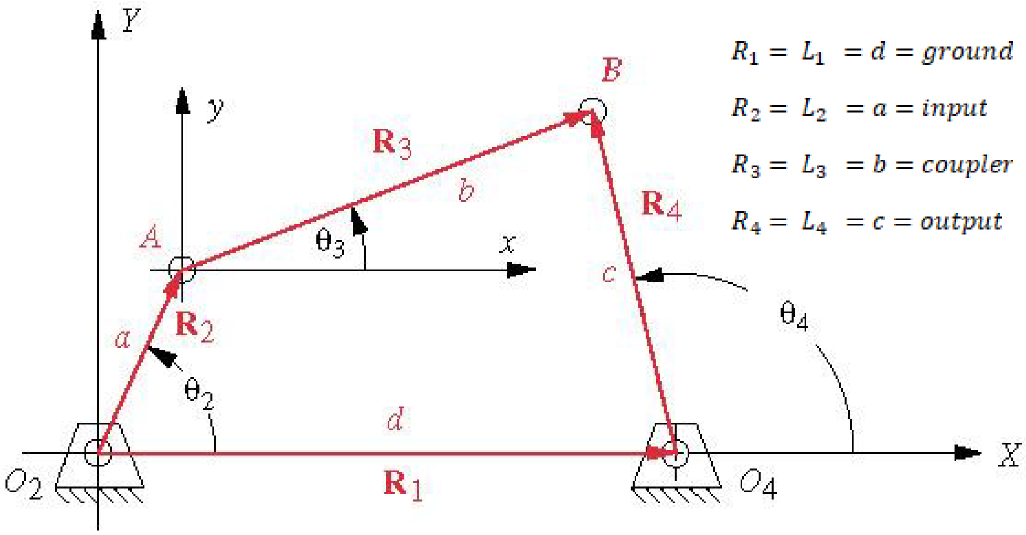


Figure 1: *Four bar linkage*

The link opposite the frame is called the *coupler link*, and the links which are hinged to the frame are called *side links*. A link which is free to rotate through 360 degree with respect to a second link will be said to *revolve* relative to the second link (not necessarily a frame). If it is possible for all four bars to become simultaneously aligned, such a state is called a *change point*.

Some important concepts in link mechanisms are:

1. **Crank**

   A side link which revolves relative to the frame is called a *crank*.

2. **Rocker**

   Any link which does not revolve is called a *rocker*.

3. **Coupler**

   Link with complex motion and it is not connected to the ground.

4. **Ground**

   Fixed link or reference

2. Classification

Before classifying four-bar linkages, we need to introduce some basic nomenclature. In a four-bar linkage, we refer to the line segment between joint on a given link as a bar

The four-bar linkage has been shown to be the simplest possible pin-jointed mechanism for
The Grashof condition is a very simple relationship that predict the rotation behavior or rotatability of a four bar linkage's inversions based only on the link lengths.

The linkage is Grashof if

$$\mathbf{S + L \leq P + Q}$$

Let:
S= length of shortest link
L = length of longest link
P= length of one remaining link
Q= length of another remaining link

If the linkage is Grashof that is mean at least one link will be capable of making a full evolution with respect to the ground plane.
If it's not, then the linkage is non-Grashof and no link will be capable of a complete revolution relative to any other link.

TABLE 2-4 **Barker's Complete Classification of Planar Fourbar Mechanisms**

Adapted from ref. (10). s = shortest link, l = longest link, Gxxx = Grashof, RRRx = non-Grashof, Sxx = Special case

Type	$s + l$ vs. $p + q$	Inversion	Class	Barker's Designation	Code	Also Known As
1	<	$L_1 = s =$ ground	I-1	Grashof crank-crank-crank	GCCC	double-crank
2	<	$L_2 = s =$ input	I-2	Grashof crank-rocker-rocker	GCRR	crank-rocker
3	<	$L_3 = s =$ coupler	I-3	Grashof rocker-crank-rocker	GRCR	double-rocker
4	<	$L_4 = s =$ output	I-4	Grashof rocker-rocker-crank	GRRC	rocker-crank
5	>	$L_1 = l =$ ground	II-1	Class 1 rocker-rocker-rocker	RRR1	triple-rocker
6	>	$L_2 = l =$ input	II-2	Class 2 rocker-rocker-rocker	RRR2	triple-rocker
7	>	$L_3 = l =$ coupler	II-3	Class 3 rocker-rocker-rocker	RRR3	triple-rocker
8	>	$L_4 = l =$ output	II-4	Class 4 rocker-rocker-rocker	RRR4	triple-rocker
9	=	$L_1 = s =$ ground	III-1	change point crank-crank-crank	SCCC	SC* double -crank
10	=	$L_2 = s =$ input	III-2	change point crank-rocker-rocker	SCRR	SC crank-rocker
11	=	$L_3 = s =$ coupler	III-3	change point rocker-crank-rocker	SRCR	SC double-rocker
12	=	$L_4 = s =$ output	III-4	change point rocker-rocker-crank	SRRC	SC rocker-crank
13	=	two equal pairs	III-5	double change point	S2X	parallelogram or deltoid
14	=	$L_1 = L_2 = L_3 = L_4$	III-6	triple change point	S3X	square

* SC = special case.

***Table 1:** Barker's classification of planar four bar mechanism*

Experiment 1

Aim:

Identify the main types of four-bar mechanism that identify the Grashof condition.

Composition:

1. Working panel
2. 50 mm link
3. 70 mm link
4. 150 mm link
5. 2 bearing joints
6. 2 screws
7. 2 nuts
8. 2 plastic ball bearing

Exercise 1

I. If you make the shortest link (50 mm) as input L2, link 150 mm as coupler L3 and the link 100 mm as output.

Which one of those ground link dimensions identify Grashof condition GCRR?

a) L1=20.23 cm
b) L1=17.78 cm
c) L1=25.24 cm

II. Draw the schematic representative to scale and illustrate the motion describe crank rocker

Exercise 2

If you make the link (150 mm) as input L2, the shortest link (50 mm) as coupler L3, the link 100 mm as output and 177.8 mm as ground link.

I. Draw the schematic representative to scale and illustrate the motion describe this condition

Exercise 3

If you make the link (150 mm) as input L2, link 100 mm as coupler L3, the shortest link (50 mm) as output and 177.8 mm as ground link.

I. Draw the schematic representative to scale and illustrate the motion describe this condition

Exercise 4

If you make the link L2 150 mm as a input L2, link 70 mm as coupler L3, the link 150 mm as output and the shortest link 50 mm as a ground.

Draw the schematic representative to scale and illustrate the motion describe this condition

<u>Exercise 5</u>

In the previous 4 exercises (check the above), we used the same 4 link bar dimensions.
Fill the following table accordingly

Type	Fourbar Mechanism	Code	Input link dimension (mm)	Coupler link dimension (mm)	Output link dimension (mm)	Ground link dimension (mm)
1						
2						
3						
4						

Based on the different mechanisms listed in the above table, what is the needed modification to transform a mechanism to another one?

Experiment 2

Aim:
Identify angular position of the output as a function of the input Θ_2.

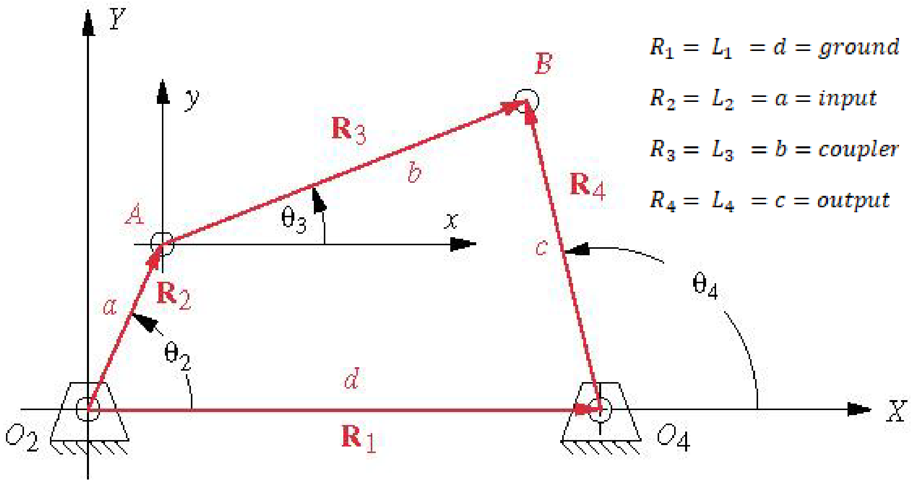


Figure 2: *Four bar mechanism co-ordination*

Composition:

1. Working panel
2. 50 mm link
3. 100 mm link
4. 150 mm link
5. 2 bearing joints
6. 2 screws
7. 2 nuts
8. 2 plastic ball bearing
9. Graph paper

<u>Exercise 1</u>

1. Make the shortest link (50 mm) as input L2, link 150 mm as coupler L3 , the link 100 mm as output and the link 177.8 mm as ground.

Which is the type of four bar mechanism?

a) Theories measurement

1. For Θ_2 **= 120 °,** calculate the value of $\Theta_4\ and\ \Theta_3$

a= b= c= d=

$k_1 = \frac{d}{a}$	
$k_2 = \frac{d}{c}$	
$k_3 = \frac{a^2 - b^2 + d^2 + c^2}{c}$	
$k_4 = \frac{d}{b}$	
$k_5 = \frac{c^2 - d^2 - a^2 - b^2}{c}$	
A=$\cos\Theta_2 - k_1 - k_2\cos\Theta_2 + k_3$	
E=B=$-2\sin\Theta_2$	
C=$k_1 - (k_2 + 1)\cos\Theta_2 + k_3$	
D=$\cos\Theta_2 - k_1 + k_4\cos\Theta_2 + k_5$	
F =$k_1 - (k_4 - 1)\cos\Theta_2 + k_5$	
$\Theta_4 = -2\arctan(\frac{-B \pm \sqrt{B^2 - 4AC}}{2A})$	
$\Theta_3 = -2\arctan(\frac{-E \pm \sqrt{E^2 - 4DF}}{2AD})$	

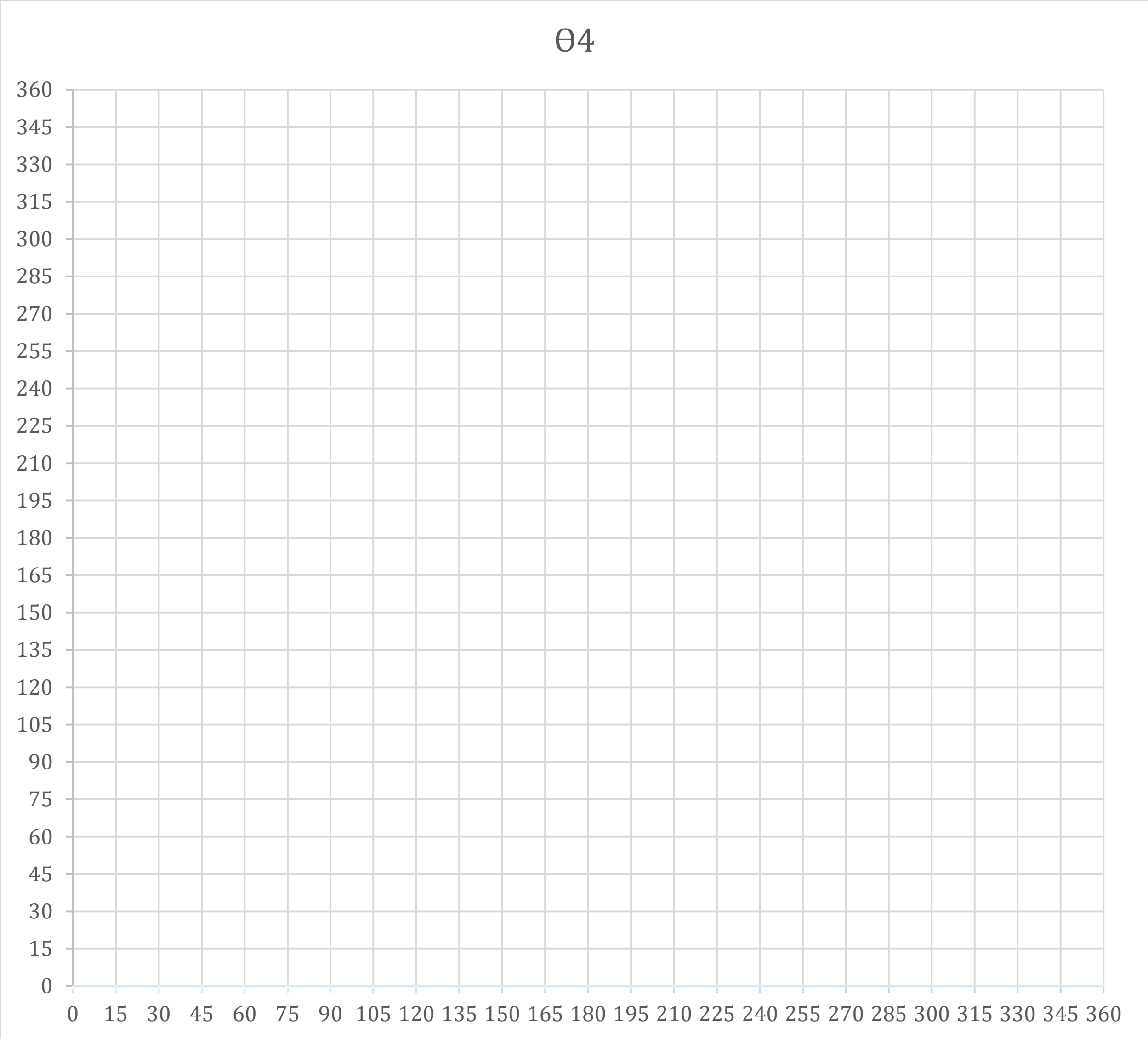
b) Experimental measurement

2. On a graph paper, plot θ_4, θ_3 angles for each input angle. Fill the table below

θ_2	θ_3	θ_4
10°		
30 °		
60 °		
90 °		
120 °		
180 °		
220 °		
250°		
300 °		
330 °		
350 °		

3. Represent the result value of Θ_4 as a function of Θ_2

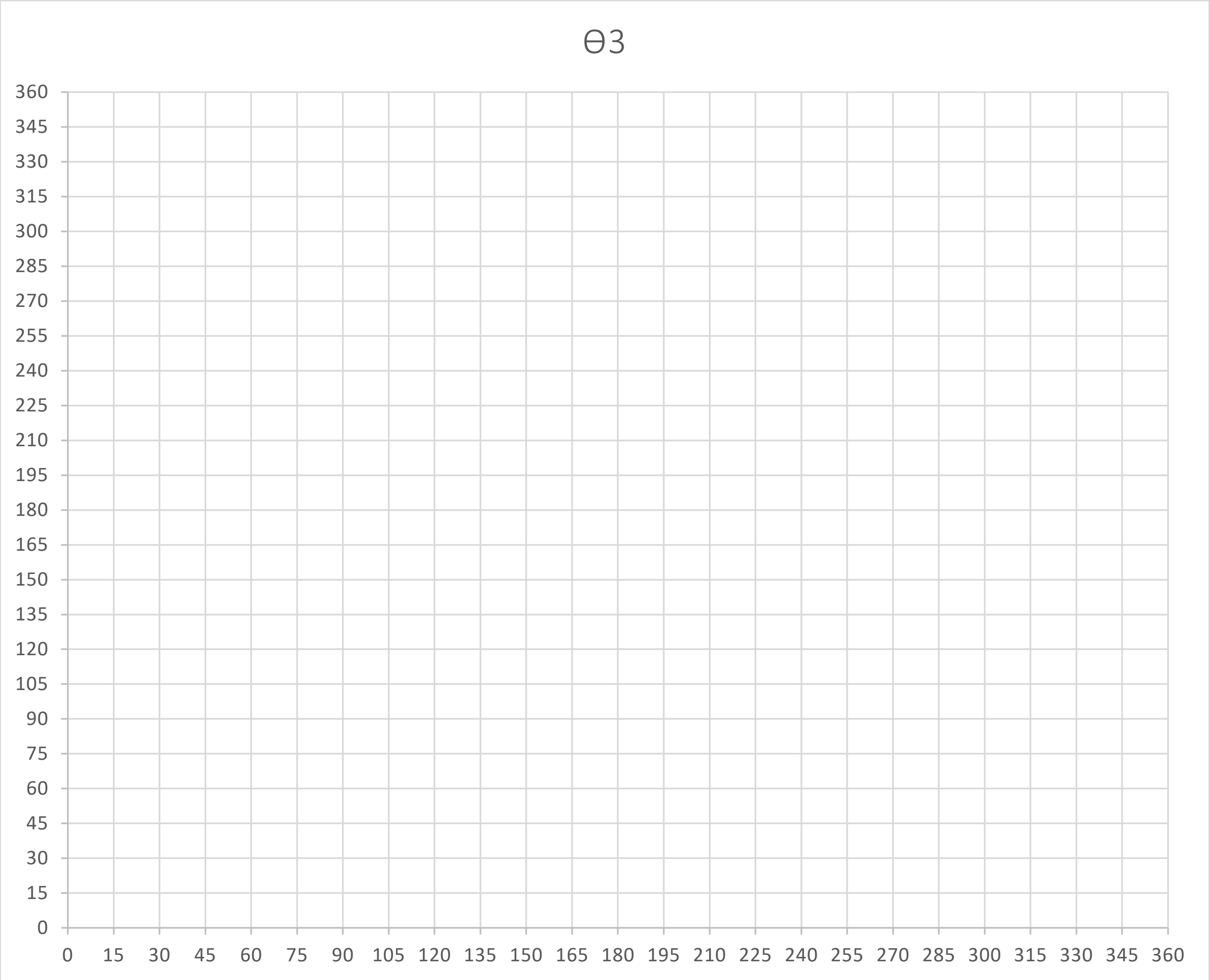
$\Theta_4 = f(\Theta_2)$



4. Describe this result:

5. Represent the result value of Θ_3 as a function of Θ_2

$\Theta_3 \; = \; f\,(\Theta_2)$



6. Describe this result:

Experiment 3

Design a Slider – crank mechanism

Slider-crank mechanism, arrangement of mechanical parts designed to convert straight-line motion to rotary motion, as in a reciprocating piston engine, or to convert rotary motion to straight-line motion, as in a reciprocating piston pump. The basic nature of the mechanism and the relative motion of the parts can best be described with the aid of the accompanying figure, in which the moving parts are lightly shaded. The darkly shaded part 1, the fixed frame or block of the pump or engine, contains a cylinder, depicted in cross section by its walls *DE* and *FG,* in which the piston, part 4, slides back and forth.

The small circle at *A* represents the main crankshaft bearing, which is also in part 1. The crankshaft, part 2, is shown as a straight member extending from the main bearing at *A* to the crankpin bearing at *B,* which connects it to the connecting rod, part 3.

The connecting rod is shown as a straight member extending from the crankpin bearing at *B* to the wristpin bearing at *C,* which connects it to the piston, part 4, which is shown as a rectangle.

The three bearings shown as circles at *A, B,* and *C* permit the connected members to rotate freely with respect to one another. The path of *B* is a circle of radius *AB;* when *B* is at point *h* the piston will be in position *H,* and when *B* is at point *j* the piston will be in position *J.*

On a gasoline engine, the head end of the cylinder (where the explosion of the gasoline-air mixture takes place) is at *EG;* the pressure produced by the explosion will push the piston from position *H* to position *J;* return motion from *J* to *H* will require the rotational energy of a flywheel attached to the crankshaft and rotating about a bearing collinear with bearing *A.* On a reciprocating piston pump the crankshaft would be driven by a motor.

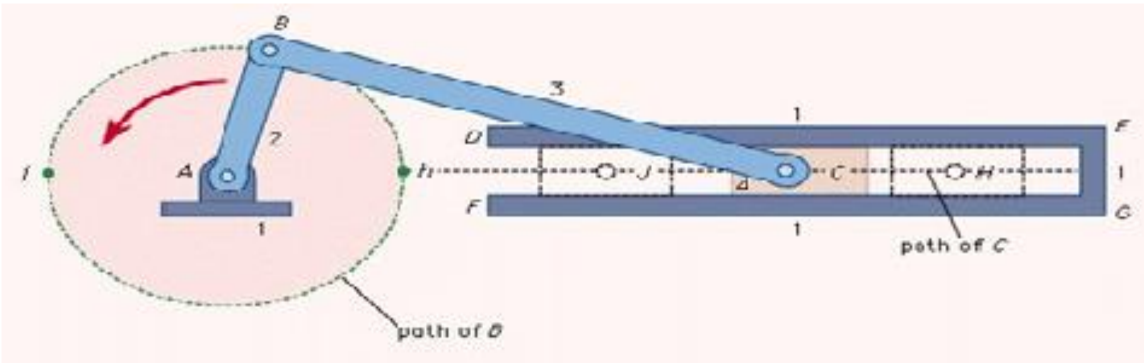


***Figure 3**: Slider – crank mechanism*

Composition:

1. Working panel
2. 50 mm link
3. 100 mm link
4. 150 mm link
5. 2 bearing joints
6. 2 screws
7. 2 nuts
8. 6 plastic ball bearing
9. Graph paper

Exercice 1

Design a simple slider crank mechanism using:
L2: 5 cm
L3: 15 cm

Draw the schematic representative to scale, and fill all missing values in the table below

θ_2	**Position of the slider AC**
0°	
30°	
60°	
90°	
120°	
150°	
180°	
210°	
240°	
270°	
300°	
330°	

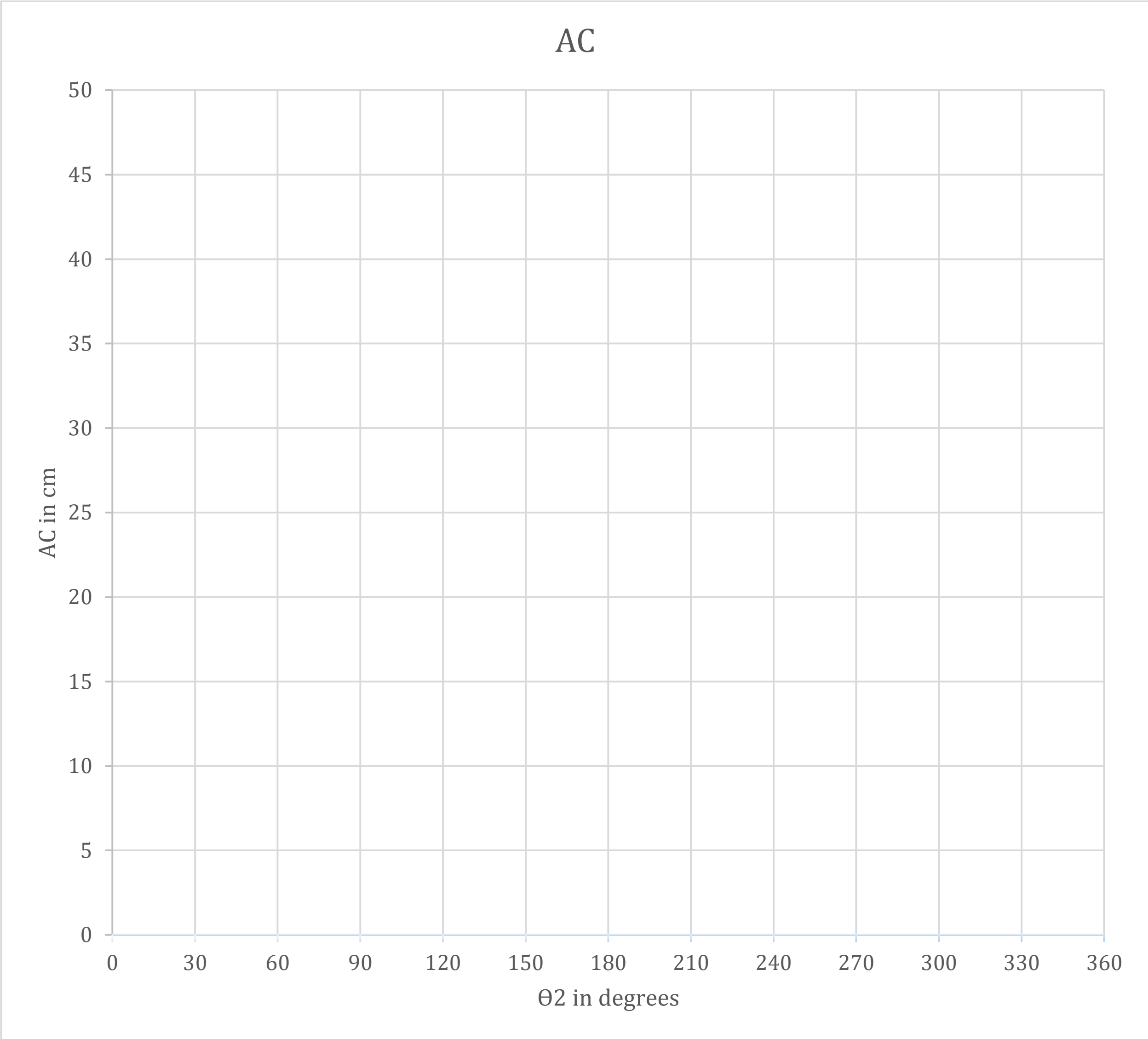
Exercice 2

Design a simple slider crank mechanism using:
L2: 10 cm
L3: 15 cm

Draw the schematic representative to scale and fill all missing values in the table below

θ_2	Position of the slider AC
0°	
30°	
60°	
90°	
120°	
150°	
180°	
210°	
240°	
270°	
300°	
330°	

Represent these results on the same graph.



<u>Experiment 4</u>

Aim:

Path of point arbitrary analysis of point P situated on the triangular link a function of the input Θ_2.

Composition:

1. Working panel
2. Triangular link (a = 15 , b = 7.5 , c = 10)
3. 50 mm link
4. 100 mm link
5. 177.8 mm link
6. 2 bearing joints
7. 2 screws
8. 2 nuts
9. 2 plastic ball bearing
10. Graph paper

<u>Exercise 1</u>

1. Propose a simple industrial application, design Grashof condition GCRR using those links and Draw the schematic representative to scale

2. For each value of Θ_2 define exact location of point P ($|O_2P|$, $\Theta = (O_2P\ ,\ O_2O_4)$

Θ_2	$\boldsymbol{|O_2P|}$	$\boldsymbol{\Theta = (O_2P\ ,\ O_2O_4)}$
0°		
30°		
60°		
90°		
120°		
150°		
180°		
210°		
240°		
270°		
300°		
330°		

Experiment 5

Aim:

Identify and measure all the gear tooth specification and verify that they respect the AGMA full depth gear tooth specifications.

Gear and Pully kit

1. Definition of gear

Gear is used to transmit motion from one shaft to another shaft or between a shaft and slide. This is accomplished by successively engaging teeth.

2. Classification of gear

Gears can be classified according to the relative position of their shaft axis are follows:

- Parallel shaft: spur gear, spur gear and pinion, helical spur gear
- Intersecting shaft: straight bevel gear, spiral bevel gear
- Skew shaft: Non-parallel non-intersecting shaft.

3. Nomenclature of spur gear

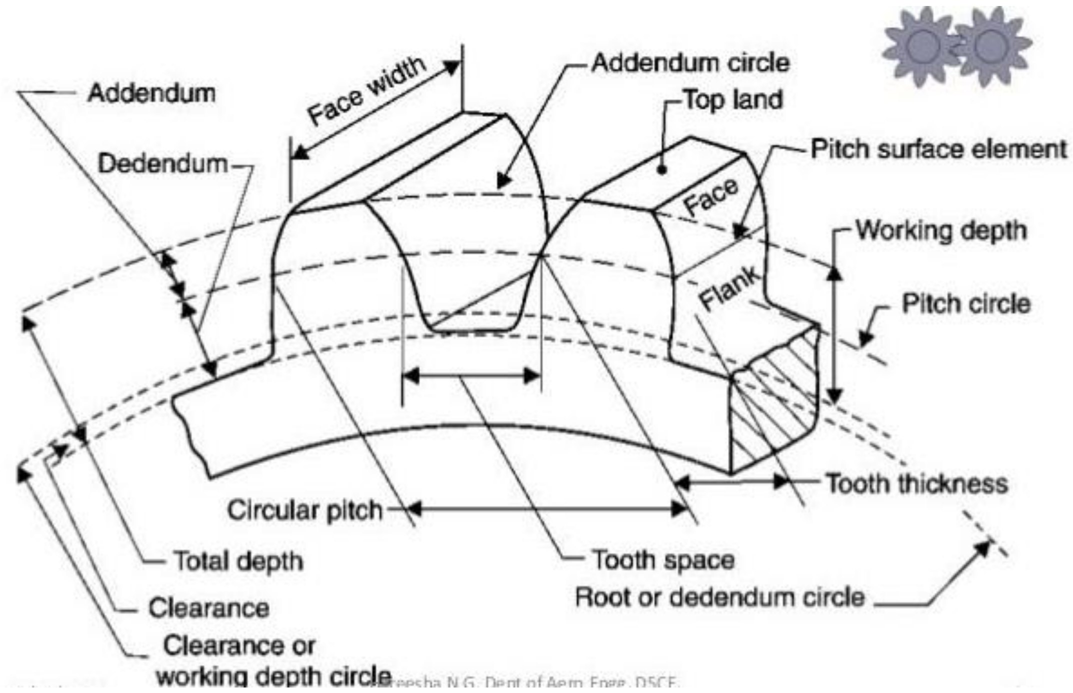


***Figure 4**: Spur gear*

- **Pitch Cylinder:**

Pitch cylinders of a pair of gears in mesh are the imaginary friction cylinders, which by pure rolling together, transmit the same motion as the pair of gears.

- **Pitch circle:**

Pitch circle is the imaginary circle on the gear about which it may be supposed to roll without slipping with pitch circle of another gear.

- **Pitch point:**

The point of contact of two pitch circle becomes the pitch point.

- **Pitch surface:**

Surface of the pitch cylinder.

- **Line of centers:**

Line through the centers of rotation of a pair of mating gears.

- **Pinion:**

Smaller and usually the driving gear of a pair of mated gears.

- **Circular Pitch p_c (in):**

Distance measured along the circumference of the pitch circle from a point on one tooth to the corresponding point on the adjacent tooth.

$$p_c = \frac{\pi d}{N}$$

Where: d is the pitch diameter in [in]
N nb of teeth

- **Diametral pitch P_d [l/in]**

Number of teeth per unit length of the pitch circle diameter.

$$\boldsymbol{P_d = \frac{N}{d} \quad P_d = \frac{\pi}{p_c}}$$

The diametric pitch must be the same for gears in mesh

- **Module (m)**

Ratio of pitch diameter to the number of teeth.

$$\mathbf{m} = \frac{d}{N} \ , \ \mathrm{m} = \frac{25.4}{p_d}$$

- **Gear Ratio:**

Ratio of Number of teeth on the gear to that on the pinion.

$$\boldsymbol{m_G = \frac{N_2}{N_1}}$$

- **Clearance**

The distance between the top of tooth and the bottom of the space into which it fits on the meshing gear.

- **Full depth of teeth or total depth**

Total radial depth of the tooth space, Full depth = Addendum + Dedendum.

- **Working depth:**

The depth to which a tooth extends into the space between teeth on the mating gear. It is the sum of addendum of two gears.

- **Space Width:**

Width of the tooth space along the pitch circle.

- **Tooth thickness:**

Thickness of the tooth measured along the pitch circle.

- **Backlash:**

Play between mating teeth. It is the difference between space width and tooth thickness along the pitch circle.

- **Face width:**

Length of the tooth parallel to the gear axis.

- **Top Land:**

Surface of the top of the tooth.

- **Bottom Land:**

Surface of the bottom of tooth between the adjacent fillets.

- **Face:**

Tooth surface between the pitch circle and the top land.

- **Flank:**

Tooth surface between pitch circle and bottom land.

- **Fillet:**

Curved portion of the tooth flank.

- **Velocity & Torque Ratio:**

Ratio of angular velocity of the follower (driven) to the angular velocity of the driving ear.

The velocity ratio $$m_v = \pm\frac{d_{in}}{d_{out}} = \pm\frac{N_{in}}{N_{out}} = \pm\frac{R_{out}}{R_{in}} = \pm\frac{\omega_{out}}{\omega_{in}}$$

The torque ratio $$m_T = \pm\frac{d_{out}}{d_{in}} = \pm\frac{N_{out}}{N_{in}}$$

Let
d: Pitch diameter
N: number of teeth
W: angular velocity (rad/s)
R: Speed (rpm)
Subscript (1=driver, 2=follower (driven))

- **Line of action/Pressure Line/Force Line**

  Consider 2 involute gears, meshing with each other and one driving another. Now to drive the 2nd gear, a tooth of first gear must push the tooth on 2nd gear, i.e. apply force on it. Now this force will act a long a line. That line is called line of action or Force line or pressure line.

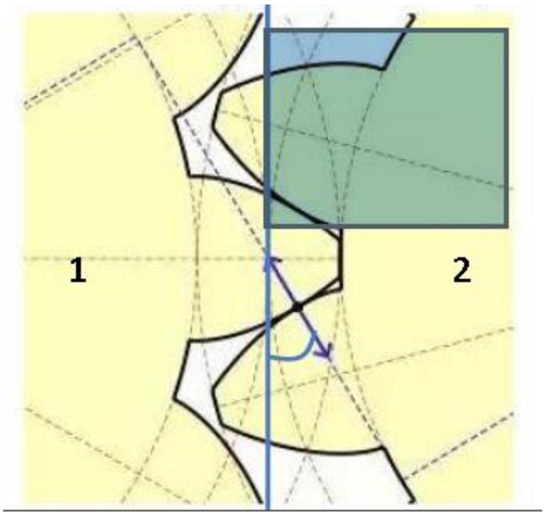


Figure 5*: Line of action/Pressure Line/Force Line*

- **<u>Pressure angle or angle of obliquity (Φ):</u>**

Angle between the tangent to the pitch circle at the pitch point and the pressure line.

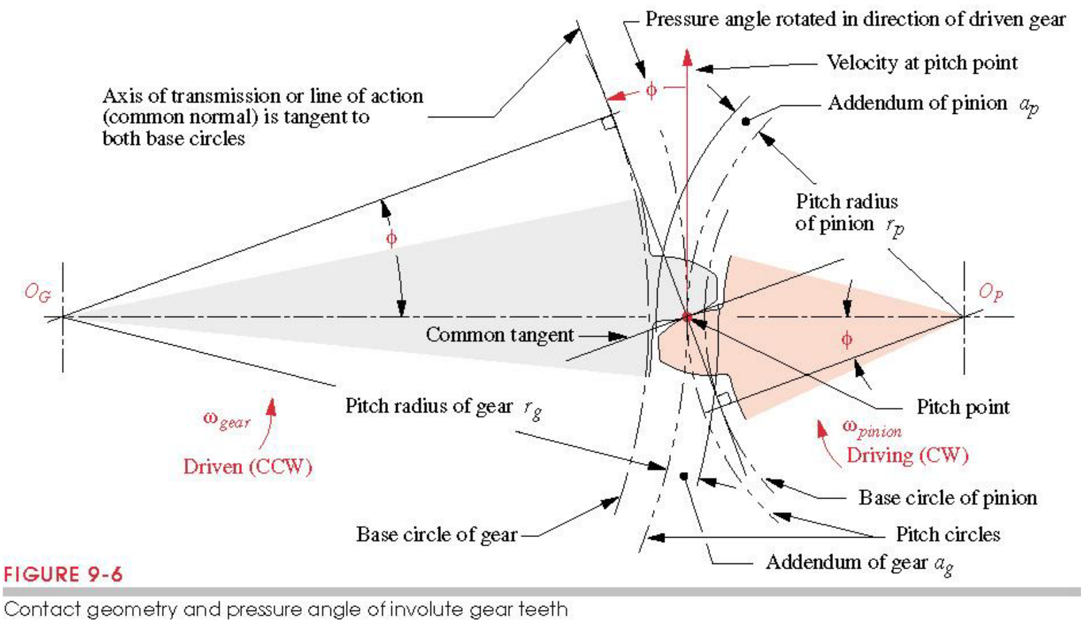


Figure 6*: Pressure angle or angle*

TABLE 9-1 AGMA Full-Depth Gear Tooth Specifications

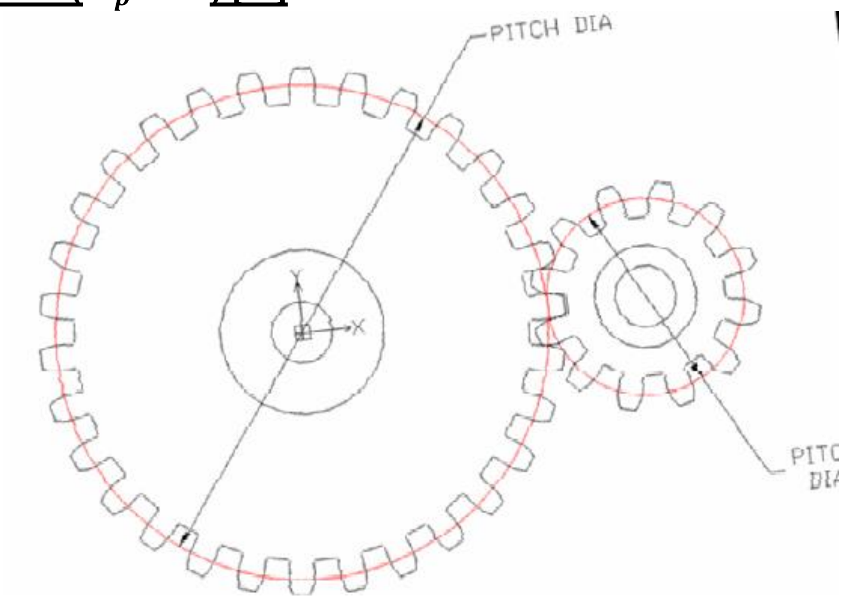
Parameter	Coarse Pitch ($p_d < 20$)	Fine Pitch ($p_d \geq 20$)
Pressure angle ϕ	20° or 25°	20°
Addendum a	$1.000 / p_d$	$1.000 / p_d$
Dedendum b	$1.250 / p_d$	$1.250 / p_d$
Working depth	$2.000 / p_d$	$2.000 / p_d$
Whole depth	$2.250 / p_d$	$2.200 / p_d + 0.002$ in
Circular tooth thickness	$1.571 / p_d$	$1.571 / p_d$
Fillet radius—basic rack	$0.300 / p_d$	Not standardized
Minimum basic clearance	$0.250 / p_d$	$0.200 / p_d + 0.002$ in
Minimum width of top land	$0.250 / p_d$	Not standardized
Clearance (shaved or ground teeth)	$0.350 / p_d$	$0.350 / p_d + 0.002$ in

***Table 2**: AGMA full-Depth Gear Tooth Specifications*

Composition:

1. **10** teeth Spur gear ($P_d = 5\ in^{-1}$, $d_p = 2\ in$) : SP_1
2. **15** teeth Spur gear ($P_d = 5\ in^{-1}$, $d_p = 3\ in$) : SP_2
3. **20** teeth Spur gear ($P_d = 5\ in^{-1}$, $d_p = 4\ in$) : SP_3

1. Pitch Diameter (d_p or d) [in]



- The diameter of an imaginary pitch circle on which a gear tooth is designed
- Pitch circles of 2 gears are tangent
- $\boldsymbol{d_p} = d = \frac{N}{P_d}$

2. Diametral Pitch (P_d)

- A ratio equal to the number of teeth on a gear per inch of diameter
- $\boldsymbol{P_d} = \frac{N}{d_p} = \frac{N}{d}$

3. Number of Teeth

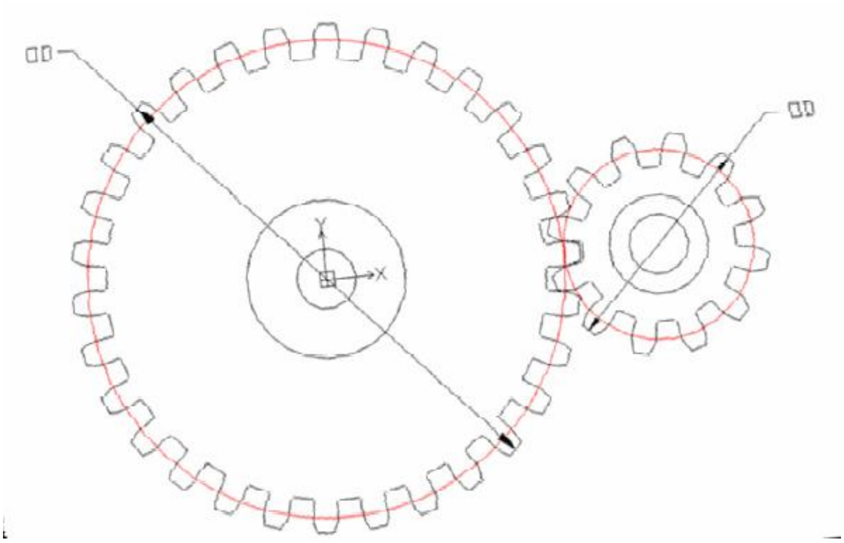
N is the number of teeth

N = $\boldsymbol{P_d \ x \ d_p}$

Verify these 3-spur gear.

Spur gear	**Diametral pitch $\mathbf{P_d}$**	**Pitch diameter $\mathbf{d_p}$ or d**	**Number of teeth**
$\mathbf{SP_1}$	$\mathbf{P_d = 5\ in^{-1}}$	$\mathbf{d_p = 2\ in}$	$\mathbf{N_1 =}$
$\mathbf{SP_2}$	$\mathbf{P_d = 5\ in^{-1}}$	$\mathbf{d_p = 3\ in}$	$\mathbf{N_2 =}$
$\mathbf{SP_3}$	$\mathbf{P_d = 5\ in^{-1}}$	$\mathbf{d_p = 4\ in}$	$\mathbf{N_3 =}$

4. Outside Diameter (OD), diameter for addendum cercle

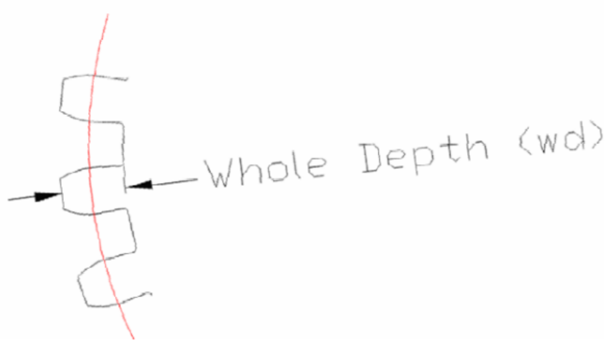


Outside diameter (OD) is the overall diameter of the gear

$$OD = \frac{N+2}{p_d}$$

Spur gear	Number of teeth	Diametral pitch P_d	Outside diameter (OD) By calculation	Outside diameter (OD) By Caliper
SP_1	$N_1 =$	$P_d = 5\ in^{-1}$	$OD_1 =$	$OD_1 =$
SP_2	$N_2 =$	$P_d = 5\ in^{-1}$	$OD_2 =$	$OD_2 =$
SP_3	$N_3 =$	$P_d = 5\ in^{-1}$	$OD_3 =$	$OD_3 =$

5. Whole Depth (WD)

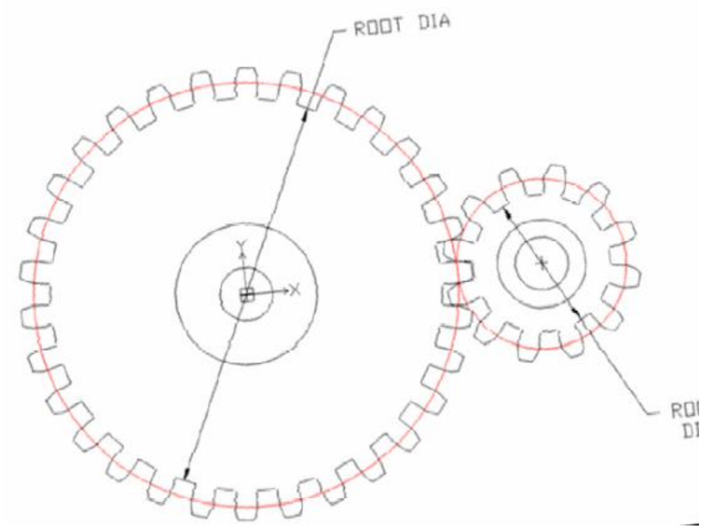


Whole depth is the full height of the tooth.

$$WD = \frac{2.25}{P_d}$$

Spur gear	Diametral pitch P_d	Pitch diameter d_p or d	Whole depth WD By calculation	Whole depth WD By Caliper
SP_1	$P_d = 5\ in^{-1}$	$d_p = 2\ in$	$WD_1 =$	$WD_1 =$
SP_2	$P_d = 5\ in^{-1}$	$d_p = 3\ in$	$WD_2 =$	$WD_2 =$
SP_3	$P_d = 5\ in^{-1}$	$d_p = 4\ in$	$WD_3 =$	$WD_3 =$

6. Root Diameter (RD)

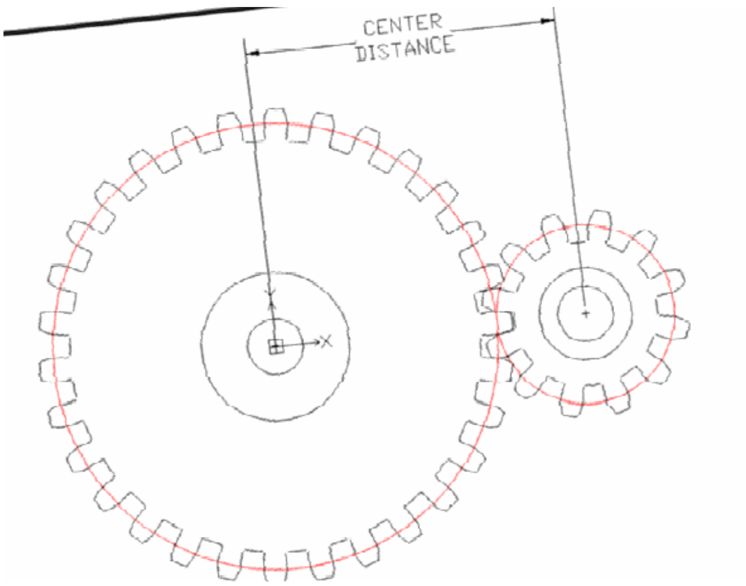


The diameter of a circle coincident with the bottom of the tooth spaces.

$RD = OD - 2\ x\ \boldsymbol{W_D}$

Spur gear	Outside diameter (OD)	Whole depth	Root diameter (RD) By calculation	Root diameter (RD) By Caliper
$\boldsymbol{SP_1}$	$\boldsymbol{OD_1} =$	$\boldsymbol{WD_1} =$	$\boldsymbol{RD_1} =$	$\boldsymbol{RD_1} =$
$\boldsymbol{SP_2}$	$\boldsymbol{OD_2} =$	$\boldsymbol{WD_2} =$	$\boldsymbol{RD_2} =$	$\boldsymbol{RD_2} =$
$\boldsymbol{SP_3}$	$\boldsymbol{OD_3} =$	$\boldsymbol{WD_3} =$	$\boldsymbol{RD_3} =$	$\boldsymbol{RD_3} =$

7. Center Distance (CD)

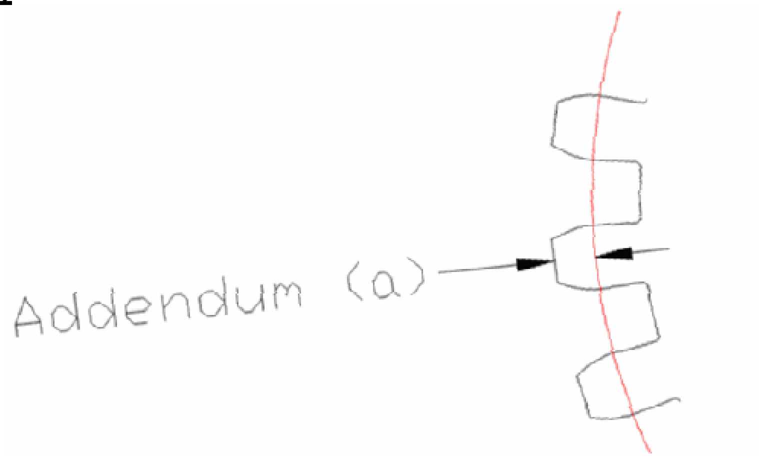


The distance between the axis of 2 mating gears

$$\mathbf{CD} = \frac{d_{p\ gear\ 1}}{2} + \frac{d_{p\ gear\ 2}}{2}$$

2 mating Spur gear	Diametral pitch	Center Distance (CD) By calculation	Center Distance (CD) By Caliper
$SP_1 - SP_2$	$d_p = 2\ in\ \&\ d_p = 3\ in$	$CD_1 =$	$CD_1 =$
$SP_1 - SP_3$	$d_p = 2\ in\ \&\ d_p = 4\ in$	$CD_2 =$	$CD_2 =$
$SP_2 - SP_3$	$d_p = 3\ in\ \&\ d_p = 4\ in$	$CD_3 =$	$CD_3 =$

8. Addendum (a)

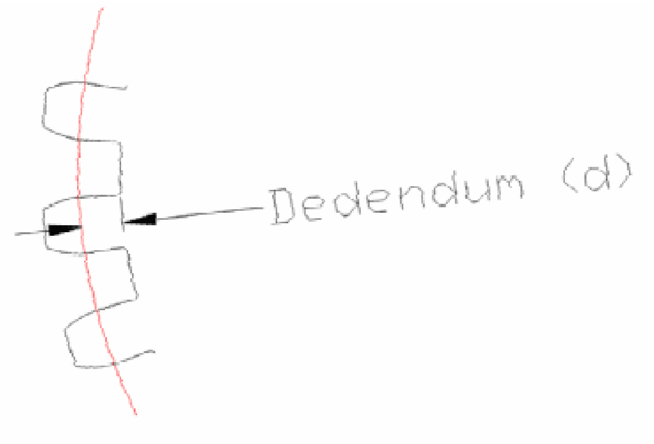


The radial distance from the pitch circle to the top of the tooth.

$$a = \frac{1}{P_d}$$

Spur gear	Diametral pitch P_d	Pitch diameter d_p or d	Addendum a By calculation	Addendum a By Caliper
SP_1	$P_d = 5\ in^{-1}$	$d_p = 2\ in$	$a_1 =$	$a_1 =$
SP_2	$P_d = 5\ in^{-1}$	$d_p = 3\ in$	$a_2 =$	$a_2 =$
SP_3	$P_d = 5\ in^{-1}$	$d_p = 4\ in$	$a_3 =$	$a_3 =$

9. Dedendum (d)

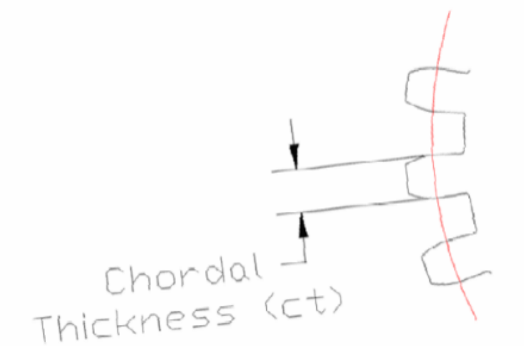


The radial distance from the pitch circle to the bottom of the tooth.

b $=\frac{1.25}{P_d}$

Spur gear	Diametral pitch P_d	Pitch diameter d_p or d	Reddendum b By calculation	Reddendum b By Caliper
SP_1	$P_d = 5\ in^{-1}$	$d_p = 2\ in$	$b_1 =$	$b_1 =$
SP_2	$P_d = 5\ in^{-1}$	$d_p = 3\ in$	$b_2 =$	$b_2 =$
SP_3	$P_d = 5\ in^{-1}$	$d_p = 4\ in$	$b_3 =$	$b_3 =$

10. Chordal Thickness (c_t)

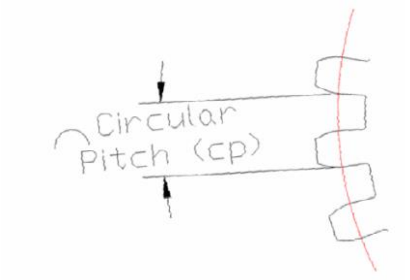


The straight-line thickness of a gear tooth measured on the pitch circle.

$$c_t = d_p\ x\ \sin\left(\frac{90}{N}\right)$$

Spur gear	Pitch diameter d_p or d	Number of teeth	Chordal Thickness By calculation	Chordal Thickness By Caliper
SP_1	$d_p = 2\ in$	$N_1 =$	$c_{t_1} =$	$c_{t_1} =$
SP_2	$d_p = 3\ in$	$N_2 =$	$c_{t_2} =$	$c_{t_2} =$
SP_3	$d_p = 4\ in$	$N_3 =$	$c_{t_3} =$	$c_{t_3} =$

11. Circular Pitch (C_P)

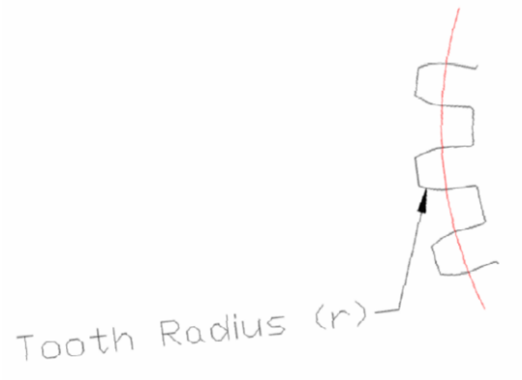


The distance from a point on one tooth to the corresponding point on the adjacent tooth, Measured on the pitch circle.

$$C_P = \frac{3.1416}{p_d}$$

Spur gear	Diametral pitch P_d	Circular Pitch C_P By calculation	Circular Pitch C_P By Caliper
SP_1	$P_d = 5\ in^{-1}$	$C_{P_1} =$	$C_{P_1} =$
SP_2	$P_d = 5\ in^{-1}$	$C_{P_2} =$	$C_{P_2} =$
SP_3	$P_d = 5\ in^{-1}$	$C_{P_3} =$	$C_{P_3} =$

12. Tooth Radius (r)



Tooth radius is Radius of tooth profile.

$$r = \frac{0.3}{C_P}$$

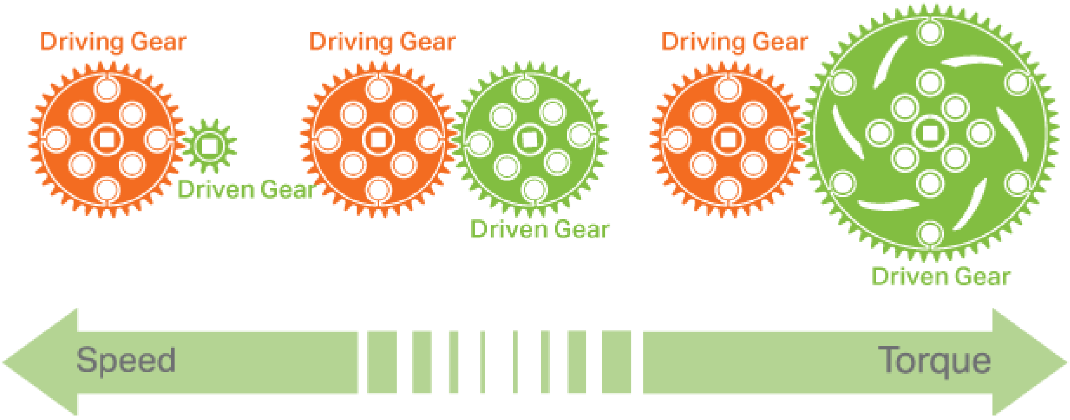
Spur gear	Circular Pitch C_P By calculation	Tooth radius By calculation	Tooth radius By Caliper
$\boldsymbol{SP_1}$	$C_{P\mathbf{1}} =$	$\boldsymbol{r_1} =$	$\boldsymbol{r_1} =$
$\boldsymbol{SP_2}$	$C_{P\mathbf{2}} =$	$\boldsymbol{r_2} =$	$\boldsymbol{r_2} =$
$\boldsymbol{SP_3}$	$C_{P\mathbf{3}} =$	$\boldsymbol{r_3} =$	$\boldsymbol{r_3} =$

Experiment 6

Aim:

Identify gear ratio of gear train & design gear train.

A gear ratio is a direct measure of the ratio of the rotational speeds of two or more interlocking gears. As a general rule, when dealing with two gears, if the drive gear (the one directly receiving rotational force from the engine, motor, etc.) is bigger than the driven gear, the latter will turn more quickly, and vice versa.
We can express this basic concept with the formula Gear ratio = N2/N1, where N1 is the number of teeth on the first gear and N2 is the number of teeth on the second.
To be able to determine a gear ratio, you must have at least two gears engaged with each other, this is called a "gear train".
Usually, the first gear is a "drive gear" attached to the motor shaft and the second is a "driven gear" attached to the load shaft.
There may also be any number of gears between these two to transmit power from the drive gear to the driven gear: these are called idler gears.



When you have a system with a Driving Gear that is SMALLER than the Driven Gear you will increase Torque and decrease Speed.
Making this kind of change to Mechanical Advantage is helpful when you are trying to move slower mechanically, lift heavier objects, and/or have more pushing ability.

When you have a system with a Driving Gear that is LARGER than the Driven Gear you will increase Speed and decrease Torque.
Making this kind of change to Mechanical Advantage is helpful when you are trying to lift or move faster mechanically, you don't require the ability to lift heavy objects.

Composition:

1. $\boldsymbol{(P_d = 5\ in^{-1}\ , d_p = 2\ in\ ) : SP_1}$

2. $(P_d = 5\ in^{-1}, d_p = 3\ in) : SP_2$

3. $(P_d = 5\ in^{-1}, d_p = 4\ in) : SP_3$

Exercise 1: Start with a two-gear train

Let us look at a gear train with only two gears in it. To be able to find a gear ratio, these gears must be interacting with each other — in other words, their teeth need to be meshed and one should be turning the other.

For example, purposes, let us say that you have one small drive gear (SP_1) turning a larger driven gear (SP_2).

Step 1: Count the number of teeth on the drive gear (SP_1)

One simple way to find the gear ratio between two interlocking gears is to compare the number of teeth that they both have.

Start by determining how many teeth are on the drive gear.

$$N_1 =$$

You can do this by counting manually or, sometimes, by checking for this information labeled on the gear itself

Step 2: Count the number of teeth on the driven gear (SP_2)

Next, determine how many teeth are on the driven gear exactly as you did before for the drive gear.

$$N_2 =$$

Step 3: Divide one teeth count by the other

Now that you know how many teeth are on each gear, you can find the **gear ratio** relatively simply.

Divide the driven gear teeth by the drive gear teeth. Depending on your assignment, you may write your answer as a decimal, a fraction, or in ratio form

In our example, dividing $\boldsymbol{N_2}$ (the number of teeth of the driven gear) by $\boldsymbol{N_1}$ (the 20 teeth of the drive gear).

$$m_G = \frac{\boldsymbol{N_2}}{\boldsymbol{N_1}} =$$

What this gear ratio means is that the smaller driver gear must turn times to get the larger driven gear to make turn.

This makes sense — since the driven gear is bigger, it will turn more slowly

<u>Exercise 2:</u>

Make a Design and assemble a simple gear set according to $m_G = 2$, using 2 gears then calculate velocity and torque ratio.

Exercise 3: Gear train of more than two gears

Step 1: determine the driver, driven and idler gear

As its name suggests, a "gear train" can also be made from a long sequence of gears, not just a single driver gear and a single driven gear.

The first gear remains the driver gear, the last gear remains the driven gear, and the ones in the middle become "**idler gears**."

These are often used to change the direction of rotation or to connect two gears when direct gearing would make them unwieldy or not readily available.

Let's say for example purposes that the two-gear train described above **(** $(\boldsymbol{SP_1})$ **,** $(\boldsymbol{SP_2})$ **)** is now driven by a $(\boldsymbol{SP_3})$.

In this case, determine the driver, driven and idler gear:

$(\boldsymbol{SP_1})$ **is the** …………………. $\boldsymbol{N_1} =$.........................

$(\boldsymbol{SP_2})$ **is the** …………………. $\boldsymbol{N_2} =$.........................

$(\boldsymbol{SP_3})$ **is the** …………………. $\boldsymbol{N_3} =$.........................

Step 2: Divide the teeth numbers

The important thing to remember when dealing with gear trains with more than two gears is that only the driver and driven gears (usually the first and last ones) matter.

In other words, the idler gears do not affect the gear ratio of the overall train at all. When you have identified your driver gear and your driven gear, you can find the gear ratio exactly as before.

You can find the gear ratios involving the idler gears as well, and you may want to in certain situations.

In these cases, start from the drive gear and work toward the load gear. Treat the preceding gear as if it were the drive gear as far as the next gear is concerned. Divide the number of teeth on each "driven" gear by the number of teeth on the "drive" gear for each interlocking set of gears to calculate the intermediate gear ratios.

In our example, the intermediate gear ratios are:

$$m_{G1} = \frac{\boldsymbol{N_{DRIVEN\,1}}}{\boldsymbol{N_{DRIVER\,1}}} =$$

$$m_{G2} = \frac{\boldsymbol{N_{DRIVEN\,2}}}{\boldsymbol{N_{DRIVER\,2}}} =$$

In general, the intermediate gear ratios of a gear train will multiply together to equal the overall gear ratio

$$m_{G1}\ x\ m_{G2} =$$

We would find the gear ratio by dividing the number of teeth of the driven gear by the number of teeth of our new driver

$$m_G = \frac{\boldsymbol{N_{DRIVEN}}}{\boldsymbol{N_{DRIVER}}} =$$

This means that the driver gear has to turn about ……….. Times to get the much larger driven gear to turn …………………..

Compare those 2 values m_G and $m_{G1}\ x\ m_{G2}$:

…………………………………………………………………………………………………….

EXERCISE 4: Making Ratio/Speed Calculations

Using the idea of gear ratios, it is easy to figure out how quickly a driven gear is rotating based on the "input" speed of the drive gear.

To start, find the rotational speed of your drive gear. In most gear calculations, this is given in rotations per minute (rpm), though other units of velocity will also work

For example, let's say that in the example gear train above with a $(\boldsymbol{SP_1})$ driver gear and a $(\boldsymbol{SP_2})$ driven gear, the drive gear is rotating at 130 rpms. With this information, we will find the speed of the driven gear

$S_{1\ X}\, N_1 = S_{2\ X}\, N_2$, $m_G = \frac{\boldsymbol{N_2}}{\boldsymbol{N_1}} = \frac{\boldsymbol{S_1}}{\boldsymbol{S_2}} = \frac{\boldsymbol{1}}{\boldsymbol{m_v}}$

Exercise 5:

Make a Design and assemble a gear train using 4 gears to increase the speed $\boldsymbol{S_1}$ from 500 rpms to 1500 rpms