ME-302L Mechanics of Machines Lab

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Lab Guidelines

0.1 Course Learning Outcomes (CLOs)

The learning outcomes that are expected to be attained by the student at the end of the course are given in Table 0.1-1. The **CLO #3** is applicable only if lab is **Open Ended Lab (OEL)**. The List of **Program Learning Outcomes (PLOs)** of BS program of Mechanical Engineering Department are given in **Appendix A**.

Table 0.1-1: Course learning outcomes of ME-302L Mechanics of Machines Lab

Sr. No.	CLOs	Domain	Level	PLO
1.	**DISPLAY** basic proficiency in operation of the apparatus and **PERFORM** the experiment to determine the solution of the engineering problems related to the subject.	Psychomotor	4	4
2.	**Communicate** the learned concepts using different media i.e., verbal and written.	Affective	2	10
3.	**Manifest** the professional responsibilities and norms of engineering practice.	Affective	3	8

The **Detail of Domains** and their Levels mentioned against each course learning outcome, is mentioned in **Appendix B**. The mapping of course learning outcomes with the program learning outcomes is given as in Table 0.1-2. The performance of you in course will be measured based on above learning outcomes using **Rubrics** mentioned in **Appendix C**.

Table 0.1-2: Relation of CLOs of Mechanics of Machines La with PLOs

PLO #	PLO Statement	CLO1	CLO2	CLO3
PLO-1	**Engineering Knowledge**			
PLO-2	**Problem Analysis**			
PLO-3	**Design/Development of Solution**			
PLO-4	**Investigation**	✓		
PLO-5	**Modern Tool Usage**			
PLO-6	**The Engineer and Society**			
PLO-7	**Environment and Stability**			

PLO-8	**Ethics**			✓
PLO-9	**Individual and Team Work**			
PLO-10	**Communication**		✓	
PLO-11	**Project Management**			
PLO-12	**Life Long Learning**			

0.2 Guidelines for Lab Report

Lab report must be submitted/checked within **7 days effectively** after the experiment is conducted. Lab report may not be accepted/checked after due date and lab report marks may be deducted.

0.2.1 Content

The content contain guidelines about the report structure, the constituent headings and content to be written under the headings.

0.2.1.1 Cover Page

The cover page should contain the followings

- Lab Name
- Experiment Name
- Students' Name
- Group #
- Lab Instructor Name
- Date on which lab Experiment was conducted (See the Lab schedule for it)
- Submission date of Lab Report

The format and Alignment and arrangement of above mentioned is student's own choice.

0.2.1.2 Abstract

The abstract contains summary lab activity done and contains the following main points.

1. Purpose/ objective(s) of the experiment
2. Main results in the experiment
3. Main results of experiment
4. Main conclusion

The abstract should be of one paragraph with words not more than 200 words.

0.2.1.3 Introduction

This section is meant for describing the worth/importance/significance of your work. As a part of arguments for proving your work a useful one it is logical to briefly point out the similar work already done by others but a detailed literature review is not a part of introduction.

As a part of description of the importance of work you may also justify your choice of problem solution methodology. When there are potentially more than one approaches available for the solution of the same problem; it is logical to opt for the best available choice giving due regard to the resource constraints.

Through introduction of the report you try to convince the reader that your work is really useful. According to a researcher “Introduction is setting up the scene”.

Wherever necessary there may be a separate section of theory but it must not be dragged into introduction.

0.2.1.4 Theory

It is an optional section and is included to appraise the reader the theory of your work. In the lab reports we normally do not recommend to include this section.

0.2.1.5 Procedure

In this section it is recommended to enlist the sequential steps for taking proper data. Wherever applicable a block diagram of the experimental set up is to be included. The diagrams should be properly labeled.

While writing a lab experiment procedure do not adopt the style of instructor. It is generally recommended to use past tense and passive voice. In technical writings the use of “I” and “We” is generally not appreciated.

0.2.1.6 Observations & calculations

It includes tabulation of observed data and calculations are required to be made for the meaningful analysis of results. Formulae involved in calculations need to be mentioned along with a sample of calculations. Graphical representation is a more effective way (than tabulation) of the presentation of results.

0.2.1.7 Conclusions

The conclusion expresses the main points (one or two) of the final results the lab.

0.2.1.8 Discussion

In this section you are supposed to justify your results. The expected results need to be justified with the help of some standard references. Reasons should be mentioned for the unexpected results. In this case all possible sources of error need to be looked at while giving consideration to the individual contribution of each source of error towards the overall error in the final results. Comparison of results with similar investigations (already made using same or different technique) is an essential component of the discussion section of a report.

0.2.1.9 References

Whatever information (other than own work of present report) has been used in writing of report needs to be properly referred (using a standard format of referring a book, a paper of a journal, a paper of a conference and information on a website). It is not sufficient to put a list of references at the end of a report. These references should also appear as numbers in square brackets in the main body of report.

0.2.2 Format

From **Semester 1** to **semester 4**, the report to be submitted containing the content as mentioned above, should be hand written. For **Semester 5 to Semester 8**, report to be submitted should be written on computer.

The following format should be followed for writing report on computer

Title page should always be documented on computer.

- **Font** should be **Times New Roman** (Whole Report)
- **Line Spacing** = 1.15 (whole report)
- **Title** should be of **font size = 16, Bold,**
- **Heading 1** should be of **font size = 14, Bold**
- **Heading 2** should be of **font size = 13, Bold**
- **Heading 3** should be of **font size = 12, Italic, Bold**
- **Page #** should be added.
- List of figure, List of table and Table of content**.**

0.2.3 Caption

For table: Above the Table aligned in center with table. **Font size: 10**

For Figure: Below the Figure aligned in center with figure. **Font size: 10**

0.2.4 References

Should be added in **IEEE format** using Endnote/word.

0.3 General Guidelines in a Lab for safety

The following guidelines are to be followed in a lab.

- No Laboratory work should be carried out without supervision of the Instructor or Lab technician.
- Do only experiment assigned to you and do not perform unauthorized experiment by yourself.
- Do not play with the equipment that are not part of experimental setup.
- Never leave an in progress experiment unattended.
- Don not exceed voltage limits of devices when plugging them into electrical outlets.
- Don not try to repair or modify any lab equipment.
- Always wear a protective lab coat/overall and safety shoes. Long hair should be tied back.
- Be alert to unsafe conditions and actions and call them to the attention of the instructor immediately.
- Be careful not to touch any heated surfaces as they might cause a burn.
- Don’t touch live conductor or wire with the bare hand.
- Don’t work in lab all alone.
- Report all damages to lab instructor immediately.
- Leave equipment in proper places at the end of your experiments and cleanup.
- After completion of the experiments, return the items borrowed, if any.
- Don’t run or paly in the lab.
- Eating drinking, smoking or chewing of gum is not permitted in the laboratory.
- Don’t use cell phones inside the laboratory.
- Everyone is responsible for housekeeping and cleaning up after themselves. Aisles and doorways, including access to the service hallway and electrical boxes, are to be kept clear for purposes of safe passage.
- Report any cases of vandalism or theft to your instructor or staff member.
- Students should not perform any type of maintenance on equipment in the lab without prior authorization and direct supervision of the lab manager.
- Use appropriate safety equipment for the task at hand (i.e. safety glasses, ear protection, gloves). See your instructor or a staff member for guidance.
- In case of fire or hazardous chemical spill evacuate the premises immediately

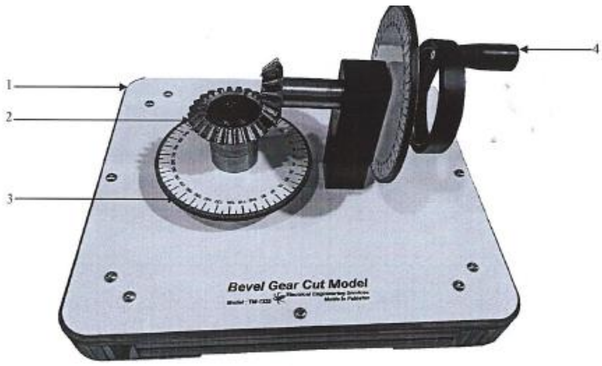
Experiment 1. To Investigate the Behavior of Bevel Gear and Rack and Pinion

1.1 Objective

To demonstrate the working of bevel gear and rack and pinon

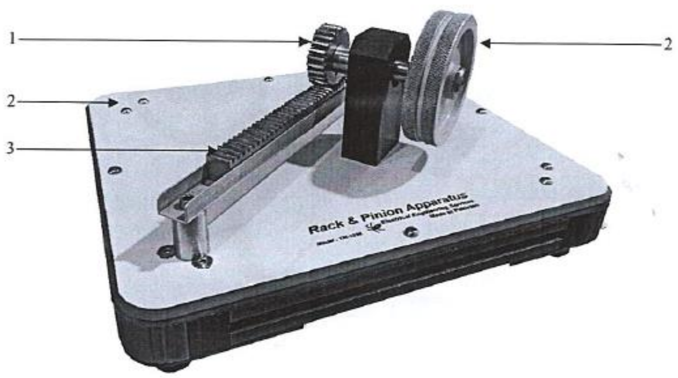
1.2 List of Required Equipment

- Bevel Gear (Figure 1.2-1)
- Rack and Pinon (Figure 1.2-2)



1. Base Frame	2. Bevel Gear
3. Protector	4. Handle for rotation

Figure 1.2-1: Detailed description of the bevel gear apparatus.



1. Pinion	2. Base frame
3. Rack	4. Handle

Figure 1.2-2: Detailed description of rack and pinion gear apparatus.

1.3 Procedure

1. Rotate the handle at the input and note down the rotations of both bevel gears
2. Calculate the gear ratio and velocity ratio of the bevel gears
3. Count the number of teeth of bevel gears and calculate the gear ratio
4. Rotate the pinon and observe the motion of rack

1.4 Observations and Calculations

Input Angle	0	10	20	30	40	…	360
Output Angle							

1.5 Safety Issues

Do not put your fingers inside gear while rotating

1.6 Result and Discussions

i. Discuss the applications, advantages and different types of bevel gears
ii. Compare the theoretical and experimental gear ratio of bevel gears
iii. Discuss the applications and advantages of rack and pinion
iv. Discuss about the gear ratio and mechanical advantage of rack and pinon

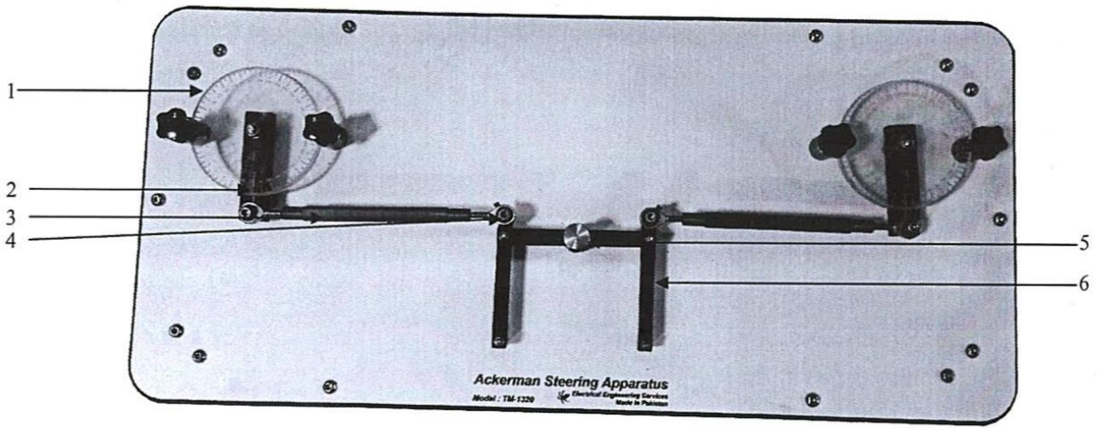
Experiment 2. Study of Ackerman Steering Mechanism

2.1 Learning Objectives

To study the behavior of Ackerman steering mechanism at varying steering geometries and to find the best configuration of mechanism for sharp turns

2.2 List of required equipment and accessories

- Ackerman steering mechanism (Figure 2.2-1)



1. Protector	2. Angle pointer
3. Adjustable Tie Rods	4. Tie lock nut
5. Steering lever	6. Tie rod arm

Figure 2.2-1: Detailed description of Ackerman steering mechanism.

2.3 Procedure

1. Set the equal length of connecting arms
2. Check those pointer on 900 positions
3. Now turn the arm in such a way that pointers deviate from original angles
4. According to direction of turning, one pointer shows inner-angle δ_i and the other shows the outer angle δ_o.
5. Note the angles that both pointers show
6. Compare them with theoretical values

2.4 Observations and Calculations

δ_o	δ_i	$cot\delta_o - cot\delta_i = \frac{w}{l}\ (exp)$	w (mm)	l (mm)	w/l (theo)	Deviation (%)

2.5 Safety Issues

1. Don’t slide or push the pointer hard, it could cut your hand
2. Don’t tighten the bolts of the track rod; it would seize the mechanism

2.6 Discussion

i. Plot graph between δ_i and δ_o at different values of w/l

ii. Discuss the reasons for error and possible ways to eliminate those errors

iii. Discuss the steering of vehicle at different δ_i and δ_o

iv. Discuss about the most efficient values of δ_i and δ_o for sharp and long turns

Experiment 3. Study of Four-Bar Mechanism

3.1 Learning Objectives

This experiment is intended to inform the students about one of the most common fundamental mechanism used in machinery. The students analyze it for position, velocity and acceleration of output rocker link relative to the input crank link.

3.2 List of required equipment

- Lab model four-bar mechanism (Figure 3.3-1). This consists of Crank-Coupler-Rocker links.

3.3 Procedure

1. Record angular position of the crank (LINK2) and the rocker (LINK4) in degrees starting with the crank (LINK2) and the connecting rod (LINK3) are in the same straight line.
2. Turn crank (LINK2) to a complete cycle (360°) and record the positions of the crank (LINK2) and the rocker (LINK4) for every 10° of the crank (LINK2) rotation.
3. Determine relative motion for displacement, velocity and acceleration, between crank and rocker as is explained below.

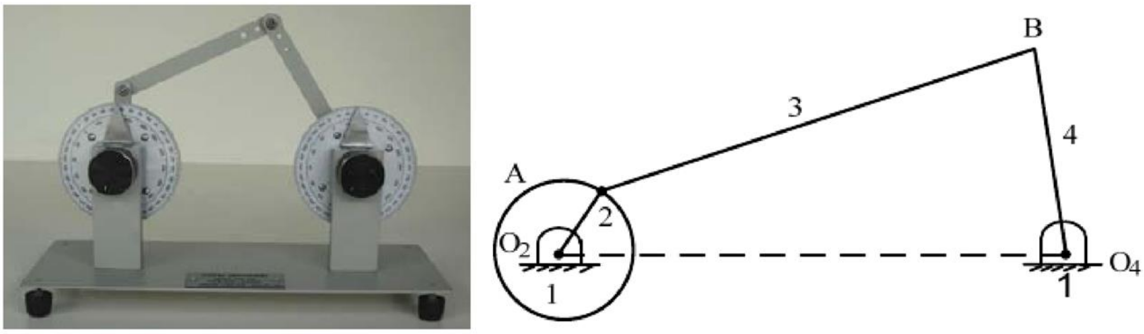


Figure 3.3-1: Four bar mechanism: apparatus and schematics.

3.4 Observations and Calculations

Crank position:	0º	10º	20º	30º	40º	50º	60º	…	300º	310º	320º	330º	340º	350º
Rocker position:														

3.5 Graphs

i. Draw angular position of rocker versus angular position of crank.

ii. Assuming that the crank is driven at a constant angular velocity, the rocker's angular velocity as a function of time is determined graphically by finding out slope of first graph at different points. These values of slope represent rocker's angular velocity at different times, i.e. angular velocity at ti, $\omega i = \frac{\Delta\theta}{\Delta t_i}$ where Δti are time intervals taken equally on the graph.

iii. Similar to step 2 above, determine angular acceleration of rocker $\alpha_i = \frac{\Delta\omega_i}{\Delta t_i}$.

3.6 Safety Issues

This equipment is very simple and there are no particular safety issues.

3.7 Discussion

i. Discuss uses and applications of this type of mechanism in various mechanical devices.

ii. Discuss different outputs when lengths of the links are changed.

iii. Discuss about errors in the graphical differentiation.

Experiment 4. Study of Crank-Slider Mechanism

4.1 Learning Objectives

This experiment is intended to inform the students about one of the most common fundamental mechanism used in machinery. The students analyze it for position, velocity and acceleration of output slider block relative to the input crank link.

4.2 List of required equipment

- Lab model crank-slider mechanism (Figure 4.3-1). This consists of Crank-Coupler-Slider links.

4.3 Procedure

1. Record angular position of the crank (LINK2) in degrees and the slider block (LINK4) in mm starting with crank (LINK2) and connecting rod (LINK3) in the same straight line.
2. Turn crank (LINK2) to a complete cycle (360°) and record the positions of the crank (LINK2) and the slider (LINK4) for every 10° of the crank (LINK2) rotation.
3. Determine relative motion for displacement, velocity and acceleration, between crank and slider block as explained below.

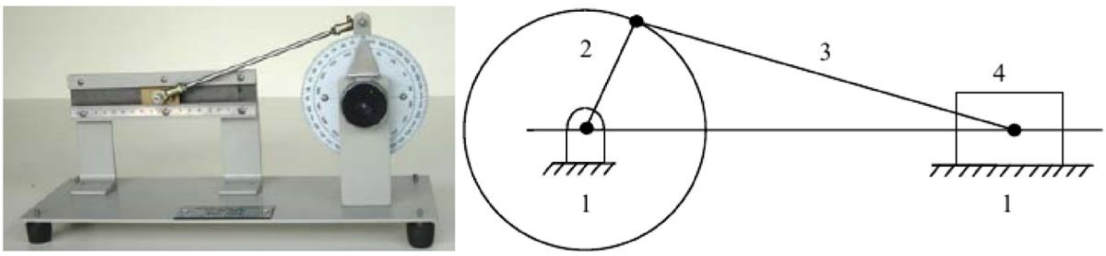


Figure 4.3-1: Slider crank mechanism: apparatus and schematic.

4.4 Observations and Calculations

Crank position:	0^o	10^o	20^o	30^o	40^o	50^o	60^o	…	300^o	310^o	320^o	330^o	340^o	350^o
Slider position:														

4.5 Graphs

i. Draw angular position of rocker versus angular position of crank.

ii. Assuming that the crank is driven at a constant angular velocity, the rocker's angular velocity as a function of time is determined graphically by finding out slope of first graph at different points. These values of slope represent rocker's angular velocity at different times i.e. angular velocity at ti, $\omega_i = \frac{\Delta\theta}{\Delta t_i}$, where Δt_i are time intervals taken equally on the graph.

iii. Similar to step 2 above, determine angular acceleration of rocker $\alpha_i = \frac{\Delta\omega_i}{\Delta t_i}$.

4.6 Safety Issues

This equipment is very simple and there are no particular safety issues.

4.7 Points of discussion in report

i. Discuss uses and applications of this type of mechanism in various mechanical devices.

ii. Discuss different outputs when lengths of the links are changed.

iii. Discuss about errors in the graphical differentiation.

Experiment 5. Study of Slotted-Link Mechanism

5.1 Learning Objectives

This experiment is intended to inform the students about a quick-return mechanism. The students analyze it for position, velocity and acceleration of output slider block relative to input crank link.

5.2 List of required equipment

- Lab model slotted-link mechanism (Figure 5.3-1). This is an isomer of Stephenson's six-bar isomer.

5.3 Procedure

1. Record angular position of the crank (LINK2) in degrees and the slider block (LINK6) in mm starting with slider (LINK6) at an extreme position.
2. Turn crank (LINK2) to a complete cycle (360°) and record the positions of the crank (LINK2) and the slider (LINK6) for every 10° of the crank (LINK2) rotation.
3. Determine relative motion for displacement, velocity and acceleration, between crank and slider block as explained below.

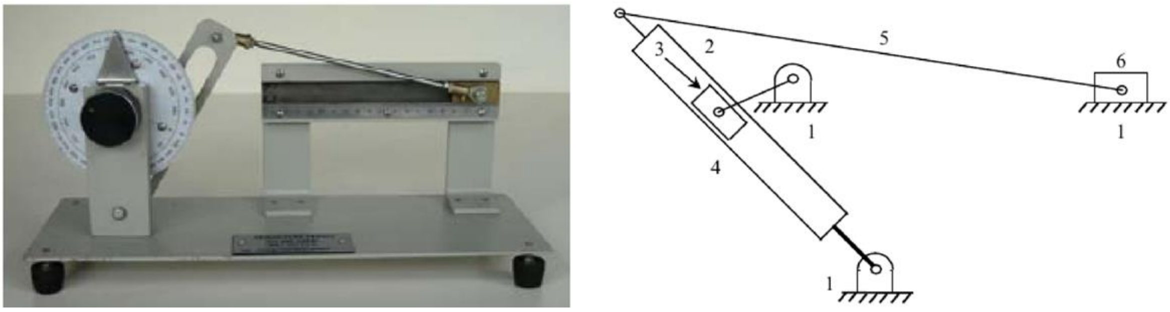


Figure 5.3-1: Slotted link mechanism: apparatus and schematic.

5.4 Observations and Calculations

Crank position:	0°	10°	20°	30°	40°	50°	60°	…	300°	310°	320°	330°	340°	350°
Slider position:														

5.5 Graphs

i. Plot displacement of slider versus angular position of crank.

ii. Assuming that the crank is driven at a constant angular velocity, the slider's velocity as a function of time is determined graphically by finding out slope of first graph at different points. These values of slope represent slider's velocity at different times i.e. velocity at $t_i, v_i = \frac{\Delta x}{\Delta t_i}$ where Δt_i are time intervals taken equally on the graph.

iii. Similar to step 2 above, determine acceleration of slider block $a_i = \frac{\Delta v_i}{\Delta t_i}$ and plot it.

5.6 Safety Issues

This equipment is very simple and there are no particular safety issues.

5.7 Discussion

i. Discuss uses and applications of this type of mechanism in various mechanical devices.

ii. Discuss what happened at toggle point.

iii. Discuss about errors in the graphical differentiation.

Experiment 6. Study of Cam & Follower Mechanism

6.1 Learning Objectives

This experiment is intended to inform the students about a very common mechanism. The students analyze it for position, velocity and acceleration of follower relative to the cam rotation for different types of cams.

6.2 List of required equipment

- Cam follower mechanism with different cams as shown in Figure 6.2-1Figure 6.2-2.

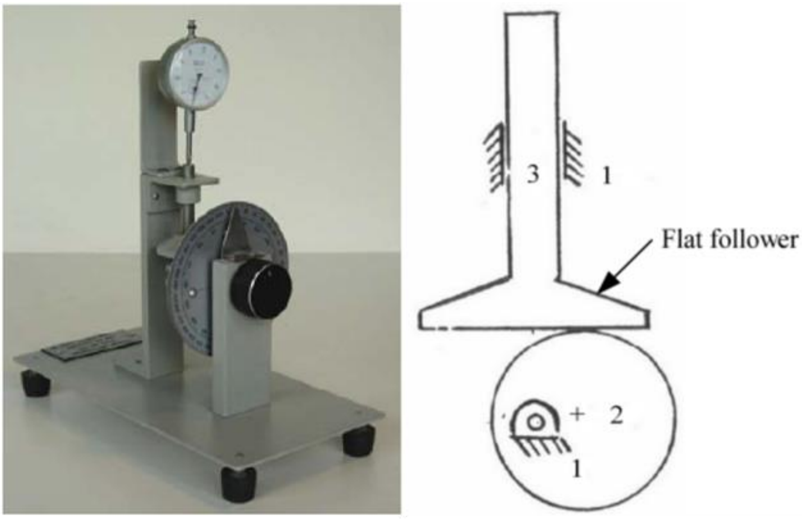
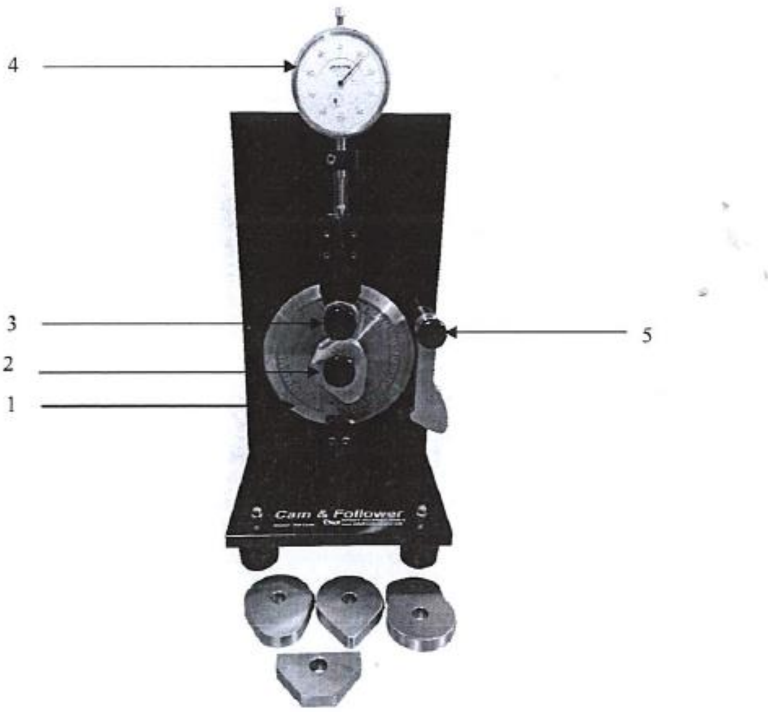


Figure 6.2-1: Cam follower mechanism.



1. Protractor	2. Cam
3. Follower	4. Dial Gauge
5. Rocker	

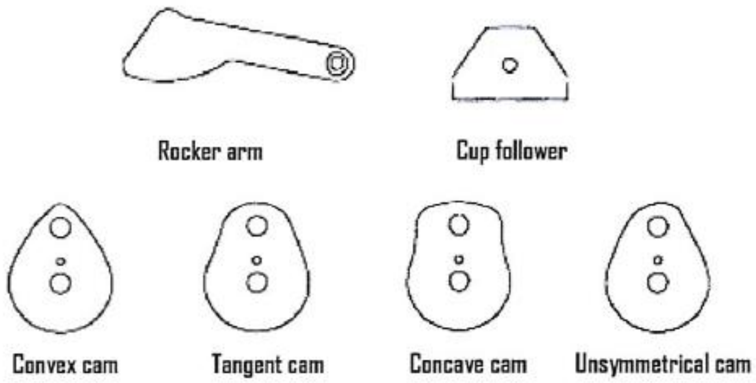


Figure 6.2-2: Detailed description of cam follower mechanism.

6.3 Procedure

1. Attach the required cam to the mechanism
2. Record angular position of the cam (LINK2) in degrees and the follower (LINK3) in mm.
3. Turn cam (LINK2) to a complete cycle (360°) and record the angular position of the cam (LINK2) and follower's displacement for every 10° of the cam rotation.
4. Determine relative motion for displacement, velocity and acceleration, between cam and follower as explained below.

5. Change the cam type and repeat the above steps

6.4 Observations and Calculations

Cam position	0^o	10^o	20^o	30^o	40^o	50^o	60^o	…	300^o	310^o	320^o	330^o	340^o	350^o
Follower displacement														

6.5 Graphs

i. Plot displacement of follower versus angular position of cam.
ii. Assuming that cam is driven at constant angular velocity, the follower's velocity as a function of time is determined graphically by finding out slope of first graph at different points.
iii. Similar to step 2 above, determine acceleration of slider block and plot it.
iv. If the above graphs are obtained neatly, try plotting jerk (derivative of acceleration).

6.6 Safety Issues

This equipment is very simple and there are no particular safety issues.

6.7 Discussion

i. Discuss uses and applications of this type of mechanism in various mechanical devices.
ii. Discuss about errors in the graphical differentiation.

Experiment 7. Study of Epicyclic Gear Train

7.1 Learning Objectives

This experiment is intended to inform the students about a very useful mechanism. The students analyze it for position, velocity and acceleration of output shaft relative to input shaft.

7.2 List of required equipment

- Lab model epicyclic gear train as shown in Figure 7.3-1.

7.3 Procedure

1. Check and record the number of teeth on gears *a*, *c* and *d*.
2. Set shaft *a* angle as *0º* and note that output shaft (arm *b*) is at *0º*, *120º* or *240º*.
3. Fix gear *d* by turning in the thumb bolt to lock gear *d*.
4. Record input shaft (gear *a*) and output shaft (arm *b*) readings.
5. Turn gears a at 30°increment and record both input shaft (gear a) and corresponding output shaft (arm *b*) readings.
6. Plot a curve of input shaft vs. output shaft rotation and determine the slope or gear ratio.
7. Unlock gear *d* by unscrewing the thumb bolt.
8. Grip output shaft (arm *b*) and rotate input shaft (arm a) and note the movement of ring gear *d*.

Number of teeth on gears:

$Sun\ gear\ T_a\ =\ 60$

$Planet\ gears\ T_c =\ 30$

$Ring\ gear\ T_d =$

$120\ (internal\ teeth)$

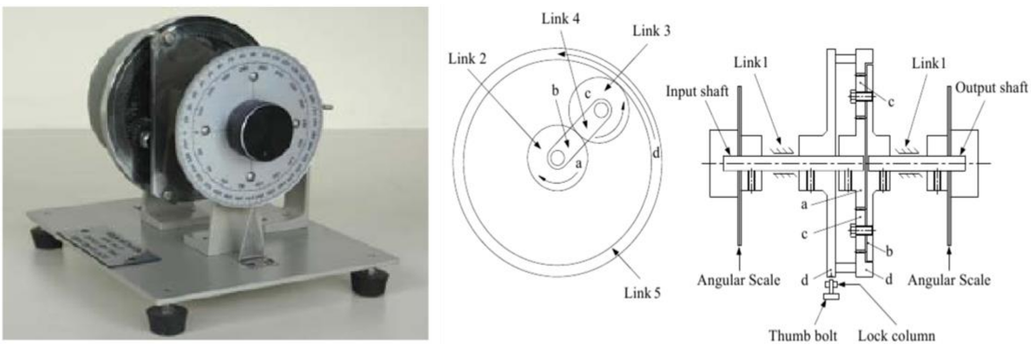


Figure 7.3-1: Detailed description of epicyclic gear train.

7.4 Observations and Calculations

Input shaft position	0^o	30^o	60^o	90^o	120^o	150^o	180^o	210^o	240^o	270^o	300^o	330^o
Output shaft position												

7.5 Graphs

i. Plot displacement of output shaft versus angular position of input shaft.
ii. Assuming that input shaft is driven at constant angular velocity, the output shaft's velocity as a function of time is determined graphically by finding out slope of first graph at different points thus giving the gear ratio.

7.6 Safety Issues

Do not insert fingers into the mechanism while the gears are moving. Keep parts of loose clothings clearly away from the gears, as they may get torn and may even hurt the person.

7.7 Points of discussion in report

i. Discuss uses and applications of this type of mechanism in various mechanical devices.
ii. Discuss about errors in the graphical differentiation.

Experiment 8. Study of Compound Gear Train

8.1 Learning Objectives

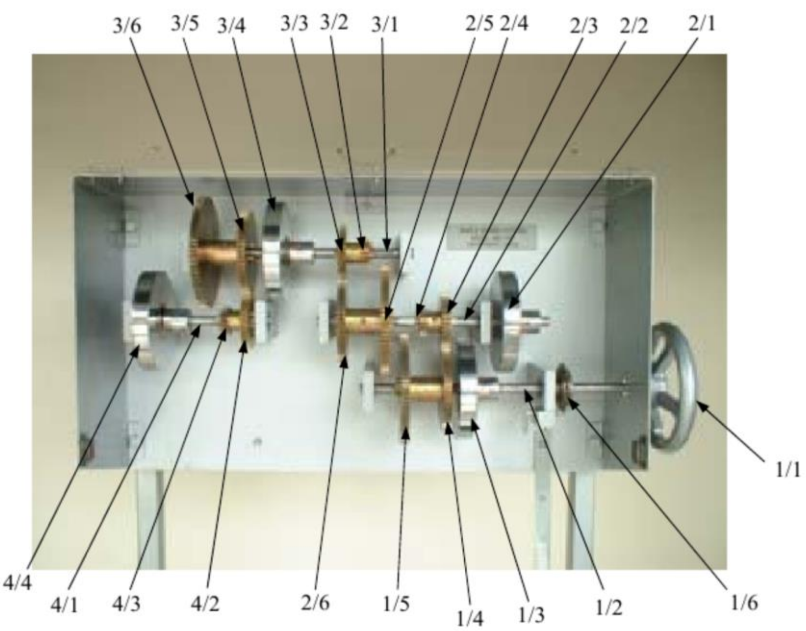
This experiment is intended to inform the students about kinematics of compound gear trains. The students visualize various gear ratios and relative velocities.

8.2 List of required equipment

• The compound gear train system as shown in Figure 8.3-1.

8.3 Procedure

1. Check and record the number of teeth on all the gears.
2. Connect the gears in various combinations possible.
3. Calculate the overall train ratios in each case and verify experimentally.
4. Especially observe:
   i. Backlash within each gear set and its effect on overall gear-train performance.
   ii. Input torque requirements as overall train ratio increases.



1/1 Hand wheel
1/2 Shaft 1
1/3 Mass and drum 1
1/4 Gear = 60 T
1/5 Gear = 80 T
1/6 Sprocket and lock pin
2/1 Mass and drum 2
2/2 Shaft 2
2/3 Gear = 40 T
2/4 Gear = 20 T
2/5 Gear = 80 T
2/6 Gear = 60 T
3/1 Shaft 3
3/2 Gear = 20 T
3/3 Gear = 40 T
3/4 Mass and drum 3
3/5 Gear = 60 T
3/6 Gear = 80 T
4/1 Shaft 4
4/2 Gear = 40 T
4/3 Gear = 20 T

Figure 8.3-1: Detailed description of compound gear train.

8.4 Observations and Calculations

Calculate the gear ratio and torque ratio the overall train using formula below:

$$\frac{\omega_1}{\omega_2} = \frac{N_1}{N_2} = \frac{T_2}{T_1}$$

8.5 Safety Issues

1. Keep your hands away from running gears
2. Long hairs must be tight back before the operation
3. Gear must mesh with each other properly before applying force
4. Always wear shoes before operating the equipment
5. Remove all weights before changing the gear

8.6 Discussion

i. Discuss about the general structure of compound gear train

ii. Discuss about the energy conservation along the compound gear train

iii. Discuss about any trend that you have observed in torque requirements while increasing/decreasing the gear ratio

iv. What are the applications and significance of compound gear train

v. Discuss about the backlash in gears and methods to avoid it

Experiment 9. Study of Hooke's Universal Joint

9.1 Learning Objectives

This experiment is intended to inform the students about a common mechanism used in machinery. This mechanism demonstrates relative angular motion in degrees between two intersecting shafts through a cross-member.

9.2 List of required equipment

- Lab model Hooke's universal joint (Figure 9.3-1).

9.3 Procedure

1. Adjust the angle between the input (link2) and output shafts (link3) at a specific angle $\delta 1$.
2. Record angular position of the input shaft ($\theta 2$) and the output shaft ($\theta 3$) in degrees.
3. Turn input shaft to a complete cycle (360°) and record the positions of both the input shaft and the output shaft for every 10° of rotation.
4. Determine relative motion for displacement and velocity between input and output.

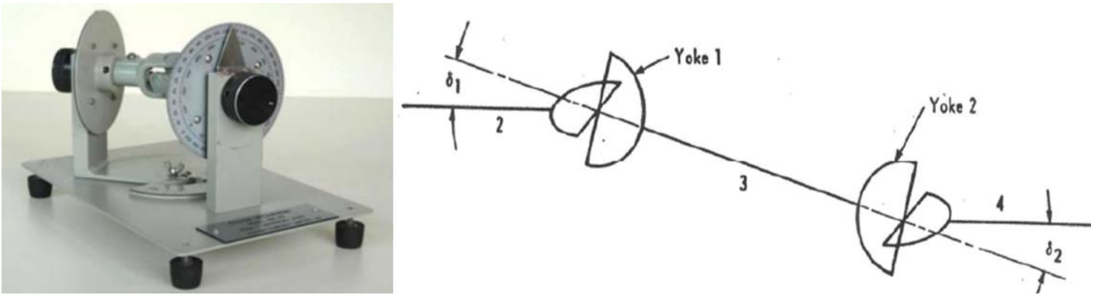


Figure 9.3-1: Hooke's universal joint: apparatus and schematic.

9.4 Observations and Calculations

Input shaft position	0°	10°	20°	30°	40°	50°	60°	…	300°	310°	320°	330°	340°	350°
Output Shaft Position														

9.5 Theory

Let: δ_1 = angle between the input and output shafts,

θ_2, θ_3 = position of input and shafts, respectively,

ω_2, ω_3= angular velocity of input and output shafts, respectively. T

Then $\cos \delta_1 = \frac{\tan(\theta_2)}{\tan(\theta_3)} \Rightarrow \frac{\omega_2}{\omega_3} = \frac{\cos(\delta_1)}{1-\sin^2\theta_3 \sin^2 \delta}, where \;\; \omega 2 \neq \; \omega 3$

9.6 Graphs

i. Draw angular position of output versus angular position of input shaft.

ii. Note the slight variations from a straight line.

9.7 Safety Issues

This equipment is very simple and there are no particular safety issues.

9.8 Discussion

i. Discuss uses and applications of this type of mechanism in various mechanical devices.

ii. Discuss different outputs when angle $\delta_1$is changed.

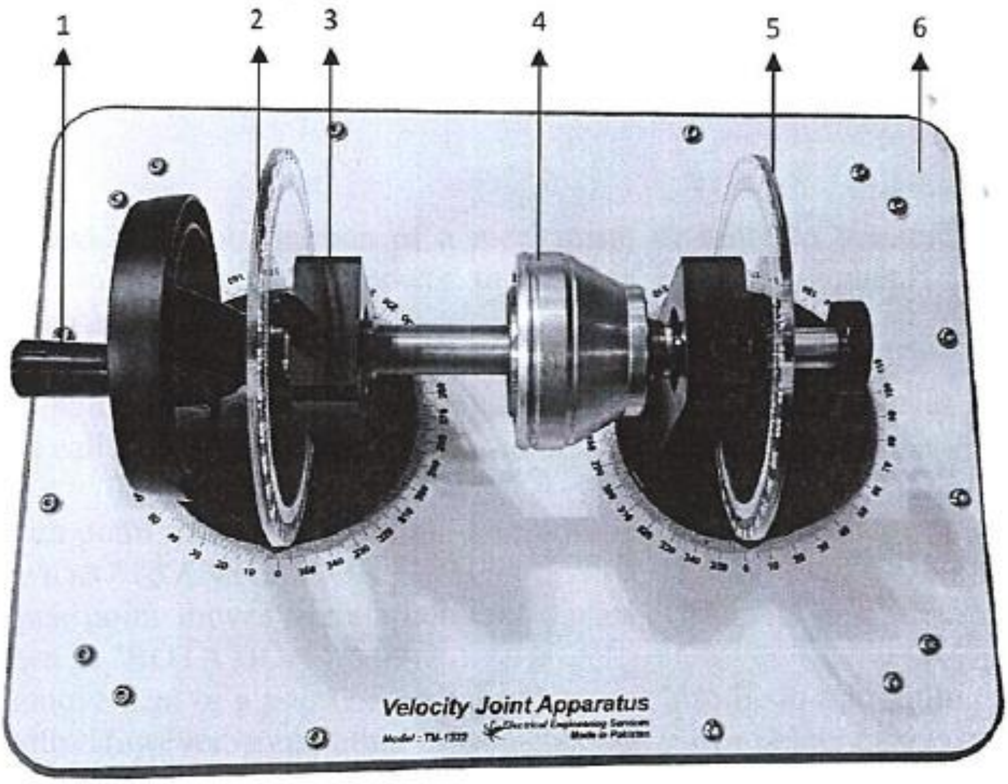
Experiment 10. Study of Velocity Joint Apparatus

10.1 Learning Objectives

To provide the variation of displacement of a constant velocity joints

10.2 List of required equipment

• Velocity joint apparatus (Figure 10.2-1)



1. Handle for rotation	2. Protector 1
3. Bracket	4. Velocity joint
5. Protector 2	6. Base frame

Figure 10.2-1: Detailed description of velocity joint apparatus.

10.3 Procedure

1. Bring the bearing support dial and the shaft dial to the reference position
2. For a given angle of rotation (fixed) to the support dial, note down the shaft rotation
3. Plot a graph between the rotation of the driving and driven shaft

4. Change the shaft angle and repeat the process

10.4 Observations and Calculations

Driven shaft tilt w.r.t driving shaft	Driving Shaft Rotation (Degrees)	Driven Shaft Rotation (Degrees)
0		
5		
10		
15		

10.5 Safety Issues

There are no safety issues associated with this equipment

10.6 Discussions

i. Discuss the detailed structure of velocity joint
ii. Discuss and Plot the velocity of driving shaft w.r.t driven shaft
iii. Discuss different applications of velocity joint apparatus

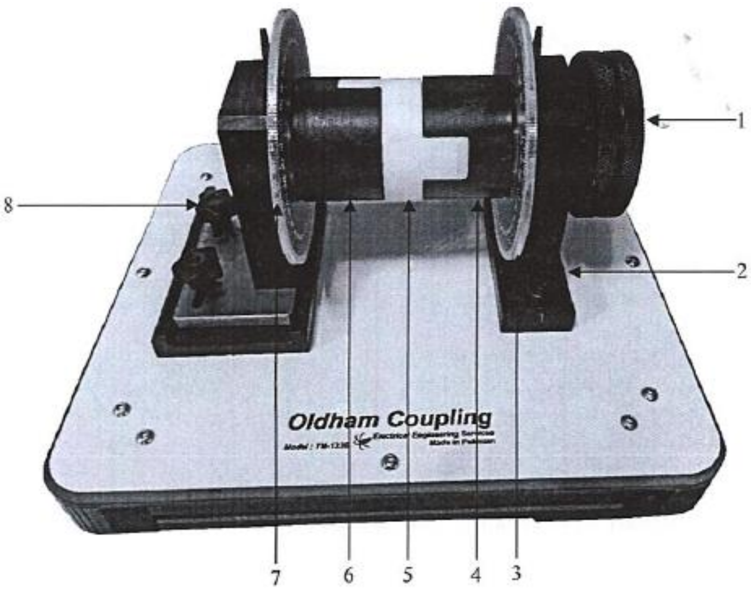
Experiment 11. Study of Oldham Coupling

11.1 Learning Objectives

To determine the velocity ratio across the coupling with various displacements and plot central disc displacement against the rotational position

11.2 List of required equipment

- Oldham coupling (Figure 11.2-1)



1. Rotating pointer	2. Bracket
3. Degree scale 1	4. Coupling hub 1
5. Coupling	6. Coupling hub 2
7. Degree scale 2	8. Sliding scale

Figure 11.2-1: Detailed description of oldham coupling.

11.3 Procedure

1. Start with both shaft scales on zero
2. Turn the input shaft through 10º and read the output shaft
3. Do this for a full 360º and tabulate your results in the table
4. Set the shaft displacement to the maximum of 15 mm.
5. Use a ruler to measure the central disc's horizontal displacement relative to either the input or the output shaft boss
6. Take readings every 10º

11.4 Observations and Calculations

Input Shaft º	Output shaft º	Displacement (mm)	Velocity (mm/s)	Acceleration (mm/s)

11.5 Safety Issues

There are no safety issues associated with this equipment

11.6 Discussions

i. Draw a graph of displacement against rotation
ii. Discuss about the motion of central disc
iii. How the central disc motion is liked to shaft displacement
iv. Discuss about the possible problems of operating the shaft at higher rpm

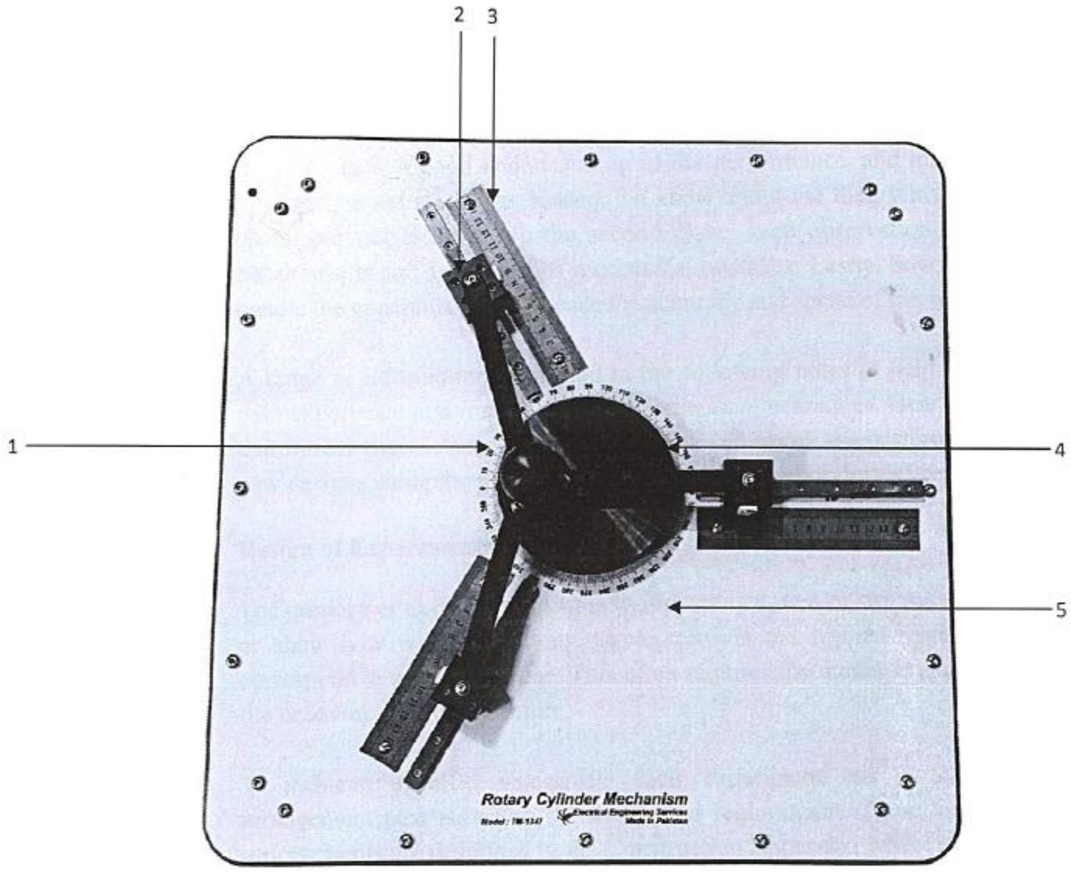
Experiment 12. Study of Rotary Cylinder Mechanism

12.1 Learning Objectives

To understand the crank mechanism with rotary cylinder

12.2 List of Required Equipment

- Rotary cylinder mechanism (Figure 12.2-1)



1. Protector	2. Slider crank
3. Scale	4. Rotary cylinder
5. Baseboard	

Figure 12.2-1: Detailed description of rotary cylinder mechanism.

12.3 Procedure

1. Bring the crank and rotary cylinder at reference points and note these points
2. For a given angle of rotation, note down the displacement of every crank
3. Plot a graph between crank angle and displacement
4. Observe how the displacement varies as the angle changes for a fixed cylinder

12.4 Observations and Calculations

Sr#	Input Angle	Displacement 1 (mm)	Displacement 2 (mm)	Displacement 3 (mm)

12.5 Discussion

i. Discuss about different uses of rotary cylinder mechanism
ii. Discuss about the offset between three displacements
iii. Plot the displacements vs input angle

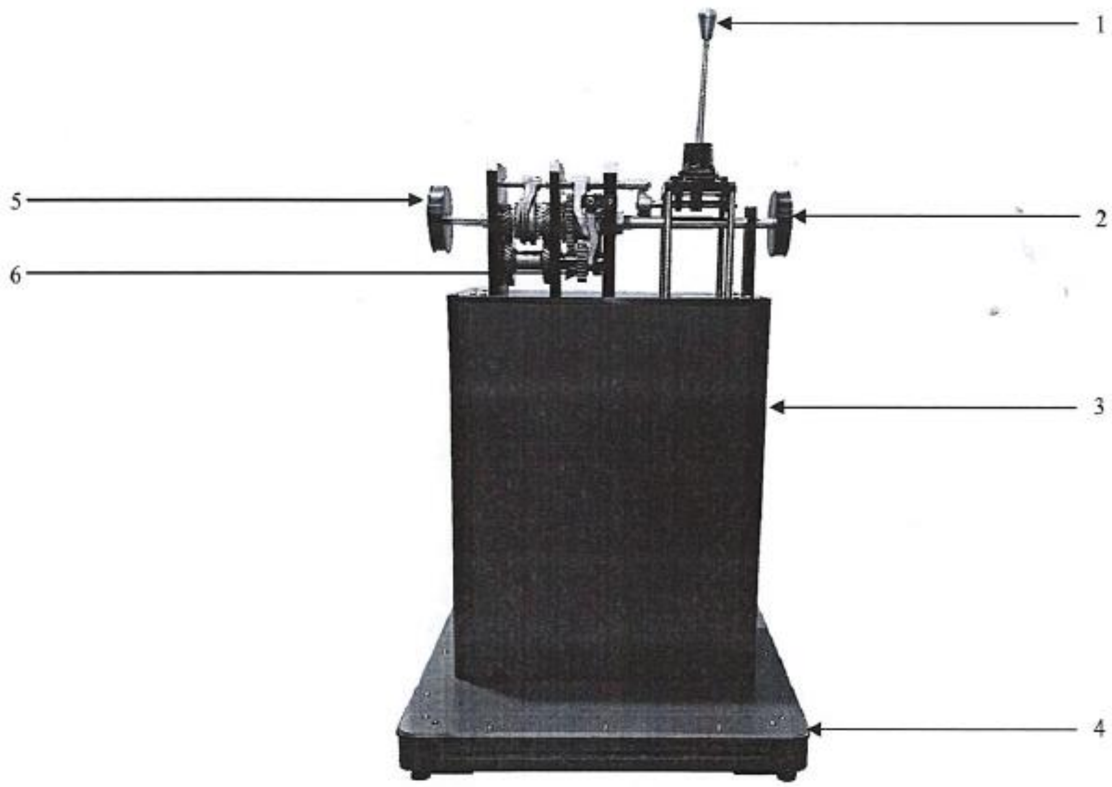
Experiment 13. Study of Gearbox Apparatus

13.1 Learning Objective

Study and understanding of gear ratio and transmission using constant mesh gearbox

13.2 List of Required equipment

- Gear box Apparatus (Figure 13.2-1)
- Weights and weight hangers



1. Gear lever	2. Input shaft
3. Stand for gear box	4. Base
5. Output shaft	6. Gears

Figure 13.2-1: Detailed description of gear box apparatus.

13.3 Procedure

1. At first, make sure that the gear lever is in a neutral position
2. With the gear lever's help adjust the position of gears according to the operations need
3. Make sure that the teeth of gears are meshing properly with each other
4. Apply known load at output shaft and gradually increase the force at input shaft by adding weights
5. Increase load at the input shaft until weight at the input shaft starts to move downward
6. Also, ensure that load at the output shaft also starts to move upward as force increases at the input shaft
7. Note down load and effort
8. Remove load and effort from output and input shaft
9. Change the position of gears with the help of a gear lever
10. Repeat the above procedure and note the load and effort

13.4Observations and Calculations

Sr No	Gear	Load	Effort	Mechanical Advantage
1				
2				
3				
4				

Mechanical Advantage = Load/Effort

13.5 Safety Issues

6. Keep your hands away from running gears
7. Long hairs must be tight back before the operation
8. Gear must mesh with each other properly before applying force
9. Always wear shoes before operating the equipment
10. Remove all weights before changing the gear

13.6 Discussion

i. Discuss the operation and type of gear box

ii. Discuss the significance of mechanical advantage in different operation modes

iii. Discuss specifically about the mechanical advantage of reverse gear

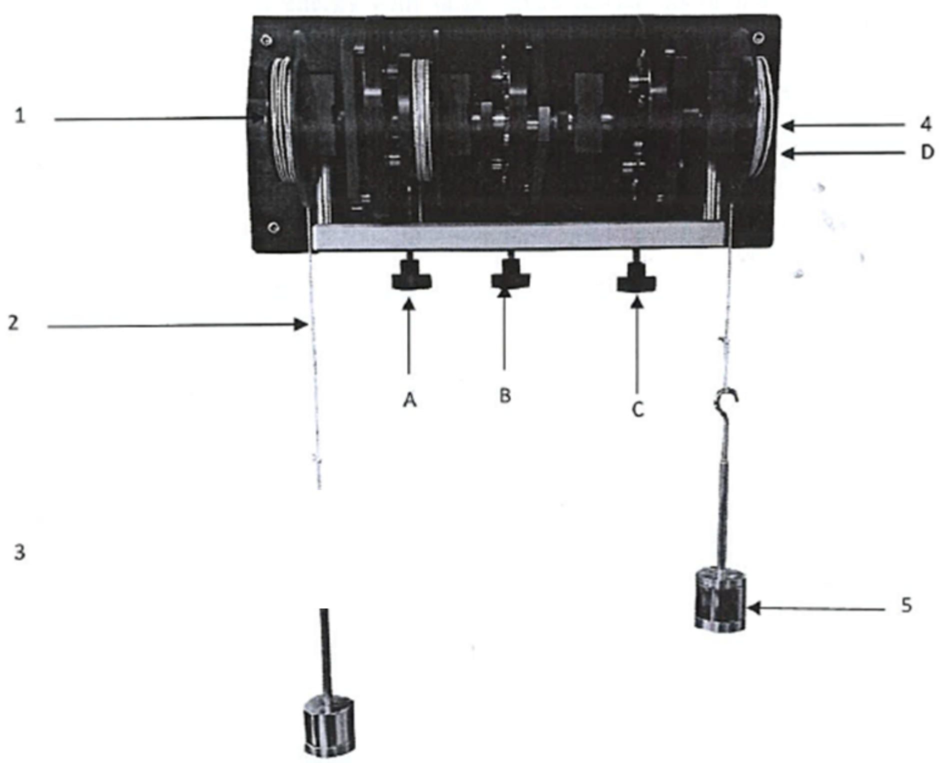
Experiment 14. Study of Three Stage Epicyclic Gear Train

14.1 Learning Objective

To calculate and experimentally observe the velocity ratios of three stage epicyclic gear train in different modes

14.2 List of Required Equipment

- Wall mounted three stage epicyclic gear train (Figure 14.2-1)
- Weights and weight hangers



1. Input Shaft	2.Cord
3. Hanger	4. Output Shaft
5. Weight	6. A-D Engage/Disengage

Gear	Type	Teeth on Gear
Sun	Driving	20
Planet	Driven	16
Annulus	Fixed	52

Figure 14.2-1: Detailed description of three stage epicyclic gear train.

14.3 Procedure

1. To calculate the velocity ratio of the unit, rotate the input shaft one full turn clockwise or turn clockwise until required out complete its one rotation 360
2. Observe the sense and magnitude of rotation of the different outputs
3. For different outputs lock and unlock the knobs according different conditions
4. Repeat above procedure and note down next reading

14.4 Observations and Calculations

Sr No	Input	Output 1	Output 2	Output 3	Reverse	Condition	
	Degree	**Degree**	**Degree**	**Degree**	**Degree**	**Lock**	**Unlock**
1							
2							
3							
5							

$$\text{Velocity Ratio} = \frac{\text{Input Shaft Revolution}}{Output\ Shaft\ Revolution}$$

14.5 Safety Issues

11. Keep your hands away from running gears
12. Long hairs must be tight back before the operation
13. Gear must mesh with each other properly before applying force
14. Always wear shoes before operating the equipment
15. Remove all weights before changing the gear

14.6 Discussion

i. Plot the output versus input angle
ii. Discuss the operation of three stage epicyclic gear train under different conditions
iii. Discuss the significance of velocity ratio in different operation modes
iv. Discuss specifically about the mechanical advantage of reverse gear

Experiment 15. Study of Pantograph

15.1 Learning Objective

To demonstrate the principle of pantograph and to study the magnification of different shapes

15.2 List of Required Equipment

- Pantograph (Figure 15.2-1)
- Pencils
- White Paper

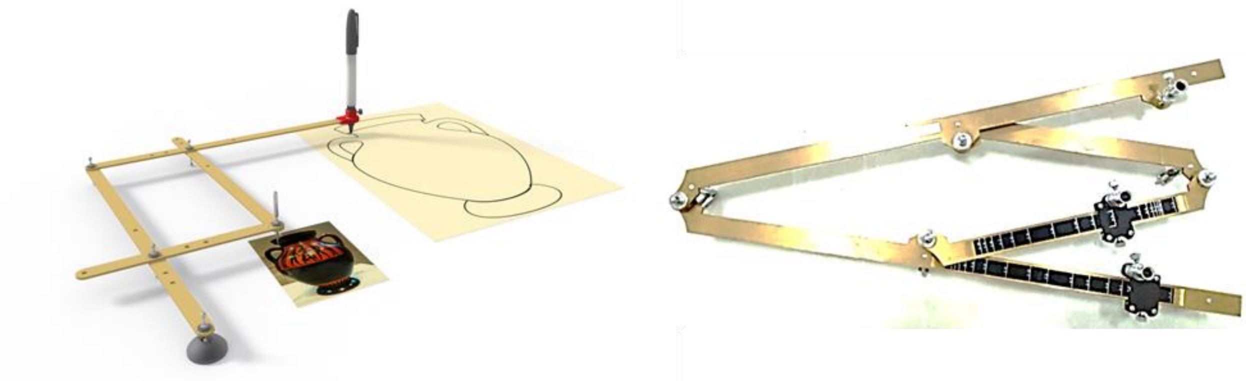


Figure 15.2-1: Pantograph.

15.3 Procedure

1. Loosen the joints of pantograph so that it is easily moveable
2. Place a white paper for drawing on the table and position it at the drawing side
3. Position the pantograph on the table and pinned it from the origin on the table
4. Set the two scales to desired lengths
5. Position the image to be magnified in the middle of pantograph
6. Insert two pencils, one in the mid and one on the drawing side.
7. Move the middle pencil on the reference to magnify it
8. Change the scale size and repeat the process

15.4 Observations and Calculations

A list of sketches will be generated using the pantograph

- Circle
- Ellipse
- Alphabetical Letters

- Any random image

15.5 Safety Issues

- Do not touch the sharp edges on the pantograph

15.6 Discussion

i. Discuss the working of pantograph

ii. Discuss in detail the synthesis of linkage used for pantograph

iii. Search and discuss other possible linkages that can be used to magnify images

Appendix

Appendix A

Program Learning Outcomes (PLOs)

On the basis of the Knowledge Attributes defined in the Washington Accord, twelve (12) Program Learning Outcomes, also known as Graduate Attributes, are listed below:

(i) **Engineering Knowledge**: An ability to apply knowledge of mathematics, science and engineering fundamentals and an engineering specialization to the solution of complex engineering problems.

(ii) **Problem Analysis**: An ability to identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences.

(iii) **Design / Development of Solutions**: An ability to design solutions for complex engineering problems and design systems, components, or processes that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations.

(iv) **Investigation**: An ability to investigate complex engineering problems in a methodical way including literature survey, design and conduct of experiments, analysis and interpretation of experimental data, and synthesis of information to derive valid conclusions.

(v) **Modern Tool Usage**: An ability to create, select and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modeling, to complex engineering activities, with an understanding of the limitations.

(vi) **The Engineer and Society**: An ability to apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice and solution to complex engineering problems.

(vii) **Environment and Sustainability**: An ability to understand the impact of professional engineering solutions in societal and environmental contexts and demonstrate knowledge of and need for sustainable development.

(viii) **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice.

(ix) **Individual and Team Work**: An ability to work effectively, as an individual or in a team, on multifaceted and/or multidisciplinary settings.

(x) **Communication**: An ability to communicate effectively, orally as well as in writing on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentations, make effective presentations, and give and receive clear instructions.

(xi) **Project Management**: An ability to demonstrate management skills and apply engineering principles to one's own work, as a member and/or leader in a team to manage projects in a multidisciplinary environment.

(xii) **Lifelong Learning**: An ability to recognize importance of, and pursue lifelong learning in the broader context of innovation and technological developments.

Appendix B

Details of Domains

Cognitive		Affective		Psychomotor	
Level 1	Knowledge	Level 1	Receiving	Level 1	Perception
Level 2	Comprehension	Level 2	Responding	Level 2	Set
Level 3	Application	Level 3	Valuing	Level 3	Guided Response
Level 4	Analysis	Level 4	Organization	Level 4	Mechanism
Level 5	Synthesis	Level 5	Characterization by value or value complex	Level 5	Complex over response
Level 6	Evaluation			Level 6	Adaption
				Level 7	Organization

Appendix C

Lab Rubrics for ME-302L Mechanics of Machines Lab

CLOs	Criteria	Poor (0 to 4)	Satisfactory (5-6)	Good (7-8)	Excellent (9-10)
CLO-1	Apparatus Handling, Experiment Performance and Calculations	No knowledge of apparatus, experiment not performed, nor any calculations done	Knows basic operation of the apparatus, performed the experiment with major errors in calculations	Can handle the apparatus well, experiment completely performed, and calculations have few mistakes	Fully understands the complete operation of the apparatus, experiment performed, and all calculations are correct
	Planning and Execution of an Experiment [OEL]	Experiment not planned for proper execution	Experiment planned but not executed properly	Experiment planned and executed but slight omissions	Experiment correctly planned and executed
CLO-2	Communication [Report]	Report neither covers technical details of experiment nor according to format	Correct report submitted according to format but not covering essential technical details	Report well written technically but format not completely followed / slight mistakes	Well-composed flawless report covering technical aspects of experiment
	Communication [Viva]	Either does not understand or cannot communicate concepts related to experiment	Understands the concepts related to experiment but does not communicate in technical terms	Understands and able to communicate the learned concepts but with slight mistakes	Fully understands all the concepts and can express them technically
CLO-3	Punctuality, Teamwork and Safety	Arrives too late for experiment with disregard to teamwork or safety	Arrives little late for experiment, somewhat adheres to teamwork and safety	Punctual but slightly lacking in teamwork and safety consciousness	Punctual, works as a team and adheres to safety instructions