ME-202L Engineering Mechanics Lab (Manual)

Department of Mechanical Engineering

Pakistan Institute of Engineering and Applied Sciences

(PIEAS)

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Experiment 0. 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 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-202L Engineering Mechanics Lab

Sr. #	CLO Statement	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 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 Engineering Mechanics Lab 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 Determine the Coefficient of Friction between Flat Leather Belt and Cast-Iron Pulley

1.1 Learning Objectives

The main objective is to observe the scatter of the experimental results of μ.

1.2 List of Required Equipment & Accessories

It includes the following.

i. A cast iron pulley mounted on a vertical board.
ii. A flat leather belt with the provision of attachment of a spring balance to its one end and weight hanger at its other end.
iii. An arrangement of holes (made at pre-determined angular interval) for varying the contact angle of the flat belt with the pulley.

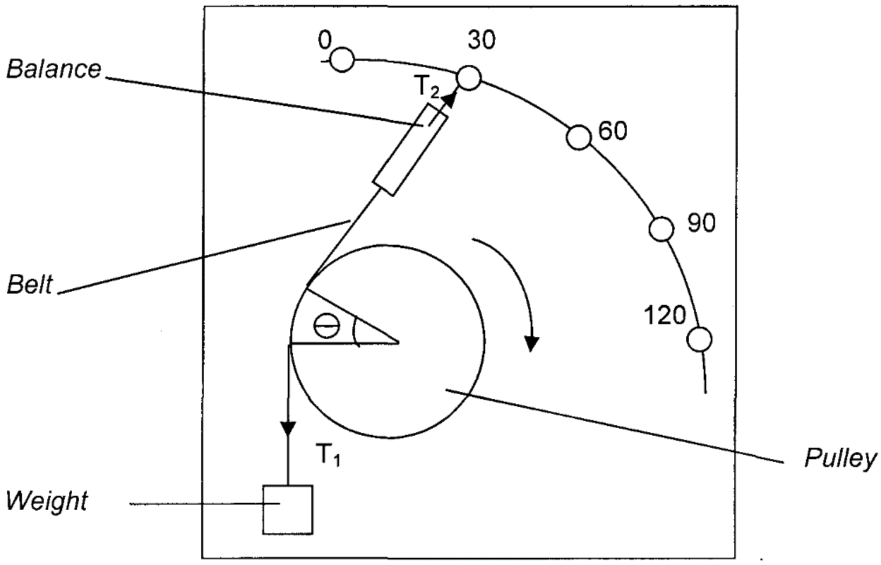


Figure 1.2-1 An Outline of the Experimental Set Up.

Procedure:

1. By fixing θ = 30 degree T_2 is observed for three values of T_1 (500g, 1000g and 1500g) when the pulley is moved clockwise at a steady speed. In this way we get data for calculating 03 values of $\mu_{kinetic}$.

2. By repeating the same procedure for contact angles of 60, 90 and 120 degrees 09 more values of the coefficient of friction are obtained.
3. Average of the 12 calculated values is reported along with its stabdard deviation.

1.3 Tabulation of Results

Table 1.3-1 Data for the calculation of μ

Contact Angle θ		**Tensions (grams)**			**$\mu = [\ln (T_1/T_2)]/\theta$**		
Degree	**radian**	**T_1= 1000 gram**	**T_1= 1500 gram**	**T_1= 2000 gram**	**T_1= 1000 gram**	**T_1= 1500 gram**	**T_1= 2000 gram**
		T_2	**T_2**	**T_2**			
30							
60							
90							
120							

1.4 Points of Discussion in the Lab Report

Scatter in the values of coefficient of friction and its comparison with the value of a standard reference are the main points to be emphasized while discussing the results of the experiment.

Experiment 2. To determine the reaction of simply supported beams subjected to two loads.

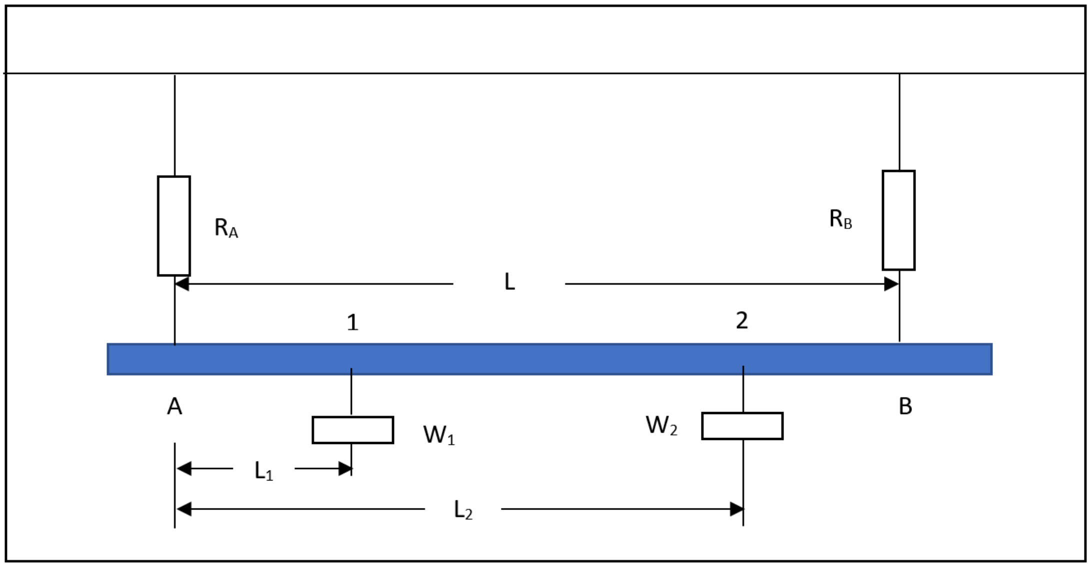
2.1 Objectives:

i. To apply the laws of static equilibrium
ii. To experimentally find the reactions of the beam

2.2 Apparatus Required:

i. Wooden beam
ii. Meter rod
iii. Two spring balances
iv. Slotted weights with hanger

2.3 Theory:



$$R_A + R_B = W_1 + W_2$$

$$R_A = W_1 + W_2 - R_B$$

$$R_B = \frac{W_1 L_1 + W_2 L_2}{L}$$

2.4 Procedure:

i. Place the apparatus on a horizontal smooth surface and then hang the wooden beam in hooks connected to spring balances. The positions of these hooks are named as A and B.
ii. Note down the readings of spring balances. Subtract these readings from experimental values.
iii. Hang two weights on the beam at positions 1 and 2.
iv. Find out the corresponding lengths and perform the calculations.
v. Compare the readings of spring balances with calculations.

2.5 Precautions:

i. Beam must be horizontal during experimentation.
ii. Weight of the beam must be subtracted from both reactions.
iii. If the distance is changed, initial readings must be noted again.

2.6 Observations and Calculations:

Initial reading of spring balance A, $R_{A,i}$ =

Initial reading of spring balance B, R_B =

Sr. No.	**Loads (g)**		**Lengths (cm)**			**Reactions (Experimental) (g)**	
	W_1	**W_2**	**L_1**	**L_2**	**L_3**	**R_A = Spring balance reading - $R_{A,i}$**	**R_B = Spring balance reading - $R_{B,i}$**
1							
2							
3							

Difference = Experimental – Theoretical

2.7 Report:

Discuss results in the report.

Experiment 3. To Determine the Resultant of Two Coplanar Forces with the Help of Coplanar Apparatus

3.1 Objective

To determine the resultant of coplanar forces with the help of coplanar apparatus

3.2 List of Required Equipment & Accessories

Graduated round board with pulleys, Set of slotted weights with hangers, Stand, Center ring, Center axel and thread.

3.3 Theory

By three different methods we can find out resultant of two vectors/forces.

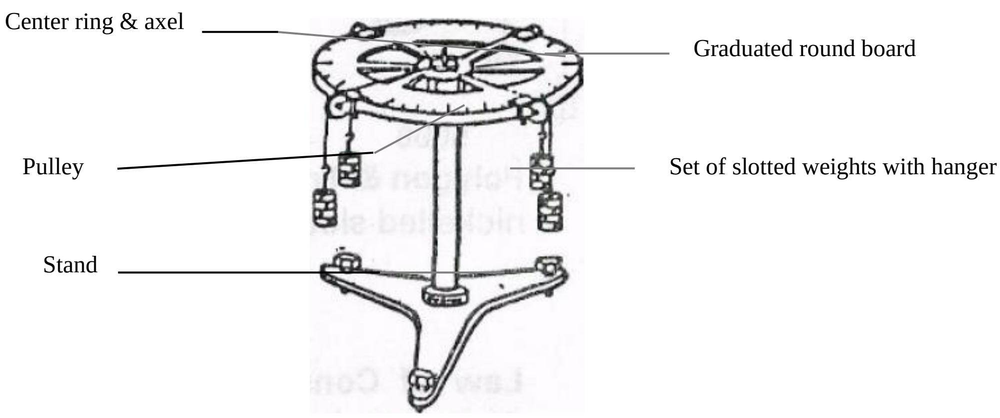


Figure 3.3-1: Coplanar Apparatus

3.4 Experimental Method

Apply two forces (F_A and F_B) on the coplanar apparatus by hanging weights over pulleys positioned at certain angles. Hang the third weight over a pulley in such a way that it balances the two forces as shown in fig. 2. This third force is called the equilibrant (F_E). The equilibrant F_E is equal in magnitude to the resultant F_R but opposite in direction then:

$$-F_E = F_R = F_A + F_B$$

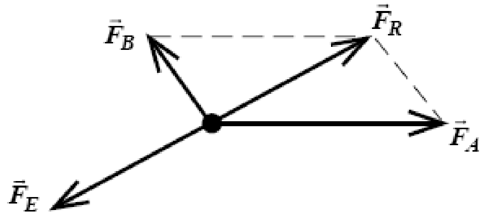


Figure 3.4-1

3.4.1 Component Method

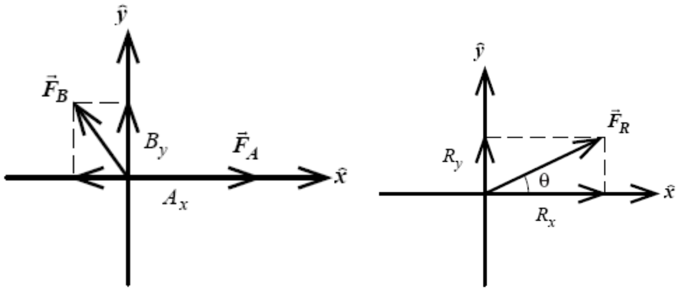


Figure 3

According to trigonometry resolve two forces into their x and y components as shown in Fig 3:

$$F_A = A_x x + A_y y$$

And,

$$F_B = B_x x + B_y y$$

As;

$$F_R = F_A + F_B$$

$$F_R = A_x x + A_y y + B_x x + B_y y$$

$$F_R = (A_x + B_x)x + (A_y + B_y)y = R_x x + R_y y$$

The resultant force must be in the form of a magnitude and a direction. So, as the components are at right angle then according to the Pythagorean Theorem:

$$F_R = R_x^2 + R_y^2$$

And

$$Tan\,\theta = \frac{R_x}{R_y}$$

3.5 Graphical Method

Draw the force $\mathbf{F_B}$ in such a way that its tail touches the head of the force $\mathbf{F_A}$ as shown in Fig. 4. The resultant $\mathbf{F_R}$ is drawn from the tail of $\mathbf{F_A}$ to the head of $\mathbf{F_B}$. Then the magnitude of the resultant can be measured directly from the diagram and converted to the proper force using the chosen scale. The angle can also be measured using the protractor.

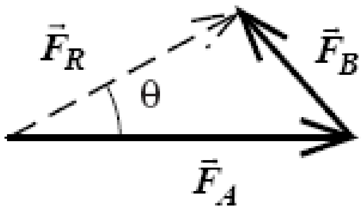


Figure 4

3.6 Procedure

Place the stand on an even surface and screw the graduated round board on it. Place the ring on the top of stand and tight the axel so that it hold the ring as shown in Fig 1. Take two pulleys and tight them on the graduated board. Note down the position of first pulley, take it as a reference point and note down the position of second pulley according to that reference point. Take two threads, tie one end of each thread to the center ring and tie two weights on the other ends of the threads, note down these weights. By hit and trial method, find out the angle for the third pulley and the weight which must be suspended in order to balance the previous two forces. This third force is called the equilibrant F_E. The equilibrant F_E is equal in magnitude to the resultant F_R but opposite in direction then:

$$-F_E = F_R = F_A + F_B$$

Note down the weight and angle of the third pulley to put the system into equilibrium, apply components and graphical methods also and record the readings and put them in the following table 1.

Table 3.6-1: Forces and their direction (readings to be taken in lab)

Serial no.	1st Force F1	Θ1 (degrees)	2nd force F2	Θ2 (degrees)	3rd force F3	Θ3 (degrees)	Resultant R	ΘR (degrees)
1								
2								
3								
4								
5								

Table 3.6-2: Comparison of the three methods of finding resultant

Method	**Equilibrant F_E**	
	Magnitude	**Angle**

Experiment		
Component		
Graphical		

3.7 Precautions

i. The ring should not touch the axle or the disc.

ii. The position of the threads should rightly observe.

iii. The graduated disc should be made horizontal by adjusting the screws at its base.

Experiment 4. To Determine the Coefficient of Sliding Friction Using a Horizontal Plane

4.1 Learning Objectives

These include the following.

i. To establish the factors over which the coefficient of friction between two contacting surfaces depends.
ii. The realization of the experimental difficulties in determining μ_{static}
iii. Demonstration of the scatter of the experimental results.

4.2 List of Required Equipment & Accessories

It includes the following.

i. A horizontal wooden plate, having a pulley at its one end, placed on a table.
ii. Thread
iii. Weight hanger and various weights (the smallest one of 5 g)
iv. Three wooden block with bottom surface as wood, glass and sandpaper.
v. Three weights of 100 g each.
vi. A spring balance.

(a)

(b)

Figure 4.2-1 A Photograph of the Exp. Set Up a) Overall View b) Enlarged View of a Portion

4.3 Procedure

1. Take a wooden block with a glass piece fitted at bottom surface and take its weight in grams using a pring balance. This is the first value of ‘M’ (mass to be pulled by a hanging mass ‘m’).
2. Take a thread. Connect one end of the thread with the block placed on wooden horizontal surface and other end of the thread with a weight hanger while the thread is pasing over a pulley. The first value of the hanging mass ‘m’ is the mass of the hanger alone.
3. Keeping the first value of ‘M’ fixed gradually increase the value of ‘m’ in steps of 5g for recording the value of ‘m’ which is just sufficient for inducing a very slow sliding motion in ‘M’.
4. $\mu = m_{av} / M$. Where m_{av} is the value of ‘m’ which is responsible for inducing a very slow sliding motion (of zero acceleration) in ‘M’. Generally a relatively fast movement of ‘M’ is observed for a certain value of ‘m’ while no movement at all is observed at the previus value of ‘m’ which is only 5g less than the present value of ‘m’. For these cases m_{av} is approxiated as mean of ‘m’ for no movement and ‘m’ for relatively fast movement. In case fast movement is observed even with hanger alone acting as ‘m’ then for this ‘M’ calculation of μ is not possible.
5. Repeat the above procedure for three more values of ‘M’ , obtained through placement of 100g weight on the block placed on horizontal wooden surface. In this way we can have 3 to 4 values of μ for Wood-Glass interface. The mean along with standard deviation is to be reported as the result which is to be compared with that reported in standard references.
6. Following the same procedure μ for Wood-Wood and Wood-Sandpaper interface is also to be determined.

4.4 Tabulation of Results

Table 4.4-1 Experimental Data of μ for Wood-Glass Interface

M(g)	m(g)	Observation	m_{av} (g)	$\mu = m_{av}/M$

μ_{av} = mean of the tabulated values

4.5 Points of Discussion in the Lab Report

Following points are not to be ignored.

i. Scatter in the values of μ for various 'M' but for for the same contact sutface.
ii. Variation of μ with the change of contact surface.
iii. Difference of the results of this experiment in comparison with the values quoted in standard references.

Experiment 5. To determine the Mechanical Advantage of Inclined plane

5.1 Learning Objective:

i. To determine the mechanical advantage of inclined plane experimentally and compare the results with the theoretical calculations.

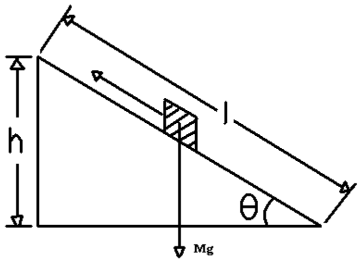
5.2 Introduction

5.2.1 Simple machine

Inclined plane is a simple machine. A simple machine is a mechanical device that changes the direction or magnitude of a force. In general, they can be defined as the simplest mechanisms that use mechanical advantage (also called leverage) to multiply force. A simple machine uses a single applied force to do work against a single load.

Measuring the mechanical advantage (MA) is a mathematical way to determine how much a machine affects the amount of force needed to do work. Scientists find the mechanical advantage of a machine by dividing the force the machine delivers by the effort put into the machine. The theoretical, or ideal, mechanical advantage of a machine is the advantage it would produce if the machine were perfect. In simple machines, the main source of imperfection is friction. Friction results from two bodies moving against each other in different directions. Friction always opposes motion and makes doing work harder. Since friction is present in almost every machine, the actual mechanical advantage is always less than the theoretical mechanical advantage.

Because simple machines increase mechanical advantage by increasing the distance over which the effort is applied, one way to compute theoretical mechanical advantage is to divide the distance the effort is applied by the distance the load actually travels.



If we ignore friction and all external effects, then by Law of Conservation of Energy

$$L \times h = E \times l \qquad => \qquad M.A = \frac{L}{E} = \frac{l}{h}$$

Where E = Effort applied

L = Load raised

l = Effort Arm = Length of inclined plane

h = Load Arm = Height of inclined plane

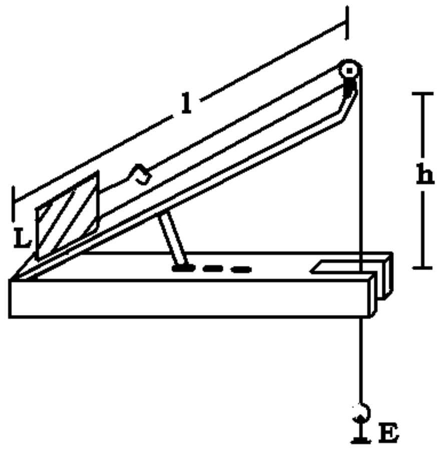
$$M.A = \frac{1}{sin\theta} = \frac{l}{h}$$

5.3 Apparatus

Inclined Plane, hanger and weights, thread, meter rod, protractor

5.4 PROCEDURE

1. Firstly measure the length of the inclined plane with meter rod.
2. Set the angle of the inclined plane by holding the plane on one of three holes on horizontal plane as shown in figure.
3. Measure the height attained by the plane with meter rod.
4. Applied load on the inclined plane as shown in figure, **L** denotes the load.
5. Keep on putting weight with a difference of 5g on vertical hanger as effort, as shown in figure. In figure **E** shows effort.



6. There will be a point where the load will start to move, that is effective effort.
7. Calculate the theoretical and experimental mechanical advantages and efficiency of the inclined plane by the formulae discussed in introduction section.
8. Repeat all the above steps by changing positions of the support.

5.5 Observations and Calculations

Load on the inclined plane = L = ____ g

Length of inclined plane = l = ____ cm

Table 5.5-1 Mechanical Advantage observed and calculated values

Sr. No.	**Height**	**Angle of inclination**	**Effort**	**Theoretical M.A.**	**Experimental M.A.**	**Work input**	**Work output**	**Efficiency (Input / Output) x 100**
	h (cm)	***θ°***	***E (g)***	***l/h=1/sin(θ)***	***L / E***	**Lsin$\theta \times l$**	**L × h**	
1								
2								
3								

$$\%\, error = \frac{Theoretical\ MA - Experimental\ MA}{Theoretical\ MA} \times 100$$

5.6 Report

Discuss results in lab report.

Experiment 6. To determine relationship between load and effort for screw jack.

6.1 Objectives

(Include values for both lowering and raising the load)

i. To find Co-efficient of Friction
ii. To show Relation between load and effort (use a piece of graph paper).
iii. To find mechanical advantage and efficiency of screw jack.

6.2 Introduction

A screw jack is a device by which the heavy load can be lifted by applying a very little force. Jacks are used frequently in raising car so that a tire can be changed. A screw jack is commonly used with cars but is also used in many other ways, including industrial machinery and even airplanes. They can be short, tall, fat, or thin depending on the amount of pressure they will be under and the space that they need to fit into. A jackscrew's compressive force is obtained through the tension force applied by its lead screw. An Acme thread is most often used, as this thread is very strong and can resist the large loads imposed on most jackscrews while not being dramatically weakened by wear over many rotations. These types are self-locking, which makes them intrinsically safer than other jack technologies like hydraulic actuators which require continual pressure to remain in a locked position.
In our experiment, the larger pulley acts as the station which rotates as well as move upward and force applied is equal to the tension in thread which is produced by the weight of hanger and weights applied on it. This tension in the thread is the responsible gent for the larger pulley or the station to rotate as well as travel some vertical distance.
Different formulae which will be used in calculations are summarized below;

$$M.A = Mechanical\ Advantage = \frac{W}{E}$$

$$V.R = velocity\ Ratio = \frac{distance\ moved\ by\ Effort}{distance\ moved\ by\ load} = \frac{2\pi R}{p}$$

$$Efficiency = \frac{M.A}{V.R}$$

6.2.1 For coefficient of friction for lowering jack

$$ER = Wr\left(\frac{p - 2\pi r\mu}{2\pi r + \mu p}\right)$$

$$T = ER = Wr\left(\frac{p - 2\mu r\pi}{2\pi r + \mu p}\right)$$

$$\frac{ER}{Wr}(2\pi r + \mu p) = p - 2\pi r\mu$$

$$2\pi r\frac{ER}{Wr} + \mu p\frac{ER}{Wr} + 2\pi r\mu = p$$

$$2\pi r\frac{ER}{Wr} + \mu\left(p\frac{ER}{Wr} + 2\pi r\right) = p$$

$$\mu\,(ERp + 2\pi Wr^2) = pWr - 2\pi rER$$

$$\mu = \frac{(pWr - 2\pi rER)}{(ERp + 2\pi Wr^2)}$$

6.2.2 Similarly for raising jack

$$ER = Wr\left(\frac{p + 2\pi r\mu}{2\pi r - \mu p}\right)$$

$$\frac{ER}{Wr}(2\pi r - \mu p) = p + 2\pi r\mu$$

$$2\pi r\frac{ER}{Wr} - \mu p\frac{ER}{Wr} - 2\pi r\mu = p$$

$$2\pi r\frac{ER}{Wr} - \mu\left(p\frac{ER}{Wr} + 2\pi r\right) = p$$

$$2\pi rER - \mu\,(ERp + 2\pi Wr^2) = Wrp$$

$$\mu = \frac{2\pi rER - Wrp}{ERp + 2\pi Wr^2}$$

In above formulae following symbols are used:

p = pitch of the screw of the larger pulley

R = radius of the platform pulley (larger pulley)

r = mean thread radius

T = ER = applied torque

μ = coefficient of friction

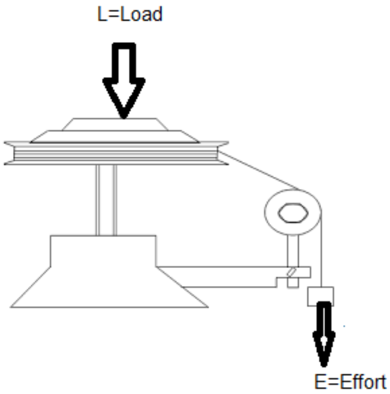
E = effort applied by the weight placed on the hanger

W = weight placed on the platform pulley (larger pulley)

6.3 List of required equipment

Two pulleys (smaller and larger), thread, hanger and weights, screw

6.4 Procedure



Rotate larger pulley anticlockwise. Place weight (L) on larger pulley and then increase weight shown as effort (E) in the figure 1 so that weight E starts to move down. That is effort corresponding to load L. Repeat the experiment for clock wise case. And repeat the same for different loads and fill the table given.

6.5 OBSERVATIONS AND CALCULATIONS

Weight of the pulley including thread = W_1 = 880g = 8.6 N

p = 1.5mm , R = 95/2 mm , r = 4.5mm

Table 6.5-1 Screw Jack observations and calculations

Sr. No.	W2 (N)	W = W1 + W2 (N)	Effort	
			Raise (N)	Lower (N)

1.				
2.				
3.				
4.				
5.				

6.6 Report

Explain results in report.

Draw graphs of efficiency vs load for both cases (raising and lowering).

Draw graph of effort vs load for both cases (raising and lowering).

Calculate the value of μ for both cases (raising and lowering).

Experiment 7. To determine Mechanical Advantage of Toggle Joint

7.1 Objective

i. To determine the mechanical advantage of a toggle joint experimentally and compare it with theoretically calculated mechanical advantage.

7.2 Apparatus

The toggle joint apparatus, spring balance and hanger & weights, meter rod

7.3 Introduction

A toggle joint is a joint made of two arms attached by a pivot shaped like an elbow, allowing force to be exerted at the ends of the arms as the joint is expanded. It is also used to apply pressure at the two ends by straightening the joint. Toggle joint mechanisms are suitable for a wide range of applications as different parts and accessories can be welded together to create a customized toggle clamp that is able to satisfy all clamping requirements.

It can be used in robotics, in pedals in adjustable carriage tops, in printing presses, in machines used for stamping metals, leather, wood etc. and occasionally in copying presses when the desired pressure is greater than that could be readily obtained from a screw.

Now come to the mechanical advantage. As we know measuring the mechanical advantage (MA) is a mathematical way to determine how much a machine affects the amount of force needed to do work. Scientists find the mechanical advantage of a machine by dividing the force the machine delivers by the effort put into the machine. The theoretical or ideal mechanical advantage of a machine is the advantage it would produce if the machine is perfect. Mechanical advantage of toggle joint can be measured by two different ways i.e. by experimental way and the other one is theoretical way.

Experimental value of mechanical advantage of the toggle joint is given by the formula

$$Experimental\ M.A = \frac{\text{load}}{\text{effort}}$$

Theoretical value of mechanical advantage of the toggle joint is given by the formula

$$Theoretical\ M.A = \frac{\mathbf{D}}{\mathbf{4h}}$$

Figure:

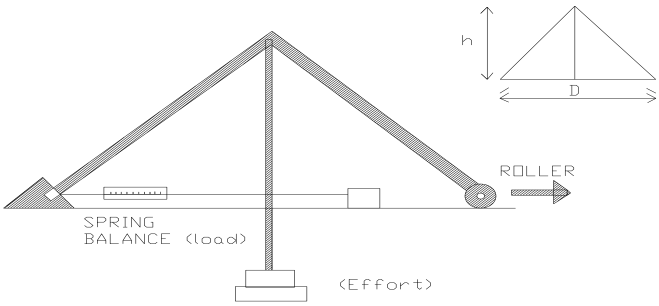


Figure 7.3-1: Toggle Joint Apparatus

7.4 Procedure

Arrange the apparatus in the given position. Then load the effort weight hanger and note the corresponding force on the spring balance. Then perform calculation according to pattern given in the table.

7.5 Observations & Calculations

Initial reading of spring balance: ______g

Table 7.5-1 Toggle Joint Observation and calculation

SR NO.	Load(g) L	Effort(g) E	Height(cm) h	Length(cm) D	Mechanical Advantage		%age Error*
					Exp.(L/E)	Theoretical($\frac{D}{4h}$)	
1.							
2.							
3.							
4.							
5.							

*Percentage Errors: {(Theoretical value– Experimental value)/ Theoretical value} x 100.

7.6 Precautions

i. Check the toggle joint apparatus for any fault.
ii. Apply oil to roller to overcome the friction.
iii. Surface should be smooth so that roller can move easily.
iv. Apparatus should be at right angle.

Report:

Discuss results in your report.

Experiment 8. To Determine Forces on the Members of a Jib Crane

8.1 Objective

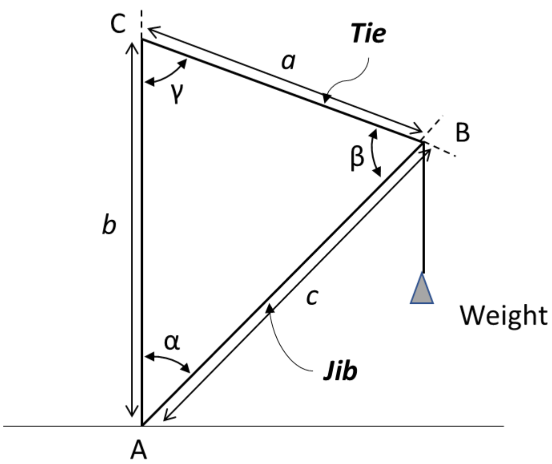
ii. To determine the Forces in Tie and Jib Members Experimentally and compare it with analytical and graphical method.

8.2 Apparatus

- The Jib crane apparatus,
- Weights
- Thread
- meter rod

8.3 Introduction

A toggle joint is a joint made of two arms attached by a pivot shaped like an elbow, allowing force to be exerted at the ends of the arms as the joint is expanded. It is also used to apply pressure at the two ends by straightening the joint. Toggle joint mechanisms are suitable for a wide range of applications as different parts and accessories can be welded.



8.4 Procedure:

- Note down the initial readings (or zero error) in the compression balances and the tension spring balance separately.

- Suspend a known wt (**W**) from the point. B i.e. the hook of the hanging chain and note down the final readings of the balances separately.
- Subtract the initial readings from the final readings. The difference between the two readings of the tension spring balance will give the observed value of the force in the tie ($\mathbf{F_{Tie}}$) and that of the compression balance, the observed value of the force in the jib ($\mathbf{F_{Jib}}$).
- Measure the lengths of the vertical post, tie and jib.
- From these measurements (taken to a suitable scale) draw the space diagram.
- Select a suitable scale and draw **bc** parallel to BC and cut equal to W. Draw **ca** parallel to CA and **ab** parallel to AB meeting at A. Then vectors **ca** and **ab** represent forces in the tie (tension) and jib (compression) respectively.

Mathematically,

In Δ ABC, measure **α, β** and **γ**.

Using sine law, we get

$$\frac{a}{\sin\alpha} = \frac{b}{\sin\beta} = \frac{c}{\sin\gamma} \dots\dots\dots\dots\dots (8.1)$$

And In the form of forces

$$\frac{\boldsymbol{F_{Tie}}}{\sin\alpha} = \frac{\boldsymbol{W}}{\sin\beta} = \frac{\boldsymbol{F_{Jib}}}{\sin\gamma} \dots\dots\dots\dots\dots (8.2)$$

Dividing equation 8.2 with equation 8.1 we get

$$\frac{\boldsymbol{F_{Tie}}}{a} = \frac{\boldsymbol{W}}{b} = \frac{\boldsymbol{F_{Jib}}}{c} \dots\dots\dots\dots\dots (8.3)$$

- The value of $\mathbf{F_{Tie}}$ and $\mathbf{F_{Jib}}$ can be calculated. The percentage error can be calculated in the observed and calculated values of forces in the jib and tie.
- Increase the weight at B and proceed as before. Take in this way about more readings.

Sr. No	Weight (N)	Length (cm)			Angle (Deg)			Forces in Spring (N)		Forces Calculated (N)		%error
		a	b	c	α	β	γ	Tie	Jib	Tie	Jib	

8.5 Precaution

- Do not suspend the wt (W) from B with a jerk.
- If the readings in compression balance are different for a same wt (W) then take three such readings and find their mean.
- Consider the zero error of the balances.
- Measure the lengths with a fine inextensible thread.

Experiment 9. To Study the Relationship between Load and Extension of a Helical Spring

Learning Objectives: The experiment is mean for

- illustration of the concept of Elasticity.
- demonstrating that the Spring Constant is a characteristics of a spring which is determined experimentally.
- demonstrating that the experimental error(s) may result in deviation of the results from that expected ideally (in this case linear variation of the spring extension as a function of applied load).

List of Required Equipment & Accessories

i. A variety of helical springs
ii. A stand with an arrangement of hanging the spring and fitted with a scale for noting the extensions associated with various applied loads.
iii. A weight hanger and the slotted weights.

9.1 Procedure

- Hang the first helical spring with the stand and attach the load hanger to it in such a way that its needle shows the reference scale reading.
- Keep on adding (one by one) few slotted weights and note down the scale reading corresponding to each load.
- The extension corresponding to each load is the difference of scale reading for that load and the reference scale reading.
- The spring constant is slope of the line fitted through data points plotted by taking Load along Y axis and Extension along X axis.
- Repeat the same procedure for other available helical springs.

9.2 Precautions

- While taking reading make sure that the spring-load system is stationary and the the eye is kept at the level of needle.
- While adding load it is bettter to support the bottom of hanger with your hand and then gradually lower the hand for avoiding jerks in the application of load.
- Avoid excessive loading for not excceding the elastic limit of the spring.

9.3 Tabulation of Data

Table 9.3-1 Data of Load vs Extension for Helical Spring No.1

Load (N)	Scale Reading (mm)	Extension (mm)
Hanger		-
50		
100		
150		
200		

9.4 Points of Discussion:

Following points should be especially focused while discussing the results.

i. Any observed deviation from the linearity among load and extension.
ii. It is expected that each spring has its own characteristic value of the spring constant.

Experiment 10. To Determine the Mass Moment of Inertia of a Flywheel by Applying the Law of Conservation of Energy

10.1 Objective

- To determine the mass moment of inertia of a flywheel
- To find the energy stored in a flywheel by supplying a known quantity of energy

10.2 List of Required Equipment & Accessories

The flywheel apparatus, string, stop watch, set of slotted weights with hanger, vernier caliper and meter rod.

10.3 Theory

10.3.1 Kinetic and Potential Energies of a Body

Kinetic Energy

It is the energy possessed by a body by virtue of its motion.

- If body undergoes translation:

$$KE = \frac{mv^2}{2}$$

- If body undergoes rotation:

$$KE = \frac{Iw^2}{2}$$

10.3.2 Potential Energy

It is the energy possessed by a body by virtue of its position. In mechanics, *PE* due to gravity (weight) and elastic spring is important.

$PE = mgh$

10.3.3 Law of Conservation of Energy

In mechanics, it is sometimes known as Law of Conservation of Mechanical Energy. It states that during motion, sum of kinetic and potential energies of a body remains constant. For these to occur, kinetic energy must be transformed to potential energy & vice versa.

10.3.4 Derivation of Formula for I

In this experiment a flywheel is so mounted that torques can be applied to it by hanging a mass *m* from the free end of a string, the remainder of which is wrapped around the axle as shown below. The string would be fully unwounded as the mass reaches the floor.

Figure 10.3-1 Flywheel Apparatus

10.3.4.1 Phase 1

As the mass *m* falls through a vertical height of *h*, it loses its potential energy *mgh*. This *PE* is converted into:

1. Translational *KE* of the mass *m* = $\frac{mv^2}{2}$
2. Rotational *KE* of the flywheel = $\frac{Iw^2}{2}$
3. Frictional energy loss $n_1 W_f$ in bearings; where W_f is frictional energy loss in one revolution.

Law of conservation of energy implies:

Loss in *PE* of mass = gained in *KE* of mass + gained in *KE* of flywheel + work done against friction in bearings

$$\Rightarrow \quad mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 + n_1 W_f \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

Where,

v = Final velocity of the mass just before it hits the ground

w = Angular velocity of the flywheel just before the mass hits the ground

n_1 = Number of revolutions the flywheel makes before the mass reaches the ground

W_f = Work done against friction per revolution

10.3.4.2 Phase 2

After the mass reaches the floor, the string falls off the axle and the flywheel continues to rotate due to its inertia until it is brought to rest by the friction. The instant when the falling mass is detached, the flywheel is having rotational KE equal to $\frac{Iw^2}{2}$. This energy is lost in friction in the bearings. If number of revolutions made by the flywheel after detachment of mass are n_2, then the energy lost in friction will be $n_2 W_f$.

This means:

$$\frac{Iw^2}{2} = n_2 W_f \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$\Rightarrow W_f = \frac{Iw^2}{2n_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Equation (3) and (1) gives:

$$mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 + n_1\left(\frac{Iw^2}{2n_2}\right)$$

$$\Rightarrow mgh - \frac{mv^2}{2} = \frac{1}{2}I\omega^2 + n_1\left(\frac{Iw^2}{2n_2}\right)$$

$$\Rightarrow mgh - \frac{mv^2}{2} = \frac{1}{2}I\omega^2\left(1 + \frac{n_1}{n_2}\right)$$

$$\Rightarrow \frac{2m}{w^2}\left(gh - \frac{v^2}{2}\right) = I\left(\frac{n_1 + n_2}{n_2}\right)$$

$$\Rightarrow \frac{2m}{v^2/r^2}\left(gh - \frac{v^2}{2}\right) = I\left(\frac{n_1 + n_2}{n_2}\right) \qquad \left(\because v = rw \Rightarrow w = \frac{v}{r}\right)$$

$$\Rightarrow \frac{2mr^2}{v^2}\left(gh - \frac{v^2}{2}\right) = I\left(\frac{n_1 + n_2}{n_2}\right)$$

$$\Rightarrow I = \frac{2mr^2}{\left(2h/t\right)^2}\left(gh - \frac{\left(2h/t\right)^2}{2}\right)\left(\frac{n_2}{n_1+n_2}\right) \qquad \left(\because h = \frac{v}{2}t \Rightarrow v = \frac{2h}{t}\right)$$

$$\Rightarrow I = \frac{mr^2t^2}{2h^2}\left(gh - \frac{2h^2}{t^2}\right)\left(\frac{n_2}{n_1+n_2}\right)$$

$$\Rightarrow I = \frac{mr^2t^2h}{2h^2}\left(\frac{gt^2-2h}{t^2}\right)\left(\frac{n_2}{n_1+n_2}\right)$$

$$\Rightarrow I = mr^2\left(\frac{gt^2}{2h}-1\right)\left(\frac{n_2}{n_1+n_2}\right)$$

$$\Rightarrow I = \frac{md^2}{4}\left(\frac{gt^2}{2h}-1\right)\left(\frac{n_2}{n_1+n_2}\right) \quad \ldots\ldots\ldots\ldots (4) \qquad \left(\because r = \frac{d}{2}\right)$$

Where, d is the diameter of the axle. Also, if needed, we can find h, w, and v from the following relations:

$$h = 2\pi r n_1, \qquad w = (4\pi n_1)/t, \qquad v = (4\pi r n_1)/t$$

10.4Procedure

Set up the flywheel apparatus.

Measure the diameter of the axle *(d)* of the flywheel with the help of vernier caliper.

The string should be of sufficient length so that the mass attached to it in hanger can reach to the ground.

Load the hanger with some slotted weight and un-wind the string until the hanger touches the ground.

Mark the surface of the flywheel behind the pointer with chalk and lift the mass attached to the hanger to height (h) by giving n_1 complete rotations to the flywheel.

Measure the height (h) of the mass from the ground with meter rod.

Release the mass and note the time *(t)* it takes to reach to the ground with the help of a stop watch.

As soon as the mass hits the floor, count the number of revolutions *n2* which the flywheel will make before it comes to rest.

Repeat the experiment three times by increasing the mass in the hanger.

10.5 Observations & Calculations

Diameter of the axle of the flywheel, d = ---------- (m)

Radius of the axle of the flywheel, *r* = ---------- (m)

Height of the mass attached to the string from the ground, *h* = ---------- (m)

No. of revolutions 'n_1' made by the flywheel before the mass hits the ground = --------- (rev)

Table 10.5-1: Parameters for determining the mass moment of inertia

S. No	Mass attached to the string *m* (Kg)	Time taken *t* (sec)	No. of revolutions n_2	Mass moment of inertia *I* (Kg-m^2)
1				
2				
3				

10.6 Conclusions & Discussions

The mass moment of inertia of the flywheel is measured and found to be I_{avg} = ------------ Kg-m^2

10.6.1 Errors and Improvement

- ***The reaction times error:*** This can be improved by straighten the hand when taking the time.
- **The number of revolutions n2** that the flywheel performed cannot be accurately obtained. This can be improved by counting the number of revolutions by two students instead of one and to repeat the experiment more times.
- ***Unsteady hands:*** When the hand released the mass, force may be push to the mass. To improve this, student should release the mass slowly and softly.

10.7 Precautions

1. The mass and the height from which the mass falls should be chosen such that the falling time is long enough for measurement to be taken accurately.
2. The mass should be wound up to the same height in all trials.
3. The first few turns of the string should overlap the others.
4. The later turns of the string should not overlap the others.

Experiment 11. To Investigate A Relation Between Linear and Angular Displacement

11.1 Objectives:

The main learning objective is familiarization with the concepts of experimental error and error propagation.

11.2 List of Required Equipment & Accessories: .

- The main equipment consists of a stepped shaft with three diameters (25, 50 and 75 mm) attached to a bracket. Each diameter has a string and a mass (500 gram; not involved in any of the calculations of the experiment).
- Two meter rods

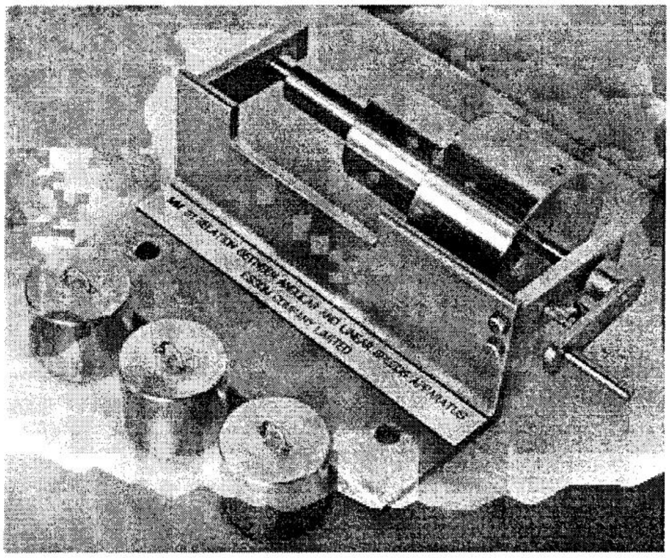


Fig.1 A Photograph of the Main Equipment

11.3 Procedure:

- At the start of the experiment the masses attached to 03 diameters of the shaft are at the same level.
- After each turn of the shaft the masses are raised to different levels (proportionate to the various diametrs of the shaft) which are measured using meter rods.

11.4 Precautions:

- While taking height readings eye should be at the level of reading point.
- A small unmarked region at the ends of meter rods should also be taken into account.

11.5Tabulation of Results.

Table No. 1 Data of Relationship Between Angular and Linear Displacements

N (No. of Rev.)	Measured Height (mm) of the attached mass			Calculated Height (mm) of the attached mass			% Difference in Measured & Calculated Height		
	Shaft Dia 25 mm	Shaft Dia 50 mm	Shaft Dia 75 mm	Shaft Dia 25 mm	Shaft Dia 50 mm	Shaft Dia 75 mm	Shaft Dia 25 mm	Shaft Dia 50 mm	Shaft Dia 75 mm
1									
2									
3									
4									

Calculated Height = π D N

11.6Theory:

The philosophy of the experiment is presented through following sketch.

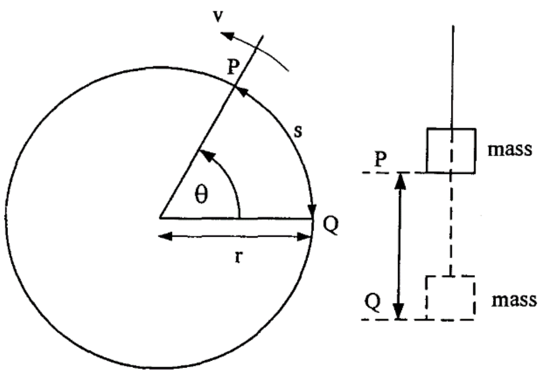


Fig. 2 A Sketch Related to the Experimental Theory

Angular displacement and linear displacement are related through following relationship.

s = rθ, where s, r and θ represent linear displacement , readius of the rotating body and angular displacement respectively. Dividing both sides of this equation by time results in v = rω, which is relation between linear and angular speed. We may generalize that

Linear Quantity = Radius * Corresponding Angular Quantity

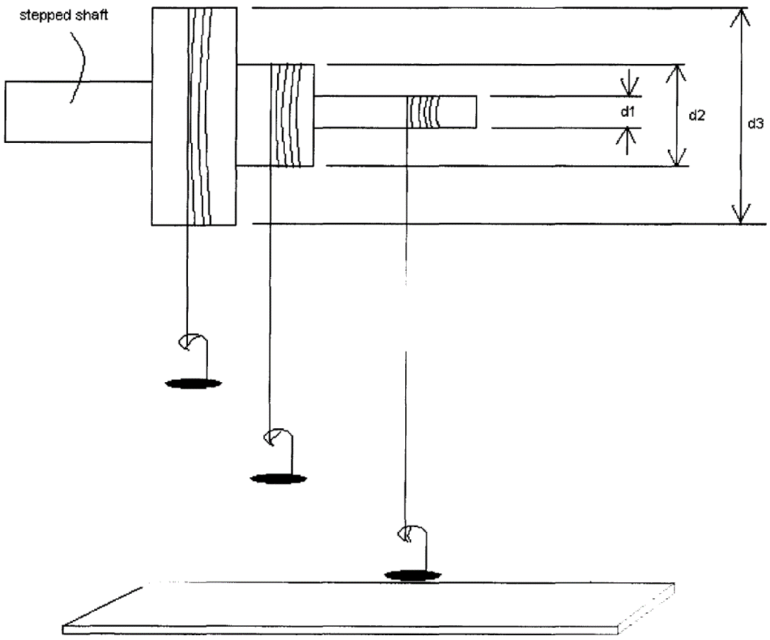


Fig. 3 Illustration of the Fact that for Same Angular Displacement Linear Displacement is Proportional to the Dia of Each Shaft

11.7 Points of Discussion in the Lab Report:

Following points deserve special attention while discussing the results.

i. Causes of the difference between measured and calculated heights.
ii. Trend of variation of % difference with increasing number of revolutions.

Experiment 12. To Demonstrate Laws of Equilibrium of Moments in Static Systems

12.1 Objective

To demonstrate laws of equilibrium of moments in static systems

12.2 List of Required Equipment & Accessories

Simple wheel and axle apparatus set of slotted weights and hangers, and thread.

12.3 Theory

Work is defined as the movement of an object through a distance by the application of a force. Simple machines make it easier to do work by changing either the force we must apply, or the distance through which we must apply it.

The term "mechanical advantage" is used to describe how much easier the work is made by a given machine. The mechanical advantage of a simple machine can be expressed as a numerical value.

The wheel and axle is a version of another simple machine, the lever (in effect, a wheel is a lever which rotates about a fixed point).

Levers are classified by the relative positions of the fulcrum and the input and output forces. It is common to call the input force the 'effort' and the output force the 'load' or the 'resistance'.

Class 1: Fulcrum in the middle

Class 2: Resistance in the middle

Class 3: Effort in the middle

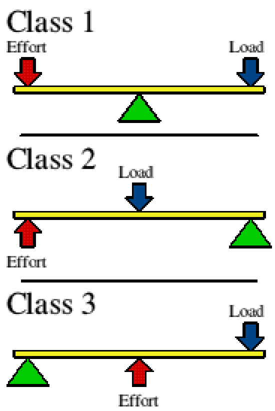


Figure 12.3-1: Three Classes of Levers

Mechanical advantage of a lever increases with the ratio of the effort arm to the resistance arm.

A simple fixed pulley has a mechanical advantage of 1, because the resistance and effort are equidistant from the fulcrum (in this case, the center of the wheel). However, a stepped wheel (like ours) used as a pulley can have different mechanical advantage values. The wheel from which a load is suspended is the resistance wheel or axel. The wheel to which a force is applied is the effort wheel.Mechanical advantage increases with the ratio of the radius of the effort wheel to the radius of the resistance wheel.

Figure 12.3-2: Simple Wheel and Axle Apparatus

12.4 Procedure

1. Set the apparatus as shown in figure above.
2. Attach one 100g mass to the cord at 15cm radius wheel, and one 200g mass to the cord at 7.5cm radius axel.
3. When a mass of weight W (100g) is suspended at radius R (15cm), and a mass of weight w (200g) is suspended at radius r (7.5cm), we have equilibrium with the condition $W \times R = w \times r$
4. Repeat the same experiment with different slotted weights.

12.5 Observations & Calculations

Test *NUMBER*	***Wheel***			***Axel***			***Equilibrium***
	Mass *(W) gm*	***Radius*** *(R) cm*	***Work done*** *(WxR)*	***Mass*** *(w) gm*	***Radius*** *(r) cm*	***Work done*** *(wxr)*	$W \times R = w \times r$

12.6 Precautions

1. Personal error may occur because of inexperience of performer.
2. Error may occur due to irregular and non-uniform rotation of the pulleys.
3. Error may occur if the edges of hanging weights are damaged.

Experiment 13. To Find the Resultant of Two Vectors with the Help of Pulley and Board Apparatus in Vertical Plane

13.1 Objective:

To find resultant of two vectors with the help of Pulley and Board Apparatus in vertical plane

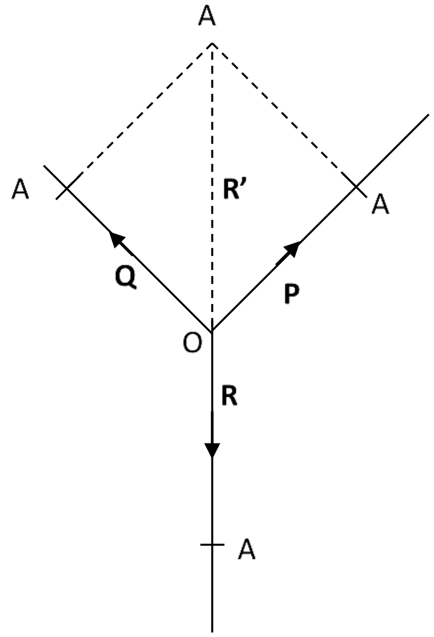
13.2 List of Required Equipment & Accessories:

Pulley and board apparatus, Set of slotted weights and hangers, Plane mirror strips, Plane paper sheet, Drawing pins, pencil and thread.

13.3Procedure:

1. Fix pulley and board apparatus on the wall with the help of clips.
2. Fix a plane paper sheet on the board with the help of drawing pins.
3. Take three pieces of thread and tie one end of each thread together.
4. Pass two of them over frictionless pulleys while the third thread point downwards.
5. Take three hangers and tie the remaining free ends of three threads with them.
6. Add the slotted weights in the hangers in such a way that the knot comes at the center of the paper.
7. The hanger points downward represent the resultant force of the remaining two.
8. Note the position of threads by placing mirror strip under the threads.
9. Remove the hangers and thread from the pulleys and join the points with a ruler. The three lines OA, OB and OC will meet at a point “O” as shown in the figure. OA, OB and OC represents the three forces (vector quantity) P, Q and R.
10. Note the weight on each hanger.
11. According to a suitable scale cut the lines OA, OB and OC according to the weight on each hanger.
12. Now complete the parallelogram OADB by drawing lines AD and BD parallel to OB and OA, equal in magnitude respectively.
13. Connect O to D to get OD. Actually OD is the diagonal and gives the required resultant vector R’.

14. Measure OD and convert the length OD into force with the same selected scale. R' is the resulting of the two forces P and Q.
15. Compare it with R.
16. Note the difference of the two forces (R – R')



13.4 Observations & Calculations:

Scale: 0.1 N = 1 cm.

Value of g = 9.8 m/sec^2 ~ = 10 m/s^2.

Conversion: 20gm/1000 x 10 m/ sec^2= 0.2 Kg m/ sec^2= 0.2N

No. of Obs.	Force i.e. weight in N			Length according to selected scale(cm)			Length of OD (cm)	Resultant force R' = OD x selected scale (N)	Difference (R-R') (N)
	P	Q	R	OA	OB	OC			

13.5 Precautions:

1. The pulleys should be frictionless.
2. The board should be vertical.

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

Lab CLOs

Sr. #	CLO Statement	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

Appendix C

Lab Rubrics for ME-202L Engineering Mechanics 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