GOVT CO-ED POLYTECHNIC

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LAB MANUAL

Branch: Mechanical Engineering

Year & Semester: 1st Year / 2nd Semester

2000290(037) – Applied Mechanics (Lab)

CONTENTS

Experiment No. 1

TITLE: Law of Polygon of Forces

OBJECTIVE:

To verify the law of polygon of forces for a numbers of coplanar forces in equilibrium.

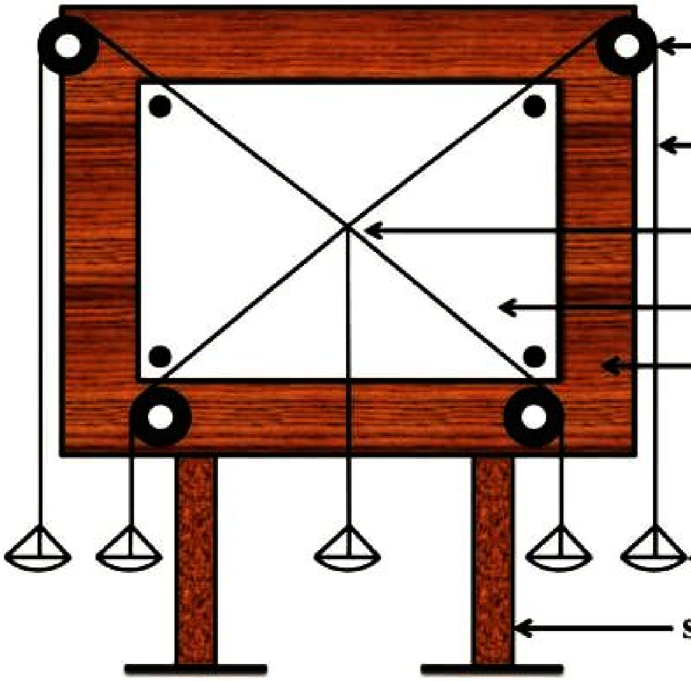

Figure 1.1: Labeled diagram of the apparatus

THEORY:

The Law of Polygon of Forces states that – if any number of coplanar concurrent forces can be represented in magnitude and direction by the sides of a polygon taken in order; then their resultant will be represented by the closing side of the polygon taken in opposite order".

Also, if the forces form a closed polygon, then the system is in equilibrium. Fig. 1.2 and 1.3 shows a system of five forces F_1, F_2, F_3, F_3 and F_5. The forces are forming a closed polygon in the first figure, hence they are in equilibrium. In the second figure, the system is not in equilibrium, and the closing side, shown by dotted line, denotes the Resultant (R) of the force system.

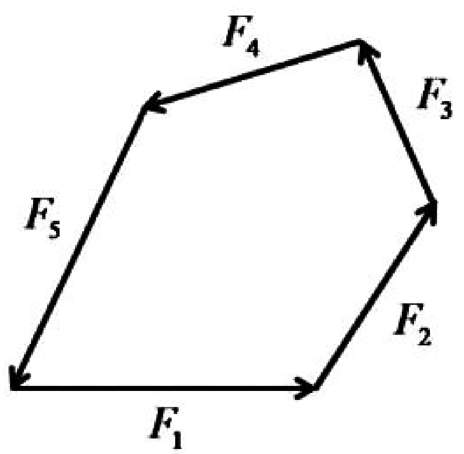

Figure 1.2

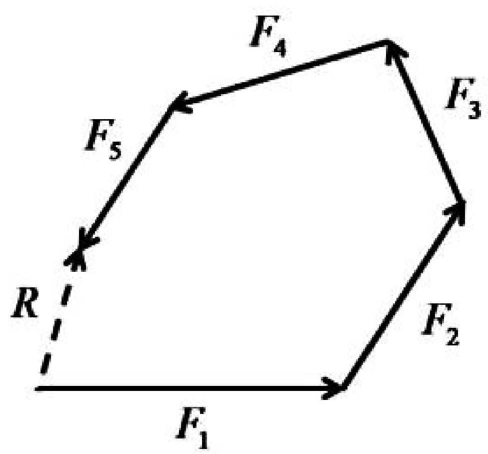

Figure 1.3

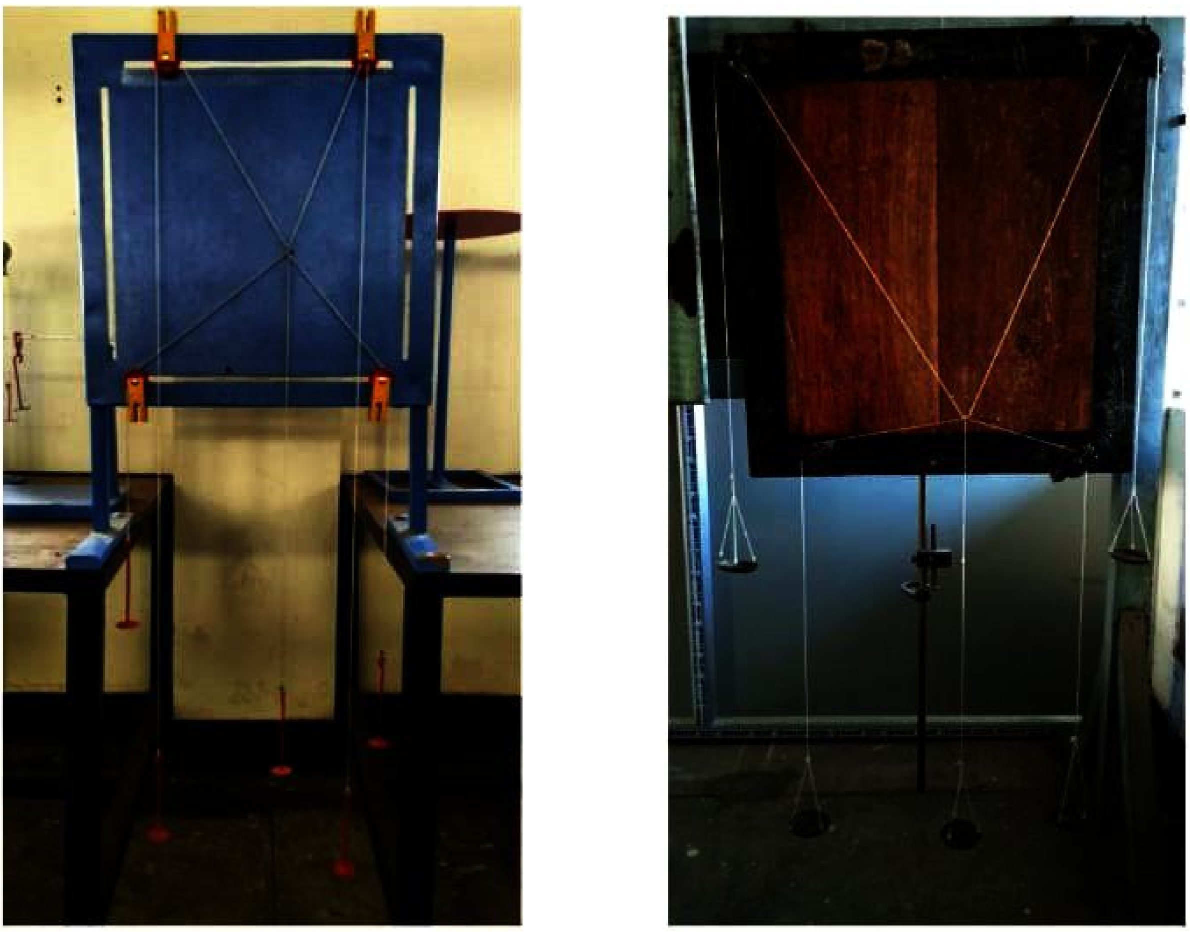

Figure 1.4: Experimental setup in the lab

PROCEDURE:

1. Set up the apparatus provided after measuring and recording the weights of the pans.
2. Put different weights on the pan (W_1, W_2, W_3, W_4 and W_5) and let the system come to rest and then note their values.
3. Now, fix a sheet of paper on the drawing board and mark the central point (point where the strings meet and the directions of the string with pencil.
4. Remove the paper from the drawing board and draw the lines of actions of the forces.
5. Draw the force polygon by representing W_1, W_2, W_3, W_4 and W_5 in magnitude and direction.
6. The polygon may not be closed. The error (unclosed distance of the polygon) is due to error in experimentation and the friction in various moving parts.
7. Repeat the procedure 4 times and complete the experiment.

DATA PROVIDED:

The weight of the Pan = 46.649 gm

TABULATION OF RESULTS:

Observation Number	Weights in different pans (gm)				Resultant (Error) (gm)	
	W_1	W_2	W_3	W_4	Analytical Method	Graphical Method
1						
2						
3						
4						

CALCULATIONS:

For each observation, first do the Analytical Calculation, and then find the result using Graphical Method. For graphical method, draw one Space Diagram and one Vector Diagram. Do mention the Scale for the Vector Diagram. Do attach the Sheet of Paper, on which the experiment is performed, with this journal.

Observation – 1

Observation – 2

Observation – 3

Observation – 4

Exp. No. 1	**Title:** Law of Polygon of Forces
Name of Student:	
Roll No.:	
Date of Experiment:	
Date of Submission:	

Signature of Teacher
with Date of Check

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Experiment No. 2

TITLE: Parallel Forces Apparatus

OBJECTIVE:

(1) To show experimentally the inverse relationship between reactive forces at support and the distance of the point of application of loads from supports.

(2) To find the reactive forces at the supports using:

(a) Experimentally, (b) Analytical method

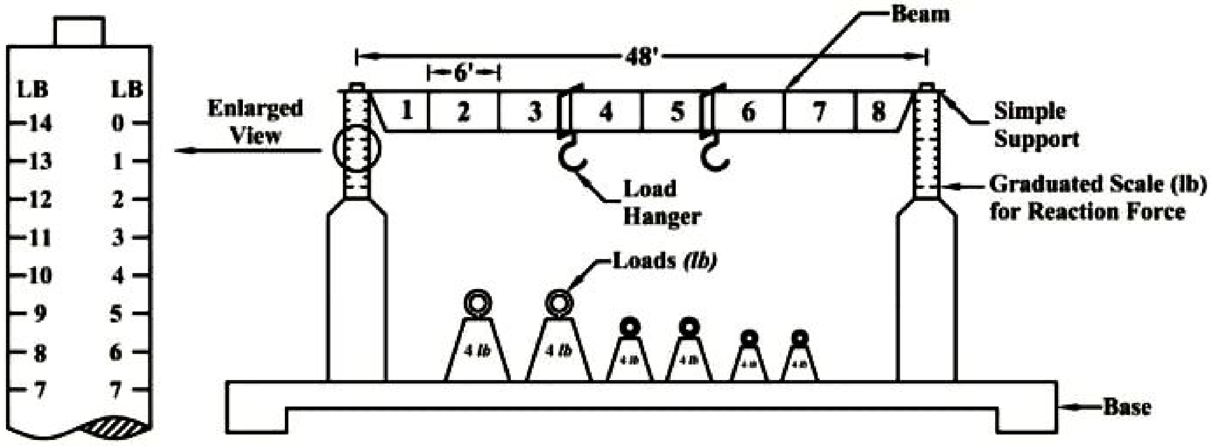

Figure 2.1: Labeled diagram of Parallel Force Apparatus

THEORY:

The system is in equilibrium. So we can apply conditions of equilibrium are given as:

(1) Sum of Moment of all forces about any support (a or b) is equals to zero [see equ. (i)].
(2) Summation of all forces in horizontal and vertical direction equals to zero [see eq. (ii) & eq. (iii)]

Equations for the conditions of equilibrium are given as:

$$\sum M_a \quad or \quad \sum M_b = 0 \quad \ldots\ldots\ldots\ldots \quad (i)$$

$$\sum F_x = 0 \quad \ldots\ldots\ldots \quad (ii)$$

$$\sum F_y = 0 \quad \ldots\ldots\ldots \quad (iii)$$

DESCRIPTION OF THE APPAPATUS:

(1) Parallel forces apparatus, (2) Different Loads (Weights) and (3) Two hangers.

Figure 2.2: Experimental setup in the lab

PROCEDURE:

(1) Set up the apparatus and note the initial readings.

(2) Put the hangers at different positions with weights (W_1 and W_2) and note down the readings.

(3) The difference gives the reading of the spring balance R_1 and R_2.

(4) Change the positions of the hangers and repeat the same experiment.

(5) Record the observed data in Table, the format of which is provided below.

(6) Repeat the above procedure 4 times and tabulate the result.

OBSERVATION TABLE:

Sl. No.	W_1 (lb)	W_2 (lb)	Distance of the Loads from $(inch)$		Analytical (lb)		Graphical (lb)		Observed Readings (lb)				Calculated Readings (lb)	
			Right Hand Support	Left Hand Support	Reaction at Right Hand Support	Reaction at Left Hand Support	Reaction at Right Hand Support	Reaction at Left Hand Support	Initial Reading Right Hand Support (i)	Initial Reading Left Hand Support (ii)	Final Reading Right Hand Support (iii)	Final Readin g Left Hand Support (iv)	Reaction at Right Hand Support $(iii) - (i)$	Reaction at Left Hand Support $(iv) - (ii)$
1														
2														
3														
4														
5														

Calculation:

For each observation, first find the reaction forces at the supports by using Analytical Method and then do the Graphical Method. Do mention Scales for each Space and Vector diagram while using graphical method. Tabulate the results in the above table.

Observation – 1

<u>**Observation – 2**</u>

Observation – 3

Observation – 4

Observation – 5

Exp. No. 2	**Title:** Parallel Force Apparatus
Name of Student:	
Roll No.:	
Date of Experiment:	
Date of Submission:	

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Experiment No. 3

TITLE: Rolling Friction Apparatus

OBJECTIVE:

Experimental Computation of Co-Efficient of Friction between an Inclined Plane (Glass) and Trolley (Iron).

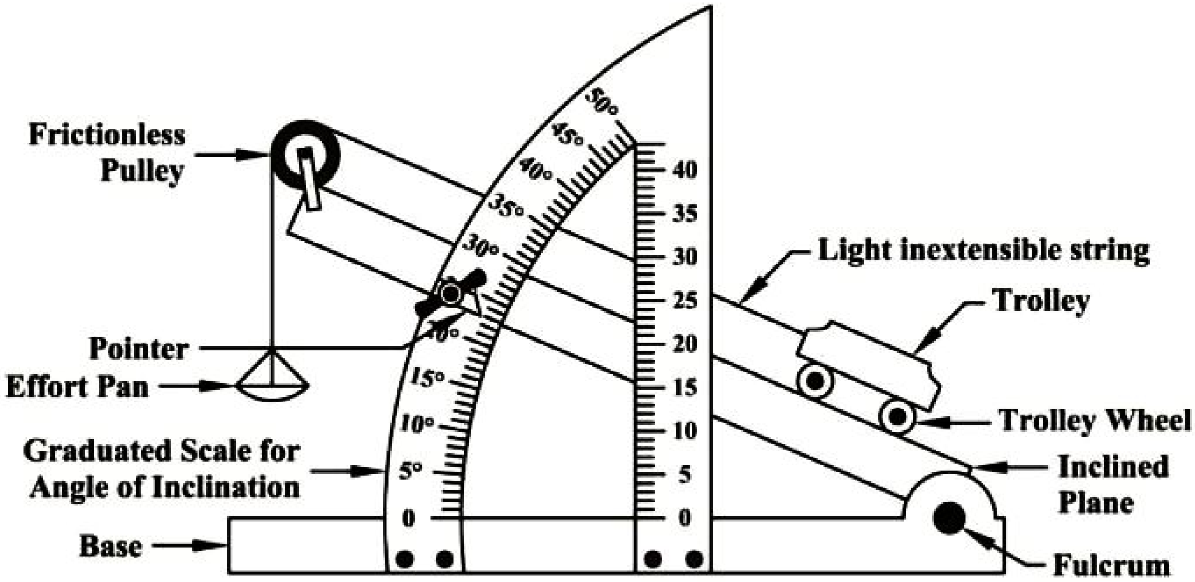


Figure 3.1: Labeled diagram of the apparatus

THEORY:

If,

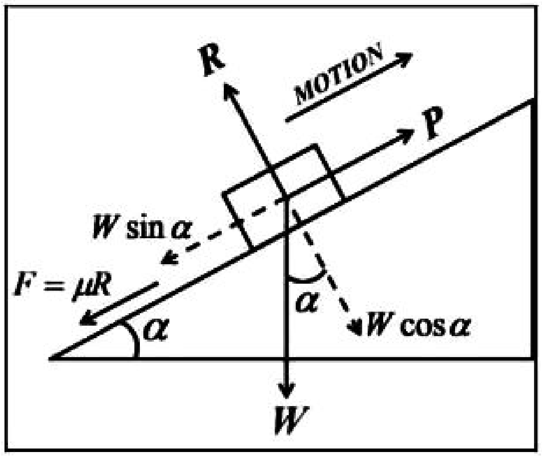
α = Angle of inclination of the plane with the horizontal at which the trolley moves with a minimum uniform speed up the plane.

W = Load on the slider

P = Force which pulls the trolley up with uniform movement

R = Normal Reaction

F = Frictional forces acting against the movement



From the Free Body Diagram, for equilibrium

Resolving along the plane $\quad P = \mu R + W \sin\alpha$ .... (1)

Perpendicular to the plane $\quad R - W\cos\alpha = 0$ .... (2)

From (1) and (2), $\quad \mu = (P/W\cos\alpha) - \tan\alpha$

DESCRIPTION OF APPARATUS:

(1) Inclined plane, (2) Trolley, and (3) Spirit level and Weights.

Figure 3.2: Experimental setup in the lab

PROCEDURE:

(1) Level the plane with a sprit level and set the pointer at zero.

(2) Put suitable load on the pan and adjust the angle of plane so that the trolley moves with uniform speed up the plane.

(3) Note the value of W, P and α.

(4) Repeat the experiment for different value of W, P and α.

(5) Calculate value of μ for each reading.

(6) Find the average of μ.

DATA PROVIDED

The weight of pan = 61.5 gm   Weight of trolley = 505 gm   1 lb = 453.6 gm

Note

1. It is required to put the cord parallel to the plane.
2. Keep α as small as possible.
3. Avoid slipping of the trolley by proper adjustment of weights.

OBSERVATION TABLE:

Observation number	W (gm)	P (gm)	α (degree)	μ	Average μ
1.(a)					
1.(b)					
2.(a)					
2.(b)					
3.(a)					
3.(b)					

Note: (a) Reading of W without weight on the slider.

(b) Reading of W with weights on the slider.

CALCULATIONS:

Observation – 1:

Observation – 2:

Observation – 3:

Observation – 4:

Observation – 5:

Observation – 6:

Exp. No. 3	**Title:** Rolling Friction Apparatus
Name of Student:	
Roll No.:	
Date of Experiment:	
Date of Submission:	

Signature of Teacher
with Date of Check

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Experiment No. 4

TITLE: Square Threaded Screw Jack.

OBJECTIVE:

1. To determine the Velocity Ratio, Mechanical Advantage and Efficiency of a Square Threaded Screw Jack

2. To construct the Curves showing relations of P – W, MA – W, η - W

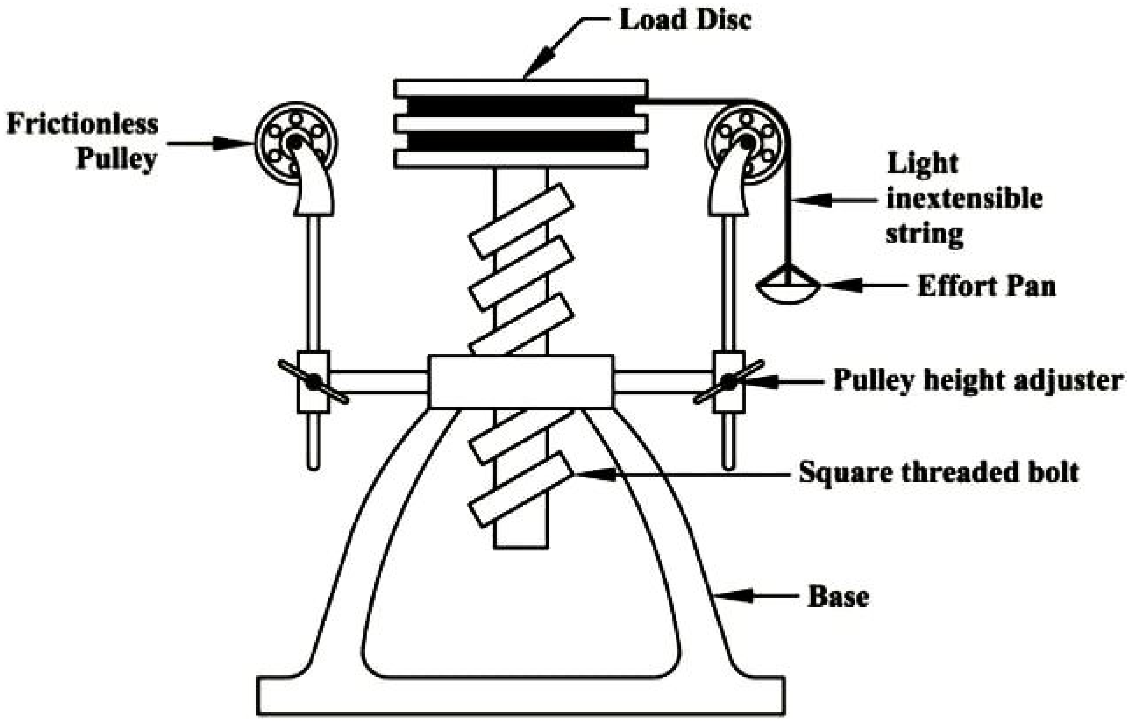

Figure 4.1: Labeled diagram of the apparatus (Screw Jack)

THEORY:

If x = Displacement of Effort (P)

y = Displacement of the Load (W)

Then,

1.Velocity Ratio (VR) $= x/y = \pi(D + d)/p$

Where, D = diameter of the Disc

p =pitch of the screw , d =diameter of the chord

2. **Mechanical Advantage (MA)**= W/P

3. **Efficiency (η)** $= MA/VR$

Figure 4.2: Experimental setup in the lab

APPARATUS:

1. Screw Jack
2. Scale with Pan Attachment
3. Weights

PROCEDURE:

1. One end of the disc is fixed by means of a pin and to the other end a scale pan is fitted.
2. A load is placed on the disc.
3. Suitable loads are gradually put in the scale pan until the scale pan moves steadily in the downward direction. The experiment is repeated for 6 times changing the loads (W) which is placed on the disc.
4. Readings are to be taken for ascending and descending values of the lifting loads.
5. Plot the value in graph papers to construct the following Curves

   (a) P Vs. W
   (b) MA Vs. W
   (c) η Vs. W

Data Provided:

The weight of the Pan = 50.61 g	Pitch of the Screw = 0.5 cm
Diameter of the Chord = 0.5 cm	Diameter of the Disc = 20.63 cm
Weight of the Disc = 4500 g	

OBSERVATION TABLE:

	Observation Number	Velocity Ratio (VR)	Load Lifted (W)	Total Effort Required (P)	MA	Average of MA	Efficiency	Average of η
Ascending	1							
	2							
	3							
Descending	4							
	5							
	6							

P vs. W Graph

M.A. vs. W Graph

η vs. W Graph

Exp. No. 4	**Title:** Square Threaded Screw Jack
Name of Student:	
Roll No.:	
Date of Experiment:	
Date of Submission:	

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Experiment No. 5

TITLE: Bell Crank Lever

OBJECTIVE:

To verify the Law of Moments by using a Bell Crank Lever.

THEORY:

Principle of Moments states, 'the algebraic sum of the moments of a system of coplanar forces about any point in the plane is equal to the moment of the resultant force of the system about the same point. Or the sum of all moments about any point equals to zero when the system is in equilibrium. This principle would be verified for a bell crank lever arrangement.

A lever whose two arms form a right angle, or nearly a right angle and having its fulcrum at the apex of the angle is referred to as a bell crank lever. These levers were originally used to operate the bell from a long distance and hence the name. Now bell crank levers are used in machines to convert the direction of reciprocation movement.

DESCRIPTION OF THE APPAPATUS:

(1) Bell crank lever, (2) Hanger, (3) Weight grams

Figure 5.1: Experimental setup in the lab

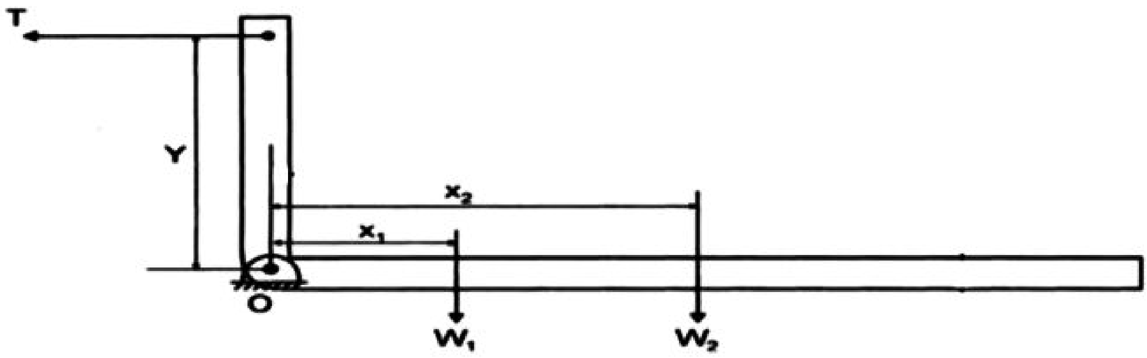

Figure 5.2

SPECIFICATIONS:

Height of vertical arm from hinge	Y = 30 cm
Distance of first groove on horizontal arm from hinge	= 9.5 cm
Distance between each grooves on horizontal arm	= 5 cm
Weight of each hanger	= 69.558 gm

X_1 & X_2 are the distance of load W_1 and W_2 respectively from hinged point on horizontal arm.

PROCEDURE:

1. Arrange two hangers at arbitrary locations on the horizontal arm and note the locations x_1, and x_2, of these hangers from the hinge.
2. Adjust the tension in the spring connected to the vertical arm such that the arm which has loads comes in horizontal position.
3. Note the tensile force in the spring as the initial tension T_i .
4. Hang the weights W_1 and W_2 from the hangers. This will cause the arms to tilt and the pointers to move away from each other. Now again adjust the tension in the spring such that that the arm which has loads comes in horizontal position.
5. Note the tensile force in the spring as the final tension T_f .
6. The tensile force T due to the application of loads on horizontal arm is equals to $T_f - T_i$.

7. Therefore, to verify the principle of moments we need to take moments $(\sum M)$ of all the external forces (which include the weights of the hangers hanging from the horizontal arm) and the tension in the spring connected to the vertical arm about the hinge.

8. If the total sum is zero, verifies the law of moments since the moment of the resultant is also zero about the hinge.

9. Repeat the above steps by changing the weights and their location on the horizontal arm for two more set of observations.

SPECIMEN CALCULATIONS:

$$\sum \boldsymbol{M_0} = (\boldsymbol{W_1} \times \boldsymbol{X_1}) + (\boldsymbol{W_2} \times \boldsymbol{X_2}) - (\boldsymbol{T} \times \boldsymbol{Y})$$

OBSERVATION TABLE:

Sl. No.	T_i (N)	W_1 (N)	W_2 (N)	X_1 (m)	X_2 (m)	Y (m)	T_f (N)	$T= (T_f - T_i)$ (N)	ΣM_o (Nm)
1									
2									
3									

Exp. No. 5	**Title:** Bell Crank Lever
Name of Student:	
Roll No.:	
Date of Experiment:	
Date of Submission:	

Signature of Teacher with Date of Check **SEAL**

Experiment No. 6

TITLE: Equilibrium Forces Apparatus

OBJECTIVE:

To verify theequilibrium of forces with the help of force polygon appartus.

THEORY:

The law states:

"When more than two coplanar forces acting at a point are represented in magnitude and direction by the sides of a polygon taken in order, the closing side from the first to the last point of the polygon represents the resultant of the force system in magnitude and direction".

If any number of forces acting on a particle be presented in magnitude and direction by the side of closed polygon, taken in order they shall be in equilibrium. Converse of polygon law of forces states that If any number of forces acting on a particle are in equilibrium, a closed polygon can be drawn whose sides can be presents these forces both in magnitude and direction. The converse of polygon law of forces is true in the sense that if any number of coplaner forces acting at a point are in equilibrium if sides are drawn parallel and if proportional to the forces then the sides will form only one closed polygon. But if the sides are drawn only parallel and not to proportional to the forces then they can not be represented by the sides of such polygon as any number of such polygon can be drawn. Therfore the converse of polygon law of forces is not true in the same way as the converse of triangle of law of forces.

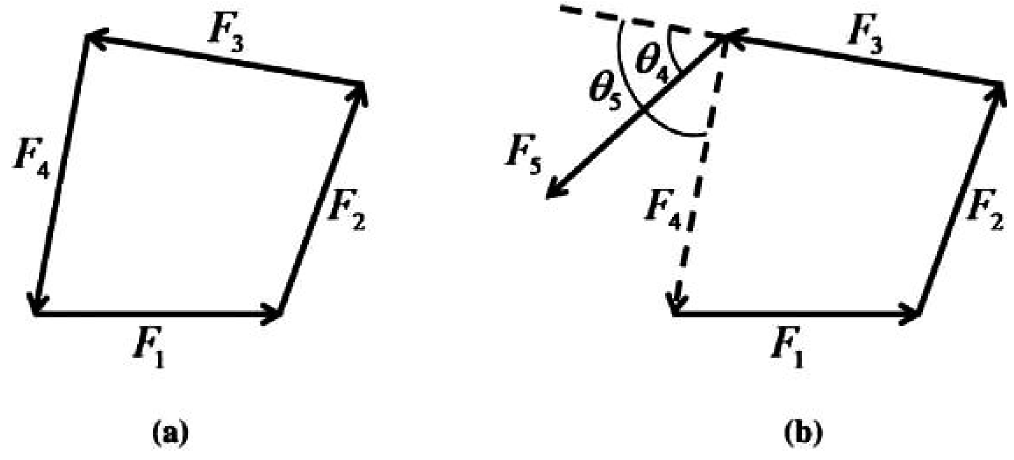

Figure 6.1: **(a)** Under equilibrium condition, **(b)** Under un-balanced condition

DESCRIPTION OF THE APPARATUS:

1. Force table
2. Strings
3. Weights

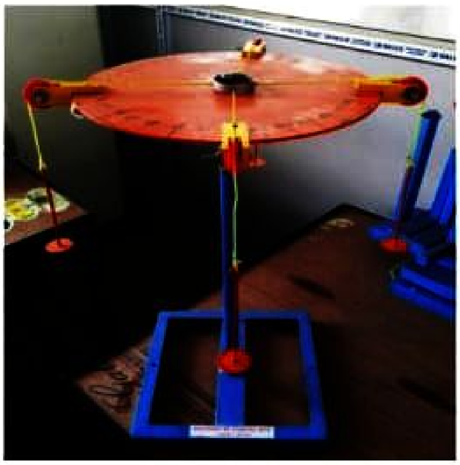

Figure 6.2: Experimental setup in the lab

SPECIFICATIONS:

Weight of each hanger stick = 35.28 gm

PROCEDURE:

1. Make the graduated disc horizontal by adjusting the screw at its base. This can be tested with the help of spirit level.
2. Put a white sheet on the force table.
3. One end of string of fastened to small ring on the table while other end is fastened with hanger, which is to carry weights hanging freely through a pulley. Connect other four strings in the same manner.
4. Place small weights in to the different hangers. In the last hanger, place weights in such a quantity that the small ring comes at the center of the table. Check that the ring is place symmetrically round the axis and does not touch the axis or the plane surface of the graduated disc to avoid any reaction on the ring.
5. Note the position of the one string on the disc and note also the relative positions of the other rings.
6. Mark the directions of the strings by drawing straight line on the paper. Note the weight applied on each string in each direction.
7. Draw the scale diagram of forces acting at point cutting the line of action of each force proportional to the magnitude of forces.
8. Draw the stress diagram and verify the polygon.
9. Repeat the experiment three times by changing weight in hangers and angles between them.

PRECAUTIONS:

1. Pulley should be friction less.
2. There should not be any knot in the string.
3. Direction of the string should be marked carefully.
4. The ring should not touch the axis of the disc.
5. The graduated disc should be made horizontal by adjusting the screws at a base.

OBSERVATION TABLE:

Sl. No.	Weight				Angle				Last force **E** observed **Yes/No**	Magnitude of **E** from polygon Theorem	% Error $\frac{\lvert(E-D)\rvert}{E} \times 100$	% Error Between angles $\frac{\lvert\theta_5-\theta_4\rvert}{\theta_5} \times 100$
	A	B	C	D	θ_1	θ_2	θ_3	θ_4				
1												
2												
3												

Observation – 1

Observation – 2

Observation – 3

Exp. No. 6	**Title:** Equilibrium Forces Apparatus
Name of Student:	
Roll No.:	
Date of Experiment:	
Date of Submission:	

Signature of Teacher
with Date of Check

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Experiment No. 7

TITLE: Sliding Friction Apparatus.

OBJECTIVE:

To determine the co-efficient of friction between the slider and the inclined plane (sliding friction).

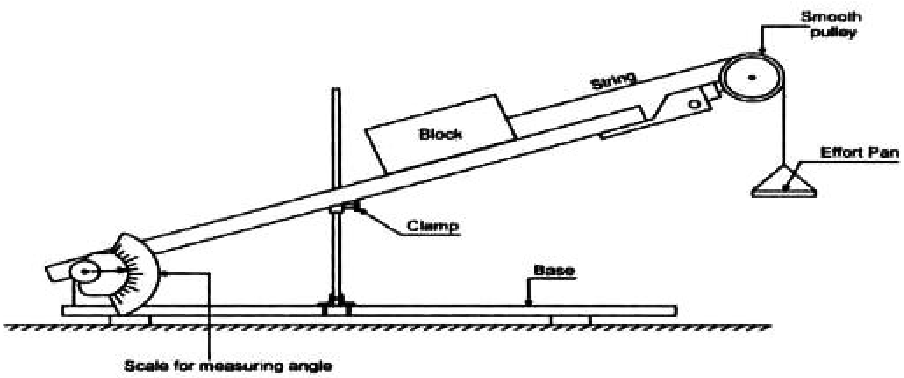

Figure 7.1: Labeled diagram of the apparatus

THEORY:

If,

α = angle of inclination of the plane with the horizontal at which the slider moves with a minimum uniform speed up the plane.

W = Load on the Slider

P = Force which pulls the slider up with uniform movement

R = Normal Reaction

F = Frictional forces acting against the movement

From free body diagram, for equilibrium

Resolving along the plane $P = \mu R + W \sin\alpha$ ....(1)

Perpendicular to the plane $R - W \cos\alpha = 0$ ....(2)

From (1) and (2), $\mu = (P/W \cos\alpha) - \tan\alpha$

APPARATUS:

(1) Inclined plane, (2) Slider, (3) Spirit level and (4) Weights

Figure 7.2: Experimental setup in the lab

PROCEDURE:

(1) Level the plane with a sprit level and set the pointer at zero.

(2) Slowly add weights in the effort pan. A stage would come when the effort pan just slides down pulling the box up the plane. Using fractional weights up to a least count of 5 gm, find the least possible weight in the pan that causes the slider to just slide up the plane. Note the weight in the effort pan. This is force 'P'.

(3) Repeat the above steps 1 to 3 by changing the weights in the box for two more sets of observations.

(4) Note the value of W, P and α.

(5) Repeat the experiment for different value of W, P and α.

(6) Calculate value of μ for each reading.

(7) Find the average of μ.

DATA PROVIDED:

The weight of pan = 61.5 gm

Weight of block = 351.48 gm 1 lb = 453.6 gm

NOTE:

1. It is required to put the cord parallel to the plane.
2. Keep α as small as possible.
3. Avoid slipping of the slider by proper adjustment of weights.

OBSERVATION TABLE:

Observation number	W (Unit)	P (Unit)	α	μ	Average μ
1.(a)					
1.(b)					
2.(a)					
2.(b)					
3.(a)					
3.(b)					

NOTE:

(1) Reading of W without weight on the slider.

(2) Reading of W with weights on the slider.

Exp. No. 7	**Title:** Sliding Friction Apparatus
Name of Student:	
Roll No.:	
Date of Experiment:	
Date of Submission:	

Signature of Teacher
with Date of Check

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