ENGINEERING MECHANICS LAB
(ES 101)

LIST OF EXPERIMENTS

EXPERIMENT NO. 1
TO VERIFY THE LAW OF FORCE POLYGON

1. Objective	**2. Apparatus**	**3. Theory**	**4. Procedure**
5. Observations	**6. Results and discussion**	**7. Precautions**	**8. Viva Questions**

1. OBJECTIVE:

To verify the law of force polygon with the help of Universal Force Table

2. APPARATUS:

The apparatus consists of a horizontal circular aluminum force table, which is called universal force table (refer figure). It has a disc graduated in 360°. At the centre of table a small pin is fixed. The table has the provision to fix at a desired angle. It is provided with leveling screws, clamping pulleys. It has a circular central ring placed at the centre of the table. This has the provision to apply weight at four places. There are four chords attached to the ring. One end of chord is attached to the circular ring while the other end is attached to the hook which passes over a friction less pulley. The pulley is attached to the table near the edge using a sliding clamping device at different angular positions. The weight is placed on the weight holder hanged to hook.

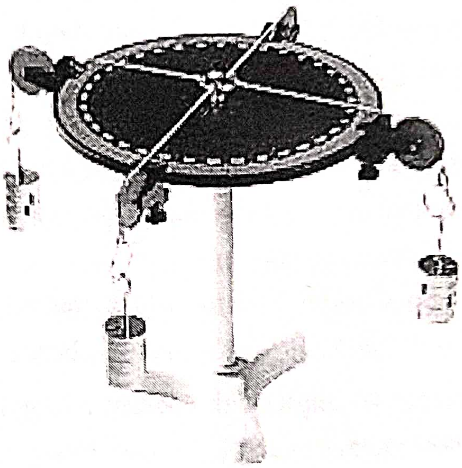

Figure 1: Universal force table

3. THEORY:

Law of Force polygon: If more than two forces are acting on a body and if they can be represented by consecutive sides of a polygon taken in order then their resultant will be represented by closing side of polygon taken in opposite order. As shown in figure 2, total five forces are acting at a point. If the system is in equilibrium then the resultant force of the system will be zero. If force polygon is drawn then the magnitude of resultant force will be zero. This means tail of first force and head of last force will meet at the same point. Force polygon has been drawn in figure for the force system as shown in figure 2.

Force polygon can be drawn for coplanar concurrent force system, if more than two forces are acting on a body. It can be started from any one force acting on a body. Draw a line of for F1 (equivalent length in cm) at a point A. This line should be parallel to force F1 and the magnitude will be equivalent length of Force. All the forces acting on body are represented in the force diagram in terms of equivalent length. Draw second force parallel to F2 in such a way so that the tail end of next force is joined at the head of previous force (F1). Similarly draw all forces in the same way. In doing so, the head of last force will touch the tail of first force. Figure 2 shows a concurrent coplanar force system in which five forces are acting and the system is in equilibrium. Using these forces a force polygon has been drawn as shown in fig. 3. As all the forces are to be plotted graphically; choose a suitable scale to represent a force. For example: 500N = 1 cm, i.e. 1 cm length will be used to represent a force of 500N. Follow the following steps to draw a force polygon:

(i) Choose any one force as reference force. Let F1 is taken as reference force. It makes zero degree with X-axis. Hence, draw a horizontal line at 'A'. The magnitude of line will be as per scale assumed.

(ii) After drawing first force take another force (F2, F3 etc). Here, second force is taken as F2. As F2 makes θ_1 with force F1, hence draw a line at head end of previous force (F1) which makes θ1 angle with F1. Cut a length on this line equivalent to force of magnitude F2 as per assumed scale.

(iii) Similarly, draw the force F3; F4 and F5 as per step (ii). In doing so, a polygon is formed as shown in fig 3. The head end of last force will meet the tail end of first force.

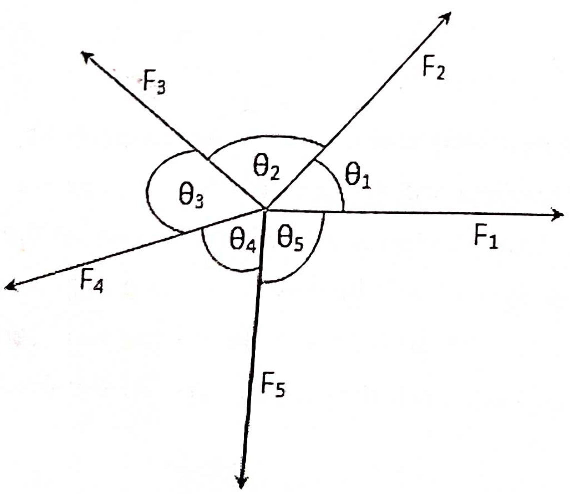

Figure 2: Force diagram

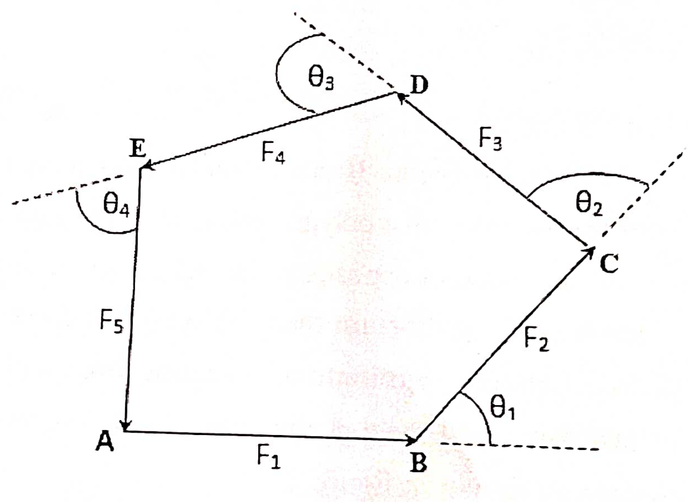

Figure 3: Force polygon

4. PROCEDURE:

On horizontal circular aluminum force table weights are acting as five points. The weight is hanging with the help of frictionless pulley. A continuous chord will have same tension. The FBD of any one pulley is made it will be similar to figure as shown 4. The magnitude of tension in a chord will equal to the weight applied on weight carrier.

Using these five forces a force polygon is drawn. In drawing force polygon only four forces are used and the closing side of polygon will be the fifth unknown forces. The magnitude and direction of fifth forces can be getting from graphically. This can be measured experimentally also.

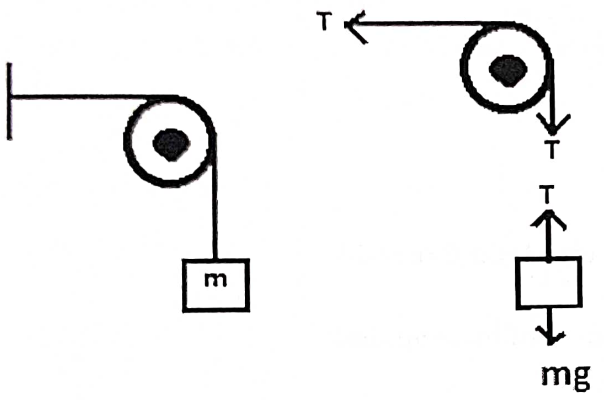

Figure 4: FBD of any one pulley

Step 1: Make the graduated disc horizontal by adjusting the screws at its base. This can be tested with the help of spirit level.

Step 2: As there are five weight hangers attached to the central ring. Hence, fix the sliding clamping device at four different places on the table. Make them perfectly tight. Check the proper free movement of chord passing over pulley. Try to remove any constrains in the free movement of chord over pulley in all four chords.

Step 3: Fix the reference on the graduated disc. This can be set by fixing any one weight hanger at 0° position on the graduated disc. The weight hanging at this position will be taken first force (say F1).

Step 4: Place small weights to the different hangers slowly. Apply weight in all four hanger is such a ways so that the central ring comes at the centre of the table. If there is difficulty matching the in ring centre with the central pin, then sliding clamping device along circumference to re-fix at new angular position on the table.

Step 5: Note down applied mass and with its angular position of all locations in table and in pictorial diagram shown in fig 5.

Step 6: Draw the force polygon as explained in section 3. In the force polygon, draw only four forces and draw the closing side. Note down the magnitude and angular information of Fifth force. This will give the value of unknown force graphically, if the system is in equilibrium. Compare this force from experimentally observed fifth force.

Step 7: Repeat the experiment three times by changing weights and angular positions of hangers.

5. OBSERVATIONS:

Record the data in the FBD as shown below in figure 5.

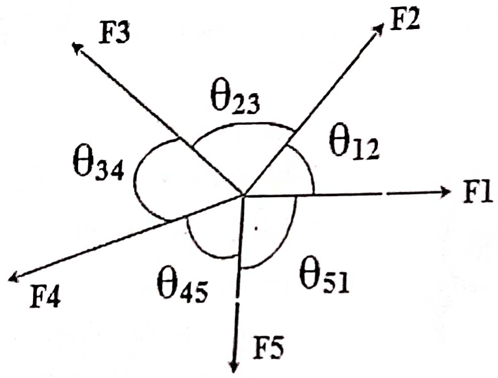

Figure 5: Angular position of five chords on force table

Table No 1: Record of mass applied

SN.	Chord Numbers				
	1	2	3	4	5
Mass applied (kg)					
Tension developed in chord (mg)					

Draw a force diagram using experimental data.

6. RESULTS AND DISCUSSIONS:

Draw force polygon. Determine the value of fifth Force from force polygon by measuring the length of fifth side. Compare the value of F5 obtained graphically.

Experimental value of F5 =

Graphical measured value of F5

Percentage error =

There are chances of error due to measurement of length of line in force polygon, angle, accuracy die to angle. Some error will also be included due to scaling also.

7. PRECAUTIONS:

(i) The board should be horizontal to make coplanar force system.

(ii) Pulleys should be frictionless.

(iii)Directions of the string should be marked carefully.

(iv) Weight should be applied slowly.

(v) The graduate disc should be made horizontal by adjusting the screw its base.

8. VIVA QUESTIONS:

(i) What is parallelogram law of forces?

(ii) Explain triangle law of force?

(iii)What is the condition for equilibrium of a body under various concurrent forces?

(iv) What do you mean by concurrent forces?

EXPERIMENT NO. 2

TO VERIFY THE LAW OF MOMENTS USING PARALLEL FORCE APPARATUS

1. Objective	**2. Apparatus**	**3. Theory**	**4. Procedure**
5. Observations	**6. Results and discussion**	**7. Precautions**	**8. Viva Questions**

1. OBJECTIVE:

To verify the reactions of simply supported beam at the supports

2. APPARATUS:

The apparatus consists of two dial type compression balance and a wooden bar fixed on a wooden board. The measurement unit of dial type compression balance is in kg.

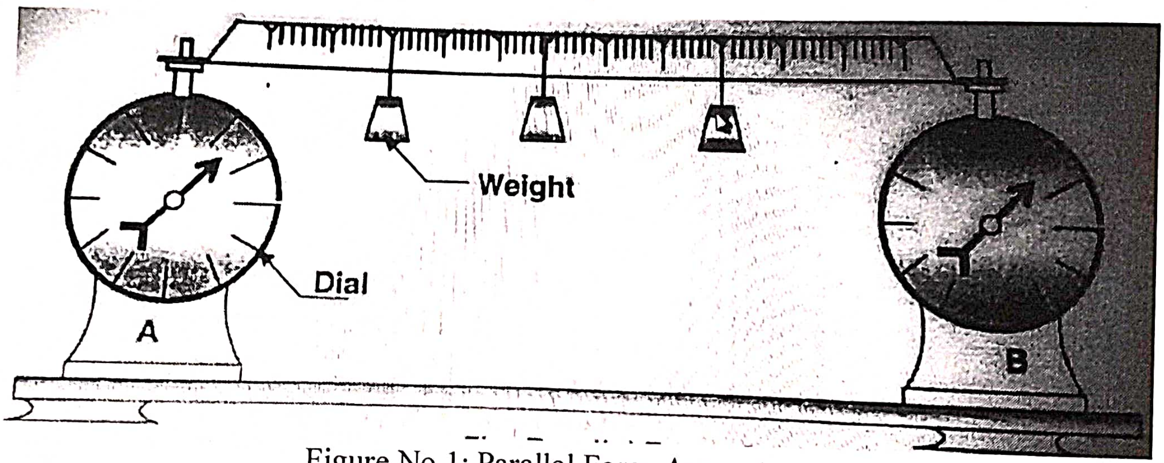

Figure No 1: Parallel Force Apparatus

3. THEORY:

If a system of coplanar forces acting on a rigid body keeps it in equilibrium then the algebraic sum of forces in any direction and their moments about any point in their plane is zero. Reactions in a simply supported beam are determined by using the principle of Static Equilibrium i.e.

$$\sum F_x = 0$$

$$\sum F_y = 0 \quad \text{and}$$

$$\sum M = 0$$

In the figure, AB is a simply supported beam supported at A and B. When two loads W_1 and W_2 are applied at points C and D situated at distance X_1 and X_2 respectively from end

A, then from Newton's third law, reactions R_A and R_B are developed at A and B supports.

Applying condition of static equilibrium, we have:

Applying condition of static equilibrium,

$$\sum F_y = 0$$

$$R_A + R_B = W_1 + W_2 \qquad (1)$$

$\sum M = 0$, Taking moments about A, we have

$$-R_B.L + W_2.X_2 + W_1X_1 = 0$$

$$R_B.L = W_1X_1 + W_2X_2$$

$$R_B = \frac{W_1X_1 + W_2X_2}{L} \qquad (2)$$

From Equation (1), $R_A = W_1 + W_2 - R_B$ (3)

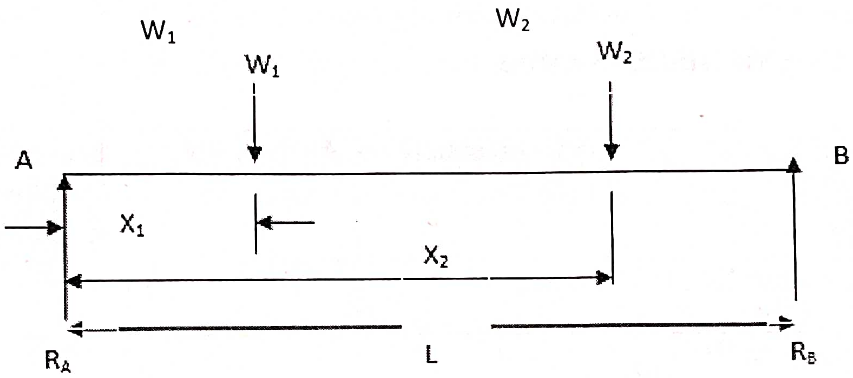

Figure No.2: Load Diagram

4. PROCEDURE:

(i) Check for zero error in dial gauge. If any, note down the zero error for all the compression balances.

(ii) Suspend two weights W_1 and W_2 at arbitrary distances X_1 and X_2 respectively from 'A' (left side).

(iii) Note the reaction on the beam given by the readings of compression balances (R_A and R_B) and takes in to account the zero error from each reading. Readings thus obtained are R_A' and R_B'.

(iv) Calculate R_A and R_B from the equation (2) and (3) by substituting the value of W_1 and W_2 in kg so that the value of R_A and R_B will be in kg.

(v) Repeat the experiment by taking different positions of W_1 and W_2.

(vi) Find out percentage error between calculated and observed readings.

5. OBSERVATION

Distance between the supports, L =1m

Zero error in compression balance left side (E_A) =

Zero error in compression balance right side (E_B) =

Observation Table

S. No.	Weights applied on beam (kg)		Distance of weights from left support (cm)		Final readings at A and B (kg)		Reactions observed (kg)	
	W_1	W_2	X_1	X_2	R_A	R_B	$R_A = R_A - E_A$	$R_B = R_B - E_B$

Obtain the value of R_A and R_B using equation of static equilibrium.

6. RESULTS AND DISCUSSIONS:

	Experimentally observed	Analytically obtained	% error (with respect to analytical value)
Reactive force 'A', R_A			
Reactive force 'B', R_B			

7. PRECAUTIONS:

(i) Zero error of the compression balances must be taken in to account.

(ii) Weights should not be put on the beam with a jerk.

(iii) The distance X_1 & X_2 should be measured accurately. Readings of spring balances at A and B should be taken accurately.

(iv) Slightly press the beam to remove any frictional resistance at the supports before taking the readings.

8. VIVA QUESTIONS:

(i) What are the reasons for the deviation in theoretical value and experimental value?

(ii) Why in general beam is supported by one hinge and one roller supports?

(iii) Define various types of supports and which type of support is used in this experiment?

(iv) Sketch various beam sections.

EXPERIMENT NO 3

To DETERMINE THE CO-EFFICIENT OF FRICTION BETWEEN WOOD AND VARIOUS SURFACE ON AN INCLINED PLANE

1. Objective	**2. Apparatus**	**3. Theory**	**4. Procedure**
5. Observations	**6. Results and Discussion**	**7. Precautions**	**8. Viva Questions**

1. OBJECTIVE:

To determine coefficient of friction between given pair of surfaces

2. APPARATUS:

The apparatus consists of wooden plane having adjustment for setting the required angle precisely with graduated are and vertical scale is provided. A frictionless pulley is attached to the end by means of a clamp adjustable to any necessary position. It is supplied with a wheeled trolley and a set of eight slide draws having bottom of different materials, string and pan.

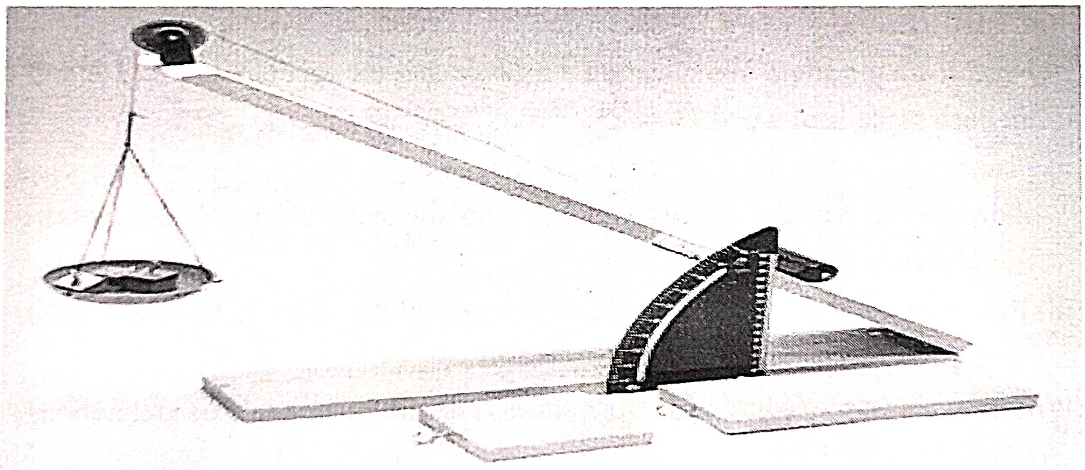

Fig1. Inclined Plane Apparatus

3. THEORY:

It has been established since long that the surface of the bodies are never perfectly smooth. Whenever one of the blocks moves or tends to move tangentially with respect to the surface, on which it rests, the interlocking property of the projecting particles opposes the motion. This opposing force, which acts in the opposite direction of the movement of the block, is called force of friction or simply friction. Consider a body of weight W on a plane having an angle of inclination α i.e. resting on an inclined plane. Suppose it just tends to move up the inclined plane when a force of P is applied. Since the body tends to move upwards, the frictional force F will be acting downwards. The force on the body can be resolved into two components perpendicular and parallel to the plane. Resolving the forces parallel to the plane, we get

$$P = \mu R + W \sin\alpha$$

The component $W\cos\alpha$ perpendicular to the plane balances the normal reaction R and the component $W \sin\alpha$ parallel to the plane provides the necessary force for the body to move down the plane. Substitution the value of R in equation (1),

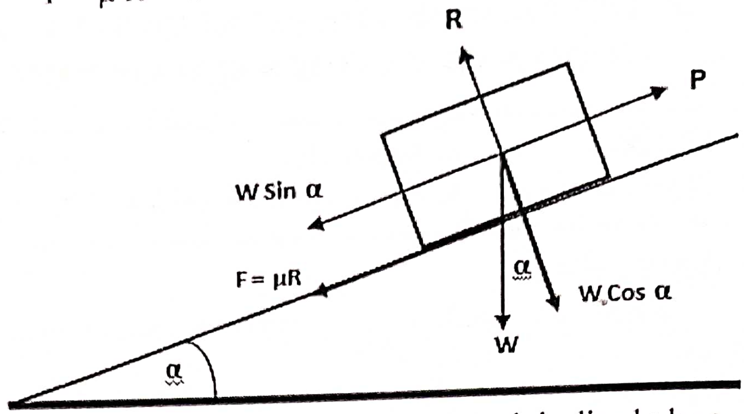

Figure No 2: Body moving up on a rough inclined plane

We get,

$$P = \mu R + W \sin\alpha$$

$$\mu W \cos\alpha = P - W \sin\alpha$$

$$\mu = \frac{P - W \cancel{\cos}\,\sin\alpha}{W\cos\alpha}$$

4. PROCEDURE:

(i) Note down the angle of inclination α after setting the inclined plane. The top surface of inclined plane is of wood.

(ii) Place the wooden block (slider) of known weight W, on the inclined plane. Tie the slider to the pan (of known weight) with the help of the thread passing over the frictionless pulley.

(iii) Put some weights in the pan without any jerk till the slider just begins to slide upwards. Note down this weight in the pan.

(iv) Repeat above procedure with other slides and with other angle of inclinations.

5. OBSERVATIONS :

Contact Surfaces: wood to wood contact

Observation Table No: 1

S. No.	Weight of Slider, W	Weight of Pan + Weights in pan, (P)	Inclination of Plane,(α)	Co- efficient of friction, $\mu = \frac{P - W \cancel{\cos}\,\sin\alpha}{W\cos\alpha}$

6. RESULTS AND DISCUSSIONS:

Mean value of coefficient of friction (μ) for given pair of surfaces =

7. PRECAUTIONS:

(i) Pulley should be frictionless.

(ii) There should not be any knot in the string.

(iii) Weight should be placed in effort pan slowly.

(iv) String should be parallel to the plane.

(v) The surface of the inclined plane should be smooth and clean.

(vi) Proper lubrication of the pulley should be done to decrease friction.

8. VIVA QUESTIONS:

(i) What is limiting friction?

(ii) Define angle of repose, angle of friction and laws of friction.

(iii) Define cone of friction.

(iv) Differentiate between static and dynamic friction.

(v) Explain the theory of dry friction.

(vi) Does force of friction depends on area of contact surface?

EXPERIMENT NO. 4

TO FIND THE FORCES IN THE MEMBERS OF JIB CRANE

1. Objective	2. Apparatus	3. Theory	4. Procedure
5. Observations	6. Results and Discussion	7. Precautions	8. Viva Questions

1. OBJECTIVE:

To find the percentage error between calculated and observed values of forces in the member of a jib crane

2. APPARATUS:

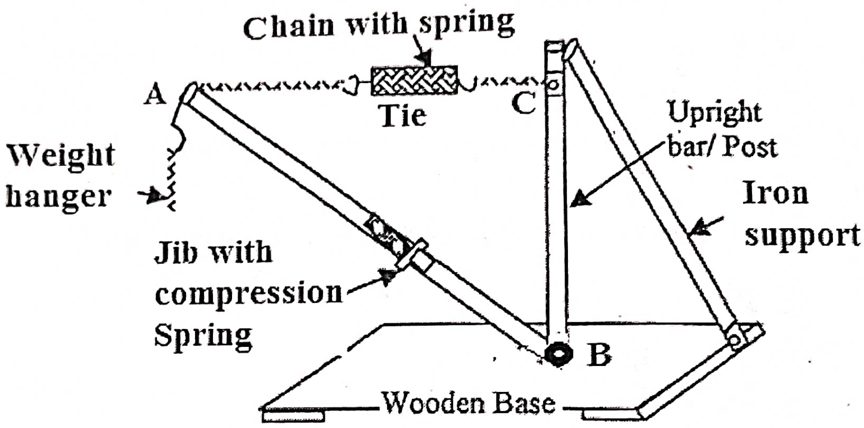

Figure No 1: Simple Jib Crane Apparatus

Jib crane apparatus, spring balance, meter scale, weights etc. The Jib crane apparatus consists of a tubular shaped jib with a compression balance. The balance is pivoted about an axis fitted to the base and a hook is attached to the other end from which a chain hangs (to carry the weight). A vertical tubular rod (Post) carries hooks at different levels. One end of the tie rope carrying a spring balance is attached to one end of the jib and the second end can be attached to any of the hooks provided on the vertical tubular rod (Post). The vertical tubular rod is fixed to a base.

3. THEORY:

As shown in the fig. 1, the jib crane is an example of three concurrent forces. The forces in the tie and the jib can be calculated experimentally. Analytically it can be found by making use of Lami's theorem, which states that when three forces acting on a body are in equilibrium, then each force is proportional to the *Sin* of the angle between the other two forces. Jib crane consists of an inclined member supported by a rope or any other type of structural member attached to a vertical mast or frame. Load is usually suspended from the outer end of this inclined mast. The outreach of the jib may be fixed or variable. The cranes may be either fixed or moveable.

Lifting capacity of such cranes may vary from 1/2 ton to 200 ton and outreach from a few meter to 50 meter. Such cranes find various applications in port area, ship yards, construction sites, and other outdoor works for lifting heavy machinery and equipments.

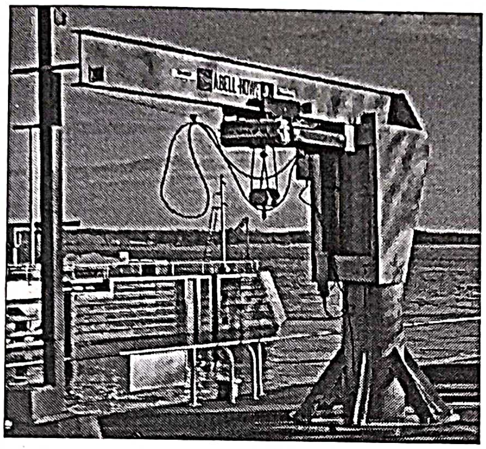

Figure No 2: 5 ton pedestal jib crane

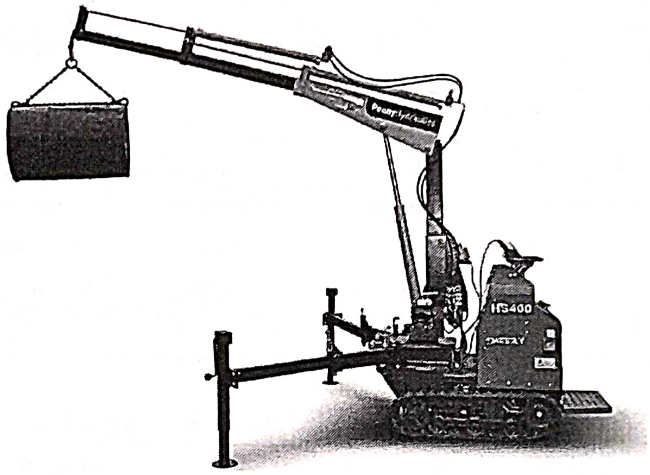

Figure No 3: Crawler mounted mobile jib crane

4. PROCEDURE:

(i) Check for zero error in all spring scales. As per loading style there will be compression in the jib and tension in the tie rod. Note the initial reading in the all spring balances.

(ii) Gradually apply a known weight in the hanger at the apex.

(iii) Note the final readings in the spring. After that know the value of force acting in tie and jib rod accordingly using relationship: Effective force=Final reading – initial reading

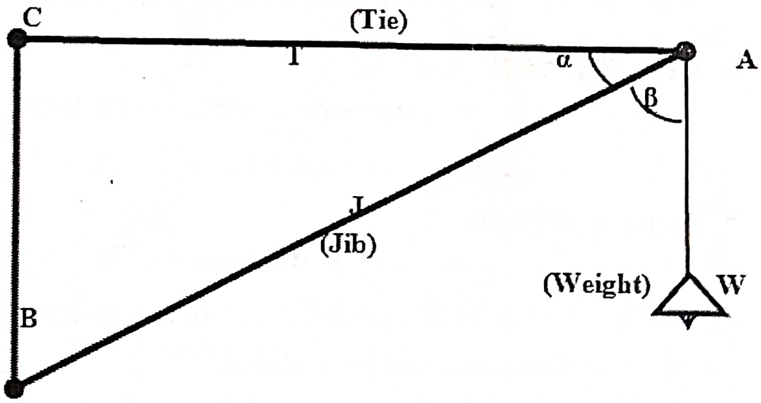

Figure No 4: Schematic diagram

(iv) Measure the length of tie chain and jibe. Note the height of upright post (BC in figure 1) which is fixed.

(v) Draw load diagram. Use properties of triangle or graphical method to know all (three) internal angles.

(vi) Draw the FBD of joint at 'A' and calculate the force in jibe and tie analytically. Or apply Lam's theorem at 'A' to know the forces in jibe and tie.

(vii) Compare the experimental and experimental results.

5. OBSERVATIONS

Zero error (initial reading) in the tension spring balance =

Zero error (initial reading) in the compression balance =

Length of post, cm =

SN	Load Applied (kg)	Load in Jibs			Load in Tie		
		Initial spring reading	Final spring reading	Effective load in Jibs (differences)	Initial spring reading	Final spring reading	Effective load in Tie (differences)
1							

Do all calculation to fill the following table:

SN	Load Applied (kg)	Load on members (kg)						Percentage error (%)	
		Experimentally		Analytically					
				Resolution of Forces		Lami's theorem			
		Jib	Tie	Jib	Tie	Jib	Tie	Jib	Tie

add Table for lengths

6. RESULT AND DISCUSSION

Mean percentage error in the Jib is =

Mean percentage error in the Tie is =

7. PRECAUTIONS

(i) Do not suspend the weight (W) from A with a jerk.

(ii) If the reading in compression balance is different for a same weight (W) then take three such readings and find their mean.

(iii) Take into account the zero error of the balances.

(iv) Measure the lengths with a fine inextensible thread.

8. VIVA QUESTIONS

(i) Define the principle on which this experiment is based.

(ii) Explain the practical use of this experiment.

(iii) Define triangle law of forces?

(iv) If three coplanar, collinear and like forces are acting on a body, will it be stable?

EXPERIMENT NO. 5

TO DETERMINE THE MECHANICAL ADVANTAGE, VELOCITY RATIO AND EFFICIENCY OF A SCREW JACK

1. Objective	**2. Apparatus**	**3. Theory**	**4. Procedure**
5. Observations	**6. Results and discussion**	**7. Precautions**	**8.Viva Questions**

1. OBJECTIVE:

To determine the Mechanical Advantage, Velocity Ratio, Efficiency and condition for self-locking of simple Screw Jack

2. APPARATUS:

The apparatus consists of a jack apparatus with two strings, pans, weight sets and a meter scale or outside calliper.

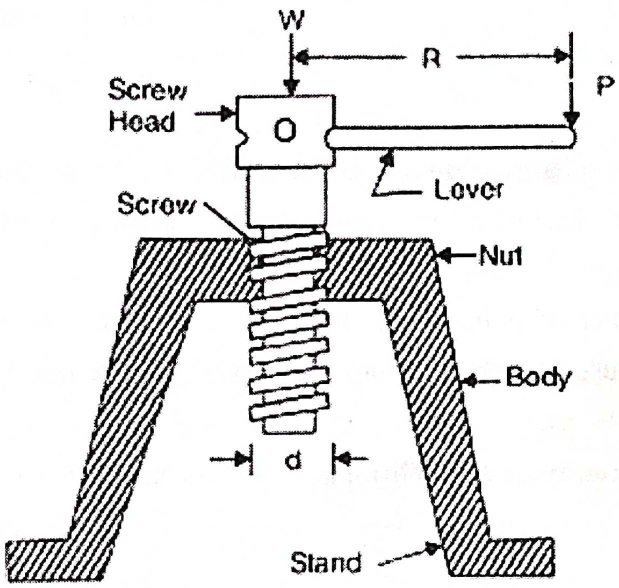

Figure No 1: Schematic diagram of a Simple Screw Jack Apparatus

3. THEORY:

Machine: It is a device which is use for doing a particular work. There are two types of machine namely simple machine and compound machine. Simple Machine has only one point for the application of effort and one point for load.eg: Lever, screw jack etc. Compound machine has more than one point for the application of effort and for load. E.g.: Printing machine, milling machine, planer, shaper etc.

Lifting Machine: Lifting machine is also known as lifting gear. This is a general term for any equipment that can be used to lift loads. This includes jacks cranes etc. In this device effort P is required to overcome a load, W.

A jack is a mechanical device used a as a lifting device to lift heavy loads or to apply great forces. A mechanical jack employs a screw thread for lifting heavy equipment. A hydraulic jack uses hydraulic power. The most common form is a car jack, floor jack or garage jack, which lifts vehicles so that maintenance can be performed. Jacks are usually rated for a maximum lifting capacity (for example, 1.5 tons or 3 tons).

Mechanical Advantage: (M.A.): The purpose of a machine is to create a mechanical advantage that will facilitate your ability to move an object against resistive forces. Mechanical advantage means that the output of the machine is greater than the input. It is a measure of the force amplification achieved by using a tool, mechanical device or machine system. It is the output divided by the input. If the effort applied 'P; to lift a weight 'W', then

$$M.A. = \frac{W}{P}$$

Velocity ratio (V.R.): It is the ratio of the distance moved by the effort (y) to the distance (x) moved by the load.

$$V.R. = \frac{\text{Distance moved by effort}}{\text{Distance moved by load}}$$

$$V.R. = \frac{y}{x}$$

Input of a machine: It is the work done on the machine. In a lifting machine, it is measured by the product of effort and the distance through which it has moved (i.e., P.y).

Output of a machine: It is the actual work done by the machine. In a lifting machine it is measured by the product of the weight lifted and the distance through which it has been lifted i.e., (W.x).

Efficiency of a machine (η): It is the ratio of output to the input of a machine.

$$\eta = \frac{Output}{Input}$$

Ideal machine: A machine is said to be ideal if its efficiency is 100%. In this case, output is equal to input.

Screw Jack: It is a device used for lifting heavy loads which are usually centrally loaded by applying smaller effort. It works on the principle of inclined plane. The device consists of a nut and screw. The load is carried by screw head. The body consisting of a nut is fixed and screw is rotated by means of a lever.

The axial distance moved by the screw when it makes one complete revolution is known as the Lead of the screw. The distance between two consecutive threads is called Pitch of the screw. For single threaded screw Lead = Pitch, and for double threaded screw L = 2p.

Let D = Diameter of effort wheel

p = Pitch of the screw

T = Number of teeth on worm wheel

W = Load lifted and

P = Effort applied to lift the weight

For one revolution of the effort wheel,

Distance moved by effort = π D

Distance moved by load = p

$$V.R. = \frac{\text{Distance moved by effort}}{\text{Distance moved by load}} = \frac{\pi D}{p}$$

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

Self locking: It is condition when load does not comes down on its own, after the removal of effort. For example, car does not come down as we remove the effort. Mathematically we can state that if efficiency of screw jack is less than 50% then it is a self locking machine.

4. PROCEDURE:

(i) Note down the pitch 'p' of the screw, number of teeth on the worm screw.

(ii) Measure the diameter of the effort wheel with an inextensible thread and meter Scale or measure the diameter with the help of outside caliper.

(iii) Wound one end of the string on the wheel in clock wise direction and attached a in the opposite direction.

(iv) Place a load 'W' on the top of the flanged table and start adding weights on to the effort pan gradually till the load starts lifting. P is the weight (effort) in the pan.

(v) Calculate M.A., V.R. and % efficiency.

(vi) Repeat the above procedure by increasing the load 'W' on table in and note down the corresponding efforts applied.

5. OBSERVATIONS:

Pitch of the screw p. mm =

Diameter of the effort pulley D, mm = 182 cm

Number of teeth on the worm wheel, T =

Velocity ratio (V.R.) =

Weight of the pan (a) in ~~kg~~ gm = 307 + 307 = 614 gm

Observation Table No 1

SN	Load W(kg)	Effort P= Weight applied +a (Kg)	$M.A. = \frac{W}{P}$	% Efficiency= $\eta = \frac{M.A.}{V.R.} \times 100$

6. RESULTS AND DISCUSSION

Mechanical advantage is .....

Mean % efficiency of the apparatus is ____

7. PRECAUTIONS:

(i) There should not be any overlapping of the strings.

(ii) Weights in the pan should be placed very gently.

(iii) The pulley should be free from friction.

(iv) The screw should be well lubricated to reduce the friction.

(v) Note the effort readings as the load just moves: (a) Frictions in the pulley and (b) effort being pulled suddenly.

8. VIVA QUESTIONS:

(i) List the practical application of this experiment.

(ii) Define Machine, MA, VR and Efficiency?

(iii) What is self locking and state its mathematical condition.

EXPERIMENT NO. 6

TO DETERMINE THE MECHANICAL ADVANTAGE, VELOCITY RATIO AND MECHANICAL EFFICIENCY OF WHEEL AND AXLE

1. Objective	**2. Apparatus**	**3. Theory**	**4. Procedure**
5. Observations	**6. Results and discussions**	**7. Precautions**	**8. Viva Questions**

1. OBJECTIVE:

To determine the mechanical advantage, velocity ratio and efficiency of simple wheel and axle

2. APPARATUS:

Simple wheel and axle apparatus consists of two grooved wooden wheels of different diameter which are fixed rigidly together and are mounted on steel centre on wooden base. Apparatus required strings, a set of weight, scale pan and meter scale.

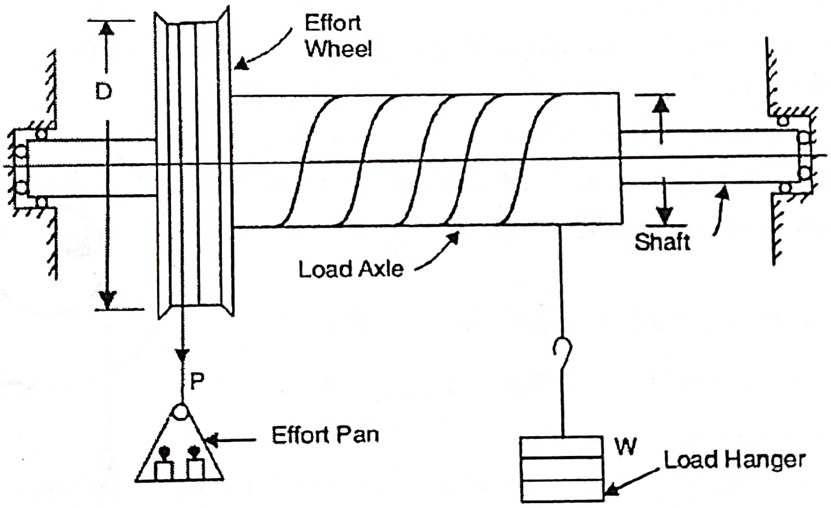

Figure No 1: Simple Wheel and Axle Apparatus

3. THEORY:

The most simple machine which is in use, since ages is the simple wheel and axle used for drawing up water from a well. It is used on the village wells even till date. Simple wheel and axle is used to lift loads. Simple wheel and axle consists of an effort wheel and an axle of different diameters which are keyed to the same spindle. The diameter of the wheel is greater than the diameter of the axle to reduce the frictional resistance. A string is wound on the axle, with one end fixed to it. The other end of this rope carries the load W, which is to be lifted. A second string is wound round the wheel, in a direction opposite to that of the rope on axle. One end of this rope is fixed to the wheel while to the other and effort P is applied. Since the two strings are would in opposite directions, therefore, a downward motion of P will lift the load W.

Let D = Diameter of the effort wheel,

d = Diameter of the axle,

W = Load to be lifted and

P = Effort applied to lift the weight

Since the wheel and axle is mounted on the same shaft; hence revolution of the wheel, the axle will be same. In one revolution of shaft,

Distance moved by Load $= \pi d$

Distance moved by Effort $= \pi D$

$$V.R. = \frac{\text{Distance moved by effort}}{\text{Distance moved by load}}$$

$$V.R. = \frac{\pi D}{\pi d}$$

$$\text{Or,} \quad V.R. = \frac{D}{d}$$

The velocity ratio is function of physical parameters; hence it can be calculated without conducting experiments also.

For lifting of a weight, the moment due to load on shaft axis will be counterbalanced by the moment applied by effort P. Free body diagram of shaft is shown in fig. 2.

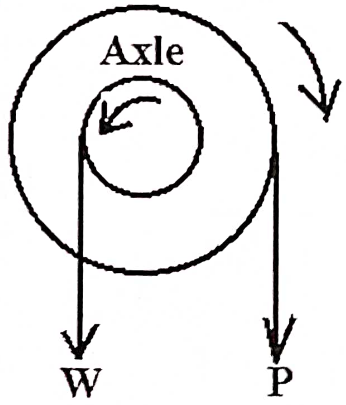

Figure No 2: FBD

Moment applied on the shaft due to Load, $M_{LOAD} = Wd$

Moment applied on the shaft due to Effort, $M_{EFFORT} = P \times D$

Condition for lifting the load,

$$M_{EFFORT} = M_{LOAD}$$

$$P \times D = Wd$$

$$\text{Hence,} \quad \frac{W}{P} = \frac{D}{d}$$

Now, as per definition of Mechanical advantage, Mechanical Advantage, $M.A. = \frac{W}{P}$

$$\text{Hence,} \quad M.A. = \frac{W}{P} = \frac{D}{d} = V.R.$$

MA can be calculated experimentally as well as analytically with the help of above equation. The efficiency of an ideal machine is 100%, this means input power will be equals to the output power.

Here, input power = Effort × Velocity of effort

$$\text{Input Power} = P \times V_{EFFORT}$$

Output power = Load × Velocity of Load

$$\text{Output Power} = W \times V_{LOAD}$$

For Ideal machine,

$$\text{Input power} = \text{Output power}$$

$$P \times V_{EFFORT} = W \times V_{LOAD}$$

Hence, $\frac{W}{P} = \frac{V_{EFFORT}}{V_{LOAD}}$

Or $M.A. = V.R.$

In actual machine power requirement is more due to friction, stretch and wear, which means the effort is actually more than the load, which means the mechanical advantage of the real system will be less than that calculated for an ideal machine.

Efficiency: The efficiency of a machine is the ratio of output power and input power.

$$\eta = \frac{\text{Output Power}}{\text{Input Power}}$$

$$\eta = \frac{W \times V_{LOAD}}{P \times V_{EFFORT}}$$

$$\eta = \frac{(\frac{W}{P})}{\left(\frac{V_{EFFORT}}{V_{LOAD}}\right)} = \frac{M.A.}{V.R.}$$

4. PROCEDURE:

(i) Measure the diameter of the wheel as D by the help of outside caliper.

(ii) Measure the diameter of the axle as d by the help of outside caliper.

(iii) Wind one string on the effort wheel and attaché scale pan to carry effort P.

(iv) Wind other string on the axle to hang load.

(v) Put the weight in the load pan.

(vi) Now place the weight slowly in the effort pan unless and until the load Pan just starts to lift up.

(vii) Note the weight place in the effort Pan.

(viii) Calculate M.A., V.R. and % efficiency.

(ix) Repeat the above procedure by increasing the load in the load pan and note down the corresponding effort.

5. OBSERVATIONS

Diameter of wheel, D, cm = 15.29 cm

Diameter of axle, d, cm = 5.41 cm

V.R., D/d =

Weight of load pan/ hanger, a, gm = 25 gms

Weight of effort pan/ hanger, b, gm = 25 gms

Observation Table

SN	Load		Effort		$M.A.=\frac{W}{P}$	$\eta=\frac{MA}{VR}\times 100$
	Wt. in Pan, w_1 (gm)	Total weight W = a + w_1 (gm)	Wt. in Pan, W_2 (gm)	Total weight, P = b + w_2 (gm)		

6. RESULTS AND DISCUSSION

Mean % efficiency of the apparatus is __________ .

7. PRECAUTIONS:

(i) There should not be any overlapping of the strings.

(ii) Weights in the pan/hanger should be placed very gently.

(iii) The string should be free from knot.

(iv) Do not increase the effort by throwing the weight on the pan. Increase the effort gently.

8. VIVA QUESTIONS:

(i) Where is a flywheel most commonly used? And what is its primary use?

(ii) What is relationship between power and tensions in the belt?

(iii) Define moment of inertia?

(iv) What is the formula for moment of inertia of a hollow circular lamina about its centroidal axis?

EXPERIMENT NO. 7

TO DETERMINE THE MECHANICAL ADVANTAGE, VELOCITY RATIO AND MECHANICAL EFFICIENCY OF WORM WHEEL

1. Objective	2. Apparatus	3. Theory	4. Procedure
5. Observations	6. Result and discussions	7. Precautions	8. Viva Questions

1. OBJECTIVE:

To determine the Mechanical Advantage, Velocity Ratio and efficiency of worm and worm wheel apparatus

2 APPARATUS:

The apparatus consists of a machine cut gear of 250 mm diameter, a metal drum of 120 mm diameter and a machine cut worm on steel spindle carrying 120 mm pulley at its end. Apparatus is fitted with string and hooks. Fig. 1 shows the general arrangement of worm and worm wheel apparatus.

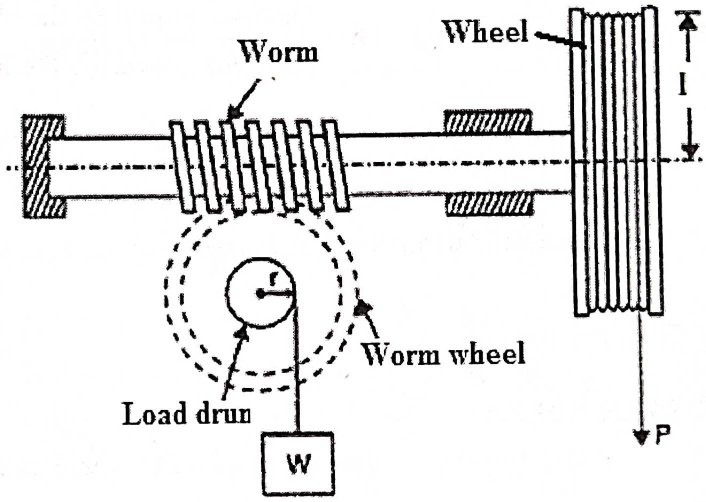

Figure No .1: Worm and worm wheel apparatus

3. THEORY:

Worm and worm wheel is used for lifting heavy loads and consists of a square threaded screw (worm) and a toothed wheel (worm wheel) geared with each other. Worm is attached to a gear, which is meshed with other gear. The shaft connected with this gear is connected to an effort pulley over which a rope is passed. The effort P is applied at the end of this rope. A load drum is securely mounted on the worm wheel. A string is wound round the drum to carry weight 'W' to be lifted. Where,

D	= Diameter of the effort pulley
d	= Diameter of load drum
T	= Number of teeth on worm wheel
T_1	= Number of teeth on the gear connected to the effort pulley
T_2	= Number of teeth on the gear connected to the worm
W	= Load lifted
P	= Effort applied to lift the weight

Now, if the effort pulley be given N_1 revolutions then the gear A will take N_1 revolutions whereas gear B takes N_2 revolution: $N_1T_1=N_2T_2$

From above relation N_2 is computed as $N_2 = \frac{N_1T_1}{T_2}$; The worm will also take N_2 revolutions.

Now the worm wheel takes one revolution if worm is given T revolutions. Therefore in this case the worm will take $\frac{N_2}{T}$ revolutions i.e. $\frac{N_1T_1}{T_2 \times T}$

Check

Therefore, the distance moved by load $= \frac{N_1T_1}{T_2 \times T} \times \pi d$ -------------------- (1)

Distance moved by the effort (P) $= N_1 \times \pi D$ -------------------- (2)

Also, the Velocity Ratio, $VR = \frac{\text{Distance moved by the effort}}{\text{Distance moved by the load}}$

$$VR = \frac{T \times T_2 \times D}{T_1 d}$$

Now Mechanical Advantage, $MA = \frac{W}{P}$

Efficiency, $\eta = \frac{MA}{VR}$

4. PROCEDURE:

(i) Measure the circumference of effort wheel and load drum with the help of threads and meter scale as πD and πd.

(ii) Note the number of teeth (T) on the worm wheel, T_1 and T_2 of the gears.

(iii) Fasten one end of the string on the load drum and wound it in clockwise direction and attach a scale pan for load. Note the total load (weight of pan and load placed in it).

(iv) Note the weight of pan for effort wheel. Fasten one end of string on the effort wheel and wound it in anticlockwise direction.

(v) Put some weight in loading pan and note it. Now put some weights in the pan attached for effort. Increase the weight in the effort pan till the effort pan starts to move down. Load will move up. Note the effort weight.

(vi) Repeat the above procedure for different weights in load pan

5. OBSERVATIONS:

Number of teeth on worm wheel, T = 120

Diameter of effort wheel D, mm = 112 mm

Diameter of load drum, d, mm = 125 mm

Number of teeth on the gear connected to the effort pulley, T_1 = 25

Number of teeth on the gear connected to the worm, T_2 = 50

Weight of load pan/ hanger, a, gm = 25gm

Weight of effort pan/ hanger, b, gm = 25gm

Observation Table

SN	Load		Effort		$MA = \frac{W}{P}$	$\eta = \frac{MA}{VR} \times 100$
	Wt. in Pan. W_1 (gm)	Total weight $W = a + w_1$ (gm)	Wt. in Pan, w_2 (gm)	Total weight, $P = b + w_2$ (gm)		
1						
2						
3						

6. RESULTS AND DISCUSSION:

Mean percentage efficiency of the apparatus is __________.

7. PRECAUTIONS:

(i) Lubricate the screw before starting the experiment

(ii) Trapping should be done after adding the weight in the effort hanger

(iii)There should not be any know in the string.

(iv)Overlapping of string should not be there.

8. VIVA QUESTIONS:

(i) Define mechanical advantage and velocity ratio?

(ii) How error can be minimized in the experiments?

(iii)For what purpose worm and worm wheel is used?

(iv)For double threaded wheel what will be the moment of wheel?

(v) On what principle worm and worm wheel apparatus work?

(vi) What is maximum limit of efficiency in case of worm and worm wheel apparatus?

EXPERIMENT NO. 8

TO VERIFY THE FORCE TRANSMITTED BY MEMBERS OF A GIVEN TRUSS

1. Objective	2. Apparatus	3. Theory	4. Procedure
5. Observations	6. Result and discussion	7. Precautions	8. Viva Questions

1. OBJECTIVE:

To calculate the forces in the members of simple roof truss and find the percentage error between the observed and calculated values

2. APPARATUS:

The apparatus consists of two legs whose one leg is fitted on an unmoveable bracket and the other on rollers. Spring balance shows tension in the rod and the compression on rafters.

3. THEORY:

Triangle law of forces will be applied in this apparatus. It states" If two forces are acting simultaneously on a particle, be represented in magnitude and direction by the two sides of a triangle, taken in order, their resultant may be represented in magnitude and direction by third side of the triangle, taken in opposite order." Fig 1 shows the Joint Roof Truss Apparatus.

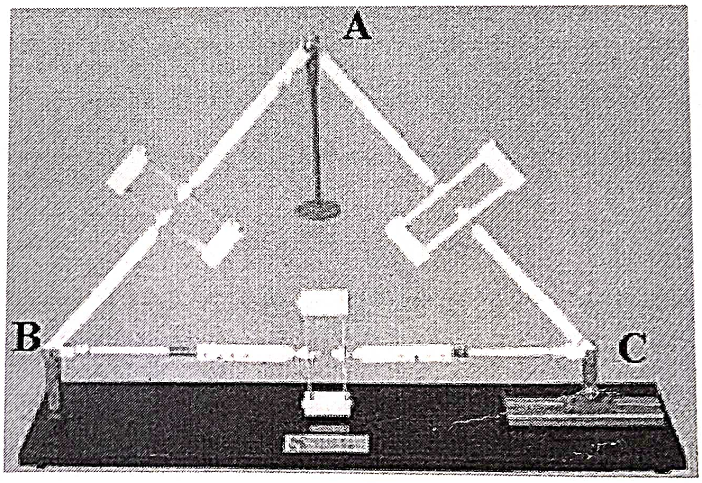

Figure No: 1: Joint Roof Truss Apparatus

4. PROCEDURE:

(i) Note the initial reading of all spring balances. Inclined members will be in compression and horizontal member will be in tension.

(ii) Apply a Weight (W) from the point A. By doing so, the chain BC will be elongated and compression will be observed in AB, AC. Record the final reading all spring balance. Force is a member will be obtained by subtracting final reading and initial readings.

(iii)Measure the length of AB, BC and AC using scale.

(iv) Draw the triangle ABC, taking BC as a horizontal line. From triangle measure the internal angles.

(v) Draw the FBD at joint 'A' and find out the values of forces in AB and AC analytically.

(vi)Find the % age error between the observed and calculated values of these forces.

(vii) Change the weight (W) and repeat the steps from (i) to (vi) and record another set experiments. Take in this way about four or five readings.

5. OBSERVATION

Observation Table No 1

S N	W (kg)	AB			BC			AC		
		Observed	Calculated	% Error	Observed	Calculated	% Error	Observed	Calculated	% Error
1										
2										
3										

6. RESULTS AND DISCUSSION:

Mean % error in S_1 =

Mean % error in S_2 =

Mean % error in S_3 =

7. PRECAUTIONS:

(i) Do not suspend the weight (W) with a jerk.

(i) If the readings in compression balance are different for a same Weight (W) then take three such readings and find their mean.

(ii) Take into account the zero error of the balances.

(iii) Measure the lengths with a five inextensible thread.

8. VIVA QUESTIONS:

(i) What is the condition for perfect frame?

(ii) What is a framed structure? List its application.

(iii)Define a truss?

(iv)Differentiate between perfect truss and imperfect truss?

(v) What do you understand by space truss and plane truss?

(vi) What are the methods for force study in truss?

EXPERIMENT NO. 9

TO VERIFY THE LAW OF MOMENTS USING BELL CRANK LEVER

1. Objective	2. Apparatus	3. Theory	4. Procedure
5. Observation	6. Result and discussions	7. Precautions	8. Viva Questions

1. OBJECTIVE:

To verify the principle of moments using Bell Crank Lever Apparatus

2. APPARATUS:

Bell Crank is a lever bent at 90^0 angle forming fulcrum, between its two arms. One arm is longer and other is shorter. This works on the principle of moments. Longer arm is horizontal while shorter arm is vertical. The lever arm is engraved with a scale. On the free end of longer arm, load is applied and on the shorter arm effort is measured from the spring balance. If the algebraic sum of the moment of load and effort about the fulcrum is zero, then the principle of moments is provided.

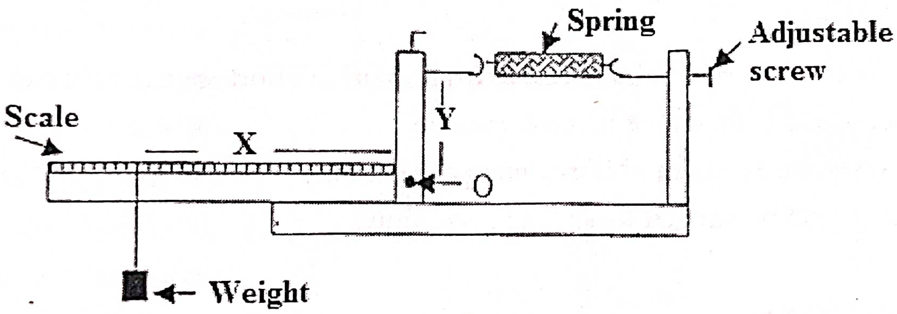

Figure No 1: Bell Crank Lever Apparatus

3. THEORY:

The algebraic sum of the moments of all the forces about a point in a body is zero for equilibrium. In other works sum of the clock wise moment about a point is equal to the sum of the anti-clock wise moments about the same point for equilibrium.

4. PROCEDURE

(i) Keep hook (hanger) at a distance X from fulcrum on horizontal long arm of the Bell Crank Lever Apparatus. Weights will be placed on weight carrier.

(ii) Measure the distance X accurately and note down initial reading (T_1) of spring balance.

(iii) Put weight (W) on the hanger and note it. Due to weight, there will be angular displacement of horizontal arm and it will not remain in horizontal position.

(iv) Use the adjustable screw to bring back the horizontal arm in horizontal position.

(v) Take final reading (T_2) of spring balance.

(vi) Note down vertical distance (Y) between fulcrum (O) to the point of application of effort P.

(vii) Repeat above steps by changing the position of weight and weight for another set of readings.

5. OBSERVATIONS:

Observation Table No 1:

S. No.	Weight W (kg)	Distance X from fulcrum (cm)	W. X (kg cm)	Reading of spring Balance		Effort T	Distance y (cm)	T. y	W x-Ty	% error
				Internal T_1	Final T_2					

6. RESULTS AND DISCUSSION

Mean error of Apparatus is ----------------------

7. PRECAUTIONS:

(i) Readings of the spring balance for measurement of effort should be taken accurately.

(ii) Distance x and y should be taken accurately.

(iii) Reading should be taken in horizontal position only.

(iv) Weight should be hanged freely and accurately.

8. VIVA QUESTIONS:

(i) Define moment of a force.

(ii) Discuss Varignon's theorem and its application.

(iii) What do you mean by principle of moment?

EXPERIMENT NO. 10

TO DETERMINE MECHANICAL ADVANTAGE, VELOCITY RATIO AND MECHANICAL EFFICIENCY OF A DIFFERENTIAL WHEEL AND AXLE

1. Objective	**2. Apparatus**	**3. Theory**	**4. Procedure**
5. Observations	**6. Result and discussion**	**7. Precautions**	**8. Viva Questions**

1. OBJECTIVE:

To determine the mechanical advantage, velocity ratio and Mechanical efficiency of a differential wheel and axle

2. APPARATUS:

The apparatus consists of a wheel A and a wound axles B and C (made up of two different diameters). The wheel and the axle are keyed to the same shaft, which is mounted on ball bearing in order to reduce the friction to minimum. Apparatus requires rope, a set of weights, scale pan and meter scale.

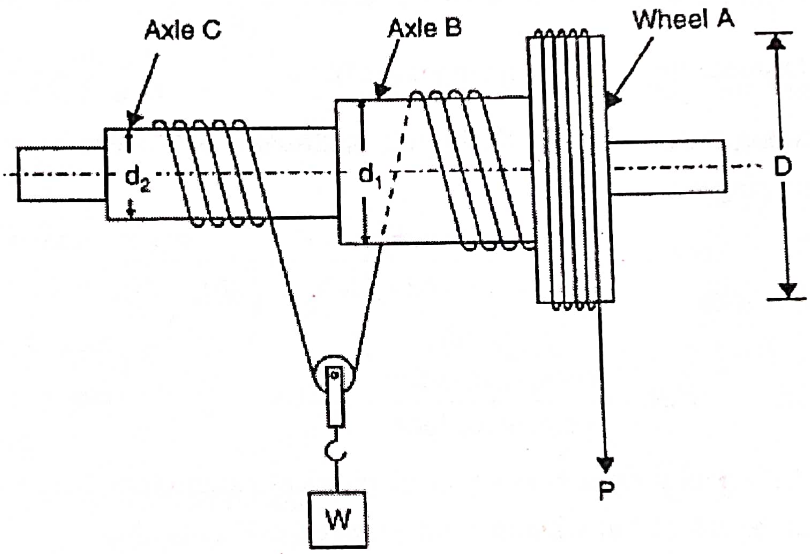

Figure No 1: Differential wheel and axle

3. THEORY:

Differential wheel and axle is used to lift heavy loads. In differential wheel and axle, the axle used is a compound axle. The axle is made in two parts having different diameters Axles and wheel are fitted on the same shaft.

A rope is wrapped round the two parts of the axle. The rope is attached at two diametrically opposite side of axle B and C. It is tied in such a way so that while rotating the shaft, the rope is wrapped at one axle while unwrapped at another axle. The lifting load is attached to this rope with the help of a hook and frictionless pulley. Another rope is wrapped to the wheel and tied near a point on the edge of wheel. The effort is applied at the other end of rope which is attached to the wheel. The direction of winding of these two strings is such that when the string of wheel unwraps; then the string of outer axle unwraps and wraps on the central axle. This means that direction of wrapping of two strings on wheel and outer axle is same.

Let D = Diameter of the effort wheel A

d_1 = Diameter of axle B

d_2 = Diameter of the axle C

W = Load to be lifted by the machine and

P = Effort applied to lift the load

As the axle A, B and wheel C is mounted on the same shaft. Hence, in one revolution of shaft,

The distance moved by wheel (effort) $= \pi D$

Length of string that wraps on the larger axle B $= \pi d_1$

Length of string that unwraps form the axle C $= \pi d_2$

Since $d_1 > d_2$; the winding of the rope on C is more than the unwinding on B. Hence, the length of string which will be wrapped on axle B $= \pi d_1 - \pi d_2$

Distance through which the load is lifted $= \dfrac{\pi d_1 - \pi d_2}{2}$

Since, the distance moved by the load is half, as the rope is passing over the pulley.

$$V.R. = \frac{\text{Distance moved by effort}}{\text{Distance moved by load}} = \frac{\pi D}{\left(\dfrac{\pi d_1 - \pi d_2}{2}\right)}$$

Or, $$V.R. = \frac{\text{Velocity of effort}}{\text{Velocity of load}} = \frac{V_{EFFORT}}{V_{LOAD}}$$

The velocity ratio is function of physical parameters; hence it can be calculated without conducting experiments also.

For lifting of a weight, the moment due to load on shaft axis will be counterbalanced by the moment applied by effort P. Free body diagram of axles and pulley is shown in fig. 2. Although ropes are not exactly vertical, but is has been assumed to simplify the calculations. A continuous chord/rope will have same tensions; hence the tension in the rope connected with the axle will be same. Writing equation of equilibrium on pulley, $\sum Fy = 0;$ $T + T = W$

Hence, $T = \dfrac{W}{2}$

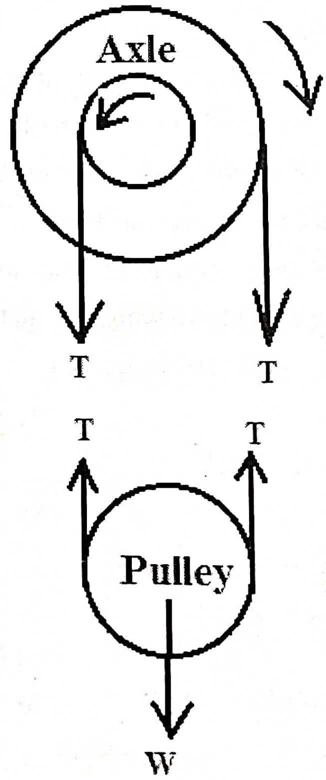

Figure No 2: FBD

Moment applied on the shaft due to Load,

$$M_{LOAD} = Td_1 - Td_2$$

$$M_{LOAD} = T(d_1 - d_2) = \frac{W}{2}(d_1 - d_2) \quad \text{--------- (i)}$$

Moment applied on the shaft due to effort,

$$M_{EFFORT} = P \times D \quad \text{----- (ii)}$$

Condition for lifting the load,

$$M_{EFFORT} = M_{LOAD}$$

$$P \times D = \frac{W}{2}(d_1 - d_2)$$

$$\text{Or, } \frac{W}{P} = \frac{2D}{(d_1 - d_2)} \quad \text{------------ (iii)}$$

Now, Mechanical Advantage, $M.A. = \frac{W}{P}$

MA can be calculated experimentally as well as analytically with the help of equation (iii). For an ideal machine efficiency is 100%, this means input power will be equals to the output power.

Here, input power = Effort × Velocity of effort

$$\text{Input Power} = P \times V_{EFFORT}$$

Output power = Load × Velocity of Load

$$\text{Output Power} = W \times V_{LOAD}$$

For Ideal machine,

$$\text{Input power} = \text{Output power}$$

$$P \times V_{EFFORT} = W \times V_{LOAD}$$

$$\text{Hence, } \frac{W}{P} = \frac{V_{EFFORT}}{V_{LOAD}}$$

$$\text{Or } M.A. = V.R.$$

In actual machine power requirement is more due to friction, stretch and wear, which means the effort is actually more than the load, which means the mechanical advantage of the real system will be less than that calculated for an ideal machine.

Efficiency: The efficiency of a machine is the ratio of output power and input power.

$$\eta = \frac{\text{Output Power}}{\text{Input Power}}$$

$$\eta = \frac{W \times V_{LOAD}}{P \times V_{EFFORT}}$$

$$\eta = \frac{\left(\frac{W}{P}\right)}{\left(\frac{V_{EFFORT}}{V_{LOAD}}\right)} = \frac{M.A.}{V.R.}$$

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

Calculate the efficiency of machine based on actual experimental data as velocity ratio is fixed.

$$\eta = \frac{\left(\frac{W}{P}\right)}{V.R.}$$

4. PROCEDURE:

(i) Wind one string on the effort wheel and attach scale pan / hanger to carry effort P.

(ii) Wind other string on the larger axle and bring it to other side of smaller axle.

(iii) Put movable pulley to carry load W through scale pan.

(iv) Now place the weight slowly in the effort pan unless and until the load pan just starts to lift up.

(v) Note the weight placed in the effort pan.

(vi) Repeat the above procedure for different weight in load pan.

5. OBSERVATIONS:

Diameter of wheel (load drum), D = 282 mm

Diameter of bigger axle, d1 =130 mm and Diameter of smaller axle, d_2=65 mm

Velocity Ratio, $\boxed{V.R. = \frac{2D}{d_1 - d_2}} = \frac{2 \times 282}{130 - 65} = 8.68$

Weight of Load pan/ hanger, a =25 gm and Weight of efforts pan / hanger, b=307gm

Observation Table No: 1

SN	Load W= ~~b~~ a+ applied weight (gm)	Effort P= b+ applied weight (gm)	$M.A. = \frac{W}{P}$	$\% \ \eta = \frac{MA}{VR} \times 100$
1				
2				
3				
4				

6. RESULTS AND DISCUSSION:

Mechanical advantage is ....

Efficiency of machine is ....

7. PRECAUTIONS:

(i) String should not be overlapped.

(ii) There should not be any knot in the string.

(iii) Weights should be placed gently.

(iv) Machine should be frictionless.

(v) Do not increase the effort by throwing the weight on the pan. Increase the effort gently.

8. VIVA QUESTIONS:

(i) Explain the practical application of this experiment?

(ii) What do you mean by velocity ratio"

(iii) Explain the term mechanical advantage?