HMR Institute of Technology & Management

ENGINEERING MECHANICS

LABORATORY MANUAL

Name……………………………………….

Roll. No……………………………………..

Class……………………………………….

Group………………………………………

ENGINEERING MECHANICS LABORATORY RECORD

Name______________Group_________Enrollment No.__________

S.No.	Experiment*(pages)*	Date conducted	Submission Date	Grade	Signature of Teacher
1.	Force Table *(2-7)*				
2.	Parallel Beam *(8-13)*				
3.	Friction *(14-21)*				
4.	Jib Crane *(22-27)*				
5.	Screw jack *(29-33)*				
6.	Wheel & Axle *(34-38)*				
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9	Bell crank lever (49-54)				

EXPERIMENT NO 1

POLYGON LAW
OF
COPLANAR FORCES

(UNIVERSAL FORCE TABLE)

Experiment No. 1 UNIVERSAL FORCE TABLE

AIM

To Verify The Polygon Law Of Forces Using Universal Force Table.

APPRATUS:

A Universal force table, spirit level, five hangers, standard weights and inextensible threads.

THEORY: ***POLYGON LAW:***

It states that *"if there are number of coplanar forces acting simultaneously at a point (concurrent) such that they can be represented in magnitude and direction by the sides of a polygon taken in order, their resultant is represented by the closing side taken in the opposite order."*

The **state of equilibrium** of a particle refers to a state of uniform velocity or rest. In present case, we are interested in the state of equilibrium of rest of a small circular ring. Hence, under equilibrium condition, the Polygon Law states that if a number of coplanar forces are acting at a point such that they can be represented in magnitude and direction by the sides of the polygon taken in order will form a closed polygon i.e. the resultant will be zero.

$$\sum \vec{F} = \vec{F_1} + \vec{F_2} + \vec{F_3} + \ldots + \vec{F_n} = 0$$

PROCEDURE

Figure 1:- UNIVERSAL FORCE TABLE

1) Prepare the universal force table horizontal. Spirit level is used to check whether the table is placed horizontally. When the bubble of the spirit level is at the centre, then the surface is said to be horizontal.

For this, spirit level is used in two positions:

a. Spirit level is placed on the table parallel to any two screws out of the three provided on the legs of the table. Adjust these screws so that the bubble comes at the center.
b. Now, place spirit level in the perpendicular position to the previous position (parallel to the third leg). **Do not touch the above two screws.** Adjust the third screw only so that the bubble of the spirit level comes in the center and hence table becomes horizontal.

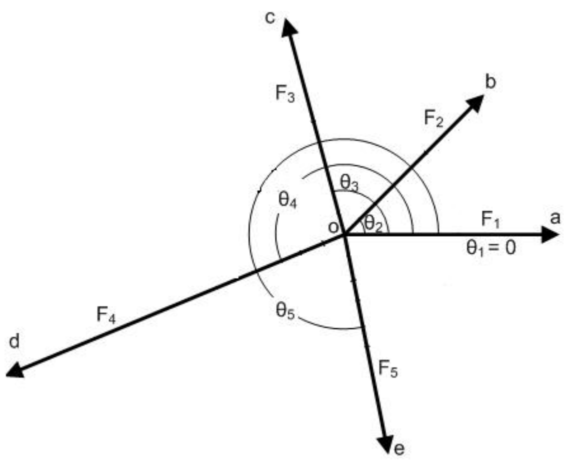
This makes the table surface completely horizontal to the ground.

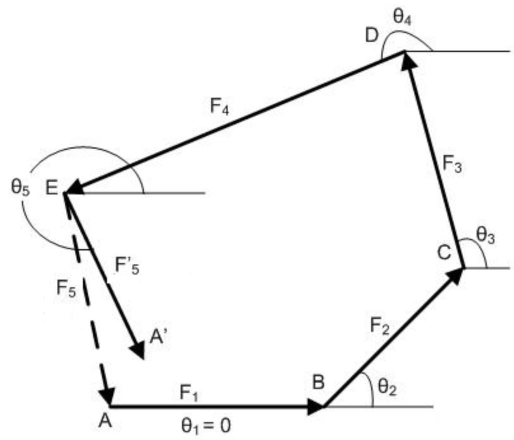
Note: There is a pin at the center of the table. The table has graduations around 0° to 360°.

2) Set one of the pulleys at 0° on the graduated table. This becomes the reference point for all other forces. Thereafter set the remaining pulleys at various angles of the force table.
   (All pulleys are assumed to be friction-less)
3) Take the set of five threads radially attached to an iron ring. Pass the five threads over the pulleys and suspend the hangers (weights) on them.
   (All threads are assumed to be inextensible)
4) Add the weights on the hangers. The threads should be at the same height above the table (by assuming that all the pulleys are at the same height) so that the iron ring and the threads become coplanar (if needed adjust the pulley height). ***(The pin should be at the Centre of the iron ring).*** The force (tension due to hanging weight) in thread at 0° on the graduated table is taken as force F_1.Moving in clockwise direction name the forces in other threads as F_2, F_3, F_4, F_5.
5) Now by adjusting the weights, bring the iron ring concentric to the pin and also all the ***threads should appear to pass through the center of the pin***. At this position, the graduation of degrees will be correct. Note the forces F_1, F_2, F_3, F_4, F_5 and all the angles.(Refer diagram below to also find **F'**, **θ_5')**

Sample Observation

F_1	F_2	F_3	F_4	F_5	θ_1	θ_2	θ_3	θ_4	θ_5	$F_5 - F_{5'}$	$\theta_5 - \theta_5'$
200	190	250	270	210	0°	60°	110°	210°	280°		





Drawing of Vector Diagram

1) Initially choose an appropriate scale to draw the magnitude of forces into the proportional lengths.
2) Let '**oa**' be the proportional length for force $\mathbf{F_1}$. Draw **oa** as a horizontal line i.e. $\theta_1 = 0°$. This becomes the reference for all other forces in magnitude and direction.
3) Now at an angle $\theta_2$draw ob. (length proportional to magnitude) indicating force $\mathbf{F_2}$.
4) Similarly, again taking '**o**' as common point for all forces, draw **'oc'**, **'od'** and '**oe**' representing the forces $\mathbf{F_3}$, $\mathbf{F_4}$ and $\mathbf{F_5}$ respectively in magnitude. The directions are given by θ_3, θ_4 and θ_5 from the reference i.e. '**oa**'.
5) Hence, the vector diagram of coplanar concurrent forces is obtained and concurrency is indicated at point **'o'**.

Drawing of Polygon

1) Draw a horizontal line **AX**. Take **AB** as length of force **F_1**proportional to its magnitude and here the value of angle **θ_1** is **0°**.
2) Draw **BC** parallel to **ob** and equal in magnitude. Similarly draw **CD** parallel to **oc**, **DE** parallel to **od** and **EA'** parallel to **oe**.
3) The force **F_5** is drawn along **EA'**. If all the readings are correct, **A'** coincides with **A**.
4) If not so, there is error (**EA' – EA**) in magnitude and angle **AEA'** is the error in direction and the force is represented by **F_5'**.
5) Repeat the procedure by changing the position of the weights (angles) on the graduated table and thereby adjusting the weights.

PRECAUTIONS:

1) The pulleys should be frictionless.
2) Weights & Pans should not touch any surface.
3) Threads should not overlap the pulleys.
4) Direction of threads should be marked carefully.
5) Direction of weights should be gradual.

OBSERVATION TABLE AND RESULT

Observations											Results	
S No	FORCES (In grams or N)					ANGLE OF FORCES (in degrees)as indicated on the force table					$\left(\frac{F5 - F5'}{F5}\right) \times 100$	$\left(\frac{\theta 5 - \theta 5'}{\theta 5}\right) \times 100$
	F_1	F_2	F_3	F_4	F_5	θ_1	θ_2	θ_3	θ_4	θ_5		
1.						0°						
2.						0°						
3.						0°						
4.						0°						
5.						0°						

RESULTS:

Through measurements in lengths and angles from graph the error in forces and angles can be calculated. Hence the polygon law of forces was verified.

Comment on the accuracy of the results:

VIVA QUESTIONS:

Q1. What is polygon law of forces? Give some practical application where this law is used?

Q2. What are the conditions of equilibrium of coplanar forces? What are non coplanar forces?

Q3. Why should the table be kept horizontal? Why should the ring be at the center of the table? Can the law be verified in the inclined position of force table? Explain.

Q4. How will you find the weight of unknown body with the help of this experiment?

Q5. How the force-table is made horizontal?

Q6.Why is it preferable to use inextensible strings? What is the effect of extensible string on the force applied through it? Can the law be verified by using extensible strings? Explain

Q7. Define the term resultant of a force system.

EXPERIMENT NO. 2

SUPPORT REACTIONS OF A BEAM

(PARALLEL FORCE APPARATUS)

Experiment No.2 PARALLEL BEAM

AIM:

To verify the law of moments using Parallel Force Apparatus (Simply Supported type).

APPARATUS:

Simply supported beam apparatus consisting of graduated beam supported on two compression spring balances, sliding hooks and weights.

THEORY:

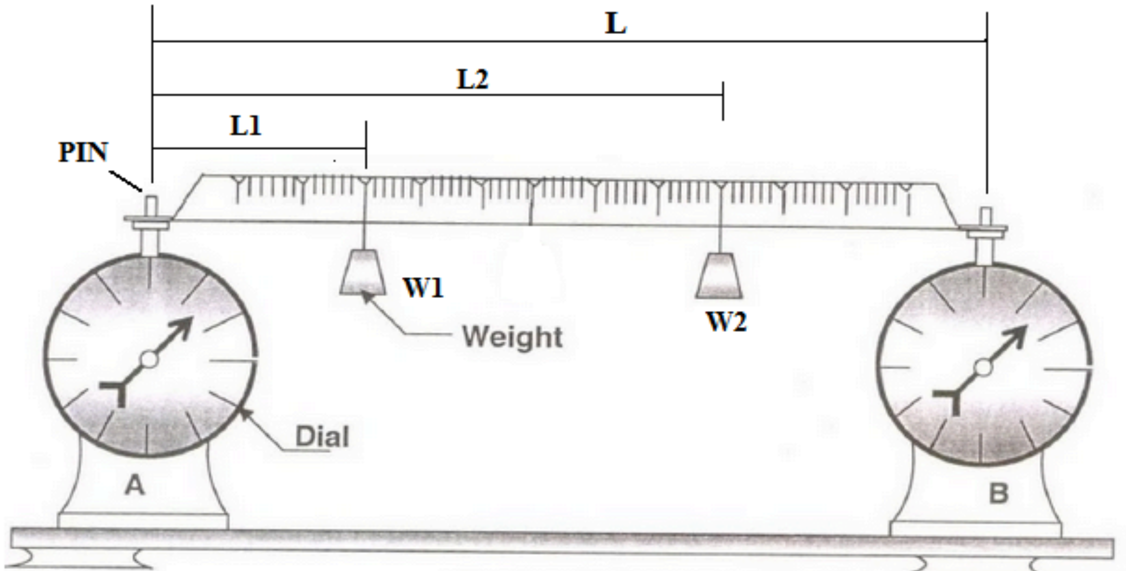
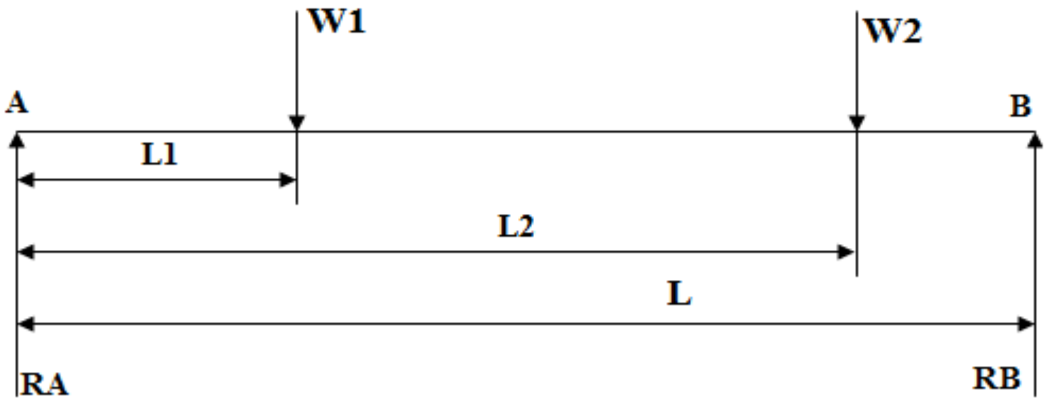


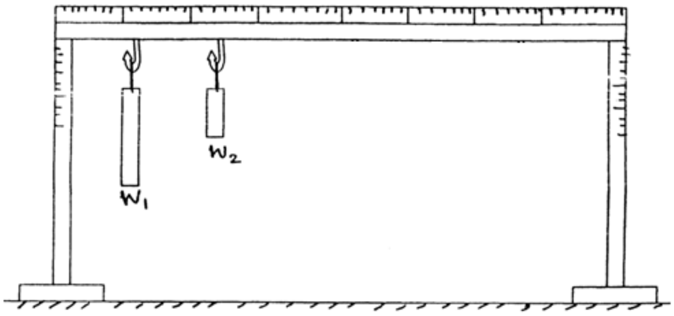
Fig. Parallel Force Apparatus



The experiment is based on the "*principle of moments*" which states that if a system of coplanar forces acting on a rigid beam keeps it in the equilibrium condition, then:

1. Summation of all vertical forces is zero i.e. $\sum F_y = 0$
2. Summation of all horizontal forces is zero i.e. $\sum F_x = 0$

3. The algebraic sum of their moments about any point in their plane is zero, i.e. $\sum \mathbf{M_p = 0}$



Consider a simply supported beam AB of length ‘L’. Now let,

L_1 and L_2 are lengths from A of weight W_1 and W_2 respectively.

R_A and R_B are the observed reactions (experimental) at A and B respectively.

And R'_A and R'_B are the theoretical reaction at A & B calculated by the equations given below:

Now apply principle of moments in the equilibrium condition.

Taking moment about A

$W_1 l_1 + W_2 l_2 - R_B * L = 0$

$R_B * L = W_1 l_1 + W_2 l_2$

$$R_B = \frac{W_1 l_1 + W_2 l_2}{L}$$

Also $R_A + R_B = W_1 + W_2$

$\therefore \quad R_A = (W_1 + W_2) - R_B$

$\therefore$ Percentage error in reaction R_A at A

$$= \frac{R_A - R'_A}{R_A} \times 100$$

Percentage error in reaction R_B at B

$$= \frac{R_B - R'_B}{R_B} \times 100$$

PROCEDURE:

1. Note the initial readings of the compression spring balances/ Dial, R_{AO}& R_{BO}, when the beam is supported at its ends and the sliding hooks are removed. If the spring balances have no zero error, sum of the readings is equal to the weight of the beam. Alternately adjust the screws to make the reading zero. Take these points into account while doing the calculations.

2. Place each sliding hook with weights at predetermined lengths. Distances are to be measured from the center of the pin over which beam is placed. Name them L1 and L2 for weights W1 and W2 (including the weight of hanger) respectively. Also note, zero of the scale is at the center of the graduated beam. **Just noting the scale reading will lead to errors.**

3. Note the final reactions R_A& R_B of the compression spring balances/Dial at the supports A & B respectively.

4. Subtract the initial reading from the final readings and this indicates the actual reactions at the supports A & B.

5. Draw the line diagram of the beam showing the weights, reactions and distances.

6. Take moments of all the forces about left and right ends and find the reaction with the help of principle moments as explained. Take more readings by changing the location of weights.

PRECAUTIONS:

1) Measure the Distances Accurately.
2) The weight should be suspended gently from hooks.
3) The initial & final readings of the spring balances should be noted carefully.
4) Before noting down the final readings the beam should be slightly pressed downwards so as to avoid any friction at the support.

OBSERVATION TABLE:

Starting R_{AO} = ________________ R_{BO} = ________________ L = 102 cm

l_1, l_2(in cm): All reactions in kg (even though kg is a unit of mass, here it represents 9.81N)

S.No	l_1 (cm)	l_2 (cm)	OBSERVED VALUES		CALCULATED VALUES		ERROR IN	ERROR IN	% ERROR in R_A	% ERROR in R_B
			R'_A	R'_B	R_A	R_B	R_A	R_B		
1										
2										
3										
4										
5										

RESULTS:

The mean experimental error in the calculation of R_A = ________.

The mean experimental error in the calculation of R_B = ________.

Comment on the accuracy of the results:

VIVA QUESTIONS:

Q1. What is the effect of width of groove in measurement of distances?

Q2. Will the beam be horizontal when the readings are taken?

Q3. If the spring balances are defective, by what procedure corrected measurement of load is possible?

Q4. Define Law of Moments.

Q5. By what procedure the weight of beam and hangers is neglected?

Q6. Can this apparatus be used for more than two weights?

EXPERIMENT NO.3

FRICTION

Experiment No. 3 FRICTION

AIM:

To determine the coefficient of friction (μ_s) between Wood and Various surface (Like Leather, Wood, Aluminium etc.) on an inclined plane.

APPARATUS REQUIRED:

Inclined plane Apparatus, Slider, pan attached trolley, Weight box, Thread etc.

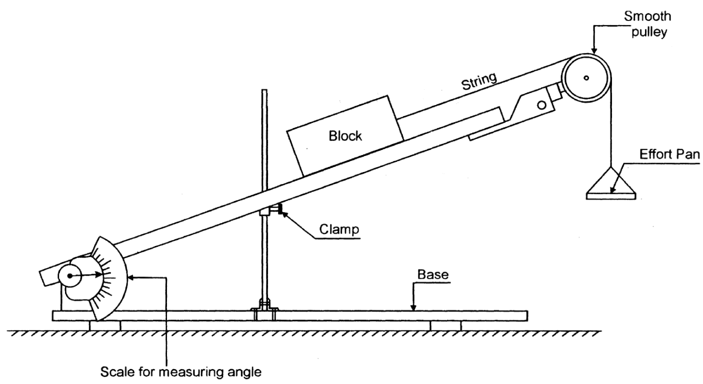
THEORY:

When two bodies are pressed together with a certain force, it is difficult to slide one with respect to the other. It is due to the frictional force which always opposes the relative motion between contacting surfaces.

It can be seen from daily life experience that friction can be both boon and bane for various applications. In general, friction is often associated with losses but it also has certain positive aspect like in walking, frictional clutches, brakes etc. So by conducting this experiment we can determine the coefficient of friction between surfaces in contact and judicious selection of friction material can be made.

Before we proceed further it is important to appreciate the concept of **effect and cause** .It means that if something is happening (effect), there must be strong reason for it (cause).

When a wooden block is resting on a floor and a force is applied to slide it by pulling or pushing, there is a resistance to motion. When the block does not move it means that net force is zero and there must be opposing force of equal magnitude. This opposing force is known as **frictional force** . This force is a variable force whose least value is zero and it has a maximum value when the block is about to slide. This maximum value of frictional force is called the limiting force of friction (F_{max}).



FRICTION PLANE APPARATUS

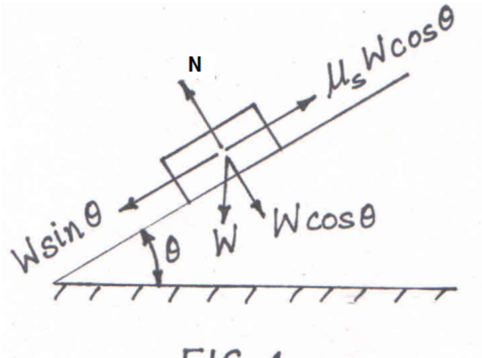


FIG. 1

$F_{max} = \mu_s N$ {where N is normal reaction and μ_s is the coefficient of static friction.}

Since the aim of the present experiment is to determine coefficient of static friction at impending state. But the problem is that impending state is not known to us. To overcome this difficulty there should be some arrangement by which we can alter the applied force (it should be measurable) and up to the impending state - the condition when the block is just about to move. This applied force is equal to frictional force.

The applied force can be increased by increasing the angle of incline. Since the applied force can be measured so as the limiting force of friction. Once this is known then coefficient of friction can be computed, $\mu_s = F_{max}/N$. One such arrangement is an adjustable inclined plane.

Now the block of known mass is placed on the adjustable inclined plane having minimum angle of inclination as θ. The downward force acting on the block is W sinθ. Here W is the weight of the block. Now the downward force (W sinθ) can be increased by increasing the angle of inclined plane, so θ can be slowly increased till the block is impending to slide down. The minimum angle of the incline at which block is on the verge of downward movement is called angle of repose(θ)

The tangent of that angle is equal to coefficient of static friction between the contacting materials. It can be easily appreciated that angle of repose is independent of weight of the block. So coefficient of static friction (μ_s) = tan θ. So by measuring the angle of repose, coefficient of static friction can be computed. Fig 1 shows the above arrangement. The procedure adapted to measure angle of repose is given below.

PROCEDURE: Angle of Repose

1) Select the combination of material between which coefficients of static friction has to be computed.
2) For this a wooden adjustable incline plane to which a stainless steel, Aluminium or any other material sheet is fixed on the surface is taken.
3) Take a wooden block of known mass, bottom of which is fixed with either the Aluminium, wood or graphite sheet.
4) Set the incline to the least value and place the block on the plane.
5) Mark a reference point on the incline so as to judge the movement of block at the same place.
6) Tap the incline gently and observe for the impending state (at the impending state the block would just move and then stop).
7) Increase the angle of incline till the impending state has reached.
8) Measure the angle of incline at the point of impending motion. The angle can be measured by taking horizontal distance between two points of the incline (a) and taking vertical distance of corresponding points about same datum surface (ℓ_1 and ℓ_2), then

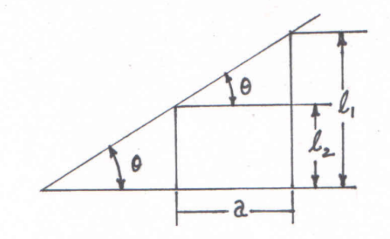
   

   FIG. 2

   $$\tan\theta = (\ell_1 - \ell_2) / a$$

   The distances should be measured with the help of set squares. It can be easily shown by Fig 2.
   Let this angle be θ.
9) Then $\mu_s = \tan\theta$ (by force balance along the plane and normal to the plane).

   At the impending state: ℓ_1 = _______ mm; ℓ_2 =________ mm; a =_______ mm

$$\mu_s = \tan\theta = (\ell_1 - \ell_2)/a$$

SOURCE OF ERROR:

1) The surface of incline or the bottom of block is uneven.
2) The angle of incline is suddenly increased which leads to crossing of impending state. Therefore to avoid this situation decrease the angle of incline so that impending state can be achieved.
3) The impending state is not carefully monitored.
4) The surface of incline and block is not clean.

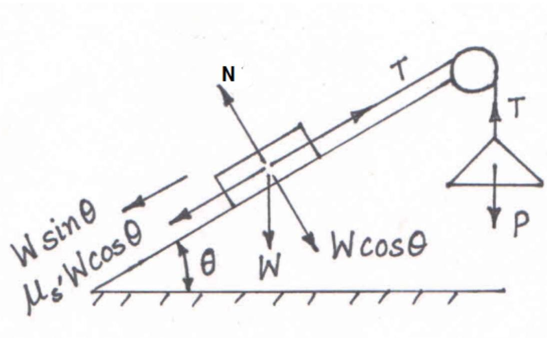


FIG. 3

The second method used to determine coefficient of static friction is shown schematically in Fig 3. Here a block is placed on an adjustable incline and a force parallel to the inclined surface (P) is applied on the block in the upward direction, such that the block is on the verge of movement. The downward forces acting along the plane is Wsin θ and $\mu_{s'}$ Wcos θ. Since at the impending state the net force on the block is zero, it means that upward force on the block is equal to the downward force along the plane. Here

W = weight of the block

θ = Angle of the inclined plane

$\mu_{s'}$ = Coefficient of static friction between block and incline plane

$$\mu_s' = \frac{P - W\sin\theta}{W\cos\theta}$$

If the coefficient of static frictions by two above mentioned methods is not equal, then the percentage error can be found out.

PROCEDURE:

1. Set the inclined plane at any angle, clean it and measure it by earlier mentioned procedure. Let this angle be θ.
2. Lubricate the pulley so that there is negligible friction between pulley and string.
3. Place the trolley (block) on the inclined plane at a specified region and tie it with one end of string while the other end of the string passes over the pulley and carries a scale pan at the free end. While doing so, it is important to note that the string is parallel to the inclined plane and string is knot free.
4. Mark a reference point on the plane so as to judge the movement of block at the same place.
5. Put weights slowly in the scale pan till the block just begins to move up the plane and then stop. Note this weight. This is the effort (P). it is worth important that movement of the block should be parallel to the string and string should be parallel to the incline surface.
6. Determine μ_s**'** from the formula (by taking force balance for the pan as well as for the block)

7. (a) Take two readings by changing weight of the trolley keeping angle of plane constant
   (b) Three readings by changing angle of incline and keeping weight of trolley constant.

OBSERVATION TABLE:

WOOD AND WOOD (OR) LEATHER OR ASBESTOS OR STAINLESS STEEL OR.........................OR…………………. (please tick the chosen):

S.N.	Load W (weight of box) (In gm)	Effort (p) (In gm)	Data Required to Calculate θ			$\theta = \tan^{-1}\frac{(l1-l2)}{a}$	$\mu_s = \tan\theta$	$\mu_s' = \frac{P - WSin\theta}{Wcos\theta}$	% error= $\frac{\mu_s' - \mu_s}{\mu'_s} \times 100$
			l_1 (cm)	**l_2 (cm)**	**a (cm)**	**θ**			
1									
2									
3									
4									

RESULTS:

Mean coefficient of friction between ………………&…………is ________.

Mean percentage error for ……….and………..calculated by the two methods is __________.

Comments on the accuracy of the results:

VIVA QUESTIONS:

Q1. Define frictional force and limiting force of friction? What are the characteristics of force of limiting friction?

Q2. What are the causes of friction? Can the friction be made zero?

Q3. Differentiate between:

a) Static and Dynamic coefficient of friction

b) Angle of friction and angle of repose

Q4. Friction is a necessity and evil too. Justify this, giving the practical examples around you.

Q5. What is the effect on the performance of the experiment if the box does not ideally move parallel to the connecting thread?

Q6. If the connecting thread is not parallel to the plane of the apparatus. What type of error is introduced?

Q7. What is the effect of presence of water on the roads on the motion of a car?

Q8. While conducting this experiment, we have determined coefficient of friction by angle of repose and by applying force to the block to make it move upwards. Why?

Q9. Whether coefficient of friction is a property of individual material or the combination of material along which relative motion or a tendency of relative motion exists?

EXPERIMENT NO. 4

JIB CRANE

Experiment No. 4 JIB CRANE

AIM

To Verify the Triangle Law of Forces by using the model of Jib-crane.

APPRATUS:

Jib Crane Apparatus, Weights, Meter scale

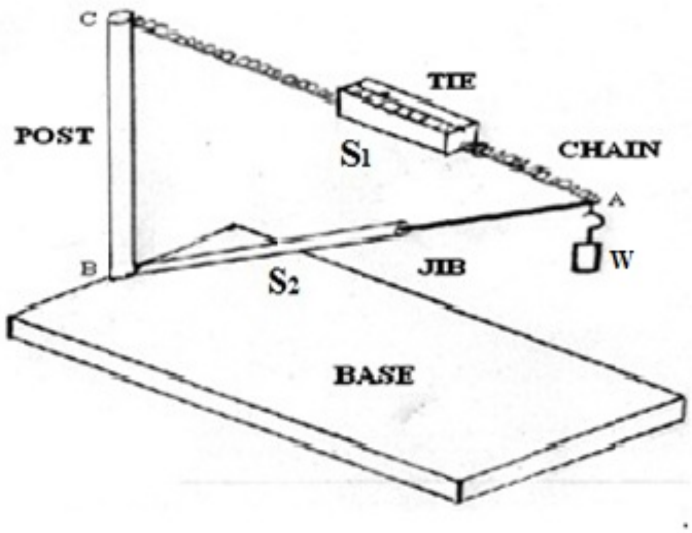
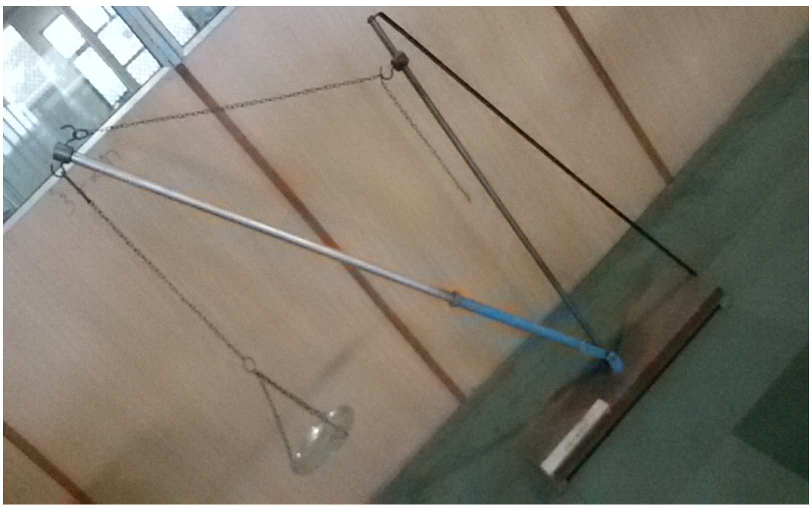


Figure: JIB CRANE APPARATUS

APPARATUS DESCRIPTION:

The Jib Crane has three members. The arm BC is called the post which is vertical. The chain AC is called a Tie and arm AB is called Jib. When a load W is suspended vertically through hook/pan, the arm AC is elongated and the arm AB is compressed. The tensile stress in the arm AC (Tie) is found by the spring balance S_1 attached to the tie (Chain). The arm AB (Jib) is a telescopic pipe containing a spring, which is a compressive spring with value of force S_2 is indicated by graduations marked on the inner pipe.



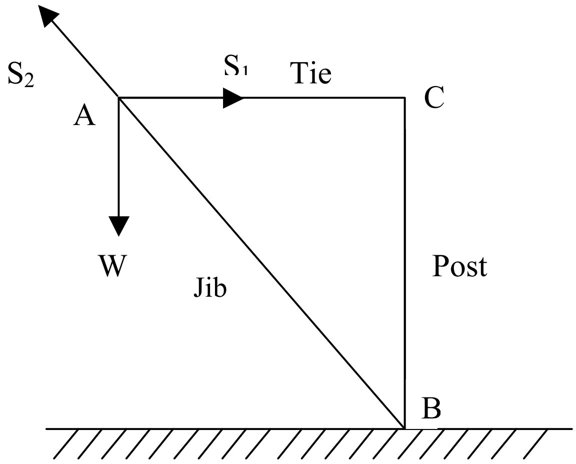


Figure 1: Free body diagram of jib crane

There are three forces S_1, S_2, and W acting at the point A and they keep point A in equilibrium. Whereas the magnitude of force W can be treated as correct, the readings S1 and S2 may not be correct. Let us assume S'1 and S'2 are correct magnitudes. Then a force triangle **abc** can be drawn using forces S'_1, S'_2, and W. By considering the jib crane apparatus, force in the chain is in the direction S_1, jib force is in the direction of S_2, weight W and the post are vertical. Thus the triangle ABC has all the three sides parallel to force triangle **abc**. Therefore they are similar by AAA properties. This results in sides being proportional to forces. It can be seen that we actually do not know S'1 and S'2 at this stage.

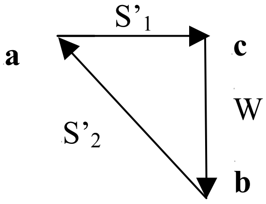


Figure 2: Force Triangle

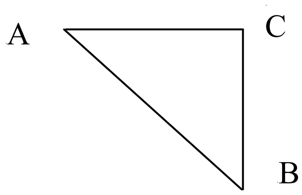


Figure 3: Geometrical Triangle

THEORY

A triangle ABC is constructed using the lengths AB, BC, AC. By using the property of similar triangles (force triangle and length triangle) we get the following formulae:

$$\frac{S'_1}{AC} = \frac{S'_2}{AB} = \frac{W}{BC}$$

It can be assumed that lengths and value of W are correct. This formula is used to calculate the magnitude of forces S'_1 and S'_2.These values are then compared with the measured values of the spring balances S_1, S_2 and the % errors are calculated.

PROCEDURE

1. Make sure the post BC (B is fulcrum, C is where tie is attached) is vertical and measure its length.
2. Suspend a weight W from a point A (without any jerk) and note down the readings of spring S_1 and compression balances S_2.
3. Measure the length of the elongated arm AC and the compressed arm AB using scale.

4. Draw the diagram of triangle ABC to a certain scale, whose sides represent the load W and tensile force (S_1) and compressive forces (S_2). S_1', S_2' can be computed by using $\frac{S_1'}{AC} = \frac{S_2'}{AB} = \frac{W}{BC}$ or by similar triangles properties.
5. Find the % error ((S_1'-S_1/ S_1')*100) between the observed and calculated values.
6. Take at least 5 sets of readings by changing the weight W.

PRECAUTIONS:

1. Measure the lengths accurately.
2. The weight should be suspended gently without any jerk.
3. The initial & final readings of the spring balances should be noted carefully.
4. The jib and the tie spring balances must be properly oiled for free movement.

OBSERVATION TABLE:

S.NO	W kg	LENGTH OF		OBSERVED FORCE		CALCULATED FORCE		PERCENTAGE (%) ERROR	
		TIE (AC) (cm)	JIB (AB) (cm)	TIE (S_1)	JIB (S_2)	TIE (S_1')	JIB (S_2')	TIE $\frac{S1'-S1}{S1'} \times 100$	JIB $\frac{S2'-S2}{S2'} \times 100$
1									
2									
3									
4									
5									

Sources of Error:-

1) The chain has a weight and this will definitely have an effect on S_1, S_2.
2) The jib has a mass and this will also definitely have an effect on S_1, S_2.
3) Zero error in S_1, S_2.
4) Friction in fulcrum at B.

RESULT

The limits of error are varying from __ % to __% in the Tie and from ______% to_____ % in the Jib.

Comment on the accuracy of the results:

VIVA QUESTIONS

Q1. What is a crane? Where it is used?

Q2. What are tie and strut members in the apparatus?

Q3. If three forces are not ideally concurrent, what is the effect on verification? What will be the conditions of equilibrium for this situation?

Q4. The chain has a definite mass and also the jib. What is the effect of these on the final result?

Q.5. In case the post is not vertical; say it makes 87^{o} instead of 90^{o} to the table in some plane,what the effect on the results?

LIFTING MACHINES
(THEORY COMMON TO EXPERIMENTS 5, 6, 7)

A **lifting machine** is used to lift a heavier load ‘W’ by employing a smaller force ‘P’ at some other convenient point thus providing a net Mechanical Advantage. During the process distance moved by effort P is y is and it is much more than the distance moved by load W- x. Crow bar, pulleys, screw jack, winch, worm wheel are some of the lifting machines in use.

The following analysis is applicable for all.

Mechanical Advantage (M.A) = $\frac{\text{Load lifted (W)}}{\text{Effort applied (P)}}$

Velocity Ratio (VR) = $\frac{\text{Distance moved by effort (y)}}{\text{Distance moved by Load (x)}}$

Output Work =W.x
Input work = P.y
Energy spent on friction (E) = P.y – W.x
Efficiency of the machine (η) = (W.x)/ (P.y) = (W/P) / (y/x) = M.A / V.R.

If the η is 100%, then P.y=W.x and E=0. Ideal load is (P.y) / x and the actual load lifted is W. Because of friction, we can lift lesser load than (P.y) / x. The force needed to overcome friction is therefore defined

Frictional force F= (P.y) / (x – W)

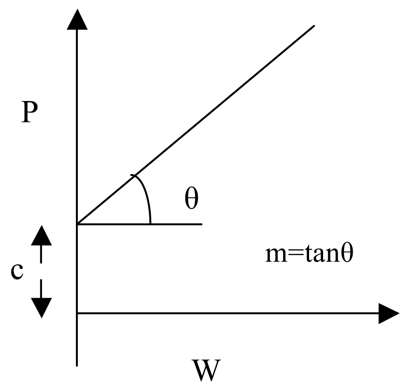
The Law of Machine: “It states that the effort ‘P’ required to lift the load ‘W’ bears a linear relationship with it”. **P=mW +c** (m is the slope of the line AB in the plot between P and W shown below and c is the intercept on Y axis.)

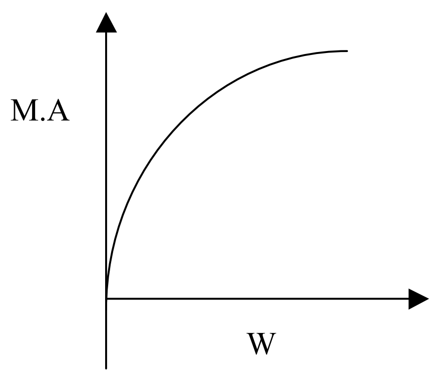
Therefore (P/W) = m + (c/W) or (W/P) = (1/ (m + c/W))

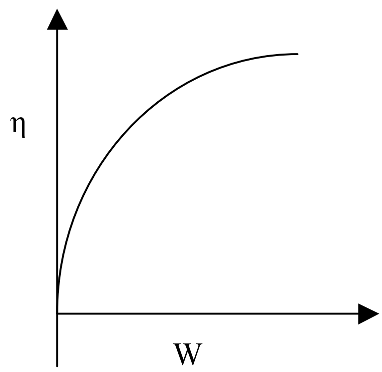
As W $\rightarrow\infty$, (c/W) $\rightarrow$0 and then $\eta \rightarrow \eta_{max}$ also called limiting efficiency.

And corresponding $\text{M.A.} = \frac{1}{m}$ so $\eta_{max} = \frac{1}{\text{V.R.} \times m}$

Now the graph between P &W will be linear if the value of F is constant over various values of W. **<u>In case, the graph P&W is not linear, plot curve between F and W on the same graph.</u>** This will validate the law of machines. The graphs between M.A. & W and η &W should be non linear as shown in the diagrams.







EXPERIMENT NO. 5

SCREW JACK

Experiment No. 5 SCREW JACK

AIM:
To determine the Mechanical advantage, velocity ratio and efficiency of a screw jack and to plot the various graphs i.e. plot the curves between efficiency vs. load, mechanical advantage vs. load, establish the law of machine and find the limiting efficiency.

APPARATUS:
Screw jack, Slotted weights, weight box, hangers, and string.

THEORY

Reversibility and irreversibility of the machine:

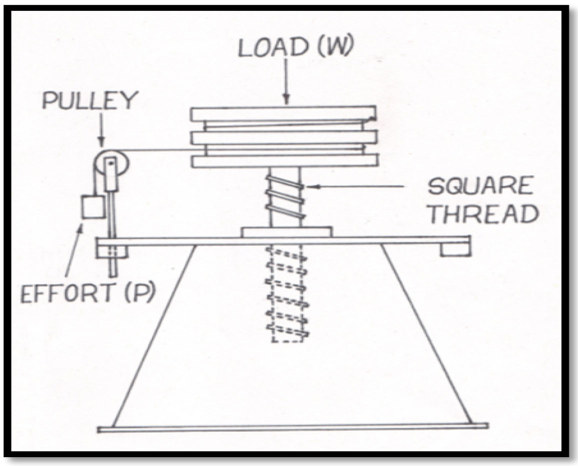
Screw jack is used to lift heavy loads like a car. So, during the operation (like changing a car wheel) if the effort is removed then the car should not come down by itself to prevent the injury to a person working under it. It is possible only when it is self-locked.
Reverse operation of the machine refers to the reverse motion of the machine under the application of load W only when the effort P is removed. It is possible only when the work done by the load overcomes the frictional work.
For irreversible nature of machine

$$Wl_1 \leq Pl_2 - Wl_1 ; 2Wl_1 \leq Pl_2 \quad ; \quad \frac{W/P}{l_2/l_1} \leq 0.5 \quad ; \quad \eta \leq 0.5$$

A machine will therefore not operate in reverse direction on the removal of the effort if its efficiency is less than 50% and hence the machine will be called a self locking machine.

Related Terms:

1. Lead: It is the axial distance moved by the screw in one complete revolution.
2. Pitch: It is the distance between two similar points of consecutive threads in the axial direction.
3. Single start screw: If the lead of the screw is equal to its pitch then it is called Single start screw.
4. Double start Screw: If the lead of the screw is two times the pitch of the screw rod then it is called double start screw.



A screw jack is a lifting device consisting of a square threaded screw which can turn in a fixed nut which generally forms a part of the body of screw jack. If "**D**" is the average diameter of the load pulley and "**p**" is the pitch of the screw, then the distance moved by effort is equal to the rope unwounded from the load pulley which is '$\boldsymbol{\pi}$**D**' in one revolution and the distance moved by the load is "**p**" for single start screw jack.

PROCEDURE:

1. Wrap the rope around the pulley of the screw and pass it over the effort pulley and attach the hanger to the free end of the rope.
2. Put a known value of heavy weight on the head of the screw rod.
3. Now, put a small weight on hanger which is effort P.
4. Now, gently increase the effort by putting the weights of known quantity on the hanger followed by tapping of the load pulley. It should go on until the load pulley just start moving on tapping.
5. Note down that value of weights put on hanger to determine the effort P.
6. Repeat the experiments at least 6 times for different combinations of W and P.

PRECAUTIONS:

1. Pans of both sides should hang freely.
2. Small pulley must be light and frictionless.
3. To reduce friction, lubricate the apparatus.
4. To apply the effort P, both the small pulleys must be used.
5. To calculate effective circumference (πd+t) i.e., distance travelled by the effort P, the thickness of the string (t) should be measured with the help of vernier caliper.
6. To calculate complete effort, the weigh of both the empty pans should be added in the weights placed on the each pan ($P=P_1+P_2+P_3+P_4$).
7. The circumference of the grooved pulley should be measured by thin and inextensible thread.
8. Weights and Efforts should be applied gradually.
9. The string of the grooves should be wound single.
10. On the application of correct Effort, the load will lift upward gradually eith uniform speed.

OBSERVATIONS AND CALCULATIONS:

No. Of starts of screw = double, Pitch of screw(p) = ________________

Average diameter of the pulley, **Dp** = ………..

Velocity Ratio, $\mathbf{VR}=\frac{\mathrm{N\pi Dp}}{\boldsymbol{p}}$

N=Number of revolution of pulley for one pitch=…………………..

S. No.	Load W (in Kg)	Effort P (in grams)	$M.A. = W/P$	V.R	$\eta = \left(M.A./V.R. \right) X\ 100$
1					
2					
3					
4					
5					

RESULTS:

1. Plot the graph between P Vs W, F Vs W; M.A. Vs W and ç Vs W.
2. From graph P Vs W m = _______ c = ________

   Law of machine, P = mW + c = ________
3. From graphs, Maximum efficiency = 1/(VR X m) = ________________

From the plot F Vs W, comment on Law of Machine:

POINTS FOR DISCUSSION:

1. Discuss the variation of graphs. How the efficiency of the arrangement varies with load as indicated by graph.
2. Discuss the limiting efficiency with respect to maximum efficiency obtained from the graph.

VIVA QUESTIONS:

Q.1. If the screw is double start, how does the efficiency changes?

Q.2. Explain irreversibility of the screw jack?

Q.3. Define Law of Machine.

Q.4. What types of threads are used in a screw jack & why?

EXPERIMENT NO. 6

WHEEL AND AXLE

Experiment No. 6 WHEEL & AXLE

AIM:

To determine the Mechanical Advantage (M.A.), Velocity Ratio (V.R.) and Efficiency (η)and to plot the various curves between effort Vs load, Friction force Vs load, M.A. Vs load and efficiency Vs load and establish the law of machine and find limiting efficiency. of a differential wheel & axle.

APPARATUS:
Differential Wheel and Axle Apparatus, Weights, Weight Box, Hangers, String, Meter Scale, Scale, Pan etc

THEORY:

DIFFERENTIAL WHEEL AND AXLE:

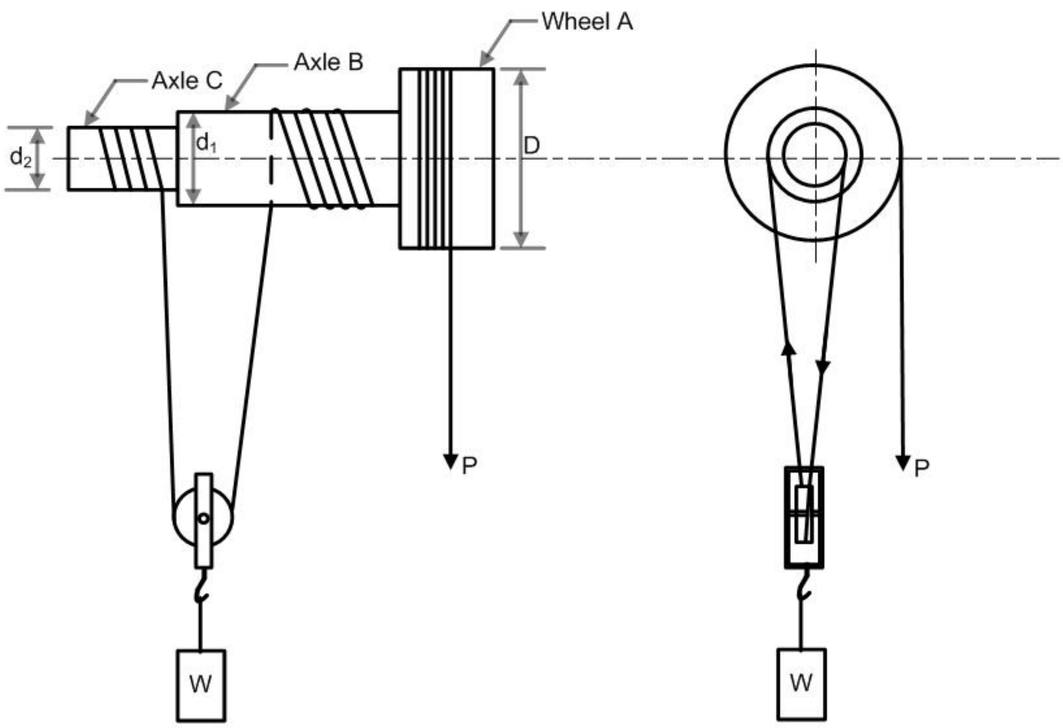


FIG 1. DIFFERENTIAL WHEEL AND AXLE

The arrangement has 3 different diameters d_1, d_2, D as shown above. In this case, The effort string is wound round the wheel A. another string wound round the axle B, which after passing round a movable pulley (to which load W is attached) is wound around the axle C in opposite direction to that of axle B; care being taken to wind the string on wheel A and axle C in same direction. As a result of this, when the string unwinds from wheel A, the other string also unwinds from axle C. but it winds on axle B (observe the above diagram carefully).

Let D= Diameter of effort wheel
d_1= Diameter of the axle B
d_2= Diameter of axle C
W= Load lifted
P= Effort applied to lift the load.

In one revolution of effort wheel, distance moved by effort $= \pi D$
Length of string, which will wound on axle B in one revolution $= \pi d_1$
Length of string, which will unwound in axle C in one revolution $= \pi d_2$
So length of string which will wound effectively in one revolution $= \pi(d_1 - d_2)$

The net distance traveled by load in upward direction $= \dfrac{\pi(d_1 - d_2)}{2}$

Hence the Velocity Ratio of simple wheel and axle, canceling π, $= \dfrac{2D}{d_1 - d_2}$

Also the Mechanical Advantage $= \dfrac{W}{P}$ Efficiency $\eta = \dfrac{M.A.}{V.R.}$

PROCEDURE:

1. Rotate the wheel by some revolution to check whether the rotations are smooth or not.
2. Place some load of known value in the hook without any jerks.
3. Gently increase the effort by putting the weights of known quantity on the pan attached to the effort wheel rope till the load starts lifting slowly for a small distance.
4. Note down the values of load and the effort.
5. Repeat the experiment by taking different values of load.

PRECAUTIONS:

1. Lubricate well the bearing to decrease the frication.
2. Add the weights in the pan gently.
3. The pan carrying the weights should not touch the wall.
4. The load and effort should move slowly.

OBSERVATIONS AND CALCULATIONS:

For Differential Wheel and Axle

Diameter of effort wheel (D) = ______________
Diameter of the larger axle having load (d_1) = ______________
Diameter of the smaller axle having load (d_2) = ______________

S. No.	Load W (in grams)	Effort P (in grams)	$M.A. = W/P$	$V.R. = 2D/(d_1 - d_2)$	$\eta = (M.A./V.R.) \times 100$
1					
2					
3					
4					
5					

Plot the graph between P *Vs*W, F *Vs*W, M.A. Vs W and η Vs W for differential wheel and axle
Find m from graph P Vs W = ________________________

Also find c from graph P Vs W = ________________________

Law of Machine for differential wheel and axle:

RESULTS:

From the graph for differential wheel and axle maximum efficiency = ______________

Value of limiting efficiency = 1/ (m VR) = ______________

Comment on the accuracy of the results:

VIVA QUESTIONS

Q.1 What is the difference between simple wheel & axle and differential wheel & axle?

Q.2 What is Law of Machine and limiting efficiency?

Q.3 What is the effect on the velocity ratio if the diameter of either(load / effort) pulley increases?

Q.4 Is it a reversible or an irreversible arrangement and why?

Q.5 How will you identify effort wheel and load wheel?

EXPERIMENT NO. 7

WORM AND WORM WHEEL

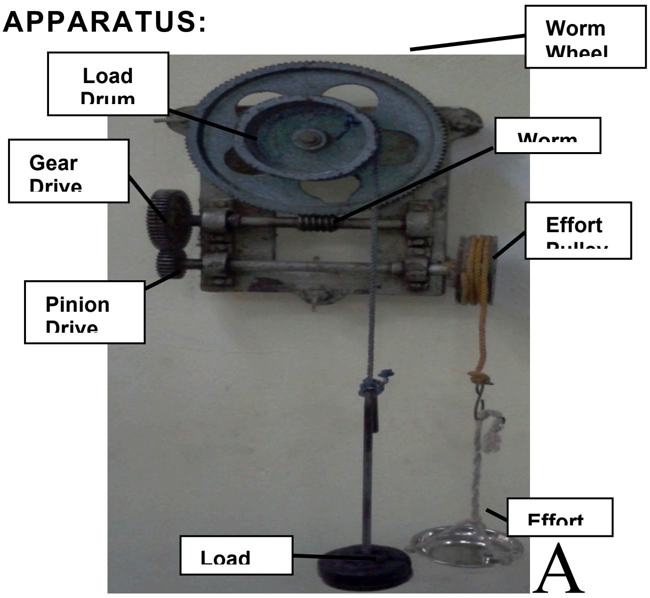
Experiment No. 7 WORM AND WORM WHEEL

AIM:
To determine the Mechanical advantage (M.A.), Velocity Ratio (V.R.) and Efficiency (η) of a **Worm and Worm Wheel** and to plot various graphs i.e. between effort Vs load, M.A. Vs load, efficiency Vs load and establish the law of machine and find the limiting efficiency.

APPARATUS:

Worm and worm wheel apparatus (A), weights, weight box, hangers, string, outside caliper, meter scale, pan.

DESCRIPTION OF APPARATUS:



D_L = Diameter of the load drum = 138 mm

D_P **=** Diameter of the effort pulley = 120 mm

T_W = No. of teeth on the worm wheel = 120

$\mathbf{T_G}$ **=** No. of teeth on the gear of the gear drive = 50

T_P = No. of teeth on the pinion of the gear drive = 25

Worm & Worm Wheel apparatus setup:

The worm and worm wheel consists of a square threaded screw called worm which is engaged to a toothed wheel called worm wheel.

PROCEDURE:

1. Determine the diameters of effort pulley and load drum. Measure the circumference of effort pulley and load drum with the help of outside caliper or meter scale. Note the values. Find the number of teeth on the worm wheel (T_W) and note these. Verify the values from the data given above.
2. Find effective circumference of effort pulley and load drum with the help of threads and meter scale. Note these.
3. Ensure the wheels move freely.
4. Fasten one end of a string on the load drum and wind it in clockwise direction and attach the hanger for applying load. Note the total load (W).

5. Fasten one end of a string on the effort pulley and wind it in anticlockwise direction. Note the weight of scale pan for effort pulley.
6. Attach pan with free end of the string and put some known weights gently. Add more weights till the effort pan starts to move down. Load will move up at the same rate. Effort pulley should rotate slowly for at least one revolution. Note the value of effort weight (P).
7. Repeat this at least six times by changing the values of load lifted (W).

PRECAUTIONS:

1. Lubricate well the bearing of worm and teeth of worm wheel to decrease the frication.
2. Add the weights in the pan gently.
3. The pan carrying the weights should not touch the wall.
4. The load and effort should move slowly.
5. The spring should not overlap on the drum or the pulley.

In one revolution of the effort pulley, the distance moved by effort $= \pi D_P$

And in one revolution of the effort pulley, the worm wheel will rotate by T_P/T_G revolutions.

During this period the worm (or the worm shaft) will rotate by $(1 / T_W) \times (T_P / T_G)$ **revolutions**.

Hence distance moved by load= $\pi D_L \times (1 / T_W) \times (T_P / T_G)$

$$\text{Velocity Ratio (V.R.)} = \frac{\text{Distance moved by effort}}{\text{Distance moved by load}}$$

$$= \frac{\pi D_P}{\pi D_L \times (1 / T_W) \times (T_P/T_G)}$$

$$= \frac{D_P \times T_W \times T_G}{D_L \times T_P}$$

$$\text{Efficiency of the machine } (\eta) = \frac{\text{Mechanical Advantage (M.A.)} \times 100\ \%}{\text{Velocity Ratio (V.R.)}}$$

$$\text{Where Mechanical Advantage (M.A.)} = \frac{\text{Load lifted (W)}}{\text{Effort applied (P)}}$$

OBSERVATIONS:

S. No.	**Load W** (in grams)	**Effort P** (in grams)	**M.A = W/P**	**V.R.=** $\frac{D_P \times T_W \times T_G}{D_L \times T_P}$	**Efficiency η (%) =** $\frac{M.A}{V.R} \times 100$
1					
2					
3					
4					
5					

CALCULATIONS:

Now the plot between P Vs W, η Vs W and M.A. Vs W should be non linear as shown in the diagram.

POINTS FOR DISCUSSION:

From graph 1: Law of Machines m=___________; C=____________; P=___________

From graph 3: max η = __________; Limiting η = 1/ (m VR) = ________________

Comment on the accuracy of the result:

VIVA VOCE QUESTIONS

Q1. Define Mechanical Advantage, Velocity Ratio and Efficiency of a machine?

Q2. In case of an ideal machine, what is the value of M.A. / V.R.?

Q3. What does the value of ‘c’ in the curve between effort vs load indicate?

Q4. If instead of worm another pair of gears was used. What will be the change in V.R.?

Q5. How will you identify effort and load wheels?

EXPERIMENT NO. 8

TRUSS

Experiment No. 8 TRUSS

AIM:

To verify forces in the members of a Truss.

APPARATUS:

A Truss (i.e. triangular truss) having one hinged and one roller supports, weights, spring balance, measuring tape.

THEORY:

A truss is a structure that comprises triangular units or system of uniform bars or members joined together at their ends by rivets or welding and constructed to support loads. The members of a truss are straight members and the loads are applied only at the joints. Every member of a truss is a two-force member.

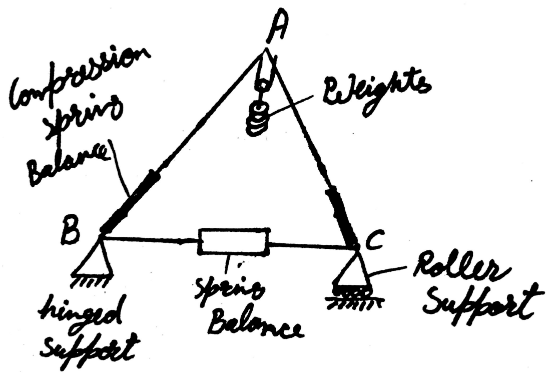


Figure:-Truss

PROCEDURE:

1. Note down the initial force readings in the truss.
2. Apply one kg weight on the vertex A of the triangular truss and note the readings of force in all the members of truss as shown in spring balance.
3. Measure the length of all the members of truss.
4. Repeat the steps by increasing the suspended load.
5. Take at least 4-5 readings.

PRECAUTIONS:

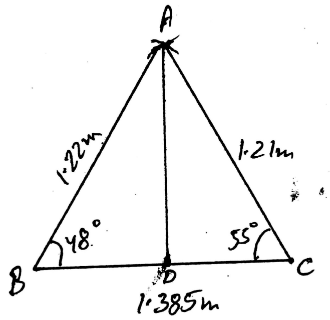
1. Apply the loads without any jerk.
2. Check or read the force in spring balance accurately.
3. Do not forget to subtract force due to its own weight from the force in members due to applied load or suspended load.

OBSERVATION TABLE:

S.NO.	Length (mm) in			Initial force (kg) in			Final force (kg) in			Weight (kg)
	AB	AC	BC	AB	AC	BC	AB	AC	BC	
1										
2										
3										
4										
5										

S.NO.	Observed force (kg) in			Calculated force (kg)			Percentage error (%) in		
	AB	AC	BC	AB	AC	BC	AB	AC	BC
1									
2									
3									
4									
5									

SAMPLE CALCULATION:



Let W=5 kg
BD = AB Cos 48^0
BD = 0.82 m
Moment across B =R_C * 1.385 = 5 * 0.82
R_B = 2.96 Kg R_C = 2.04 Kg
Using joint B, F_{AB} = R_B/(Sin 48°)= 3.98 Kg

F_{BC} = F_{AB} cos48° = 2.66 Kg
Using joint C, F_{AC} = R_C/(Sin 55°) = 2.49 Kg

RESULTS:

The forces in members of a truss are verified with limited percentage error.

Comment on the accuracy of the results:

VIVA QUESTIONS

Q1. What is Statically Determinate Truss?

Q2. What is difference between truss and frame?

Q3. What do you mean by redundant truss?

Q4. What do you mean by deficient truss?

EXPERIMENT NO.9

BELL CRANK LEVER

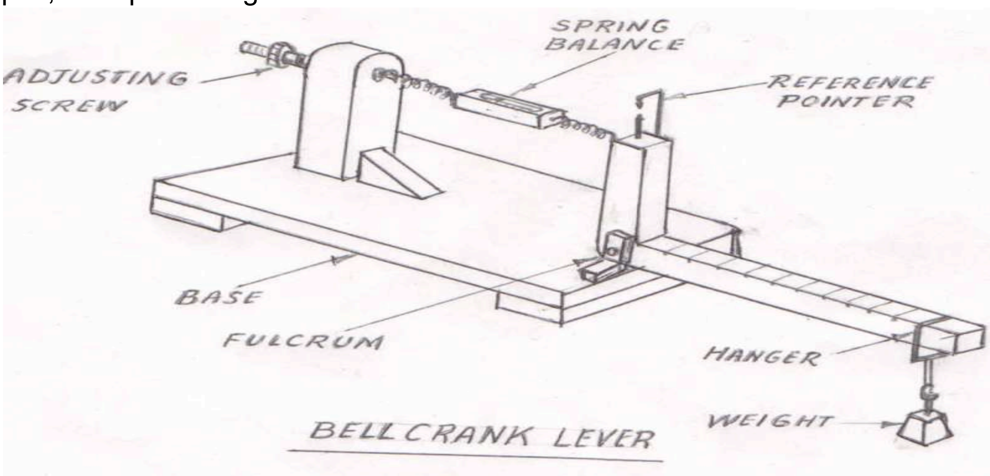
Experiment No-9 BELL CRANK LEVER

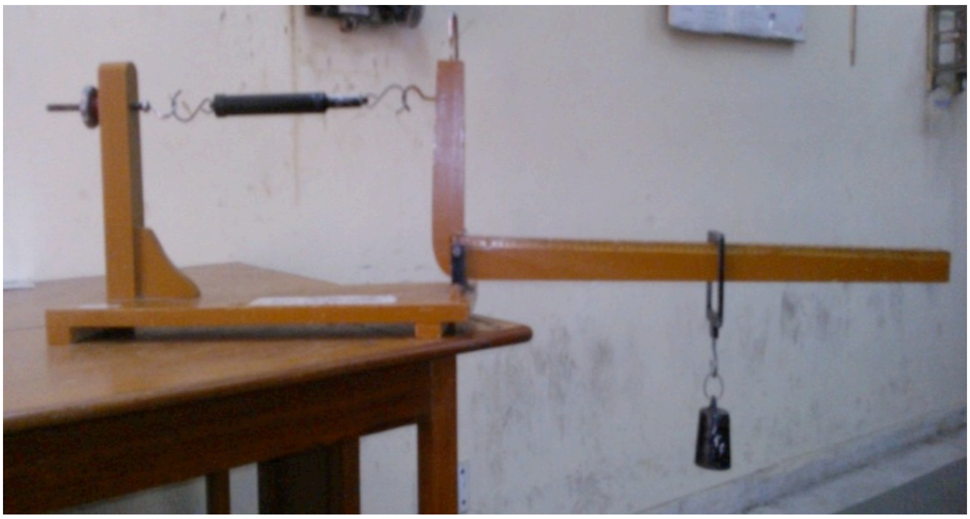
AIM
To Verify Law of Moments Using Bell Crank Lever

APPARATUS
Bell Crank Lever, weights, hanger, meter scale, spirit level.

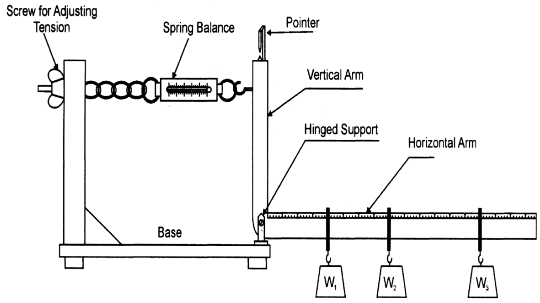
THEORY

According to the law of moments, "The algebraic sum of the moments of all the forces about a point in a body is zero for equilibrium." In other words, sum of the clockwise moments about a point is equal to the sum of anticlockwise moments about the same point for equilibrium. Here, in this experiment, the Bell Crank Lever (bent at 90^0) apparatus is used to verify the law of moments.
As refer to the fig (1), the moment of suspended load (W) about the fulcrum should be equal to moment of tension (T) (or reading in the spring balance) about the fulcrum. If the two moments are not equal, then percentage error is found between the two moments.





(Fig-1) Bell Crank Lever



BELL CRANK LEVER APPARATUS

PROCEDURE:

1. Using spirit level ensure the base is horizontal. Keep the spirit level on the lever arm and adjust the screw to make it horizontal. At this position, check if the pointer A is exactly above pointer B. If not, make adjustment. In this position, the lever arm is horizontal and the other arm is vertical.
2. Note the initial reading of spring balance (because of chain & self weight of lever).
3. Note the distances as indicated in Fig 2. Observe the scale on the lever arm. Does zero start at Fulcrum? If not, identify and apply the correction to be made in the distances measured.
4. A weight 'W' at the lever arm was suspended at a known distance say (x) from the fulcrum 'F', the orientation of point 'A' and 'B' will get disturbed.
5. The orientation was established again by adjusting the screw 'S' as explained, by coinciding pointers A is just above B. The spring balance reading was noted down and the difference between this reading and initial reading of spring balance was noted down say (**To**).
6. The perpendicular distance (y) from the chain carrying the spring balance from the fulcrum F was noted.
7. Now compute Tc from the equation:

   $W \times x = Tc \times y$

   If Tc and To (corrected considering initial reading) are not same, there is an error. Calculate the percentage error-

   = 100 x (Tc-To)/Tc.

7. Take three sets of readings with different weights suspended at different distances/space holes.

PRECAUTIONS:

1) Do not overload the horizontal arm as it may bend or crack at the hinge.

2) Note if any, the zero error of the spring balance& accordingly correct the readings of the tensile force.
3) Carefully place the loads in the hangers as they may slip & cause accident.

OBSERVATION TABLE

Initial reading of Spring Balance = …………..kg
Perpendicular distance y of Chain from Fulcrum (F) = ………… cm [as shown in figure2]
Suspended weight (W) = …………kg

S.No	Distance (x)of W from fulcrum F(cm)	Spring balance reading (To) (Final-Initial)	Calculated value $Tc=\frac{W*x}{y}$	Difference (Tc-To)	%Error = [(Tc-To)×100]/Tc
1					
2					
3					
4					
5					
6					

RESULTS:
From calculation the law of moment is verified as clockwise moment is equal to anticlockwise moment within the percentage error of ………….. %.

Comment on the accuracy of the results:

VIVA VOCE QUESTIONS:

Q.1 Why is it named as bell crank lever?

Q.2 Why is it necessary to bring the lower arm of lever in horizontal position after applying the load?

Q.3 What is the effect of weight of spring balance & weight of the chain on the horizontal fixing hook?

Q.4 Apart from using it for ringing the bell give any other practical applications?

Q.5 What is the effect of friction at the fulcrum on the performance of the experiment?

Q.6 If a ball bearing is substituted at the fulcrum, how is its performance affected?

Q.7 What will be the total force at hinge of bell crank lever?

Q.8 Draw the Free Body Diagram of Bell Crank Lever.

END