

## Experiment no. 1

### PARALLELOGRAM LAW OF FORCES

#### Aim:

To verify the Parallelogram Law of Forces.

#### Apparatus:

Drawing sheet, pins, mirrors, weight pan, weights and pulleys.

#### Theory:

The parallelogram law of forces enables us to determine the single force called resultant which can replace the two forces acting at a point with the same effect as that of the two forces. This law was formulated based on experimental results. This law states that if two forces acting simultaneously on a body at a point are represented in magnitude and direction by the two adjacent sides of a parallelogram, their resultant is represented in magnitude and direction by the diagonal of the parallelogram which passes through the point of intersection of the two sides representing the forces.

$$R = \sqrt{P^2 + Q^2 + 2PQ \cos \theta}$$

Where R is the resultant force

$\theta$  is the angle between P and Q.

$$\tan \alpha = \frac{Q \sin \theta}{P + Q \cos \theta}$$

Where  $\alpha$  is the angle between P and R.

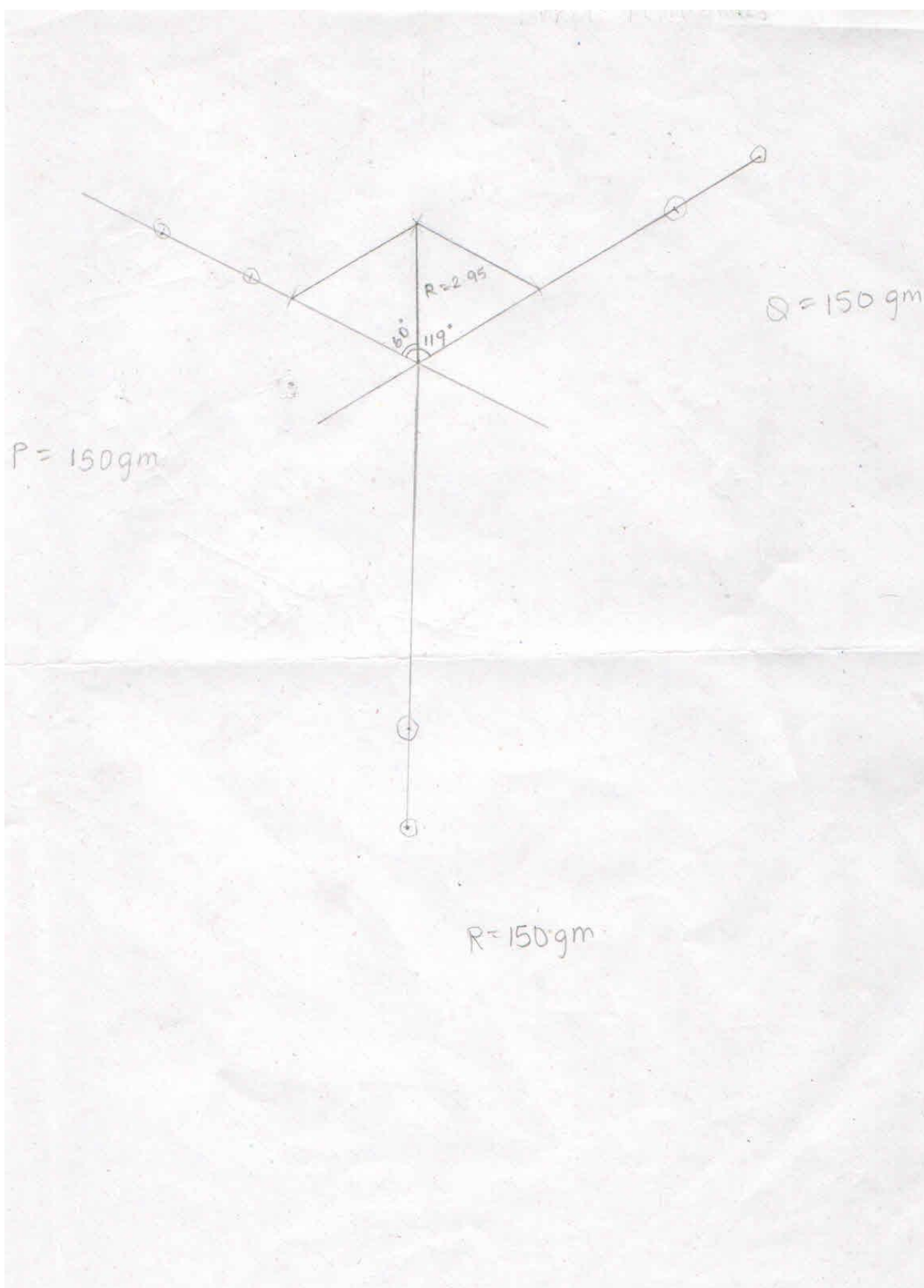
#### Procedure:

- 1) Two pulleys are mounted on a board, which is fixed on a wall. A string is passed through both the pulleys. Another string is tied to this string at the center of the pulleys. Weight pans are attached to the two ends of the string.

- 2) Fix a drawing sheet on the board. Add weights in any two pans in such a way that the sum of the weights in any two pans is greater than the third. The system of forces will come to equilibrium on some part of the drawing sheet.
- 3) Take a mirror and place it behind the strings. Mark the images of the strings on the drawing sheet. Remove the drawing sheet and find the resultant of the two forces graphically and analytically.
- 4) Change the weights and repeat the procedure for each set of weights.

**Observation table:**

Force ( in grams)			Resultant R Graphically	Angle Between P and Q	Resultant Angle $\alpha$ Between P and R	Angle $\alpha$ Analytically Between P and R	Resultant R analytically
P	Q	R					
150	150	150	$2.95 \times 50 = 147.5$	$119^\circ$	$60^\circ$	$59.5^\circ$	152.25



**Model Calculations:**

$$R = \sqrt{3^2 + 3^2 + 2PQ \cos 119}$$

$$= 3.045 \times 50 = 152.25$$

$$\tan \alpha = \frac{3 \times \sin 119}{150 + 150 \cos 119}$$

$$\alpha = 59.5^\circ$$

**Result:**

# PRINCIPLE OF MOMENTS

## Aim:

The verification of principle of moments.

## Apparatus:

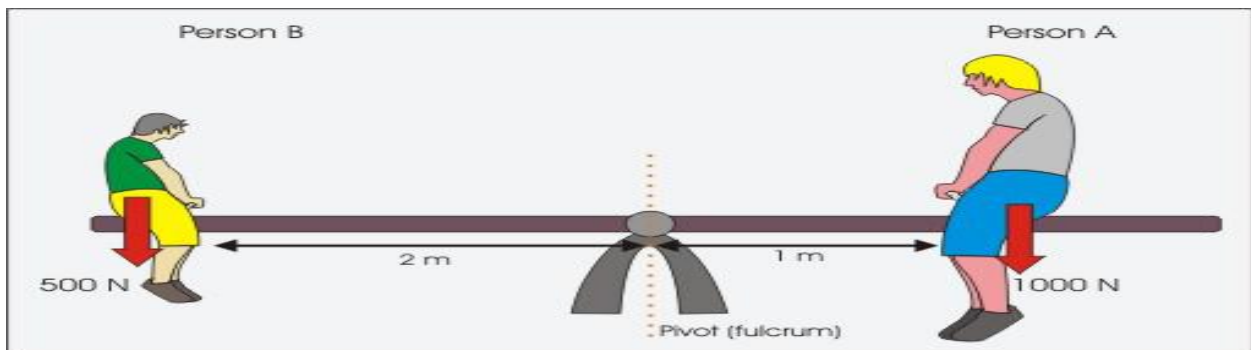
Drawing sheet, pins, mirrors, weight pan, weights and pulleys.

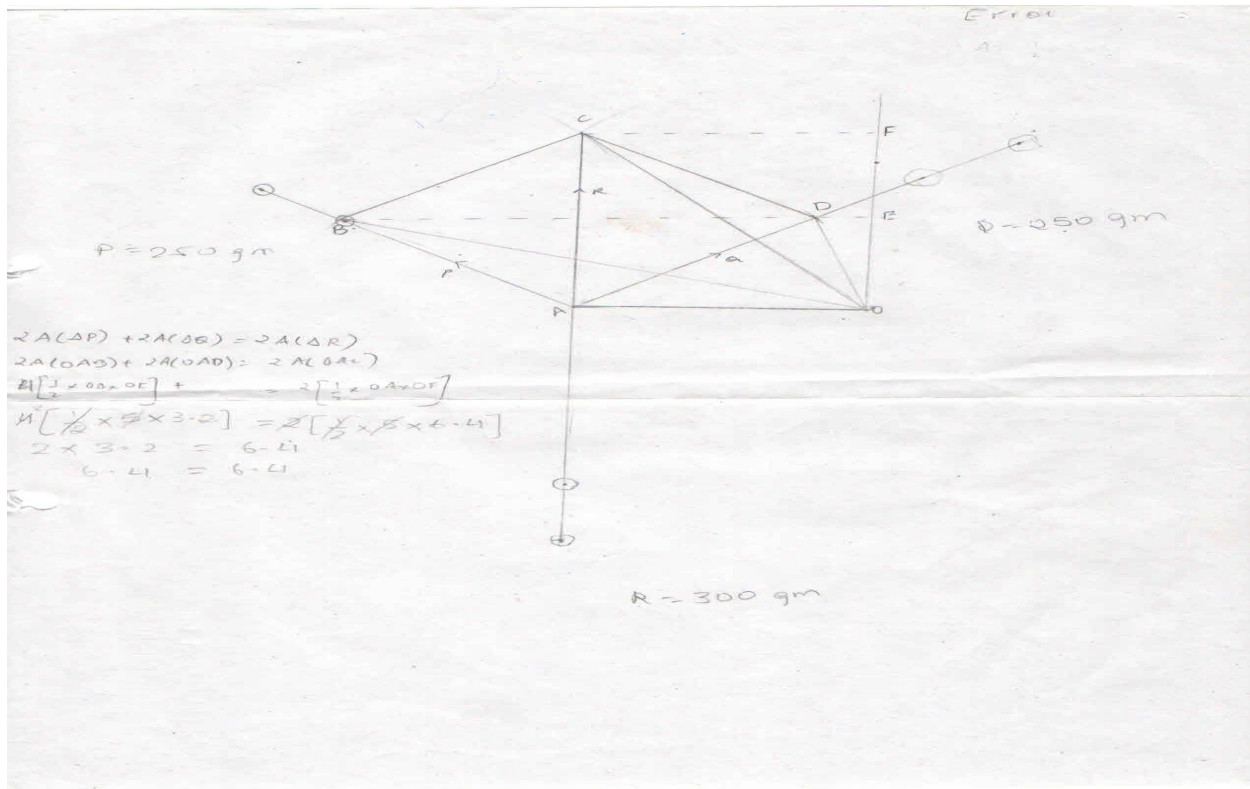
## Theory:

The moment of a force at a point is equal to the product of force and the perpendicular distance of the point from the line of action of the force. Principle of moment states that the moment of the force about a point is equal to sum of the moments of its components about the same point. Geometrically the moment of the force is equal to twice the area of the triangle whose base is the line representing the force.

## Procedure:

- 1) Two pulleys are mounted on a board, which is fixed on a wall. A string is passed through both the pulleys. Another string is tied to this string at the center of the pulleys. Weight pans are attached to the two ends of the string.
- 2) Fix a drawing sheet on the board. Add weights in any two pans in such a way that the sum of the weights in any two pans is greater than the third. The system of forces will come to equilibrium on some part of the drawing sheet.
- 3) Take a mirror and place it behind the strings. Mark the images of the strings on the drawing sheet.
- 4) Remove the drawing sheet and find the resultant of the two forces graphically. Change the weights and repeat the procedure for a different set of weights.
- 5) After completing the parallelogram, consider any point O which is the moment centre. Join all the corners of the parallelogram to this point O, to form triangles.
- 6) Find the areas of the triangles so as to verify the principle of moments.





### Model Calculations:

$$2A(\Delta P) + 2A(\Delta Q) = 2A(\Delta R)$$

$$2A(\Delta OAB) + 2A(\Delta OAD) = 2A(\Delta OAC)$$

$$2(0.5 \times OA \times OE) + 2(0.5 \times OA \times OE) = 2(0.5 \times OA \times OF)$$

$$6.4 = 6.4$$

### Result:

### Experiment no. 3

## CONCURRENT AND NON-CONCURRENT FORCES

### Aim:

To verify the system of given concurrent and non-concurrent forces are in equilibrium using converse of the law of polygon of forces.

### Apparatus:

Drawing sheet, pins, mirrors, weight pan, weights and pulleys.

### Theory:

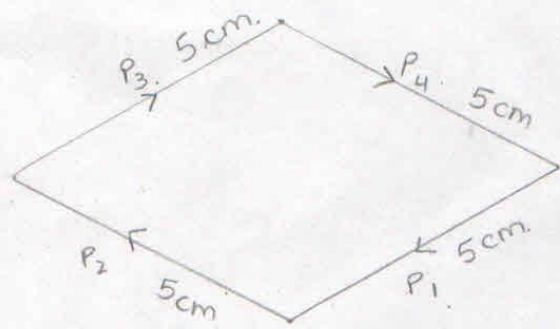
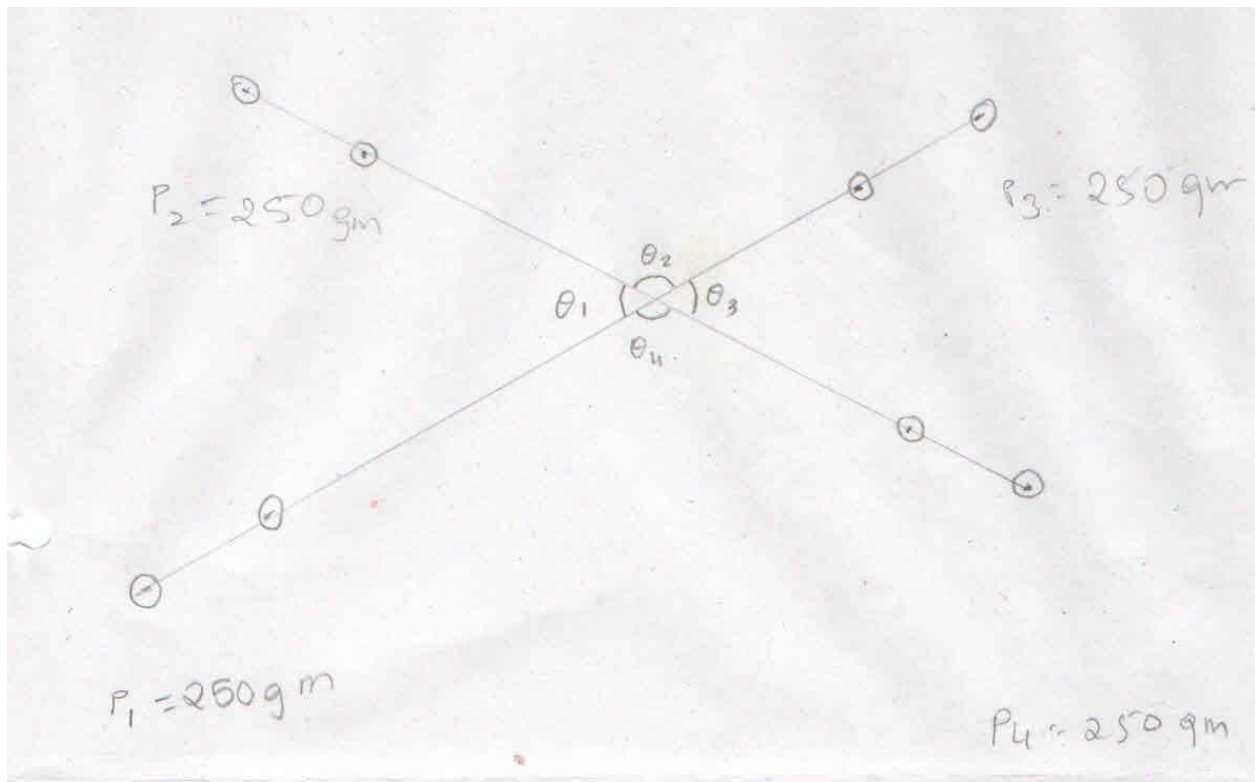
According to the converse of the law of polygon of forces, if the number of forces acting at a point is represented in magnitude and direction, by the sides of a closed polygon taken in order, the forces shall be in equilibrium.

### Procedure:

- 1) Two pulleys are mounted on a board, which is fixed on a wall. A string is passed through both the pulleys. Another string is tied to this string at the center of the pulleys. Weight pans are attached to the two ends of the string.
- 2) Fix a drawing sheet on the board. Add weights in any two pans in such a way that the sum of the weights in any two pans is greater than the third. The system of forces will come to equilibrium on some part of the drawing sheet.
- 3) Take a mirror and place it behind the strings. Mark the images of the strings on the drawing sheet.
- 4) Change the weights and repeat the procedure for a different set of weights.
- 5) Remove the drawing sheets and draw the closed polygon.

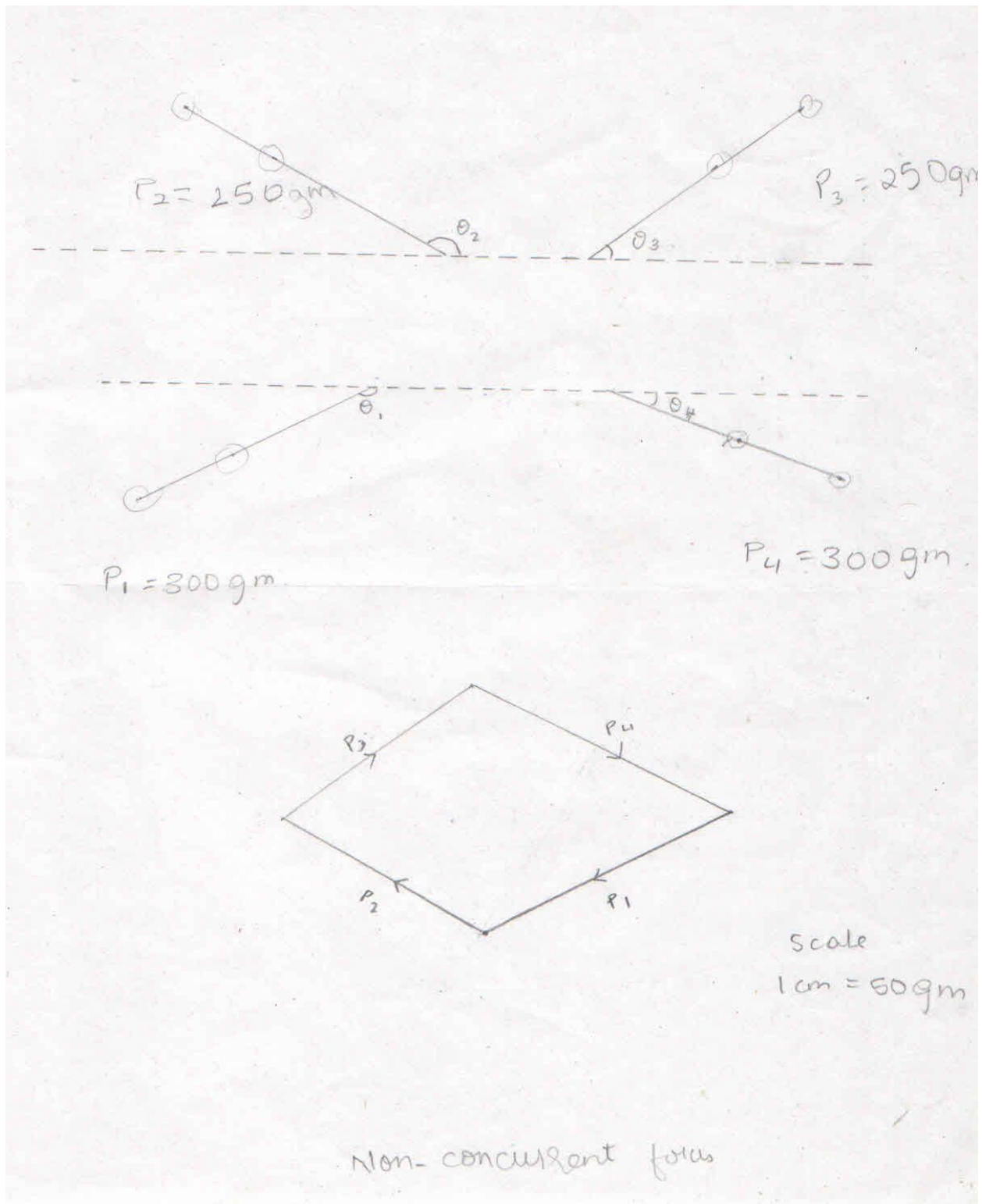
### Observations:

Type of Force system	Obs. No.	$\theta_1$	$\theta_2$	$\theta_3$	$\theta_4$	P1 gms	P2 gms	P3 gms	P4 gms
Concurrent Force system	O1	$57^\circ$	$123^\circ$	$57^\circ$	$123^\circ$	250	250	250	250
Non-Concurrent Force system	O2	$151^\circ$	$150^\circ$	$39^\circ$	$21^\circ$	300	250	250	300



Scale  
 $1 \text{ cm} = 50 \text{ g}$

concurrent



**Result:**

## Experiment No. 4

### JIB CRANE

#### Aim:

To find out forces in the jib member and tie member of the jib crane experimentally and verify it analytically and graphically.

#### Apparatus:

Jib crane, load hanger, weights and measuring tape.

#### Theory:

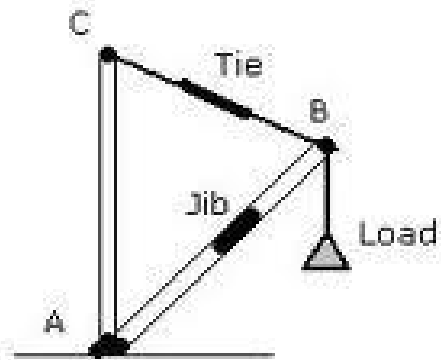
The jib crane is an example of three concurrent forces. The forces in the tie and the jib can be calculated experimentally. Analytically it can be found by making use of Lami's theorem, which states that when three forces acting on a body are in equilibrium, then each force is proportional to the sine of the angle between the other two forces.

#### Procedure:

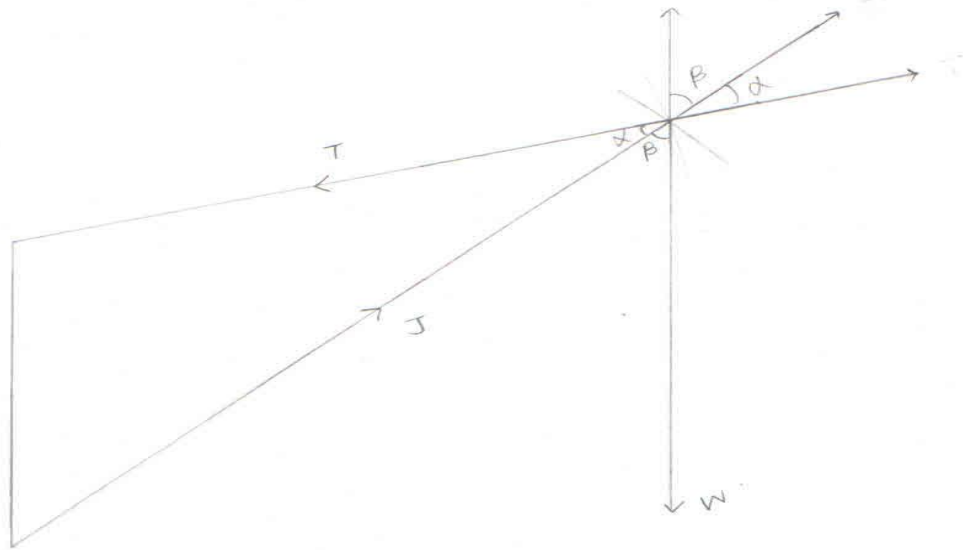
- 1) Note the initial reading in the spring balance at the tie member and spring support at the jib.
- 2) Suspend a known weight in the hanger at the apex.
- 3) Note the final readings in the spring balance and spring support.
- 4) Determine the effective forces in the jib and tie. (Final reading – initial reading)
- 5) Repeat the procedure for different values of the suspended weight.
- 6) Forces in the jib and tie members are found analytically using Lami's theorem.
- 7) Forces in the jib and tie members are found graphically by drawing the space vector diagram.

#### Observation table:

Load At apex (kg)	Spring support				Experimentally (kg)		Analytically (kg)	
	Final		Initial		Jib	Tie	Jib	Tie
	Jib	Tie	Jib	Tie				



Experimental setup



$$\frac{J}{\sin(\alpha + \beta)} = \frac{T}{\sin(180 - \beta)} = \frac{W}{\sin(180 - \alpha)}$$

since  $W = 1.006$

$$J = \frac{1.006 \times \sin(29.0 + 45.5)}{\sin(180 - 29.0)}$$

$$= 1.999 = 2 \text{ kg}$$

For 1.006 kg

$$T = \frac{1.006 \times \sin(180 - 45.5)}{\sin(180 - 29.0)}$$

$$= 1.48 \text{ kg}$$

$$\alpha = 29.2^\circ$$

$$\beta = 45.5^\circ$$

**Result:**

## Experiment No. 5

### COEFFICIENT OF FRICTION

#### Aim:

To determine the co-efficient of friction between wood and glass.

#### Apparatus:

Glass pane, wooden block, pulleys and weights.

#### Theory:

When one body moves, or tends to move tangentially over the surface of the other, it experiences a force which opposes the motion. This force acting opposite to the direction of motion is called friction.

- a) Angle of friction: The normal reaction and the frictional force can be combined into one single resultant force. The angle which this resultant makes with the normal reaction is called angle of friction. It is denoted by  $\Phi$ .

$$\tan \Phi = \mu$$

Where  $\mu$  is co-efficient of friction.

- b) Co-efficient of friction ( $\mu$ ) : It is the ratio of limiting frictional force to the normal reaction.

$$\mu = \frac{F}{N}$$

where F is the frictional force

N is the normal reaction

#### Procedure:

- 1) Set the plane horizontally either with the help of a spirit level or by making the inclination of the plane  $0^\circ$ .
- 2) Take a string with a pan attached to it and pass the string over the pulley fixed to the plane in such a way that the string is parallel to the plane.
- 3) Attached to the other end of the string, is a wooden block kept on the plane.
- 4) Place the weights in the pan and record the weights in the pan. Record the weight at which the wooden block is about to move.
- 5) Repeat the procedure by placing different weights on the wooden block for two more readings.

**Observation table:**

Weight Of block W1 (gms)	Weight On block W2 (gms)	Total Weight W=W1+W2 (gms)	Weight of Pan P1 (gms)	Weight in Pan P2 (gms)	Total Effort P=P1+P2 (gms)	$\mu = \frac{P}{W}$
50	200	250	31	20	51	0.2



Fig. 3. The Inclined Plane

**Result:**

**Experiment No. 6**  
**BEAM REACTIONS**

**Aim:**

To determine the reactions of the beam experimentally and analytically for the following cases of beam:

- i) Simply supported at both ends.
- ii) Simply supported with an overhang on one side.
- iii) Simply supported with an overhang on both sides.

**Apparatus:**

A beam with spring support, a load hanger, weights and measuring tape.

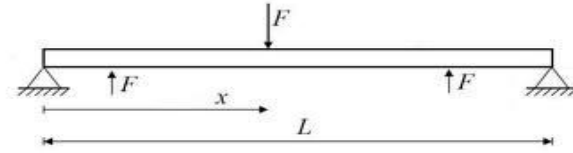
**Theory:**

A beam is a structural element which has one dimension (length) considerably larger than the other two dimensions in the cross-section and is supported at few points. It is subjected to lateral loads. Due to applied loads, reactions develop at supports and the system of forces consisting of applied loads, self weight and reactions keep the beam in equilibrium. The forces constitute a system of coplanar non-concurrent system in equilibrium. Thus if a body is in equilibrium, then the conditions of equilibrium to be followed are as follows:

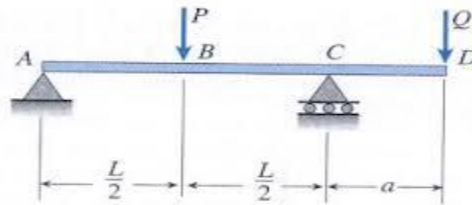
- i)  $\Sigma H = 0$
- ii)  $\Sigma V = 0$
- iii)  $\Sigma M = 0$

**Procedure:**

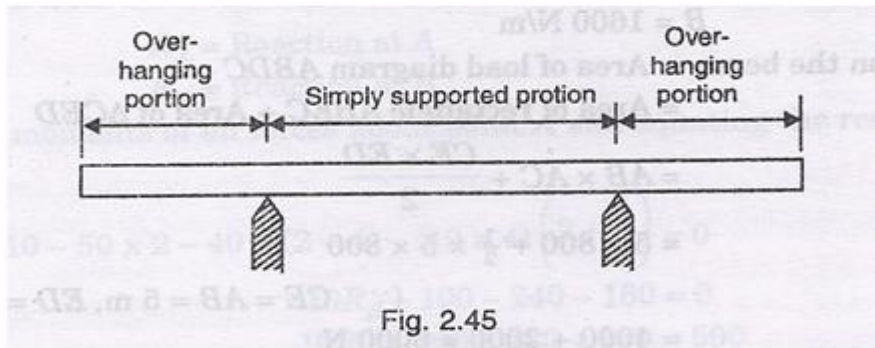
- 1) Measure the span of the beam which is the centre to centre distance between the spring supports.
- 2) Note the initial readings on both the spring supports.
- 3) Add some weight on the load hanger which may be placed at any point in the span of the beam and note down the distances of the load from the supports.
- 4) Also note down the readings of the spring balance. The first reading will give the experimental value of the support reaction.
- 5) Change the position of the beam support such that the beam is overhanging on one side and thereafter repeat the procedure after making the beam overhanging on both sides.



**Beam simply supported at both ends**



**Beam with overhang on one side**



**Beam with overhang on both ends**

**Observation table:**

Type of Beam	Spring support reading (kg)				Experimentally (kg)		Analytically (kg)	
	Final		Initial					
	Ra	Rb	Ra	Rb	Ra	Rb	Ra	Rb
Simply Supported								
Overhang on one side								
Overhang on both sides								

**Result:**