EXPERIMENT. NO.1

REACTIVE FORCES IN SIMPLE SUPPORTED BEAM

Objective:-

To verify the reactions of beam & principle of moments with the help of simply supported beam

Apparatus: -

Simply supported beam apparatus, meter scale, weights etc.

Theory: -

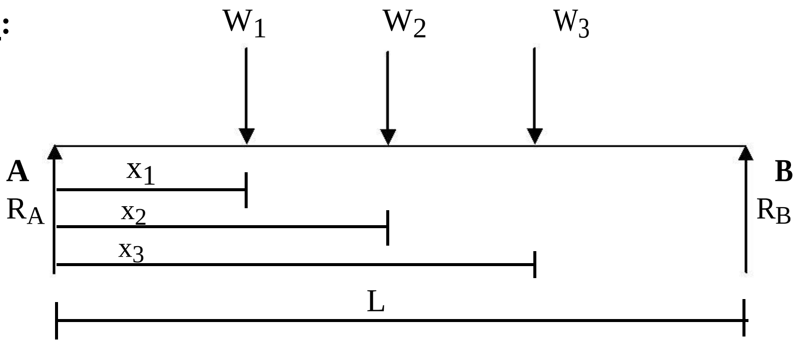
A rigid body is said to be in equilibrium, when all forces whether, active & reactive forces acting on the body reduce to zero.

Thus the system of equilibrium forces, will not impart motion of translation or rotation of rigid bodies.

Therefore the equations of equilibrium are

$\Sigma F_X = 0, \Sigma F_Y = 0, \Sigma M = 0.$

Figure:



Procedure: -

a) Note the initial reading on the compression balance A & B when the beam is supported.

b) Suspend two different weights from the sliding hook against any division marked on beam.

c) Note the reaction on the beam given by reading of compression balance taking in to account the initial0 reading.

d) Calculate the reaction at both ends analytically.

e) Find out the % error in reactions.

Repeat the above procedure for different masses at different positions & take five reading.

Observation Table –

i.	Initial reading on scale A	=	0 N
ii.	Initial reading on scale B	=	0 N
iii.	Length of the beam (L)	=	1000 mm

Sr No	Reading on scale A (N)	Reading on scale B (N)	W_1 (N)	W_2 (N)	W_3 (N)	x_1 (mm)	x_2 (mm)	x_3 (mm)
1.	14.715	14.715	9.81	9.81	9.81	300	500	750
2.	16.677	23.544	9.81	9.81	19.62	300	500	750
3.	15.696	14.715	9.81	9.81	9.81	250	550	700
4.	20.601	18.639	9.81	19.62	9.81	250	550	700

<u>Formulae:</u> –

$\sum M_A = 0$

$$\therefore R_B = \frac{W_1 * (x_1) + W_2 * (x_2) + W_3 * (x_3)}{L}$$

$\sum F_Y = 0$

$\therefore R_A = W_1 + W_2 + W_3 - R_B$

<u>Results</u>: –

Sr no.	Observed Reaction A (N)	Analytical Reaction A (N)	% Error	Observed Reaction B (N)	Analytical Reaction B (N)	% Error
1.	14.715	14.224	3.45	14.715	15.20	3.22
2.	16.677	16.677	0	23.544	22.56[illegible]	4.34
3.	15.696	14.715	6.66	14.715	14.715	0
4.	20.601	19.1295	7.69	18.639	20.110	7.3
5.						

<u>Conclusion</u>: -

1. Studied coplanar parallel force system.
2. Observed value and analytical values of reactions are approximately same.
3. Some error occurred due to instrument & manual handling.

<u>Sample Calculation</u>

EXPERIMENT. NO. 2
BELT FRICTION – FLAT BELTS

Objective: -

To determine coefficient of friction.

Apparatus: - Belt friction apparatus, Flat belt and Weights.

Theory: -

A) Law of friction –

Coulomb has conducted several experiments on friction, the results of which are summarized as laws of friction.

1) Total friction that can be developed is independent of the magnitude of area of contact.

2) The total friction that can be developed is proportional to the normal force.

3) Coefficient of kinetic friction is slightly less than the coefficient of static friction.

B) Static & Kinetic friction: -

The above laws of friction may be expressed by the following formula.

$F_s = \mu_s N$

$F_k = \mu_k N$

$F_k < F_s$

F_s = Static frictional force

F_k = Kinetic frictional force

μ_s = Coefficient of static friction

μ_k = Coefficient of dynamic friction

C) Belt Friction :-

For adjusting lap angle β on drum, a pulley is used.(Assumption: The friction between pulley and belt is zero.)Driving force is generated by the flat belt passing over the pulley. The friction that is developed between a flexible belt and drum can be utilised for transmission of power and applying brakes.

D) Flat Belts:

In the figure, a pulley is driven in the direction as shown. It is evident that the tension T_1 T_2. T_1 is called *tight side* & T_2 is called *slack side tension*. The relation between T_1 & T_2 when slipping of the belt impends is given by :

$T_1/T_2 = e^{\mu\beta}$ Where, β= angle of lap in radians.

μ = Coefficient of static friction

Case1:-

Determination of μ by maintaining β as constant.

1) Adjust the angle β by rotating the graduated disc such that desired angle β is observed below the pointer.
2) Clean the surfaces of belt & pulley.
3) By holding the belt, add known wt. on T_2 side (slack side.)
4) Adjust the weights on T_1 side such that the belt just starts sliding over the pulley.
5) Repeat the procedure for five different values of T_2 & tabulate the result.
6) Find the value of μ each time from following equation.

   $\mu = (1 / \beta) * \log_e (T_1 / T_2)$

7) Plot the graph of T_1 Vs T_2. Slope of this graph is 'm'.
8) Find μ from graph.

   $\mu = \log_e(m) / \beta$ (rad)

Case 2:-

Determination of μ by maintaining T_2 as constant (for flat belt).

1) Perform the experiment in the manner similar to case 1 by keeping T_2 as constant varying the value of β (lap angle).
2) Repeat the procedure for five different value of β and tabulate the result.
3) Find the value of μ every time from following equation.

   $\mu = (1 / \beta) * \log_e (T_1 / T_2)$

4) Plot the graph of $\log_e (T_1)$ vs β.
5) Slope of this graph is ‘m’
6) Find μ from the graph.

   $\mu = m =$ slope of the graph.

Figure: -

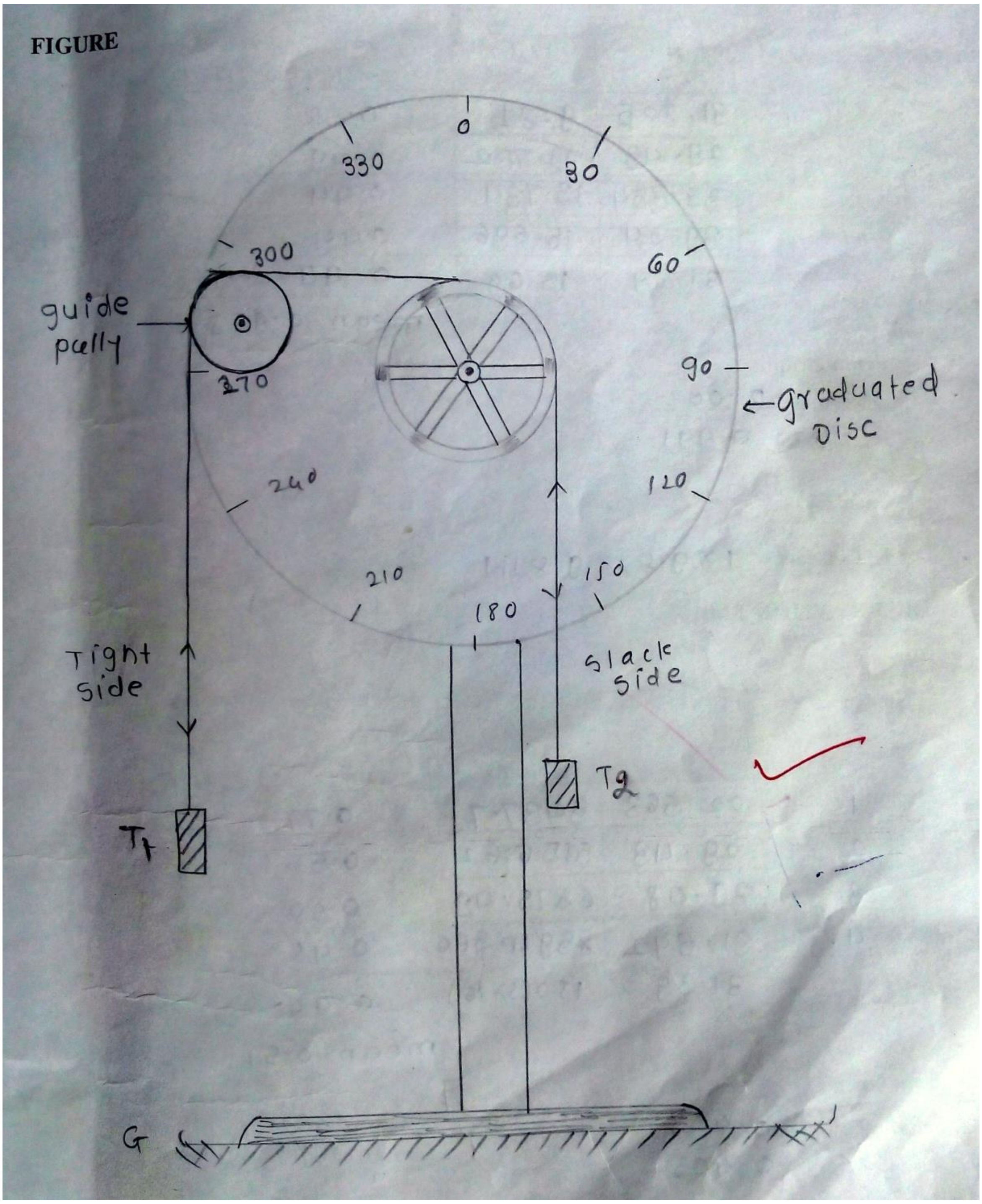


FIGURE
0
330
30
300
60
guide pully
90
270
graduated Disc
240
120
210
150
180
Tight side
slack side
T_1
T_2
G

Observation Table:-

1. **Flat Belt :**

Case 1 : β Constant = Π / 2

Sr. No.	**T_1 (N)**	**T_2 (N)**	**μ** **$\mu = (1/\beta) * \log_e (T_1/T_2)$**
1.	24.52	9.81	0.58
2.	25.50	11.77	0.49
3.	27.46	13.73	0.44
4.	29.43	14.71	0.44
5.	31.39	15.69	0.44

From Graph

Slope = m = ----------------

$\mu = \log_e (m) / \beta$ = ----------------

Case 2 : **T_2 constant = 1 x 9.81 = 9.81 N**

Sr. No.	**T_1 (N)**	**β (Rad)**	**μ** **$\mu = (1/\beta) * \log_e (T_1/T_2)$**
1.	14.71	Π / 6	0.77
2.	17.65	Π / 3	0.56
3.	24.52	Π / 2	0.58
4.	25.50	2Π / 3	0.48
5.	31.39	5Π / 6	0.44

From Graph

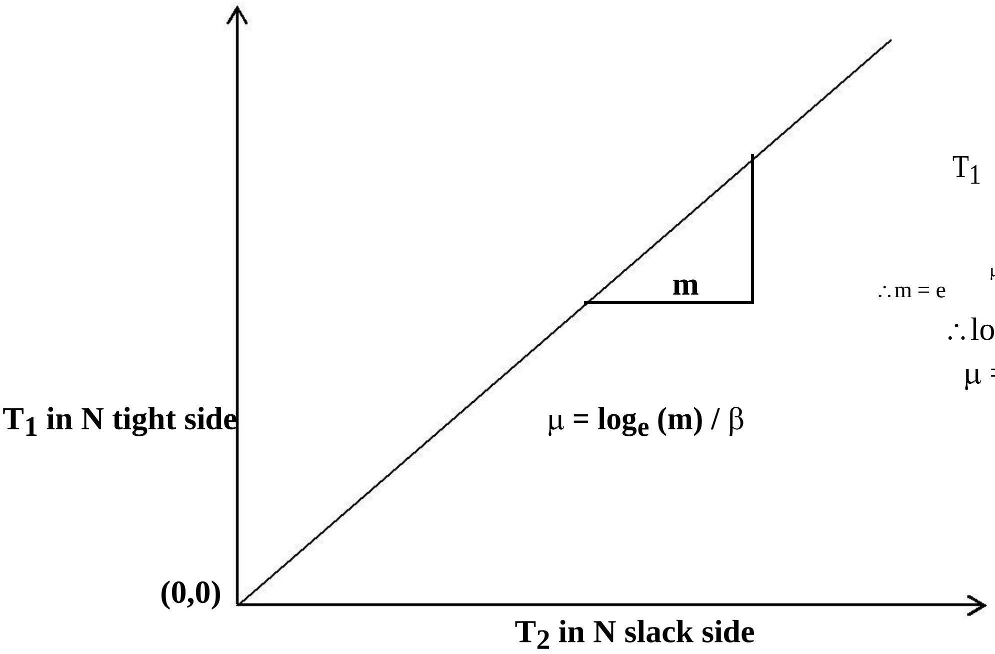
Slope = m = --------------

μ ='m' = --------------

Sample Calculations: -

Case 1: β constant

Graph of T_1 vs T_2



$T_1 / T_2 = e^{\mu\beta}$

$T_1 = e^{\mu\beta} * T_2$

$y = mx$

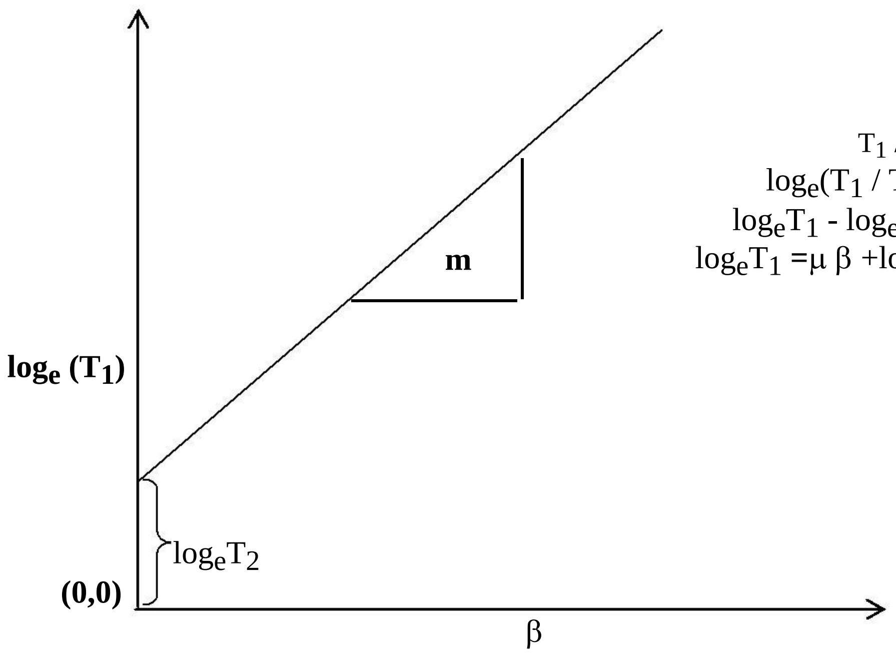
$\therefore m = e^{\mu\beta}$

$\therefore \log_e m = \mu\beta$

$\mu = (\log_e m)/\beta$

<u>Case 2: T_2 constant</u>

Graph of $\log_e (T_1)$ vs β



$T_1 / T_2 = e^{\mu\beta}$

$\log_e(T_1 / T_2) = \mu \beta$

$\log_e T_1 - \log_e T_2 = \mu \beta$

$\log_e T_1 = \mu \beta + \log_e T_2$

$y = mx + c$

$\mu = m$

Result: -

Flat Belt: Values of μ			
Case 1 : β Constant		Case 2: T_2 Constant	
Analytical	*Graphical*	*Analytical*	*Graphical*
0.478	0.441	0.51	0.408

Conclusion: -

- Coefficient of friction analytical and graphical is approximately same.
- As the angle changes the value of coefficient of friction decreases
- Value of coefficient of friction depends on nature of surface area.

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EXPERIMENT

CONCURRENT FORCE SYSTEM IN SPACE

Aim : To study the equilibrium of a particle subjected to forces in the spaces (Non-coplanar)

Apparatus : Space force frame, Weighing pans, Weights, Scale, Drawing sheets and Plum bob

Description of Apparatus :

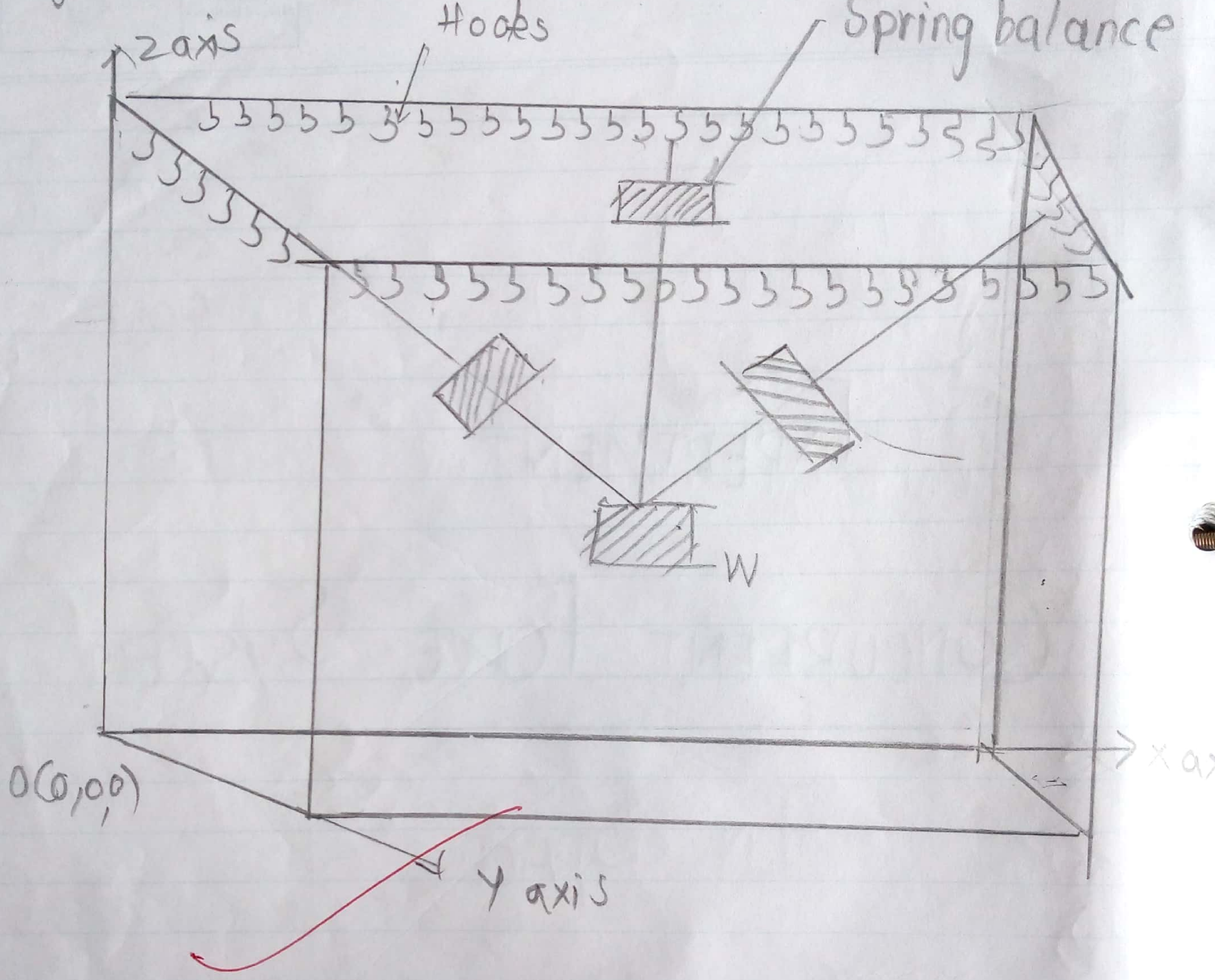
1) The space force frame is a ring supported on three legs.
2) Four strings are tied by a single knot, which acts as the point in equilibrium.
3) Three out of these four strings pass over three pulleys suspended on frame. To the other ends of these strings, pans are attached which can hold weights.
4) The forth string hangs vertically and support a weight.
5) A blank paper spread under the apparatus is used for transferring and making the directions of the string for later measurement.
6) A plum bob or a suitable tool is used for vertically transferring the points in space on to the drawing sheets.

Theory : If a particle is in equilibrium under four or more non coplanar and concurrent forces, they are said to be under a system of spatial forces in equilibrium. Such forces satisfy the following three equilibrium conditions

$$\Sigma F_x = 0, \quad \Sigma F_y = 0, \quad \Sigma F_z = 0$$

Thus the aim of this experiment is to verify these cond^n.

Diagram :



Space force setup

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Procedure : 1) The space force system is brought in equilibrium by placing some weights in the pan and hanging the forth weight to the central vertical thread.

2) Several times the system is disturbed and it is ensured that it comes back to its previous position. This confirms that the system is in stable equilibrium.

3) The directions of the three strings are transferred and marked on the paper using a plum bob.

4) x, y, z coordinates of the knot and three more arbitrary points on the inclined string (one on each string) are used for this purpose. The points are taken as far from each other as possible. This takes care of the accuracy of the directional measurement.

5) The fourth string being vertical does not need a second point for transferring the direction. The vertical projection of the knot on to the paper is assumed to have coordinates (0, 0, 0).

6) Thus a record of observations consists of four weights and z coordinates of four pts AB, C, D. The x, y cordinates are measured from the traced positions on the paper.

7) It is assumed that the pulleys are frictionless, and hence the tension in the three strings is same as the weights they are supporting.

8) The following table shows the observations taken during the experiment. A percentile check is taken to ensure that the observations are within reasonable limits.

Obs. table

Sr. No.	Weight (W)	Points	Coordinates (cm) x	y	z	Experimentally (N) T_{AD}	T_{BD}	T_{CD}	Analytically (N) T_{AD}	T_{BD}	T_{CD}
1.	400gm	A	0	60	100						
	= 3.92 ~~k~~N	B	100	90	100	2.3	2.9	3.4	1.8	4.36	-4.58
		C	40	0	100						
		D	60	40	68						
2.	500 gm	A	0	20	100						
	= 4.90 ~~k~~N	B	60	100	100	3.3	2.1	4.0	-4.04	-1.85	-3.87
		C	100	30	100						
		D	59	39	64						
3.	350 gm	A	0	60	100						
	= 3.43 N	B	90	100	100	2.3	2.3	3.2	-4.2	-0.539	-3.99
		C	80	0	100						
		D	61	39	68						

Calculations : We have, $W = 3.92\ kN$

Now, if $\bar{F} = F \times \bar{\lambda}$ then

$$\bar{\lambda} = \frac{(x_2 - x_1)\hat{i} + (y_2 - y_1)\hat{j} + (z_2 - z_1)\hat{k}}{\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2}}$$

In this case,

$$\bar{T}_{AD} = T_{AD} \times \bar{\lambda}_{AD} \quad \ldots (1)$$

$$\therefore \bar{\lambda}_{AD} = \frac{60\hat{i} - 20\hat{j} - 32\hat{k}}{\sqrt{60^2 + (-20)^2 + (-32)^2}} = \frac{60\hat{i} - 20\hat{j} - 32\hat{k}}{70.88}$$

$$\therefore \bar{\lambda}_{AD} = 0.846\hat{i} - 0.28\hat{j} - 0.45\hat{k} \quad \dots (2)$$

From (1) and (2)

$$\bar{T}_{AD} = T_{AD}(0.846\hat{i} - 0.28\hat{j} - 0.45\hat{k})$$

$$\therefore \bar{T}_{AD} = 0.846T_{AD}\hat{i} - 0.28T_{AD}\hat{j} - 0.45T_{AD}\hat{k} \quad \dots (I)$$

Now, $\bar{T}_{BD} = T_{BD} \times \bar{\lambda}_{BD} \quad \dots (3)$

$$\therefore \bar{\lambda}_{BD} = \frac{-40\hat{i} - 50\hat{j} - 32\hat{k}}{\sqrt{(-40)^2 + (-50)^2 + (-32)^2}} = \frac{-40\hat{i} - 50\hat{j} - 32\hat{k}}{71.58}$$

$$\therefore \bar{\lambda}_{BD} = -0.55\hat{i} - 0.69\hat{j} - 0.44\hat{k} \quad \dots (4)$$

From (3) and (4)

$$\bar{T}_{BD} = T_{BD}(-0.55\hat{i} - 0.69\hat{j} - 0.44\hat{k})$$

$$\bar{T}_{BD} = -0.55T_{BD}\hat{i} - 0.69T_{BD}\hat{j} - 0.44T_{BD}\hat{k} \quad \dots (II)$$

Now, $\bar{T}_{CD} = T_{CD} \times \bar{\lambda}_{CD} \quad \dots (5)$

$$\therefore \bar{\lambda}_{CD} = \frac{-10\hat{i} - 40\hat{j} - 32\hat{k}}{\sqrt{(-10)^2 + (-40)^2 + (-32)^2}} = \frac{-10\hat{i} - 40\hat{j} - 32\hat{k}}{52.19}$$

$$\bar{\lambda}_{CD} = -0.19\hat{i} - 0.766\hat{j} - 0.613\hat{k} \quad \dots (6)$$

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From (5) and (6)

$$\bar{T}_{CD} = T_{CD}(-0.19\hat{i} - 0.766\hat{j} - 0.613\hat{k})$$

$$\bar{T}_{CD} = -0.19T_{CD}\hat{i} - 0.766T_{CD}\hat{j} - 0.613T_{CD}\hat{k} \quad \ldots \text{(III)}$$

Also, $\bar{w} = W\bar{\lambda}$

$$\bar{w} = -3.92\hat{k} \quad \ldots \text{(IV)}$$

Adding $\hat{i}$, $\hat{j}$, $\hat{k}$ terms separately

$$0.846T_{AD} - 0.55T_{BD} - 0.19T_{CD} = 0 \quad \ldots \text{(i)}$$

$$-0.28T_{AD} - 0.69T_{BD} - 0.766T_{CD} = 0 \quad \ldots \text{(ii)}$$

$$-0.45T_{AD} - 0.44T_{BD} - 0.613T_{CD} = 3.92 \quad \ldots \text{(iii)}$$

Solving (i), (ii), (iii) simultaneously

$$T_{AD} = 1.8 \text{ kN}$$

$$T_{BD} = 4.36 \text{ kN}$$

$$T_{CD} = -4.58 \text{ kN}$$

Conclusion: studied space force system (non coplanar, concurrent force system. Tension experimentally and analytically ~~are~~ different due to instrumental error.

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EXPERIMENT

GENERAL COPLANAR FORCE SYSTEM

Aim : To verify parallelogram law of forces with the help of Gravesand's apparatus.

Apparatus : Wooden board, Gravesand's apparatus, paper sheet, weight, thread, pans, set square, pencil, drawing sheet and pin, etc.

Theory : 'Parallelogram law of forces' states that if a particle is acted by the two forces represented in magnitude and direction by the two sides of a parallelogram drawn from a point then the resultant is completely represented by the diagonal passing through the same point.

The conditions of equilibrium

$\Sigma fx = 0$, $\Sigma fy = 0$ and $\Sigma M = 0$

Parallelogram law of forces

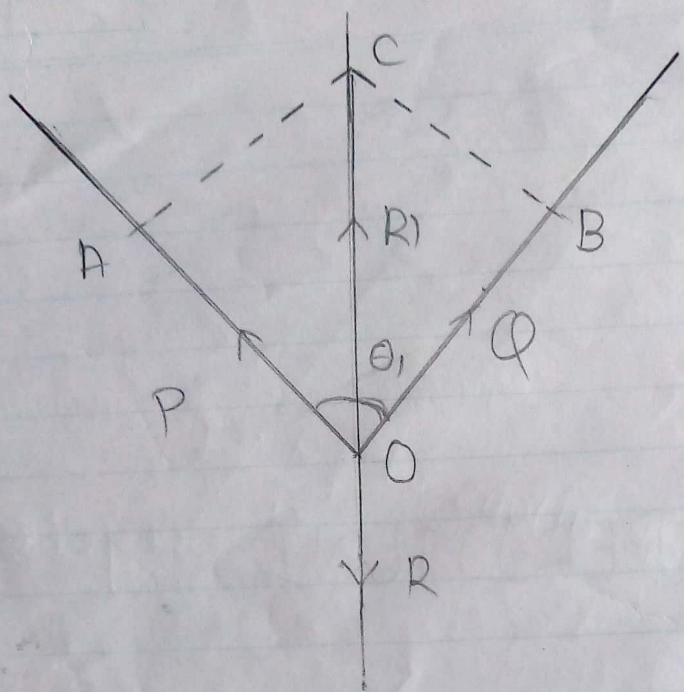
Analytical Method :

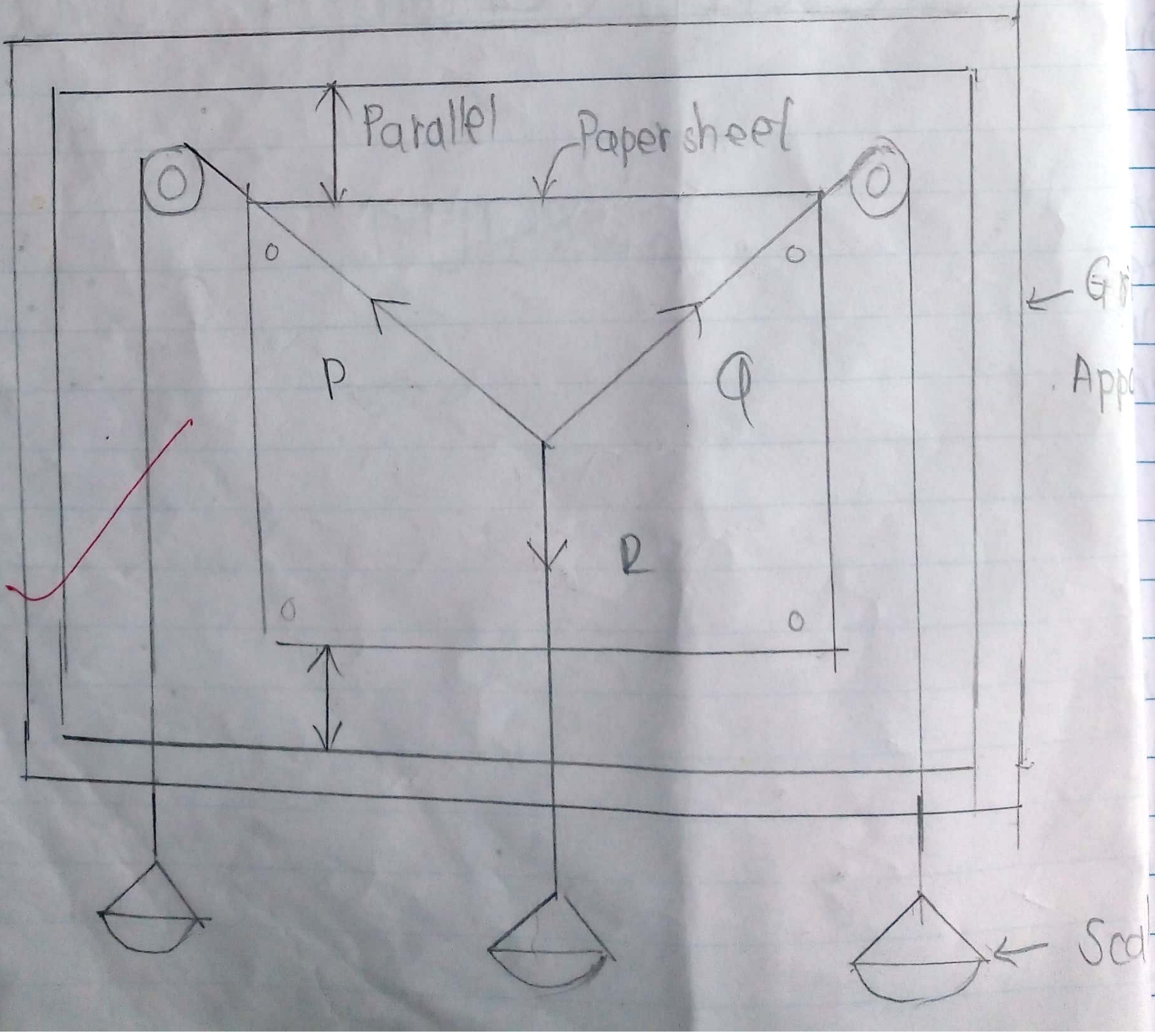
Measure the angles θ_1 and by using resultant formula $R_1 R_2 = \sqrt{P_2 + Q_2 + 2PQ\cos\theta}$

Graphical Method :

Cut $OA = P$ and $OB = Q$ in suitable scale. From A draw AC parallel to OB and BC parallel to OA. R_1 represents resultant force of force P and Q

Diagram :





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As the system is in equilibrium it must be equal to R. Note that R and R' are in opposite direction.

Procedure ; 1) Fix the paper sheet with drawing pin on the board set in a vertical plane such that it should be parallel to the edge of board.

2) Pass one thread over the pulleys carrying a pan at its each end. Take a second thread and tie its one end at the middle of the first thread and tie a pan at its other end.

3) Add weights in the pan in such a manner that the small knot comes approximately in the centre

4) Displace the slightly pans from their positions of equilibrium and note if they come to their original position of rest. This will ensure the free movement of the pulleys.

5) Mark lines of forces represented by thread without disturbing the equilibrium of the system and write the magnitude of forces i.e Pan Weight + Added Weight. Polygon law of Coplanar Force

6) Remove the paper from the board and produce the line to meet at O.

7) Use Bow's notation to name the force P, Q, R as AB, BC and CA.

8) Select a suitable scale and draw the line ab parallel to force P and cut it equal to the magnitude of P. From b draw the line bc parallel to force Q and cut it to equal mag. of Q. Calculate the magnitude of ca i.e (R) which will be equal to the third force R which proves the triangle law of forces

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If R_1 differs from original magnitude of R, the percentage error is found as follows:

$$\text{Percentage Error} = \left(\frac{R - R_1}{R}\right) 100$$

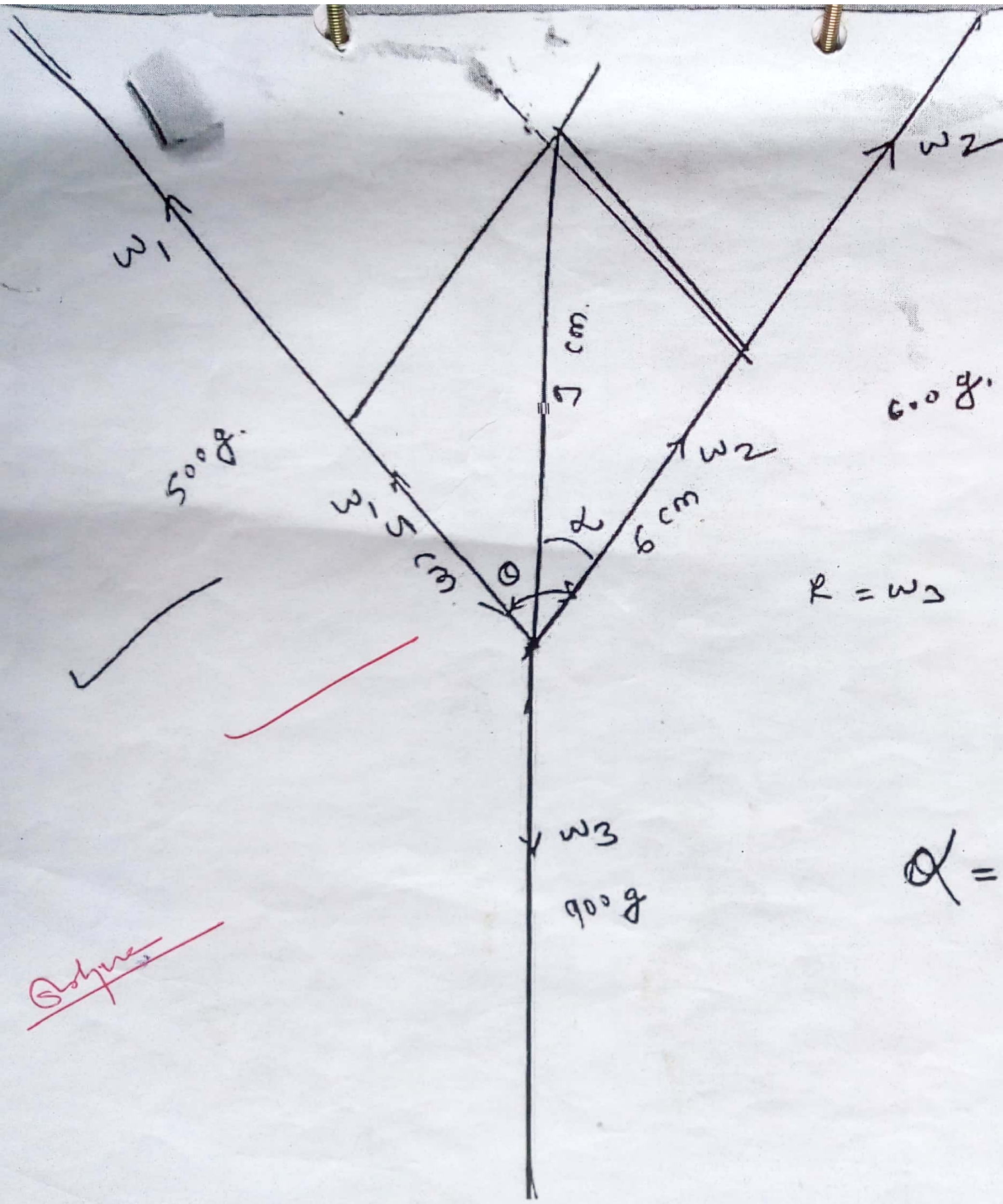
Observation Table :

Law	Total Weight of pan P	Total Weight of pan Q	Total Weight of pan R	Calculated Resultant	% Error
Parallelogram Law	500 g	600 g	900 g	891.95	$\frac{891.5 - 900}{891.5}$ $= -0.95\%$

Result : 1) The force polygons for the three sets of observations were drawn and found to be closed polygons. Hence the Polygon Law of Coplanar force is verified.
2) The unknown weight found experimentally is N. Within limits of experimental error, these values are found to be same and hence experiment is verified.

Conclusion : Studied and verified parallelogram law of forces graphically and analytically. Resultant from both the methods are approximately equal.

Sadhana



1 cm = 100 gm

(on drawing sheet

$$R = \sqrt{w_1^2 + w_2^2 + 2w_1 w_2 \cos}$$

$$R = \sqrt{25 + 36 + 60 \times 0.}$$

$$\boxed{R = 8.93}\ N$$

$$\alpha = \tan^{-1}\left(\frac{P\cos\theta}{Q + P\sin\theta}\right)$$

$\theta = 72^\circ$

EXPERIMENT. NO. 5
COEFFICIENT OF RESTITUTION

Objective: -

To determine Coefficient of Restitution.

Apparatus: -

Meter scale, Rubber ball, Table tennis ball, Marble ball etc.

Theory: -

For two bodies A & B, if u_1 & u_2 = initial velocity of A & B respectively before impact and v_1 & v_2 = final velocity of A & B respectively after impact, then the coefficient of restitution (e) is equal to the ratio of the relative velocity of the particles' separation just after impact (v_2 - v_1) to the relative velocity of the particles' approach just before impact (u_1- u_2). (Consider $u_1 > u_2$)

$$e = \left\{\frac{v_2 - v_1}{u_1 - u_2}\right\}$$

For perfectly elastic bodies, e =1 & perfectly plastic bodies e = 0. In practice, however no material is perfectly elastic or plastic. Hence the value of 'e' is always between 0 & 1

Coefficient of restitution can be approximately calculated by bouncing spherical balls against a rigid support. e.g. a heavy slab. The object B in this case is fixed & having zero velocity.

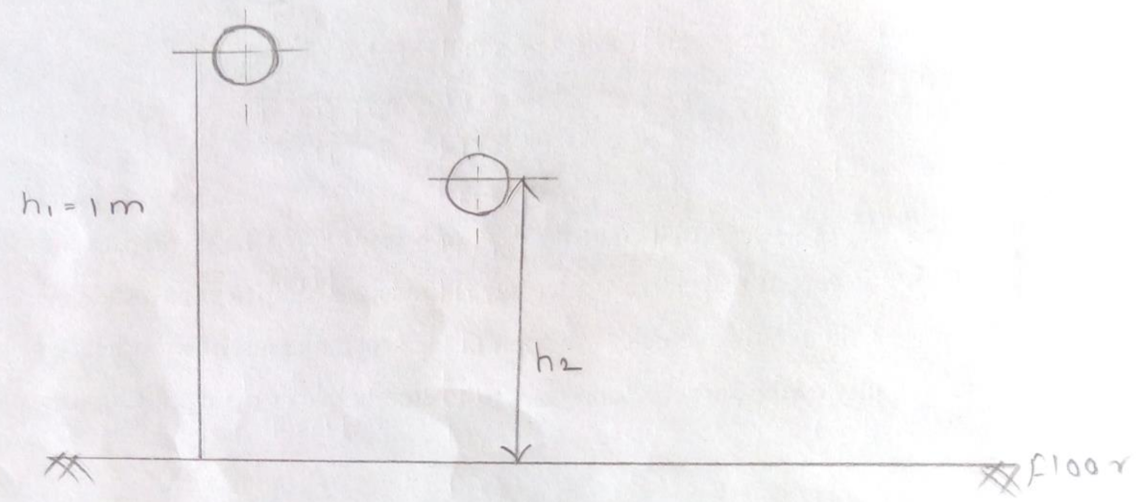
$\therefore u_1 = \sqrt{2g\,h_1}$, $v_1 = -\sqrt{2gh_2}$ (against gravity), $u_2 = v_2 = 0$ (as floor is stationary),

$$\therefore e = -\left\{\frac{v_1}{u_1}\right\} \qquad \therefore e = \sqrt{h_2 / h_1}.$$

Procedure: -

1) Drop rubber ball vertically from a height (h_1).
2) Record the height at which the rubber ball bounces back (h_2).
3) Calculate the coefficient of restitution.
4) Take three more readings with different height h_1.
5) Calculate coefficient of restitution for other balls by repeating the above procedure.

Figure: -



h_1 = Initial ht. of fall of object
h_2 = Rebounced ht. of object

Coefficient of Restitution.

$$e = \frac{\text{Velocity of seperation / im after pact}}{\text{Velocity of approach / before impact.}}$$

$$e = \frac{v_2 - v_1}{u_1 - u_2}$$

$$e = \sqrt{\frac{h_2}{h_1}}.$$

m_1 : mass of ball
m_2 = ∞ mass of floor

Sample Calculations: -

1. Plastic - i) $h_1 = 1000\,mm$, $h_2 = 410\,mm$

$$\therefore e = \sqrt{\frac{h_2}{h_1}} = \sqrt{\frac{410}{1000}} = 0.640$$

~~2. ii) h1 = 1 Sponeg - ii)~~

2. Sponge - ii) $h_1 = 1000\,mm$, $h_2 = 370\,mm$

$$\therefore e = \sqrt{\frac{h_2}{h_1}} = \sqrt{\frac{370}{1000}} = 0.608$$

3. Rubber - iii) $h_1 = 1000\,mm$, $h_2 = 460\,mm$

$$\therefore e = \sqrt{\frac{h_2}{h_1}} = \sqrt{\frac{460}{1000}} = 0.67$$

4. Bouncy - iv) $h_1 = 1000\,mm$, $h_2 = 730\,mm$

$$\therefore e = \sqrt{\frac{h_2}{h_1}} = \sqrt{\frac{730}{1000}} = 0.85$$

Observation table: -

Sr. No.	Object	h_1 (mm)	h_2 (mm)	$e = (h_2/h_1)^{1/2}$	Avg.
1	Plastic	1000	410	0.64	0.632
2		1000	430	0.65	
3		1000	370	0.608	
1	Sponge	1000	370	0.608	0.608
2		1000	360	0.6	
3		1000	380	0.616	
1	Rubber	1000	460	0.67	0.703
2		1000	520	0.72	
3		1000	530	0.72	
1	Bouncy	1000	730	0.85	0.823
2		1000	680	0.82	
3		1000	650	0.8	

Result: -

Sr. no	Object	Coefficient of restitution
1	Plastic	0.632
2	Sponge	0.608
3	Rubber	0.703
4	Bouncy	0.823

Conclusion: -

The coefficient of restitution depends on the type of material also on shape and size. The value of ‘e’ vary from 0 to 1. Here coefficient of restitution is more of bouncy ball as compared to plastic, sponge and rubber.

EXPERIMENT. NO. 4

CURVILINEAR MOTION

Objective: -

To study kinematics of curvilinear motion of a particle.

Apparatus: -

Cycle rim fixed in a vertical plane, balls of different materials & different sizes, scale, powder, thread.

Theory: -

When a particle moves along a curve other than a straight line, then the particle is said to be in curvilinear motion.

Instantaneous Velocity is given by

$$\bar{V} = \frac{dr}{dt}$$

Where, r is position vector.

Instantaneous acceleration is given by,

$$\bar{a} = \frac{d\bar{v}}{dt}$$

The particle starts from point A and leaves at point B. (Refer Fig.)

Hence by applying the Work Energy Principle

Energy at A = Energy at B

$\therefore$ mgr = mg (rcosθ) +1/ 2 mv^2

$\therefore$ gr = gr cosθ + 1/2 v^2

$\therefore$ v^2 = 2gr (1- cosθ)s

$$V = \sqrt{2gr(1 - \cos\theta)}$$

Hence v is the velocity at point B.

At point B,

$$\frac{mv2}{r} = mg\cos\theta$$

$$\frac{m(2gr)(1 - \cos\theta)}{r} = mg\cos\theta$$

$\therefore$2-2cosθ = cosθ

$\therefore$2 = 3cosθ

$\therefore$cosθ = 2/3

$\therefore$θ **= cos^{-1} (2/3)**

As the particle leaves the rim at point B, it follows principle of projectile motion and falls to the ground at distance ‘b’.

The path followed is tangential.

$s = ut + \frac{1}{2} at^2$

$y = (u\sin\theta)t - \frac{1}{2} gt^2$

$$r(1+\cos\theta) = (u\sin\theta)t - \frac{1}{2} gt^2$$

$$r\left(1+\frac{2}{3}\right) = \sqrt{2gr(1-\cos\theta)}\ (\sin\theta)\times t - \frac{1}{2} gt^2$$

$$\frac{5}{3}r = \left\{\sqrt{2\times 9.81\times r\left(1-\frac{2}{3}\right)}\right\}\sqrt{\frac{5}{3}}\times t - \frac{1}{2}\times 9.81\times t^2$$

$$t = 0.42\sqrt{r}$$

$$Distance\quad b = (u\cos\theta)\,t + r\sin\theta$$

$$\therefore b = \left(\sqrt{2gr(1-\cos\theta)}\right)\times\cos\theta\,(0.42\sqrt{r}) + \sqrt{\frac{5}{3}}\times r$$

$$\therefore b = 2.55\sqrt{r}\times\frac{2}{3}(0.42)\sqrt{r} + \left(\frac{\sqrt{5}}{3}\right) r$$

$$\therefore b = 1.456\,r$$

<u>Procedure</u>: -

1. Measure the diameter of rim.
2. Place the ball / marble on circular path at the highest position A. Allow it to move along path AB. The ball / marble will follow and leave circular path at B, and follow trajectory BC and hit the surface at C.
3. Mark point B on the rim & point C on the platform by spreading powder on circular track and ground.
4. Measure horizontal distance DC on ground.
5. Find angle θ through which particle move in circular path.
6. Compare distance DC and angle θ with analytical values.
7. Compare results with analytical solution.

<u>Analytical solution:-</u>

$\cos\theta = 2/3$

$\theta = \cos^{-1}(2/3)$

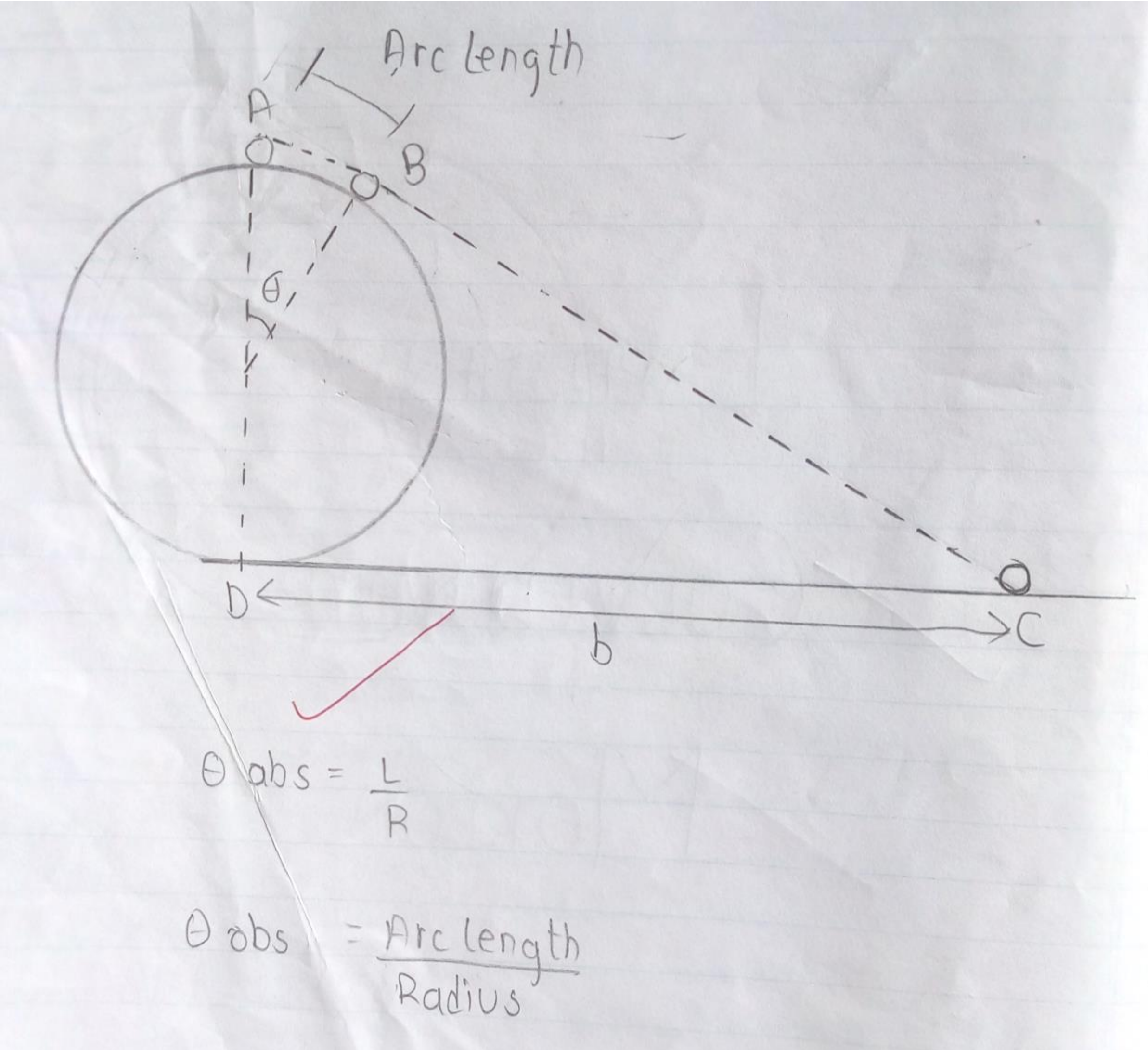
$\theta = 48.18°$

$b = 1.456\,(r)$ $\qquad$ $b = 1.456\,(325) = 473.2$ mm

$\therefore$ **$\theta_{analytical} = 48.18°$**

$\therefore$ **$b_{analytical} = 473.2$ mm.**

Figure: -



Sample Calculations: -

1) For radius R

$$2\pi R = 1.6 \times 1000 = 1600$$

$$R = \frac{1600}{2\pi}$$

$$R = 254.64$$

2) For Reading 1

$b_{obs} = 490$ mm

$b_{ana} = 473.2$ mm

Arc length AB $= l = 250$ mm

$\theta_{ana} = 48.18$

$$\% \text{ Error} = \frac{b_{obs} - b_{ana}}{b_{obs}} \times 100$$

$$= -\frac{(490 - 473.2)}{473.2} = \frac{473.2 - 490}{473.2}$$

$$= -3.55$$

Now, $\theta = \frac{l}{R} = \frac{250}{254.64} = 0.98^c$

Now, $0.98^c = 0.98 \times \frac{180}{\pi} = 56.15^\circ$

Now, $\% \text{ error in } \theta = \frac{\theta_{ana} - \theta_{obs}}{\theta_{ana}} \times 100$

$$= \frac{48.18 - 56.15}{48.18} \times 100$$

$\%$ error in $\theta = -16\ \%$

Average horizontal distance $= \frac{\text{Reading 1} + \text{Reading 2} + \text{Reading 3}}{3}$

$$= \frac{490 + 468 + 464}{3}$$

$$= 474 \text{ mm}$$

Average angle $= \frac{\text{Reading 1} + \text{Reading 2} + \text{Readin}}{3}$

$$= \frac{56.15 + 76.2 + 73.91}{3}$$

$$= 68.75$$

Result: Average horizontal distance is 474 mm & average angle is 68.75

Observation table:-

Sr. No.	Horizontal distance b (mm)			Arc length AB =l	θ obs = l /r		θ_{ana} Deg.	% error
	B obs (mm)	b ana (mm)	% error		Rad	Deg.		
1	490	473.2	-3.55	250	0.98	56.15	48.18	-15
2	468	473.2	1.11	340	1.33	76.2	48.18	-58
3	464	473.2	1.98	329	1.29	73.91	48.18	-53

Conclusion: -

The analytical and practical distance in above experiment is same. Even the analytical and practical value of angle is approximately equal.