Dinkarrao K. Shinde Smarak Trust's

Dr. A.D. Shinde College of Engineering

Guddai, Bhadgaon, Tal: - Gadhinglaj , Dist: - Kolhapur

Manual On

ENGINEERING MECHANICS

Faculty: -

Department of First Year Engineering

Index

Sl. No	Name of the Experiment	Conducted Date	Date of Checking	Remark with Sign
1.				
2.				
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5.				
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8.				
9.				
10.				

Course Teacher

Department of First Year Engineering

Assessment Matrix

Experiment No	Cognitive (thinking, knowledge) (04)	Psychomotor Skills (doing, skills) (04)	Affective domain (feeling & attitude) (02)	Total (10)
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				

Experiment No – 01 - Verification of Triangle law of forces (Lami's theorem) using Jib Crane

1.1 Aim

To verify the Triangle law of forces (Lami's theorem) using Jib Crane.

1.2 Apparatus

Jib-crane apparatus consists of a vertical part, the chain, Compression jib, weights, scale spring etc.

1.3 Theory

Lami's Theorem:

If three forces are acting on a system & if it is Equilibrium, then these forces can be represented by three sides of triangle & each force is proportional to the sine of the angle between the remaining two forces.

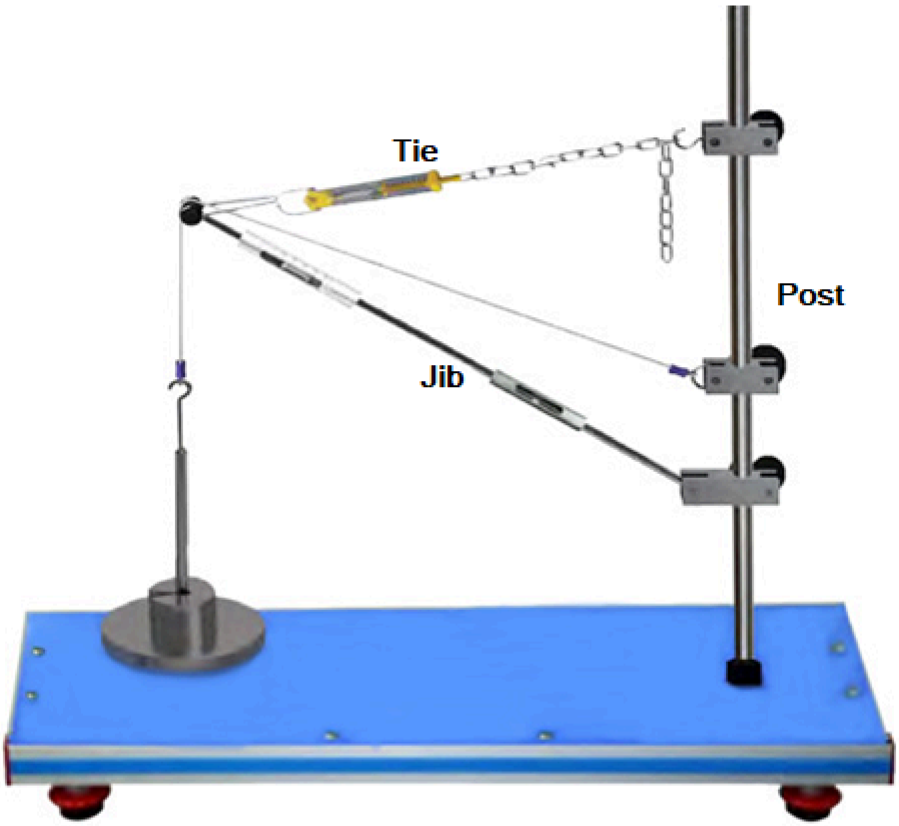


Figure 1-1 Jib Crane

1.4 Procedure

1. Carefully study the working of apparatus.
2. Note down the error, if any on the spring balance.
3. Apply weights at the apex points using a hanger frame.
4. Note-down the readings on the spring balance.
5. Note down the length of vertical part, tie & jib as well as horizontal balance.

6. Draw the space diagram of jib crane using suitable scale.
7. Measure the angles at the apex point from the diagram.
8. Using Lamin's theorem find the forces in the jib & tie.
9. Draw the triangle of forces to suitable scale.
10. Find the forces in the jib & tie from the triangle of forces by graphical method.

1.5 Precautions

1. The initial readings should be taken carefully.
2. Measures the angles accurately.

1.6 Observation table

1. Initial reading of tie =   N.
2. Initial reading of jib balance =   cm.

Sr. No.	Load (N) W	Length in cm			Observed Reading		Corrected Reading	
		Jib	Tie	Post	Jib (cm)	Tie (N)	Jib (cm)	Tie (N)
1.								
2.								
3.								
4.								
5.								

Sr. No.	α (degrees)	β (degrees)	θ (degrees)	Value From Graph	
				Jib (cm)	Tie (N)
1.					
2.					
3.					
4.					
5.					

Sr. No.	Analytical value of Tie (gm)	Analytical Value in Jib (gm)	% Error	Spring Constant in Jib (gm/cm)	Average Error	Average Spring constant	
1.							

2.							
3.							
4.							
5.							

1.6.1 Calculation - Analytical and Graphical

1.7 Result and Conclusion

Cognitive (thinking, knowledge) (04)	Psychomotor Skills (doing, skills) (04)	Affective domain (feeling & attitude) (02)	Total (10)	Sign

Experiment No – 02 - Law of polygon of forces

2.1 Aim

To verify the law of polygon of forces with the help of universal force table apparatus.

2.2 Apparatus

Universal Forces table with five pulleys, rings with five string weight, slotted weight, plain paper and geometry box.

2.3 Theory

Polygon law of forces states that if a number of concurrent forces are acting simultaneously on a body, are represented in magnitude and direction by the sides of a polygon, taken in order, then the resultant is represented in magnitude and direction by the closing side of the polygon, taken in opposite order.

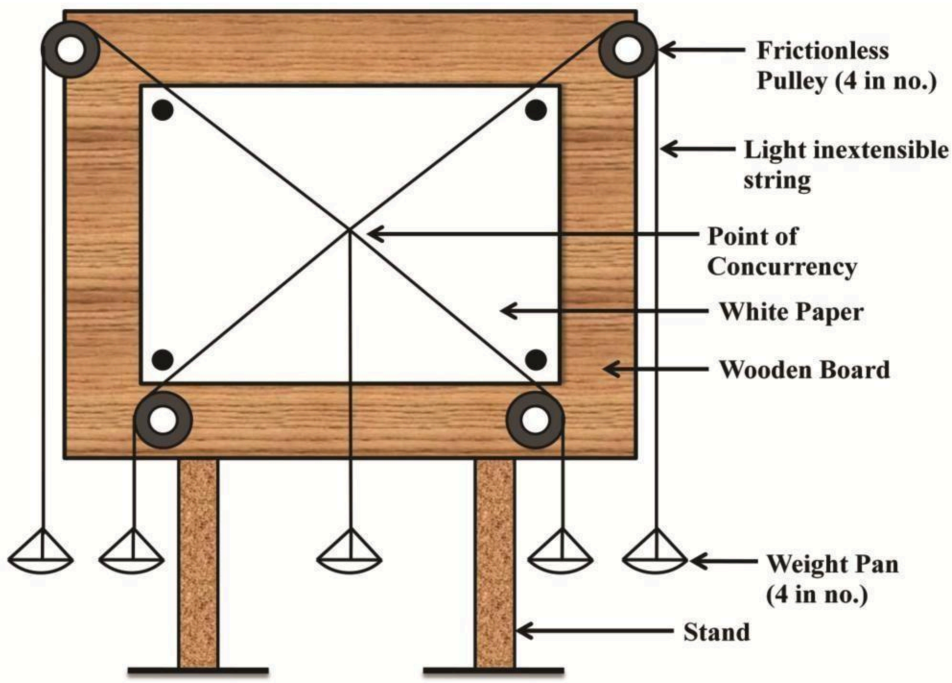


Figure 2-1 Universal Forces table

2.4 Procedure

1. Before starting the experiment make the graduated table horizontal with the help of levelling screw.
2. Clamp the pulley to the graduated disc of the force table.
3. Tie one of thread to the circumference of small rings and place it around the central axis of the apparatus.
4. Attach other end of the string to the weight hangs which will carry small, slotted weight.
5. Pass one string over each pulley.
6. Place slotted weight on the weight hanger in such a manner that ring is placed around the centre.

7. Note down the angle between different threads and corresponding weights.
8. Draw a space diagram of the force acting a part such that the time of action of each force corresponding to the angles of forces between them.
9. Chose a suitable scale and make mark a point on a paper and draw the vector diagram of force system acting at a point by drawing parallel line of each force proportional to the chosen scale.

2.5 Procedure to draw vector diagram:

1. Draw a line OA parallel and equal to W_1 assuming a suitable scale.
2. Draw a line AB parallel and equal to W_2 from point A assuming the same scale.
3. Similarly draw BC and CD parallel and equal to the force W_3 and W_4.
4. Join OD i.e., the closing side by dotted line, which represents the resultant of polygon (graphically).
5. Measure the line OD and compare it with W5 by using the same scale.
6. Find the error by using the formula given in the observation table. Error should be positive.

2.6 Observation table

Sr No	Forces in grams					Angles in Degrees					Experimental Value of R	Analytical Value of R	error
	w_1	w_2	w_3	w_4	w_5	θ_1	θ_2	θ_3	θ_4	θ_5			
1.													
2.													
3.													
4.													
5.													
											Average Error %		

2.6.1 Calculation of Analytical Value of R

- Calculate $\sum Fx \; and \sum Fy$
- Calculate Magnitude of R, $R_{ana} = \sqrt{\sum F_x^2 + \sum F_y^2}$
- Calculate Direction of R, $\theta = \frac{\sum Fy}{\sum Fx}$

2.6.2 Error Calculation

$$Error = \frac{(R_{anal} - R_{expt})}{R_{anal}} \; x \; 100$$

2.7 Result and Conclusion

Cognitive (thinking, knowledge) (04)	Psychomotor Skills (doing, skills) (04)	Affective domain (feeling & attitude) (02)	Total (10)	Sign

Experiment No – 03 - Reactions at the supports of a simply supported beam

3.1 Aim

To find experimentally the reactions at the supports of a simply supported beam and compare the results with analytical values.

3.2 Apparatus

Simply supported beam setup, hangers, and loads.

3.3 Theory

Beam is a structural member usually horizontal and straight provided to carry loads that are vertical or inclined to its axis. A simply supported beam is one whose ends are resting freely on the supports that provide only vertical reactions. Simply supported beam becomes unstable if it is subjected to oblique or inclined loads. When simply supported beam is subjected to only vertical loads, its FBD forms a system of parallel forces in equilibrium.

Conditions of equilibrium $\sum F_x = 0$, $\sum F_y = 0$ and $\sum M = 0$ can be applied to determine the support reactions analytically.

3.4 Procedure

1. Place the beam of length L on simple supports. Note that below both the simple supports there is a spring arrangement. On loading, the spring compresses due to the reaction force and this compressive force is indicated on the dial.
2. Arrange the load hangers arbitrarily on the beam and set the left and right dial pointers to zero. This will nullify the effect due to self-weight of the beam and the hangers.
3. Suspend the loads from the hangers. Note the load values $W1,$ and so on and their distances X and so on from the left support.
4. Note the left and right support dial readings
5. Repeat the above steps 1 to 3 by changing the weights in the hangers and also the hanger position for two more sets of observations.
6. Compare the experimental values with analytical values obtained by applying Conditions of Equilibrium.

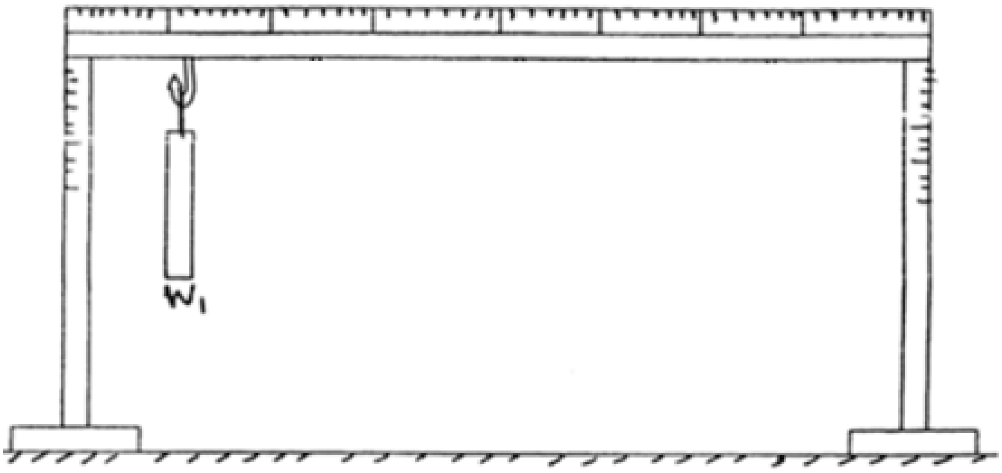


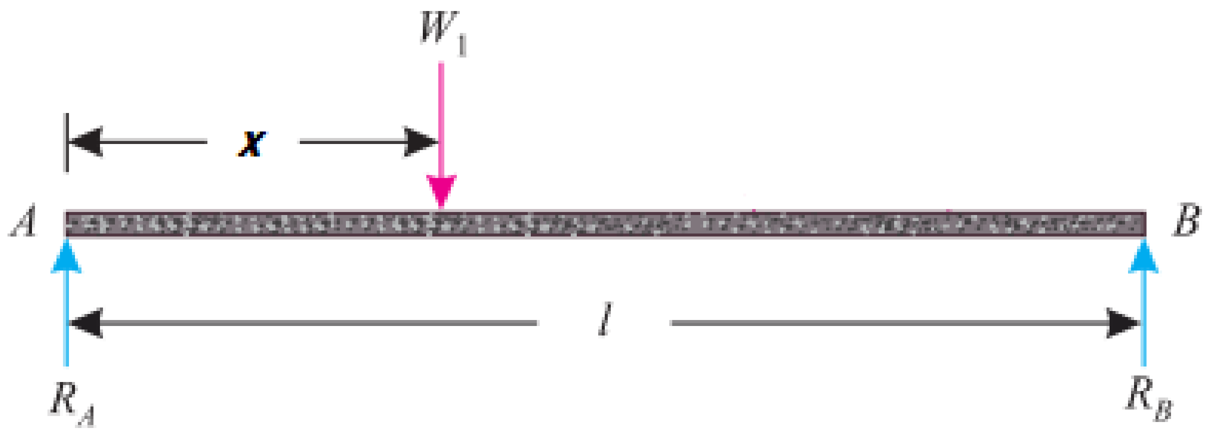
Figure 3-1 Support Reaction

3.5 Observation table

Sr. No	W in grams	X in mm	$R_{A\ expt}$	$R_{B\ expt}$	$R_{A\ anal}$	$R_{B\ anal}$	% Error in R_A	% Error in R_B
1.								
2.								
3.								
4.						Avg. Error		

3.6 Calculations

- Analytical values of support reactions



$$R_A = \frac{W_1 * (l - x)}{l}$$

$$R_B = \frac{W_1 * x}{l}$$

$$Error = \frac{(R_{anal} - R_{expt})}{R_{anal}} \, x \, 100$$

3.7 Results and Calculation

Cognitive (thinking, knowledge) (04)	Psychomotor Skills (doing, skills) (04)	Affective domain (feeling & attitude) (02)	Total (10)	Sign

Experiment No – 04 - Principle of Moments using the Bell Crank Lever apparatus

4.1 Aim

To verify the Principle of Moments using the Bell Crank Lever apparatus.

4.2 Apparatus

Bell crank lever apparatus, hangers, weights, scale.

4.3 Theory

Principle of Moments states, "the algebraic sum of the moments of a system of coplanar forces about any point in the plane is equal to the moment of the resultant force of the system about the same point'. This principle would be verified for a bell crank lever arrangement. A lever whose two arms form a right angle, or nearly a right angle and having its fulcrum at the apex of the angle is referred to as a bell crank lever. These levers were originally used to operate the bell from a long distance especially where change in direction of bell wires was involved and hence the name. Now bell crank levers are used in machines to convert the direction of reciprocation movement.

Figure 4-1 Bell Crank

4.4 Procedure:

1. Arrange three hangers at arbitrary locations on the horizontal arm. Note the locations x_1, x_2, and x_3 of these hangers from the hinge. Adjust the tension in the spring connected to the vertical arm such that the two pointers come in the same vertical line. In this position the horizontal arm is truly horizontal. Note the tensile force in the spring as the initial tension Ti. Also note the location Y of the spring from the hinge.

2. Hang the weights W_1, W_2 and W_3 from the hangers. This will cause the arms to tilt and the pointers to move away from each other. Now adjust the tension in the spring such that the pointers once again come in the same vertical line. The horizontal arm is once again in its horizontal position. Note the tensile force in the spring as the final tension Tf. The tensile force T on the vertical arm is the difference $Tf — Ti$.
3. Since the external forces are being supported by the single hinge at the apex of the arms, implies that the resultant of these external applied forces passes through the supporting hinge. Therefore, to verify the principle of moments we need to take moments (ΣM) of all the external forces (which includes the weights of the hangers hanging from the horizontal arm and the tension in the spring connected to the vertical arm) about the hinge and if the total sum is zero, verifies the law of moments since the moment of the resultant is also zero at the hinge.
4. Repeat the above steps by changing the weights and their location on the horizontal arm for two more set of observations.

4.5 Observation table

Sr. No	T_i gms	Y cm	W_1 gms	W_2 gms	W_3 gms	x_1 cm	x_2 cm	x_3 cm	T_f gms	$T = T_{f-}T_i$	$\sum M$
1.											
2.											
3.											
4.											

Sr. No	T_A	T_{Exp}	Error %	Average Error
1.				
2.				
3.				
4.				

4.6 Calculations

Summation moments of all external forces at the hinge O.

$$\sum M_0 = Ty - w_1 x_1 - w_2 x_2 - w_3 x_3 T = \frac{w_1 x_1 - w_2 x_2 - w_3 x_3}{y}$$

4.7 Results and Conclusion

Cognitive (thinking, knowledge) (04)	Psychomotor Skills (doing, skills) (04)	Affective domain (feeling & attitude) (02)	Total (10)	Sign

Experiment No – 05 – Determination of Coefficient of static friction for motion on horizontal Plane

5.1 Aim

Determination of Coefficient of static friction for motion on horizontal plane

5.2 Apparatus

An adjustable inclined glass plane with pulley at one end, wooden block having different material at bottom surface, inextensible string, pan and standard weights.

5.3 Theory

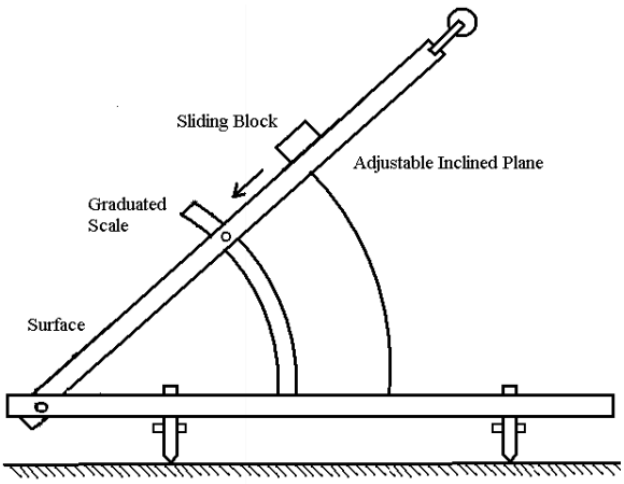


Figure 5-1 Apparatus Used to Find Coefficient of Static Friction

5.3.1 Frictional Force (F)

"When a body moves or tends to move over another body, a force opposing the motion develops at the contact surfaces. This force which opposes the movement, or the tendency of movement is called frictional force or simply friction".

If the contact surfaces are perfectly smooth, there is no friction in machines, friction is both liability and an assist, where it causes loss of power and / or wear it is undesirable. On the other hand, friction is essential for various holding and fastening devices, brakes, belt drives etc.

5.3.2 Limiting Friction Force (Fm)

The maximum friction force developed between two surfaces when the body just starts to move in the direction of effort. i.e. Max. Friction force developed in impending condition.

- When F < Fm: Block is in equilibrium & Friction Force developed = F
- When F = Fm: Block is in impending condition & Friction Force developed = Fm=μs* N
- When F > Fm: Block is in motion & Friction Force developed = FK = μK* N

5.3.3 Coefficient of Static Friction (μ_s):

The ratio of limiting friction force (Fm) to the normal Reaction (N) which are generated between two surfaces.

$$\mu_s = \frac{F_m}{N}$$

5.3.4 Angle of Static Friction (Φs):

Angle made by the resultant (R) of normal reaction (N) and the friction force (Fm) to the normal reaction (N), when the body is in impending condition is called angle of static friction.

$$\tan tan\, \phi s = \frac{F_m}{N}$$

Relation between angle of Static Friction and Coefficient of Static Friction: $\mu_s = \tan tan\, \phi s$

5.3.5 Angle of Repose (θ):

The angle of an inclination with horizontal at which the block just slides down due to its self-weight is called angle of Repose.

OR

The maximum inclination of plane at which the body can remain in equilibrium over the plane entirely by the assistance of friction is called the angle of repose.

(It will be seen that angle of static friction and angle of repose are equal.)

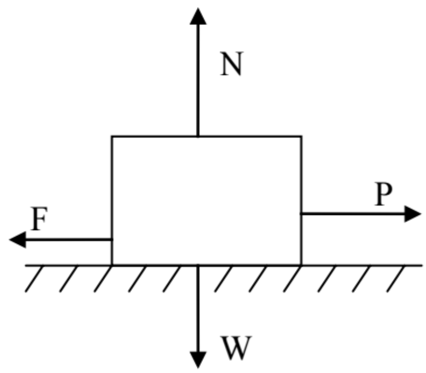


Figure 5-2 Block Resting on Horizontal Surface

5.3.6 Coefficient of static friction (μ_s): for horizontal surfaces:

$$5.3.7\ \mu_s = \frac{F_m}{N} = \frac{P}{W}$$

Where,

μ_s = Coefficient of Static friction

W = Load

P = Effort applied

α = Inclination of plane with the horizontal

Fm = Limiting Friction force

N = Normal Reaction

5.4 Procedure

1. Set the angle of inclination of the working plane to horizontal glass surface.
2. Place the given wooden block having glass bottom surface (W1) on the surface of apparatus and place known weights (W2) in this block. Here, the contact surfaces are glass and glass.
3. Connect the block to effort pan (P1) passing through a frictionless pulley.
4. Apply effort (P2) in small increments such that the block impends.
5. Note the value of load and effort and calculate the coefficient of friction between the surfaces.
6. Take two observations for the same block and calculate the average coefficient of friction.
7. Also measure the angle of repose by keeping the same block on the surface and gradually tilting the incline such that the block starts slipping down, corresponding angle with the horizontal is the angle of repose. Note down that angle.
8. Repeat steps 1 to 7 for other blocks having wooden bottom surface and metal bottom surface.

5.5 Observations

1. Self-weight of the effort pan = P1 = ____________ = N
2. Self-weight of the ________________ bottom Block = W1 = ____________ = N
3. Self-weight of the ________________bottom Block = W1 = ____________ = N
4. Self-weight of the ________________bottom Block = W1 = ____________ = N

5.6 Observation Table

Sr. No.	Surface in Contact	Reading No.	Additional Load Applied in Block (W_2) (N)	Effort Required in Pan (P_2) (N)	Total Load moved ($W=W_1+W_2$) (N)	Total Effort applied ($P=P_1+P_2$) (N)	Co- efficient of Friction (μ_s)	Avg. Co-efficient of Friction (μ_s)	Angle of Repose (θ)
1.		**1**							
		2							
		3							
2.		**1**							
		2							
		3							
3.		**1**							
		2							
		3							

5.7 Calculations

5.8 Result and Conclusion

Cognitive (thinking, knowledge) (04)	Psychomotor Skills (doing, skills) (04)	Affective domain (feeling & attitude) (02)	Total (10)	Sign

Experiment No – 06– Determination of Coefficient of static friction for motion on inclined Plane

6.1 Aim

Determination of Coefficient of static friction for motion on inclined plane

6.2 Apparatus

An adjustable inclined glass plane with pulley at one end, wooden block having different material at bottom surface, inextensible string, pan and standard weights.

6.3 Theory

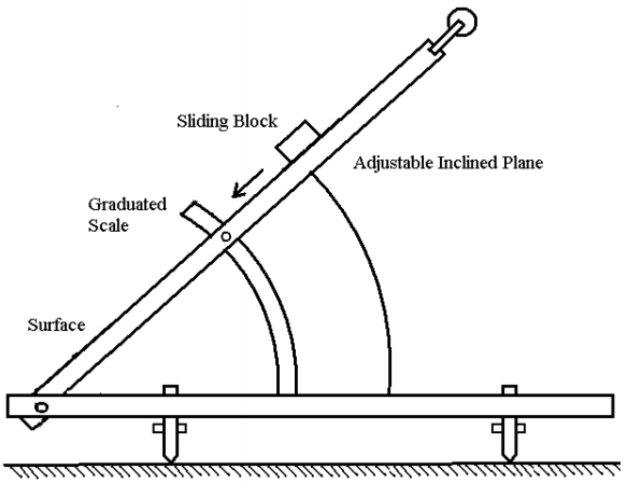


Figure 6-1 Apparatus Used to Find Coefficient of Static Friction

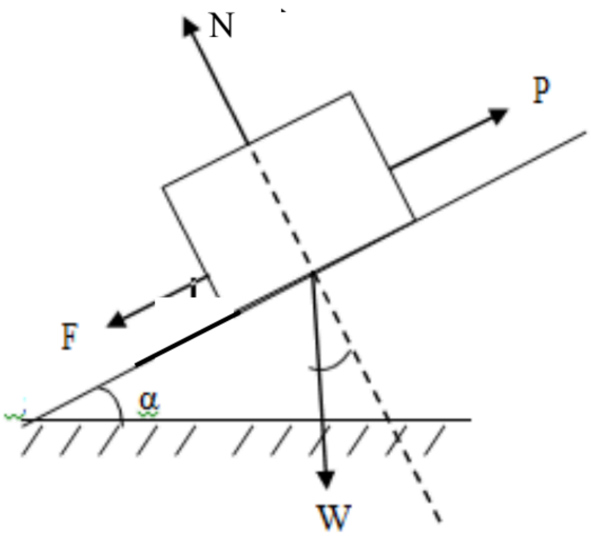


Figure 6-2 Block Resting on Inclined Surface

6.3.1 Coefficient of static friction (μ_s): For Inclined Surfaces:

$$\mu_s = \frac{F_m}{N} = \frac{P - W\sin\sin\alpha}{W\cos\cos\alpha}$$

Where,

μ_s = Coefficient of Static friction

W = Load

P = Effort applied

α = Inclination of plane with the horizontal

Fm = Limiting Friction force

N = Normal Reaction

6.4 Procedure

1. Set the angle of inclination of the working plane to horizontal glass surface.
2. Place the given wooden block having glass bottom surface (W1) on the surface of apparatus and place known weights (W2) in this block. Here, the contact surfaces are glass and glass.
3. Connect the block to effort pan (P1) passing through a frictionless pulley.
4. Apply effort (P2) in small increments such that the block impends.
5. Note the value of load and effort and calculate the coefficient of friction between the surfaces.
6. Take two observations for the same block and calculate the average coefficient of friction.
7. Also measure the angle of repose by keeping the same block on the surface and gradually tilting the incline such that the block starts slipping down, corresponding angle with the horizontal is the angle of repose. Note down that angle.
8. Repeat steps 1 to 7 for other blocks having wooden bottom surface and metal bottom surface.

6.5 Observations

1. Self-weight of the effort pan = P1 = ____________ = N
2. Self-weight of the ________________ bottom Block = W1 = ____________ = N
3. Self-weight of the ________________bottom Block = W1 = ____________ = N
4. Self-weight of the ________________bottom Block = W1 = ____________ = N

6.6 Observation Table

Sr. No.	Surface in Contact	Reading No.	Angle of Inclination of plane with Horizontal (α) in degree	Additional Load Applied in Block (W_2) (N)	Effort Required in Pan (P_2) (N)	Total Load moved ($W=W_1+W_2$) (N)	Total Effort applied ($P=P_1+P_2$) (N)	Co-efficient of Friction (μ_s)	Avg. Co-efficient of Friction (μ_s)	Angle of Repose (θ)
1.		1								
		2								
		3								
2.		1								
		2								
		3								
3.		1								
		2								
		3								

6.7 Calculations

6.8 Result and Conclusion

Cognitive (thinking, knowledge) (04)	Psychomotor Skills (doing, skills) (04)	Affective domain (feeling & attitude) (02)	Total (10)	Sign

Experiment No – 07 – Determination of Support reaction of statically determinate beams by graphical method

7.1 Aim

To verify the conditions of equilibrium of a rigid body under the action of coplanar non-concurrent, parallel force system with the help of a simply supported beam using graphical method.

7.2 Apparatus

Graduated beam, standard weights and hooks.

7.3 Theory

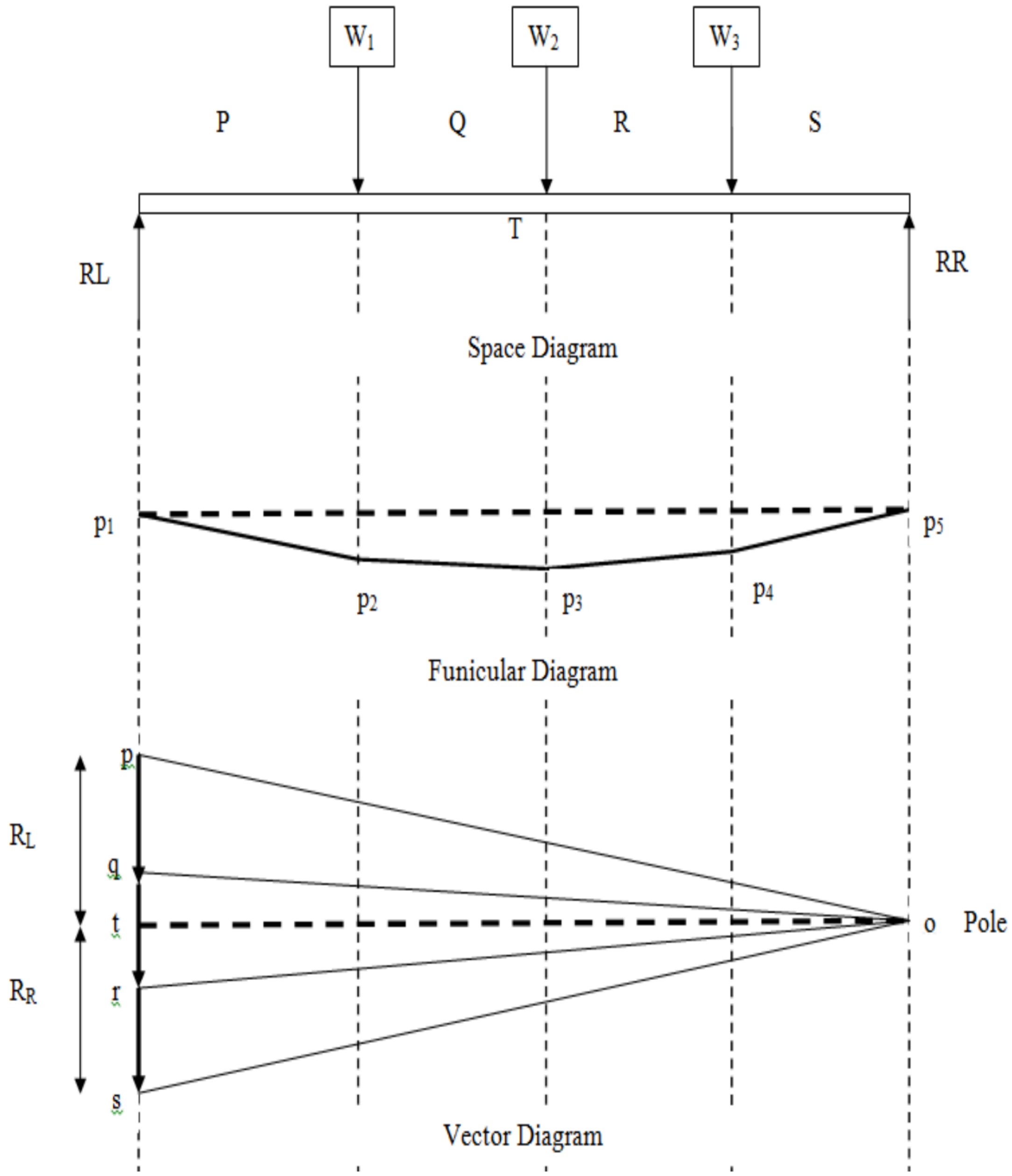
- Parallel Force System: Forces which are acting parallel to each other in direction are called parallel force system.
- Non-concurrent Force System: Forces whose line of action does not meet at a single point are called non-concurrent force system.
- Beam: is a structural member having cross-sectional dimensions very smaller than its length and is subjected to transverse loads (load acting perpendicular to the longitudinal axis of the beam).
- Beam is an example of Coplanar Non-concurrent Force System under the equilibrium condition.

7.3.1 Graphical Conditions of Equilibrium:

1. Force polygon should close which indicates that there is no motion of translation.
2. Funicular polygon should close which indicates that there is no motion of rotation.

7.4 Procedure

1. Draw the space diagram of the beam, and name all the loads according to Bow’s notation.
2. Construct Vector diagram. For that select some suitable point ‘p’ and draw ‘pq’ parallel and equal to load W1 to some scale. Similarly, through ‘q’ draw ‘qr’ parallel and equal to load W2 and through ‘r’ draw ‘rs’ parallel and equal to load W3 to the scale.
3. Select any suitable point ‘o’ and join ‘op’,’oq’, ’or’ and ‘os’.
4. Construct funicular diagram. For that select any point ‘p1’ on the line of action of the reaction ‘RL’. Through ‘p1’ draw ‘p1p2’ parallel to ‘op’ intersecting the line of action of the load W1 at p2.
5. Similarly, draw ‘p2p3’,’p3p4 and ‘p4p5’ parallel to ‘pq’ , ‘or’ and ‘os’ respectively. Join p1 with p5 and through o draw a line ‘ot’ parallel to this line.
6. Now the lengths ‘tp’ and ‘st’, in the vector diagram, given the magnitude of the reaction R_L and R_R respectively to the scale.


W1
W2
W3
P
Q
R
S
T
RL
RR
Space Diagram
p1
p2
p3
p4
p5
Funicular Diagram
p
q
t
r
s
RL
RR
o
Pole
Vector Diagram

7.5 Observation table

7. Length of the Beam

Sr. No	Applied Loads			Observed Reactions by Experiment			Distance of Loads from Left Support (From 'A') (mm)		
1.									
2.									
3.									
4.									
5.									

7.6 Calculation – Reactions by analytical and graphical method.

7.7 Result and Conclusion

Sr. No	Experimentally (N)		Analytically (N)		Graphically (N)	
	R_L	R_R	R_L	R_R	R_L	R_R
1.						
2.						
3.						

Cognitive (thinking, knowledge) (04)	Psychomotor Skills (doing, skills) (04)	Affective domain (feeling & attitude) (02)	Total (10)	Sign

Experiment No – 08 – Determination of coefficient of restitution.

8.1 Aim

To study the coefficient of restitution for a given pair of materials.

8.2 Apparatus

Balls of different materials, Measuring Tape etc.

8.3 Theory

The coefficient of restitution (e) is defined as the ratio of relative velocity of departure to the relative velocity of approach.

$$e = \frac{V_2 - V_1}{U_1 - U_2} = \frac{V_{\frac{2}{1}}}{U_{\frac{1}{2}}}$$

Where,

U_1 & U_2 are the velocities of the two bodies, just before impact

V_1 & V_2 are the velocities of the two bodies, just after impact.

In case one of the two bodies remains at rest both before & after impact then

$$U_2 = V_2 = 0.$$

An example is an impact between a rubber ball dropped on to a concrete floor, here the concrete floor remains at rest before & after impact.

In case ball is dropped from a height 'H' from the floor, the ball would rebound to a new height 'h'. From Rectilinear Equations we get,

$$U_1 = \sqrt{2gH} \text{ and } V_1 = \sqrt{2gh}$$

Where,

U_1 = Velocity of ball just before impact

V_1 = Velocity of ball just after impact

$$e = \sqrt{\frac{2gh}{2gH}}$$

The value of 'e' for a pair of bodies depends upon the surface properties of the materials to a large extent, size of the bodies and their geometry.

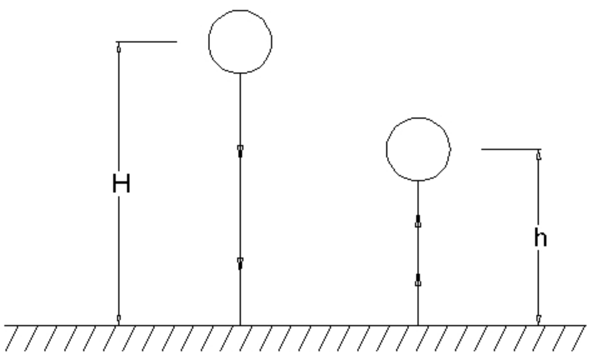


Figure 8-1 Restitution

8.4 Procedure

1. The ball and base material is selected.
2. The height of ball from base material is fixed and is recorded as ’H’.
3. The ball is released on base material.
4. The height of first redound is carefully seen and is recorded as ‘h’.
5. Steps 1 to 4 are repeated for different combinations of ball and base materials.

8.5 Observation table

Sr. No.	Ball Material	Base Material	Height of drop (H) mm	Height of 1st rebound (h) mm	Coefficient of restitution (e)
1.					
2.					
3.					
4.					
5.					
6.					

8.6 Calculation

8.7 Result and Conclusion

Cognitive (thinking, knowledge) (04)	Psychomotor Skills (doing, skills) (04)	Affective domain (feeling & attitude) (02)	Total (10)	Sign

Experiment No – 09 – Determination of centroid of various shapes of plates.

9.1 Aim

To determine the center of gravity of different shaped plane lamina with uniform thickness

9.2 Apparatus

Plumb bob, white sheet and different shaped plane lamina of uniform thickness.

9.3 Theory

9.3.1 Center of Gravity:

The center of gravity of a body is the point where the entire weight of body is assumed to be concentrated and is attracted towards the center of earth. The center of gravity does not depend on orientation of the body. Whenever the body is freely suspended, its center of gravity always remains below the line of suspension. Everybody has one and only one center of gravity.

9.3.2 Centroid:

It is defined as a point about which the entire line, area, or volume of a body is assumed to be concentrated. It is used for calculating the center of gravity of figures where weight factor does not come into picture.

9.3.3 Center of Mass:

It is defined as the point about where the entire mass of the body is assumed to be concentrated. If a body is homogenous and isotropic in nature, center of gravity and center of mass would be same.

9.3.4 Axis of Symmetry:

It is defined as the axis about which if the given figure is folded, then one portion exactly superimposes the other portion.

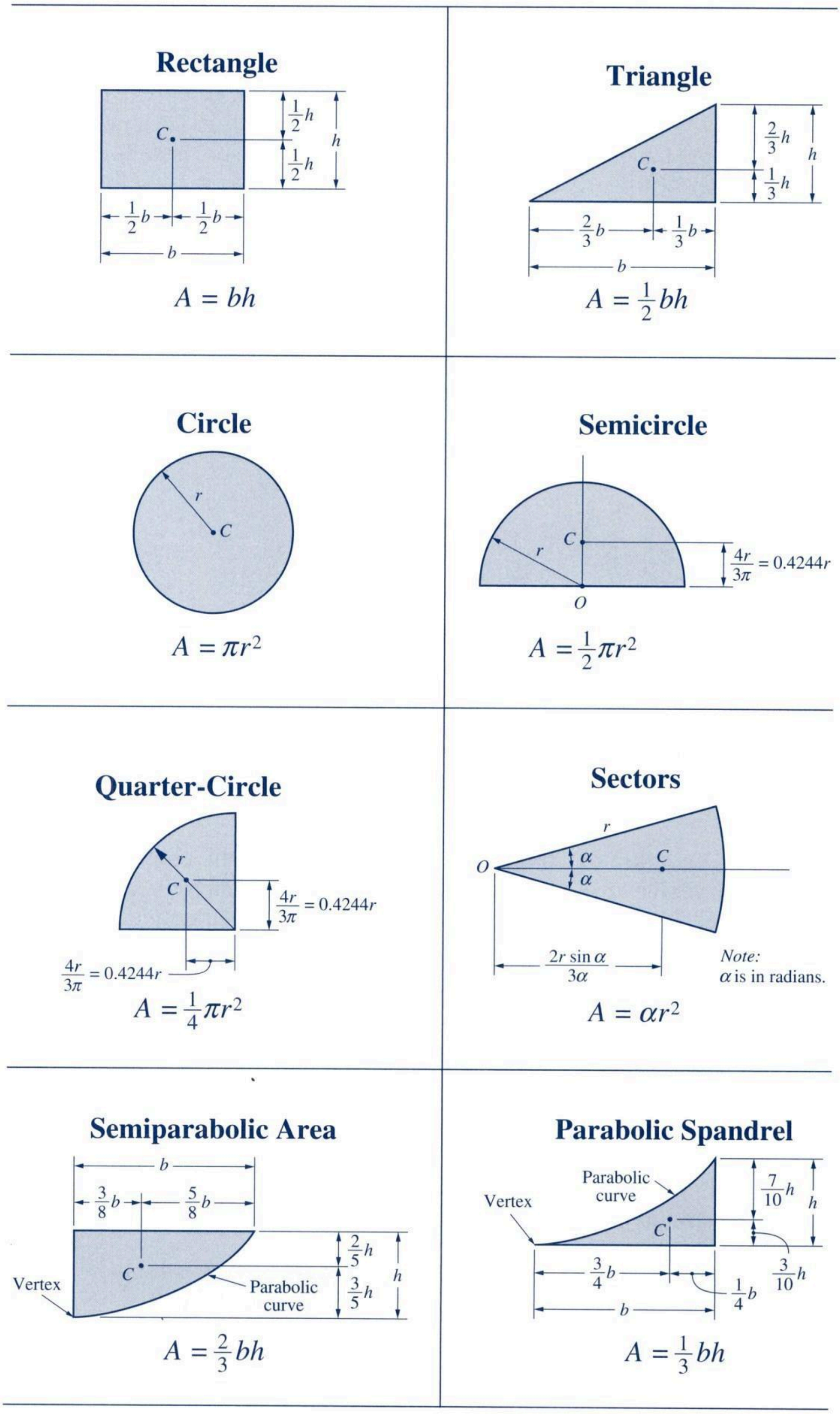


Figure 9-1 Centroid of standard shapes

9.4 Procedure

1. Fix a white paper exactly as of the size of the plane lamina.
2. Suspend the given lamina by a thread from one of the points given at its periphery.
3. Draw the vertical line on the area of lamina through the line of suspension of the thread.
4. Suspend the lamina again from another point given on the periphery and draw the line through the line of suspension of the thread.
5. Check further suspending the lamina from third point of lamina whether the line of suspension thread co-insides the same intersection point. Repeat the procedure for all the points.
6. The point of intersection of these lines gives the center of gravity of that lamina by experimentally.
7. Also calculate the center of gravity of that plane lamina by analytically.

9.5 Observation table

1. Axis of References through point 'O': ____________

Sr. No	Types of Lamina	Experimentally/Graphically		Analytically	
		$\overline{X}$ mm	$\overline{Y}$ mm	$\overline{X}$ mm	$\overline{Y}$mm
1.					
2.					
3.					

9.6 Calculation Experimental and Analytical

9.7 Result and Conclusion

Cognitive (thinking, knowledge) (04)	Psychomotor Skills (doing, skills) (04)	Affective domain (feeling & attitude) (02)	Total (10)	Sign

Experiment No – 10 – Determination of Mass moment of Inertia (Fly wheel).

10.1 Aim

To Determination of Mass moment of Inertia (Fly wheel).

10.2 Apparatus

Apparatus of Flywheel, stopwatch, weights, scale, etc.

10.3 Theory

$$I = 2n_2(mgh - \frac{1}{2}mv^2)/(\omega^2(n_1 + n_2)$$

ɿ	=	No. of turns of cord on axle.
	=	No. of rotations flywheel makes till detachment of falling mass.
ɿ	=	No. of rotations which flywheel make after detachment of falling mass till it stops.
h	=	Displacement of falling mass till detachment.
	=	$2\pi rn_1$
r	=	radius of Axle of flywheel.
□	=	Angular velocity of flywheel at the instant of detachment. = $4\pi n_1/t$
t	=	Time taken by flywheel for n_1 rotations.
v	=	v= linear velocity of falling mass at the instant of detachment.
	=	r□

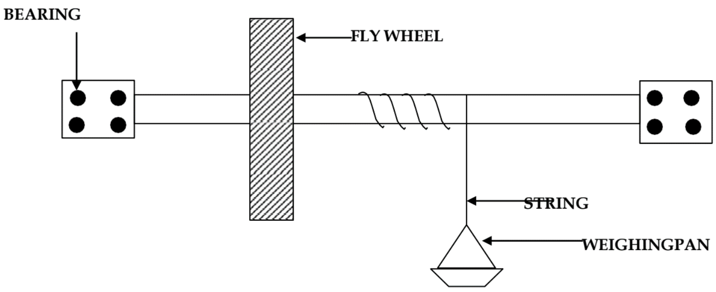


Figure 10-1 fly Wheel Apparatus

10.3.1 Kinetic & potential Energies of a body

1. Kinetic Energy: - It is the energy possessed by a body by virtue of its motion.

- If body undergoes translation:

 K.E. = $\frac{1}{2}mv^2$

- If body undergoes rotation:

 K.E. = $\frac{1}{2}m\omega^2$

10.3.2 Potential Energy

It is the energy possessed by a body by virtue of its position. In mechanics, P.E. due to gravity (weight) and elastic spring is important.

10.3.3 Law of conservation of Energy

In mechanics, it is sometimes known as Law of conservation of mechanical energy. It states that during motion, sum of kinetic energy must be transformed to potential energy and vice versa.

10.3.4 Derivation of formula for I

Moment of inertia I represents measure of resistance of a body to angular acceleration. It is defined as the integral of second moment about an axis of all elements of mass dm.

I = r^2 dm.

10.3.5 Phase I

The mass m falls through a vertical height of h and loses its potential energy mgh. This potential energy is converted in to:

1. Transnational K.E. = 1/2 mv^2 of falling mass m.
2. Rotational K.E. = 1/2$m\omega^2$ of flywheel where I is M.I. of flywheel about its axis of rotation.
3. Frictional energy loss n_1F is bearing where F is frictional energy loss in one revolution.

- Law of conservation of energy implies:

$$mgh = \frac{1}{2}mv^2 + \frac{1}{2}m\omega^2 + n_1F \quad \text{---1}$$

10.3.6 Phase II

When falling mass is detached, the flywheel is having rotational K.E. equal to 1/2Iω. This energy is lost in friction. If no. of revolutions of flywheel after detachment of mass is n2, this frictional loss is equal to n2F.

This means:

$$\frac{1}{2}I\omega^2 = n_2F \quad \text{------------------------------------ 2}$$

$$F = \frac{I\omega^2}{2n_2} \quad \text{------------------------------------ 3}$$

Equation (3) in (1) gives

$$mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 + \frac{n_1I\omega^2}{2n_2}$$

$$mgh - \frac{1}{2}mv^2 =+ \frac{1}{2}I\omega^2 + \frac{n_1I\omega^2}{2n_2}$$

$$mgh - \frac{1}{2}mv^2 =+ \frac{1}{2}I\omega^2\left(1 + \frac{n_1}{n_2}\right)$$

$$mgh - \frac{1}{2}mv^2 =+ \frac{1}{2}I\omega^2\left(\frac{n_1+n_2}{n_2}\right)$$

$$I = \frac{2n_2}{\omega^2\left(\frac{n_1+n_2}{n_2}\right)} * \left(mgh - \frac{1}{2}mv^2\right) \quad \text{------------------------------------ 4}$$

Here $V = r\omega$ ------------------------------------ 5

But $\omega = \omega_0 + \alpha t$

$\omega = \alpha t$ since $\omega_0 = 0$ ------------------------------------ 6

But $a = r\alpha$ ------------------------------------ 7

Also $S = V_0 * t + \frac{1}{2}at^2$

Here $S = h = (2\pi r)n_1$ $V_o = 0$

$$(2\pi r)n_1 = \frac{1}{2}at^2$$

$$a = \frac{4\pi r n_1}{t^2} \quad \text{------------------------------------ 8}$$

Equation (8) in (7) gives

$$\frac{4\pi r n_1}{t^2} = r\alpha$$

$$\alpha = \frac{4\pi n_1}{t^2} \quad \text{------------------------------------ 9}$$

Equation (9) in (6) gives

$$\omega = \frac{4\pi n_1}{t} \quad \text{----------------------------------- 10}$$

ω in (5) gives

$$V = \frac{4\pi r n_1}{t} \quad \text{----------------------------------- 11}$$

10.4 Procedure

1. Record mass of pan & radius of axle of flywheel.
2. Take a cord of length less than the distance of axle from ground.
3. Make loop at one end and attach pan at other end.
4. Slip on the loop to small pin on axle of wheel.
5. Start wrapping string when pin is exactly horizontal by slowly turning flywheel. Give few turns say "n_1".
6. A short horizontal line is marked when pin is horizontal.
7. Put some mass say 100 gms in pan & record mass "m" inclusive wt of pan.
8. Release the pan & start stopwatch
9. Count no. of revolution till mass is detached (these should be n_1) stopwatch is stopped when mass is detached from fly wheel. Note time " t" required for 'n_1' revolution.
10. Record no. of revolution 'n_2' that fly wheel makes after mass is detached.
11. Repeat the experiment for different value of n_1 & mass.

10.5 Observation table

12. Radius of the axle = cm

Sr. No.	Mass in gram	No. of turns of cord on Axle n_1	$h = 2\pi r n_1$	Time for detachment "t" sec	No. of revolution after detachment n_2	$\omega = 4\pi n1/t$ Rad/sec	I = gm-cm^2
1.							
2.							
3.							
4.							
5.							

10.6 Calculation Experimental and Analytical

10.7 Result and Conclusion

Cognitive (thinking, knowledge) (04)	Psychomotor Skills (doing, skills) (04)	Affective domain (feeling & attitude) (02)	Total (10)	Sign