MGM University's

Jawaharlal Nehru Engineering College

Aurangabad, Maharashtra.

NAAC 'A' Grade, ISO 9001:2008, 14001:2004 Certified, AICTE Approved.

First Year B. Tech

Department of Civil Engineering

Lab Manual

CIV21MMP107: ENGINEERING MECHANICS LAB

Lab Incharge	Reviewed by	Approved by
N. B. Sonar	**Dr. V. S. Pradhan**	**Dr. H. H. Shinde**
Asst. Prof.	**Head of Department**	**Principal**

Vision

Applied Science department is committed to provide the best learning and creative experience of basic sciences i.e. Physics, Chemistry and Mathematics, which is the background of engineering studies.

Mission

To provide sound background of basic concepts, principles of physics, chemistry and Mathematics to engineering students which develops firm base for further studies in engineering field.

Lab Objectives

1. To describe the working principle of machines and correlate them with day to day engineering applications.
2. To formulate and solve mechanics problems based on law of moments, conditions of equilibrium, etc. by using spreadsheet program.
3. To verify theoretical concepts through analytical, experimental and graphical methods.

Jawaharlal Nehru Engineering College

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This is to certify that Mr./Ms.…………………………….……...……... of class ……...……...…… Roll No. ……………...…has performed the experiments mentioned above in the premises of institution.

Date: / / Lecturer In charge Head of Dept. Principal

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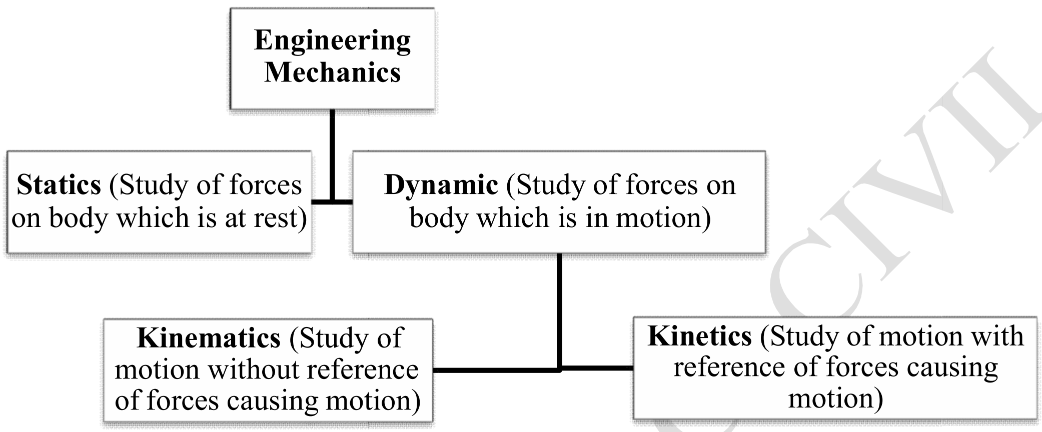
Time Allotted for each Practical Session = 02 Hrs.

PRE - REQUISITE-I

PRE-REQUISITE -I

Engineering Mechanics: Engineering Mechanics is the physical science which deals with the study of forces and their effects on the bodies.



Force: An external agent which changes or tends to change the state of rest or uniform motion of a body upon which it acts is known as force.

Characteristics of Force: In order to identify a force completely we must know the following four characteristics about it.

- Magnitude
- Direction
- Point of application
- Line of Action

Weight: The gravitational force of attraction exerted by the earth on a body is known as the weight of the body. Since this attraction is a force, the weight of body is expressed in Newton (N) in SI units.

$$\text{Weight} = \text{Mass} \times \text{Gravitational acceleration}$$

$$W = m \times g$$

Displacement: It is the change of position of a particle in a definite direction & it is measured by a straight distance between the initial and final position of the particle.

Speed: It is defined as the rate of change of distance with respect to time. Speed is a scalar quantity and its unit is m/s.

Velocity: It is defined as the rate of change displacement with respect to the time. It is vector quantity and its unit is m/s.

Acceleration: The rate of change of velocity with respect of time is called acceleration.

Distance: It is the length measured along the path of a body. Distance is a scalar quantity

Motion: It the change in position of a body with respect to a reference point. There are three types of motion viz. Translational motion, Rotational motion and general plane motion.

Translation: If a straight line drawn on the moving body remains parallel to its original position, then such motion is called translation. Translation can be sub divided into two types,

1.Rectilinear motion: When particle moves along a straight path is called rectilinear motion or linear motion.

2.Curvilinear motion: The motion of a particle along a curved path other than a straight line is known as curvilinear motion.

Angular Motion: The motion of a particle in curvilinear motion is on a curved path, without changing the position of its centre is called as angular motion.

Projectile: The freely projected particles which are having the combined effect of a vertical and a horizontal motion are called projectiles.

Newton's First Law:

Newton's First Law of motion states if a body is in state of rest, it will remain in the state of rest and if it is in the state of motion it will remain in the state of the motion with same velocity and same direction unless an external force is applied on it.

Newton's Second Law:

The second law of motion states that the rate of change of momentum of an object is proportional to the applied unbalanced force in the direction of force.

Mathematically, the law says that force is the product of mass and acceleration.

i.e. $F = ma$

where, m = Mass of the object, a = Acceleration

Newton's third law of motion:

It states that to every action there is always an equal and opposite reaction.

When two objects A and B act on each other, the force exerted by A on B (F_{AB}) is equal to the force exerted by object B on A (F_{BA}) in magnitude but are in opposite directions.

i.e. $F_{AB} = -F_{BA}$

or $F_{AB} + F_{BA} = 0$

Centre of Gravity: Everybody is attracted towards the centre of the earth due gravity. The force of attraction is proportional to mass of the body. Everybody consists of innumerable particles; however, the entire weight of a body is assumed to act through a single point and such a single point is called centre of gravity. Everybody has one and only one centre of gravity.

Moment of Inertia: It is a measure of an object's resistance to changes to its rotation. It must be specified with respect to a chosen axis of rotation.

PRE-REQUISITE-II

STUDY OF SIMPLE MACHINES

STUDY OF SIMPLE MACHINES

Aim: To study simple machines.

Machine:

An apparatus using mechanical power and having several parts each with a definite function and together performing a particular task. At its simplest, a machine is an invention that does a job better and faster and more powerfully than a human being.

Load (W):

This is the resistance which machine has to overcome.

Effort (P):

This is the force necessary to work the machine so as to overcome the load and any other resistance against movement.

Mechanical advantage (M.A.):

This is the ratio of the load applied to the effort applied to the machine i.e.

M.A. = Load applied / Effort applied = W / P

Velocity Ratio (V.R.):

This is the ratio of the distance moved by the effort in any interval of time to the corresponding distance, moved by the load in the same interval of time.

V.R. = Distance moved by effort / Distance moved by load = Sp / Sw

Input of machine:

This is the total work done on the machine or energy supplied to the machine. This is same as work done by the effort. The importance of machine is to lift the load and overcome the resistance. (Friction of the machine)

Resistance of machine:

This is the resistance against the movement of load. Resistance of the machine is mainly due to the friction between the moving parts of the machine.

Output of machine:

It is defined as useful work got out of the machine, i.e. the work done by the load.

Efficiency of machine: (η):

This is ratio of output of machine to the input. This is also same as the ratio of useful work done by the machine to the energy supplied to it.

Efficiency of machine = Output of machine / Input of machine

= Useful work done / Actual energy supplied

$= (W \times S_w) / (P \times S_p)$

$= (W/P) / (S_p/S_w)$

= M.A. / V.R.

$\eta\%$ = (M.A. / V.R.)*100 i.e. efficiency in %.

Ideal machine:

A machine whose efficiency is 100% is called an ideal machine. This machine is absolutely free from the frictional resistance. In other words, in an ideal machine, the output is equal to input.

Input = Output

$W / P = S_p / S_w$

$P \times S_p = W \times S_w$

M.A. = V.R.

Ideal Effort (Pi):

For ideal machine V.R. = M.A. i.e. W/P = V.R.

Therefore P = W / V.R.

Hence ideal effort is the ratio of load applied to the velocity ratio.

$$P_i = W / V.R.$$

Frictional Effort (Pf):

Frictional effort = Actual effort – Ideal effort

$P_f = P_a - P_i$

Law of machine:

–Law of machine is an equation which states the relation between effort & load. It gives an effort required for certain load or load that can be lifted with given effort. It can be expressed in the form of:

$$P = mW + C$$

Where, P = Effort applied in 'N'

W = Load applied in 'N'

m = Slope of graph line (Graph of actual effort Vs Load)

C = Intercept of line on Y axis / Constant.

Reversibility of simple machine:

A lifting machine in which the load starts moving back to its original position when the effort is removed is called reversible machine.

If efficiency of machine is >= 50%, machine is reversible.

If efficiency of machine is <50%, machine is irreversible / self-locking.

<u>EXPERIMENT NO. 01</u>

SIMPLE SCREW JACK

Date of Performance	
Date of Submission	
Grade	
Signature of Teacher	

EXPERIMENT NO. 01

SIMPLE SCREW JACK

Aim: To study simple screw jack and find its V.R. and its various performances

Apparatus: Simple screw jack, thread, pan, weights, etc.

Theory:

A screw jack is used to lift & support heavy loads. Jacks used for lifting trucks or cars for repairs are screw jack. To lift such heavy loads, comparatively very small effort is applied at the end of the handle.

Screw jack consists of a screw & a drum is mounted at its head. Load is kept on the drum therefore it is called as Load drum. Load drum is rotated with the help of the thread passing over the pulley and having effort applied at its end.

When screw jack completes on the rotation load drum will also complete one rotation. Distance moved by effort is equals to the circumference of the load drum at the same time load is lifted by distance equals to the pitch of the screw.

Therefore, velocity ratio $= \dfrac{\text{Distance moved by effort}}{\text{Distance moved by load}}$

$$= \frac{\text{Circumference of load drum}}{\text{Pitch of the screw}} = \frac{C_W}{P}$$

Procedure:

1. Observe the machine – ‘Screw Jack.’ Identify the various components Such as screw, load drum, pulley.

2. Measure the pitch of the screw and circumference of load drum.

3. Find the velocity ratio.

4. Set up the machine and attach heavy load drum.

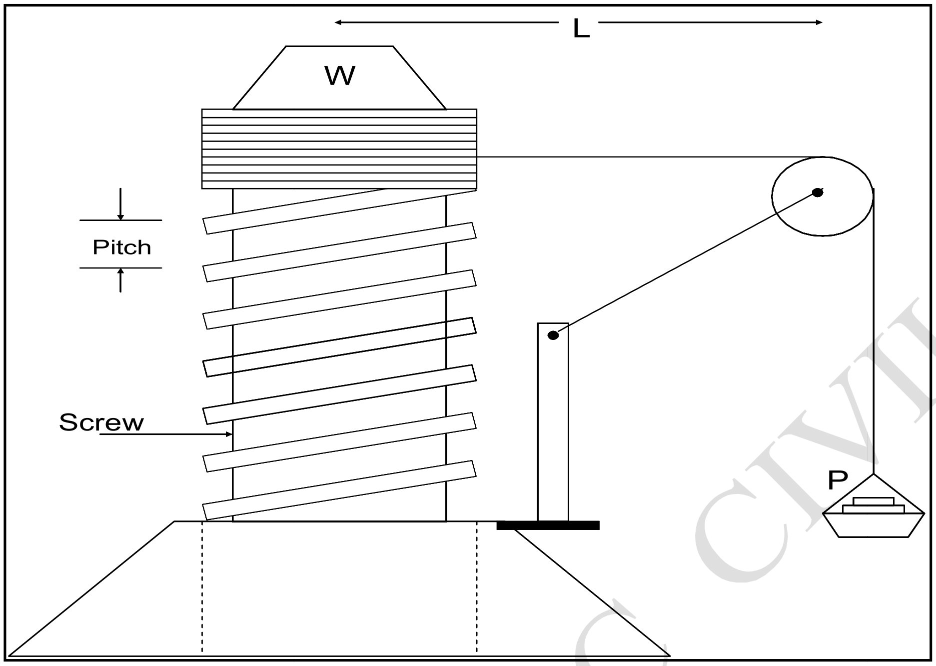


Figure 7: Screw Jack

5. Find corresponding effort (P) by gradually increasing the value so that when effort (P) moves down, load (W) just starts moving up. Label the motions in the diagram.

6. Repeat the procedure for different heavy load W.

7. Draw the graph by taking load values on x-axis and effort values onY-axis with suitable scale. Note the co-linear relationship between efforts & load W.

8. Find slope (m) and intercept (C) on y-axis for the straight line, and write relation in the form of P= (m.W+C). Note this equation is called as Law of machine.

9. Calculate mechanical advantage & subsequently efficiency for each set of load (W) & corresponding effort (P) by relation MA= load (W) /Effort (P) &efficiency (%η) = MA/V.R. x 100. Tabulate the same in observation table.

10. Calculate ideal effort (Pi) for each of load (W) by a relation P_i = W / V.R. & tabulate it. Note that effort (P) in actual machine is greater than ideal effort (Pi) required in ideal machine. Plot the graph of ideal effort - P_i(On y-axis) & Load –W (On x-axis).

11. Note linear relationship between them.

12. Calculate effort lost in friction (P_f) for each of the load (W) by relation P_f = P – W / V.R. & tabulate the same.

13. Plot the graph of 'Effort lost in friction' P_f (on y-axis) against Load (W) on X-axis. Note the linear relationship between P_f& W.

14. Draw an interference from the graph plotted.

15. Draw the graph taking load on x-axis and mechanical advantage & efficiency on y-axis.

16. Calculate load loss in friction by the formula W_f= P x V.R. – W.

17. Find the maximum mechanical advantage & maximum efficiency for the machine.

Observations:

1. Diameter of load table: D =
2. Pitch of Screw: p =
3. Circumference of load table: πD =
4. Velocity Ratio: $S_p/S_w = \pi D/p$ =

Observation Table:

Sr. No.	Load (W) Newton	Effort (P_a) Newton	M.A. = W/P_a	η%= M.A./V.R. * 100	$P_i = W/V.R.$	$P_f = P_a - P_i$
01						
02						
03						
04						
05						

Calculations:

Result:

i. V.R. of machine: = S_p/S_w

S_p = Circumference of load table = πD =_______

S_w = Pitch of screw = p= ______

Therefore V.R. = $S_p/ S_w= \pi D/p$= ___________

ii. Efficiency of machine = M.A. /V.R.= _________

iii. Percentage of efficiency = (M.A./V.R.)*100=__________

Conclusion:

i. Efficiency of machine is less than 50%, the machine is irreversible.
ii. V.R. of machine remains constant.
iii. Efficiency of machine increases with load in the beginning and then remains constant.
iv. The graph line indicates a linear motion.
v. As load on machine increases, the effort required to lift also increases.

Exercise

1. Define velocity ratio.

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2. What is efficiency of machine?

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3. Define mechanical advantage.

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EXPERIMENT NO. 02

POLYGON LAW
OF
COPLANAR FORCES

Date of Performance	
Date of Submission	
Grade	
Signature of Teacher	

EXPERIMENT NO. 02

POLYGON LAW OF COPLANAR FORCES

Aim: To verify law of polygon and calculate the resultant of coplanar concurrent force system

Equipment: Force table, pulleys, set of weights, light inextensible string, spirit level, and circular ring.

Theory: If more than three coplanar concurrent forces are acting on rigid body be represented by the sides of polygon taken in order (tail of second force coincides with tip of first force) then, closing line of polygon represents the resultant taken in reverse order (tip of resultant force coincides with tip of last force). At equilibrium force is zero. Therefore, tail of the first force coincides with tip of last force i.e. polygon is closed figure.

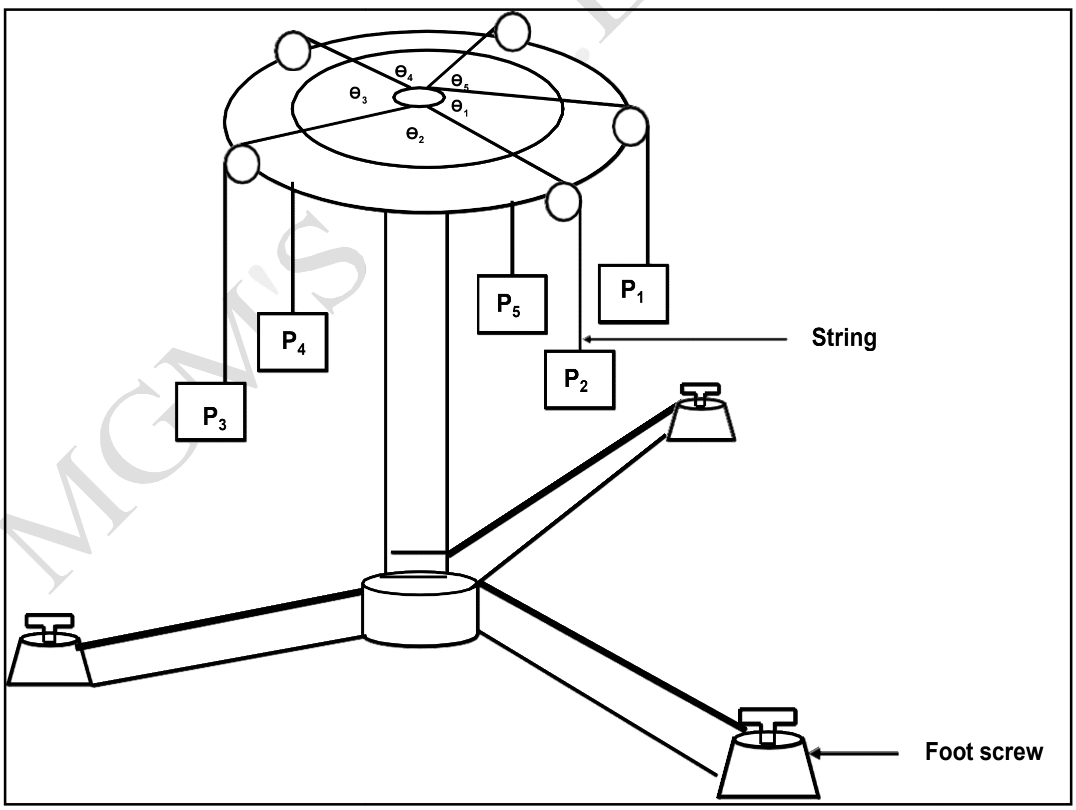

Figure1: Force Table

Procedure:

1. Organize the physical set up of experiment &study it.
2. Level the force table by adjusting the foot screws &check it with help of bubble tube.
3. Apply the forces P_1, P_2, P_3, P_4& P_5 so that the pivot remains at centre of ring. Note down the magnitude & direction of forces.
4. Observe the angles between consecutive forces & note it.
5. Draw space diagrams for each reading using Bow's notation & then draw the force polygon with proper scale for all forces on graph paper.
6. Observe the nature of polygon whether it is open or closed.
7. Apply unknown weight on one of the strings& adjust the forces in other strings to so that the pivot remains at centre of ring.
8. Find the unknown weight by drawing space diagram & force polygon.

Observation Table:

Sr. No.	Magnitude of forces (N)					Angle between consecutive forces					Remark
	P_1	P_2	P_3	P_4	P_5	θ_1	θ_2	θ_3	θ_4	θ_5	
1.											
2.											
3.											

Calculations: Analytical Calculations

Result:

Sr. No.	Resultant calculated by analytical method	Resultant calculated by graphical method
1.		
2.		
3.		

Conclusion:

Resultant of the force system calculated by analytical method and graphical method is ....(Nearly same / Exactly same).

Exercise

1. **Which is the correct statement about law of polygon of forces?**
   A. If any number of forces acting at a point can be represented by the sides of a polygon taken in order, then the forces are in equilibrium.
   B. If any number of forces acting at a point can be represented in direction and magnitude by the sides of a polygon, then the forces are in equilibrium.
   C. If a polygon representing forces acting at a point is closed then forces are in equilibrium.
   D. If any number of forces acting at a point can be represented in direction and magnitude by the sides of a polygon taken in order, then the forces are in equilibrium.

   Answer:

2. **State triangle law of forces.**

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EXPERIMENT NO. 03

BELL CRANK LEVER

Date of Performance	
Date of Submission	
Grade	
Signature of Teacher	

EXPERIMENT NO.03

BELL CRANK LEVER

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

Apparatus: Bell crank lever apparatus, hangers, weights, scale.

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.

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 T_f. The tensile force T on the vertical arm is the difference T_f —T_i.
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.

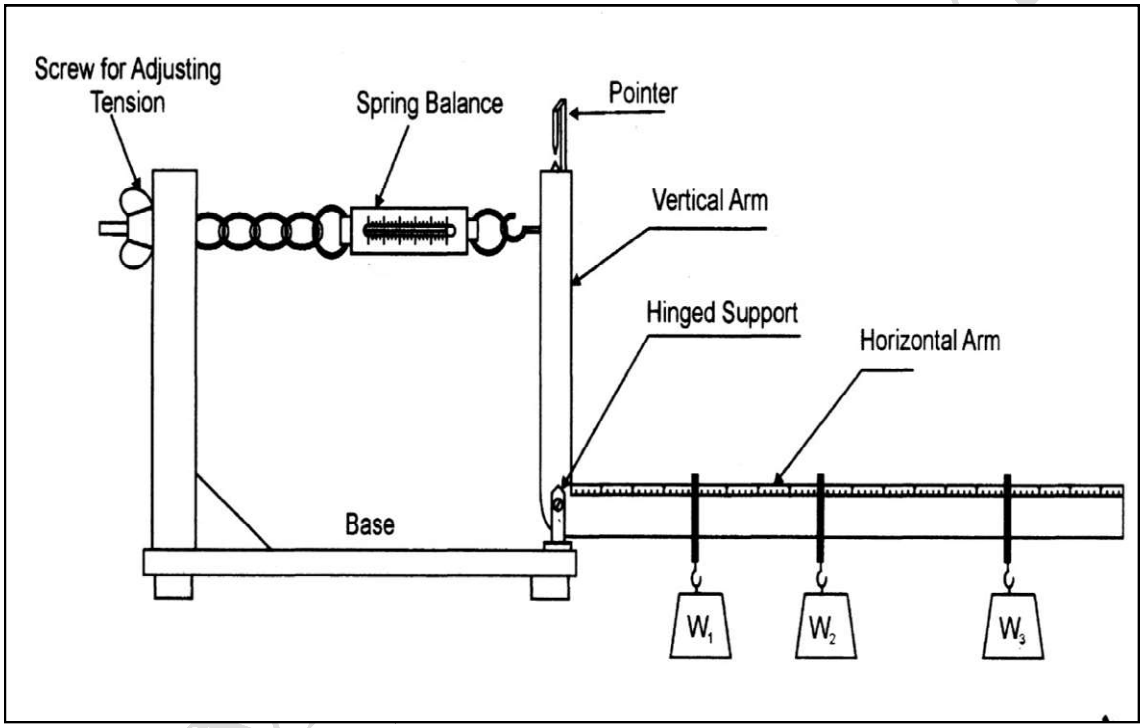

Figure 3: Bell Crank Lever

Observation Table:

Sr. No.	T_i(N)	Y (m)	W_1 (N)	W_2 (N)	X_1 (m)	X_2 (m)	T_f (N)	$T= T_f-T_n$	$\Sigma M=T\times Y-W_1\times X_1 - W_2\times X_2 - W_3\times X_3$
1.									
2.									
3.									

Calculations:

Summation of moments of all external forces at the hinge O.

$\Sigma M_o = (T \times Y) - (W_1 \times X_1) - (W_2 \times X_2) - (W_3 \times X_3)$

Conclusion:

The sum of moments of all the applied external forces on the bell crank lever, within limits of experimental error being close to zero, is in accordance to the 'Principle of Moments'.

Hence the experiment is verified.

Exercise

1. What is mean by moment?

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2. What is the principle of moments?

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3. What is unit moment?

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EXPERIMENT NO. 04

LAMI'S THEOREM

Date of Performance	
Date of Submission	
Grade	
Signature of Teacher	

EXPERIMENT NO. 04

LAMI’S THEOREM

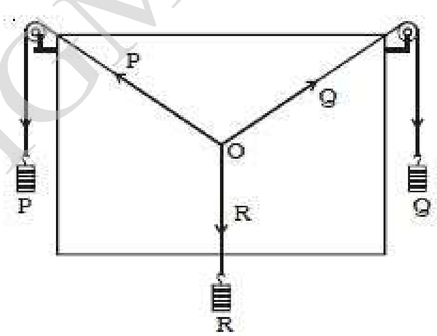
Aim: To verify Lami’s theorem with equilibrium of three parallel forces

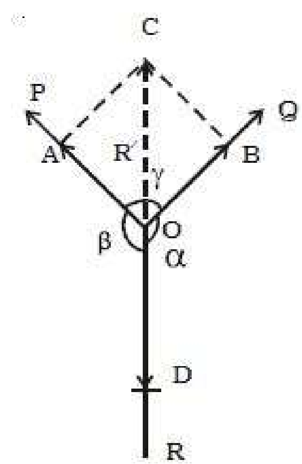
Apparatus: Force table, pulleys, set of weights, light inextensible string, spirit level, and circular ring.

Theory: Lami’s theorem states that, if three concurrent forces act on a body keeping it in Equilibrium, then each force is proportional to the sine of the angle between the other two forces. According to this theorem, when three coplanar, concurrent and non-co-linear forces act on a body which is in symmetry then the magnitude of each force is proportional to the sine of the angle between the other two forces.

Procedure:

1) Two smooth small pulleys are fixed, one each at the top corners of a universal force table as shown in Figure. The pulleys should move freely without any friction. A light string is made to pass over both the pulleys. Two slotted weights P and Q (of the order of 50 g) are taken and are tied to the two free ends of the string. Another short string is tied to the center of the first string at O. A third slotted weight R is attached to the free end of the short string. The weights P, Q, and R are adjusted such that the system is at rest.





2) If the point O is in equilibrium under the action of the three forces P, Q and R acting along the strings then, note the weights attached to each string P, Q, R. Also, note the angle opposite to each string i.e. the angle between other two forces. For example, note α as angle opposite P and between Q-R, β as angle opposite Q and between P-R, and γ as angle opposite R and between P-Q.
3) Calculate the ratio of each force to the sine of angle opposite it and check whether it is equal to the ratio of other two forces to the sine of angle opposite them, individually.
4) The experiment is repeated for different values of P, Q, and R and the values are tabulated.

Observation table:

Sr. No.	P (N)	Q (N)	R (N)	α (º)	β (º)	γ (º)
1						
2						
3						

Calculations:

Result:

Sr. No.	P/Sin α	Q/Sin β	R/Sin γ
1			
2			
3			

Conclusion:

1) The ratio of (P/Sin α), (Q/Sin β) and (R/Sin γ) are ________ to each other. (Equal / Nearly equal)
   Hence, the Lami's theorem is verified.

Exercise:

1) State Lami's theorem.

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2) State the applications of Lami's theorem.

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EXPERIMENT NO. 05

EQUILIBRIUM OF PARALLEL FORCES

Date of Performance	
Date of Submission	
Grade	
Signature of Teacher	

EXPERIMENT NO. 05

EQUILIBRIUM OF PARALLEL FORCES

Aim: To study Equilibrium of parallel forces – simply supported beam reactions.

Apparatus: Beam reaction apparatus, hooks & weights with hangers.

Theory: When system of parallel forces act on body & keeps the body in equilibrium then algebraic sum of forces is equals to zero & sum of moment of forces (active & reactive) about any point in plane of forces is equals to zero.

Procedure:

1. Organize the physical set up of experiment study it.
2. Measure span of beam.
3. Note down initial reading (reactive forces) at support A & B.
4. Apply loads P_1, P_2, (active forces) at different positions & measure the distances d_1, d_2, respectively from support A & note it.
5. Take final readings of reactive forces at supports A & B after loading & note down in observation table.
6. Calculate analytically support reaction at support A & B.
7. Compare the support reactions at supports A & B calculated by analytical method with support reactions calculated by deducting initial readings from final readings at each support.
8. Repeat the procedure for four sets of loadings.

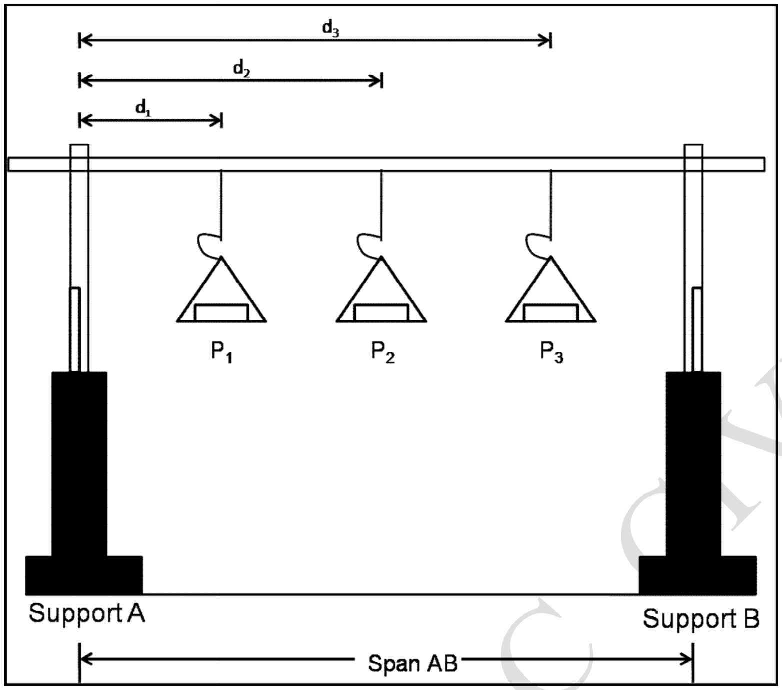

Figure 4: Parallel Force Table

Observation:

a) Span of AB = L =........................m
b) Initial readings at support A =…......................N
c) Initial readings at support B =......................... N

Observation table:

Sr. No.	Loads (N)		Distance from support A		Support Reactions				Support reactions by analytical method		Remark
	P1	P2	D1	D2	At A		At B		RA	RB	
					Final Reading (gm)	RA (N)	Final Reading (gm)	RB (N)			
1.											
2.											
3.											

Calculations:

Result:

Sr. No.	Reactions calculated by Experimental method	Reactions calculated by Analytical method
1.		
2.		
3.		

Conclusion: Support reactions calculated by analytical method and experimental method are ....(Nearly same/ exactly same)

Exercise

1. Define co-planer parallel force system.
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   ………………………………………………………………………………………
   ………………………………………………………………………………………

2. What is meant by equilibrium?
   ………………………………………………………………………………………
   ………………………………………………………………………………………
   ………………………………………………………………………………………

3. What are the static equilibrium conditions for co-planer concurrent force system?
   ………………………………………………………………………………………
   ………………………………………………………………………………………
   ………………………………………………………………………………………

4. Explain the term ‘support reactions.

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EXPERIMENT NO. 06

BEAM REACTION BY GRAPHICAL METHOD

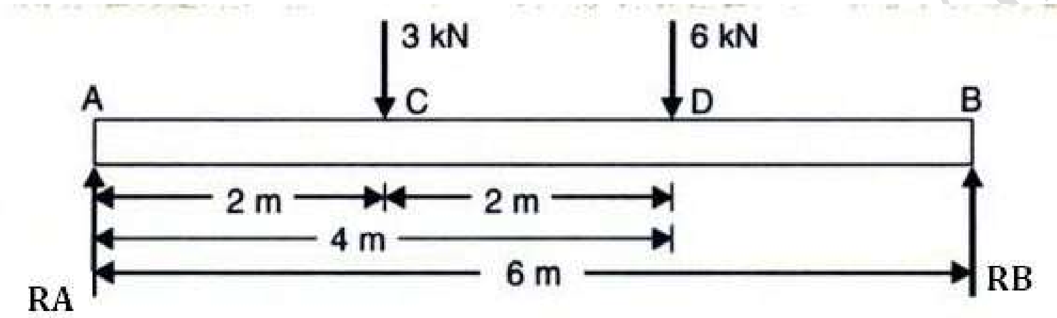
Date of Performance	
Date of Submission	
Grade	
Signature of Teacher	

EXPERIMENT NO.06

Beam Reaction by Graphical Method

Aim: To calculate the support reactions by graphical method.

Statement: A Simply supported beam AB Of span 6 m carries point loads 3 kN and 6 kN at a distance of 2 m and 4 m from the end A as shown in Fig. Find the reactions at A and B Graphically.



Procedure: - Graphical Method.

1. First of all, draw the space diagram of the beam to a suitable scale. Let 1 cm length in space diagram represents 1 m length of beam, hence take AB = 6 cm, distance of load 3 kN from A = 2 cm and distance of 6 kN from A =4 cm as shown in Fig, A.
2. Now name the loads and reactions according to Bow's notation i.e. load 3 kN is named by PQ. load 6 kN named by QR, reaction RB by SR and reaction RA by SP.

Now the vector diagram is drawn according to the following steps refer to Fig. b.

3. Choose suitable scale to represent various toads. Let 1 cm represents 1 kN load. Hence load PQ (i.e., 3 kN) will he equal to 3 cm and load QR (i.e.,6 kN) 6 cm.
4. Now take any point p and draw line pq parallel to load PQ (i.e., 3 kN). Take pq = 3 cm to represent the 3 kN,
5. Through q, draw line qr parallel 10 load QR (i.e., 6 kN). Cut qr equal to 6 cm to represent the load of 6 kN.
6. Take any point O. Join the point O to the points q and r as shown in Fig. b.

7. Now in Fig. a extend the lines of action of the loads (3 kN and 6 kN). and the two reactions. Take any point 1, on the line of action of the reaction RA. Through 1, draw the line 1-2 parallel to pO, intersecting the line of action of load 3 kN at point 2.
8. From point 2, draw line 2-3 parallel to qO, intersecting the line of action of load 6 k N at 3. Similarly, from point 3. draw a line 3-4 parallel to rO, intersecting the line of action Oi reaction RB at B point 4.
9. Join 1 and 4. The line 1-4 is known as closing line, From the vector diagram, from point O, draw line Osparallel to line 1-4.
10. Measure the length sp and rs. The length sp represents reaction RA and length rs represents reaction RB.

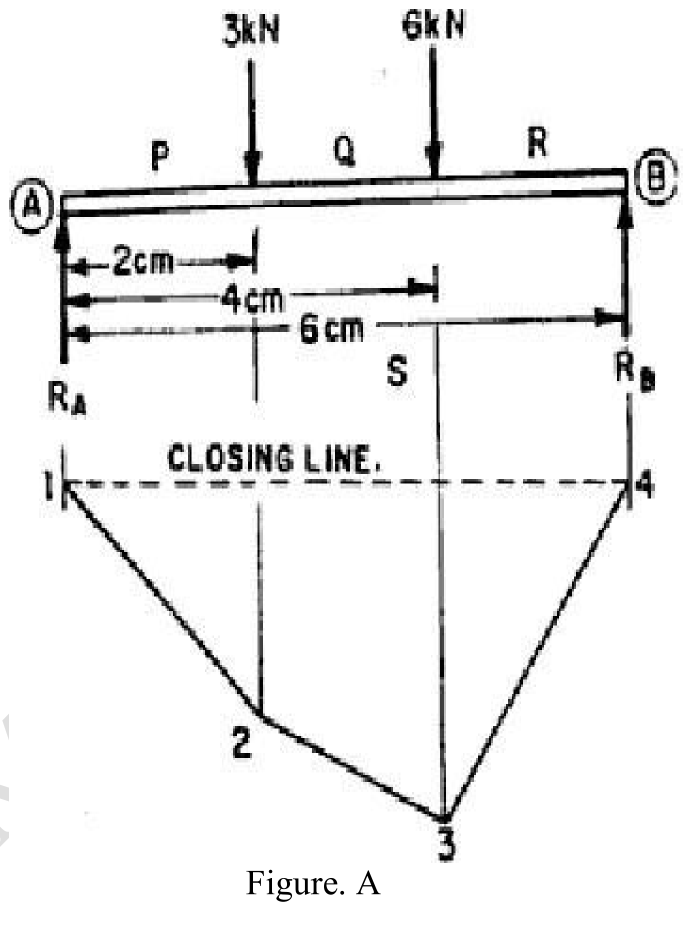


Figure. A

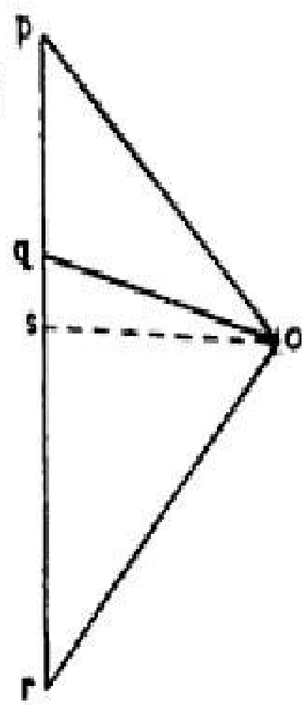


Figure. B

Calculations of support reaction by Analytical Method:

Observation table:

Sr. No.	Loads (N)		Distance from support A		Support Reactions By graphical Method		Support reactions by analytical method		Remark
	P1	P2	D1	D2	At A	At B	RA	RB	
					RA (N)	RB (N)			
1.									
2.									

Result:

Sr. No.	Reactions calculated by Graphical method	Reactions calculated by Analytical method
1.		
2.		

Conclusion: Support reactions calculated by analytical method and Graphical method are .... (Nearly same/ exactly same)

Exercise

1. What are different types of supports?

   ………………………………………………………………………………
   ………………………………………………………………………………
   ………………………………………………………………………………

2. What are the Graphical equilibrium conditions for co-planer concurrent force system?

   ………………………………………………………………………………
   ………………………………………………………………………………
   ………………………………………………………………………………

3. Explain Bow's notations.

   ………………………………………………………………………………
   ………………………………………………………………………………
   ………………………………………………………………………………

EXPERIMENT NO. 07

FRICTION

Date of Performance	
Date of Submission	
Grade	
Signature of Teacher	

EXPERIMENT NO. 7

FRICTION

Aim: To find the Coefficient of Friction between two surfaces.

Apparatus: Inclined Plane with pulley, weights, block, weight pan, etc.

Theory: Friction force is developed whenever there is a motion or tendency ofmotion of one body with respect to the other body involving rubbing of thesurfaces of contact. Friction is therefore a resistance force to sliding betweentwo bodies produced at the common surfaces of contact.

Friction occurs because no surface is perfectly smooth, however flat it may appear. On every surface there are 'microscopic hills and valleys' and due to this the surfaces get interlocked making it difficult for one surface to slide over the other. During static state the friction force developed at the contact surface depends on the magnitude of the disturbing force. When the body is on the verge of motion the contact surface offers maximum frictional force called as 'Limiting Frictional Force'.

In 1781 the French Physicist Charles de Coulomb found that the limiting frictional force did not depend on the area of contact but depends on the materials involved and the pressure (normal reaction) between them.

Thus, frictional force $F \alpha N$, or

$$F = \mu_s N$$

Here μ_s is the coefficient of static friction, a term introduced by Coulomb. The value of $\mu_s$lies between 0 and 1 and it depends on both the surfaces of contact.

Coefficient of static friction 'μ_s' between two surfaces can be found out experimentally by two methods, viz. Angle of Repose method and Friction Plane method.

The minimum angle of an inclined plane at which a body kept on it slides down the plane without the application of any external force is known as Angle of Repose. It is denoted by letter φ.

Angle of repose, $\varphi = \tan^{-1} \mu_s$

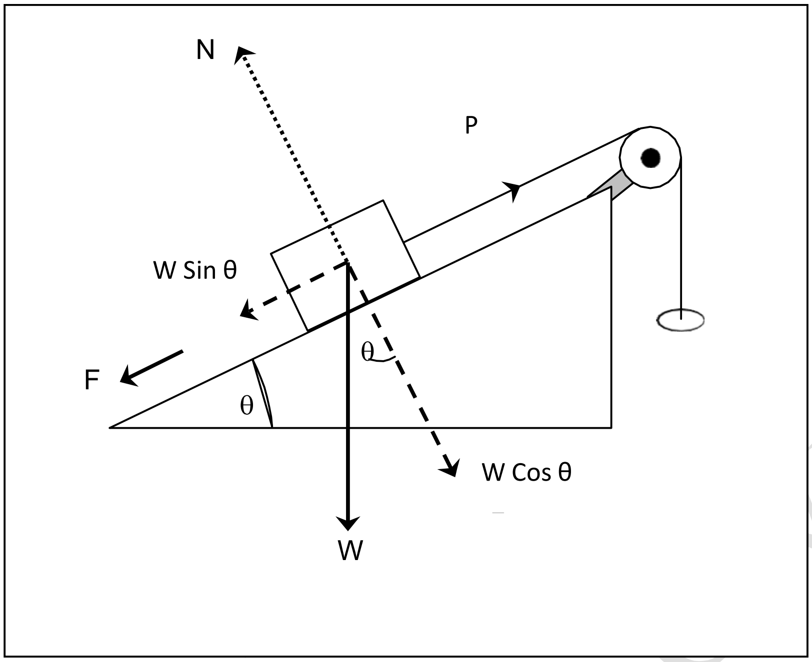


Figure 5: Friction factor apparatus

Applying Condition of Equilibrium

$$\sum F_x = 0$$

$$P - W\sin\theta - \mu_S N = 0 \qquad \text{......... (1)}$$

$$\sum F_y = 0$$

$$N - W\cos\theta = 0 \qquad \text{......... (2)}$$

From equations (1) and (2) we get

$$P - W\sin\theta - \mu_S (W\cos\theta) = 0$$

or $$\boxed{\mu_S = \frac{P - W\sin\theta}{W\cos\theta}}$$

Procedure:

1. Set the inclined plane with glass top at some angle with the horizontal. Note the inclination θ of the plane on the quadrant scale. Take a box of known weight, note its bottom surface (whether surface is soft wood, or sand paper, or card board etc,) and weight W (weight of box)
2. Tie a string to the box and passing the string over a smooth pulley, attach an effort pan to it.

3. Slowly add weights in the effort pan. A stage would come when the effort pan just slides down pulling the box up the plane. Using fractional weights up to a least count of 5 gm, find the least possible weight in the pan that causes the box to just slide up the plane. Note the weight in the effort pan. This is force 'P'.

4. Repeat the above steps 1 to 3 by changing the weights in the box for two more sets of observations.

Observation Table:

Type of surface	Weight of block (W) in 'N'	Angle of the Plane (θ)	Weight in effort pan (P) in 'N'	Coefficient of Friction (μ)	Average (μ)	Angle of Repose	
						Analytical	experimental
Wood							
Carpet Cloth							

Calculations:

Result:

Coefficient of friction between glass and wood is………………….

Coefficient of friction between glass and carpet cloth is …………….

Conclusion:

Wooden block has smooth contacting surface than carpet cloth, therefore its coefficient of friction is...................(less than/ more than) carpet cloth.

Exercise

1. Define friction.
   ………………………………………………………………………………
   ………………………………………………………………………………
   ………………………………………………………………………………

2. What is mean by coefficient of friction?
   ………………………………………………………………………………
   ………………………………………………………………………………
   ………………………………………………………………………………

3. Define angle of repose.
   ………………………………………………………………………………
   ………………………………………………………………………………
   ………………………………………………………………………………

EXPERIMENT NO. 08

CENTRE OF GRAVITY
OF
IRREGULAROBJECTS

Date of Performance	
Date of Submission	
Grade	
Signature of Teacher	

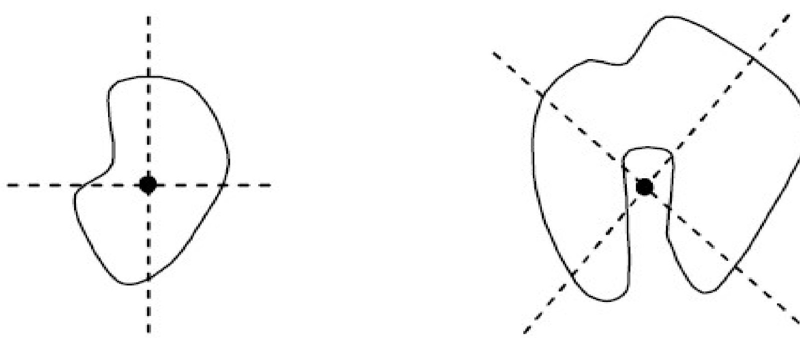
EXPERIMENT NO.08
CENTRE OF GRAVITY OF IRREGULAR OBJECTS

Aim: To determine the centre of gravity of irregular objects.

Material Required: Cardboards of different shapes, thread, nail, pencil,rule/straight edge, load, etc.

Theory: All bodies are attracted towards the centre of the earth with a force which is equal to its weight. The point in the body at which the weight appears to be concentrated is called its 'centre of gravity'.

The point where the total mass of the body seems to act is the centre of gravity. The centre of gravity of all bodies can be determined by balancing the body on a knife edge or by suspension with a plumb line from several points. In most cases, the centre of gravity of a body lies in the body itself, but in few cases such as the horse-shoe magnet, wine glass and conical flask, the centre of gravity lies outside as shown in figure.



(a) (b)

Procedure -

1. Cut an irregular shape from cardboard.
2. Make three holes close to the edges of the irregularly shaped cardboard.
3. Suspend the object to swing freely on a needle or nail through one of the holes created.
4. Attach a plumb line to the needle or nail and mark its position on the cardboard with the help of a rule or a straight edge.
5. Repeat steps 3 and 4 for the remaining holes, mark the positions of the plumb-lines carefully.

6. Locate the intersection of the three lines drawn; this indicates the centre ofgravity of the object.

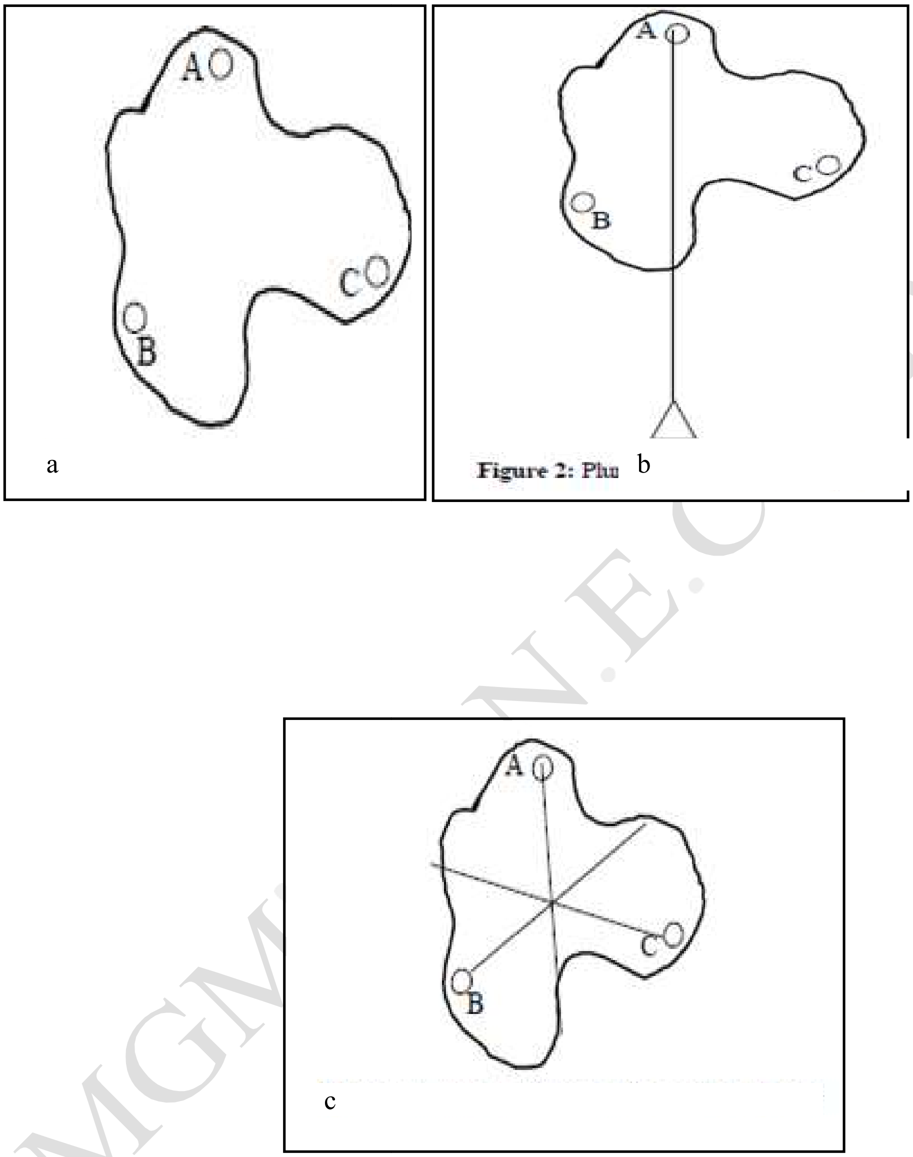


Figure 2: Steps for locating Centre of Gravity

Exercise

1. Define Centroid.

……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………

2. State centre of gravity

……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………

3. Differentiate between centroid and centre of gravity.

……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………

EXPERIMENT NO. 09

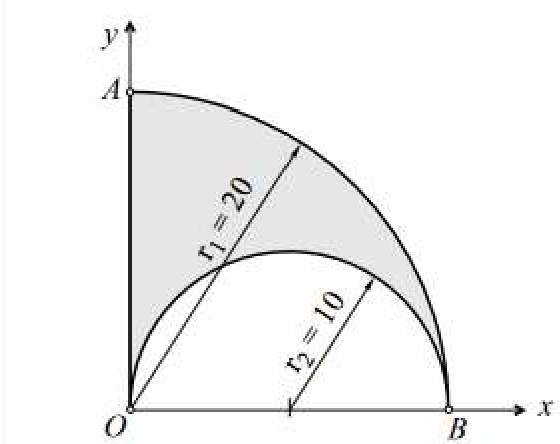
CENTER OF GRAVITY

FOR

COMPOSITE SECTIONS

Date of Performance	
Date of Submission	
Grade	
Signature of Teacher	

Find the coordinates of the centroid of the area shown in figure -



Ans:G (6.98, 12.74) cm

Find the centroid of the following shaded plane areas shown in figure -

1.

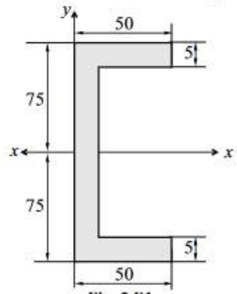


Fig. 5.E1

[*Ans.* $\bar{x}$ = 11.875 mm and $\bar{y}$ = 0.]

2.

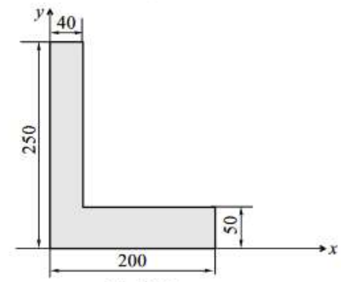


Fig. 5.E2

[*Ans.* $\bar{x}$ = 64.4 mm and $\bar{y}$ = 80.5 mm.]

3.

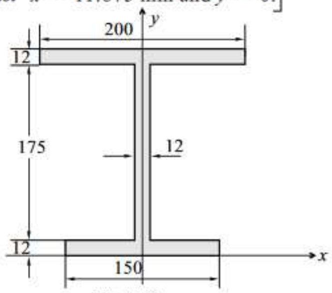


Fig. 5.E3

[*Ans.* $\bar{x}$ = 0 and $\bar{y}$ = 108.4 mm.]

4.

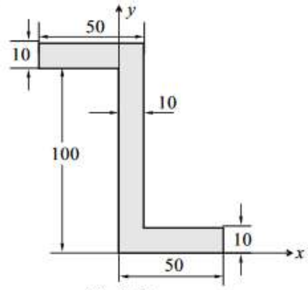


Fig. 5.E4

[*Ans.* $\bar{x}$ = 5 mm and $\bar{y}$ = 55 mm.]

Find the centroid of the following shaded plane areas shown in figure -

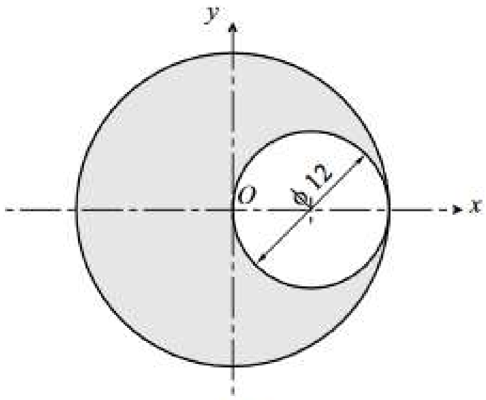


Fig. 5.E7

[***Ans.*** $\overline{x} = -2$ mm and $\overline{y} = 0$.]

EXPERIMENT NO. 10

MOMENT OF INERTIA

FOR

COMPOSITE SECTIONS

Date of Performance	
Date of Submission	
Grade	
Signature of Teacher	

Find the Moment of inertia of the following shaded plane areas shown in figure -

1.

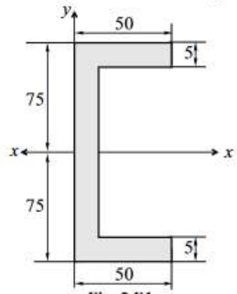


Fig. 5.E1

[**Ans.** $\bar{x}$ = 11.875 mm and $\bar{y}$ = 0.]

2.

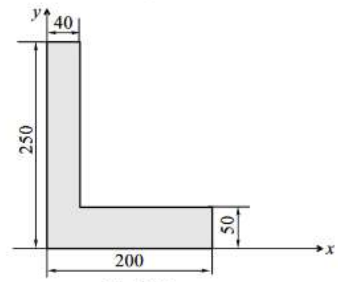


Fig. 5.E2

[**Ans.** $\bar{x}$ = 64.4 mm and $\bar{y}$ = 80.5 mm.]

3.

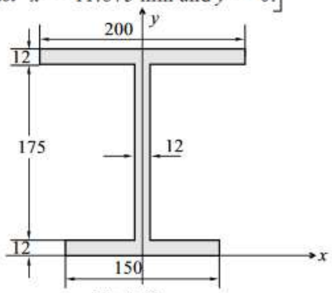


Fig. 5.E3

[**Ans.** $\bar{x}$ = 0 and $\bar{y}$ = 108.4 mm.]

4.

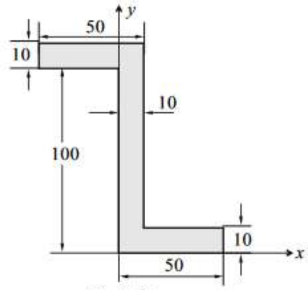
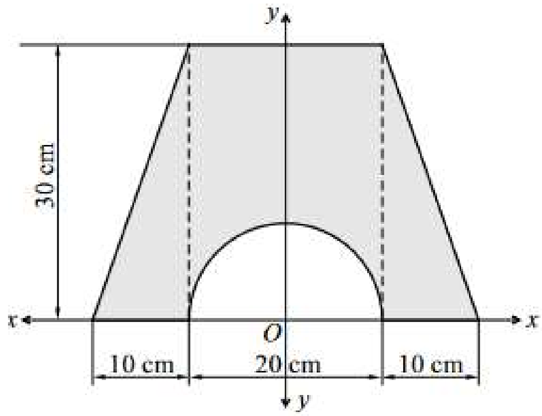


Fig. 5.E4

[**Ans.** $\bar{x}$ = 5 mm and $\bar{y}$ = 55 mm.]

Find the moment of inertia of shaded area shown in figure about x-x axis and y-y axis.

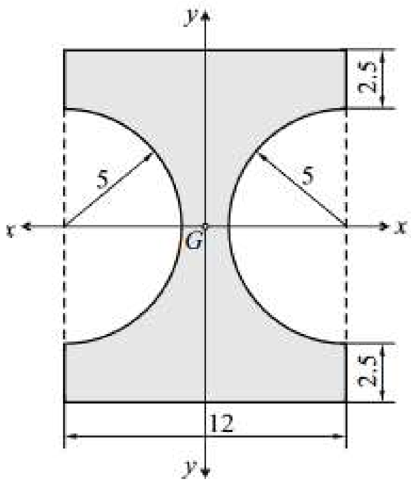


Ans:

$I_{xx} = 221073.01 \text{ cm}^4$

$I_{yy} = 71046.35 \text{ cm}^4$

Determine moment of inertia of plane area shown in figure about centroidal x- axis & y-axis.



Ans:

$$I_{xx_G} = 2884.13 \text{ cm}^4$$

$$I_{yy_G} = 841.39 \text{ cm}^4$$

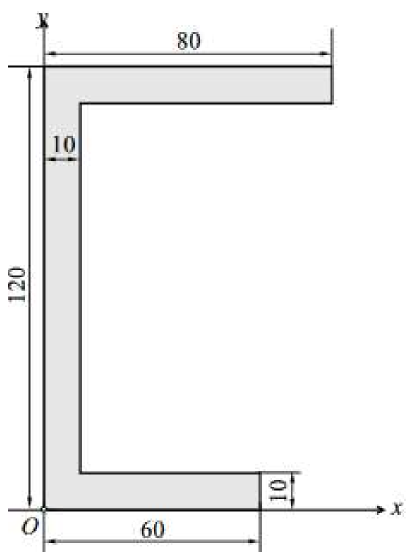
Find the MI of a section shown in figure about -

(i) x-axis

(ii) y-axis

(iii) Parallel centroidal x-axis

(iv) Parallel centroidal y-axis.



EXPERIMENT NO. 11

MOMENT OF INERTIA

OF

FLY WHEEL

Date of Performance	
Date of Submission	
Grade	
Signature of Teacher	

EXPERIMENT NO. 11

MOMENT OF INERTIA OF FLYWHEEL

Aim: To find moment of inertia of flywheel

Apparatus: Flywheel mounted on axle and supported by bearing, pan, weights, and stop watch.

Theory:

Moment of Inertia is the property of the body by virtue of which it resists the change in the state of its angular motion about any axis. It depends upon the mass of the body and the distance with respect to axis of rotation.

For falling mass,

Initial velocity = $v = 0$

Height of fall = h

$a = 2h / t^2$

Resultant force = $T - mg$

$-F = T - mg$

$-ma = T - mg$

$T = m(g - a)$

Moment 'M'= $I\alpha$

$T * r = I * a / r$ (since $a = r\,\alpha$)

$I = T\,r^2 / a$

$I = m\,(g - a)\,r^2 / a$

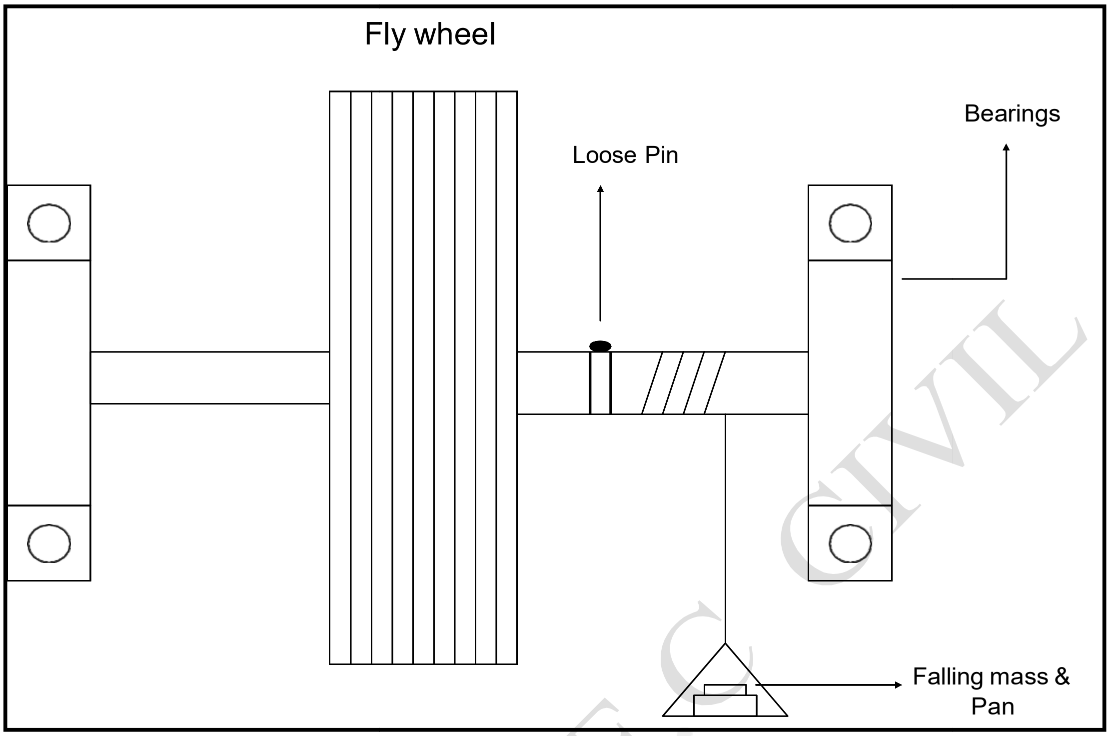


Figure 6: Fly Wheel

Procedure:

1. Attach a long thread about 1.8 m length to the axle of flywheel and end of thread is attached to the axle while the pan is attached to the outer end of the thread.

2. Weight should be added so that pan must be in suitable line on the wheel by which we can calculate number of revolutions of the wheel.

3. Wrap the thread on the axle and measure the height of the pan from the ground level, and then add the weights in the pan and take readings of time required for pan to touch the ground.

4. This time is calculated by using the stop watch as soon as weight starts moving down.

5. Take different weights and corresponding time and complete the observation table.

Observation table:

Sr. No.	Mass (m) kg	Time (t) sec	Acceleration (a) $a = 2h / t^2$, m/s^2	Tension (T) $T = m (g – a)$ $Kg.m/s^2$	M.I. = $(T \times r^2) / a$ $Kg\text{-}m^2$
1.					
2.					
3.					
4.					
5.					

Calculations:

Result: Moment of Inertia of fly wheel is--------------- Kg- m^2.

Exercise

1. Define moment of inertia.
   …………………………………………………………………………………
   …………………………………………………………………………………
   …………………………………………………………………………………
2. State theorem of parallel axis.
   …………………………………………………………………………………
   …………………………………………………………………………………
   …………………………………………………………………………………
3. Define radius of gyration.
   …………………………………………………………………………………
   …………………………………………………………………………………
   …………………………………………………………………………………
4. What do you mean by second moment of area?
   …………………………………………………………………………………
   …………………………………………………………………………………
   …………………………………………………………………………………

<u>EXPERIMENT NO. 12</u>

COMPOUND PENDULUM

Date of Performance	
Date of Submission	
Grade	
Signature of Teacher	

EXPERIMENT NO. 12

COMPOUND PENDULUM

Aim: To find the moment of inertia of the compound pendulum.

Apparatus: A steel rod with holes in it for suspension (bar pendulum), A knife edged fulcrum, stop watch, meter scale.

Theory: Compound pendulum is defined as a right body suspended in a vertical plane, from a point on the body other than centre of gravity. On giving small angular displacements, it oscillates and performs harmonic motion.

Relation for time period of free oscillation of a compound Pendulum.

Consider a rigid body of mass 'm' suspended from a point 'O' (other than G) on it. Let 'b' be the distance between O and G. The rigid body is now disturbed from its equilibrium position such that the line OG which was initially vertical, now makes a small angle 'θ' with the vertical.

From Newton's 2nd Law

$$\Sigma M_O = I_O \alpha \quad \curvearrowleft + \text{ve}$$

$$-\, mg\sin\theta \times b = I_O \alpha$$

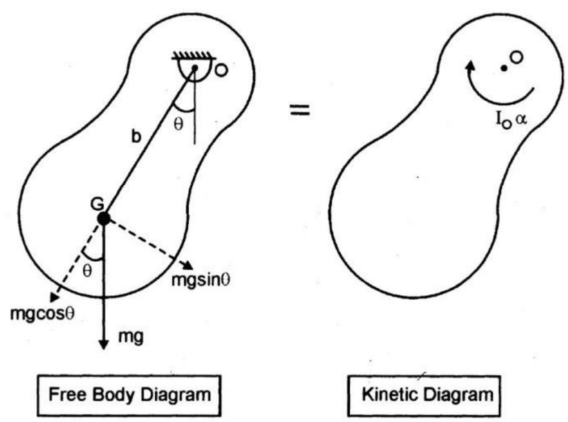
$$\therefore \quad I_O \alpha + mg\sin\theta . b = 0$$

since θ is very small $\sin\theta \approx \theta$

$$\text{also} \quad \alpha = \frac{d^2\theta}{dt^2} = \ddot{\theta}$$

$$\therefore \quad I_O \ddot{\theta} + mg\theta . b = 0$$

$$\text{or} \quad \ddot{\theta} + \frac{mgb}{I_O} . \theta = 0$$



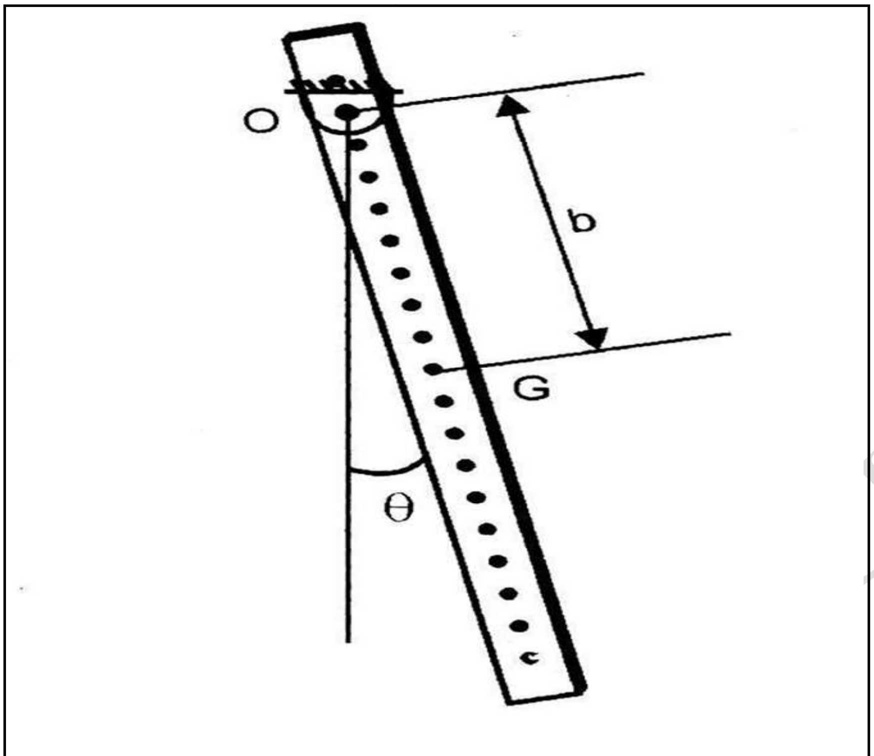
comparing the above equation with standard differential form of SHM equation which is $\ddot{\theta} + p^2\theta = 0$

We have,

$$p^2 = \frac{mgb}{I_O} \qquad \text{or} \qquad p = \sqrt{\frac{mgb}{I_O}}$$

$$\text{time period} \quad t = \frac{2\pi}{p} = \frac{2\pi}{\sqrt{\frac{mgb}{I_O}}}$$

Io= (t^2 mgb/4π) & IG= (Io mb^2)



Displaced position of pendulum

Observations:

Mass of uniform bar, m= ------kg

No. of oscillations = 20

Length of the bar L = 1m

Analytically,

$IG = mL^2/12$.

Observation Table:

Sr. No.	b (m)	T(sec)	t=T/20 (sec)	$Io=(t^2 mgb/4\pi)$	$IG=(Io\ mb^2)$	I_G (Average)
1						
2						
3						

Result:

1. Moment of inertia of the compound pendulum (experimental)=…………………
2. Moment of inertia of the compound pendulum (analytical) =………………………

Exercise

1. If the mass moment inertia of the object is increased to 4 times then what will be the effect of time period of the compound pendulum?

   a) Doubled

   b) Remains same

   c) Halved

   d) Decreases by √2 times

Answer: …….

2. All simple pendulums are compound pendulums.

   a) True

   b) False

Answer: …….

3. Which of the following shape of the body can be considered as compound pendulum?

   a) Cylindrical

   b) Cubical

   c) Cuboidal

   d) Any rigid body

Answer: ……….