THAKUR COLLEGE OF ENGINEERING & TECHNOLOGY

Estd. 2001

Lab Manual

2021 - 2022

Subject: Engineering Mechanics

Name of the Student: ________________________________

Class: F.E. **Division:**__________ **Batch:**______________

Branch: ________________________ **Roll No:** ____________

Department: ES&H **Semester: II**

VISION

"Thakur College of Engineering and Technology

will excel in Technical Education to become an internationally renowned premier Institute of Engineering and Technology"

MISSION

"To provide state-of-the-art infrastructure and right

academic ambience for developing professional skills as well as an environment for growth of leadership and managerial skills to students which will make them competent engineers to deliver quality results in industry"

QUALITY POLICY

We, the Staff, Faculty and the Management of Thakur College of Engineering and Technology, are committed to provide state-of the-art infrastructure and facilities, conducive academic environment to deliver Quality Technical Education to our students.

We shall work as a team and interact with the students in pro-active manner to achieve our Institutional Quality Objectives and fulfill all academic and regulatory requirements to continually enhance the satisfaction of our students.

The Graduate Attributes

1. **Engineering Knowledge:** Apply knowledge of mathematics, science, engineering fundamentals and an engineering specialization to the solution of complex engineering problems.
2. **Problem Analysis:** Identify, formulate, research literature and analyze complex engineering problem using first principles of mathematics, natural sciences and engineering sciences.
3. **Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet specified needs with appropriate consideration for public health and safety, cultural, societal and environmental considerations.
4. **Conduct Investigation of complex problems** using research-based knowledge and research methods including design of experiments, analysis and interpretation of data and synthesis of information to provide valid conclusions.
5. **Modern Tool usage:** Create, select and apply appropriate techniques, resources and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of limitation.
6. **The Engineer and Society:** Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice.
7. **Environment and Sustainability:** Understand the impact of professional engineering solutions in societal and environmental context and demonstrate knowledge of and need for sustainable development.
8. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice.
9. **Individual and Team work:** Function effectively as an individual, and as a member to leader in diverse teams and in multi-disciplinary settings.
10. **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations and give and receive clear instructions.
11. **Life long learning:** Recognize the need for life-long learning in the broadest context of technological change.
12. **Project Management and Finance:** Demonstrate knowledge and understanding of engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

TCET/FRM/IP-02/18 Revision: A

Term Work Index Sheet

Sr. No.	Name	DOP	DOC	Marks Obtained (100)	Signature of Faculty
Basic Experiments					
1	Law of Polygon of Forces	___/___/2020	___/___/2020		
2	Equilibrium of Parallel system of forces	___/___/2020	___/___/2020		
3	Law of Moments	___/___/2020	___/___/2020		
4	Inclined Plane (Friction)	___/___/2020	___/___/2020		
5	Gravitational acceleration	___/___/2020	___/___/2020		
6	Collision of Elastic bodies	___/___/2020	___/___/2020		
7	Design of Flywheel	___/___/2020	___/___/2020		
8	Design of Equilibrium System by finding the Equilibrant	___/___/2020	___/___/2020		
Design Experiments / Project / Case Study					
9	Finding the point of suspension of a composite plane area (using centroid) for stability of a system	___/___/2020	___/___/2020		
10	Mini Project	___/___/2020	___/___/2020		
11		___/___/2020	___/___/2020		
12		___/___/2020	___/___/2020		
13		___/___/2020	___/___/2020		
14		___/___/2020	___/___/2020		
Assignments / Seminar / Test / Remedial					
15		___/___/2020	___/___/2020		
16		___/___/2020	___/___/2020		
17		___/___/2020	___/___/2020		
18		___/___/2020	___/___/2020		

DOP- Date of Performance, DOC- Date of Completion

Certificate

This is to certify that Mr./Ms.____Class________Roll No. Course ____________________________________has successfully completed the term work requirements in the Subject______________________________during academic Year 2019-2020.

Signature of Faculty
Date:

Signature of HOD
Date:

Signature of Dean (Academic)
Date:

LAB EVALUATION SHEET

TCET/FRM/IP-02/24 (Revision: A) Cycle 1
Experiment/Tutorial No: Roll No.______

Parameters	Weightage	Category	Performance					
			Excel-lent (5)	Very Good (4)	Good (3)	Average (2)	Below Average (1)	Score
Technical Knowledge (Preparedness and Execution)	30	Prerequisites (2)						
		Skills in performing experiment (2)						
		Learning(1)						
Technical Documentation (Developing skills for Journal Writing and Maintenance of Lab notebook)	30	Format(1)						
		Contents as per format(2)						
		Quality(2)						
Level of Interaction (Developing Expression Power)	10	Level of understanding (2)						
		Questions & Answers(2)						
		Application(1)						
Behavioural (Attitude towards Learning)	10	Attitude(1)						
		Regularity(2)						
		Team Work/Group Activity(2)						
Compliance (Attainment of Objectives/ Outcomes)	20	Course Attainment(3)						
		Learning objective attainment(2)						
Total	**100**							

Signature of Subject Teacher

LAB EVALUATION SHEET

TCET/FRM/IP-02/24 (Revision: A) Cycle 2
Experiment/Tutorial No: Roll No.______

Parameters	Weightage	Category	Performance					
			Excel-lent (5)	Very Good (4)	Good (3)	Average (2)	Below Average (1)	Score
Technical Knowledge (Preparedness and Execution)	30	Prerequisites (2)						
		Skills in performing experiment (2)						
		Learning(1)						
Technical Documentation (Developing skills for Journal Writing and Maintenance of Lab notebook)	20	Format(1)						
		Contents as per format(2)						
		Quality(2)						
Level of Interaction (Developing Expression Power)	10	Level of understanding (2)						
		Questions & Answers(2)						
		Application(1)						
Behavioural (Attitude towards Learning)	10	Attitude(1)						
		Regularity(2)						
		Team Work/Group Activity(2)						
Compliance (Attainment of Objectives/ Outcomes)	20	Course Attainment(3)						
		Learning objective attainment(2)						
Total	**100**							

Signature of Subject Teacher

Sr. No.	**Cycle**	**Expt. No.**	**TK**	**TD**	**LI**	**B**	**C**	**Total**
1	**Cycle 1**							
2	**Cycle 2**							
	Total							
	Average							

Signature of Subject Teacher

Course Objective:

1. To have knowledge of engineering fundamentals
2. To have in-depth technical competence in engineering discipline.
3. To be able to understand, identify and formulate the problems.
4. To enhance the creativity and logical ability for problem solving methods.
5. Provide and facilitate teamwork and multi-disciplinary experiences throughout the curriculum.

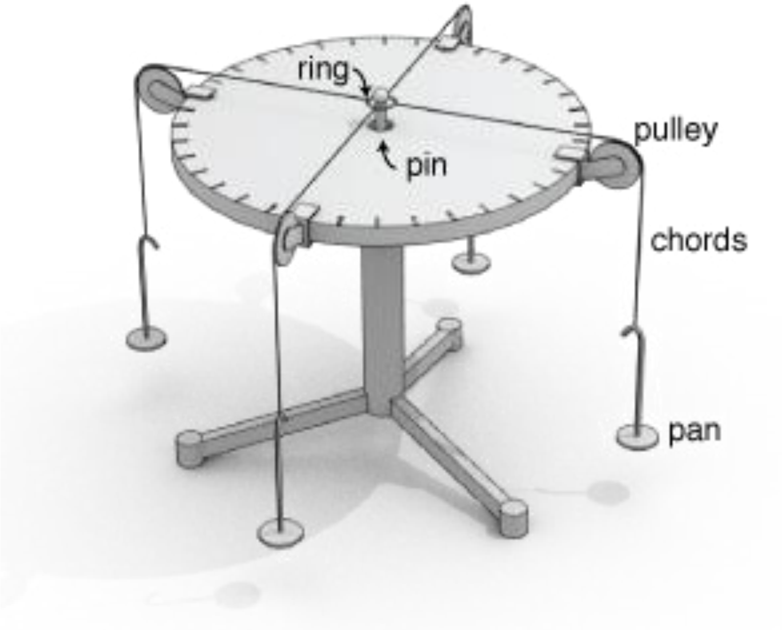
Course Outcome:

1. The ability to apply solutions from engineering sciences and mathematics.
2. The ability to identify, formulates, analyze and solve engineering problems.
3. The ability to design a system and conduct experiments to analyze and interpret data.
4. The ability to work effectively as an individual, in teams & in multi-disciplinary settings together with the capacity to undertake lifelong learning.
5. The ability to communicate effectively with engineering community.

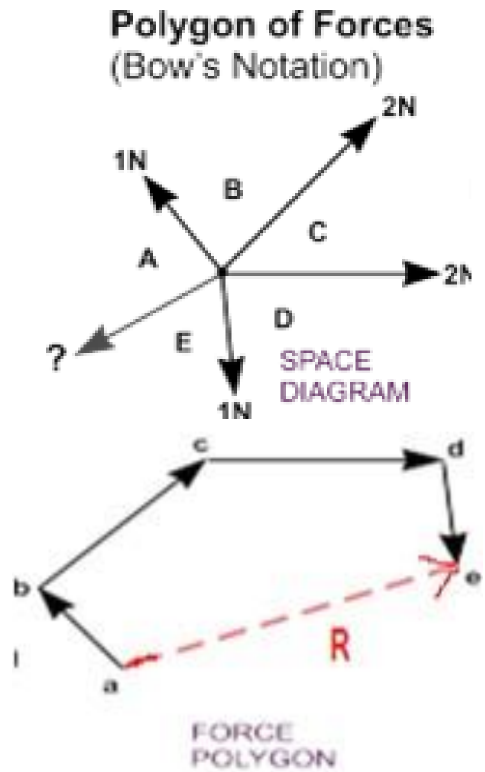
Mapping of CO with Experiments

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1															
CO2															
CO3															
CO4															
CO5															

EXPERIMENT 1



Universal Force Table



Observation Table:

PRO 1	PRO 2				PRO 3
Spirit Level Reading	**Force (F)**		**Angle (θ)**		**Ring Position**
Zero	F_1		θ_1		Center with table pin
	F_2		θ_2		
	F_3		θ_3		
	F_4		θ_4		
	F_5		θ_5		

PRO 4				PRO 5	
Method Name	**R**	**θ**	**Equilibrant**	**Standard Value**	**Error**
Experimentally					
Graphical					

Free Body Diagram

Experiment No. 01: LAW OF POLYGON OF FORCES

Aim: ____

____

Objective:

After performing the practical, the learner will be able to:

- PRO 1: Understand the use of Spirit Level and level the Universal force table
- PRO 2: Use pulley and weight arrangement
- PRO 3: Maintaining the force system in equilibrium
- PRO 4: State and formulate law of polygon of forces
- PRO 5: Verify law of polygon of forces experimentally and graphically

Apparatus:

Spirit level, weights with hanger, ring with threads, pulleys with clamping system.

Theoretical Background:

Universal Force table is used to apply and visualize different types of force systems and application of force in many directions and planes. The top face can be made perfectly horizontal with the help of spirit level. Other inclination can be given to the face with the tilting arrangement provided just below the top face. Force of know magnitude can be applied with the pulley and hanger system. All pulleys pull a common ring with the threads provided. The system will be in equilibrium if the ring stays in the central position with the pin provided on the top center of the top face. This system of equilibrium can then be formulated to an analytical system and the resultant equilibrant force can be found.

Spirit Level: A spirit level, bubble level or simply a level is an instrument designed to indicate whether a surface is horizontal (level) or vertical (plumb). Different types of spirit levels may be used by carpenters, stonemasons, bricklayers, other building trades workers, surveyors, millwrights and other metalworkers, and in some photographic or video-graphic work. In the middle of the spirit level is a small window where the bubble and the tube is mounted. Two notches (or rings) designate where the bubble should be if the surface is level. Often an indicator for a 45° inclination is also included.

Pulley and weight arrangement: A rope and pulley system is characterized by the use of a single continuous rope to transmit a tension force to lift or move a load. One end of the rope is attached to the ring which is placed on the center of the table and a set of hanging weights is applied to the other end to create proportionate tension. Hanging weights consist of two sets, a hanger and set of known weights which are slotted up-to the center for proper assembly with the hanger. The self weight of hanger is 50 grams which is loaded with combination of 50 grams weights as per the load needed. A clamp with screw is accompanied to every pulley in order to firmly attach the assembly to the table. Clockwise rotation of the screw advances and creates a tightening force whereas an anti-clockwise rotation loosens the pulley system so that they can be removed or moved on the circular table.

Equilibrium: A very basic concept when dealing with forces is the idea of equilibrium or balance. In general, an object can be acted on by several forces at the same time. A force is a vector quantity which means that it has both a magnitude (size) and a direction associated with it. If the size and direction of the forces acting on an object are exactly balanced, then there is no net force acting on the object and the object is said to be in equilibrium. Because there is no net force acting on an object in equilibrium, then from Newton's first law of motion, an object at rest will stay at rest, and an object in motion will stay in motion. A total of 5 external forces are applied in this practical and the system can be said in equilibrium if the ring stays in the center of the table.

Law of polygon of forces: “If number of concurrent forces acting at a point will be represented in magnitude and direction by the sides of a polygon taken in order then, their resultant will be represented in magnitude and direction by the closing side of the polygon taken in opposite order.”

Formulae:

$$\sum Fx = 0$$

$$\sum Fy = 0$$

$$\sum M_F = 0$$

$$R = \sqrt{\sum Fx^2 + \sum Fy^2}$$

$$\theta = \tan^{-1}\left(\frac{\sum Fy}{\sum Fx}\right)$$

Where,

R= Resultant of the system of forces.

θ= angle between R and X-axis.

Space for Calculations:

Procedure:

PRO1: 1.1 Place the Universal force table on the floor and place of spirit level on the top.
1.2 At first position put, the spirit level parallel to any two lengths and bring the bubble at the center.
1.3 Once you get this position keep the spirit level perpendicular to first position and adjust the bubble at the center with the help of level screw.

PRO2: 2.1 Fix five pulleys at different angles on the table with the help of clamps.
2.2 Now pass thread over the pulleys then hang weights with the help of hanger.
2.3 Then go on adding weights to each hanger so that the ring comes at the center position.

PRO3: 3.1 Once you get the ring at the center, it means that the system is in equilibrium.
3.2 Note down the angle and magnitude of the force in the observation table.
3.3 Draw the force diagram consisting of the 5 forces.

PRO4: 4.1 Pen down law of polygon of forces.
4.2 Write the conditions of equilibrium.
4.3 Formulate triangle law and method of resolution to find the magnitude and direction of resultant force.

PRO5: 5.1 Using the force diagram constructed in 3.3, construct force polygon on the graph.
5.2 Scale down forces using proper scale so as to fit them on graph. Draw forces one by one connecting the end points of the adjacent force at the measured angle. Angles should be measured from right horizontal side for every force.
5.3 The end point of last force and start point of first force is the resultant. Measure the length of line and angle.
5.4 Using the equations written in step 4.2 and 4.3, calculate the magnitude and direction of resultant force.

Result & Discussion:

PRO 1: ____________________

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PRO 2: ____________________

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PRO 3: ____________________

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PRO 4: ____________________

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PRO 5: ____________________

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Space for Calculation:

Test your skills of calculating the resultant at:

http://www.mrwaynesclass.com/teacher/Vectors/Force_Table/

Conclusion:

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Precautions:

While performing the experiment, a learner has to:

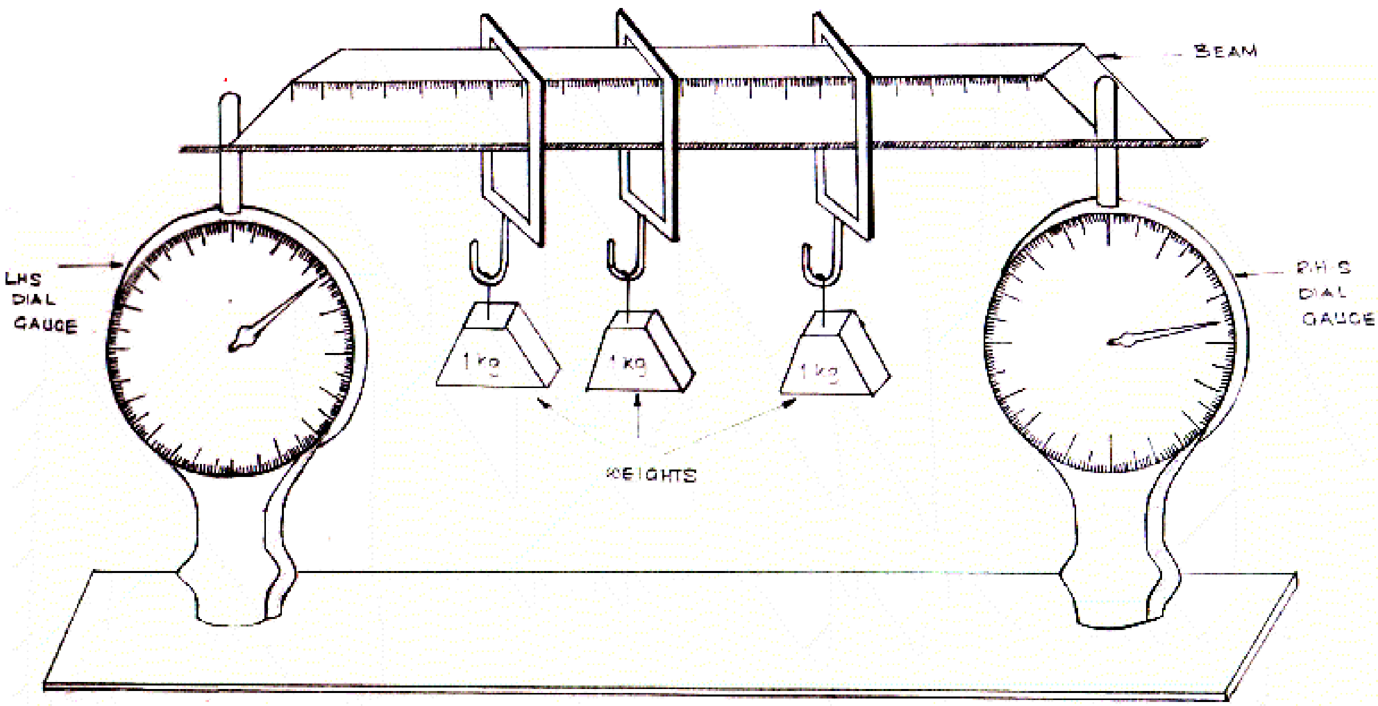
1. Take care of the glass tube on the spirit level.
2. Attach the spirit level to the surface from the magnetic base. Do not press and scratch the surface.
3. Apply limited weight on the thread so that it does not break.
4. Tighten and loosen the pulley with the screw arrangement provided at the bottom only.
5. Slowly and gradually apply weights on the pulley one weight bit at a time.
6. Draw proper graph using the correct force directions.
7. Keep safe distance from the hanging weights.

Quiz :

1. What is the use of Spirit Level and Universal force table?
2. Why is pulley and weight system used for? How to switch between concurrent and parallel force system?
3. When will any force system remain in Equilibrium? Where does resultant act in this system?
4. What is law of Polygon of forces? What formulas does the law state?
5. How do you validate the law of polygon of forces?

Objective	PRO 1	PRO 2	PRO 3	PRO 4	PRO 5	Total Score
Weight Points	20	20	20	20	20	
Score						
Earned Points (EP) = Total Score/100 =				Marks in 100 = EP *20		

EXPERIMENT 2



SIMPLY SUPPORTED BEAM

Observation Table:

Sr. No.	PRO 1			PRO 2			PRO 3			
	Weights in N			Distance from LHS			Experimental values		Calculated values	
	W_1	W_2	W_3	X_1	X_2	X_3	R_a (N)	R_b (N)	R_a (N)	R_b (N)
1										
2										
3										

Sr. No.	PRO 4					
	Standard Values		Observed Values		% Error	
	Difference in experimental and calculated R_a (N)	Difference in experimental and calculated R_b (N)	Difference in experimental and calculated R_a (N)	Difference in experimental and calculated R_b (N)	R_a (N)	R_b (N)
1						
2						
3						

Experiment No. 02: EQUILIBRIUM OF PARALLEL SYSTEM OF FORCES

Aim: ____

Objective:

After performing the practical, the learner will be able to:

PRO 1: Use spring balance

PRO 2: Understand different types of supports

PRO 3: State and formulate conditions of equilibrium

PRO 4: Verify conditions of equilibrium.

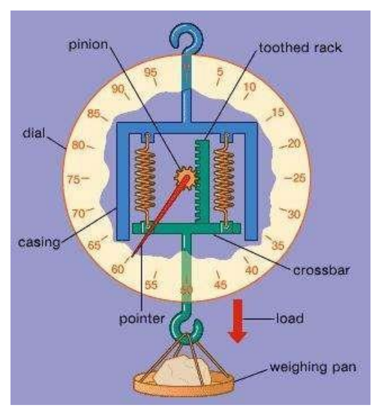
Apparatus:

Simply supported beam with dial spring balance, weights and hangers.

Theoretical Background:

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 can be applied to determine the support reactions analytically.

Spring Balance: Spring balance, weighing device that utilizes the relation between the applied load and the deformation of a spring. This relationship is usually linear; i.e., if the load is doubled, the deformation is doubled. In the circular balance shown in the figure, the upper ends of the helical springs are attached to the casing and the lower ends to a crossbar that can move relative to the casing and to which the load hook is attached. The pinion to which the indicating pointer is attached is pivoted in the casing and meshes with the rack, which is pivotally connected to the crossbar and is pressed into contact with the pinion by the rack spring.



When a load is applied, the springs are stretched, and movement of the crossbar with the rack attached rotates the pinion and the load-indicating pointer. The dial is graduated in scale units that depend on the stiffness of the springs: the stiffer springs have larger scale units and higher load capacity.

Spring balances are widely used commercially. Those with high-load capacities are frequently suspended from crane hooks and are known as crane scales. Smaller units for household use are called fish scales.

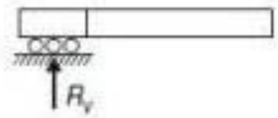
Types of Supports: Supports in a structure transfers the load to the ground and provides stability to the structure supported on it. Supports are arguably one of the most important aspects of a structure, as it specifies how the forces within the structure are transferred to the ground. This knowledge is required before solving the model, as it tells us what the boundary conditions are.

1. Fixed Support: A fixed support is the most rigid type of support or connection. It constrains the member in all translations and rotations (i.e. it cannot move or rotate in any direction). The easiest example of a fixed support would be a pole or column in concrete. The pole cannot twist, rotate or displace; it is basically restricted in all its movements at this connection.

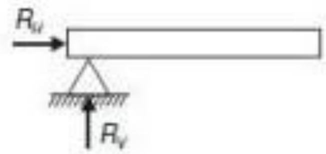
Application: Fixed supports are extremely beneficial when you can only use a single support. The fixed support provides all the constraints necessary to ensure the structure is static. It is most widely used as

Simple support

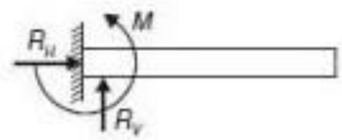
Roller support



Hinged (Pin) support



Fixed support



Free Body Diagram

the only support for a cantilever.

Limitations: Fixed supports offers absolutely no 'give'. In a sense, its greatest advantage can also be its downfall, as sometimes a structure requires a little deflection or 'play' to protect other surrounding materials. For instance, as concrete continues to gain its strength it also expands. So if a support is not designed correctly the expansion could lead to a reduction in durability.

2. Pinned Support: A pinned support is a very common type of support and is most commonly compared to a hinge in engineering. Like a hinge, a pinned support allows rotation to occur but no translation (i.e. it resists horizontal and vertical forces but not a moment). Think of your elbow; you are able to extend and flex the elbow (rotation) but you cannot move your forearm left to right (translation).

Application: Pinned supports can be used in trusses. By linking multiple members joined by hinge connections, the members will push against each other; inducing an axial force within the member. The benefit of this is that the members contain no internal moment forces, and can be designed according to their axial force only.

Limitations: A single pinned support can not completely restrain a structure, as you need at least two supports to resist the moment.

3. Roller Support: Roller supports can resist a vertical force but not a horizontal force. A roller support or connection is free to move horizontally as there is nothing constraining it.

Application: The most common use of a roller support is in a bridge. In civil engineering, a bridge will typically contain a roller support at one end to account for vertical displacement and expansion from changes in temperature. This is required to prevent the expansion causing damage to a pinned support.

Limitations: This type of support does not resist any horizontal forces. This obviously has limitations in itself as it means the structure will require another support to resist this type of force.

4. Simple Support: A simple support is basically just where the member rests on an external structure. They are quite similar to roller supports in a sense that they are able to restrain vertical forces but not horizontal forces. The member simply rests on an external structure to which the force is transferred to. In this case, if you apply a vertical force it will not be able to support it. An example is a plank of wood resting on two concrete blocks. The plank can support any downward (vertical) force but if you apply a horizontal force, the plank will simply slide off the concrete blocks.

Simple supports aren't widely used in real life structures unless the engineer can be sure that the member will not translate; otherwise they run the risk of the member simply falling off the support.

Equilibrium of forces:

Definition: A balanced state of a body under the action of given forces, is known as equilibrium. In this state the net effect of all the forces is nil.

A body in equilibrium has no resultant and no couple acting on it. Such a body has no linear or angular acceleration. It may be either at rest or moving with uniform velocity.

Conditions of equilibrium: On a body at equilibrium there is no resultant force and also there is no moment i.e. there is no couple acting on it. Resultant is zero only if the algebraic sum of components along two mutually perpendicular axes is zero.

Therefore analytical conditions of equilibrium are:

$\sum F_x = 0$ Means algebraic sum of components of all the forces along any direction (say x-axis) is zero.

$\sum F_y = 0$ Means algebraic sum of components of all the forces in a direction (say y-axis) at 90 to the first direction is zero.

Space for Calculation:

$\sum M = 0$ Means algebraic sum of moments of all the forces about any point in their plane is zero. The first two conditions are applicable for concurrent forces and all the three conditions must be applicable for non-concurrent forces.

Procedure:

PRO 1: 1.1 Carefully load the spring balance with the notched beam and three empty hangers (no weights) on both the sides.

1.2 Ensure zero reading on both the scales.

1.3 In-case the scale still shows some non-zero value, adjust the pointer with the adjusting screw provided on the top.

PRO 2: 2.1 Every notch on the simply support beam is at 50 mm apart.

2.2 Assuming the left hand support to be zero, place the three hangers at known distance and note the same.

2.3 Add weights to each hanger and note the deflection of the spring balance scale.

2.4 Repeat the steps from 2.2 to 2.3 for different weights and different position of hanger on the simply supported beam.

PRO 3: 3.1 For every reading, draw the Free Body diagram of simply supported beam showing the three weights as known value.

3.2 Using law of equilibrium calculate the values of reaction on the two supports.

PRO 4: 4.1 Calculate the difference in between the observed and calculated reaction forces.

4.2 Compare the calculated vales with the standard error.

Result & Discussion:

PRO 1: ______________________________

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PRO 2: ______________________________

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PRO 3: ______________________________

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PRO 4: ______________________________

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Do calculate the support reactions via the online calculator and test your calculation skills for more complex supports and loading conditions at:

http://beamguru.com/online/beam-calculator/

https://www.engineeringtoolbox.com/beams-support-forces-d_1311.html

Conclusion:

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Space for Calculation:

Precautions:

While performing the experiment, a learner has to:

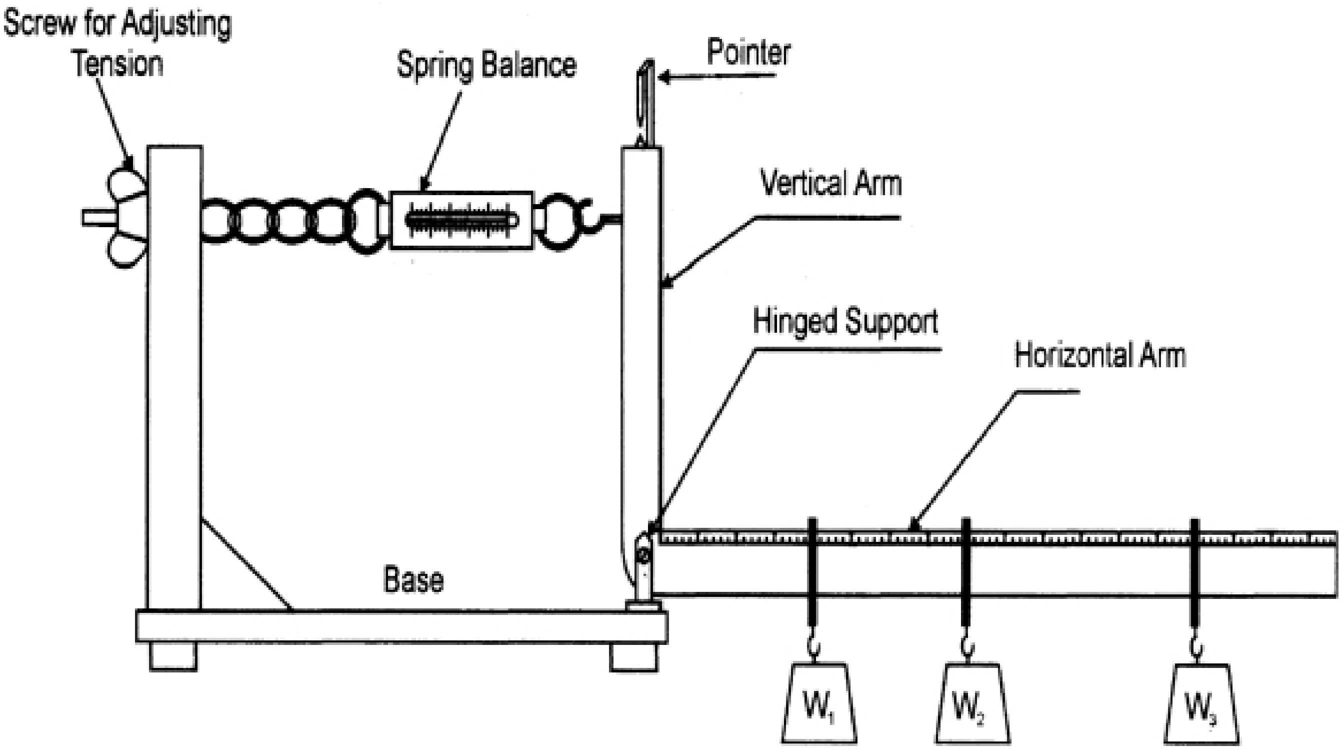
1. Load and unload the beam carefully.
2. Be careful while attaching weights to the hanger.
3. Load the center weight first then add weights to the other sides.
4. Avoid loading the spring balance with physical force.

Quiz :

1. What is the use of spring balance and how to calibrate it?
2. What do you mean by simply supported beam?
3. What are the different types of beams? (with regards to the supports)
4. What do you mean by indeterminate beam?
5. What are the conditions of equilibrium?
6. What are the components of reaction you get at the fixed support?

<table>
<tr><td>Objective</td><td>PRO 1</td><td>PRO 2</td><td>PRO 3</td><td>PRO 4</td><td></td><td rowspan="3">Total Score</td></tr>
<tr><td>Weight</td><td>20</td><td>20</td><td>20</td><td>20</td><td></td></tr>
<tr><td>Points</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Score</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="5">Earned Points (EP) = Total Score/80 = ______</td><td colspan="2">Marks in 100 = EP *20</td></tr>
</table>

EXPERIMENT 3



Bell Crank Lever apparatus

Observation Table:

PRO 1							
Weights in N			Distance in cm			Initial T_i N	Final T_f N
W_1	W_2	W_3	X_1	X_2	X_3		

Value of Y = constant= 21cm

PRO 2			PRO 3		
$T_e = T_f - T_i$ (N)	$W_1 X_1 + W_2 X_2 + W_3 X_3$ (N-cm)	$T_e Y$ (N-cm)	Difference in moments	Standard Value	Error

Experiment No. 03: LAW OF MOMENTS

Aim: ____

Objective:

After performing the practical, the learner will be able to:

PRO 1: Understand bell crank lever

PRO 2: State and formulate law of moments

PRO 3: Verify principle of moments using the bell crank lever apparatus.

Apparatus:

Bell Crank Lever, Weights, Scale, Thread.

Theoretical Background:

Principle of Moments will be verified for a bell crank lever arrangement. A simple arrangement consisting of a bell crank lever with some weights applied to it and a point of reaction will be used. 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.

Bell Crank Lever: A bell-crank is a type of crank that changes motion through an angle. The angle can be any angle from 0 to 360 degrees, but 90 degrees and 180 degrees are most common. The name comes from its first use, changing the vertical pull on a rope to a horizontal pull on the striker of a bell, used for calling staff in large houses or commercial establishments.

The Brake Caliper on a bicycle is a common device which uses the principle of this mechanism. Here the force from the handlebar lever is turned through 90° to squeeze the brake block against the wheel rim.

If the fulcrum or pivot is at an equal distance from the input and output then the movement of the output will be equal to the movement of the input. Otherwise the movement will be different and the system will have some degree of Mechanical Advantage.

Law of moments: "Sum of the moments of all the forces about any point is equal to the moment of the resultant about the same point".

Procedure:

PRO 1: 1.1 Carefully study the apparatus and identify the two arms, fulcrum and spring balance.

1.2 Place the empty hangers on the horizontal arm and note the distance from fulcrum as X_1, X_2 and X_3.

1.3 Adjust the screw so that the pointer on the top aligns with the marking.

1.4 Note the initial tension reading on scale as T_i.

1.5 Now load the hangers with known weights W_1, W_2 and W_3 placed at distance X_1, X_2 and X_3 respectively.

1.6 Due to the applied load, the bell crank lever with change the position. Adjust the screw to ensure the realignment of pointer at the top with its initial position.

1.7 Note the final tension reading on scale as T_f.

Ensure zero reading on both the scales.

1.8 Repeat the procedure for different sets of load and position.

PRO 2: 2.1 Calculate the difference between the final and initial tension which is the net effective tension acting on the bell crank lever.

2.2 Using the law of moments, calculate the moment of forces acing on the horizontal arm.

PRO 3: 3.1 Calculate the moment acting on the vertical armdue to the effective tension T_e acting at a distance Y from the fulcrum of the lever.

3.2 Calculate the difference between the moment obtained on the horizontal and vertical arm.

Space for Calculation:

Result & Discussion:

PRO 1: ____

____

____

PRO 2: ____

____

____

PRO 3: ____

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____

Let us see how much you can balance, do calculate and place the objects and test your skills at:
https://phet.colorado.edu/sims/html/balancing-act/latest/balancing-act_en.html

Conclusion:

____

____

____

Precautions:

While performing the experiment, a learner has to:

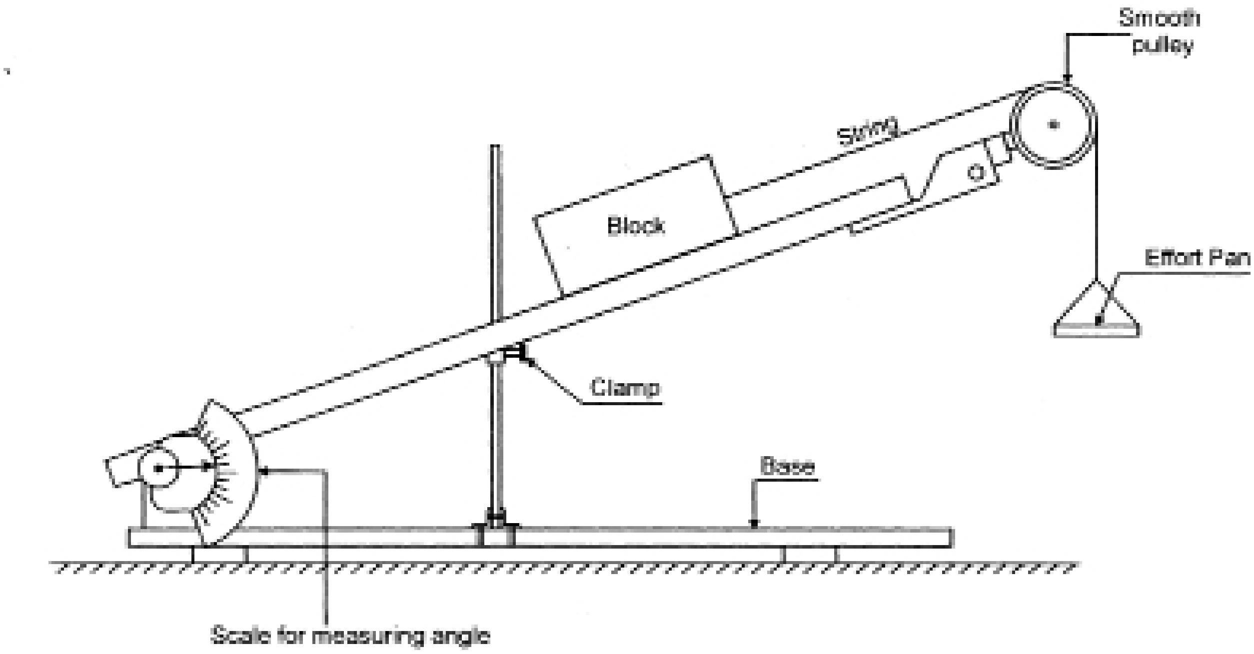
1. Use the spring balance and screw system carefully.
2. Let the system get stable and take readings.
3. Apply weight gradually.
4. Tighten and loosen the screw by holding the bolt on other side.
5. Keep safe distance from the hanging weights.
6. Give proper clearance to the horizontal arm of the bell crank lever to bend once loaded.

Quiz :

1. Why is bell crank lever used and state its applications?
2. What are the conditions of equilibrium for concurrent, parallel and general system of forces in plane?
3. What is law of moments?
4. State and prove Varignon's theorem.
5. Which point is chosen as moment center and why?

<table>
<tr><td>Objective</td><td>PRO 1</td><td>PRO 2</td><td>PRO 3</td><td></td><td></td><td rowspan="3">Total Score</td></tr>
<tr><td>Weight</td><td>20</td><td>20</td><td>20</td><td></td><td></td></tr>
<tr><td>Points</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Score</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="4">Earned Points (EP) = Total Score/60 =______</td><td colspan="3">Marks in 100 = EP *20</td></tr>
</table>

EXPERIMENT 4



INCLINED PLANE APPARATUS

Free Body Diagram

Experiment No. 04: FRICTION

Aim:

____

Objective:

After performing the practical, the learner will be able to:

PRO 1: Understand the apparatus for Friction and the use of spirit level.

PRO 2: Understand the need of taking the initial weight of the system.

PRO 3: Apply appropriate weight in the pan and trolley such that only downward impending motion is attained.

PRO 4: Arrange and adjust the Inclined Plane for proper direction of impending motion of the trolley.

PRO 5: Calculate the Coefficient of Friction using the formula as well as verify it using theoretical calculation by Conditions of Equilibrium.

Apparatus:

Inclined plane apparatus with glass surface and arrangement mode for angles, trolleys with different base surfaces, spirit level, small pan, weights.

Theoretical Background:

In this practical, the learner will learn the application of Friction, a phenomenon used in our day- to-day life. It consists of an inclined plane apparatus with a Trolley-Pulley-Pan arrangement on the inclined plane where the weight will be added in trolley and pulley. As the weight increases sufficiently, it will overcome the frictional resistance offered by the contact surfaces and motion will take place. This is where the weight will be noted down and with the help of appropriate formula, the coefficient of friction will be calculated, the validation of which is done by condition of equilibrium.

Inclined Plane Apparatus: An inclined plane, also known as a ramp, is a flat supporting surface tilted at an angle, with one end higher than the other, used as an aid for raising or lowering a load. The inclined plane is one of the six classical simple machines defined by Renaissance scientists. Inclined planes are widely used to move heavy loads over vertical obstacles; examples vary from a ramp used to load goods into a truck, to a person walking up a pedestrian ramp, to an automobile or railroad train climbing a grade. Moving an object up an inclined plane requires less force than lifting it straight up, at a cost of an increase in the distance moved. The mechanical advantage of an inclined plane, the factor by which the force is reduced, is equal to the ratio of the length of the sloped surface to the height it spans. Due to conservation of energy, the same amount of mechanical energy (work) is required to lift a given object by a given vertical distance, disregarding losses from friction, but the inclined plane allows the same work to be done with a smaller force exerted over a greater distance.

Friction: Friction is the force resisting the relative motion of solid surfaces, fluid layers, and material elements sliding against each other. When surfaces in contact move relative to each other, the friction between the two surfaces converts kinetic energy into thermal energy (that is, it converts work to heat). This property can have dramatic consequences, as illustrated by the use of friction created by rubbing pieces of wood together to start a fire. Kinetic energy is converted to thermal energy whenever motion with friction occurs, for example when a viscous fluid is stirred. Another important consequence of many types of friction can be wear, which may lead to performance degradation or damage to components. Friction is a component of the science of tribology.

Coefficient of Friction (μ): Ratio of the Limiting Frictional Force to Normal Reaction.

Observations:

1. For Glass Surface

Self weight of Trolley = _______ Self weight of Pan = _______

Observation Table

	PRO 1	PRO 2	PRO 3	Pro 4	Pro 5	
Sr. No	**Spirit Level**	**Weight of Trolley and weight added in the Trolley W (N)**	**Weight of the pan and weight added in the pan P (N)**	θ	$\mu = \{P - w \sin(\theta)\} / (w \cos(\theta))$	**Average μ**
1	Aligned					
2	Aligned					
3	Aligned					

Calculation:

Angle of Repose (Ψ) = $\tan^{-1}(\mu)$

2. For Aluminum Surface

Self weight of Trolley = _______ Self weight of Pan = _______

Observation Table

	PRO 1	PRO 2	PRO 3	Pro 4	Pro 5	
Sr. No	**Spirit Level**	**Weight of Trolley and weight added in the Trolley W (N)**	**Weight of the pan and weight added in the pan P (N)**	θ	$\mu = \{P - w \sin(\theta)\} / (w \cos(\theta))$	**Average μ**
1	Aligned					
2	Aligned					
3	Aligned					

Calculation:

Angle of Repose (Ψ) = $\tan^{-1}(\mu)$

3. For Wood Surface

Self weight of Trolley = _______ Self weight of Pan = _______

Observation Table

	PRO 1	PRO 2	PRO 3	Pro 4	Pro 5	
Sr. No	**Spirit Level**	**Weight of Trolley and weight added in the Trolley W (N)**	**Weight of the pan and weight added in the pan P (N)**	θ	$\mu = \{P - w \sin(\theta)\} / (w \cos(\theta))$	**Average μ**
1	Aligned					
2	Aligned					
3	Aligned					

Calculation:

Angle of Repose (Ψ) = $\tan^{-1}(\mu)$

Angle of Friction (θ): Angle made by the resultant with the Normal Reaction.

Angle of Repose (α): Angle made by inclined plane with horizontal when the body just starts to move down the plane due to the weights.

Procedure:

PRO 1: 1.1 The working of apparatus should be studied carefully.
1.2 The plane is made horizontal with the help of spirit level.

PRO 2: 2.1 Weight of the pan and trolley should be noted.

PRO 3: 3.1 The plane is made inclined at an angle which is considered as θ
3.2 Some weights are kept in the trolley and it is kept on the inclined plane.

PRO 4: 4.1 The string is taken over the pulley and pan is attached to the other end.
4.2 Weights are kept in the pan until the trolley just start to move.
4.3 Three such readings are taken with suitable angles of inclination.

PRO 5: 5.1 The string is detached from the trolley and the angle of inclination of the plane is slowly increased till trolley just moves down the plane. The angle of repose (α) is noted
5.2 The coefficient of friction is calculated by

$$\mu = \{P - w \sin(\theta)\} / (w \cos(\theta))$$

Result & Discussion:

PRO 1: ______________________________
____
____

PRO 2: ______________________________
____
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PRO 3: ______________________________
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____

PRO 4: ______________________________
____
____

PRO 5: ______________________________
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____

To simulate the same experiment with different surfaces on a horizontal plane, do visit the link below and explore more about friction:

https://www.thephysicsaviary.com/Physics/Programs/Labs/ForceFriction/index.html

Do simulate impending motion and force required to start motion on the link:

http://www.compassproject.net/sims/inclined_plane_2010.php
https://www.thephysicsaviary.com/Physics/Programs/Labs/InclinedPlaneLab/index.html
https://www.thephysicsaviary.com/Physics/Programs/Labs/ForcesOnInclineLab/index.html

Space for Calculation:

Conclusion:

____

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Precaution:

While performing the practical, the learner must:

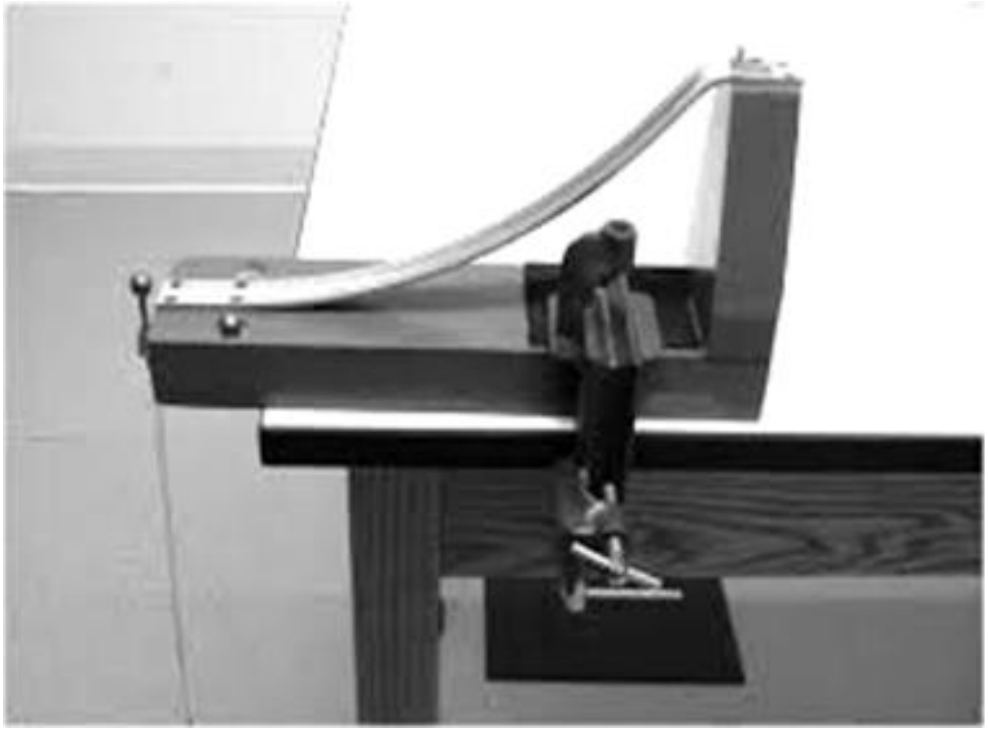
1. Take care of the weights which may slide down and fall on the ground.
2. Take care of the pulley and string arrangement since heavier pan may break it.
3. Take care while adding the weights. Add it gently to get the best results
4. Place the weights at the center of the pan (Front end).
5. Keep safe distance from the apparatus.

Quiz:

1. How to Adjust the Inclined Plane Apparatus?
2. Does the value of coefficient of friction change by adding more weight?
3. What is the formula to calculate the coefficient of friction?
4. Does the theoretical FBD calculation validate the experimental value?
5. Does the value of coefficient of friction change with change in material?

Objective	PRO 1	PRO 2	PRO 3	PRO 4	PRO 5	Total Score
Weight	20	20	20	20	20	
Points						
Score						
Earned Points (EP) = Total Score/100 =____				Marks in 100 = EP *20		

EXPERIMENT 5



COLLISION OF ELASTIC BODIES APPARATUS

Projectile Motion

Experiment No. 05: COLLISION OF ELASTIC BODIES

Aim: ____

Objective:

After performing the practical, the learner will be able to:

PRO 1: Understand the use of plumb bob
PRO 2: Understand impact
PRO 3: State and apply work energy principal
PRO 4: State and apply projectile motion
PRO 5: Find co-efficient of restitution between two bodies

Apparatus:

The impact apparatus, two to three balls of different sizes and materials, plumb blob, meter scale.

Theoretical Background:

We daily see children playing with balls of glass, rubber and other elastic materials. If we see them carefully, we will find that if a glass ball is allowed to fall on a marble floor, from a certain height, it rebounds (i.e. rises up, after striking the floor) to a certain height. This height is, generally, less than the height from which the ball is allowed to fall. If the same ball is allowed to fall on a wooden floor, then it will rebound to a lesser height. We will also see that if the balls of different materials are allowed to fall on a marble floor, they will rebound to different heights.

Plumb Bob: A plumb bob, or plummet, is a weight, usually with a pointed tip on the bottom, suspended from a string and used as a vertical reference line, or plumb-line. It is essentially the vertical equivalent of a "water level".

The instrument has been used since at least the time of ancient Egypt to ensure that constructions are "plumb", or vertical. It is also used in surveying, to establish the nadir with respect to gravity of a point in space. It is used with a variety of instruments (including levels, theodolites, and steel tapes) to set the instrument exactly over a fixed survey marker or to transcribe positions onto the ground for placing a marker.

A plumb-bob can be used to mark a point directly above or below another point. This is particularly useful, for example, when you need to transfer points from a floor layout plan to a ceiling joist, or hanging an interior door.

Impact: Impact is a collision between 2 bodies which occur in a very small interval of time during which two bodies exert on each other relatively large forces. When the mass centers of the colliding bodies lie on the line of impact, the impact is known as Central Impact. When the velocities of both the colliding bodies are along the line of impact, the impact is referred to as a Direct Central Impact.

Work Energy principle: The change in the kinetic energy of an object is equal to the net work done on the object.

$$T_1 + \sum U_{1\text{-}2} = T_2$$

where, T_1 = Initial kinetic energy
T_2 = Final kinetic energy
$\sum U_{1\text{-}2}$ = Net work done

This fact is referred to as the Work-Energy Principle and is often a very useful tool in mechanics problem solving. It is derivable from conservation of energy and the application of the relationships for work and energy, so it is not independent of the conservation laws. It is in fact a specific application of conservation of energy. However, there are so many mechanical problems which are solved efficiently by applying this principle that it merits separate attention as a working principle.

For a straight-line collision, the net work done is equal to the average force of impact times the distance traveled during the impact.

Observation Table:

	PRO 1	PRO 2								PRO 5
Material	Height	Velocity before Impact		Displacement after Impact				Velocity after Impact		Coefficient of Restitution
				Ball A		Ball B				
	H m	V_A m/s	V_B m/s	X m	Y m	X m	Y m	V_A' m/s	V_B' m/s	e
Steel & Steel										
Steel & Brass										

1. Steel & Steel

PRO 3: Using work energy principle to ball A from position 1 to 2

Apply projectile motion to ball-A and B from position 2 to 3

PRO 4			
Ball A		Ball B	
Horizontal Motion	Vertical Motion	Horizontal Motion	Vertical Motion
V=	U =	V=	U =
S=	S=	S=	S=
t=	a=	t=	a=
Using V = s/t	Using $s = ut + l/2at^2$	Using V = s/t	Using $s = ut + l/2at^2$
V_A' =	t =	V_A' =	t =

Projectile Motion: Projectile motion is a form of motion experienced by an object or particle (a projectile) that is thrown near the Earth's surface and moves along a curved path under the action of gravity only (in particular, the effects of air resistance are assumed to be negligible). This curved path was shown by Galileo to be a parabola. The study of such motions is called ballistics, and such a trajectory is a ballistic trajectory. The only force of significance that acts on the object is gravity, which acts downward, thus imparting to the object a downward acceleration. Because of the object's inertia, no external horizontal force is needed to maintain the horizontal velocity component of the object. Taking other forces into account, such as friction from aerodynamic drag or internal propulsion such as in a rocket, requires additional analysis. A ballistic missile is a missile only guided during the relatively brief initial powered phase of flight, and whose subsequent course is governed by the laws of classical mechanics.

Horizontal direction: There's no acceleration in the horizontal direction since gravity does not pull projectiles sideways, only downward. Air resistance would cause a horizontal acceleration, slowing the horizontal motion, but since we're going to only consider cases where air resistance is negligible we can assume that the horizontal velocity is constant for a projectile.

$$v = v_0 + a_c t \qquad v_x = (v_0)_x$$
$$x = x_0 + v_0 t + \tfrac{1}{2} a_c t^2; \qquad x = x_0 + (v_0)_x t$$
$$v^2 = v_0^2 + 2a_c(x - x_0); \qquad v_x = (v_0)_x$$

Vertical direction: Since the positive y axis is directed upward, then $a_y = -g$

$$v = v_0 + a_c t; \qquad v_y = (v_0)_y - gt$$
$$y = y_0 + v_0 t + \tfrac{1}{2} a_c t^2; \qquad y = y_0 + (v_0)_y t - \tfrac{1}{2} g t^2$$
$$v^2 = v_0^2 + 2a_c(y - y_0); \qquad v_y^2 = (v_0)_y^2 - 2g(y - y_0)$$

Co-efficient of restitution: It is the ratio of relative velocities after the impact to the relative velocities before the impact. If V_A and V_B are the velocities of the colliding bodies A and B before the impact and V_A' and V_B' are the velocities after the impact then the value of coefficient of restitution 'e' is always between 0 and 1 and it depends on to a large extent on the two materials involved. The velocities of impact, shape and size of the colliding bodies also affect 'e'.

$$\mathbf{e = (V_B' - V_A') / (V_A - V_B)}$$

Procedure:

PRO 1: 1.1 Place the Impact apparatus on a flat horizontal surface at some height from ground and carefully study the apparatus.

1.2 Attach the plumb bob to the lower end of the exit port and release it.

1.3 After the plumb bob becomes stable, mark a line on the horizontal floor which shows the exact vertical trace of the exit.

1.4 There are three important positions, two on the apparatus and one on the ground that needs to be noted. The top position where one ball will be placed initially is called as position 1, the exit place on the apparatus where the balls will collide is position 2 and the marking on the ground done by plumb bob where the balls will fall after collision is position 3.

1.5 Measure the vertical height from Position 2 to 3 and note the value in the observation table.

PRO 2: 2.1 Place Ball A at top position on the apparatus.

2.2 Place Ball B at position 2 and note velocity before impact of both the balls..

2.3 Gently release Ball A so that it travels height H and gains kinetic energy so that impact can happen at position 2.

2.4 Note the distances after impact of both the balls.

PRO 3: 3.1 Using work energy principle calculate the velocity of ball A just before impact.

2. Steel & Brass

PRO 3: Using work energy principle to ball A from position 1 to 2

____

____

____

____

____

Apply projectile motion to ball-A and B from position 2 to 3

PRO 4			
Ball A		**Ball B**	
Horizontal Motion	**Vertical Motion**	**Horizontal Motion**	**Vertical Motion**
V=	**U =**	**V=**	**U =**
S=	**S=**	**S=**	**S=**
t=	**a=**	**t=**	**a=**
Using V = s/t	**Using $s = ut + l/2at^2$**	**Using V = s/t**	**Using $s = ut + l/2at^2$**
V_A' =	**t =**	**V_A' =**	**t =**

PRO 4: 4.1 Applying projectile motion to bodies from position 1 to 2 and then from 2 to 3, calculate the velocities after impact.

PRO 5: 5.1 Using the formula, calculate the value of coefficient of restitution.
5.2 Repeat the procedure with balls made of different material.

Result & Discussion:

PRO 1: ____________________

PRO 2: ____________________

PRO 3: ____________________

PRO 4: ____________________

PRO 5: ____________________

Increase your skills by calculating the exact point of hit of a projectile:
https://phet.colorado.edu/sims/projectile-motion/projectile-motion_en.html

Collide more than two balls and find the co-efficient of restitution:
https://phet.colorado.edu/sims/collision-lab/collision-lab_en.html

Conclusion:

Precautions:

While performing the practical, the learner must:

1. Suspend the plumb bob carefully.
2. Keep safe distance from the flying steel balls which can cause severe damage.
3. Avoid keeping finger on the place of impact of the steel balls.
4. Keep a carpet or rubber mat at the ground so that the impact can be reduced and balls do not get damage.

Quiz:

1. What is the use of plumb bob.
2. What is impact and state its types.
3. How is work energy principle applied to two moving bodies.
4. How do you calculate the range and maximum height of a projectile
5. What is Law of Conservation of Momentum?
6. Why is the net impulse zero in colliding bodies?
7. What is Direct Central Impact?
8. Explain Coefficient of Restitution?

Objective	PRO 1	PRO 2	PRO 3	PRO 4	PRO 5	Total Score
Weight	20	20	20	20	20	
Points						
Score						380
Earned Points (EP) = Total Score/100 =_____				Marks in 100 = EP *20		

EXPERIMENT 6

Experiment No. 06: FINDING THE POINT OF SUSPENSION OF A COMPOSITE PLANE AREA (USING CENTROID) FOR STABILITY OF A SYSTEM

Aim:

____

Objective:

After performing the practical, the learner will be able to:

PRO 1: Define Centroid
PRO 2: Calculate centroid of a body
PRO 3: Differentiate between centroid, centre of gravity & centre of mass
PRO 4: Suspend a composite plane area horizontally

Apparatus:

Card board, scissor, pencil, ruler, compass etc.

Theoretical Background:

Centroid: In mathematics and physics, the centroid or geometric center of a plane figure is the arithmetic mean position of all the points in the shape. The definition extends to any object in n-dimensional space: its centroid is the mean position of all the points in all of the coordinate directions. Informally, it is the point at which a cutout of the shape could be perfectly balanced on the tip of a pin.

While in geometry the term "barycenter" is a synonym for "centroid", in astrophysics and astronomy, barycenter is the center of mass of two or more bodies which are orbiting each other. In physics, the center of mass is the arithmetic mean of all points weighted by the local density or specific weight. If a physical object has uniform density, then its center of mass is the same as the centroid of its shape.

Centre of Gravity: The center of gravity is a geometric property of any object. The center of gravity is the average location of the weight of an object. We can completely describe the motion of any object through space in terms of the translation of the center of gravity of the object from one place to another, and the rotation of the object about its center of gravity if it is free to rotate. If the object is confined to rotate about some other point, like a hinge, we can still describe its motion. In flight, both airplanes and rockets rotate about their centers of gravity. A kite, on the other hand, rotates about the bridle point. But the trim of a kite still depends on the location of the center of gravity relative to the bridle point, because for every object the weight always acts through the center of gravity.

Center of Mass: In physics, the center of mass of a distribution of mass in space is the unique point where the weighted relative position of the distributed mass sums to zero, or the point where if a force is applied it moves in the direction of the force without rotating. The distribution of mass is balanced around the center of mass and the average of the weighted position coordinates of the distributed mass defines its coordinates. Calculations in mechanics are often simplified when formulated with respect to the center of mass. It is a hypothetical point where entire mass of an object may be assumed to be concentrated to visualise its motion. In other words, the center of mass is the particle equivalent of a given object for application of Newton's laws of motion.

In the case of a single rigid body, the center of mass is fixed in relation to the body, and if the body has uniform density, it will be located at the centroid. The center of mass may be located outside the physical body, as is sometimes the case for hollow or open-shaped objects, such as a horseshoe. In the case of a distribution of separate bodies, such as the planets of the Solar System, the center of mass may not correspond to the position of any individual member of the system.

The center of mass is a useful reference point for calculations in mechanics that involve masses distributed in space, such as the linear and angular momentum of planetary bodies and rigid body dynamics. In orbital mechanics, the equations of motion of planets are formulated as point masses located at the centers of mass. The center of mass frame is an inertial frame in which the center of mass of a system is at rest with

Observation and Calculation Table:

respect to the origin of the coordinate system.

There are two major differences between "center of gravity" and "center of mass":

1) The term "center of gravity" applies to the bodies with mass and weight, while the term "centroid" applies to plan areas.

2) Center of gravity of a body is the point through which the resultant gravitational force (weight) of the body acts for any orientation of the body while centroid is the point in a plane area such that the moment of the area, about any axis, through that point is zero.

Center of gravity is the point at which a object can be suspended and be in perfect equilibrium

Procedure:

- From a given composite figure, consider each figure separately in the form of triangle, circle, semicircle, etc.
- Specify the reference axis as x-axis and y-axis, if not specified.
- Determine the area of each figure as A_1, A_2, A_3, A_4, etc. and find the addition of all areas considering the shape to be subtracted.
- Determine x_1, x_2, x_3, x_4, etc i.e. distance between centroid of the figure and references y-axis.
- Similarly for y_1, y_2, y_3, y_4, etc i.e. distance between centroid of the figure and references x-axis.
- Adding the product of area and distance ($A_i x_i$) for plane figure where as for hollow figure required figure is to be added and remaining part is to be deducted.
- By using formula, $x = (A_1 x_1 + A_2 x_2 + A_3 x_3 + A_4 x_4) / (A_1 + A_2 + A_3 + A_4)$
- $y = (A_1 y_1 + A_2 y_2 + A_3 y_3 + A_4 y_4) / (A_1 + A_2 + A_3 + A_4)$ we can determine co-ordinates of centroid with respect to the reference axis.

Formulae:

____
____
____
____
____
____
____
____

Result:

PRO 1: ____

PRO 2: ____

PRO 3: ____

PRO 4: ____

____

Discussion & Conclusion:

____
____
____

Quiz :

1. What is centre of gravity?
2. What do you mean by centroid point?
3. What is the difference between centroid, centre of gravity & centre of mass?

<table>
<tr><th>Objective</th><th>PRO 1</th><th>PRO 2</th><th>PRO 3</th><th>PRO 4</th><th></th><th rowspan="3">Total Score</th></tr>
<tr><td>Weight</td><td>20</td><td>20</td><td>20</td><td>20</td><td></td></tr>
<tr><td>Points</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Score</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="5">Earned Points (EP) = Total Score/80 = ______</td><td colspan="2">Marks in 100 = EP *20</td></tr>
</table>