

K J Somaiya College of Engineering

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Batch: Roll
Experiment / assignment / tutorial No. _____
Grade: AA / AB / BB / BC / CC / CD / DD

Signature of the Staff In-charge with date

Title: Coplanar Concurrent Force System

CO1 Evaluate resultant and moment of a force system

Objective

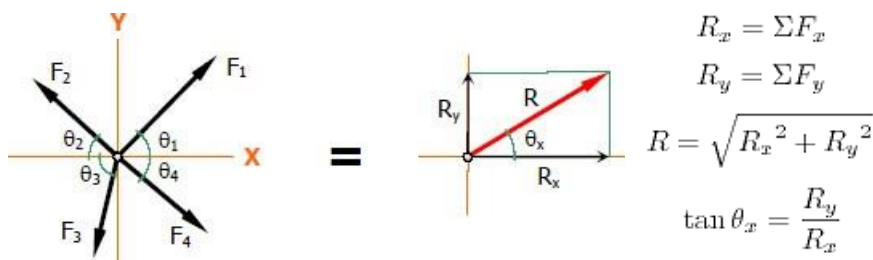
To verify the condition of equilibrium of a coplanar concurrent forces .

Theory

Resultant of a force system is a force or a couple that will have the same effect to the body, both in translation and rotation, if all the forces are removed and replaced by the resultant.

Resultant of Coplanar Concurrent Force System

The lines of action of each force in coplanar concurrent force system are on the same plane. All of these forces meet at a common point, thus concurrent. In x-y plane, the resultant can be found by the following formulas:



AIM:

To verify the condition of equilibrium of a coplanar concurrent force system and to analyze the error if any.

APPARATUS:

Universal force table, weights.

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Setup Diagram:

PROCEDURE:

1. Place the Universal force table on the firm platform.
2. Make the circular disc in horizontal position with the help of foot screws.
3. Put slotted weights to each hanger to these ends of strings passing over the pulleys.
4. Note the sum of slotted weights in each hanger and weight of hangers as five forces F_1 , F_2 , F_3 , F_4 and F_5 .
5. Measure the angles included between the two adjacent pulleys and note them as Θ_1 to Θ_5 .
6. Record these observations.
7. Repeat by changing any one or two pulley positions and take three sets of readings.
8. Draw force polygon.

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OBSERVATION TABLE:

Sr No	Forces					Angles					ΣF_x	ΣF_y
	F_1	F_2	F_3	F_4	F_5	Θ_1	Θ_2	Θ_3	Θ_4	Θ_5		
1												
2												
3												

CALCULATION:

RESULT:

CONCLUSION:

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Title – Support reaction of beam

CO4: Analyze applications of equilibrium using free body diagram

Objective

To verify the principle of forces in beams using parallel force apparatus

Theory

Beams are structural members which are generally horizontal. They are subjected to lateral forces which act orthogonal to the length of the member. There are various types of mechanisms used for supporting the beams. At these supports the reactive forces are developed which are determined by using the concept of equilibrium.

Determine the support reactions for the beam as

$$\sum F_{xi} = 0$$

$$\sum F_{yi} = 0$$

$$\sum M_o = 0$$

AIM:

To find the support reaction of a simply supported beam analytically and verify the same experimentally.

APPARATUS:

A graduated beam supported at both the ends by spring balances, hangers and weights.

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Setup Diagram:

Free body diagram:

PROCEDURE:

1. Take the initial readings of the spring balances at both the ends.
2. Suspend three known weights at different known distances from the left support of the beam.
3. Note the readings of the spring balances again.
4. The difference between the final and initial readings of the spring balances gives the reactions at the two supports.
5. Calculate the support reactions analytically.
6. Compare the same with the experimental values and find the percentage error on each of the support reactions. It is assumed that all the forces are coplanar and beam remains in the horizontal position even after loading.

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OBSERVATION TABLE:

Set no	Forces acting (N)			Distances from R_1 (cm)			Reactions by analysis (N)		Reactions observed (N)		% error in R_1	% error in R_2
	F_1	F_2	F_3	X_1	X_2	X_3	R_1	R_2	R_1	R_2		
1												
2												
3												

CALCULATION:

RESULT:

% error in R_1 =

% error in R_2 =

Conclusion:

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Batch: _____ Roll No.: _____
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Title - Friction

CO4: Analyze applications of equilibrium using free body diagram

Objective

To measure coefficient of friction of different surfaces

Theory

Friction is a force that is created whenever two surfaces move or try to move across each other.

- Friction always opposes the motion or attempted motion of one surface across another surface.
- Friction is dependent on the texture of both surfaces.
- Friction is also dependent on the amount of contact force pushing the two surfaces together

Static friction is friction between two or more solid objects that are not moving relative to each other. For example, static friction can prevent an object from sliding down a sloped surface. The coefficient of static friction, typically denoted as μ_s , is usually higher than the coefficient of kinetic friction.

AIM:

To find the coefficient of friction between two given surfaces and to find the load required to pull a body up on an inclined plane.

APPARATUS:

An inclined plane that can be set at different angles, bodies with different base materials and weights.

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Setup Diagram:

Free body diagram:

PROCEDURE:

Observation 1:

1. Keep the body on the inclined plane which is initially at the horizontal position.
2. Gradually increase the angle made by the inclined plane till the body just start sliding down.
3. Note the angle made by the inclined plane with horizontal which is angle of repose
4. Tangent of the angle of repose is the coefficient of friction between the two materials (body and the plane).

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Observation 2:

5. Set the inclined plane at any angle. Attach the string to the body whose weight is known.
6. Place the body on the inclined plane and pass the string over the pulley.
7. Load the free end of the string with the pan and the weights.
8. Add weights to the pan till the body is tending to move up. Note the load and compare it with the calculated value.

OBSERVATION TABLE 1

Materials	Angle of Repose (α)				Coefficient of friction (μ)
	1	2	3	Mean	
Ply and wood					
Ply and Aluminium					
Ply and Brass					
Ply and sand Paper					

OBSERVATION TABLE 2

Surfaces	Coefficient of friction	Weight (W)	Angle of plane (θ)	$P_{th} = W \sin \theta + \mu W \cos \theta$	P(expt.)
Ply and Wood					
Ply and aluminium					
Ply and brass					
Ply and sand paper					

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CALCULATION:

RESULT

Coefficient of Friction for

- | | |
|-----------------------|---|
| 1. Ply and wood | = |
| 2. Ply and aluminium | = |
| 3. Ply and brass | = |
| 4. Ply and sand paper | = |

Conclusion:

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Batch: _____ Roll No.: _____
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Title – Bell Crank lever

CO1: Evaluate resultant and moment of a force system

CO4: Analyze applications of equilibrium using free body diagram

Objective

To verify the principle of moments using bell crank lever.

Theory

Principle of moments states that, 'the algebraic sum of moments of a system of coplanar forces about any point in the plane is equal to the moment of the resultant of a 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 and having its fulcrum at the apex of the angle is known as bell crank lever. These levers were initially used to operate the bell from a long distance especially where change in the direction of bell wires was involved and hence the name.

AIM:

To verify the principle of moments of a coplanar non-concurrent system of forces and to find the error if any.

APPARATUS:

Bell crank lever apparatus, weights, hangers and scale.

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Setup Diagram:

Free body diagram:

PROCEDURE:

1. Arrange hanger at arbitrary location on the horizontal arm. Note the location X 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 initial spring balance reading T_1 . Also note the location of the spring from the hinge.
2. Hang the weight W from the hanger. 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 down the final spring balance reading T_2 . The tensile force on the vertical arm is the difference $T_2 - T_1$.
3. Since the external force is supported by the single hinge at the apex of the arm, implies that the resultant of these forces passes through the hinge. Therefore to verify the principle of the moments we need to take moments of all the forces about hinge and if the total sum is zero, verify the law of moments since the moment of the resultant is

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also zero at the hinge.

4. Repeat the above steps by changing the weights and their location in the horizontal arm.

OBSERVATION TABLE:

Sr No	Weight (W) Kg	Distance from fulcrum (X cm)	$M_1 =$ $w * X$ Kg cm	Reading of Spring balance		Effort $T=(T_2$ $-T_1)$ kg	Distance Y cm	$M_2 =$ $T*Y$	$M_1- M_2$	% Error
				Initial T_1	Final T_2					
1										
2										
3										

CALCULATION:

RESULT:

CONCLUSION:

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Title: Collision of Bodies

CO5 : Analyze the dynamic system using D'Alembert, work energy and impulse momentum principle.

Objective

To determine the coefficient of restitution between two steel balls.

Theory

A Collision between two bodies which occur in a very short duration of time and during which two bodies exert relatively large forces on each other is called impact. The line joining the common normal of the colliding bodies is known as line of impact. When the mass centers of the two colliding bodies lie on the line of impact, the impact is known as central impact. When the velocities of both the colliding bodies are collinear with the line of impact the impact is called as direct impact.

Coefficient of restitution “e” is the ratio of relative velocity of separation to relative velocity of approach. If u_A and u_B are the velocities before impact and V_A and V_B are the velocities after impact the

$$e = \frac{V_B - V_A}{u_A - u_B}$$

AIM:

To determine the coefficient of restitution between two steel balls.

APPARATUS:

The impact apparatus, steel balls, meter scale and carbon paper, drawing sheet.

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Setup Diagram:

PROCEDURE:

1. Fix the impact apparatus on the edge of table.
2. Place a steel ball B on the holder. Adjust the height of the holder such that the collision of the steel ball B with ball A is direct central.
3. Note the height 'y' of the holder from the ground using scale.
4. Place the steel ball on the slide at a certain vertical height 'h' from the holder. Note down the height 'h' with scale.
5. Release the ball from the position 1 and let it slide down and strike the stationary ball. Both the balls after impact undergo projectile motion, falling through a height 'y' land at different spots on the ground. Mark the spots and measure the horizontal distances of both balls.
6. Repeat the above steps by changing the height 'h'.

$V = X/t$	$u_A = \sqrt{2gh}$	$S = (ut + \frac{1}{2}at^2)_x$	$S = (ut + \frac{1}{2}at^2)_y$
$V_A = X_A/t$	$u_B = 0$	$X = Vt$	$y = (u_y t) + \frac{1}{2} * 9.81t^2$
$V_B = X_B/t$		$V = X/t$	$y = 0 + \frac{1}{2} * 9.81t^2$
		$V = X/\sqrt{2y/g}$	$t = \sqrt{2y/g}$

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OBSERVATION TABLE:

Sr No	X_A	X_B	Y	h	Initial Velocity		Final Velocity		Coefficient of restitution “e”
					u_A	u_B	$V_A = \frac{X_A}{\sqrt{2Y/g}}$	$V_B = \frac{X_B}{\sqrt{2Y/g}}$	
1									
2									
3									

CALCULATION:

RESULT:

CONCLUSION:

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Title: Flywheel

CO5: Analyze the dynamic system using D'Alembert, work energy and impulse momentum principle.

Objective

To determine the mass moment of inertia of a flywheel.

Theory

A flywheel is a rotating mechanical device that is used to store rotational energy. Flywheels have a significant moment of inertia and thus resist changes in rotational speed. The amount of energy stored in a flywheel is proportional to the square of its rotational speed. Energy is transferred to a flywheel by applying torque to it, thereby increasing its rotational speed, and hence its stored energy. Conversely, a flywheel releases stored energy by applying torque to a mechanical load, thereby decreasing its rotational speed.

Common uses of a flywheel include:

- Providing continuous energy when the energy source is discontinuous. For example, flywheels are used in reciprocating engines because the energy source, torque from the engine, is intermittent.
- Delivering energy at rates beyond the ability of a continuous energy source. This is achieved by collecting energy in the flywheel over time and then releasing the energy quickly, at rates that exceed the abilities of the energy source.
- Controlling the orientation of a mechanical system. In such applications, the angular momentum of a flywheel is purposely transferred to a load when energy is transferred to or from the flywheel.

AIM:

To find the moment of inertia of a flywheel theoretically and compare the same with experimental value.

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APPARATUS:

Flywheel mounted on ball bearings, stop watch, set of weights, string and meter scale

Setup Diagram:

PROCEDURE:

1. From the specifications of the flywheel calculate the theoretical value of Moment of Inertia.
2. Take a string of length equal to the height of the spindle of the flywheel from the ground; to one end attach a hook to carry the weight. Make a small loop on the other and attach it over the peg on the spindle of the flywheel. Wind the string over the spindle. Check whether the looped end of the string is released from the peg when the weight touches the ground.
3. Note down the 'h' from which the mass is allowed to fall. See that the red mark on the rim of the flywheel is coinciding with the pointer.
4. Attach a suitable mass on the hook and allow the mass to fall. Count the number of revolutions made by the flywheel (n) before the weight touches the ground. When the sound of the mass touching the ground is heard, start a stop watch and find the time taken (T) for the flywheel to come to rest and number of revolutions (N) made during this time.
5. Repeat the procedure for different masses.
6. Calculate the Moment of Inertia of the flywheel with the formula derived.

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OBSERVATION TABLE

Number of windings of string on the spindle (n) =

Height through which mass m falls (h) =

Sr. No	Mass Kg	Time (T) sec				No of Rev. (N)				Ang. vel. (ω) rad/sec	M.I. Kg.mm ²
		1	2	3	Avg.	1	2	3	Avg.		
1											
2											
3											

CALCULATION:

$$\text{Avg } (\omega) = (\omega_{\text{initial}} + \omega_{\text{final}})/2$$

$$\omega_{\text{final}} = 0$$

$$\omega_{\text{initial}} = 4\pi N/T$$

$$I = (2mgh - mr^2\omega^2) / \omega^2 (1 + n/N)$$

$$mgh = KE_{\text{mass}} + \text{Rotational } KE_{\text{fly}} + \text{Friction loss}$$

$$mgh = \frac{1}{2} mV^2 + \frac{1}{2} I \omega^2 + nF$$

$$nF = \frac{1}{2} I \omega^2$$

$$nF = n/N \frac{1}{2} I \omega^2$$

$$mgh = \frac{1}{2} mV^2 + \frac{1}{2} I \omega^2 + n/N \frac{1}{2} I \omega^2$$

$$2mgh = mr^2\omega^2 + I \omega^2 + n/N I \omega^2$$

$$(2mgh - mr^2\omega^2) = I \omega^2 (1 + n/N)$$

RESULTS

$$\text{Theoretical M.I. of flywheel} = 28511 \text{ Kg.mm}^2$$

$$\text{Experimental M.I. of flywheel} = \text{Kg.mm}^2$$

$$\% \text{ error} =$$

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Title: Compound pendulum

CO2: Analyze the concept of kinematics of particle and rigid body

Objective

To determine the center of gravity as well as the radius of gyration about the center of gravity by using compound pendulum.

Theory

Consider an extended body of mass M with a hole drilled through it. Suppose that the body is suspended from a fixed peg, which passes through the hole, such that it is free to swing from side to side. This setup is known as a compound pendulum.

Any object mounted on a horizontal axis so as to oscillate under the force of gravity is a compound pendulum. The one used in this experiment is a uniform rod suspended at different locations along its length.

AIM:

To find the radius of gyration of a compound pendulum and determine acceleration due to gravity.

APPARATUS

Compound pendulum, knife edge, meter scale and stop watch.

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Setup Diagram:

PROCEDURE :

- 1) Find the centroid of the compound pendulum by balancing it on a knife edge
- 2) Keep the knife edge screw in the 1st hole of the compound pendulum and tighten the screw so that the sharp edge of the knife edge is exactly downwards. Let us call this side as side A.
- 3) Measure the length 'h' between the point of the suspension and the centre of gravity
- 4) Suspend the pendulum from the knife edge and ensure that the knife edge rests on the rigid horizontal surface (so that the pendulum oscillates in a vertical plane)
- 5) Set the pendulum to oscillate with a small amplitude (less than 10 degree)
- 6) Note the time required for 20 oscillations (t), using a stop watch. Repeat this once more and find the average time required for 20 oscillations. From this average time, calculate the time required for one oscillation (i.e., the time period for the pendulum T) $T = t/20$
- 7) Repeat the step no 6 four more times, keeping the knife edge on the 3rd, 5th, 7th, 9th holes.
- 8) Calculate h^2 and hT^2 in each case

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- 9) Plot the graph of hT^2 vs h^2 , which will be straight line. Find the slope and the intercept of the line on the hT^2 axis (For plotting this line, use the line of the best fit explained later). From the slope of the line find the value of 'g' and from the intercept, find the value of 'k'

Repeat the procedure for side b of the pendulum

From the relation $T = 2\pi \sqrt{(h^2 + k^2)/gh}$

$$hT^2 = [(4\pi^2)/g] h^2 + [(4\pi^2)/g] k^2$$

Thus the plot of hT^2 vs h^2 will be a straight line, as the above equation of the form

$y = mx + c$ where m is the slope and c is the intercept on the y axis.

From the slope of the line $m = [(4\pi^2)/g]$ we can calculate the value of 'g'

From the intercept $c = \left[\frac{4\pi^2}{g} \right] k^2$, we can calculate the value of 'k'

OBSERVATION TABLE

Hole No.	h (cm)	Time for 20 oscillations (t)(sec)			T = t/20 (sec)	T ² (sec ²)	h ² (cm ²)	hT ²
		1	2	mean				
1								
3								
5								
7								
9								

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CALCULATION:

RESULT:

The value of K from graph is =

Theoretical value of K

The value of g from graph is =

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Title: Jib crane

CO4 Analyze applications of equilibrium using free body diagram

Objective

To calculate the forces in the members of a simple jib crane

Theory

A crane is a type of machine, generally equipped with a hoist, wire ropes or chains, and sheaves, that can be used both to lift and lower materials and to move them horizontally. It is mainly used for lifting heavy things and transporting them to other places. It uses one or more simple machines to create mechanical advantage and thus move loads beyond the normal capability of a human. Cranes are commonly employed in the transport industry for the loading and unloading of freight, in the construction industry for the movement of materials and in the manufacturing industry for the assembling of heavy equipment.

AIM:

To find the forces in the members of a truss.

APPARATUS:

Jib crane apparatus, spring balance, weights, scale, etc.

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Setup Diagram:

PROCEDURE:

1. Attach spring balance with BC member.
2. Put weight in pan at C.
3. With the help of scale measure the length of each member.
4. Take the readings on spring balance at members BC and AC and the weight in pan at C.
5. Find the forces in members by analytical calculations and verify the results.

OBSERVATION TABLE:

Sr. No.	Weight in Pan	Length of members		
		AB	BC	AC
1				
2				
3				

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Sr. No.	Weight in Pan	Spring balance reading at		Forces in members	
		BC	AC	BC	AC
1					
2					
3					

CALCULATION:

RESULT:

Force in Member BC = -----

Force in Member AC = -----

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