



ENGINEERING MECHANICS PRACTICAL LAB MANUAL

Department of Mechanical Engineering

LIST OF PRACTICALS

1. Study and performance of various equipment related to Engineering Mechanics.
2. Determination of M.A., V.R., efficiency and law of machine for Differential Axle and Wheel.
3. Determination of M.A., V.R., efficiency and law of machine using Simple Screw Jack.
4. Determination of M.A., V.R., efficiency and law of machine using Worm and Worm Wheel.
5. Determination of M.A., V.R., efficiency and law of machine using Single Purchase Crab.
6. Determination of M.A., V.R., efficiency and law of machine using Double Purchase Crab.
7. Determination of resultant of concurrent force system experimentally by parallelogram law of forces using force table.
8. Determination of resultant of concurrent force system graphically.
9. Determination of resultant of parallel force system graphically.
10. Verification of Lami's theorem.
11. Study of forces in various members of Jib Crane.
12. Determination of coefficient of friction for motion on horizontal and inclined plane.
13. Determination of centroid of geometrical plane figures.



EXPERIMENT 1: Study of Equipment Related to Engineering Mechanics

Objective: Perform the experiment accurately, compare measured values with theoretical relations and document the result in the prescribed format.

This experiment familiarizes the student with the construction, working principle, loading arrangement and measurement procedure of the equipment used in the remaining practicals.

1. Apparatus / Equipment

- Force table with pulleys, strings, hooks and slotted weights
- Differential axle and wheel
- Simple screw jack
- Worm and worm wheel machine
- Single purchase crab
- Double purchase crab
- Jib crane model
- Friction apparatus for horizontal and inclined planes
- Centroid apparatus / geometric cut-out set
- Measuring scale, protractor and weighing balance as applicable

2. Identification and Working Study

Equipment	Main parts	Purpose
Force table	Central ring, pulleys, strings, weight hangers	Used for concurrent force equilibrium and resultant verification.
Differential axle & wheel	Large wheel, two stepped axle diameters, rope	Lifting machine based on differential winding of rope.
Screw jack	Screw, nut, load platform, handle	Converts rotary effort into linear lifting motion.
Worm & worm wheel	Worm shaft, worm wheel, load drum	Provides high velocity ratio and compact lifting arrangement.
Single purchase crab	Single gear reduction and load drum	Lifting machine using a single stage of gearing.
Double purchase crab	Two gear reductions and load drum	Higher velocity ratio than a single purchase crab.
Jib crane	Mast, jib, tie/strut, hook	Illustrates member forces in a pin-jointed crane.
Friction apparatus	Plane, block, pulley, weights	Determines limiting friction and coefficient of friction.
Centroid setup	Plane figures / composite shapes	Determines geometric centroid by area method.

3. General Study Procedure

- Identify the equipment and read its nameplate/rated capacity, if available.
- Identify the effort input, load output, supporting members and moving parts.
- Trace the path of force or motion from the effort point to the load.
- Identify the measurements required for M.A., V.R., force equilibrium, friction or centroid calculations.
- Operate the apparatus without load first, then apply a small load and observe the motion.
- Record the main dimensions and observations in the laboratory record.

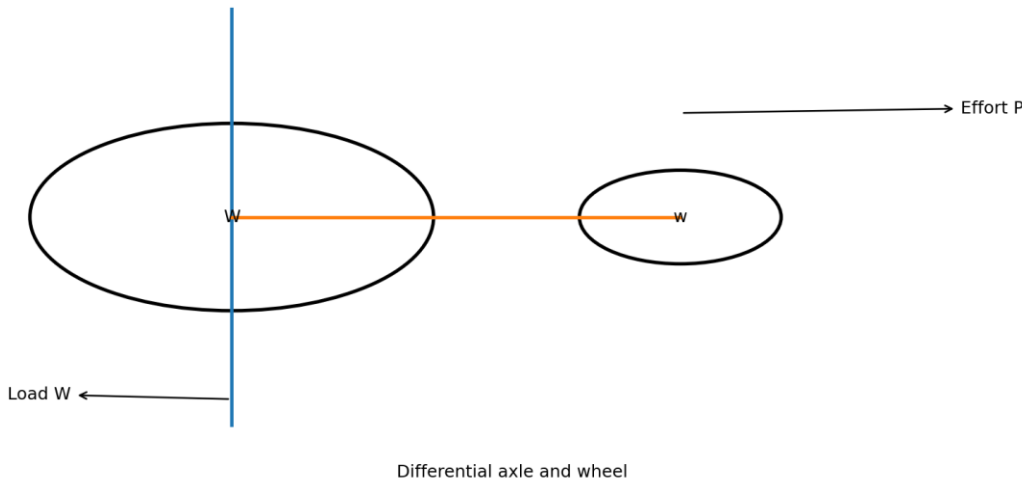
4. Tabulation

Equipment	Main dimensions	Working principle	Applications	Remarks



EXPERIMENT 2: M.A., V.R., Efficiency and Law of Machine for Differential Axle and Wheel

Objective: Perform the experiment accurately, compare measured values with theoretical relations and document the result in the prescribed format.



1. Apparatus Required

- Differential axle and wheel apparatus
- Slotted weights and weight hangers
- Spring balance / effort balance
- Measuring scale
- Spirit level, if provided

2. Theory / Principle

A differential axle and wheel consists of a wheel of radius R connected to two coaxial drums/axles of radii r_1 and r_2 ($r_1 > r_2$). When the wheel is turned, rope is wound on one axle and unwound from the other. The net shortening of the supporting rope in one revolution produces the lifting action. The machine gives a large velocity ratio because the load rope moves by only a small differential distance.

3. Formulae

$$\text{M.A.} = W/P$$

$$\text{V.R.} = \text{distance moved by effort} / \text{distance moved by load}$$

$$\eta = (\text{M.A./V.R.}) \times 100\%$$

$$\text{For an ideal differential axle and wheel: V.R.} = 2\pi R / (\pi(r_1 - r_2)) = 2R / (r_1 - r_2)$$

$$\text{Law of machine: } P = mW + C$$

4. Procedure

- Measure the wheel and axle dimensions required for calculating theoretical V.R.
- Ensure the load is suspended freely and the effort cord is correctly wound.
- Apply a known load W gradually.



- Apply effort P through the effort cord until the load just begins to rise; record P .
- Repeat for several load values, preferably increasing and decreasing the load to reduce error.
- Calculate M.A., V.R. and efficiency for each reading.
- Plot P versus W . The straight-line relation gives the law of machine $P = mW + C$.
- Compare experimental V.R. with theoretical V.R.

5. Observation Table

Trial	Load W (N)	Effort P (N)	M.A. = W/P	V.R.	Efficiency (%)

6. Calculations

Show one complete sample calculation with units. Repeat the calculation for each observation and tabulate the final values.

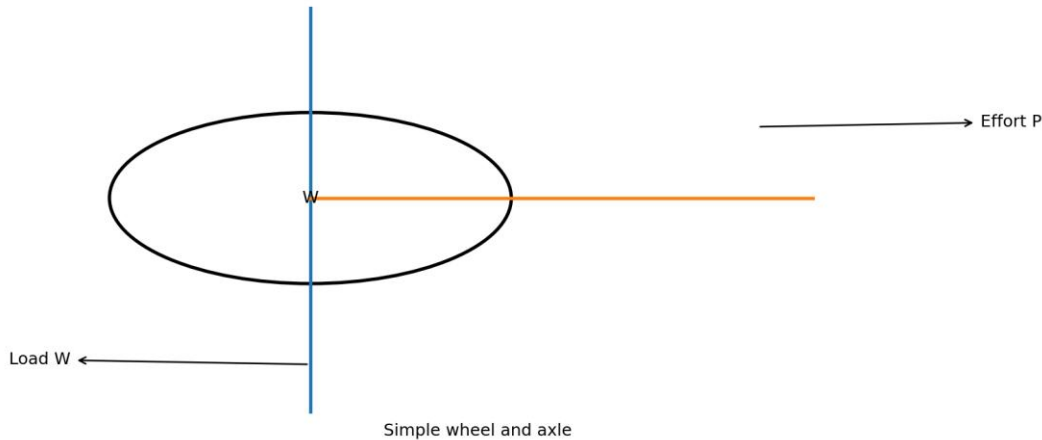
7. Result

The required quantities were determined successfully and the observed values were found to be reasonably consistent with the theoretical relation.



EXPERIMENT 3: M.A., V.R., Efficiency and Law of Machine using Simple Screw Jack

Objective: Perform the experiment accurately, compare measured values with theoretical relations and document the result in the prescribed format.



1. Apparatus Required

- Simple screw jack
- Load platform and load weights
- Effort handle
- Spring balance / effort balance
- Vernier or scale for screw dimensions, if available

2. Theory / Principle

A screw jack converts rotary motion of the handle into slow linear motion of the load platform. For one revolution, the effort point travels a circumference equal to $2\pi l$, where l is the handle radius. The load rises by the pitch p of the screw. Friction between the screw and nut and at the collar reduces efficiency.

3. Formulae

$$M.A. = W/P$$

$$V.R. = 2\pi l/p$$

$$\eta = (M.A./V.R.) \times 100\%$$

$$\text{Law of machine: } P = mW + C$$

m = slope of the P-W graph; C = intercept on the effort axis

4. Procedure

- Measure the handle radius l and screw pitch p .
- Place the load centrally on the platform.
- Apply a known load W .
- Operate the handle slowly until the load just starts to rise and note effort P .
- Repeat for at least five different loads.
- Calculate M.A., V.R. and efficiency.



- Plot effort P against load W and determine m and C .
- Compare experimental V.R. with theoretical V.R.

5. Observation Table

Trial	Load W (N)	Effort P (N)	M.A.	V.R.	Efficiency (%)

6. Calculations

Show one complete sample calculation with units. Repeat the calculation for each observation and tabulate the final values.

7. Result

The required quantities were determined successfully and the observed values were found to be reasonably consistent with the theoretical relation.

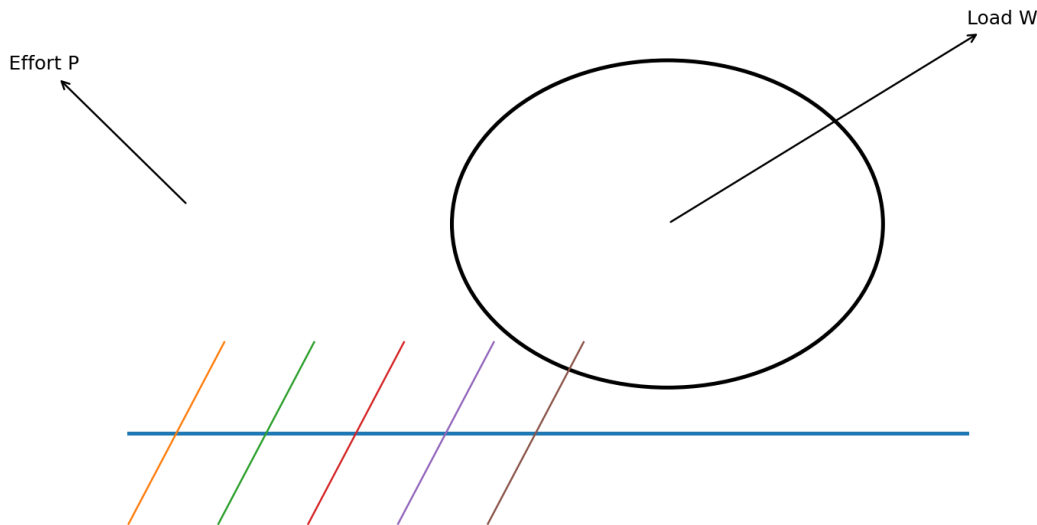


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EXPERIMENT 4: M.A., V.R., Efficiency and Law of Machine using Worm and Worm Wheel

Objective: Perform the experiment accurately, compare measured values with theoretical relations and document the result in the prescribed format.



Worm and worm wheel

1. Apparatus Required

- Worm and worm wheel apparatus
- Load drum and load
- Effort handle/worm shaft
- Spring balance
- Measuring scale

2. Theory / Principle

The worm and worm wheel mechanism consists of a worm screw driving a worm wheel. One revolution of a single-start worm advances the wheel by one tooth. The mechanism can provide a high velocity ratio and may be self-locking depending on its geometry and friction.

3. Formulae

$$\text{M.A.} = W/P$$



For a single-start worm, an ideal V.R. can be written as $V.R. = ZR/r$, where Z is the number of worm-wheel teeth, R is the effort-wheel radius and r is the load-drum radius

$$\eta = (M.A./V.R.) \times 100\%$$

$$\text{Law of machine: } P = mW + C$$

4. Procedure

- Count the teeth Z on the worm wheel and identify the number of starts n of the worm.
- Measure the effort wheel/handle radius R and load drum radius r.
- Place a known load on the load drum.
- Apply effort gradually until the load just begins to rise.
- Record P for different W values.
- Calculate M.A., theoretical V.R. and efficiency.
- Plot P versus W to obtain the law of machine.
- Compare the observed and theoretical velocity ratios.

5. Observation Table

Trial	Load W (N)	Effort P (N)	M.A.	Theoretical V.R.	Efficiency (%)

6. Calculations

Show one complete sample calculation with units. Repeat the calculation for each observation and tabulate the final values.

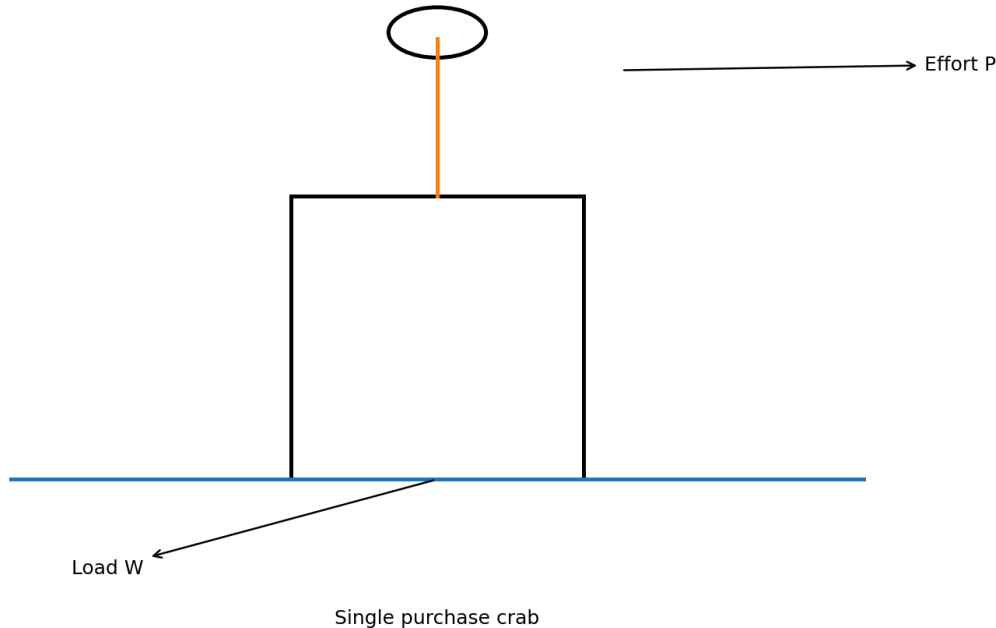
7. Result

The required quantities were determined successfully and the observed values were found to be reasonably consistent with the theoretical relation.



EXPERIMENT 5: M.A., V.R., Efficiency and Law of Machine using Single Purchase Crab

Objective: Perform the experiment accurately, compare measured values with theoretical relations and document the result in the prescribed format.



1. Apparatus Required

- Single purchase crab
- Load chain/rope and hook
- Effort handle
- Slotted weights
- Spring balance

2. Theory / Principle

A single purchase crab is a geared lifting machine in which the effort turns a pinion that drives a larger gear connected to the load drum. The velocity ratio is obtained from the ratio of effort displacement to load displacement and depends on the handle/drum radii and the gear tooth ratio.

3. Formulae

$$\text{M.A.} = W/P$$

$$\text{V.R.} = \text{distance moved by effort} / \text{distance moved by load}$$

$$\eta = (\text{M.A./V.R.}) \times 100\%$$

For a typical single-stage arrangement: $\text{V.R.} = (R/r) \times (T_G/T_P)$, where T_G and T_P are the appropriate gear and pinion tooth counts

$$\text{Law of machine: } P = mW + C$$



4. Procedure

- Identify the effort wheel, pinion, gear and load drum.
- Count the teeth of the pinion and gear and measure the relevant radii.
- Place a known load W on the hook.
- Apply effort P until the load just begins to rise.
- Repeat for different loads.
- Calculate M.A., V.R. and efficiency.
- Plot P against W and determine the law of machine.
- Compare theoretical and experimental V.R.

5. Observation Table

Trial	Load W (N)	Effort P (N)	M.A.	V.R.	Efficiency (%)

6. Calculations

Show one complete sample calculation with units. Repeat the calculation for each observation and tabulate the final values.

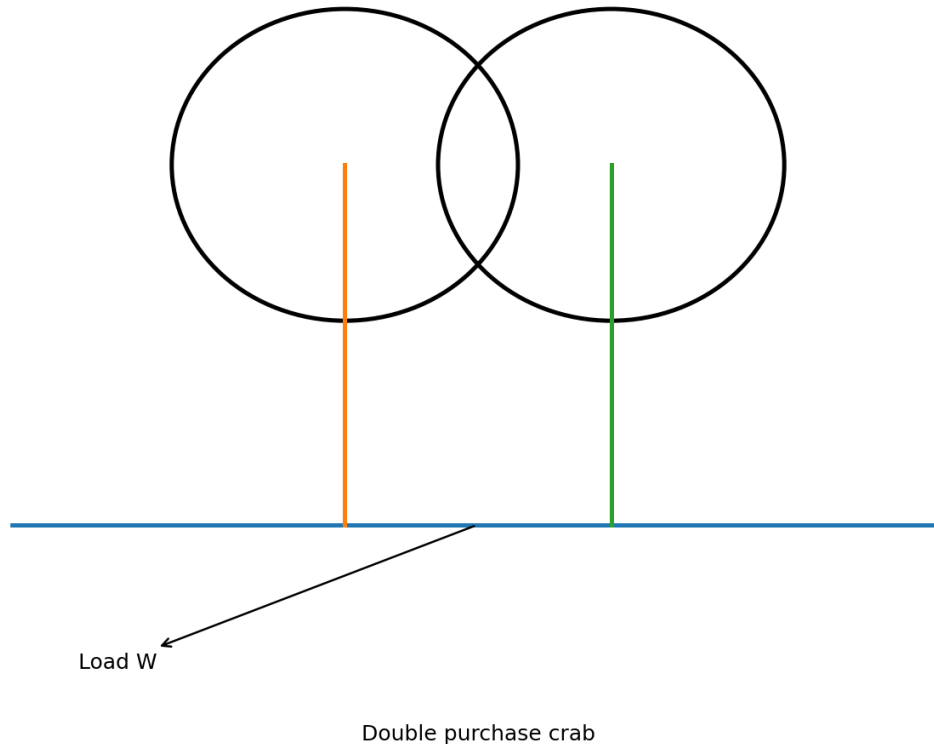
7. Result

The required quantities were determined successfully and the observed values were found to be reasonably consistent with the theoretical relation.



EXPERIMENT 6: M.A., V.R., Efficiency and Law of Machine using Double Purchase Crab

Objective: Perform the experiment accurately, compare measured values with theoretical relations and document the result in the prescribed format.



1. Apparatus Required

- Double purchase crab
- Two pairs of gears
- Load drum and hook
- Effort handle
- Slotted weights and spring balance

2. Theory / Principle

A double purchase crab uses two stages of gear reduction between the effort shaft and the load drum. The two gear ratios multiply, giving a larger velocity ratio than a single purchase crab for comparable dimensions. Actual efficiency is reduced by bearing and gear friction.

3. Formulae

$$M.A. = W/P$$

$$V.R. = \text{distance moved by effort} / \text{distance moved by load}$$

$$\eta = (M.A./V.R.) \times 100\%$$

For two gear stages: $V.R. = (R/r) \times (T_2/T_1) \times (T_4/T_3)$, using the actual tooth-count arrangement

$$\text{Law of machine: } P = mW + C$$



4. Procedure

- Identify the two gear pairs and count their teeth.
- Measure effort wheel and load drum radii.
- Place the load on the hook.
- Apply effort gradually until the load starts to rise.
- Record effort for several loads.
- Calculate M.A., V.R. and efficiency.
- Plot P versus W and determine the law of machine.
- Compare the velocity ratio and efficiency with those of a single purchase crab.

5. Observation Table

Trial	Load W (N)	Effort P (N)	M.A.	V.R.	Efficiency (%)

6. Calculations

Show one complete sample calculation with units. Repeat the calculation for each observation and tabulate the final values.

7. Result

The required quantities were determined successfully and the observed values were found to be reasonably consistent with the theoretical relation.

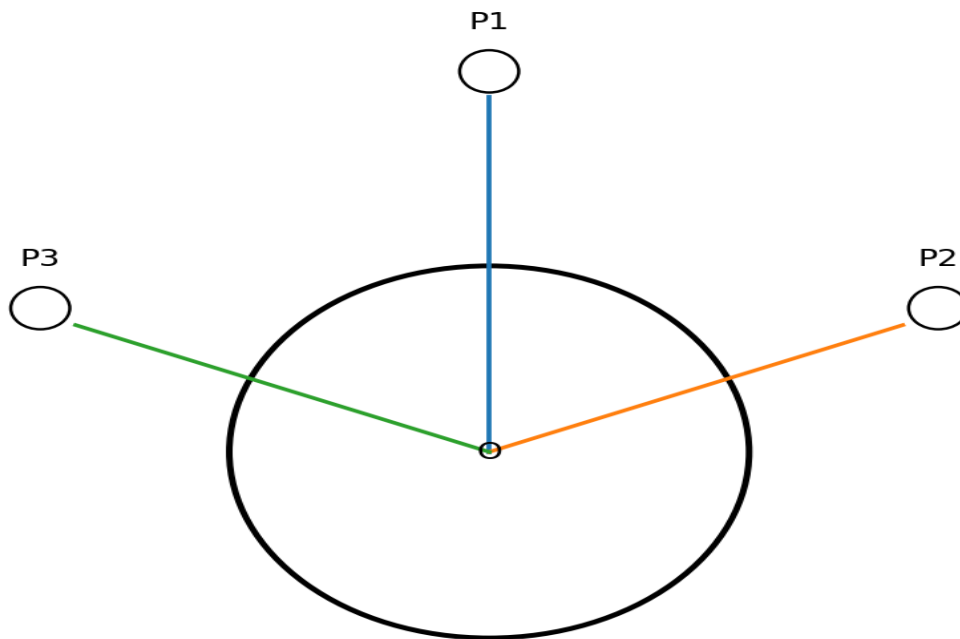


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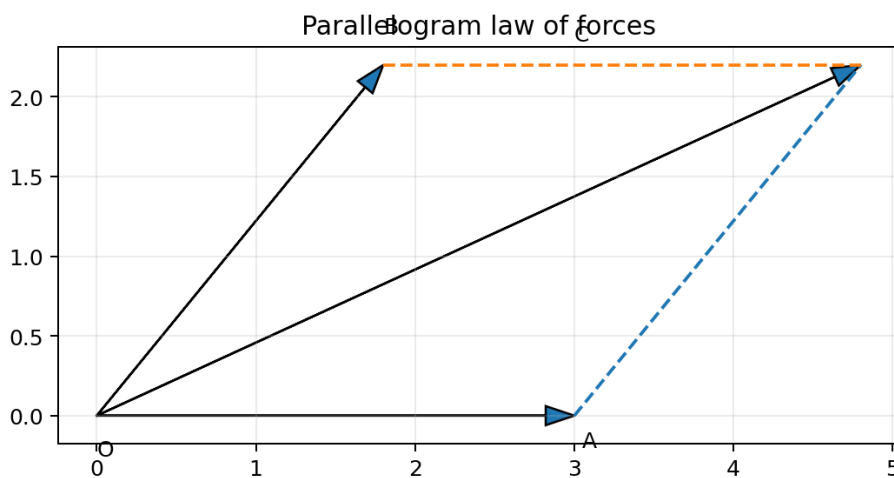


EXPERIMENT 7: Resultant of Concurrent Force System by Parallelogram Law using Force Table

Objective: Perform the experiment accurately, compare measured values with theoretical relations and document the result in the prescribed format.



Force table / concurrent force setup





1. Apparatus Required

- Force table with central ring
- Three or more pulleys
- Strings and weight hangers
- Slotted weights
- Protractor / angular scale

2. Theory / Principle

The parallelogram law states that if two concurrent forces acting at a point are represented in magnitude and direction by the two adjacent sides of a parallelogram, their resultant is represented by the diagonal passing through the common point. A force table permits the resultant/equilibrant to be checked experimentally. When the ring remains centered, the vector sum of the applied forces is approximately zero.

3. Formulae

For two forces P and Q at angle θ : $R = \sqrt{P^2 + Q^2 + 2PQ \cos\theta}$

Direction: $\tan \alpha = Q \sin\theta / (P + Q \cos\theta)$

Equilibrant $E = R$ in magnitude and acts opposite to R

Experimental error (%) = $[R_{\text{theory}} - R_{\text{exp}}] / R_{\text{theory}} \times 100$

4. Procedure

- Level the force table and place the central ring at the center.
- Attach strings from the ring over the pulleys to the weight hangers.
- Set the first force P at a selected angle and load.
- Set the second force Q at another angle.
- Determine the equilibrant by adjusting a third force until the ring is centered.
- Measure the magnitude and direction of the equilibrant.
- Reverse its direction to obtain the experimental resultant.
- Calculate the theoretical resultant and compare with experiment.

5. Observation Table

Trial	P (N)	Q (N)	Included angle θ ($^\circ$)	Experimental R (N)	Theoretical R (N)

6. Calculations

Show one complete sample calculation with units. Repeat the calculation for each observation and tabulate the final values.

7. Result

The required quantities were determined successfully and the observed values were found to be reasonably consistent with the theoretical relation.

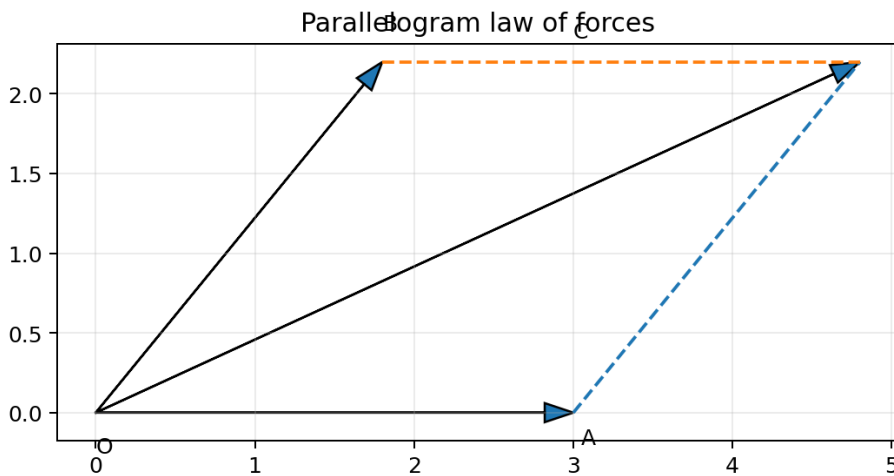


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EXPERIMENT 8: Resultant of Concurrent Force System Graphically

Objective: Perform the experiment accurately, compare measured values with theoretical relations and document the result in the prescribed format.



1. Apparatus Required

- Drawing board
- Drawing sheet
- Scale, ruler and set square
- Protractor
- Sharp pencil and eraser

2. Theory / Principle

In a concurrent force system all lines of action pass through one point. The graphical resultant can be found by drawing force vectors to scale and applying the polygon law. For two forces, the parallelogram method is convenient; for three or more forces, the force polygon method is generally preferred.

3. Formulae

Scale: 1 cm = S N (select a convenient scale)

Resultant magnitude = measured resultant length $\times$ S

Direction of resultant is measured from the selected reference axis

4. Procedure

- Choose a convenient force scale.
- Mark the common point O and draw the first force vector to scale and in the correct direction.
- From the head of the first vector, draw the second vector parallel and equal to its magnitude and direction.
- Continue vector-to-vector for all forces.
- Join the tail of the first vector to the head of the final vector. This is the resultant.
- Measure its length and direction.
- Check the graphical result against an analytical calculation if required.



5. Observation Table

Trial	Force 1 (N)	Force 2 (N)	Force 3 (N)	Graphical R (N)	Direction of R (°)

6. Calculations

Show one complete sample calculation with units. Repeat the calculation for each observation and tabulate the final values.

7. Result

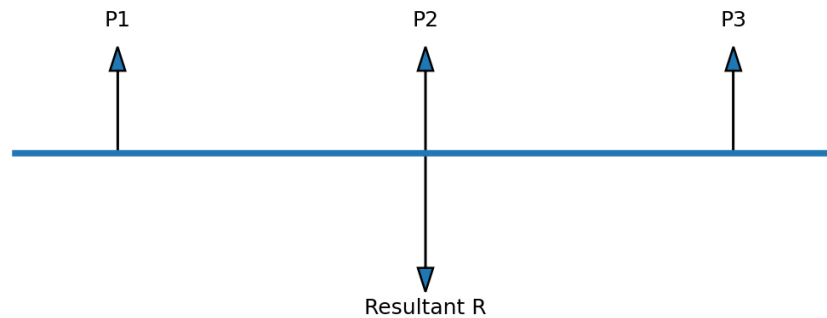
The required quantities were determined successfully and the observed values were found to be reasonably consistent with the theoretical relation.



EXPERIMENT 9: Resultant of Parallel Force System Graphically

Objective: Perform the experiment accurately, compare measured values with theoretical relations and document the result in the prescribed format.

Parallel force system



1. Apparatus Required

- Drawing board and sheet
- Scale/ruler
- Set square
- Protractor
- Pencil and eraser

2. Theory / Principle

For parallel forces, the magnitude of the resultant is the algebraic sum of the forces. Its line of action is determined by taking moments about a convenient reference point. For like parallel forces, the resultant lies between the outer forces; for unlike forces it may lie outside the region depending on magnitudes.

3. Formulae

For like parallel forces: $R = \Sigma F$

Position of resultant from O: $x_R = \Sigma (F_i x_i) / \Sigma F_i$

For equilibrium: $\Sigma F = 0$ and $\Sigma M = 0$

Use a consistent sign convention for upward/downward forces and clockwise/anticlockwise moments

4. Procedure

- Draw a reference line and mark the lines of action of the parallel forces.
- Choose a suitable force scale and represent each force by an arrow of proportional length.
- Determine the algebraic sum of the forces.
- Use the principle of moments to locate the resultant line of action.
- Draw the resultant at the calculated position.



- Verify the location by taking moments about another reference point.

5. Observation Table

Force	Magnitude (N)	Distance from O (mm)	Moment $F \times x$ (N-mm)	Sense

6. Calculations

Show one complete sample calculation with units. Repeat the calculation for each observation and tabulate the final values.

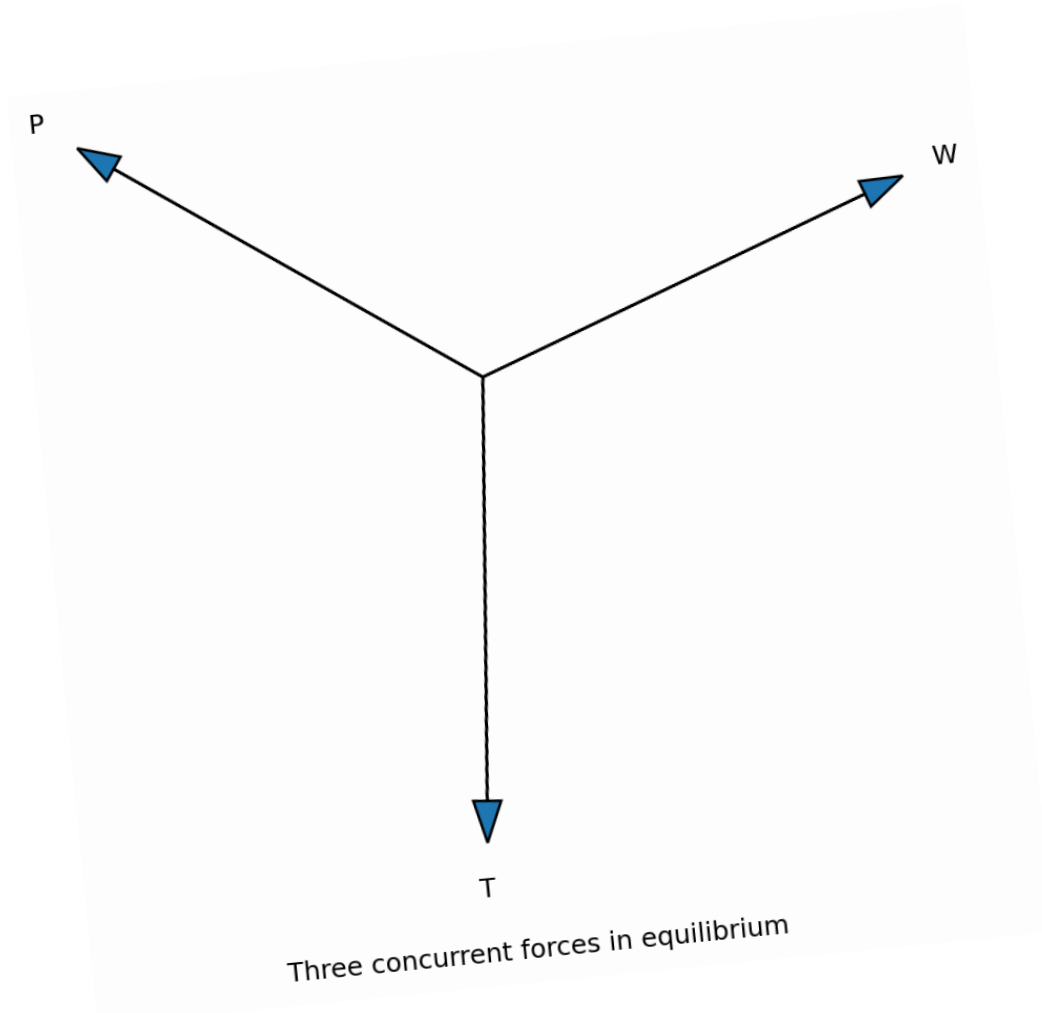
7. Result

The required quantities were determined successfully and the observed values were found to be reasonably consistent with the theoretical relation.



EXPERIMENT 10: Verification of Lami's Theorem

Objective: Perform the experiment accurately, compare measured values with theoretical relations and document the result in the prescribed format.



1. Apparatus Required

- Force table / Lami's theorem apparatus
- Pulleys and strings
- Weight hangers and slotted weights
- Protractor

2. Theory / Principle

Lami's theorem states that if a body is in equilibrium under the action of three coplanar, concurrent and non-parallel forces, each force is proportional to the sine of the angle between the other two forces.

3. Formulae

$$P/\sin \alpha = Q/\sin \beta = R/\sin \gamma$$

α is the angle between Q and R; β between R and P; γ between P and Q



4. Procedure

- Arrange the three strings so that their lines of action meet at the central ring.
- Apply known loads for two forces.
- Adjust the third load until the ring is exactly centered and the system is in equilibrium.
- Measure the three force magnitudes.
- Measure the three included angles.
- Calculate $P/\sin \alpha$, $Q/\sin \beta$ and $R/\sin \gamma$.
- Compare the three values and determine the percentage difference.

5. Observation Table

Trial	P (N)	Q (N)	R (N)	α (°)	β (°)	γ (°)	$P/\sin \alpha$	$Q/\sin \beta$	$R/\sin \gamma$

6. Calculations

Show one complete sample calculation with units. Repeat the calculation for each observation and tabulate the final values.

7. Result

The required quantities were determined successfully and the observed values were found to be reasonably consistent with the theoretical relation.



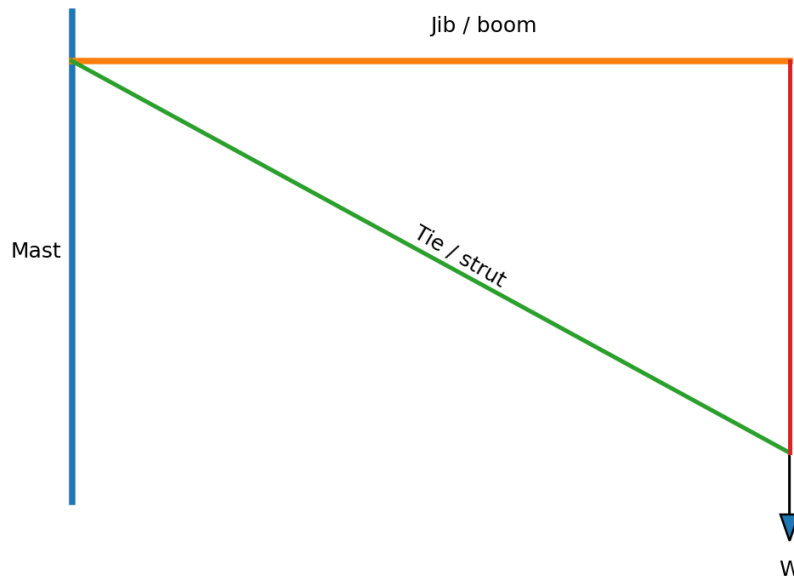
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EXPERIMENT 11: Study of Forces in Various Members of Jib Crane

Objective: Perform the experiment accurately, compare measured values with theoretical relations and document the result in the prescribed format.

Typical jib crane member-force setup



1. Apparatus Required

- Jib crane model / pin-jointed crane apparatus
- Known loads
- Force measuring devices or spring balances where provided
- Scale and protractor

2. Theory / Principle

A jib crane is a structure used to lift loads. A simplified jib crane can be treated as a pin-jointed framework. At each pin joint, the external load and member forces must satisfy equilibrium. Depending on geometry and loading, members may be in tension or compression. The method of joints or graphical triangle of forces may be used.

3. Formulae

$$\text{At any joint: } \Sigma F_x = 0 \text{ and } \Sigma F_y = 0$$

For an ideal two-force member, the force acts along the member axis

Tension: member pulls away from the joint

Compression: member pushes toward the joint

4. Procedure

- Identify the mast, jib/boom, tie or strut and hook point.
- Measure the geometry and member angles.



- Apply a known load at the hook.
- Observe/measure the force in each accessible member.
- Draw a free-body diagram of the loaded joint.
- Resolve the forces into horizontal and vertical components.
- Calculate theoretical member forces.
- Compare theoretical and experimental values and identify tension/compression.

5. Observation Table

Load W (N)	Member	Angle (°)	Observed force (N)	Calculated force (N)	Tension/Compression

6. Calculations

Show one complete sample calculation with units. Repeat the calculation for each observation and tabulate the final values.

7. Result

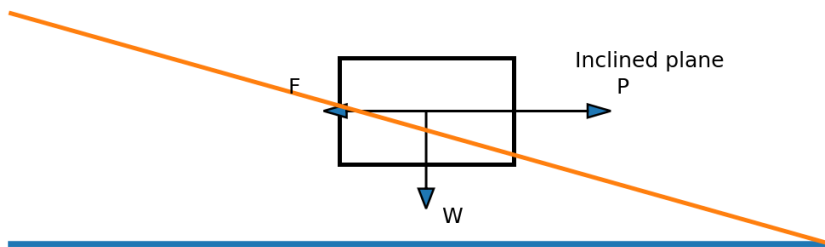
The required quantities were determined successfully and the observed values were found to be reasonably consistent with the theoretical relation.



EXPERIMENT 12: Coefficient of Friction for Motion on Horizontal and Inclined Plane

Objective: Perform the experiment accurately, compare measured values with theoretical relations and document the result in the prescribed format.

Friction on a horizontal / inclined plane



1. Apparatus Required

- Friction apparatus
- Wooden/metal block
- Horizontal or inclined plane
- Pulley, string and hanger
- Slotted weights
- Protractor for inclined plane

2. Theory / Principle

Friction is the resisting force that acts between two surfaces in contact and opposes relative motion or impending motion. At limiting friction, the frictional force reaches its maximum value. For a block on a horizontal plane, $F = \mu N$. For an inclined plane at the angle of limiting friction ϕ , $\mu = \tan \phi$.

3. Formulae

Horizontal plane: $\mu = F/N = P/W$ for a horizontal pulling arrangement

At limiting equilibrium on an inclined plane: $\mu = \tan \phi$

For a block of weight W on an incline: $N = W \cos \theta$

If the pulling force is parallel to the incline at limiting motion: $P = W \sin \theta + \mu W \cos \theta$

4. Procedure

- For horizontal-plane testing, place the block on the plane and attach the string over the pulley.
- Add weights to the hanger gradually until the block just begins to move.
- Record the load on the block and the pulling force at limiting motion.
- Repeat for different normal loads.
- For inclined-plane testing, place the block on the plane and increase the inclination slowly.
- Note the angle θ at which the block is just about to slide.



- Calculate μ from $\mu = \tan \theta$ and compare with the horizontal-plane result.

5. Observation Table

Trial	Block load W (N)	Pulling force P (N)	Normal reaction N (N)	$\mu = P/N$	Limiting angle θ (°)	$\tan \theta$

6. Calculations

Show one complete sample calculation with units. Repeat the calculation for each observation and tabulate the final values.

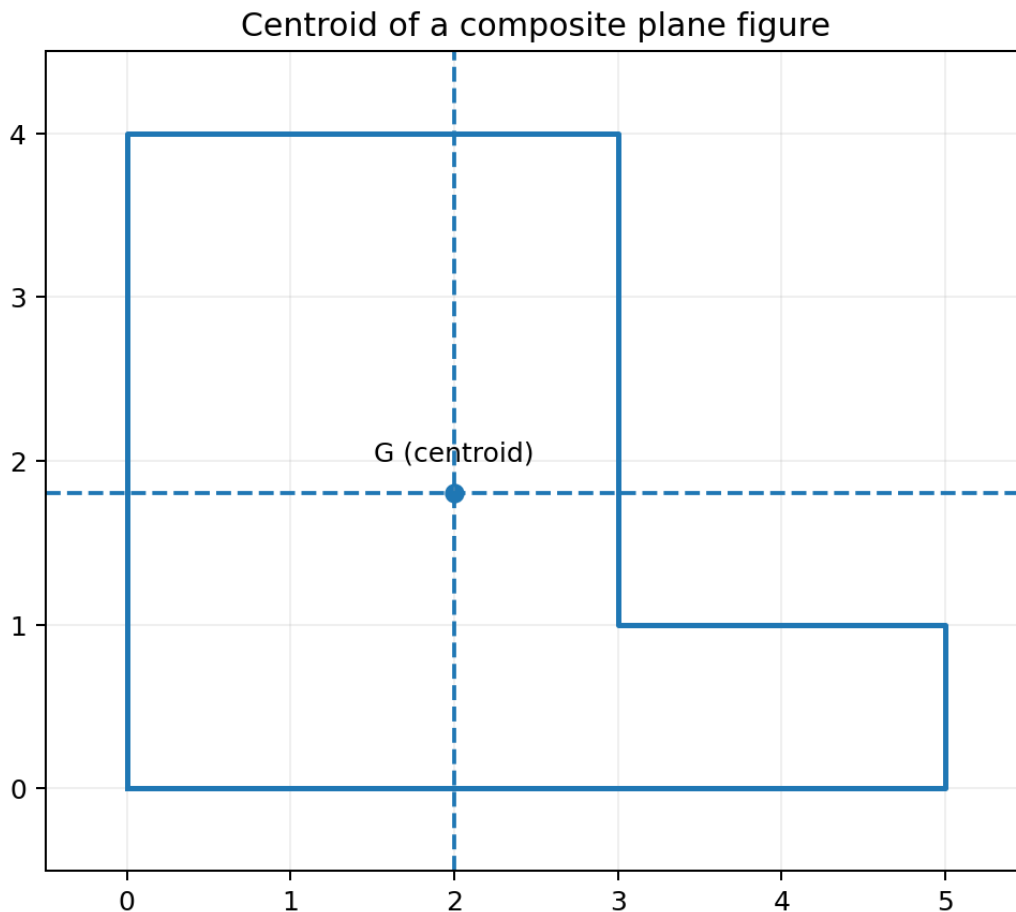
7. Result

The required quantities were determined successfully and the observed values were found to be reasonably consistent with the theoretical relation.



EXPERIMENT 13: Determination of Centroid of Geometrical Plane Figures

Objective: Perform the experiment accurately, compare measured values with theoretical relations and document the result in the prescribed format.



1. Apparatus Required

- Geometrical plane figures / composite lamina
- Ruler and vernier/scale as available
- Drawing sheet
- Plumb line or centroid apparatus, where applicable
- Calculator

2. Theory / Principle

The centroid is the geometrical center of a plane area. For a composite figure, the centroid can be determined by dividing the figure into simple areas whose centroid locations are known. Areas removed from the main figure are treated as negative areas.

3. Formulae

$$\bar{x} = \frac{\sum (A_i x_i)}{\sum A_i}$$

$$\bar{y} = \frac{\sum (A_i y_i)}{\sum A_i}$$

For a removed portion, take A_i as negative

For a uniform lamina, centroid and center of gravity coincide in a uniform gravitational field



4. Procedure

- Draw or identify the given plane figure and establish reference X-Y axes.
- Divide the figure into standard simple shapes such as rectangles, triangles, circles and semicircles.
- Calculate the area A_i of each component.
- Locate the centroid (x_i, y_i) of each component from the reference axes.
- Prepare the area-moment table.
- Calculate $\sum A_i$, $\sum A_i x_i$ and $\sum A_i y_i$.
- Determine $\bar{x}$ and $\bar{y}$.
- Mark the centroid on the drawing and verify it by an experimental/plumb-line method if apparatus is available.

5. Observation Table

Component	Area A (mm ²)	x-coordinate (mm)	y-coordinate (mm)	Ax (mm ³)	Ay (mm ³)

6. Calculations

Show one complete sample calculation with units. Repeat the calculation for each observation and tabulate the final values.

7. Result

The required quantities were determined successfully and the observed values were found to be reasonably consistent with the theoretical relation.