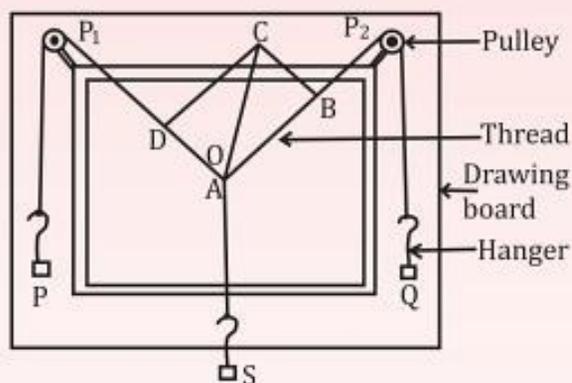# EXPERIMENT

AIM

To find the weight of a given body using parallelogram law of vectors.

MATERIAL REQUIRED

A Gravesand's apparatus, two hangers with slotted weights, a given body of unknown weight, a spring balance, plane sheet of paper, board pins, thin inelastic thread, scale, sharp pencil, mirror strip, protector set, squares and plumb line.

DIAGRAM

Gravesand's apparatus

THEORY

In the laboratory setting, Gravesand's apparatus is employed for determining the unknown weight of a body through the validation of the parallelogram law of vectors. Additionally, this apparatus has the capability to corroborate the triangle law and Lami's theorem. The operational principle of Gravesand's apparatus relies on the application of the parallelogram law of vector addition. According to this principle, when two forces act simultaneously at a point and are depicted in magnitude and direction by the two adjacent sides of a parallelogram, the resultant of the forces can be represented in both magnitude and direction by the diagonal of the parallelogram passing through the point of application of the two forces.

If P and Q are two vectors acting simultaneously on a particle placed at a point O at an angle ß as shown in figure, then these two vectors will be represented by the two sides of the triangle OAC, i.e. OA represents P and AC represents Q and the third side will represent the resultant vector R of these two vectors P and Q, i.e. OC represents the resultant vector R in the figure. Thus, the resultant vector R is given by,

$$R = P + Q \qquad \dots\dots\dots (1)$$
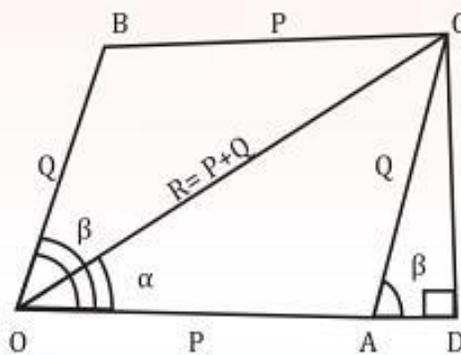
The magnitude of the resultant R can be calculated as,

$$R = \sqrt{P^2 + Q^2 + 2PQ \cos \beta} \qquad \cdots\cdots (2)$$

PROCEDURE

Setting Up the Apparatus

1. Begin by checking the fixation of the pulleys; if not fixed, secure them gently, ensuring smooth movement.
2. Position the Gravesand's apparatus vertically with its board, using a plumb line for alignment.
3. Affix a white sheet of paper to the wooden board using drawing pins after fixing the board.
4. Secure two hangers at the ends of a thread of sufficient length, tying another shorter thread in the middle to create a knot at point O. Suspend a block of unknown weight at the farther end.
5. Arrange threads carrying weights P and Q over pulleys, along with the third thread bearing the unknown weight X.
6. Ensure equilibrium at the junction or knot O, making sure neither weights nor threads touch the board or table.

Taking Impression of Three Forces on White Paper

1. With weights P, Q, and X acting at knot O in equilibrium, mark the position of O on a white paper sheet using a sharp pencil.
2. Slightly disturb slotted weights P and Q, then observe O's new position; if not closer to the original, lubricate pulleys with oil.
3. Place a mirror strip lengthwise under each thread, marking the ends of the mirrored thread image.
4. Cover the mirrored image with the thread to eliminate parallax error.
5. Mark positions for threads of weights P (P_1, P_2), Q (Q_1, Q_2), and X (X_1, X_2).
6. Remove hangers, note the weight of each hanger and slotted weights using a spring balance.

Drawing of Parallelogram

1. Remove the white sheet, then draw lines through points P_1, P_2; Q_1, Q_2; and X_1, X_2 using a meter scale, ensuring they meet at point O.
2. Confirm that the lines joining points (P_1, P_2), (Q_1, Q_2), and (X_1, X_2) form a straight line.
3. Use set squares to complete parallelogram OACB and join points O and C to get line OC.
4. Check if line OC aligns exactly with straight line XO; if not, let it meet BC at point C, measuring angle COC with a protractor.
5. Choose a suitable scale (0.5 N = 1 cm), cut off lengths OA and OB to represent forces P and Q, ensuring the drawn parallelogram covers the maximum area of the sheet.
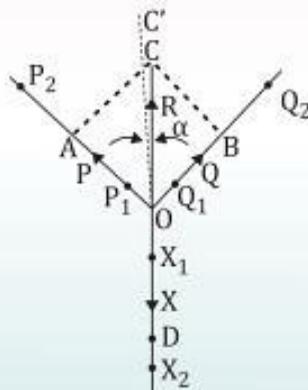
Measurement of the Weight of the Body

1. Join line OC to get resultant R of all three forces.
2. Measure dimensions of OC in cm and calculate the value of weight of the body (w_1) using the selected scale: $w_1 = OC \times 50$ g wt [1 cm = 50 g wt = 0.5 N].
3. If angle β occurs, measure weight (w_2) using parallelogram law of vector addition: $w_2 = P^2 + Q^2 + 2PQ \cos \beta$.
4. Take multiple observations with different weights P and Q and repeat the steps.
5. Find the mean weight geometrically and through parallelogram law, obtaining the weight of the body as,

$$W = \frac{(w_1 + w_2)}{2}$$

6. Measure the weight of the body (W') with a spring balance, accounting for the zero error.
7. Determine the percentage error by comparing the measured weight (W') with the calculated weight (W).

NOTE: Zero error of the spring balance should be taken into account while measuring the weight of the body.

OBSERVATIONS

1. Scale 1 cm = _____ N.
2. Zero error of the spring balance = _____ g wt.
3. Zero error correction = _____ g wt.
4. Weight of each hanger = _____ N.

TABLE FOR THE WEIGHT OF THE GIVEN BODY

S. No.	Force, P (hanger + slotted weights)		Force, Q (hanger + slotted weights)		Dimensions of OC = R (cm)	Unknown weight of given body, (N) = OC × 50 g wt	Angle COC' (β)	Unknown weight, $w_2 = \sqrt{P^2 + Q^2 + 2PQ \cos \beta}$
	P(N)	OA (cm)	Q(N)	OB (cm)				
1.								
2.								
3.								

CALCULATIONS

Measurement of the Weight of the Body

Dimensions of OC = _____ cm.

Mean weight as determined geometrically, w_1 = _____ N.

Mean weight as determined by the parallelogram law, w_2 = _____ N.

Hence, the weight of the body, $W = \frac{w_1 + w_2}{2}$ = _____ N.

Determination of the Percentage Error

To find the percentage error measure the weight (W') of the body with the help of spring balance and then put the values in the formula given below,

$$\text{Percentage error} = \frac{\text{Actual value} - \text{Experimental value}}{\text{Actual value}} \times 100 = \frac{W - W'}{W} \times 100 = \underline{\hspace{1.5cm}} \%$$

RESULT
The value of unknown weight of given object is _____ g wt.

PRECAUTIONS
1. The Gravesand's apparatus should be kept on a flat surface so that it stands stable.
2. The board should be made vertical by using plumb line.
3. The pulleys should be frictionless so that string moves freely about them.
4. Thread should have negligible weight so that its weight does not affect the results of the experiment.
5. The hangers and slotted weights should not touch the table surface or the board.
6. Care should be taken that there is no parallax between the thread and its mirror image, while marking the points on the paper.
7. The parallelogram should cover the portion of sheet properly. This is done by proper selection of scale.
8. Always use a pointed pencil to mark points.

SOURCES OF ERROR
1. Friction at the pulleys which does not allow free movement of thread, causes error of experiment.
2. Air currents within the laboratory disturb the equilibrium position of the arrangement.
3. Incorrect dimensions and measurement errors may result if the knot is not positioned in the center of the paper.
4. Inaccuracies in marking points on the white sheet of paper may occur.
5. The pulleys might lack the freedom to rotate.
6. The weight measurement may lack accuracy.

VIVA VOCE

Q1. Why can't vector quantities be added by ordinary laws of addition, as in scalar quantities?
Ans. Vector quantities have magnitude as well as direction. So, the vector addition should result in both magnitude as well as direction of resultant quantity.

Q2. State the parallelogram law of vector addition.
Ans. It states that if two vectors acting at a point simultaneously are represented by two adjacent sides of a parallelogram, then their resultant is given by the diagonal of the parallelogram, passing through that point.

Q3. What is meant by concurrent forces?
Ans. The forces which act on a body such that their lines of action meet at a single point are called concurrent forces.

Q4. What is the importance of plane mirror strip in marking the directions of forces in equilibrium position of threads?
Ans. The effect of parallax due to the thread and its image is removed and exact positions of threads are marked.

Q5. How can you verify that the result obtained by you in the above experiment for finding the

weight of body, is correct?

Ans. We can measure the weight of the body using spring balance and verify the results obtained by parallelogram law of vector addition.

Q6. **Relate kilogram-weight and newton.**

Ans. 1 kg wt. = 9.8 N

Q7. **Relate gram-weight and newton.**

Ans. 1 g wt. = 9.8×10^{-3} N

Q8. **Relate 1 gram and 1 gram weight.**

Ans. 1 g = 1 g wt.

Q9. **What do you mean by equilibrium vector?**

Ans. The vector which balances the resultant of given vectors so that the system remains in equilibrium, is called equilibrium vector.

Q10. **How do you verify the correctness of equilibrium position of the point marked O in the experiment?**

Ans. Push the unknown weight slightly downwards. Wait for the arrangement to become steady. Again, check if the position of point O now is the same as that marked before. If the two are different, check the pulleys and arrangements of the system.