EXPERIMENT 5

AIM

Measurement of the weight of a given body (a wooden block) using the parallelogram law of vector addition.

APPARATUS AND MATERIAL REQUIRED

The given body with hook, the parallelogram law of vector apparatus (Gravesand's apparatus), strong thread, slotted weights (two sets), white paper, thin mirror strip, sharp pencil.

DESCRIPTION OF MATERIAL

Gravesand's apparatus: It consists of a wooden board fixed vertically on two wooden pillars as shown in Fig. E 5.1 (a). Two pulleys P_1 and P_2 are provided on its two sides near the upper edge of the board. A thread carrying hangers for addition of slotted weights is made to pass over the pulleys so that two forces P and Q can be applied by adding weights in the hangers. By suspending the given object, whose weight is to be determined, in the middle of the thread, a third force X is applied.

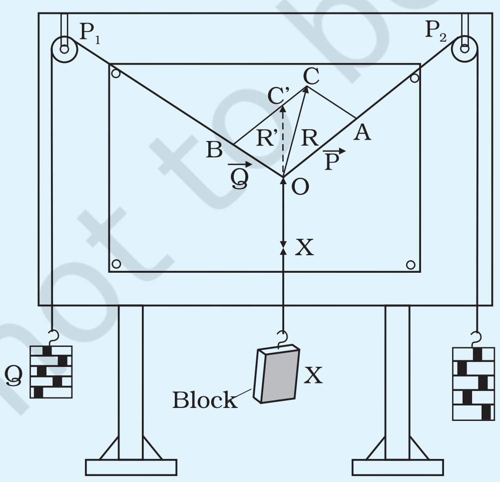

Fig. E 5.1(a): *Gravesand's apparatus*

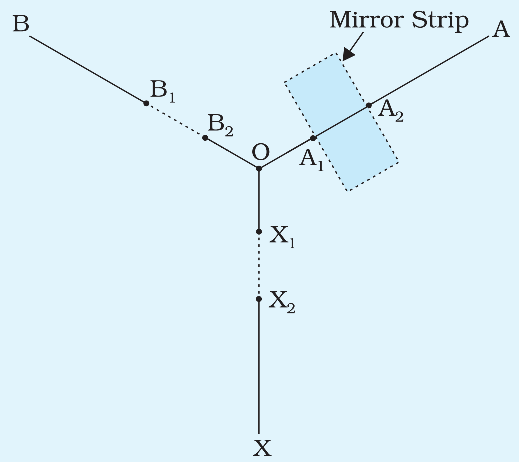

Fig. E 5.1(b): *Marking forces to scale*

PRINCIPLE

Working of this apparatus is based on the parallelogram law of vector addition. The law states that "when two forces act simultaneously at a point and are represented in magnitude and direction by the two adjacent sides of a parallelogram, then the resultant of forces can be represented both in magnitude and direction by the diagonal of the parallelogram passing through the point of application of the two forces.

Let P and Q be the magnitudes of the two forces and θ the angle between them. Then the resultant R of P and Q is given by

$$R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta}$$

If two known forces P and Q and a third unknown force due to the weight of the given body are made to act at a point O [Fig. 5.1 (a)] such that they are in equilibrium, the unknown force is equal to the resultant of the two forces. Thus, the weight of a given body can be found.

PROCEDURE

1. Set the board of Gravesand's apparatus in vertical position by using a plumb-line. **Ensure that the pulleys are moving smoothly**. Fix a sheet of white paper on the wooden board with drawing pins.

2. Take a sufficiently long piece of string and tie the two hangers at its ends. Tie another shorter string in the middle of the first string to make a knot at 'O'. Tie the body of unknown weight at the other end of the string. Arrange them on the pulley as shown in Fig. E 5.1 (a) with slotted weights on the hangers.

3. Add weights in the hangers such that the junction of the threads is in equilibrium in the lower half of the paper. **Make sure that neither the weights nor the threads touch the board or the table**.

4. Bring the knot of the three threads to position of no-friction. For this, first bring the knot to a point rather wide off its position of no-friction. On leaving there, it moves towards the position of no-friction because it is not in equilibrium. While it so moves, tap the board gently. The point where the knot thus come to rest is taken as the position of no-friction, mark this point. Repeat the procedure several times. Each time let the knot approach the position of no-friction from a different direction and mark the point where it comes to rest. Find by judgement the centre of those points which are close together. Mark this centre as O.

5. To mark the direction of the force acting along a string, place a mirror strip below the string on the paper . Adjust the position of the eye such that there is no parallax between the string and its image. Mark the two points A_1 and A_2 at the edges of the mirror where the image of the string leaves the mirror [Fig E 5.1 (b)].

   Similarly, mark the directions of other two forces by points B_1 and B_2 and by points X_1 and X_2 along the strings OB and OX respectively.

6. Remove the hangers and note the weight of each hanger and slotted weights on them.

7. Place the board flat on the table with paper on it. Join the three pairs of points marked on the paper and extend these lines to meet at O. These three lines represent the directions of the three forces.

8. Choose a suitable scale, say 0.5 N (50 g wt) = 1cm and cut off length OA and OB to represent forces P and Q respectively acting at point O. With OA and OB as adjacent sides, complete the parallelogram OACB. Ensure that the scale chosen is such that the parallelogram covers the maximum area of the sheet.

9. Join points O and C. The length of OC will measure the weight of the given body. See whether OC is along the straight line XO. If not, let it meet BC at some point C′ . Measure the angle COC′ .

10. Repeat the steps 1 to 9 by suspending two different sets of weights and calculate the mean value of the unknown weight.

OBSERVATIONS

Weight of each hanger = ... N

Scale, 1cm = ... N

Table E 5.1: Measurement of weight of given body

S. No.	Force P = wt of (hanger + slotted weight)		Force Q = wt of (hanger + slotted weight		Length OC = L	Unknown weight X = $L \times s$	Angle COC′
	P (N)	OA (cm)	Q (N)	OB (cm)	(cm)	(N)	
1							
2							
3							

RESULT

The weight of the given body is found to be ... N.

PRECAUTIONS

1. Board of Gravesand's apparatus is perpendicular to table on which it is placed, by its construction. Check up by plumb line that it is vertical. If it is not, make table top horizontal by putting packing below appropriate legs of table.

2. Take care that pulleys are free to rotate, i.e., have little friction between pulley and its axle.

SOURCES OF ERROR

1. Friction at the pulleys may persist even after oiling.

2. Slotted weights may not be accurate.

3. Slight inaccuracy may creep in while marking the position of thread.

DISCUSSION

1. The Gravesand's apparatus can also be used to verify the parallelogram law of vector addition for forces as well as triangle law of vector addition. This can be done by using the same procedure by replacing the unknown weight by a standard weight.

2. The method described above to find the point of no-friction for the junction of three threads is quite good experimentally. If you like to check up by an alternative method, move the junction to extreme left, extreme right, upper most and lower most positions where it can stay and friction is maximum. The centre of these four positions is the point of no-friction.

3. What is the effect of not locating the point of no-friction accurately? In addition to the three forces due to weight, there is a fourth force due to friction. These four are in equilibrium. Thus, the resultant of P and Q may not be vertically upwards, i.e., exactly opposite to the direction of X.

4. It is advised that values of P and Q may be checked by spring balance as slotted weights may have large error in their marked value. Also check up the result for X by spring balance.

SELF ASSESSMENT

1. State parallelogram law of vector addition.
2. Given two forces, what could be the
   (a) Maximum magnitude of resultant force.
   (b) Minimum magnitude of resultant force.
3. In which situation this parallelogram can be a rhombus.
4. If all the three forces are equal in magnitude, how will the parallelogram modify?
5. When the knot is in equilibrium position, is any force acting on the pulleys?

SUGGESTED ADDITIONAL EXPERIMENTS/ACTIVITIES

1. Interchange position of the body of unknown weight with either of the forces and then find out the weight of that body.
2. Keeping the two forces same and by varying the unknown weight, study the angle between the two forces.
3. Suggest suitable method to estimate the density of material of a given cylinder using parallelogram law of vectors.
4. Implement parallelogram law of vectors in the following situations:-

   (a) Catapult (b) Bow and arrow (c) Hand gliding
   (d) Kite (e) Cycle pedalling