ARBOR SCIENTIFIC

Force Table

93-3538

INSTRUCTIONAL GUIDE

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Introduction

The Force Table is designed for accurate quantitative demonstration of the component theory of forces. The surface of the circular table has angles from 0 to 360 degrees printed along its circumference in 1-degree intervals. The table accommodates four pulley clamps to be fixed at any point. Low-friction pulleys, adjustable legs, and quality masses allow for accurate and precise measurement of the forces acting on the central steel ring.

Background

A vector is a quantity comprised of direction and magnitude. Take force as an example. Any given force must act in some particular direction. A body may be acted on by several forces at once and its behavior is determined by the direction and magnitude of each. For instance, if two forces of equal amount act on a body from opposite directions, the body will remain at rest because the forces counteract each other and their resultant action is zero. On the other hand, if these same forces acted on the body at right angles to each other, the resultant force would be directed between the two forces.

Graphical Methods:

a. To find the resultant of two forces, draw lines representing them in length and direction, meeting at a common point. These form two side of a parallelogram. Complete the parallelogram and draw a diagonal from the meeting point of the two forces. The diagonal represents their resultant in both length and direction. Therefore, a force equal in magnitude and opposite in direction to this will balance the two original forces. This is called the parallelogram rule.

b. To find the resultant of more than two forces acting on a common point, we use what is called the polygon rule. In Figure 1, forces A, B, C, and D are acting on the point at the angles given, using OA as a reference line. Figure 2 shows all of the force vectors from Figure 1 drawn tip-to-tail, keeping OA as the reference line. The force OB is drawn to scale from point A so the external angle of AB, EAB, is 95°. OB acts in the same direction, so the external angle is found like this: 160° - 95° = 65°. When all forces are drawn using OA as the reference, draw a final line, DO, to represent the negative force required to put the system in equilibrium. This force is 180° from the resultant, R.

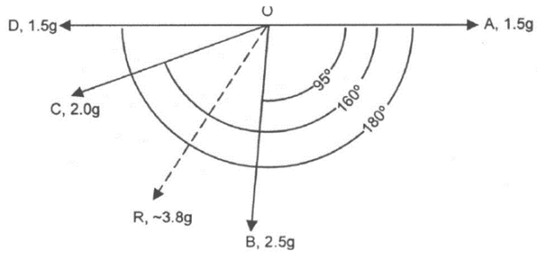

Fig. 1

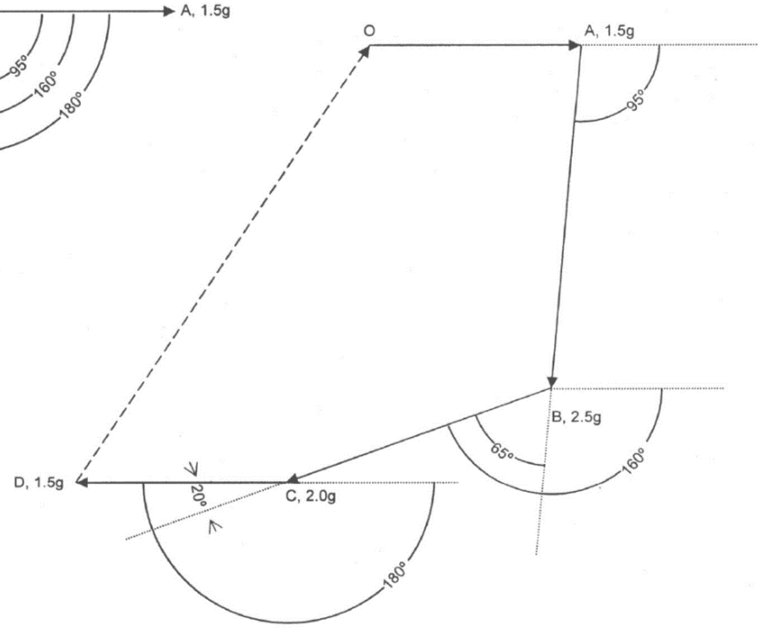

Fig. 2

Mathematical Method:

In order to sum forces mathematically, they must first be broken into perpendicular scalar components. It is convenient to choose a standard x-y coordinate plane, but any orthogonal coordinates will work. Separate each force into x and y coordinates using trigonometry. Sum the x and y components separately. Use the Pythagorean Theorem to find the magnitude of the forces and inverse trigonometric functions to find the angle. In the example, we will choose x to be to the right and y to be towards the top. This creates a right-handed coordinate system, but the angles are now in the negative direction. In this setup, the x components will use cosine and the y components will use sine.

$$A_x = A\cos(a) = 1.5g\cos(0) = 1.5g$$
$$A_y = A\sin(a) = 1.5g\sin(0) = 0$$

$$B_x = B\cos(b) = 2.5g\cos(-95°) = -0.22g$$
$$B_y = B\sin(b) = 2.5g\sin(-95°) = -2.45g$$

$$C_x = C\cos(c) = 2.0g\cos(-160°) = -1.9g$$
$$C_y = C\sin(c) = 2.0g\sin(-160°) = -0.68g$$

$$D_x = D\cos(d) = 1.5g\cos(-180°) = -1.5g$$
$$D_y = D\sin(d) = 1.5g\sin(-180°) = 0$$

$$R_x = A_x + B_x + C_x + D_x = 1.5g + (-0.22g) + (-1.9g) + (-1.5g) = -2.1g$$
$$R_y = A_y + B_y + C_y + D_y = 0 + (-2.5g) + (-0.68g) + 0 = -3.2g$$

$$R = \sqrt{R_x^2 + R_y^2} = \sqrt{(-2.1g)^2 + (-3.2g)^2} = 3.8g$$
$$r = \arctan\left(\frac{-2.1g}{-3.2g}\right) = 33°$$

It is important to remember the starting quadrant when using inverse trigonometric functions. In this case, we solved for 33° away from the *negative y-axis*, or -123° from the *positive x-axis*.

This method may be used to find the resultant of any number of forces, and may be used in place of the parallelogram rule in finding R for two forces.

Activities

Adjust the table to the height most convenient for you. When one mass hook is not being used, place it on the table since its mass would influence the reading.

1. Place two of the pulleys 60° apart. Place 50 g on one mass hanger and 300 g on the other. Using a vector diagram, determine the magnitude and direction of the resultant vector. Support this amount over a third pulley 180° from the resultant vector. Remove the center pin and displace the ring. Tap the table and see if the ring returns to the center. If it does, the forces are in equilibrium. If not, there is an error in the calculation. (Remember to account for the weight of the mass hanger)
2. Place three of the pulleys at various angles around the table with any weights on the hangers. Using method (b) above, find the force necessary to produce equilibrium. Check this experiment.
3. Place all four pulleys on one side (within 180° of one another and place any masses on the hangers. Find R by applying the polygon rule.

Related Products

Forces on Inclined Plane Demonstrator (P4-1420) This engaging piece of lab equipment makes the component theory of forces a tangible reality for every student.

Spring Scales (Complete Set) (01-6970) Clear plastic bodies reveal these scales' inner workings. Printed in grams and Newtons. 6 options include 5000g, 3000g, 2000g, 1000g, 500g, 250g. Color-coding makes it easy to find the right scale for the task.

Conceptual Physics Alive: Linear Motion, Vectors & Projectiles (PX-9101) Master teacher Paul Hewitt discusses the reasons to learn physics, and teaches Linear Motion, and Vectors & Projectiles

Digital Newton Meter (01-7000) Measuring force is so quick and precise with this new Digital Newton Meter! It can measure forces from .01 N to 20.00 N and display them clearly. Use multiple Digital Newton Scales to verify the laws of vector addition for forces as well as getting higher accuracy on your weight readings.