Name ______________________ Section ____________ Date ____________

CONCEPTUAL PHYSICS | **Experiment**

Newton's First Law of Motion—Inertia | **The Equilibrium Rule**

Walking the Plank

Purpose

To measure and interpret the forces acting on an object in equilibrium

Apparatus

meterstick
2 support rods
2 rod clamps
2 spring scales (5- or 10-newton capacity)
2 20-cm lengths of string
2 table clamps
2 crossbars (short rods)
2 collar hooks
slotted masses (two 200 g and one 500 g)
small spirit level (optional)

Discussion

Consider sign painters Burl and Paul who work on a scaffold (a plank of wood suspended by ropes at both ends). They might wonder about the tension in the ropes that support their plank. They are in a state of equilibrium, but how do the rope tensions relate to their weights and the weight of the scaffold? While the weights of Burl and Paul don't change, the tensions in the ropes do change when either of them moves along the plank. In this activity, you'll use a meterstick for such a scaffold. You'll measure the forces acting on the scaffold when it is in various arrangements, and interpret the forces that determine the condition of equilibrium.

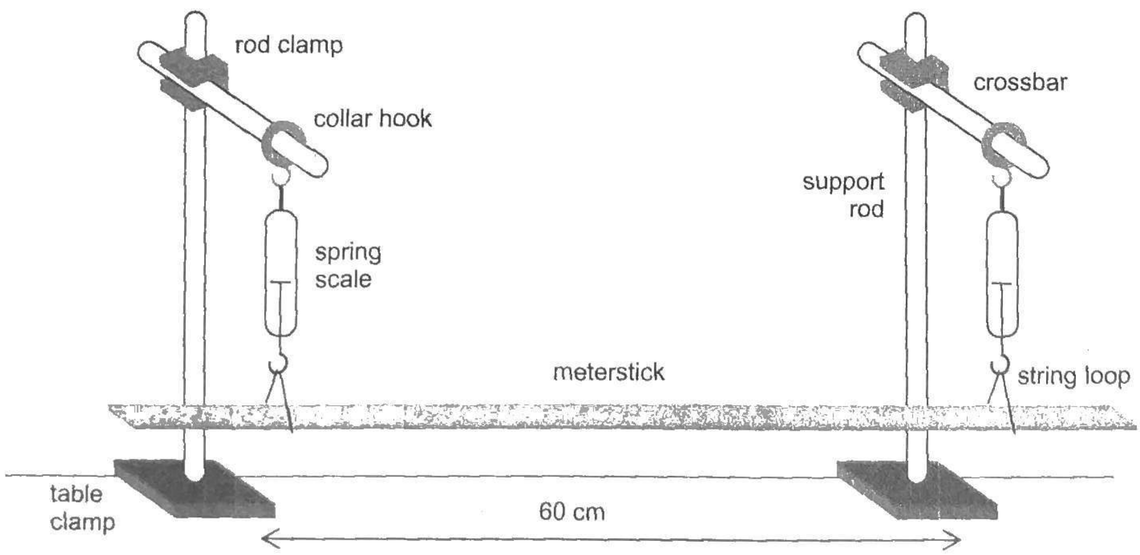

Figure 1

Procedure

Step 1: Calibrate both spring scales so that when held vertically and carrying no load, each reads zero.

Step 2: Arrange the apparatus as shown in Figure 1.

a. Position the table clamps so that the support rods are about 60 cm apart.

b. Attach the crossbars to the support rods using the clamps. Hang a spring scale from each of the crossbars using the collar hooks.

c. Tie the ends of one 20-cm length of string together to create a loop. Hang the loop from one of the spring scales. Repeat for the other spring scale.

d. Suspend the meterstick (centimeter scale up) from the loops of string. Balance the arrangement so that the 50-cm mark is centered between the string loops and the meterstick is level. (Use a spirit level—if one is available—to check the meterstick.) This structure is a model of our painters' scaffold.

e. Adjust the meterstick so that the readings on both spring scales are the same (or very nearly the same). Move the meterstick left or right or adjust the level if necessary.

Step 3: Record the readings on both scales.

Reading on left scale: ______________ **Reading on right scale:** ______________

a. Add those readings and record the result. This is the total weight of the meterstick and string loops.

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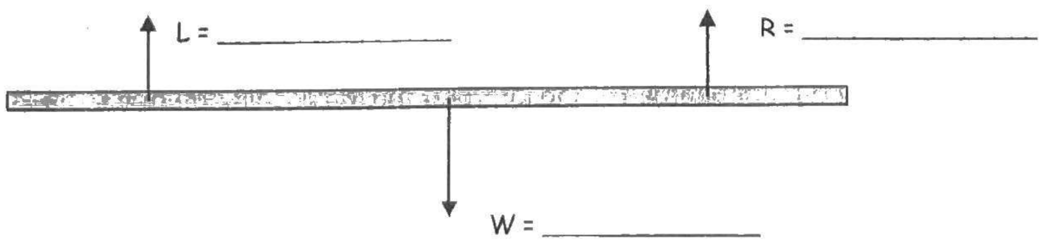
b. Complete the diagram of the meterstick with the forces acting on it. The force L is the upward force on the left, R is the force on the right, and W is the downward force of weight.



c. What is the net force on the meterstick? The net force is the sum of the forces, taking direction into account.

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Step 4: Carefully place one 200-g mass at the 40-cm mark while carefully placing the other 200-g mass at the 60-cm mark. (These represent our painters; take care so they don't fall!) Aim the slots of the slotted masses toward either end of the meterstick (0 or 100 cm).

Step 5: Record the readings for both scales.

Reading of left scale: ______________ **Reading of right scale:** ______________

a. What is the total weight of the meterstick, string loops, and masses?

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b. Sketch a diagram of the meterstick with all the forces acting on it. Include the numerical values of each force in your diagram.

c. What is the net force on the meterstick?

Step 6: Move the mass at the 40-cm to the 70-cm mark. Keep the other mass at the 60-cm mark. The scaffold is still in equilibrium, even though the load is not evenly distributed.

Step 7: Record the readings for both scales.

Reading of left scale: ______________ **Reading of right scale:** ______________

a. What is the total weight of the meterstick, string loops, and masses?

b. Sketch a diagram of the meterstick with all the forces acting on it. Include the numerical values of each force in your diagram.

c. What is the net force on the meterstick?

d. Review your findings so far. What would you say is the condition for equilibrium, a condition that was met in all the arrangements investigated so far?

Step 8: Suppose two painters with different weights used a scaffold. Simulate this by using a 500-g mass and a 200-g mass. Carefully stack the two masses at the 50-cm mark and read the scales.

Reading of left scale: ______________ **Reading of right scale:** ______________

Step 9: Carefully place the 200-g mass at the 60-cm mark and the 500-g mass at the 40-cm mark, but do not read the scales yet.

What will the scale readings add to?

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Step 10: Read *only* the left scale and record the reading.

Reading on left scale: ___________________

Predict the approximate value of the reading on the right scale and record your prediction.

Prediction on right scale: ___________________

Step 11: Read the right scale and record the reading.

Reading on right scale: ___________________

How did the reading compare to your prediction?

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Step 12: Move the 200-g mass until both spring scales have the same reading. Record the location of the 200-g mass.

Position of the 200-g mass: ____________________________

The 500-g mass is 10 cm from the center of the meterstick. How far is the 200-g mass from the center of the meterstick?

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Summing Up

1. Can the meterstick platform be in equilibrium if the two upward support forces are equal to each other? If so, give an example from your observations.

2. Can the meterstick platform be in equilibrium if the two upward support forces are unequal? If so, give an example from your observations.

3. Would the platform be in equilibrium if a 500-g mass were at the 30-cm mark and a 200-g mass were at the 60-cm mark? Explain.

4. Suppose the 500-g mass were placed at the 30-cm mark. Where could you place the 200-g mass so that both spring scales would have the same reading? Explain your answer.

5. Could you use the same masses to get both scales to have the same reading if the 500-g mass were placed at the 20-cm mark? If so, where should the 200-g mass be placed? If not, why not?