FORCE TABLE

CAT NO. PH 0347C-N8

Experiment Guide

GENERAL BACK GROUND OR THEORY ON THE EXPERIMENT:

Force tables are used primarily to help students apply Newton's Laws to calculate or predict the net force on an object that can be assumed to be a point particle. This means the net force does not cause the object to rotate. It can however result in the object undergoing circular motion.

In order for an object to be at rest, there must be either no forces acting on that object or all the forces acting on the object must be balanced.

A single vector that can replace all other vectors acting on an object is called a resultant vector.

In a force table the one vector that puts a system of two or three vectors into equilibrium is equal in magnitude but opposite in direction of the resultant is called the equilibrant. Students use a force table to find the resultant of two vectors by finding the equilibrant and then subtracting 180° from the value of the direction of the equilibrant to find the direction of the resultant vector.

REQUIRED COMPONENTS (INCLUDED)

Name of Part	Quantity
40 cm Force Table	1
Stand with three adjustable screws	1
Pulley with attached clamp	4
250g hanging slotted mass sets	4
String	2 balls
Large metal hoop	1
Small metal hoop	4
Removable metal post with hex nut base	1

REQUIRED COMPONENTS (NOT INCLUDED)

Name of Part	Quantity
Scissors	1
Level	1

RECOMMENDED COMPONENTS (NOT INCLUDED)

Name of Part	Quantity
Video Camera	1
Grid paper	1
Force probe	1

SAFE HANDLING OF APPARATUS:

Before adding or removing weights to any of the four pulleys, always check to make sure the safety pin is securely in place in the center of the force table.

Do not lean on the force table or place heavy objects on the force table as this may cause it to tip over.

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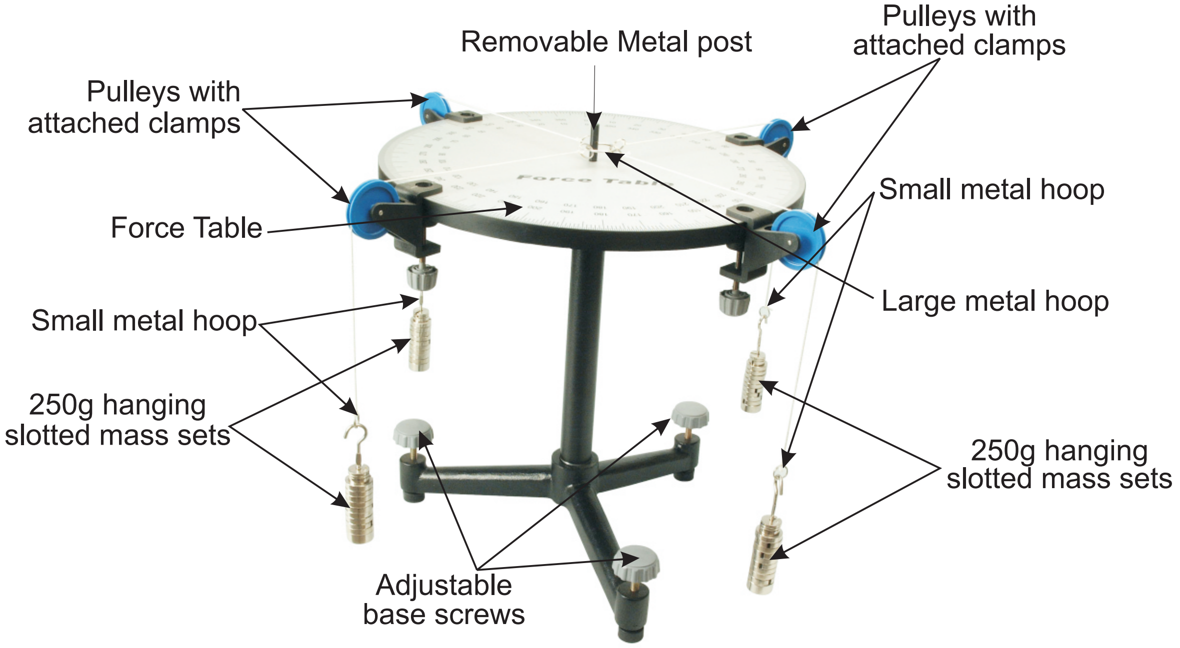
DIAGRAM LABELING ALL PARTS:



INITIAL SET UP OF APPARATUS:

Before beginning any experiments the force table needs to be set up.

How to level the Force Table:

Set force table on a level surface. Use a level and the screws at the base to adjust the force table so that the top of the force table is level with the ground. This insures that students are using vector forces in two dimensions and not three. If no level is available, a simple test can be performed with a ping pong ball. Place the ping pong ball anywhere on the surface of the table. If the ball stays at rest, then the table is level. If not, use the thumb screws to adjust the table until it is level and the ball will stay in one spot when released. Alternatively, there are free applications for smart phones that can turn your phone into a level.

How to make the strings that hold the hanging masses:

1. Cut four equal lengths of string about 60 cm long.
2. Use a square knot to attach one of the strings to one end of each of the four small metal hoops.
3. Place the large ring over the small post in the center of the force table.
4. Clamp all four pulleys on the force table. One at 0°, 90°, 180° and 270°. Make sure the white notch on the pulley lines up with the white line representing each angle on the top of the force table.
5. Hook one of the hooked masses through the small hoops and then run the lose end of the string over the pulley and through the large ring at the center of the force table.
6. Pull the string until the hooked masses are midway between the top of the force table and the top of the surface the force table is resting on.

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7. Tie two half hitch knots with the free end of the string onto the large hoop to secure the string in place and cut off any extra string so it doesn't get in your way.

8. Repeat with the other three strings.

The force table should look like this when ready to use:

Activity 1: Experimentally Adding Vectors
Teacher Instructions: Vector Addition with Force Table

QUESTION:

A vector is a measurement that has both magnitude (a size) and direction. In order to add two vectors together (to find the resultant vector) can you add the magnitude of the two vectors together? For example is 3N + 4 N= 7 N?

HYPOTHESIS:

We can use a force table to help us answer this question. A force is a vector that has both magnitude and direction. Typically force is measured in Newtons. In this lab, the force is applied by the weight of the masses.

1. Clamp a pulley on the 180° mark of the force table so that the white notch on the pulley exactly lines up with the 180° mark on the force table.

2. Clamp a second pulley on the 270° mark, again so that the white notch on the pulley exactly lines up with the 270° mark.

3. Make sure that the safety pin is in place and through the center of the ring at the center of the force table.

4. Add 200. grams of mass to the end of the string that goes over the pulley at the 180° mark.

5. Add 150. grams of mass to the end of the string that goes over the pulley at the 270° mark.

6. Calculate the force on each of the masses in the space provided below. Show your formula and substitution with units.

   Weight = Mass x Acceleration due to Gravity

= 200. g/(1000.g/kg) x 10 m/s^2	= 150. g/(1000.g/kg) x 10 m/s^2
= 2 N	= 1.5 N

7. The two masses apply two forces on the ring. In order to figure out the sum of these forces, we can balance them with an equillibrant. The equillibrant is the force on the ring that is equal in magnitude and opposite in direction of the sum of the two forces. Experimentally find the equillibrant by adding mass to a third pulley and finding the mass and angle combination that causes the ring to be perfectly balanced in the center of the force table.

8. Record the angle and mass of the equillibrant below.

   250 grams, 37°

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ANALYSIS:

1. What is the total force on the center ring if you add just the magnitude of the forces?
   3.5 N

2. How many grams is that? Show your calculation below including formula and substitution with units.

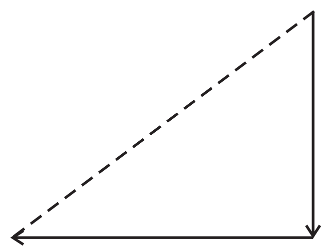
   Weight = Mass x Acceleration due to Gravity
   3.5 N = n/(1000.g/kg) x 10 m/s²
   n = 350. grams

3. Did the equillibrant equal the sum of the two initial forces? Was your hypothesis correct?
   No the equilibrant did not match the sum of the two initial forces. The equilibrant was 250 g and the sum of the two forces was 350 grams.

4. Is there any other combination of weight and angle that could balance the two initial forces?
   No, the equilibrant is the only possible weight and angle combination that can balance the two vectors.

5. Does the direction of the *equilibrant* force matter? Why or Why not?
   Yes, direction is important, only 37 degrees will be able to balance the two initial forces.

6. Draw a vector diagram to scale in the space provided below. 1cm = 0.5 N. Draw the 150 gram mass vector first and then begin drawing the 200 gram vector at the head of the first vector.



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7. Draw a dotted line from the start of the first vector to the end (head) of the second vector. This dotted line is called the resultant. Its length and direction are the sum of the two initial vectors. Measure your dotted line and then use your scale to calculate the resultant force. What is the magnitude of your resultant vector? How does the resultant vector you drew compare with the resultant vector that you found using the force table?

   The resultant vector graphically and experimentally are the same number, 3.5 N within a margin of error for this experiment.

8. Now measure the angle between the resultant vector and the first vector you drew using a protractor. What is the angle? How does this angle compare to the angle you found experimentally?

   The angle I found with my diagram is 37° and the angle I found with my experiment was also 37°, therefore both of the angles are the same. I have now successfully used two different methods to find the resultant vector.

EXTENSION OF ACTIVITY:

1. Have students graphically represent two vectors of their choice and any angles they choose. You can adjust the difficultly by limiting the chose to one dimension or having the students only use right angles as the directional separation between the two initial vectors. Have students find the magnitude of the vectors using Fg=m*g and then have them use a scale such as 1cm = 0.5 N. Have them place a piece of grid paper over top the force table and the origin should be at the center of the pin. Have students trace the direction of the two initial vectors and draw them to scale on the grid paper. Then have students find the equilibrant and trace that direction and draw the equilibrant to scale on their grid paper. Next have students mathematically find the resultant vector and compare their answers to their experimental results.

2. Have students find the equilibrant of three vectors by using the fourth pulley to balance all three forces.

   TIP: You can color one of the strings red with a magic marker in order to distinguish the initial vectors and equilibrant.

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STUDENT ACTIVITY SHEET:

Name:______________________________________ **Vector Addition with Force Table**

Date:_________________________ Partners:____________________________________

QUESTION:

A vector is a measurement that has both magnitude (a size) and direction. In order to add two vectors together (to find the resultant vector) can you add the magnitude of the two vectors together? For example is 3N + 4 N= 7 N?

We can use a force table to help us answer this question. A force is a vector in that it has both magnitude and direction. Typically force is measured in Newtons. In this lab, the force is applied by the weight of the masses.

1. Clamp a pulley on the 180° mark of the force table so that the white notch on the pulley exactly lines up with the 180° mark on the force table.

2. Clamp a second pulley on the 270° mark, again so that the white notch on the pulley exactly lines up with the 270° mark.

3. Make sure that the safety pin is in place and through the center of the ring at the center of the force table.

4. Add 200. grams of mass to the end of the string that goes over the pulley at the 180° mark.

5. Add 150. grams of mass to the end of the string that goes over the pulley at the 270° mark.

6. Calculate the force on each of the masses in the space provided below. Show your formula and substitution with units.

7. The two masses apply two forces on the ring. In order to figure out the sum of these forces, we can balance them with a resultant force. The resultant force is the force on the ring that is equal in magnitude and opposite in direction of the sum of the two forces. Experimentally find the resultant force by adding mass to a third pulley and finding the mass and angle combination that causes the ring to be perfectly balanced in the center of the force table.

8. Record the angle and mass of the resultant force below.

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ANALYSIS:

1. What is the total force on the center ring if you add just the magnitude of the forces?

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2. How many grams is that? Show your calculation below including formula and substitution with units.

3. Did the resultant force equal the sum of the two initial forces? Was your hypothesis correct?

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4. Is there any other combination of weight and angle that could balance the two initial forces?

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5. Does the direction of the resultant force matter? Why or why not?

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6. Draw a vector diagram to scale in the space provided below. 1cm = 0.5 N. Draw the 150 gram mass vector first and then begin drawing the 200 gram vector at the head of the first vector.

7. Draw a dotted line from the start of the first vector to the end (head) of the second vector. This dotted line is called the resultant. Its length and direction are the sum of the two initial vectors. Measure your dotted line and then use your scale to calculate the resultant force. What is the magnitude of your resultant vector? How does the resultant vector you drew compare with the resultant vector that you found using the force table?

8. Now measure the angle between the resultant vector and the first vector you drew using a protractor. What is the angle? How does this angle compare to the angle you found experimentally?

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TEACHER ANSWERS:

Activity 2: Maximum & Minimum Resultant of two vectors

Question: What is the maximum and minimum values of a resultant vector of two vectors whose magnitude stays the same, but whose direction can change?

1. Set up the apparatus so that the large metal ring is held in place at the top of the force table by the safety post. Arrange the pulleys so that one pulley is supporting a string attached to 150 grams of mass and the second pulley is supporting a string attached to 250 grams of mass.

2. Move the masses around to see if you can reach equilibrium at any given angle. Equilibrium is reached when the large ring is perfectly centered around the pin without touching the pin. What angle(s) make it possible for the two forces to be balanced? Justify your answer.

   No angle can balance the two forces, the 250 gram mass will always pull with more force than the 150 gram mass.

3. Add a third string supported by a pulley to the table. This string will be the resultant force. Find the resultant force experimentally and record the initial angles of all three strings as well as the mass on all three in the data table below.

4. Move the 150 gram mass/pulley system by increments of 45° around the entire table, keeping the 250 gram mass/pulley system stationary and adjusting the magnitude of the resultant force so that your recorded values are at equilibrium.

DATA TABLE:

Direction of 150 gram mass in degrees	Direction of 250 gram mass in degrees	Mass of equilibrant in grams	Direction of equilibrant in degrees
0	0	400	180
0	45	370	208
0	90	290	239
0	135	180	277
0	180	100	0
0	225	180	81
0	270	290	121
0	315	370	152
0	360	400	180

ANALYSIS:

1. What is the difference between the force applied by an object and the mass of an object? Which quantity is a vector quantity?

   The force applied by an object is a vector because it has both magnitude and direction, the mass of an object is how much stuff there is in an object and has no direction, so therefore mass is not a vector quantity.

2. How are force due to gravity and mass related?

Near the surface of Earth, mass and force due to gravity are related by the following formula: Force = mass x acceleration due to gravity (9.8 m/s^2)

3. What are your maximum and minimum equilibrant? (Express your answer in Newtons.)

*Maximum = (0.450 kg) * (9.8 m/s^2) = 4.4 N, 180°*

*Minimum = (0.100 kg) * (9.8 m/s^2) = 0.98 N, 0°*

4. For any two given vectors, the maximum resultant occurs at what angle of separation between the two vectors?

Zero degrees

5. For any two given vectors, the minimum resultant occurs at what angle of separation between the two vectors?

180 degrees

ALTERNATE METHOD:

Doing this lab using only masses and pulley to find the equilibrant will help students with skills such as measuring, trial and error and will help students conceptually understand how much a gram or a kilogram is. However, the use of force probe can also be useful. The equilibrant can be found much quicker and students can easily see where the force meter reads it's maximum and minimum values.

STUDENT ACTIVITY SHEET:
Activity 2: Maximum & Minimum resultant of two vectors

Name:_____________________________________ Maximum & Minimum Resultant

Date:________________________ Partners:___________________________________

QUESTION:

What is the maximum and minimum values of a resultant vector of two vectors whose magnitude stays the same, but whose direction can change?

1. Set up the apparatus so that the large metal ring is held in place at the top of the force table by the safety post. Arrange the pulleys so that one pulley is supporting a string attached to 150 grams of mass and the second pulley is supporting a string attached to 250 grams of mass.
2. Move the masses around to see if you can reach equilibrium at any given angle. Equilibrium is reached when the large ring is perfectly centered around the pin without touching the pin. What angle(s) make it possible for the two forces to be balanced? Justify your answer.

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3. Add a third string supported by a pulley to the table. This string will be the resultant force. Find the resultant force experimentally and record the initial angles of all three strings as well as the mass on all three in the data table below.
4. Move the 150 gram mass/pulley system by increments of 45° around the entire table, keeping the 250 gram mass/pulley system stationary and adjusting the magnitude of the resultant force so that your recorded values are at equilibrium.

DATA TABLE:

Direction of 150 gram mass in degrees	Direction of 250 gram mass in degrees	Mass of equilibrant in grams	Direction of equilibrant in degrees
0	0		
0	45		
0	90		
0	135		
0	180		
0	225		
0	270		
0	315		
0	360		

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ANALYSIS:

1. What is the difference between the force applied by an object and the mass of an object? Which quantity is a vector quantity?

2. How are force due to gravity and mass related?

3. What are your maximum and minimum equilibrant? (Express your answer in Newtons.)

4. For any two given vectors, the maximum resultant occurs at what angle of separation between the two vectors?

5. For any two given vectors, the minimum resultant occurs at what angle of separation between the two vectors?

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