VECTORS & EQUILIBRIUM
Experiment 4

INTRODUCTION:

Pictures are often more descriptive than words. In physics it is useful to represent some quantities by an arrow, called ***vector***, where the length of the arrow represents the ***magnitude***, and the head of the arrow represents the ***direction*** of the quantity. Examples of these quantities are velocity, acceleration and force. Vectors can be combined to determine their algebraic sum, called ***resultant*** vector. When the sum of all the forces acting on an object equal to zero, the object is said to be in ***equilibrium***. A state of equilibrium **does not** mean that the object is at rest. The object may be at rest, or it may be in motion.

For objects that can undergoe ***rotation***, equilibrium occurs when all the forces and ***torques*** acting on an object equal to zero. The torque produced by a force is the product of the force times the ditance it acts through (***lever arm***). Opposite torques occurring clockwise and counter clockwise can cancel each other and produce ***rotational equilibrium***.

In this experiment you will first use a force table to determine the sum of 2 different forces (vectors) acting in different directions. You will graph each force as a vector, and determine their sum, by using using the graphical "head-to-tail" method of vector addition. Then you will use a simple "moment-of-force" apparatus to study torque and rotational equilibrium. Since the acceleration of gravity is constant, mass can be used as a direct measure of force in your calculations.

APPARATUS& MATERIALS:

? Force table
? weight holders
? slotted weights
? graph paper
? ruler
? protractor
? Moment-of-force apparatus
? hooked 20-g masses
? rubber bands
? pen of unknown mass

PROCEDURE:

Part A: Addition of Vectors

Set up the force table as demonstrated in class, with the table horizontal. Place the ring on the pin at the center of the table, then adjust the pulleys so that the strings, when pulled out radially, pass over the required scale divisions. Also, remember the following points:

- ? Include the mass of the weight hanger (50 grams) in all calculations.
- ? Forces having direction >180 are assigned negative magnitudes.
- ? Check the alignment of strings on the center ring when pulleys are moved. String must “intersect” at center of ring.

1. Select 2 forces of your choice. The magnitude of the forces can be between 50 and 200 g. Each foce must be in a different quandrant, with angles 0, 90, 270 and 360 not permissable. Record information in Table 1.
2. Draw two vectors representing these forces on graph paper by choosing a scale factor, and scaling them accordingly.
3. Use the “head-to-tail” method to determine the sum (resultant) of the two vectors. Record the magnitude and angle of the resultant force in Table 1 as “Resultant, graphical”.
4. Determine the equilibrant force to the resultant by adding 180? to the direction of the resultant obtained graphically. Record in Table 1 as “Equilibrant, graphical”.
5. Set up the two forces and the equilibrant force on the force table and observe the center ring. Is the system approximately at equilibrium (balanced)? Is the ring nearly centered? If so, record the results in Table 1 as “Equilibrant, experimental”. If not, proceed to step 6.
6. Adjust the weight and the angle of the equilibrant force in order to more perfectly center the ring. Record the results after the adjustment on the Table 1 as “Equilibrant, experimental”.

Part B: Equilibrium

Set up moment-of-force apparatus as described below:

1. Attach the wooden dowel to the table-top with 2 sticker labels. About half of the length of the dowel should overlay the table-top and the other half should extend past the edge of the table-top. (See Fig. 1)

2. Attach the book-end clip to the ruler so that the center of the clip is at the center of the ruler. Be sure the centimeter scale is facing upwards(See Fig. 2)

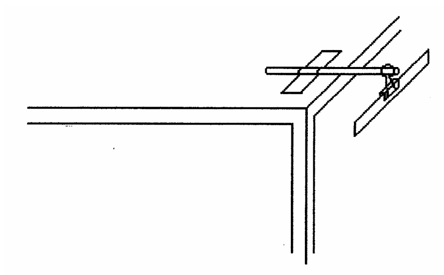


Figure 1

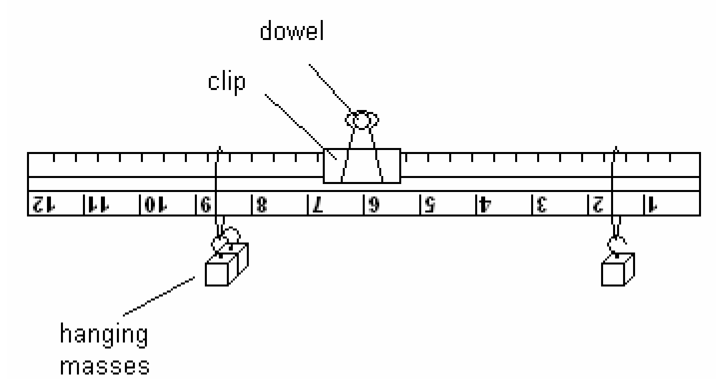


Figure 2

3. Suspend the clip with the attached ruler from the extended portion of the dowel by inserting the dowel through the metal handles of the clip. The ruler should be free to swivel about the dowel at this point. (See Fig. 1)

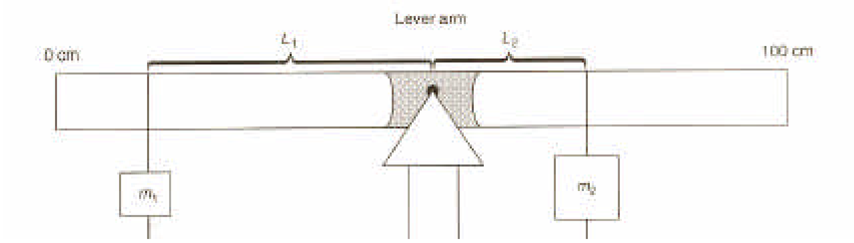
4. Using a rubber band, attach a 20-g hooked mass to the ruler at the 9-cm mark, as shown in Fig. 2.

5. Attach another 20-g mass to another rubber band and slide along the other end of the ruler. Move this mass and rubber band along the ruler, until balance occurs. Keep the 1st mass at the 9-cm mark while positioning the 2nd mass. Note the position of the second mass.

6. Attach a second 20-g mass to the first side (9-cm position), and slide the second mass on the opposite side till the system balances again. Record the positions determined in Table 2.

7. Determine the lever arm distance for each mass, as shown below, and record in Table 2.

   NOTE: Lever arm is the distance from the pivot point to the position of the hanging masses (L_1 and L_2 in the diagram below).



8. Remove all the masses, and attach a 20-g mass at the 12-cm mark on the ruler. Attach the pen eclosed with your kit to a rubber band, and slide along the opposite side of the ruler until the system balances. Record the positions and lever arms determined in Table 2.

CALCULATIONS:

1. Find the product of each mass and its lever arm for trials 1 and 2. This value is analogous to the torque produced by each mass, and can be used accordingly. Record calculations in Table 3.

Note: For the ruler to balance, the torques on each side must be approximately equal. If they are not, check your calculations and measurements carefully before proceeding further. See the instructor for any assistance.

2. Since the torques on each side must equal for balance, we can use the relationship shown below to calculate the mass of the pen.

$$(\text{mass x lever arm})_{left} = (\text{mass x lever arm})_{right}$$

$$m_1 \text{ x } L_1 = m_2 \text{ x } L_2$$

3. Determine the mass of the pen on a balance, and calculate the percent error between the measured and the calculated masses.

REPORT FORM
Experiment 4

TABLE 1

Scale Factor__________

FORCE 1	g	cm	degrees
FORCE 2	g	cm	degrees
RESULTANT (graphical)	g	cm	degrees
EQUILIBRANT (graphical)	g		degrees
EQUILIBRANT (experiemtal)	g		degrees

TABLE 2

	Counter clockwise (Left)			**Clockwise (Right)**		
Trial	**Mass** (g)	**Position** (cm)	**Lever Arm** (cm)	**Mass** (g)	**Position** (cm)	**Lever Arm** (cm)
1	**20**			**20**		
2	**40**			**20**		
3	**20**			**???**		

TABLE 3

Tria l	Quantity	Answer	Show calculations here
1	**Counter-clockwise torque**		
	Clockwise torque		
2	**Counter-clockwise torque**		
	Clockwise torque		
3	**Mass of pen** (calculated)		
	Mass of pen (measured)		
	Percent Error		

QUESTIONS:

1. What is equilibrium? Give an example of equilibrium you might encounter in your everyday life.

2. Explain why equilibrium could not be obtained if all forces were between 0? and 180?.

3. In Part B, what relationship exists between the clockwise and counter clockwise torques for each trial?

4. A 45-kg girl is sitting on one end of a see-saw, 0.6 m away from the pivot point. How far away from the pivot point must a 60-kg boy sit on the other side, in order for the see-saw to be balanced? Show all your calculations.