Experiment: The Force Table

Purpose

1. Study the equilibrium conditions $\Sigma\overrightarrow{F_i} = \vec{0}$ using the force table for the balance measurement of concurrent forces.

2. Study the equilibrium conditions of the resultant force $\Sigma\overrightarrow{F_i} = \vec{0}$ and the moment of the resultant force $\Sigma\vec{\tau} = \vec{0}$ using the force table for the balance measurement of non-concurrent forces.

Theory

1. Equilibrium of concurrent forces in a plane

When the forces act through the same point on an object, the vector addition and the acceleration are zero, so the forces are in equilibrium

Therefore,

$$\sum_{i=1}^{n}\overrightarrow{F_i} = \vec{0}$$

It's the equilibrium condition of concurrent forces

1. n=3

When three forces are in equilibrium in a plane as shown in Figure 1 (A) $\vec{F_1} + \vec{F_2} + \vec{F_3} = \vec{0}$. We know that the three forces form a closed triangle from Figure 2 (B). According to the sine law, the condition of the three-force equilibrium can be expressed as below:

$$\frac{F_1}{\sin\phi_{23}} = \frac{F_2}{\sin\phi_{31}} = \frac{F_3}{\sin\phi_{12}}$$

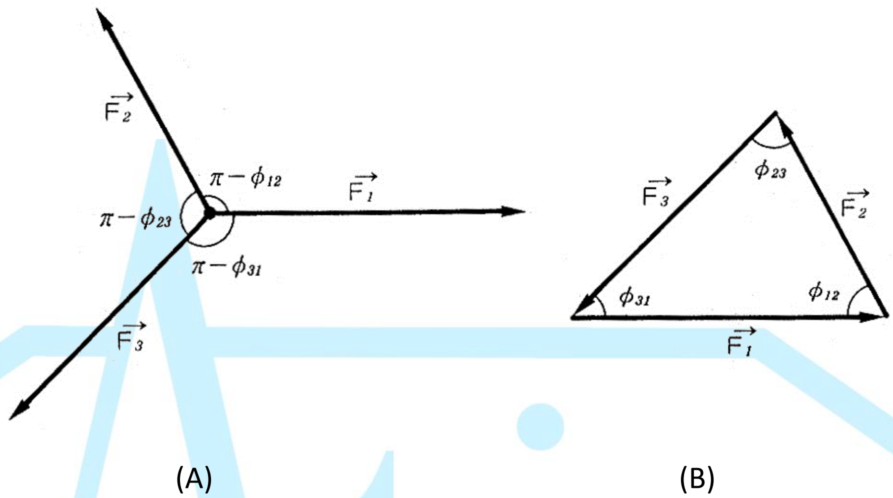


Figure 1

The other expression of the condition is to decompose the components of x and y directions, the equilibrium condition of forces can be written as below:

$$\Sigma F_{ix} = 0 \;;\; \Sigma F_{iy} = 0$$

2. n=4

When four forces are in equilibrium in a plane $\vec{F_1} + \vec{F_2} + \vec{F_3} + \vec{F_4} = \vec{0}$, form a closed quadrangle. If the forces are decomposed into components of Cartesian coordinate system. The four-force equilibrium should satisfy the equations below:

$$F_{1x} + F_{2x} + F_{3x} + F_{4x} = 0$$
$$F_{1y} + F_{2y} + F_{3y} + F_{4y} = 0$$

2. **Equilibrium of non-concurrent forces in a plane**

When the forces act through the different points on an object, if the object stays stationary, the resultant of forces and the addition of moments are zero. So mathematically it should be written as

$$\Sigma\overrightarrow{F_i}=\vec{0}\ ;\ \Sigma\vec{\tau}=\vec{\ell_1}\times\vec{F_1}+\vec{\ell_2}\times\vec{F_2}+\vec{\ell_3}\times\vec{F_3}+\vec{\ell_4}\times\vec{F_4}=\vec{0}$$

ℓ : The vertical distance from the fulcrum to each force.

In this experiment, we use the force table (Figure 3) to do two experiments for studying the balance conditions of concurrent forces and non-concurrent forces.

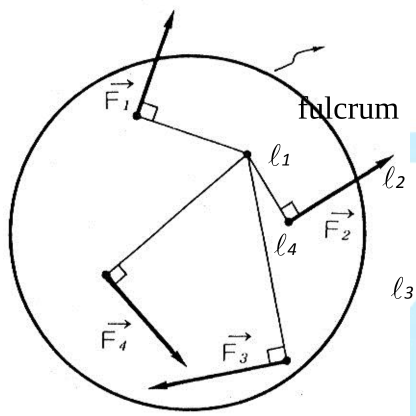


Figure 2
Non-concurrent Forces In Equilibrium

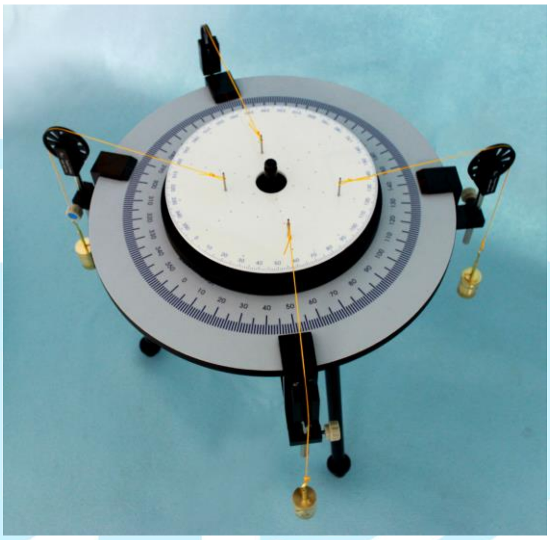
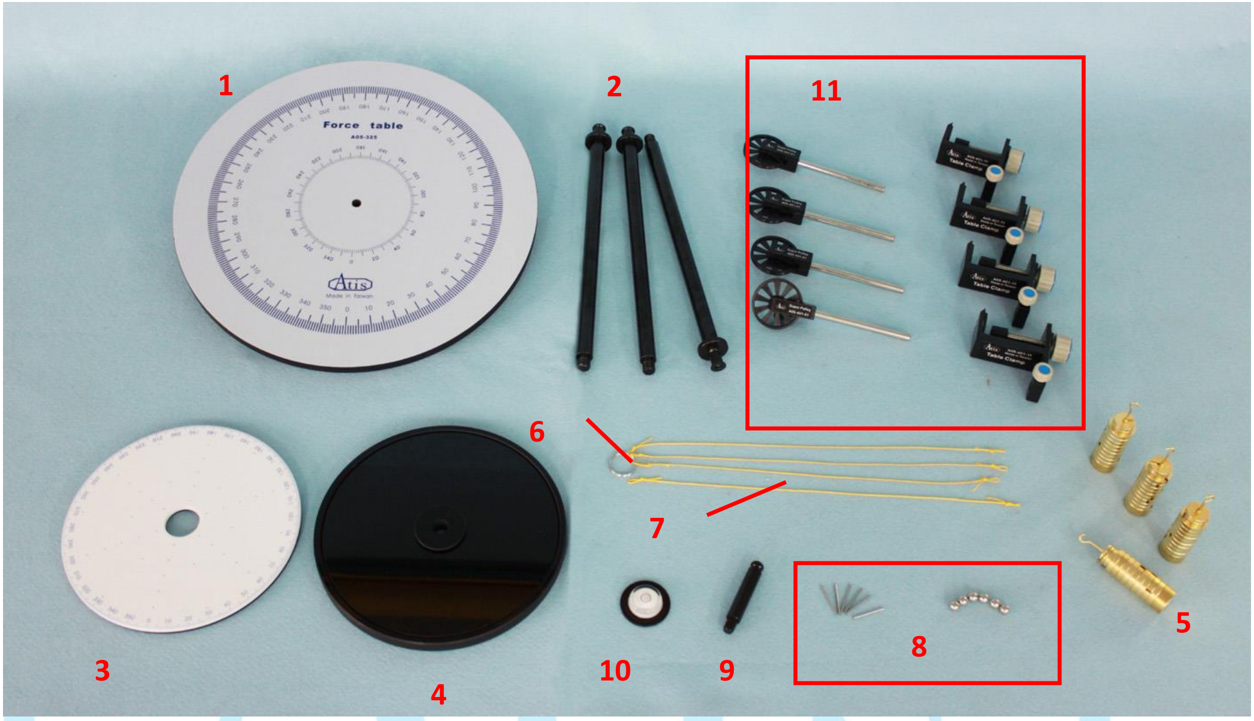


Figure 3
Force Table

Instrument

NO	Accessory	Qty	NO	Accessory	Qty
1	Force Table	1	2	Support Rod	3
3	Non-concurrent Force Disc (printed angle scale)	1	4	Non-concurrent Force Disk	1
5	Weight	4	6	Concurrent Force String	1

7	Non-concurrent Force String	1	8	Plugx6 and steel ballx6	12
9	Center Column	1	10	Level	1
11	Table Pulley with Clip	4			



Procedure

A. Equilibrium of three concurrent forces in a plane

1. Adjust the adjustable feet under the table to make it horizontal; and set the center column in the center of the table. (Use the level to adjust the horizon)

2. Set the three pulleys on the side of the table as shown in Figure 4.

Figure 4

Figure 5

3. Put the ring on the center column, and connect the three strings to the ring. Then, put the weight hanger and some appropriate weights on two hangers as shown in Figure 5. The ring will turn to the direction of the resultant force of the two forces.

4. Adjust the position and the weight of the third pulley till the ring is in static equilibrium as shown in Figure 6.

Figure 6

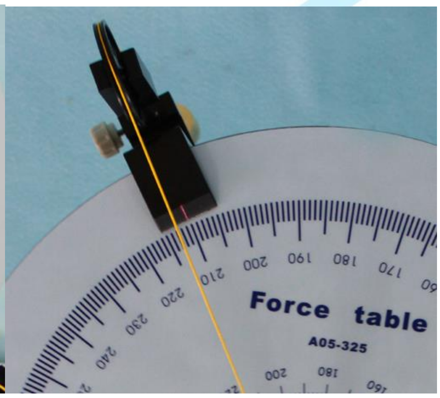


Figure 7

5. Write down the weights and the angle of the three strings on the disc as shown in

Figure 7.

6. Draw a diagram of the vectors of the three forces and check if the three forces form a closed triangle.

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7. Check if the three forces and the angles satisfy the sine law.

8. Draw the direction of the forces and measure the angle of each force with the x-axis to calculate the values of ΣF_{ix} and ΣF_{iy}, and check if the result satisfies the conditions of $\Sigma F_{ix} = 0$ and $\Sigma F_{iy} = 0$.

9. Put another pulley on the disc and repeat procedure 3 to 5 and do the experiment of four-force equilibrium. Draw the diagram and check if they form a closed quadrangle and repeat procedure 8 to confirm if the result satisfies the conditions of $\Sigma F_{ix} = 0$ and $\Sigma F_{iy} = 0$.

Figure 8

B. Equilibrium of three non-concurrent forces in a plane

In this part of the experiment, we use the acrylic disc as the force-taken object.
The steps as follow:
1. Put the center column through the disk and place four to six steel balls on, in order to reduce the friction as shown in Figure 9. Set the built-in scale disc on the top of the

steel balls. The holes on the disc are used for the plug as the point where the forces act on as shown in Figure 10.

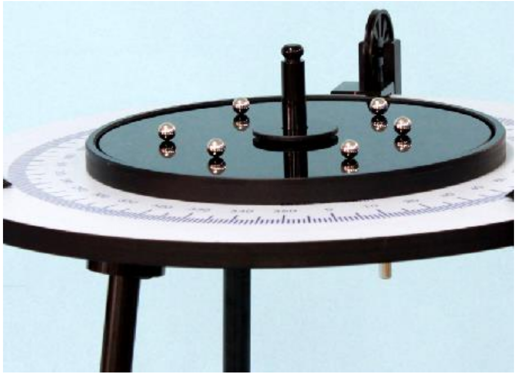

Figure 9

Figure 10

2. Fix three table pulleys on the side of the table.
3. Tie each end of the strings to the weight hanger and put it across the pulley. Then, tie it to the plug as shown in Figure 11.

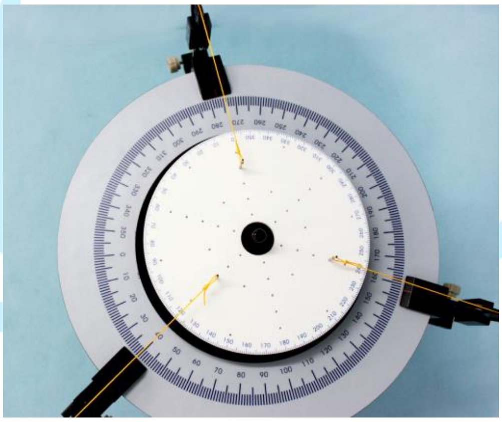

Figure 11

Figure 12

4. Put the appropriate weights on two hangers

5. Adjust the position and the weight of the third pulley, so that the disc still remains stationary, and the center of the force table coincide with the center of the disc as shown in Figure 12.

6. Draw the line of action of the force to represent the direction and magnitude of the

force.

7. Take any point as a fulcrum to draw the vertical line from the fulcrum to each line of force on the experimental paper as shown in Figure 13.

8. Draw the vector addition of the three forces, and check if it is zero.

9. Calculate the moment between each force and the fulcrum, and check if the moment addition $\Sigma\tau$ is zero.

10. Set the other pulley and appropriate weights, and repeat step 4 to 9 to do the four-force static equilibrium. (Put appropriate weights on three hangers at step 4)

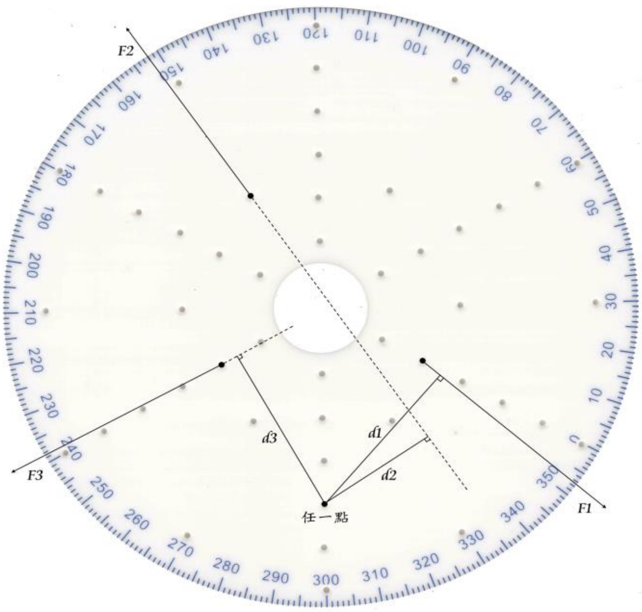

Figure 13

Experimental Record

1. Concurrent force: Equilibrium of three forces

	F_i	θ_i	F_x	F_y
1				

2				
3				
		Force addition of the components		
		ΣF		

F_i ：Force

θ_i ：Angle of F_i

F_x ： Horizontal component of F_i， $F_x = F_i \times \cos\theta_i$

F_y ： Vertical component of F_i， $F_y = F_i \times \sin\theta_i$

ΣF ： Resultant force， $\Sigma F = \sqrt{F_x^{\ 2} + F_y^{\ 2}}$

2. Concurrent force: Equilibrium of four forces

	F_i	θ_i	F_x	F_y
1				
2				
3				
4				