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General Physics Lab

Basic Mechanical Experiment

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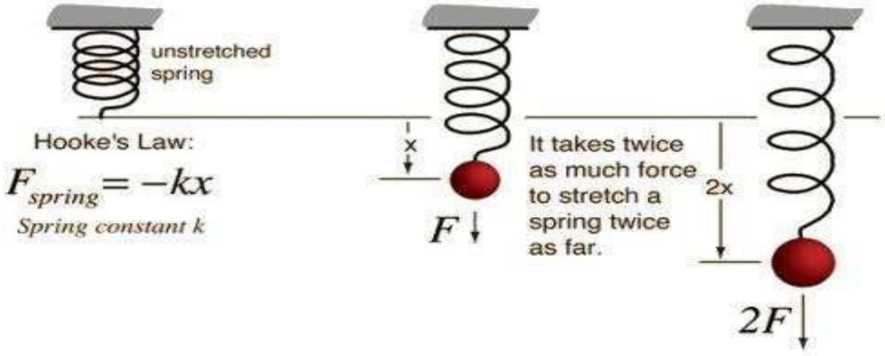
Purpose

The purpose of this report was to determine the relationship between applied force to a spring and the displacement in the spring through which it is stretched (Hook's Law). Also, it was to observe the phenomenon that, number of forces acting at a point in a plane balances each other and observe the balance condition when the rigid body is working under a number of torques. After the observations we had to verify the principle of conservation of mechanical energy and verify the relationship between friction and normal force of the contact surface, and find the sliding friction coefficient of the contact surface.

Introduction

Hooke's Law is a principle of physics that states that the force needed to extend or compress a spring by some distance is proportional to that distance. This can be mathematically expessed as $F= -kx$, where F is the force applied to the spring, x is the distance by which spring is displaced from its equilibrium position and k is the spring constant($k = -F/x$). The negative sign indicates that the restoring force is opposite to the direction of the displacement of the mass. When a mass is attached to the free end of the spring then its length increases by small amount ΔL. Therefore the length of spring is $L + \Delta L$ from the spring's support. The following is an example showing the relationship between force and distance when applied to a spring



Materials/methods

When there are three or four forces working in a horizontal plane at the same point, the total force acting on that point is zero. We used two methods by doing two experiment to get the total forces; one was the Graphical method while other was the Analysis Method.

A. Graphic Method

1. Use appropriate scale and protractor; draw these forces of equal length in three different directions as shown in figure 1 below. Length of the vector represents the magnitude of the force and arrows indicate the direction of it.
2. Draw a force on a paper as a standard force. Then, use the same proportion to draw second and third force. If your experiment is accurate then you can get the total forces should be zero.

$$\bar{F} = \bar{F}_1 + \bar{F}_2 + \bar{F}_3$$

3. If the total forces is not zero，calculate the experimental error as

$$\sigma_F = \frac{|\vec{F}|}{\frac{1}{n}\left[\sum_{i=1}^{n}|\vec{F}_i|\right]}$$

is the experimental value of total forces by graphical method；

$$|\vec{F}| = \left|\sum_{i=1}^{n}\vec{F}_i\right|$$

$\frac{1}{n}\left[\sum_{i=1}^{n}|\vec{F}_i|\right]$,is the average value for the force.

The following is an example of the Graphical method:

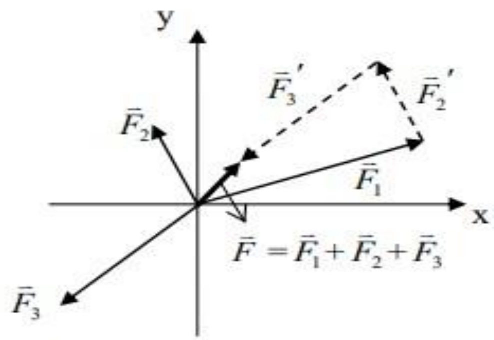


Figure1. Graphical method

B. Analysis Method

If you present the force in Cartesian coordinate system by (Fi ,θi)，then

$$F_x = \sum_i F_{ix} = \sum F_i \cos\theta_i$$

$$F_y = \sum_i F_{iy} = \sum F_i \sin\theta_i$$

Therefore magnitude of the total force is given by

$$|\vec{F}| = \sqrt{(F_x^{\,2} + F_y^{\,2})}$$ acting in a direction as: $$\theta = \tan^{-1}\frac{F_y}{F_x}$$

If your experiment is accurate then you can get the total force to be zero.
And the deviation in measuring the force be：

$$\sigma_F = \frac{|\vec{F}|}{\frac{1}{n}\left[\sum_{i=1}^{n}|\vec{F}_i|\right]}$$

$$|\vec{F}| = \sqrt{(F_x^{\,2} + F_y^{\,2})}$$

,is the experimental value of total forces by analysis method and

$$\frac{1}{n}\left[\sum_{i=1}^{n}|\vec{F}_i|\right]$$

is the average value for the force.

2. Torque balance

Consider an object rotating around a point O in a plane as shown in Figure 2. A force F acting on that object at point P， which is at a distance of OP resented by the vector r and making an angle θ with r

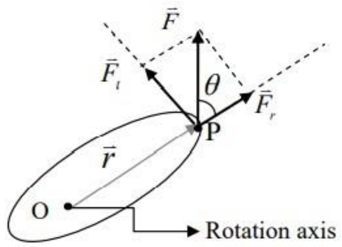


Figure 2. Rotation

τ can be defined as the tendency to produce a change in rotational motion and is given by,

$$\bar{\tau} = \vec{r} \times \vec{F}$$
$$\bar{\tau} = |\vec{r}| \cdot |\vec{F}| \cdot \sin\theta = rF_t$$

When an object is at equilibrium then, the total force is zero: $\sum_i \vec{F}_i = 0$ and the total torque is zero: $\sum_i \bar{\tau}_i = 0$

When number of forces acing on a rigid body reach to equilibrium value then object will not move and rotate i.e. the total force and torque acting on a body is zero.

C. Analysis Method:

1. Use appropriate scale and protractor to draw the size and direction of the three forces. Length represents the magnitude and arrows indicate the direction along which force is acting. Then you can get three forces

2. Find the fixed point P and draw a force arm which is looking for each force viz as shown in figure 3.

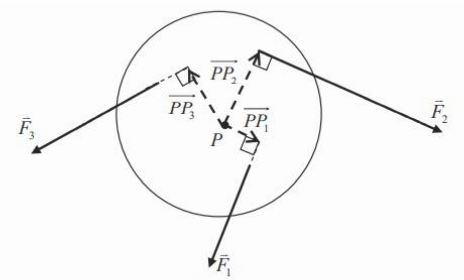


Figure 3.

3.Then torque is given by $\bar{\tau}_i = \overrightarrow{PP_i} \times \bar{F}_i$ and the direction can be decided by the right hand rule.

Calculate the value of the total torque $|\bar{\tau}| = \left|\sum_{i=1}^{n} \bar{\tau}_i\right|$ if your experiment is accurate then you can get the total forces should be zero.

4. If the total torque is not zero, calculate the experimental error.

And the deviation in the measurement is $\sigma_\tau = \dfrac{|\bar{\tau}|}{\frac{1}{n}\left[\sum_{i=1}^{n} |\bar{\tau}_i|\right]}$

$$|\bar{\tau}| = \left|\sum_{i=1}^{n} \bar{\tau}_i\right|$$ Where, is the experimental value of total torque and

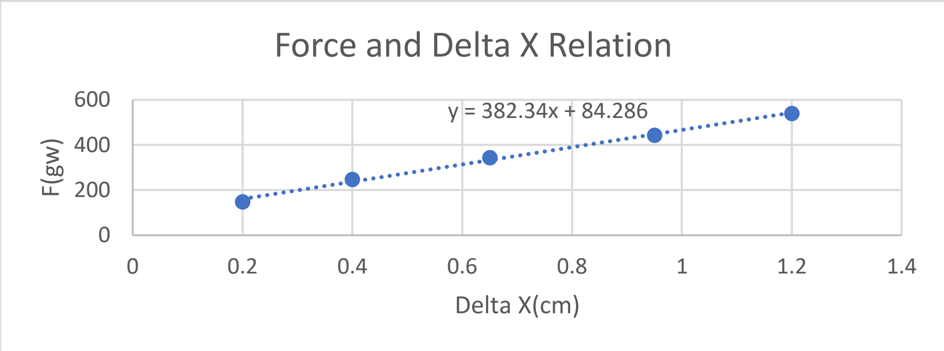
is $$\frac{1}{n}\left[\sum_{i=1}^{n} |\bar{\tau}_i|\right]$$ the average value for the torque.

The materials that were used included Magnetic plane plate, rolling cylinder, pulley, ramp slide, spring, wood, weight set, weight lifting racks, ruler.

Results

Hooke's Law

exp1	Mass(g	△X(cm	Force(g
1	9.93	0.2	97.314
2	20.01	0.4	196.098
3	29.92	0.65	293.216
4	40	0.95	392
5	49.89	1.2	488.922



The balance of Forces

exp2	Mass(g)	△X(cm)	Angle(°)	F(gw)	Fx	Fy	θ	|F|	σ(%)
F1	45.08		0	441.784	441.784	0	30.19299609	83.55314593	29%
F2	25.11		146	246.078	-204.0079078	137.6050713			
F3		0.5	210	191.17	-165.5580764	-95.585			
				293.0106667	72.21801578	42.0200713			

Torque and Equilibrium

exp3	Mass(g)	r(cm)	Zi(gw*cm)	|Zi|(gw*cm)	error(%
F1	70	0.22	150.92		8.07%
F2	40	0.78	305.76		
F3	20	0.48	94.08		

Discussion

Hooke Law

As the force has increased the stretch of the spring also increases, this is to support the formula F=kx. The results presented indicate that the relationship between displacement and force does exist. These aims were proved to be correct and accurate as in hook's law experiment a graph was used to find the constant value of K, which was later used in experiment two (The balance of forces) as the mass value for the F3.

Torque and Equilibrium

The aim was to observe the principle of torque and equilibrium when three masses were hung vertically and needed to all reach a point of equilibrium. All the three masses balanced and reached a stage of equilibrium. The torque of the masses was calculated using the formula: force * displacement. The average torque and total torque were calculated and the % error on the torque was also calculated using the formula: % error = t total/t average. The absolute function was used to make the answer positive. The error was found to be 8.07%.

The balance of Forces

The constant K was used as the mass of F3. Their displacement when hanged from the spring was also recorded and their forces were calculated using the formula: F = mg, with the constant 9.80 N/kg used as the value of g for the gravity. The angles of F1, F2, and F3 were measured and recorded with the zero scales placed on F1. The % error of the force was then calculated using the formula: % error = (F total)/F average. The error was found to be 4% which was not a bad result but needed improvement.

According to the experimental data of the previous item Compared with the experimental principle, the number of discussions According to the results, the physical meaning.

Conclusion

In conclusion, the experiment demonstrated commendable execution, benefiting from adequate equipment and a notable reduction in errors. To enhance the process, consider conducting it in a controlled environment with fewer participants and increased spatial freedom. Emphasizing a thorough understanding of the electric note before commencement could further minimize errors and contribute to the attainment of reliable, precise results. Ultimately, the pursuit of accuracy remains paramount in optimizing the experiment's outcomes.

Reference

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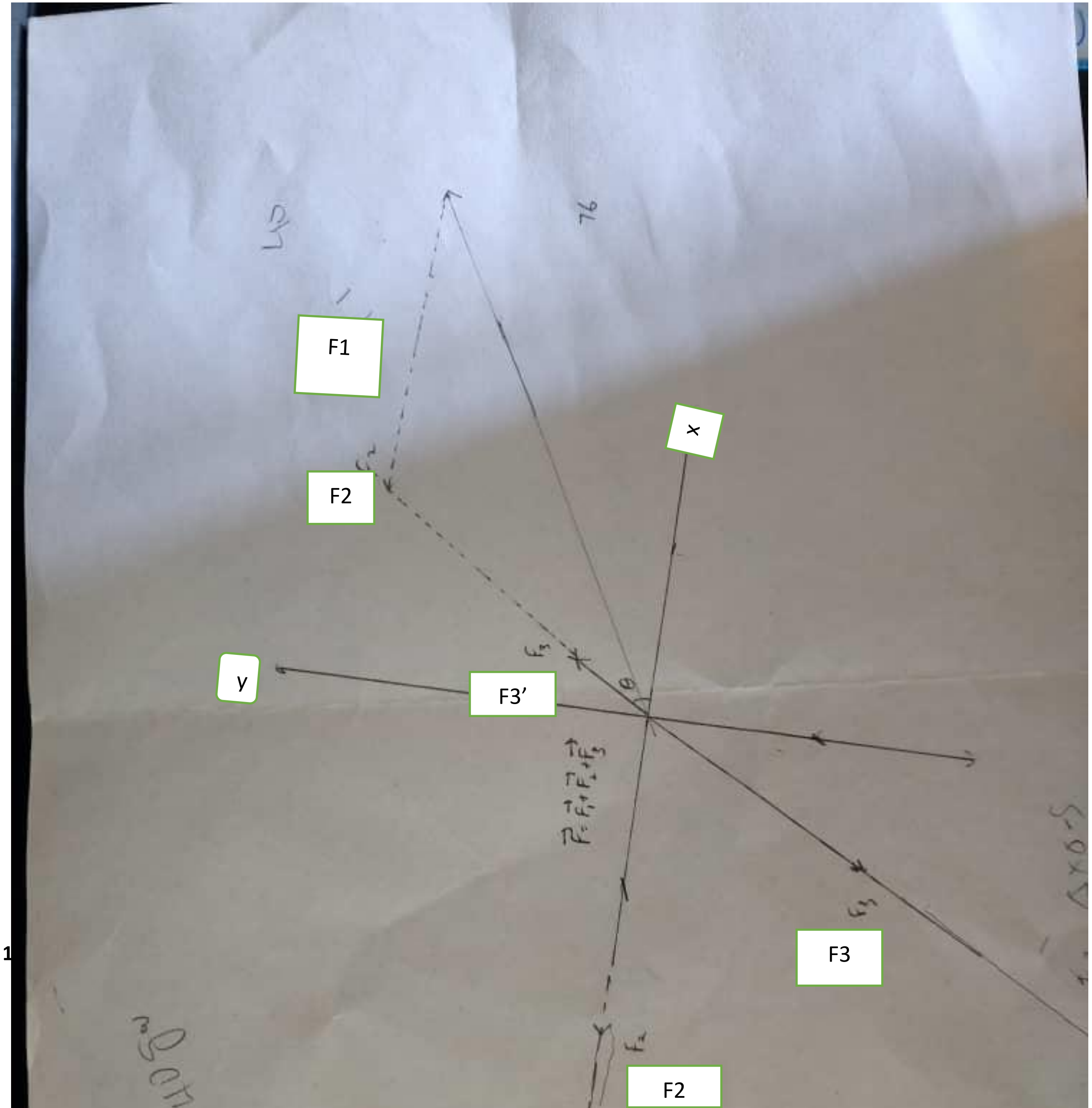

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