Experiment: Centripetal Force System Kit

Purpose

In this experiment, we study the relationship among centripetal force *F*, mass *m*, radius *r* and speed *w* rotating in uniform circular motion.

Theory

Uniform circular motion is the motion of an object in a circle at a constant speed. As an object moves in a circle, it is constantly changing its direction and moving tangent to the circle. The direction of acceleration *a* is toward to the center of the circle. The equation of the relationship among the magnitude, velocity *v* and radius *r* shown in equation (1)

$$a = \frac{v^2}{r} \qquad (1)$$

By Newton's Second Law of Motion, a racially inward net force - F_c is called centripetal force. The direction of the acceleration *a* and F_c are toward the center of the circle. The relationship among the magnitude, mass *m*, the rotating period *T*, the radius *r* and the angular velocity *w* shown in equation (2).

$$F = \frac{mv^2}{r} = mr\omega^2 \qquad (2)$$

In the equation, tangential speed $v = \omega r$ is given by the period T

$$v = \frac{2\pi \cdot r}{T} = \omega r \qquad (3)$$

From equation (2) and (3), we obtain the equation (4) of F and T

$$F = \frac{4\pi^2 mr}{T^2} \qquad (4)$$

We experientially change the value of physical quantities of mass m, radius r and centripetal force F to do different sorts of uniform circular motion. We measure the period T rotating in different experimental conditions to study the relationship among centripetal force F, mass m, radius r and speed w.

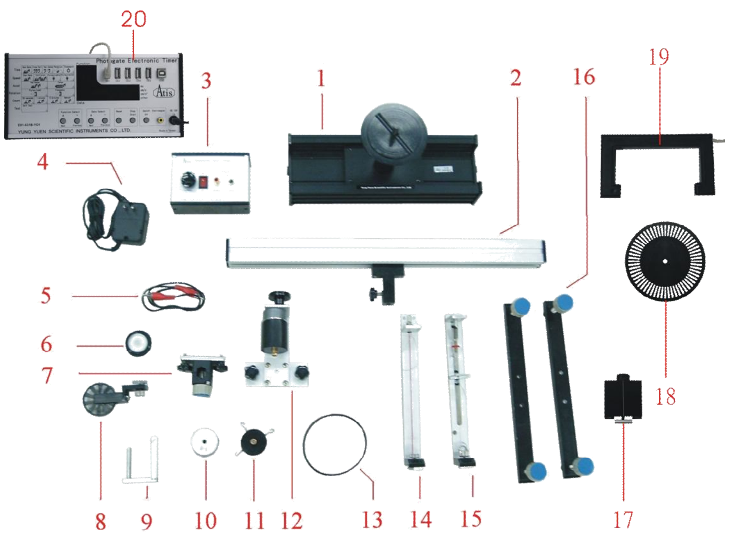
***Calculate the value of rotating period T and centripetal force Ft in different conditions-**

A. When centripetal force F_i and mass m are default values- change the value of radius r

B. When radius r and mass m are default values –change the value of centripetal force F_i

C. When centripetal force F_i and radius r are default values -change the value of mass m

Instrument



NO	Accessory	Quantity
1	Centripetal force Base	1
2	Aluminum Platform Scale	1
3	Speed Regulator	1
4	DC Power Supply (9V)	1
5	AV Connection Cable	2
6	Level Indicator	1
7	Movable Connector (B)	1
8	Pulley	8
9	L-shaped Weight Holder 25g	1
10	Weight 10g	1
11	Rotating Body 100g	1
12	DC Motor	1
13	Drive Belt	1
14	Rotating Body Hanger	1
15	Centripetal force Indicator	1
16	Adjustable Feet	2
17	Balance Weight	1
18	60-grid Fence	1
19	Photogate	1
20	Photogate Electronic Timer	1

Procedure

1. As shown in Figure 2. Set up the accessories of the instrument. Connect the photogate to the timer and the motor to the DC port input.

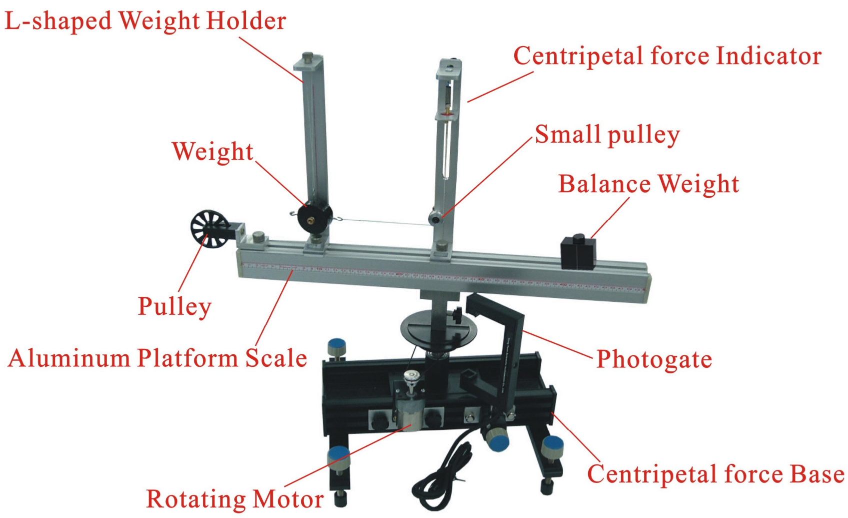


Figure 2

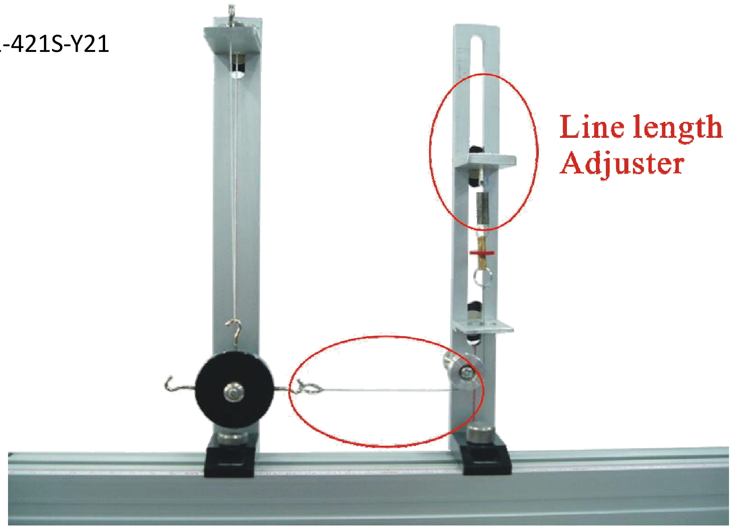
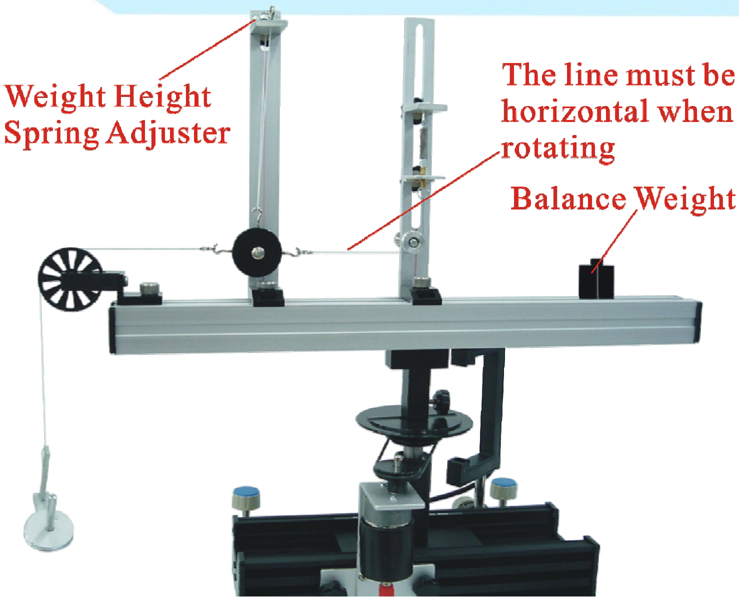


Figure 3

2. According to the built-in scale on the platform, we can adjust the distance between the rotating body and the centripetal force indicator. The distance is the radius *r*. Then, adjust the weight height to let the weight hang down naturally. Put the balance weight in position, and don't tie the line between the indicator and the pulley too tight as shown in Figure 3.

※ Place the weights on the relative position between the rotating body hanger and centripetal force indicator.

3. Connect the L-shaped weight holder to the rotating by the pulley. Then, start with a 10g weight and plus 25g of the L-shaped weight holder to obtain the total mass 35g as the default value of centripetal force F_i . And the net mass of rotating body is 100g. In addition, make sure that the line among the small pulley, the weight and the pulley is horizontal as shown in Figure 4.



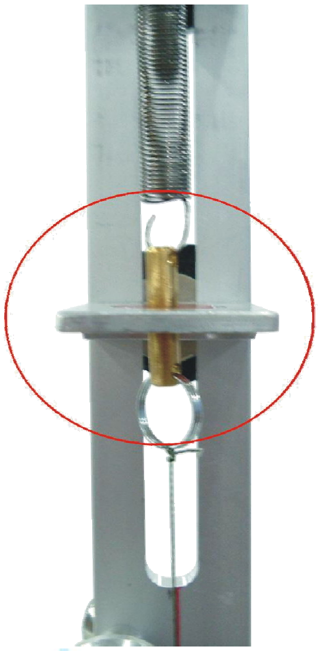
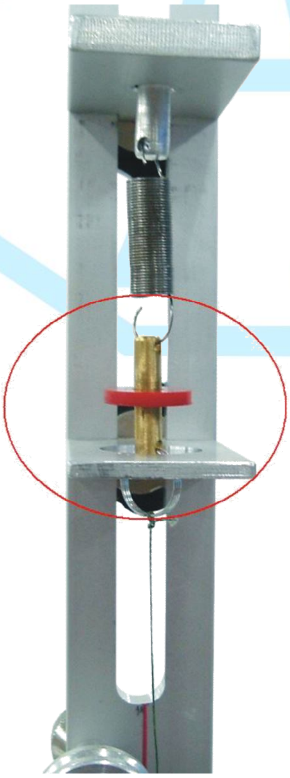


Figure 4

Figure 5

4. Adjust the red index (putting a 10g weight) in order to overlap the indicator. The elongation caused by the default value (35g) as shown in Figure 5.

5. The red index moves upward after setting up the indicator and removing the weight holder and the pulley. Switch the motor on and adjust the speed as shown in Figure 7.



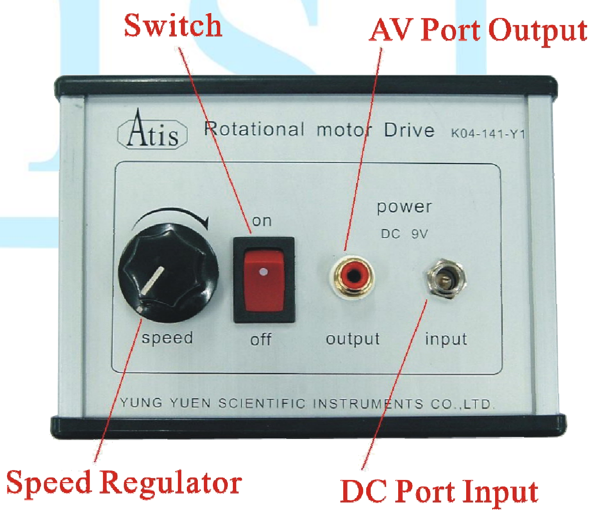


Figure 6

Figure 7

6. When rotating, the red index moves downward because of centripetal force. Make the red index overlap the indicator by adjusting the speed as shown in Figure 5.

When the two objects overlap, it means centripetal force equals the default setting weight (weight and weight bracket).

※CAUTION! Pay attention to the rotating instrument when observing the red index. Be careful not to be hit by the instrument.

※Before starting the experiment, let the motor run a few minutes to warm up, so the experimental results will be more accurate.

7. Adjust the speed and record the data of rotating period *T*.

※ first, press ‘Mode 8' and then press 'Reset' to start the experiment. Divide the data by 6.

8. Substitute mass *m*, rotating period *T* and radius *r* into the equation (4) to obtain the value of centripetal force. Compare the value with F_i.

※ NOTE: We use a 60-grid fence in this experiment, so the rotating period T should be divided by 6 as the value we want. Digital computer software has automatically modified, so don’t change the computer displayed values.

Experimental Record

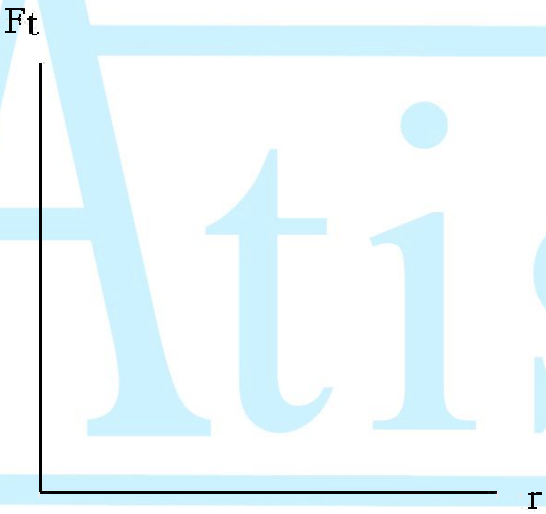
$$F = \frac{4\pi^2 mr}{T^2}$$

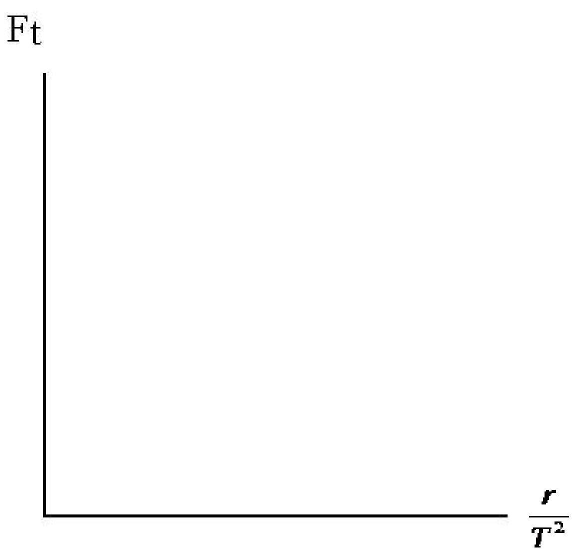
※ NOTE: The unit of Ft is N (Newton). When comparing Ft with F_i, remember to do the unit conversion.

1N=102.04g

1. Set up the default values of m and F_i, change the value of radius r to obtain rotating period *T*, so that we can calculate the experimental value F_t to observe the relationship between F_t and *r*.

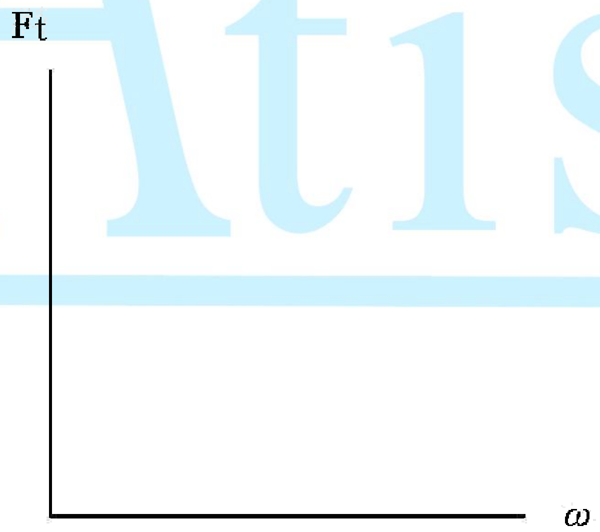
Mass m	Default value of centripetal force (total weight) F_i	Radius r	Rotating Period T	Inverse ratio of radius and square of rotating period $\frac{r}{T^2}$	Experimental Value F_t	Error $\frac{F_t - F_i}{F_i}\times 100\%$





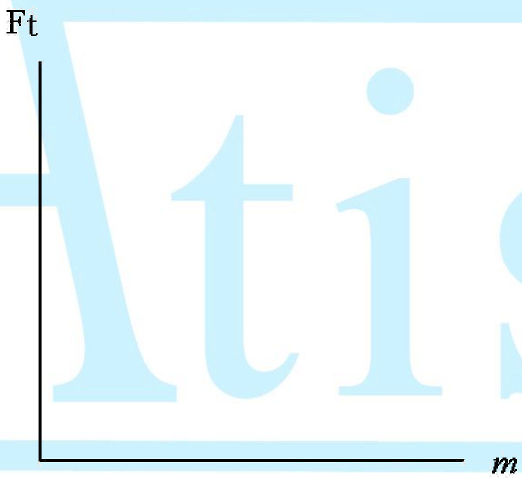
2. Set up the default values of m and r, change the value of F_i. to observe the relationship among F_t, T and ω.

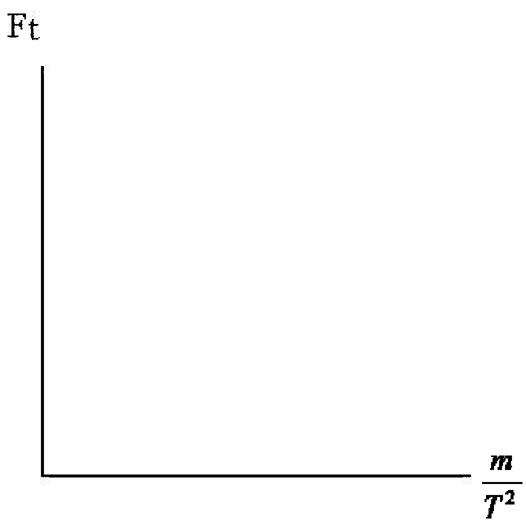
Mass m	Radius r	Default value of centripetal force (total weight) F_i	Rotating period T	Angular velocity $\omega = \frac{2\pi r}{T}$	Experimental value F_t	Error $\frac{F_t - F_i}{F_i} \times 100\%$



3. Set up the default values of m and F_i, change the value of m to observe the relationship among F_t, and m.

Radius r	Default value of centripetal force (total weight) F_i	Mass m	Rotating period T	Inverse ratio of mass and square of rotating period $\frac{m}{T^2}$	Experimental value F_t	Error $\frac{F_t - F_i}{F_i} \times 100\%$





Questions and Discussions

1. What causes the errors?
2. Is the centripetal force getting bigger or smaller when the rotating body is farther away from the center of the circle?
3. Is the centripetal force getting bigger or smaller when the mass of the rotating body is bigger?
4. Is the centripetal force getting bigger or smaller when the rotating speed is faster?

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