南京邮电大学

Nanjing University of Post & Telecom

物理实验教学中心

Physics Expeiment Center

Torsional pendulum

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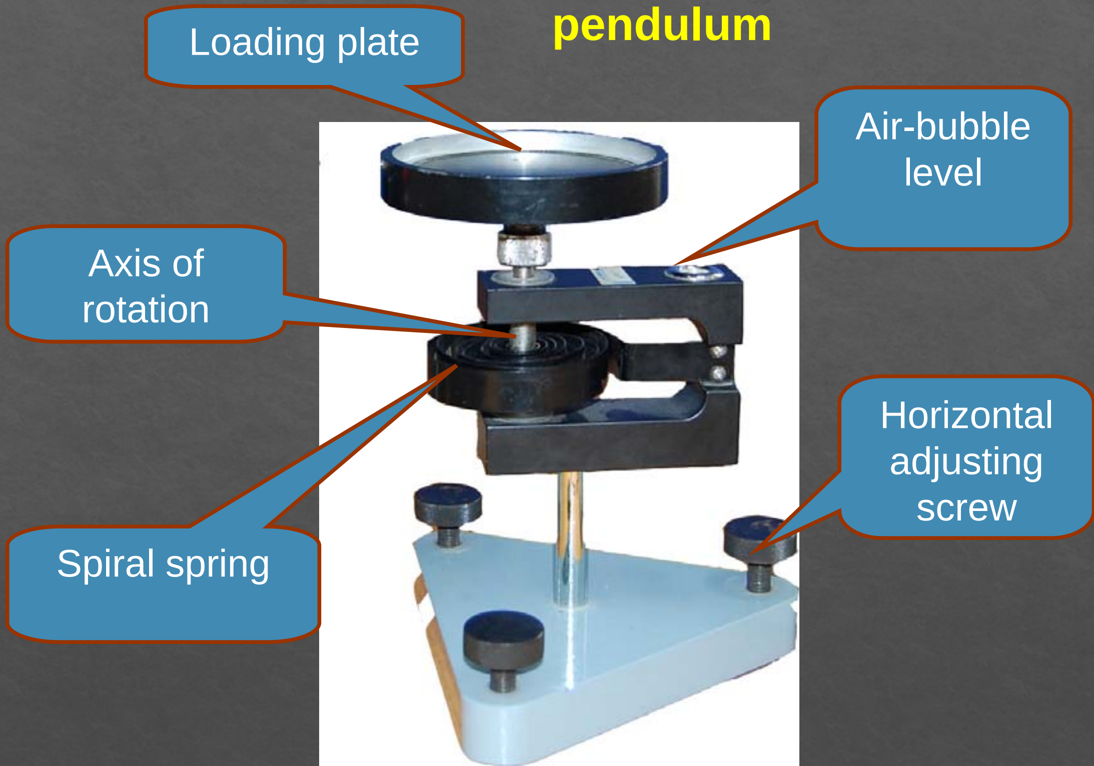
Experimental Purposes:

1. Determination of the **torsional constant** K of spiral spring using torsion pendulum;

2. Determination of the **rotational inertia** of different objects with a torsion pendulum, and compared with the theoretical value;

3. Verification of the **parallel axis theorem**.

Structure of torsional pendulum



Principles

1. Rotational inertia: I

2. Torsional pendulum

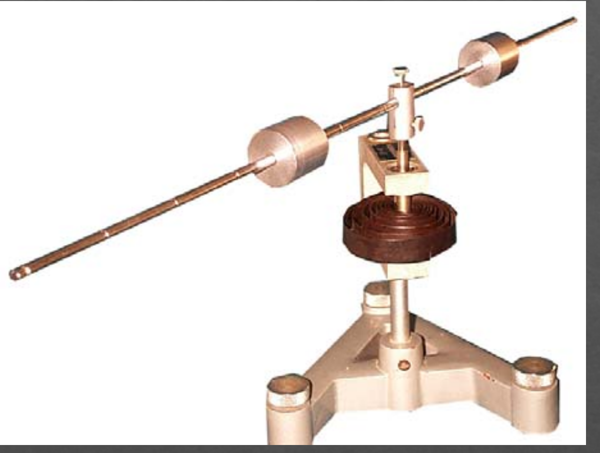
When the object is turned in a horizontal plane at a certain angle θ, the spring restoring moment M：

$M = -K^* \theta$ K is the torsional constant .

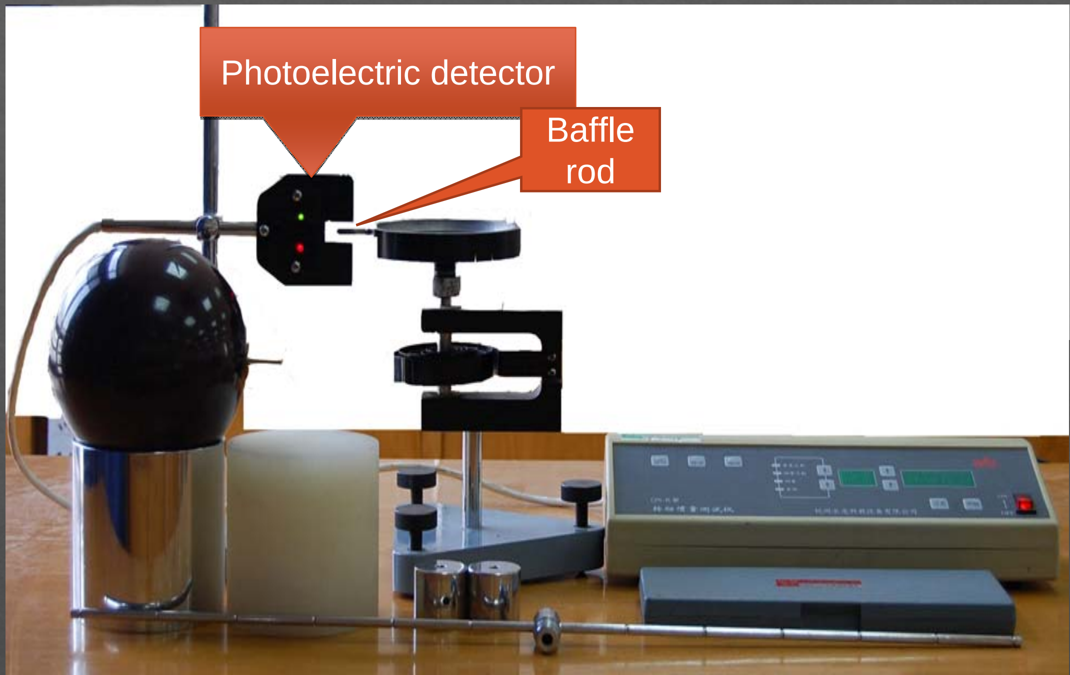
And we also know that : $M = I * \beta$,
where $\beta = d^2\theta/dt^2 = -K^*\theta/I = -\omega^{2*}\theta$,
the vibration period **$T = 2\pi/\omega = 2\pi(I/K)^{1/2}$**

3. Parallel axis theorem

$$I_c = I_0 + mx^2$$



Instruments:



A hollow metal cylinder, a solid plastic cylinder, a metal rod, and two small metal cylinders

Instrument panel

Adjustment and use：

1. Horizontal adjustment using air-bubble level;

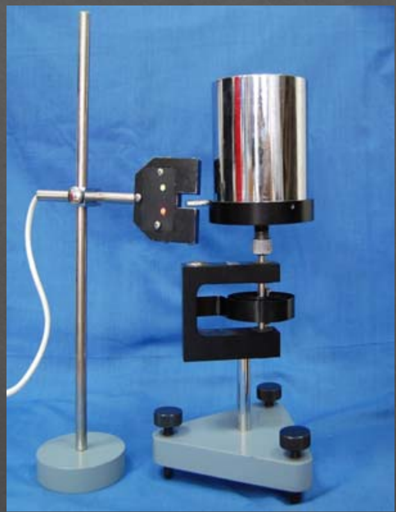
2. Baffle rod can cover the infrared emitting and receiving hole of the photoelectric detector.

3. Swing angle should be between 40 - 90 degrees.

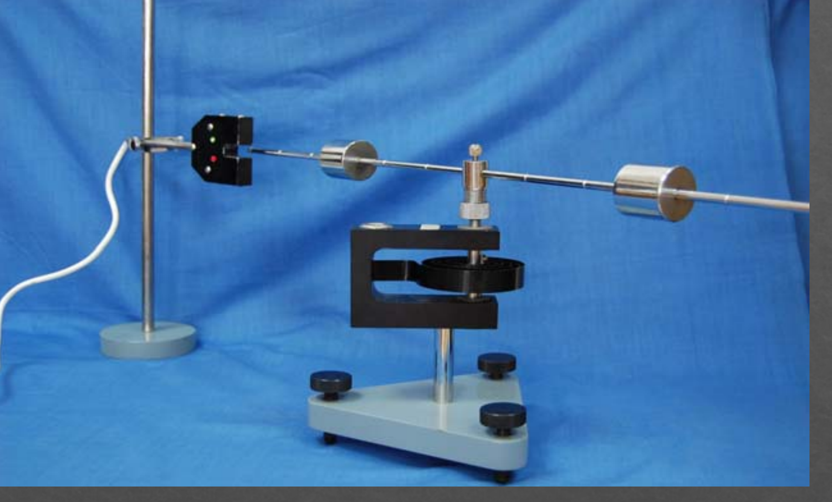
Steps：

1. Determine the vibration periods (10T) of the loading plate and with cylindrical, calculate the torsion constant K；

2. Determine the vibration periods (10T) of the hollow metal cylinder and the mental rod.



3. Verification of the parallel axis theorem；



4. Other measurements：
Electronic balance-----mass,
Tape-----length of the mental rod,
Vernier caliper-----Inside and outside diameters.

Post-processing：

1.Calculate K;

2.Calculate the experimental and theoretical rotational inertia I_{exp} and I_{theo}，

3.Calculate the percentage error η:

$$\eta = |I_{exp} - I_{theo}| / I_{theo} * 100\%$$

Rotational inertia: $k = 4\pi^2 \dfrac{I_1'}{\bar{T}_1^2 - \bar{T}_0^2} = \_\_\_\_\ \mathrm{kg \cdot m^2 \cdot s^{-2}}$

Mass of small metal cylinder: $m = \_\_\_\_\ g$

Geometry of small metal cylinder:

$$D_\mathrm{o} = \_\_\_\_\ \mathrm{mm},\ D_\mathrm{i} = \_\_\_\_\ \mathrm{mm};\ \text{Height}\ L_1 = \_\_\_\_\ \mathrm{mm}。$$

Table I. Rotational inertia

Object	Mass/kg	Geometry		Period		I_{theo} /(kg · m²)	I_{exp} /(kg · m²)	Percentage error
Plate	/	/		$10T/s$		/	$\left(I_0 = \dfrac{I_1'\bar{T}_0^2}{\bar{T}_1^2 - \bar{T}_0^2}\right)$	/
				$\bar{T}_0/s$				
Plastic cylinder		D_1/mm		$10T/s$		$\left(I_1' = \dfrac{1}{8} m \bar{D}_1^2\right)$	$\left(I_1 = \dfrac{K\bar{T}_1^2}{4\pi^2} - I_0\right)$	
		$\bar{D}_1/mm$		$\bar{T}_1/s$				
Hollow cylinder		D_{out}/mm		$10T_2/s$		$\left[I_2' = \dfrac{1}{8} m(\bar{D}_{out}^2 + \bar{D}_{in}^2)\right]$	$\left(I_2 = \dfrac{K\bar{T}_2^2}{4\pi^2} - I_0\right)$	
		$\bar{D}_{out}/mm$						
		D_{in}/mm						
		$\bar{D}_{in}/mm$		$\bar{T}_2/s$				
Metal rod		L/mm		$10T_4/s$		$\left(I_4' = \dfrac{1}{12} m L^2\right)$	$\left(I_4 = \dfrac{K}{4\pi^2}\bar{T}_4^2\right)$	
				$\bar{T}_4/s$				

Table II. Verification of the parallel axis theorem

Position $x/10^{-2}$ m	5.00	10.00	15.00	20.00	25.00
10 periods $10T/s$					
Period $\bar{T}/s$					
Exp. value/$kg \cdot m^2$ $I = \frac{k}{4\pi^2}\bar{T}^2$					
Theo. value/$kg \cdot m^2$ $I' = I_4' + 2mx^2 + I_5'$					
percentage error					

$$I_5' = 2\left[\frac{1}{16}m(D_o^2 + D_i^2) + \frac{1}{12}mL_1^2\right]$$

END