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# General Properties of Matter Lab
# PH29001

## EXPERIMENT-3

## Moment of Inertia of a Flywheel

**Aim:** Determination of Moment of Inertial of a Flywheel about its own axis of rotation.

**Apparatus:** The flywheel, weights, thread, stop-watch, slide callipers and metre scale.

**Theory**: Let $h$ be the distance fallen through by the mass before the string leaves the axle and the mass drops off, and let $v$ and $\omega$ be the linear velocity of the mass and angular velocity of the flywheel respectively at the instant the mass drops off. As the mass descends a distance $h$, it loses potential energy $mgh$ via the following three routes

i) Providing kinetic energy of translation $\frac{1}{2}mv^2$ to the falling mass

ii) Giving kinetic energy of rotation $\frac{1}{2}I\omega^2$ to the flywheel (where I is the moment of inertia of the flywheel about the axis of rotation)

iii) in doing work against friction.

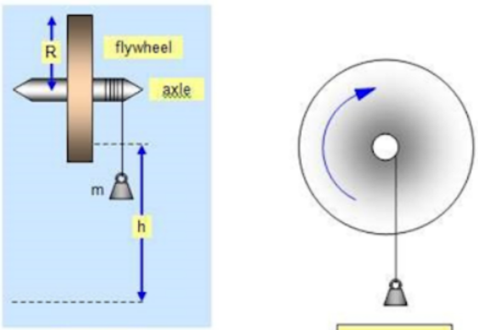



Figure 1 Figure 2

Fig: Hanging Flywheel

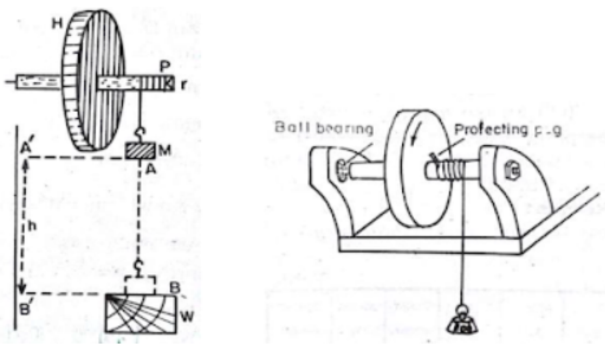



Fig: Experimental setup

If the work done against friction is steady and F per turn, and, if the number of rotation made by the flywheel till the mass detaches is equal to $n_1$, the work done against friction is equal to $n_1F$.

$$mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 + n_1F \quad \text{.................................} (1)$$

After the mass has detached the flywheel continues to rotate for a time t before it is brought to rest by friction. If it makes $n_2$ rotations in this time, the work done against friction is equal to $n_2F$ and evidently it is equal to the kinetic energy of the flywheel at the instant the mass drops off. Thus-

$$n_2F = \frac{1}{2}I\omega^2$$

$$\therefore mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 + \frac{n_1}{n_2}\frac{1}{2}I\omega^2 \quad \text{...........................} (2)$$

If $r$ is the radius of the flywheel $v = r\,\omega$

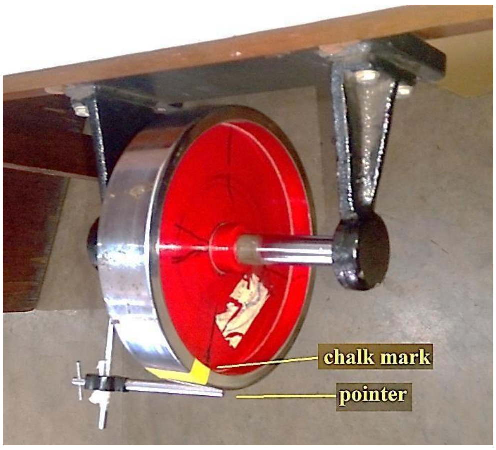
Substituting v in equation (2), and simplifying we have,

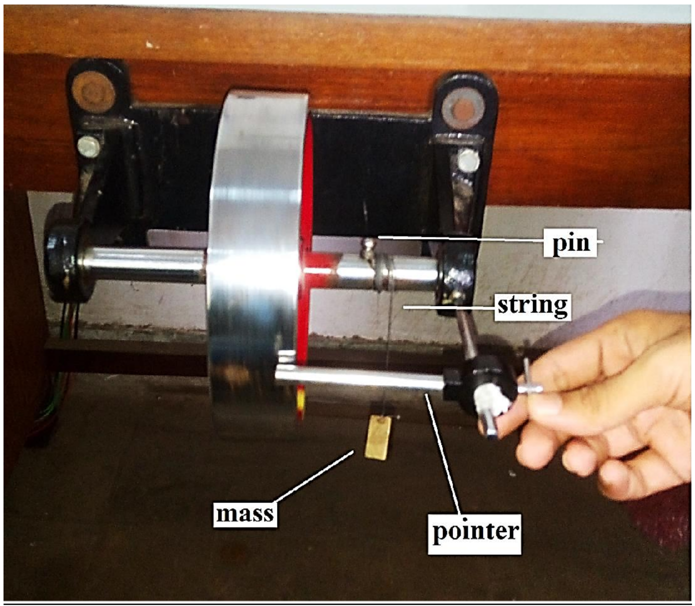
$$I = \frac{m\left(\frac{2gh}{\omega^2} - r^2\right)}{1 + \frac{n_1}{n_2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

After the mass has detached, the angular velocity of the flywheel decreases on account of friction and after some time $t$, the flywheel finally comes to rest. At the time of detachment of the mass the angular velocity of the wheel is ω and when it comes to rest its angular velocity is zero.

Assuming force of friction is steady, the motion of the flywheel is uniformly retarded till it comes to rest and the angular velocity during the interval can be approximated to (ω+0)/2 = ω/2. In one complete rotation the angular displacement is $2\pi$ radians.

Thus, $\frac{\omega}{2} = \frac{2\pi n_2}{t}$ $or, \omega = \frac{4\pi n_2}{t}$




## Observations:

Least Count of Meter Scale = 0.1cm and temperature of the laboratory while taking the measuring the values of the parameters = 30°C

1. Vernier Constant = **0.01cm** and least count of stopwatch **Δt** = **0.01s**
2. Radius of the axle, **r = 1 cm = 0.01m**
3. Circumference of the wheel, **S= 61 (cm)**
4. Mass m=**59.9gm = 0.0599kg**
5. Height, **h=0.50m**
6. Number of turns wound on the wheel, $\mathbf{n_1}$**= 8**
7. Finding $n_2$

**Table-1-**

For $n_2$; for mass, m=59.9gm

| Sl. No. | No. observations made by the wheel = x | Distance of chalk mark from the pointer = d (cm) | Fraction of revolution = d/circumference = d/S = y | Actual no. of revolutions $n_2$ = x+y | Time = t (sec.) |
|---|---|---|---|---|---|
| 1 | 8 | 31 | 0.5082 | 8.5082 | 24.66 |
| 2 | 8 | 0 | 0 | 8.0000 | 24.43 |
| 3 | 8 | 50.5 | 0.8279 | 8.8279 | 27.16 |
| 4 | 9 | 12.9 | 0.2115 | 9.2115 | 27.72 |

**Calculations-**

Mean $n_2$ = 8.6369 = (8.5082 + 8 + 8.8279 + 9.2115)/4 ≈ 8.64

Mean time t = (24.66 + 24.43 + 27.16 + 27.72 )/4 = 25.99 seconds

Average $\omega = 4\pi n_2 / t = \dfrac{4\pi \cdot 8.6369}{25.99} = 4.17389 \approx 4.18\, rad/sec$

$$I = \frac{m\left(\frac{2gh}{\omega^2} - r^2\right)}{1 + \frac{n_1}{n_2}}.$$

$$I = \frac{0.0599 \cdot \left(\frac{2g \cdot 0.5}{4.18^2} - 0.01^2\right)}{1 + \frac{8}{8.64}} = 0.017459279 \approx 0.0175\, kg - m^2$$

Therefore, the moment of inertia of a flywheel is 0.0175 kg-$m^2$.

**Error Analysis-**

$$\frac{\Delta I}{I} = \frac{\Delta m}{m} + \frac{\Delta r}{r} + \frac{2\Delta t}{t}$$

$$\frac{\Delta I}{I} = \frac{0.1}{59.9} + \frac{0.01}{1} + \frac{2(0.01)}{25.99} = 0.012438975$$

$$\Delta I = I \times 0.012438975 = 2.176820769 \times 10^{-4} kg - m^2 \approx 2.177 \times 10^{-4} kg - m^2$$

Therefore, the maximum percentage error in moment of Inertia of a flywheel is 1.24%.

**Result-**

1. The moment of inertia of flywheel is 0.0175 $\pm$ 0.0002177 kg-$m^2$
2. the maximum percentage error in moment of Inertia of a flywheel is 1.24%.

**Precautions-**

1. There should be the least friction in the flywheel.
2. A number of rotation n and time t is to be unwired correctly.
3. The length of the string should be less than the height of axle from the floor. The load should not rest on floor, it should hang freely.
4. Height 'h' is to be measured from the mark on the axle and it is to be measured correctly.
5. There should be no kink in string and string should be thin and should be wound evenly.
6. The stopwatch should be started just after detaching the loaded string. When using the stop-watch, the hand should be held straightly to minimize the reaction time error.
7. To reduce statistical error in measurements, at least 3-5 readings must be taken.
8. It's a good practise to note down the temperature of the laboratory although moment of inertia does not vary with slight variation in temperature.
9. Zero error must be noted in the measuring instruments.
10. Parallax and back-lash errors during measurement must be avoided.

**Discussions-**

1. From the experiment, the moment of inertia of flywheel has been studies thoroughly and the results are in dependency of mass and radius of the wheel.