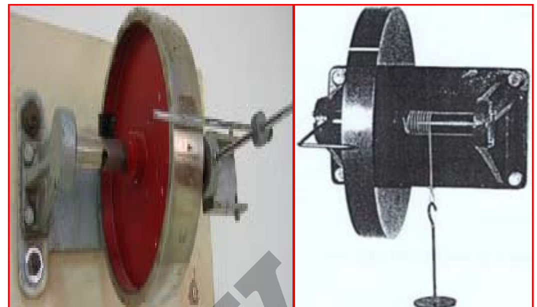
Moment of inertia of a Flywheel

OBJECT: To determine the moment of inertia of a flywheel about its own axis of rotation.

Apparatus used: Flywheel, a few masses, a strong and thin string, stop watch, vernier callipers.

Formula used: The moment of inertia of a flywheel is given by following formula:



$$I = \frac{2mgh - mr^2\omega^2}{\omega^2\left(1+\frac{n_1}{n_2}\right)} = \frac{\frac{2mgh}{\omega^2} - mr^2}{\left(1+\frac{n_1}{n_2}\right)}$$

$$Since \quad \omega = 2\times\frac{2\pi n_2}{t} \; and \; h = 2\pi r n_1$$

$$I = \frac{\frac{2mg(2\pi r n_1)t^2}{(4\pi n_2)^2} - mr^2}{\left(1+\frac{n_1}{n_2}\right)}$$

$$\boxed{I = \frac{mr\left(\frac{gt^2 n_1}{4\pi n_2^2} - r\right)}{\left(1+\frac{n_1}{n_2}\right)}}$$

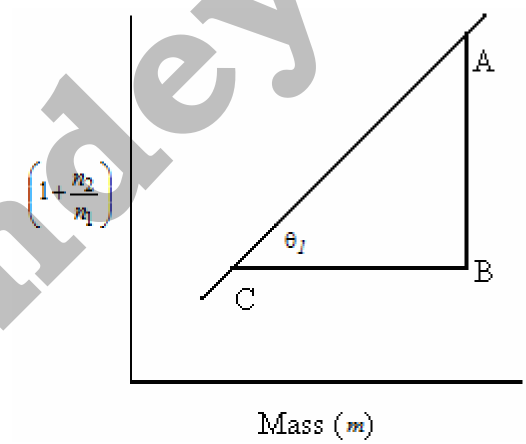
$$Since \quad \frac{gt^2 n_1}{4\pi n_2^2} >> r$$

$$I = \frac{mrgt^2 n_1}{4\pi n_2^2\left(1+\frac{n_1}{n_2}\right)} = \frac{m g r t^2}{4\pi n_2\left(1+\frac{n_2}{n_1}\right)}$$

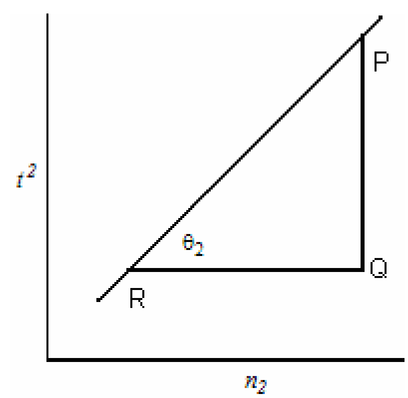
$$\boxed{I = \frac{g r}{4\pi}\frac{m}{\left(1+\frac{n_2}{n_1}\right)}\frac{t^2}{n_2} = \frac{g r}{4\pi} K C}$$

Where $K = m\Big/\left(1+\frac{n_2}{n_1}\right)$; $C = t^2/n_2$;

g = gravitational acceleration.
r = radius of flywheel axis.
m = mass suspended through string / thread.
n_1 = Number of turns of string wrapped on axis.
n_2 = Number of oscillation up to flywheel stopped after detaching the mass.
t = time of oscillation up to flywheel stopped after detaching the mass.



$$\tan\theta_1 = \frac{1}{K} = \frac{\left(1+\frac{n_2}{n_1}\right)}{m} = \frac{AB}{BC}$$



$$\tan\theta_2 = C = \frac{t^2}{n_2} = \frac{PQ}{QR}$$

Procedure:

1. Measure the diameter of the axle with vernier calipers at different points and find the mean.
2. Attach the mass with string.
3. Wrap the string or thread axle of flywheel for allotted number of turns (n_1=4 or 6 or 8).
4. Allow to fall the mass.
5. After fall of the mass, note the number of oscillation of flywheel (n_2) and corresponding time (t_2) till the flywheel stopped.
6. Repeat procedure from 2-5 at fixed n_1 for different masses (e.g. m=100, 150, 200, 250, 300gm)
7. Draw the graphs between mass (m) and $(1+\frac{n_2}{n_1})$ and between n_2 and t^2. The graph should be separate for each n_1.

Observation:

A. For radius of axle

$$Least\ count\ of\ vernier\ callipers = \frac{value\ of\ one\ division\ on\ main\ scale}{Number\ of\ division\ on\ vernier\ scale} = ...cm$$

Sr. No.	Main scale reading	Vernier scale reading	Total
1			
2			
3			
4			
5			

Diameter of axle (D=Mean of Total = ……………………………………

Radius of axle (*r=D/2*) = ………………………………………………

B. For n_2 and t

Sr. no.	n_1	m	n_2	t	$1+\frac{n_2}{n_1}$	t^2
1						
2						
3						
4						
5						

Calculation:

The moment of inertia can be calculated with following formula:

$$I = \frac{g\,r}{4\pi} K\,C = \frac{g\,r}{4\pi}\frac{\tan\theta_2}{\tan\theta_1}$$

Least count error: $\frac{\Delta I}{I} = \left\{\frac{\Delta r}{r} + 2\frac{\Delta t}{t}\right\} \Rightarrow \frac{\Delta I}{I} x100 = \left\{\frac{\Delta r}{r} + 2\frac{\Delta t}{t}\right\} x100$

Result:

The moment of inertia of fly wheel is …………….. ± …………..(unit).

Precautions:

1. There should be least friction in flywheel.
2. The length of string should be less than the height of axle from floor.
3. There should be no kink in string.
4. The string should be thin and should be wound evenly.
5. The stop watch should be started just after detaching the loaded string.