To determine the moment of inertia using Flywheel

AIM: To determine the moment of inertia of the flywheel.

APPARATUS REQUIRED: A flywheel, different masses, a mass provided with a hook, a strong and thin cotton string, a metre rod, a vernier calliper and a piece of chalk.

THEORY: A string whose one end is fixed to a small peg on the axle, is wrapped round the axle and carries weight Mg at its other end. The length of the string is adjusted so that it gets detached from axle as soon as the bottom of the mass M is just to touch the floor. Thus, from the principle of conservation of energy, decrease in PE of mass = K.E of mass + KE of flywheel + work done against friction.

$$\text{KE of mass} = \frac{1}{2}Mv^2 = \frac{1}{2}M(r\omega)^2 = \frac{1}{2}Mr^2\omega^2$$

$$\text{KE of flywheel} = \frac{1}{2}I\omega^2$$

Total energy used to overcome friction = nF

Hence $Mgh = \frac{1}{2}Mr^2\omega^2 + \frac{1}{2}I\omega^2 + nF$

where v is linear velocity and

$$I = \frac{2Mgh}{\left(\frac{4\pi n_1}{t}\right)^2\left(1+\frac{n}{n_1}\right)} - \frac{Mr^2}{\left(1+\frac{n}{n_1}\right)}$$

PROCEDURE: (1) Take a strong and thin string whose length is less than the height of the axle from the floor. Make a loose loop at its one end and slip it on the peg P, on the axle of the flywheel. Tie a suitable mass, M, to the other end of the string. Note the position of the lower surface of mass M on a scale fixed behind on the wall as at B.

(2) Now rotate the wheel and wrap the string round the axle evenly, with no overlapping.

(3) Stop rotating when the mass M is slightly below the rim of the wheel and the chalk mark is again opposite to the pointer M. Again note the position of the lower surface of the mass on the scale at B.

(4) Count the number of turns wound round the axle and let it be n. The wheel will thus make n rotations before the thread is detached.

(5) Hold the stop-watch and allow the mass to descend. As soon as the sound of weight striking the ground is heard. Start the stop-watch. Count the no. of revolutions n, made by the wheel before coming to rest and note the time t taken for purpose.

(6) Repeat the process for the same height and mass, making the wheel rotate and in opposite direction.

(7) Repeat the experiment with two more different masses.

(8) Measure the diameter of the axle in two mutually perpendicular directions with a veriner callipers and determine mean radius.

RESULT : Moment of inertia of flywheel about its axle = 2.15×10^5 gcm^2

PRECAUTIONS AND SOURCES OF ERROR :

(1) There should be least possible friction in the flywheel. Oil the axle is required.

(2) The length of the string should be just less than the height of the axle from the floor.

(3) The loop slipped over the peg should be loose enough to be detached easily.

(4) The flywheel should start on its own without any push given to it.

(5) The timing ~~and~~ counting of rotations should start from the instant the weight goes off the peg.

(6) The diameter of the axle should be determined in two manually perpendicular directions.

(7) String should be thin and should be wound evenly.

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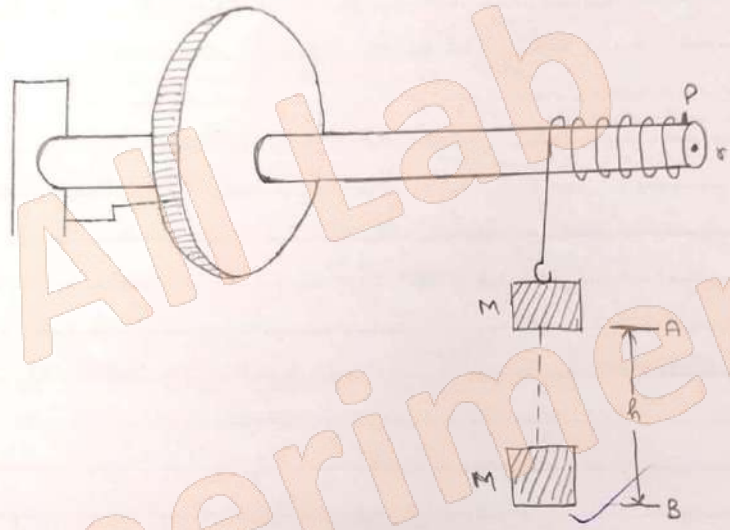
DIAGRAM :



FORMULA USED :

To calculate moment of inertia of flywheel,

$$I = \frac{2Mgh}{\left(\frac{4\pi n_1}{t}\right)^2\left(1+\frac{n}{n_1}\right)} - \frac{Mr^2}{\left(1+\frac{n}{n_1}\right)}$$

OBSERVATIONS :

Vernier constant of the callipres = 0.01 cm

Diameter of the axle = (i) 2.03 cm

(ii) 2.03 cm

(iii) 2.03 cm

Mean diameter of the axle = 2.03 cm

Radius of the axle, r = 1.015 cm

Least count of stop-watch = 0.01 sec

Fixing $n = 10$

S.No	Rotation	mass (g)	H (cm)	n_1	t (sec)	mean (n_1)	mean t (sec)	I (gcm^2)
1. (i)	Anticlock	300	67.5	183	162.56	184.5	167.155	1.94×10^5
(ii)	Anticlock	300	67.5	186	171.75			
(iii)	Clockwise	300	67.5	99	106.34	97.5	102.465	2.51×10^5
(iv)	clockwise	300	67.5	96	98.59			
2. (i)	Anticlock	200	67.5	123	130.85	124.5	129.925	1.68×10^5
(ii)	Anticlock	200	67.5	126	129.00			
(iii)	Clockwise	200	67.5	69	93.35	65	84.8	2.47×10^5
(iv)	clockwise	200	67.5	61	76.25			

Table for diameter of axle:

S.No	MSR	VSD	VSR	TR
1.	2	3	0.03	2.03
2.	2	3	0.03	2.03
3.	2	3	0.03	2.03

Radius of axle $= \frac{d}{2} = \frac{2.03}{2} = 1.015$ cm

Radius of axle $= 1.015 \times 10^{-2}$ cm

CALCULATIONS :

(1) ★ For anticlockwise :

$$I_1 = \frac{2 \times 300 \times 9.8 \times 67.5 \times 10^{-5}}{\left(\frac{4 \times 3.14 \times 184.5}{167.55}\right)^2 \left(1 + \frac{10}{184.5}\right)} - \frac{0.3 \times 10^{-4} \times 1.030}{\left(1 + \frac{10}{184.5}\right)^2}$$

$$I_1 = 0.0195 - 0.0000293$$

$$I_1 = 1.94 \times 10^5 \ gcm^2$$

★ For clockwise :

$$I_2 = \frac{2 \times 0.3 \times 9.8 \times 67.5 \times 10^{-2}}{\left(\frac{4 \times 3.14 \times 97.5}{102.465}\right)^2 \left(1 + \frac{10}{97.5}\right)} - \frac{0.3 \times 1.030 \times 10^{-4}}{\left(1 + \frac{10}{97.5}\right)}$$

$$I_2 = 0.0251745 \times 10^3 \times 10^4$$

$$I_2 = 2.51 \times 10^5 \ gcm^2$$

(2) ★ For anticlockwise :

$$I_3 = \frac{2.646}{\left(\frac{4 \times 3.14 \times 124.5}{129.925}\right)^2 \left(1 + \frac{10}{124.5}\right)} - \frac{0.206 \times 10^{-4}}{\left(1 + \frac{10}{124.5}\right)}$$

$$I_3 = 1.68 \times 10^5 \ gcm^2$$

★ For clockwise :

$$I_4 = \frac{2.646}{\left(\frac{4 \times 3.14 \times 65}{84.8}\right)^2 \left(1 + \frac{10}{65}\right)} - \frac{0.206 \times 10^{-4}}{\left(1 + \frac{10}{65}\right)}$$

$$I_4 = 2.47 \times 10^5 \ gcm^2$$

Mean for anticlockwise : $\left(\frac{I_1 + I_3}{2}\right) = \left(\frac{1.94 + 1.68}{2}\right) \times 10^5$

$$I_A = 1.81 \times 10^5 \ gcm^2$$

Mean for clockwise : $\left(\frac{I_2 + I_4}{2}\right) = \left(\frac{2.51 + 2.47}{2}\right) \times 10^5$

$$I_c = 2.49 \times 10^5 \ gcm^2$$

Mean , $I = \left(\frac{I_A + I_c}{2}\right) = \left(\frac{2.49 + 1.81}{2}\right) \times 10^5$

$$I = 2.15 \times 10^5 \ gcm^2$$

Maximum log error :

$$\frac{\Delta I}{I} = \frac{\Delta M}{M} + \frac{\Delta g}{g} + \frac{\Delta h}{h} - \left(\frac{\Delta h_1}{h_1} - \frac{2\Delta t}{t} + \frac{\Delta n}{n} - \frac{\Delta n_1}{n_1}\right) + \left[\frac{\Delta M}{M} + \frac{2\Delta r}{r} - \left(\frac{\Delta h}{h} - \frac{\Delta n_1}{n_1}\right)\right]$$

$$\frac{\Delta I}{I} = \frac{0.01}{67.5} - \left(\frac{2 \times 0.01}{76.25}\right) + \frac{2 \times 0.01}{1.015}$$ [for max^m log error]

$$\frac{\Delta I}{I} = 0.0014 + 0.00026 + 0.0019$$

$$\Delta I = 0.0036 \times 2.15 \times 10^5$$

$$\Delta I = 0.0088 \times 10^5 \ gcm^2$$

RESULT :

The moment of inertia of the flywheel is

$(2.15 \pm 0.0088) \times 10^5 \ gcm^2$