Candidate 6 evidence

Abstract:
The aim of the project was to determine the moment of inertia of a disc, hoop and cylinder. The moment of inertia of a flywheel (disc) with radius 10.2 cm and mass 7.1 kg was found to be (0.038±0.000) kg m^2. For a bicycle wheel (hoop) with radius 20.9 cm and mass 0.896 kg the moment of inertia was (0.035±0.001) kg m^2.
A cylinder with length

Introduction:

The dropping mass supplies a torque to the wheel causing it to accelerate around its axis. Since $T = Fr$ this torque can be calculated from the weight of the mass and the radius of the wheel. The torque causes the acceleration which can be calculated from the average angular velocity of the wheel as the mass descends. The wheel will revolve through a distance calculated with the circumference of the wheel and the height the mass falls as follows:

$c = 2\pi r$ for the circumference of the wheel so $\theta = h/2\pi r$ which is multiplied by 2π to convert it into radians giving $\theta = h/r$.

During the time taken for the mass to hit the ground, the wheel will have rotated θ radians so $\theta/t = \bar{\omega}$, the average angular velocity. Assuming the acceleration of the wheel is constant and that it starts from rest the final angular velocity will be double the average angular velocity so $\omega = \frac{2\theta}{t}$ and $\alpha = \omega/t$ therefore $\alpha = 2\theta/t^2$.

By rearranging $T = I\alpha$ the moment of inertia can be calculated with $I = T/\alpha$.

Determining the moment of inertia of a cylinder is possible due to the conservation of energy. The change in potential energy of the cylinder between the top and bottom of a slope will be equal to the rotational kinetic energy and linear kinetic energy when the cylinder is at the bottom of the slope after rolling down. This gives the equation $mgh = \frac{1}{2}I\omega^2 + \frac{1}{2}mv^2$ which can be rearranged making I the focus of the equation giving $I = m(2gh - v^2)/\omega^2$.

The angular velocity (ω) can be calculated from the number of radians turned by the cylinder as it travels down the slope and the time it takes to do so. The average angular velocity $(\bar{\omega} = \theta/t)$ multiplied by two will give the final angular velocity and, since it can be assumed that the acceleration of the cylinder is constant, so $\omega = 2\theta/t$. The radians turned (θ) can be found in a similar way as above using the distance travelled down the slope instead of the height the mass dropped. The velocity of the cylinder at the bottom of the slope can be determined simply, using $v = s/t$.

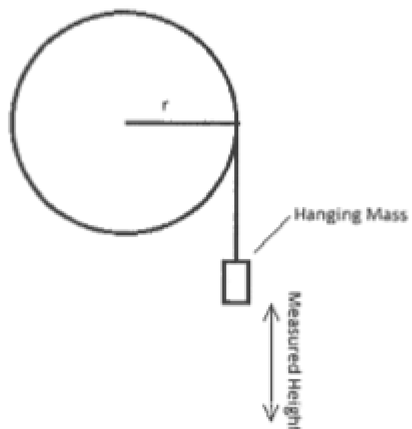
The predicted value of the moment of inertia of s cylinder is given by

$$I = \frac{1}{4}mr^2 + \frac{1}{24}ml^2$$

JULIE BOYLE – *SCHOLAR Study Guide, CfE Advanced Higher Physics,* Unit 1, Topic 3.3.2, Angular acceleration and moment to inertia.
ROBERT GORDON'S COLLEGE – *Advanced Higher Physics: Rotational Motion,* Moment of inertia and mass distribution.
F TYLER – *A laboratory Manual of Physics,* 5th edition.

Moment of Inertia of a flywheel (disc):

Procedure:



The mass and the radius of the wheel being used were measured. Attach a mass hanger to a piece of thread and then connect this to the wheel and then measure the height the mass will be dropped from. Add small masses to the hanger until the mass falls with a uniform velocity. Wind the thread around the wheel until the test mass is at the correct height and then release the mass and time the descent. Record the value of the mass being dropped and repeat the experiment 5 times for each mass.

Results:

Recorded Data:

Mass (kg)	Time for drop (s)				
	1	2	3	4	5
0.10	4.49	4.95	4.85	5.03	4.79
0.15	3.22	3.49	3.24	3.29	3.27
0.20	2.71	2.67	2.76	2.73	2.66
0.25	2.34	2.31	2.34	2.42	2.34
0.30	2.06	2.16	2.11	2.11	2.10

Radius of flywheel: (0.102±0.0005)m

Mass of flywheel: 7.1kg

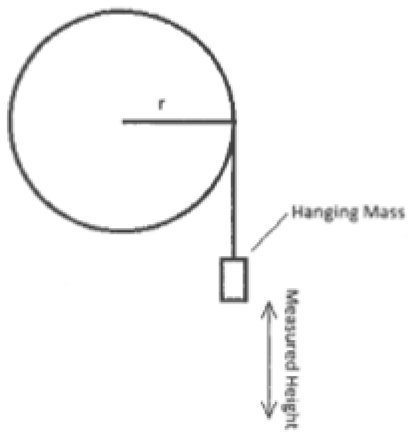
Measured height: (1.28±0.0005)m

Conclusion

The moment of inertia of the flywheel was (0.038±0.000) kg m^2. This was within 3% of the expected value of 0.037 kg m^2.

Moment of inertia of a bicycle wheel (hoop):

Procedure:



The mass and radius of the wheel being used were measured. Attach a mass hanger to a piece of thread and then connect this to the wheel and then measure the height the mass will be dropped from. Add small masses to the hanger until the mass falls with a uniform velocity. Wind the thread around the wheel until the test mass is at the correct height and then release the mass and time the descent. Record the value of the mass being dropped and repeat the experiment 5 times for each mass.

Results:

Recorded Data:

Mass (kg)	Time for drop (s)				
	1	2	3	4	5
0.03	2.47	2.42	2.43	2.49	2.41
0.04	1.99	1.87	2.02	2.01	1.95
0.05	1.69	1.77	1.77	1.74	1.78
0.06	1.52	1.57	1.49	1.52	1.55
0.07	1.38	1.38	1.40	1.40	1.38

Radius of wheel: (0.209±0.0005)m

Mass of flywheel: 0.896kg

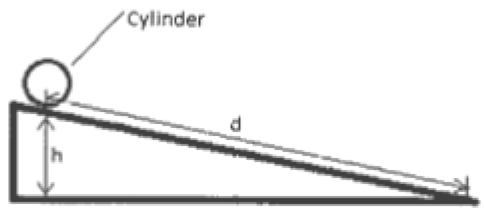
Measured height: (0.76±0.0005)m

Conclusion

The moment of inertia of the flywheel was (0.035±0.001) kg m^2. This was 11% lower than the expected value of 0.039 kg m^2.

Moment of inertia of a cylinder:

Procedure:



A series of markings are made on a slope at regular 10 cm intervals and the height difference between the bottom of the slope and marking was determined. A cylinder was placed at the lowest interval 30 cm from the bottom and allowed to roll through a light gate at the bottom of the slope to determine its final velocity. This was repeated five times and then a second light gate was placed at the marking on the slope. The time for the cylinder to pass between the two light gates was measured. This was repeated moving the cylinder up the slope to each marking.

Results:

Recorded Data:

Height (m)	Distance (m)	Time to reach bottom of ramp (s)				
		1	2	3	4	5
0.013	0.30	1.31	1.30	1.30	1.32	1.29
0.018	0.40	1.49	1.50	1.50	1.54	1.53
0.022	0.50	1.69	1.67	1.66	1.69	1.68
0.027	0.60	1.88	1.92	1.89	1.91	1.86
0.032	0.70	2.04	2.05	2.05	1.99	2.02

Height (m)	Distance (m)	Velocity at bottom of ramp (ms^{-1})				
		1	2	3	4	5
0.013	0.30	0.43	0.43	0.43	0.43	0.43
0.018	0.40	0.49	0.49	0.50	0.50	0.50
0.022	0.50	0.54	0.54	0.55	0.55	0.55
0.027	0.60	0.61	0.61	0.61	0.61	0.61
0.032	0.70	0.66	0.66	0.66	0.66	0.65

Mass of cylinder: (1.002±0.001)kg

Radius of cylinder: (0.028±0.0005)m

Length of cylinder: (0.053±0.0005)m

2gh and v^2 calculated for each height:

Conclusion

The moment of inertia of the cylinder was found to be (0.00030±0.00003) kg m^2. The expected value of 0.00031 kg m^2 lay within the uncertainty of the experimental value.