Lab 5. Moment of Forces and Moment of Inertia.

Name ………………………………………………………………………………. Date ………………………………………. Grp……. W…………………

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Objectives:

-/ Get acquainted with the concept of torque (moment of force).

-/ Determine the torsion constant of the spring.

-/ Determination of the Moment of Inertia from Oscillations.

- / Verify Huygens-Steiner's theorem

Apparatus:

1-/ A fork with a horizontal spring and a vertical axis of oscillation

2-/ A perforated metal disk with additional masses

3-/ A metal rod containing groove

4-/ PhotoGates.

5-/ Dynamometer

Theoretical study:

A torsion pendulum is an experimental device used to study the oscillations of an object suspended from a wire or spring. It allows for determining physical quantities such as the spring constant, the moment of inertia of an object, and verifying the Huygens-Steiner theorem. By measuring the oscillation period. This device is used in various physics applications, including the study of materials, fluid viscosity, and rotational dynamics.

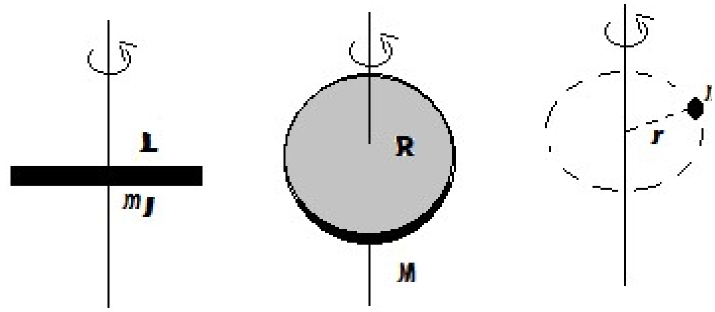
By definition, the spatial distribution of mass around the axis of rotation represents the moment of inertia. It is expressed using a volume integral $J = \int_{(V)} r^2 dm$.

The moment of inertia of a mass at a distance r from

the axis of rotation, $J_m = m.r^2$
a solid disk around its center, $J_d = \frac{1}{2} M.R^2$

and a rod of mass m_L and length L around its axis

at the middle of the rod is $J_r = \frac{1}{12} m_l . L^2$



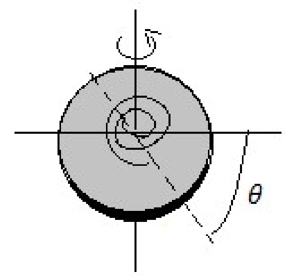
If we consider the torsion pendulum as a horizontal spring fixed to the medium of the rod with a length L, the system can be analyzed in terms of its vibrational motion

The horizontal spring provides a restoring torque when the disk rotates. The torque τ exerted by the spring is proportional to the angular displacement θ from the equilibrium position:

$\tau = -\kappa\,\theta$ where κ is the torsion constant of the spring.

Homework1

Using Newton's second law for rotational motion, find the differential equation describing the oscillatory motion of a torsion pendulum (disk):



$\frac{d^2\theta}{dt^2} + \omega^2\theta = 0$ where $\omega = \sqrt{\frac{\kappa}{J}}$ is the system's natural angular frequency.

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Part I: The torsion coefficient κ of the spiral coupling spring using a rod

Adjust the tripod's level, then use the adjustment screws to align the rod axis of rotation horizontally. In the most general form, torque is expressed as the cross product of the moment arm and the applied force. $\vec{\tau} = \vec{r} \times \vec{F}$ Where $\vec{r}$ is the position vector or moment arm and $\vec{F}$ is the force vector applied to the rod.

Using a force balance, the torsion coefficient can be determined using the relationship $F.r = \kappa.\alpha$

α is the deviation from equilibrium position.

Attach the dynamometer to the bar at various distances from the center of the axis of rotation and fill in the table below.

F(………..)	r(……………)	1/r(……………)	ΔF(……………..)	Δ(1/r)(………….)

1-/ Plot the graph, then deduce the torsion coefficient κ from the graph.

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2-/ write the result as $\kappa = \bar{\kappa} \mp \Delta\kappa$ (unit)

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Part II: Determine the moment of inertia J_r of the rod.

Deflect the rod (without masses) through 180° and measure the period T_{rod} using the Photogate.

T_{rod}= ……………………………………………………………………………………..

use the period found in homework1 to determine the value of the rod's moment of inertia
J_r(meas)=…………………………………………….

compare this value with the theoretical value of a rod's moment of inertia (see theoretical section)

J_r(theo)=…………………………………………….

Dev(%) ……………………………………………………..

Conclusion ………..

………………………………………………………………………………………………………..

Part III: The moment of inertia as a function of the distance r of the masses from the axis of rotation.

Attach the two weights to the bar successively at different symmetrical distances r to the left and right of the center of the axis of rotation.

Homwork2

use Huygens-Steiner's theorem to find the moment of inertia of this system

$J_{masses=}$……………………………………………………………………$J_{total=}$……………………………………………………………

Deflect the push rod by 180°, measure the duration of one period T using the Photogate and record the results in the following table

r (…….)	T (………)	J (……………)	J_r (……………)	J_m(meas)(………………)	J_m(theo)(………………)

Conclusion : ………

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Part IV Study of the Moment of Inertia of a Cylinder Filled with fluid

The objective of this part, it's to experimentally measure the moment of inertia of a cylinder filled with fluid as a function of the fluid level.

1-/ Measure the moment of inertia of the empty cylinder using an oscillation method

………………………………………………………………………………………..

2-/ Gradually fill the cylinder to different fluid levels (25%, 50%, 75%, 100%) and repeat the measurements

Fluid level	**J(Cylinder+fluid)(………………)**	**J(fluid)(………………)**
25%		
50%		
75%		
100%		

Conclusion:

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