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Faculty of sciences - common Basic of matter sciences

4th PRACTICAL WORK: TORSION PENDULUM

Date: ………/………./……..

	First Name	Family name	Subgroup	Professor's name
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1. Purpose

The aim of this practical work is to study the torsion pendulum motion. This motion allows us to measure the moment of inertia " I "of several differently shaped objects. For comparison, we will also calculate these moments theoretically.

2. Theoretical Part

2.1- General Description

A torsion pendulum, or torsion oscillator, usually consists of a mass suspended from a wire (or connected to a spiral spring). When the mass is twisted about the axis of the wire, the wire (or the spiral spring) exerts a torque on the mass that tends to rotate it back to its original position. Thus, when twisted and released, the mass will oscillate back and forth, performing a simple harmonic motion. The torsion pendulum is the angular version of the bouncing mass suspended from a spring.

2.2- Motion Formulation

Figure 2 shows a homogeneous rod connected to an axis by a spiral spring (torsion spring). When this rod is moved away from its equilibrium position, it begins to rotate around this axis.

The equation (equation of motion) that governs the motion of the rod can be found by applying the fundamental principle of rotational dynamics :

$$\sum \vec{\tau}_{ext} = \frac{d\vec{L}}{dt}$$; $\vec{L}$: *The angular momentum.*

$\sum \vec{\tau}_{ext}$: *The external torques.*

During its motion, the pendulum is subject to the restoring force and its inertia. The restoring force induces a restoring torque given by :

$$\|\vec{\tau}_r\| = C\,\theta$$; C : *The spring's torsion constant* [in newton·meters/radian]

θ : *The angle of twist of rod from its equilibrium position* [in radians]

1- Find the differential equation that governs this motion

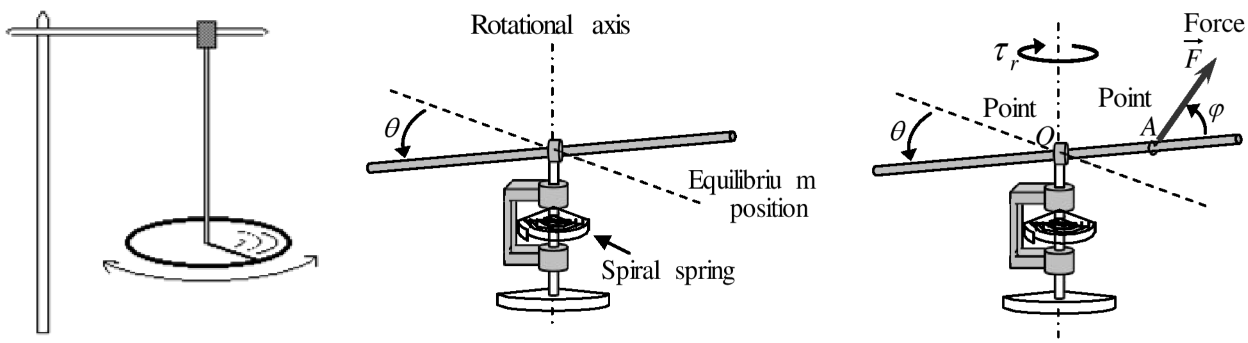

Figure 1 **Figure 2** **Figure 3**

2- Describe the type of the motion. ....

3- Write the expression that relates the moment of inertia of the rod "I" to the period of oscillation.

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4- The rod has been connected to the torsion spring and twisted from its equilibrium position. We apply a horizontal force "$\vec{F}$" at point "A", as shown in the figure 3.

The distance between "A" and the axis of rotation is "$OA = r$". The angle between the direction of "$\vec{F}$" and the rod is "$\varphi = 90°$".

At equilibrium $\sum \vec{\tau}_{ext} = \vec{0}$, find the expression of the torsion constant "C" as a function of "r", "F" and "θ".

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2.3- Theoretical moment of inertia

1- Consider a homogeneous rod with mass "$m = 132{,}2\ \text{g}$" and length "$\ell = 60\ \text{cm}$".

a) Calculate its moment of inertia "I_0" about an axis passing through its center.

$I_0 =$ ....

b) Recall the parallel-axis theorem (*Huygens' theorem*), with respect that the perpendicular distance between the two parallel axes is "r".

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c) Applying the Huygens' theorem, calculate the corresponding moment of inertia for each value of "r" (*the distance from the center of the rod*).

r (cm)	17	19	21	23	25	27
I (kg.m^2)						

2- Consider a solid sphere of mass "$m = 830\ \text{g}$" and radius "$R = 8{,}6\ \text{cm}$".

Calculate its moment of inertia "I_0" about an axis passing through its center.

$I_0 =$ ....

3- Consider a solid cylinder with mass "$m = 390\ \text{g}$" and radius "$R = 5\ \text{cm}$".

Calculate its moment of inertia "I_0" about an axis passing through its center.

$I_0 =$ ....

3. Practical Part

I- Consider a rigid rod of mass "$m = 132{,}2$ g" and length "$\ell = 60$ cm".

To measure the spring's torsion constant "C", the rod is fixed to the torsion spring at its center (as shown in Figure 3) and a dynamometer has been attached to the rod at distances "r" from the rotational axis in order to determine the force "F" required to achieve equilibrium at the angle "$\theta = 180°$" (*we'll use a light barrier to ensure the equilibrium*).

1- Complete the following table

r (cm)	**17**	**19**	**21**	**23**	**25**	**27**
F (N)						
C (N.m)						

2- Calculate the mean (or average) value of the torsion constant "C". $\overline{C} =$ ....

II-a. As shown in Figure 2, twist the rod at a small angle "θ", and then release it.

1- Measure the period (**5 times**) and complete the following table.

Order of measurement	**1**	**2**	**3**	**4**	**5**
T (s)					

2- Calculate the mean value of the period "T". $\overline{T} =$ ....

3- Calculate the absolute and the relative uncertainty. $\Delta T =$ .... , $\dfrac{\Delta T}{\overline{T}} =$ ....

4- Write the value of "T" in the form : $T = \overline{T} \pm \Delta T =$ ....

5- According to response of the theoretical question **2.2-3**, calculate the moment of inertia "I_0" about an axis passing through the center of the rod. $I_0 =$ ....

6- Compare this value with that calculated in the theoretical preparation (part **2.3-1-a**).

....

b. Twist and release the rod again, after sliding the rotational axis a distance "r" from the center.

1- Measure the period (**2 times**) and complete the following table.

r (cm)	**4**	**8**	**12**	**16**	**20**
T (s)					
$\overline{T}$ (s)					
I (kg.m^2)					
$\dfrac{(I - I_0)}{r^2}$					

2- What do you find about the value of the expression "$\dfrac{(I - I_0)}{r^2}$" ....

What does it represent ? ....

c. Attach a solid sphere ($m = 830$ g and $R = 8{,}6$ cm) to the torsion spring, then twist and release it.

1- Measure the period (**5 times**) and complete the following table.

Order of measurement	1	2	3	4	5
T (s)					

2- Calculate the mean period . $\overline{T} =$ ....

3- Calculate the moment of inertia. $I_0 =$ ....

4- Compare this value with that calculated in the theoretical preparation (part **2.3-2**).

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d. Attach a solid cylinder ($m = 390$ g and $R = 5$ cm) to the torsion spring, then twist and release it.

1- Measure the period (**5 times**) and complete the following table.

Order of measurement	1	2	3	4	5
T (s)					

2- Calculate the average period . $\overline{T} =$ ....

3- Calculate the moment of inertia. $I_0 =$ ....

4- Compare this value with that calculated in the theoretical preparation (part **2.3-3**)

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4. Conclusion

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Experiment device

1- Object to be measured (rod)

2- Torsion spring

3- Support

4- Rotational axis