# PHYS 103 LAB 8 TORQUES AND ROTATIONAL MOTION

## INTRODUCTION

In this lab is you will verify that for a body in equilibrium the sum of the *torques* must vanish. You will balance two *torques* created by the *weights* of different *masses* placed on a metal rod. You will tabulate your results in an **Excel** spreadsheet. In part 2 you'll observe the progress of differently shaped objects down an incline. In part 3 you'll look for the center of mass of an irregularly shaped piece of cardboard.

## THEORY

In your daily experience you encounter not just the action of *forces* but also of *torques*. When you pull or push on a door knob to open an unlocked door you are applying a *torque* to it; the door then swings on the hinges. As unbalanced *force* causes a change in the motion of an object, so an unbalanced *torque* changes its rotational motion. Thus for an object to remain stationary (in equilibrium), not only *forces* but also *torques* acting on it need to be balanced.

We define the *torque* as a product of a *lever arm* and the *force* applied to an object. The *lever arm* is the distance between the applied *force* and the rotational axis or fulcrum. We write

$$\tau = Fl\,, \tag{1}$$

where the Greek letter $\tau$ denotes the *torque*, $F$ is the applied *force*, and $l$ the *lever arm*.

From equation (1) you can see that the strength of the *torque* depends not only on the magnitude of the applied *force* but also on the *length* of the *lever arm*. Indeed you'd need to push the door with considerably greater strength for it to move if you apply this push close to the hinges rather than some distance away from them.

The direction of rotation produced by a *torque* can be clockwise or counter clockwise. If you are on one side of a door, if you pull on the door knob the door will open, if you push on it, it will close. If you are on the other side of a door, if you pull on the door knob the door will close, if you push on it, it will open. Since *torques* can have such opposite effects you need to establish some kind of sign convention; for example all *torques* that produce clockwise rotation are positive and all that produce counter clockwise rotation are negative. If you pull on the door knob on one side of the door, and your friend pulls on it on the other side with equal strength, the door won't move – the *torques* the two of you produce are equal but have opposite signs since they would cause the door to rotate in opposite directions and thus they cancel out, producing no net effect.

In this lab you will be balancing two *torques* created by the *weights* of different *masses* placed on a metal rod attached to a vertical pulley which will act as fulcrum (see figure 1). If the *weight* of the *mass* on the left is

$$F_{Gl} = m_l\, g, \tag{2}$$

then the *torque* it generates is

$$\tau_l = F_{Gl}\, l_l = m_l\, g\, l_l, \tag{3}$$

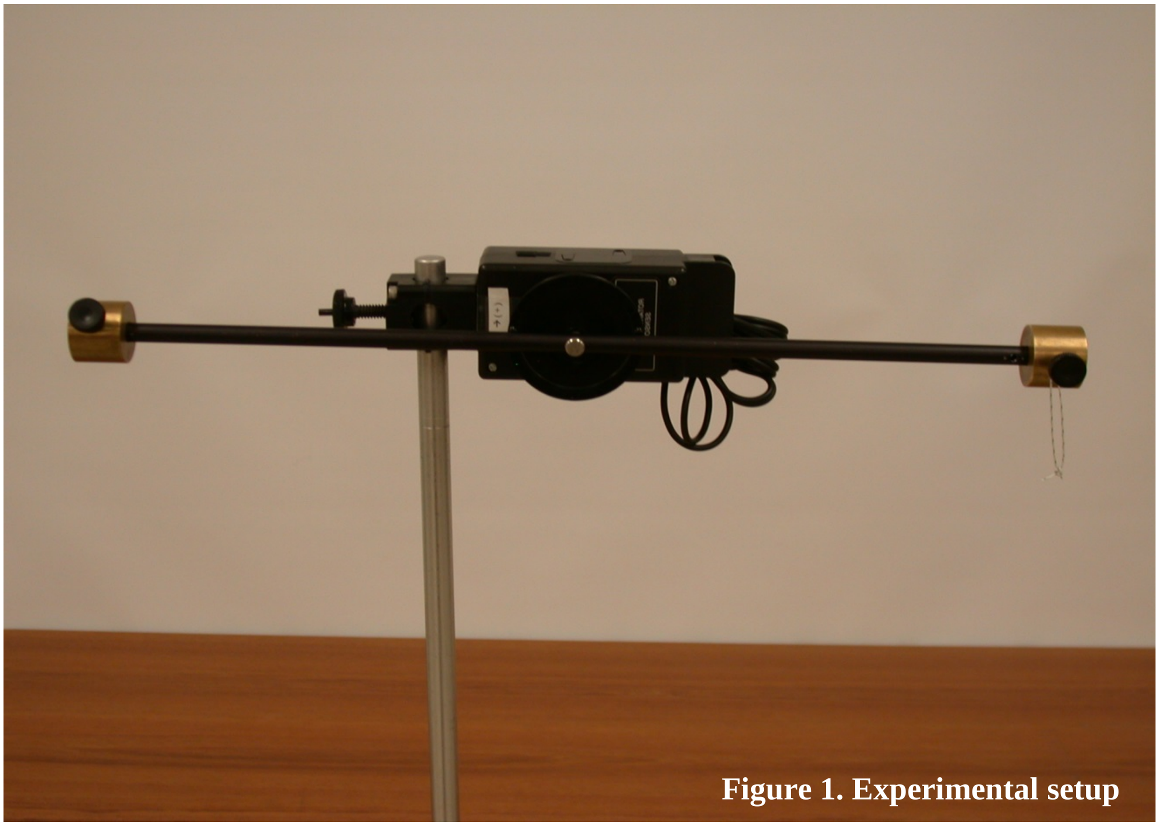

**Figure 1. Experimental setup**

where $m_l$ is the *mass* placed to the left of the pulley, and the *lever arm* $l_l$ is the distance from that *mass* to the axis of rotation (fulcrum). Similarly on the right you'll have *weight*

$$F_{Gr} = m_r\, g, \tag{4}$$

then the *torque* it generates is

$$\tau_r = F_{Gr}\, l_r = m_r\, g\, l_r, \tag{5}$$

where $m_r$ is the total *mass* placed to the right of the pulley, and the *lever arm* $l_r$ is the distance from that *mass* to the axis of rotation (fulcrum).

If the rod is to be balanced the *torques*, each acting in an opposite direction, must be equal in magnitude.

$$\tau_l = \tau_r \tag{6}$$

In part 1 of this experiment you'll vary the *mass* on the right and adjust the length of the *lever arm* on the right till the rod is balanced.

In part 2 you are asked to predict which object rolls down an incline first: a hoop or a cylinder and then confirm your prediction experimentally.

In part 3 you will try to locate the centre of mass of an irregularly shaped piece of cardboard. The center of mass of an object (often also referred to as the center of gravity) is a point about which the weight of that object exerts no torque (since it has zero lever arm). Thus you can balance the weight of the object by applying equal in magnitude normal force at the exact point of the center of mass (which then also exerts no torque on the object about its center of mass).

## PROCEDURE

### PART 1 TORQUES

1. In **Excel** generate a table similar to table 1 below. Include all needed equations: use equations (3) and (5) for *torques* on the left and on the right.

**Table 1**

| $m_r$ (kg) | $l_r$ (m) | $\tau_r$ (Nm) | $m_l$ (kg) | $l_l$ (m) | $\tau_l$ (Nm) | % difference |
|---|---|---|---|---|---|---|
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2. Remove both bobs from the rod and measure their *masses* (including the screws). Record these values in row 1 of table 1.

3. Place the bobs back on the rod as far away from the axis of rotation as possible and balance the rod.

4. Measure the length of both *lever arms* (i.e. the distance from the center of mass of each bob to the axis of rotation) and record them in your table.

5. Calculate the values of the *torques* on the left and on the right. Find percent difference between the two *torques*. If you are satisfied with the outcome move to the next step, otherwise try to refine your measurements.

6. Hang a 10 g *mass* on the string loop attached to the screw of the bob on the right (see figure 2, page 4). **Take care and make sure that masses won't fall off and hit your feet**.

7. Record the new *mass* on the right in your table. Make sure to continue to include the *mass* of the bob.

8. Adjust the *lever arm* of the bob on the right till the rod is balanced. **DO NOT CHANGE THE POSITION OF THE BOB ON THE LEFT FOR THE REST OF THIS EXPERIMENT.**

9. Measure the new value of the *lever arm* on the right and record it in your table.

10. Calculate the value of the *torque* on the right. Find percent difference between the two *torques* now acting on the rod. If you are satisfied with the outcome move to the next step, otherwise try to refine your measurements.

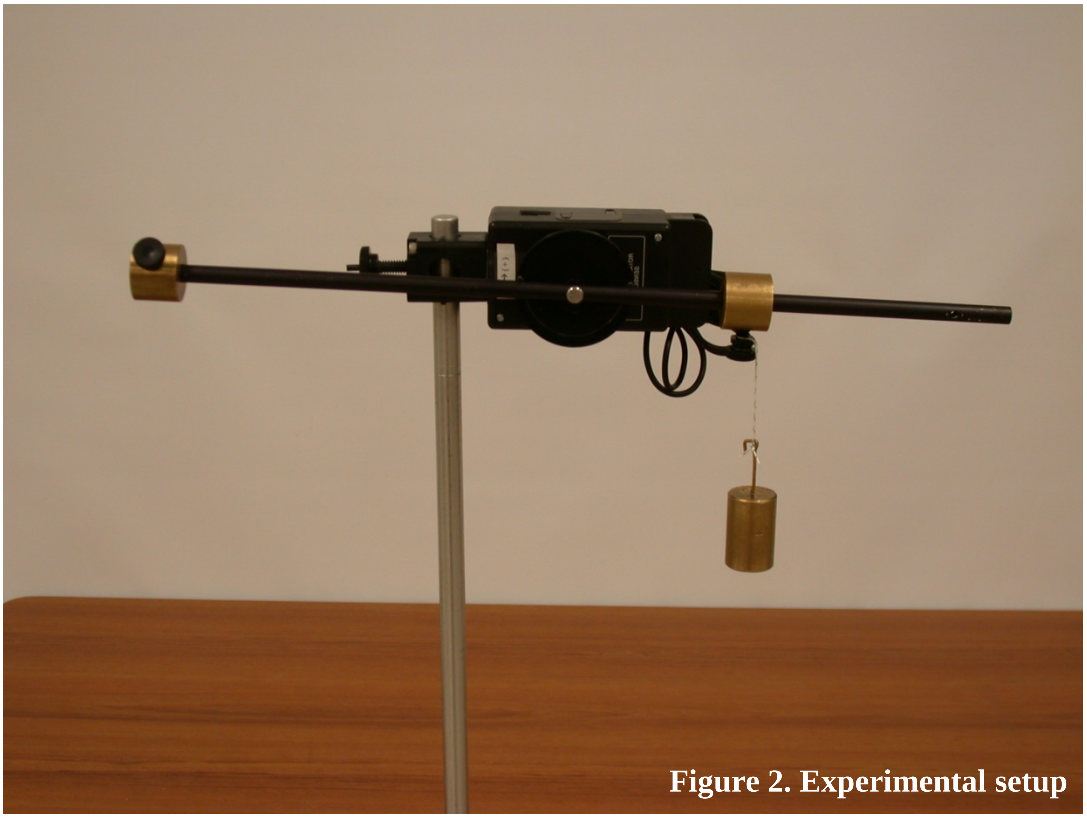

**Figure 2. Experimental setup**

11. Repeat procedure in steps 6-10 using other *masses* of: 20g, 30g, 40g, 50g, 70g, 100g, and 150g instead of 10 g *mass*.

12. Discuss your tabulated results: were the *torques* on the left the same as the *torques* on the right (within our experimental accuracy)? Should they be? Why or why not? Discuss.

## PART 2: RACE DOWN AN INCLINE

1. Predict when released from the same height, which will arrive at the bottom of an incline first: a hoop, a ball or a cylinder. State your prediction in the report.
2. Use the equipment provided to confirm (or not) your prediction. Discuss the outcome. Were your predictions correct? Explain the physics of why these object arrive at the bottom of the incline in the order that they do.

## PART 3: CENTER OF MASS

Find the center of mass of the irregularly shaped piece of cardboard provided to you. Discuss how you found the center of mass. Make a sketch of the object and show the location of its centers of mass. Attach the sketch to your report.

**Print your tables, and attach them to your report.**
**Delete your files from the computer.**
**Disconnect all equipment, close all applications, and log off your**

# LAB 8 REPORT

**Group name:** ........................................

**Partners' names:** ........................................

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## INTRODUCTION:

## DATA PRESENTATION:

### PART 1 TORQUES

12.

## PART 2: RACE DOWN AN INCLINE

**Your prediction:** list the objects (the hoop, the ball and the cylinder) in the order in which you think they'll arrive at the bottom of the incline, when released from the same height.

1)……………………………………

2)……………………………………

3)……………………………………

or choose:

☐ they'll all arrive at the bottom of the incline simultaneously.

☐ other, explain:………………………………………….…………

…………………………………………………...……………

What was the outcome of the experiment? Did it agree with your prediction? Discuss and explain the physics behind what you observed.

## PART 3: CENTER OF MASS

**REMINDERS:** Include units.
Make sure to attach all your data and graphs. No data = No credit
Please do not hand in the manual, just the report.

## CONCLUSION: