**TORQUE**Name:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_Date/Time:\_\_\_\_\_\_\_\_\_\_\_

Purpose: To investigate torque by doing the following activities:  
    a. Measuring an unknown mass                                               
    b. Measuring the mass of a meter stick  
    c. Calculating clockwise and counter clockwise torques

Apparatus: Meter stick, unknown mass, knife edge clamp, knife edge support, 3 mass-hangers, mass set, lab jack, electronic balance, and string loops.

Theory: Introduction to torque

    Think about the everyday activity of opening a door, just for a moment.



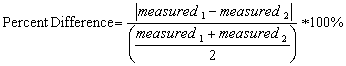
Q: What do you think you do to the door, when you open it?

A: You apply a torque.

Torque = Moment-arm X Force; Torque is a vector. Torque comes in clockwise and counter clockwise directions. Clockwise direction is the direction in which a mechanical clock turns. The opposite direction is called counter clockwise.

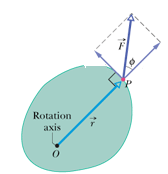
The door knob is kept away from the hinge in order to have a greater moment-arm. Imagine how hard it will be to open, if the knob is kept closer to the hinge.

Moment-arm is the perpendicular distance between the line of action of the force and axis of rotation.

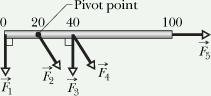


Read section 10-8, p258-259 in your text (HRW-9) and answer the following questions.

1. A doorknob is located as far as possible from the door's hinge line. Explain why.
2. The Figure below shows a cross section of a body that is free to rotate about an axis passing through *O* and perpendicular to the cross section. A force http://edugen.wiley.com/edugen/courses/crs1650/art/math/halliday8019c10/math140.gifis applied at point *P*, whose position relative to *O* is defined by a position vectorhttp://edugen.wiley.com/edugen/courses/crs1650/art/math/halliday8019c10/math141.gif. The directions of vectors http://edugen.wiley.com/edugen/courses/crs1650/art/math/halliday8019c10/math140.gifand http://edugen.wiley.com/edugen/courses/crs1650/art/math/halliday8019c10/math141.gifmake an angle http://edugen.wiley.com/edugen/courses/crs1650/art/math/halliday8019c10/math142.gifwith each other. Identify the radial and tangential components of http://edugen.wiley.com/edugen/courses/crs1650/art/math/halliday8019c10/math140.gifin the figure below.



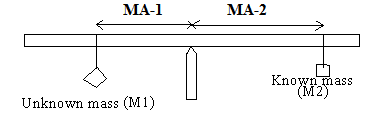
1. Which one of the following components can cause rotation?  
   a. Radial component b. Tangential component
2. Define torque.
3. Show the line of action and moment arm for the force F4 in the diagram below.



1. What is the moment arm for the force F3 shown above?\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
2. Which of the forces shown above will produce clockwise torque about the pivot point?   
   \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
3. Which of the forces shown above will produce counterclockwise torque about the pivot point?   
   \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
4. Which of the forces shown above will produce zero torque about the pivot point?   
   \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

a. Measuring an unknown mass

Meter stick is supported at the center of gravity.



Unknown mass will try to rotate the meter stick counter   
clockwise and known mass will try to rotate the meter   
stick clockwise.

Counterclockwise torque = Unknown mass X Moment-Arm-1

Clockwise torque = Known mass X Moment-Arm-2

For balance, counterclockwise torque = clockwise torque.

Unknown mass X Moment-Arm-1 = Known mass X Moment-Arm-2

Unknown mass can be determined using the above equation.

DATA for Unknown Mass  
  
Location of the center of gravity (C.G) = \_\_\_\_\_\_\_\_ cm

Location of the unknown mass          = \_\_\_\_\_\_\_\_\_ cm    \_\_\_\_\_\_\_\_\_cm    \_\_\_\_\_\_\_\_\_\_cm

Location of the known mass              = \_\_\_\_\_\_\_\_\_ cm    \_\_\_\_\_\_\_\_\_cm    \_\_\_\_\_\_\_\_\_\_cm

|  |  |  |  |
| --- | --- | --- | --- |
| Known mass, M2 (g) | Moment-arm for known mass, MA-2 | Moment-arm for unknown mass, MA-1 | Unknown mass, M1 |
| 200 | - | - | - |
| 250 | - | - | - |
| 300 | - | - | - |
| Average of the unknown mass, M1 | | | - |
| Unknown mass measured using electronic balance | | | - |
| % difference | | | - |

b. Measuring the mass of a meter stick (M)

Now you need to move the support point away from the center of gravity (C.G). This way you get the rotation effect of M, mass of the meter stick.



DATA for Mass of Meter Stick

Location of the center of gravity (C.G) = \_\_\_\_\_\_\_\_ cm.

Location of the support point               = \_\_\_\_\_\_\_\_ cm    \_\_\_\_\_\_\_\_\_\_cm    \_\_\_\_\_\_\_\_\_cm

Location of the known mass                = \_\_\_\_\_\_\_\_ cm    \_\_\_\_\_\_\_\_\_\_cm    \_\_\_\_\_\_\_\_\_cm

|  |  |  |  |
| --- | --- | --- | --- |
| Known mass, m (g) | Moment-arm for known mass, l | Moment-arm for mass of meter stick, L | Mass of meter stick, M |
| 100 | - | - | - |
| 150 | - | - | - |
| 200 | - | - | - |
| Average of the mass of meter stick, M | | | - |
| Mass of meter stick measured using electronic balance | | | - |
| % difference | | | - |

**c) Torques**

1. With the meter stick on the support stand at X0 (center of gravity) suspend a 150-g mass at the 10 cm mark and a 200-g mass at 90 cm mark. Hang a 100-g and adjust its position to obtain static equilibrium.

2. Record the location of the 100-g mass.

3. Draw a free-body diagram for the meter stick and identify all the forces acting on it.

|  |
| --- |
|  |

4. Write an equation by balancing the torques.

|  |
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|  |

5. Calculate the location for the 100-g mass, using the above equation, and compare it with the experimental value.

6. Use the experimental value of the location for the 100-g mass to calculate the counterclockwise and clockwise torques about X0 and complete the data below.

DATA:

    Experimental value of the location for the 100-g mass = \_\_\_\_\_\_\_\_\_\_\_

    Calculated value of the location for the 100-g mass    = \_\_\_\_\_\_\_\_\_\_\_

                                                    % Difference                = \_\_\_\_\_\_\_\_\_\_\_

    Counterclockwise torque about X0 = \_\_\_\_\_\_\_\_\_

    Clockwise torque about X0           = \_\_\_\_\_\_\_\_\_\_

                                    % difference = \_\_\_\_\_\_\_\_\_

Problem 1: A uniform meter stick is supported at the 40.0 cm mark. Balance is obtained when a 45.0 gram mass is suspended at the 10.0 cm mark. Draw a free body diagram for the meter stick and determine the mass of the meter stick.

Problem 2: A meter stick has a mass of 140-g and center of mass at 49.5 cm. This meter stick is supported at the center of mass using a knife edge clamp of mass 20-g. An unknown mass is hanged at 19.5 cm. Balance is obtained when 150-g is hanged at 69.5 cm. Draw a free body diagram for the meter stick and determine the unknown mass and the normal force exerted by the support stand.

|  |  |
| --- | --- |
| Q5, Ch12: Figure [12-17](http://edugen.wiley.com/edugen/courses/crs4957/halliday9118/halliday9088c12/halliday9118/halliday9088c12/halliday9088c12xlinks.xform?id=halliday9088c12-fig-0017) shows a mobile of toy penguins hanging from a ceiling. Each crossbar is horizontal, has negligible mass, and extends three times as far to the right of the wire supporting it as to the left. Penguin 4 has mass *m*4 = 1 kg. What are the masses of (a) penguin 3, (b) penguin 2, and (c) penguin 1?http://edugen.wiley.com/edugen/courses/crs4957/halliday9118/halliday9088c12/image_n/nt0025-y.gif |  |
|  |  |