Advance Reading
Urone, Ch.5-1 through 5-7.

Objective
To measure torque on a rigid body, to
determine the conditions necessary for
static equilibrium to occur, and to perform
error analysis.

Theory
When a force, F, is applied to a rigid body
at any point away from the center of mass,
a torque is produced. Torque, \( \tau \), is defined
as the tendency to cause rotation. The
magnitude of the vector is given by:

\[
\tau = Fr \sin \theta
\]  
(Eq. 4- 1)

where \( r \) is the perpendicular distance from
the axis of rotation and \( \theta \) is the angle
between the force and \( r \).

In this experiment, all forces will be acting
perpendicular to the meter stick (\( \theta = 90^\circ \),
sine \( \theta = 1 \)). The equation for torque
simplifies, and is given by:

\[
\tau = Fr
\]  
(Eq. 4- 2)

PROCEDURE
Qualitative Analysis of Torque.
1. Place a hanger clamp at the 10 cm
   position, attach the mass hanger to the
   clamp, and place 50g on the mass
   hanger. Hold the meter stick as close to
   the zero end of the meter stick as
   possible. The mass will produce a
torque acting on your hand:
   \( \tau = (9.8 \text{ m/s}^2)(.050 \text{ kg} + \text{mass of}
   \text{hanger})(\text{distance from the fulcrum}).
   \) Note how difficult it is to hold this set-
   up. Now place 100g on the mass
   hanger. Note how this feels compared
to the first time.

2. Move the mass hanger and the 100g
   mass out to the 100 cm mark of the
   meter stick in 20 cm increments,
   holding the meter stick as before. Note
   your observations. Is it easy to feel the
   torque increasing as the force moves
   further from the axis of rotation (your
   wrist)?

Quantitative Analysis of Torque
3. Place the knife-edge clamp at the 50 cm
   position of the meter stick, with the
   screw pointing down, and place this set-
   up on the fulcrum. Carefully adjust the
   fulcrum position by moving the knife-
   edge clamp until the meter stick is
   balanced (meter stick must be
   horizontal). Record the position. This
   position is \( x_{\text{cmp}} \).
4. Measure and record the mass of the
   hanger clamps.
5. Place a clamp at \( x_c = 15 \text{ cm} \) position the
   other clamp at \( x_c = 75 \text{ cm} \) position.
   Place 200 g on the clamp at 15 cm and
   enough mass on the clamp at 75 cm to
   make the system balance (static
   equilibrium). It may be necessary to
   adjust the position of the 75 cm clamp
   in order to balance the system, as
   fractional masses are not available to
   you. Record the actual position.
6. Determine the force acting at each
   position and the length of each moment
   arm. From this information, calculate
   the torque acting on each side of the
   fulcrum.
7. Calculate the sum of the torques, \( \Sigma \tau \),
   acting on the meter stick. Use the
   convention that torques acting
clockwise, \( \tau_c \), are negative and torques
   acting counterclockwise, \( \tau_{cc} \), are positive.
8. Add a hanger clamp at the 5 cm
   position and hang a 50 g mass hanger
   from it. Adjust the mass on the hanger
   at the 75 cm position to achieve static
   equilibrium. Calculate \( \Sigma \tau \).
Physics 215 - Experiment 4
Torques and Rotational Motion

One-Person See-Saw
9. Remove all clamps from the meter stick; measure and record the mass of the meter stick.
10. Place the fulcrum at the 20 cm position on the meter stick and place a mass hanger as close to the zero end as possible. Add enough mass to the mass hanger to attain static equilibrium.
11. Calculate $\Sigma r$. The meter stick can be treated as if all of its mass is concentrated at one point, the center of mass. When it is supported in a position other than the center of mass, a torque is produced.

Unknown Mass
12. Determine the mass of the marble block experimentally, using any of today’s techniques. Sketch the arrangement used, noting the positions and magnitudes of the forces.
13. Measure the mass of the block with the Dial-O-Gram balance.
14. Compare the values.

Questions
1. Explain how the Dial-O-Gram balance works.
2. Explain how the triple-beam balance works.
3. Will either balance allow us to accurately measure the mass of an object on the moon? Why or why not?
4. Describe and sketch each experimental set-up you used (position, magnitude, and direction of all forces).