PHYS 2425
Engineering Physics I

EXPERIMENT 8
CRANE BOOM EQUILIBRIUM

I. OBJECTIVE

The objective of this experiment is to study the static equilibrium of a rigid body. This will be done by measuring the external forces acting on the boom of a crane subjected to an applied load. The student will use the measured forces in the equations of equilibrium

$$\begin{aligned} \sum F_x &= 0 \\ \sum F_y &= 0 \\ \sum \tau &= 0. \end{aligned} \tag{1}$$

to check if the conditions of static equilibrium are satisfied.

II. APPARATUS

Beck equilibrium crane apparatus, weights, weight hanger, meter stick, Clinometer.

IV. EXPERIMENTAL PROCEDURE

1. Secure the crane to the wooden board and use the bubble level to level the crane.

2. Make sure all the dynamometers (springs balances) read zero. If they do not, loosen the appropriate knobs to make the readings all zero.

3. Gently unhook the boom and allow it to hang freely as shown in figure (1).

4. Hang a 0.200 kg load from the last pin on the boom as shown in figure (1). This mass includes the mass of the hanger. Measure this mass and record it in the data table.

5. The mass of the boom and the location of its center of gravity from the pivot and the mass of the floating hinge were measured and are given in the data table.

6. Adjust the tensions in the supporting strings until the floating hinge and the pin attached to it are actually floating and not in contact with or supported by the base. You may want to consult the instructor or the lab assistant to make sure this is done accurately.

7. When this condition is reached, the boom is in static equilibrium under the action of the following forces.

(a) The weight of the boom, $F_1 = m_{\text{boom}}g$. This force is applied at the center of gravity of the boom.

(b) The load applied to the boom, $F_2 = m_{\text{load}}g$.

(c) The weight of the floating hinge, $F_6 = m_{\text{hinge}}g$. This force is applied at the pivot.

(d) The tensions in the strings. These are the readings of the dynamometers, F_3, F_4 and F_5. Measure these forces and record them in the data table.

8. Measure the distance along the boom from the pivot to the point of application of the load. Call this distance l_2.

9. Measure the distance along the boom from the pivot to the point of application of F_3. Call this distance l_3.

10. Using the Clinometer measure the angle of inclination of the boom and the angle of inclination of F_3. Call these angles α and β respectively.

V. ANALYSIS

1. Complete the calculations of all the quantities in the data table.

2. Check to see if each of the equations of equilibrium is satisfied. If the forces and torques do not exactly add up to zero, how close are they to zero?

3. Write a conclusion summarizing your results. What are the two most important sources of error?

Experiment (8) Data Table
$m_{\text{boom}} = 0.3367\,\text{kg}$
$m_{\text{load}} =$
$m_{\text{hinge}} = 0.0437\,\text{kg}$
$F_1 = m_{\text{boom}}g =$
$F_2 = m_{\text{load}}g =$
$F_3 =$
$F_4 =$
$F_5 =$
$F_6 = m_{\text{hinge}}g =$
$l_1 = 0.379\,\text{m}$
$l_2 =$
$l_3 =$
$\alpha =$
$\beta =$
$x_1 =$
$x_2 =$
$x_3 =$
$y_3 =$
$\sum F_x =$
$\sum F_y =$
$\sum \tau =$

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I. OBJECTIVE

The objective of this experiment is to construct several variants of a load-bearing crane boom and to measure the tension in the crane cable. The student will use the conditions of static equilibrium of the boom to calculate the tension in the cable and the reaction forces at the hinge. The measured and calculated tensions in the cable will be compared.

II. APPARATUS

Aluminum rod, meter stick, weights, clamps and connectors.

IV. EXPERIMENTAL PROCEDURE

1. Measure the mass of the meter stick and record it in the data table. All data should be recorded with its uncertainty.
2. Locate the center of gravity of the meter stick by finding the balance point with the aid of the wooden fulcrum.
3. Make sure the spring balance reads zero. If it does not, zero it by gently pulling on the handle at the top.
4. Assemble the apparatus as shown in case (1). In this case the boom is horizontal.
5. Record the positions of the load mass, the hinge pivot point, and the point where the line of action of the cable tension crosses the middle of the meter stick.
6. Use the clinometer to make sure the boom is horizontal. Also use the clinometer to measure the angle of inclination of the of the cable.
7. Measure the tension in the cable by reading the spring balance in Newtons.
8. Disassemble the apparatus and re-assemble as shown in case (2). In this case the cable is horizontal.
9. Repeat steps 5 - 7 and record the data in the data table. This concludes the experimental procedure.

V. ANALYSIS

1. For each case, draw the free body diagram of the boom showing all the forces acting on it. Assume the tension in the cable is unknown.

2. Apply the conditions of static equilibrium to the boom to calculate the tension in the cable and the forces exerted by the hinge on the boom. Show your calculations. The conditions of static equilibrium are:

$$\begin{aligned} \sum \tau &= 0 \\ \sum F_x &= 0 \\ \sum F_y &= 0. \end{aligned} \tag{2}$$

3. Compare the measured and calculated cable tensions by calculating the % difference

$$\%\,\text{difference} = \frac{|T_{\text{calculated}} - T_{\text{measured}}|}{\left(\frac{T_{\text{calculated}} + T_{\text{measured}}}{2}\right)} \times 100 \tag{3}$$

4. In your conclusion, discuss the two main sources of error in this experiment.