Walk-in Lab 11
Equilibrium
Physics 121

CID(s): _______________________

Description

In today’s lab you get to measure and calculate a bunch of forces and torques that should add up to zero. Hopefully this will give you a feel for what it means when we say “equilibrium” – namely that all of the forces add to zero and all of the torques also add to zero.

Have fun, smile a lot, and work together. Let me know how things go and email me ideas for making the lab better. Have a great day!

Objective: To determine three unknown force components from the three equilibrium conditions measure

\[ \sum F_x = 0 \]
\[ \sum F_y = 0 \]
\[ \sum \tau_z = 0 , \]

then to measure these same three force components and check to see if they match your calculations. An angle error of even 1 degree in this lab can introduce a 4% error, so if your calculated forces agree with the measured ones to about 4%, you have done a good job.

Equipment: a cougar-shaped sign, hanging masses, pulleys, and a ruler.

Part A – Preliminary measurements

The cougar-shaped sign is supported against gravity by two forces: tension \( \vec{T} \) from the cord over the pulley on the right and contact force \( \vec{P} \) at the bearing pin, as shown in the figure below.

![Diagram of the cougar-shaped sign with forces and dimensions labeled]

The sign’s weight \( \vec{F}_y \) is the third force, which may be considered to act at the sign’s center of mass.

Before we start calculating we need to make a few measurements. The mass of the sign (\( M \)) is given on the apparatus; write it down (in kilograms) below. Insert the bearing pin and hold the sign so that it is level. Measure the distance from the center of the pin to the center of mass (\( x_{\text{CM}} \)) and the distance from the pin to where the wire connects to the sign near the cougar’s tail (\( x_T \)). Select an angle \( \phi \) between 30° and 70° and clamp the pulley on the right at this angle. Write your measurements here
Part B – The Calculations

Assume that the sign is in equilibrium as shown in the diagram in Part A. Use the condition \( \sum \tau_z = 0 \) to determine the magnitude of the force \( T \). To do this, put the coordinate system origin at the bearing pin. (This will make the moment arm for the torque from \( \vec{P} \) be zero.) On the back of this sheet, use the condition for rotational equilibrium (\( \sum \vec{\tau} = 0 \)) to find the formula for the magnitude of \( T \). Your formula should contain \( M, \phi, x_{cm}, x_T, \) and \( g \). Notice that \( \vec{P} \) does not enter this equation.

Once \( T \) is determined you can use the equations for translational equilibrium (\( \sum F_x = 0 \) and \( \sum F_y = 0 \)) to find formulas for the rectangular components of \( \vec{P} = P_x \hat{i} + P_y \hat{j} \). You can use the symbol \( T \) in your formulas for \( P_x \) and \( P_y \) if you like. Put boxes around your formulas on the back of this sheet, then use your measured values from Part A to convert these forces to numerical values in newtons and write them below.

\[
T = \text{__________ N}
\]
\[
P_x = \text{__________ N}
\]
\[
P_y = \text{__________ N}
\]

Part C – Measured values

Following the instructions provided with the equipment, adjust \( \vec{T} \) by adding weights to the hanging holder until the top of the sign is level. (Make sure that the pin is inserted into the bushing on the left in this part.) Write your values for \( T \) and for the \% error between your measurement and the calculated value you found in Part B.

\[
\text{balancing mass} = \text{__________ grams}
\]
\[
T_{\text{measured}} = \text{__________ N}
\]
\[
\% \text{ error} = \text{__________ \%}
\]

Be sure to include the mass of the weight holder and remember that \( T = mg \) is a force (not a mass!). Your predicted and measured values should agree to within about 4\%.

Now let’s see if we can make the sign ‘float’ off the bearing pin in order to measure \( \vec{P} \). Follow the instructions on the apparatus to find the floating angle \( \theta_P \), then add mass to the holder on the left until the pin floats freely inside the bushing. When you have succeeded, the force you have applied is equivalent to the force \( \vec{P} \) previously supplied by the bearing pin. Record the balancing mass and the angle \( \theta_P \) and calculate the magnitude of the force \( P \). Finally, convert this magnitude and direction angle to \( x \) and \( y \) coordinates to get \( P_x \) and \( P_y \) and compare these to your predictions from Part B.

\[
\text{balancing mass} = \text{__________ kg}
\]
\[
P_{\text{measured}} = \text{__________ N}
\]
\[
\theta_P = \text{__________ degrees}
\]
\[
P_x = \text{__________ N}
\]
\[
\% \text{ discrepancy} = \text{__________ \%}
\]
\[
P_y = \text{__________ N}
\]
\[
\% \text{ discrepancy} = \text{__________ \%}
\]