24-261 Statics, Fall 2001
Laboratory #3
Due: 1:30 PM, September 20, 2001

## INTRODUCTION

The goal of this laboratory is study moments about axes due to forces that act in three dimensions. You need to learn to determine the moment about any axis of an arbitrary force applied at an arbitrary point. Here we focus on moments about a single axis, but the ideas apply to any other axes.

## OVERVIEW OF APPARATUS

The apparatus has an arm that can pivot about a single axis. You will apply forces to various points on the arm. The springs, which are attached to the sides of the arm, balance the tendency to pivot. For each force you apply, you will measure the pivot angle with the protractor. Later, you will use the pivot angle, information on the springs and the geometry to determine the moment applied by the springs. You will also calculate the moment due to the force that you apply. You will compare the moments; ideally they should be equal since the net moment is zero.

## DEFINITIONS

The coordinate axes ***i***, ***j*** *and* ***k*** are aligned with the initial orientation of the arm as shown (see Figure 1).

The *Force Vector* should be written as 6 **i** + 7 **k** lb, for example.

The *Position Vector* represents the position of the point of load application relative to the origin A (see Figure 2 for an example), *while the arm has the load applied to it*. The position vector should be written as 5.5 **i** + 10.7 **k** in, for example. Note that you can measure the positions of the points of load application when there is no load applied. You can later calculate the position vector under load by accounting for the measured rotation (pivoting) using trigonometry. Alternatively, you can measure the position vector under load.

The *Springs Moment* is the moment that the springs together are exerting on the arm about the *y*-axis (**j**) through A. As described below, you can determine this moment from the pivot angle, from the spring information and from the geometry.

The Applied Moment is the moment about y-axis through A due to the force that you apply. You will determine this moment given the Force Vector and the perpendicular distances (which can be found from the Position Vector).

**PART 1**

For each of the force configurations in Figure 1, labeled 1 through 8, apply 5 lb to the cable in the given direction, and measure the pivot angle. Denote the pivot angle as positive if the rotation is about the positive y-axis using the right hand rule. For each force configuration, fill in the Force Vector, the Position Vector, and measured pivot angle in **Table 1**. See the section below for converting the pivot angle into the Springs' Moment.

Using the direction of the force and the perpendicular distance to the pivot axis, predict the Applied Moment and record that in the last column of Table 1. Perpendicular distances are determined from the Position Vector.

Remember that the Position Vector is based on the position of the point of load application relative to A, *when the arm is loaded*.

**PART 2**

Return to force configuration 4, and apply force magnitudes of 2, 4, 6, and 8 lb, recording the information in **Table 2**. Carry out the same steps as for Part 1.

**PART 3**

Consider now the force configurations 9 and 10, shown in Figure 2. The force in configuration 9 has a magnitude of 5 lb; the force acts in a direction that is 6 units along the –**i** direction and 10 units along the +**k** direction. The force in configuration 10 has a magnitude of 5 lb; the force acts in a direction that is 6 units along the **i** direction, 4 units along the –**k** direction and 8 units along the +**j** direction. In both cases, you should use a ruler to determine the direction of the force (at least approximately).

Apply the forces of configurations 9 and 10 using a cable attached to the spring scale, which will ensure 5 lb magnitude, with the cable oriented in the direction of the force. For each applied force, measure and record the information in **Table 3**. Carry out the same steps as for Part 1, with the following exception.

Take each of the forces, and resolve it into components along the coordinate axes. For each component individually, determine the applied moment about the y-axis theoretically, as you did previously, using the perpendicular distances. Show these contributions individually, and then sum them.

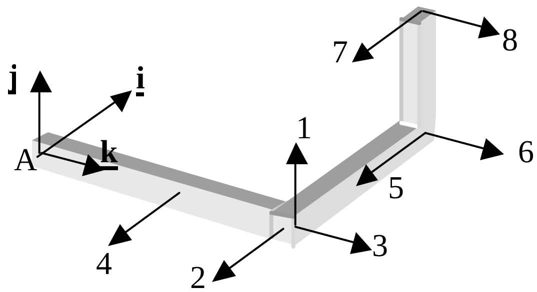


Figure 1

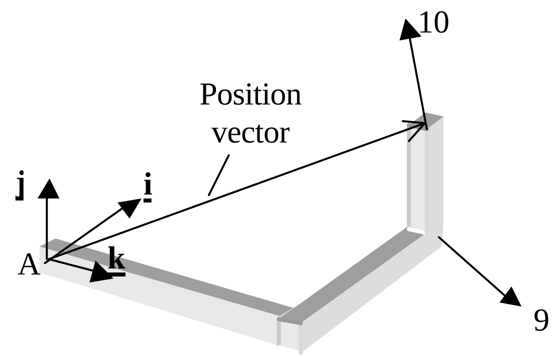


Figure 2

**Method to convert pivot angle into an applied moment.**

Each spring is part #9654K156 from McMaster-Carr (http://www.mcmaster.com). Such springs require an initial tension (15.14 lb) to begin to stretch the spring, and thereafter have a linear relation (25 lb/in) between the *increase* in stretch and the *increase* in force. The two spring forces are initially equal. From the measured pivot angle, you can determine the change in length of each spring using trigonometry. (Since the pivot angles are small, the spring mostly stretches; the reorientation of the spring can be neglected.) From the changes in length and the spring constant, you can calculate the difference in the two spring forces. From the difference in the spring forces, you can determine the moment about the hinge imposed by the springs.

Table 1. Data entry for Force Configurations #1 - #8

| Force # | Force vector | Position vector (relative to point A) | Measured Angle | Springs' Moment $M\|_{Ay}$ | Applied Moment $M\|_{Ay}$ |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
| 6 | | | | | |
| 7 | | | | | |
| 8 | | | | | |

Table 2. Data entry for Force Configuration #4; Force Magnitudes of 2, 4, 6, 8 lb

| Force vector | Position vector | Measured Angle | Springs' Moment $M\|_{Ay}$ | Applied Moment $M\|_{Ay}$ |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |

Table 3. Data entry for Force Configurations #9 - #10

| Force # | Measured Angle | Springs' Moment $M\|_{Ay}$ | Position vector | $F_x$ | $M\|_{Ay}$ due to $F_x$ | $F_y$ | $M\|_{Ay}$ due to $F_y$ | $F_z$ | $M\|_{Ay}$ due to $F_z$ | Total Applied $M\|_{Ay}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 9 | | | | | | | | | | |
| 10 | | | | | | | | | | |