

PH-1111 Constructing a Physical Model That Illustrates a Force Diagram

The objective of this short set of experiments is to demonstrate that the statements I've made about tension and force diagrams actually work about the way that you might expect. In a certain sense, this experiment will demonstrate that I have been telling the truth about how strings and forces work. Some of the statements that I made may, however, have had implications that are not instantly obvious. Sometimes experiments help you understand what a theory means.

You are going to set up a simple pendulum. You'll attach to the pendulum bob an additional string allowing you to pull the pendulum bob sideways. You'll determine all of the forces acting on the pendulum bob, and compare with sideways displacement of the pendulum.

Equipment: We provide you with a number of vertical rods, clamps, pulleys, masses, string, and other gadgets. You set up something like the experiment that we sketch, and calculate the tension in one string.

There are several key parts of the equipment. The hangers are tied to the ends of strings. As implied by their names they hang vertically and provided a downward force mg determined by the mass attached to the hanger. Small pulleys let you redirect the direction along which a string is pulling. You can use the hanger, string, and pulley to generate a horizontal force by running the string over the pulley, and having the top of the pulley level with the height at which you want to apply the horizontal force.

The objective is to create the setups shown in the sketch. Do this for several different deflecting forces. You start by creating the situation in which the pendulum simply hangs vertically. When you apply additional sideways forces to the pendulum, the pendulum will be displaced sideways, but to determine the size of that displacement you need to know exactly where the pendulum started.

The picture looks very simple, but getting this set up properly is going to create some challenges. First, as the pendulum is dragged sideways, it is actually moving in a circular arc, and therefore is moving up and down as well as sideways. As a result, if you want the force being applied to the pendulum to be precisely horizontal, you will need to move the corresponding pulley up and down so that it is at the right height relative to the central pendulum bob.

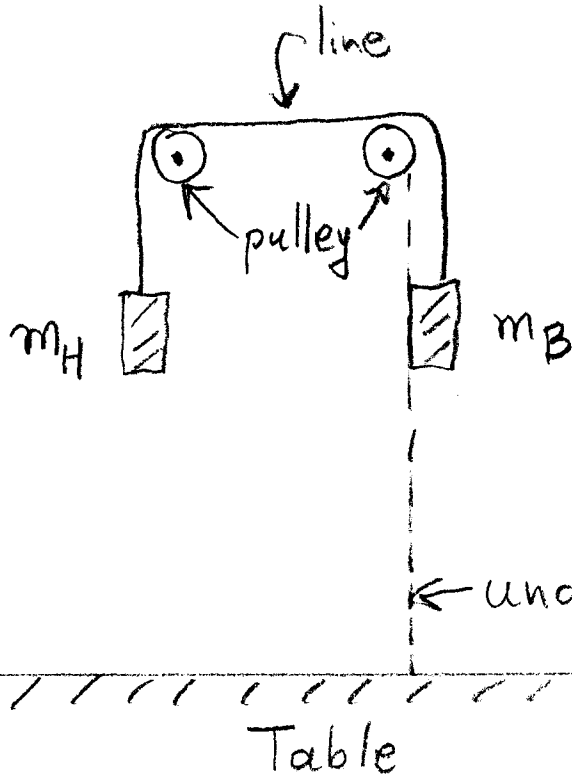
A further complication occurs because the pendulum is not simply attached to a top support. Instead, the string that holds up the pendulum goes over a pair of pulleys down to another hanger. The weight on that other hanger has to be right, in order to keep the system stationary. As you will discover, when you pull the pendulum sideways, you are increasing the tension in the string that supports the pendulum bob. Correspondingly, you have to increase how much weight is on the hanger that holds the pendulum in place. Holding the hanger in place, and gradually adding masses to it until the system is again balanced, may be relatively easy.

Advancing in small steps from the simplest possible case of no sideways force on the pendulum bob may be of some advantage. As reasonable numbers, starting with 200 g as the pendulum bob, a pendulum length of 0.7 m or so, and sideways deflections not more than 10-20 cm may make life straightforward.

How do you measure the deflection? You create a vertical reference line using clamps and rods, align the vertical carefully with the line occupied by the pendulum bob when no sidewise force is being applied, and use the reference line to measure the horizontal distance through which the pendulum bob is deflected.

What will your lab report show? First, you should do a simple theoretical analysis. There are three masses in the system, so each mass gets its own force diagram. You should write the second law for each mass. There are two strings, so each string has a tension T_i ; the tensions in the two strings do not have to be equal. Key point: All accelerations are zero, so in this special case the sum of the forces on each mass must be zero. Finally, calculate the deflection of the pendulum bob in terms of the three masses, and calculate the tension in each string.

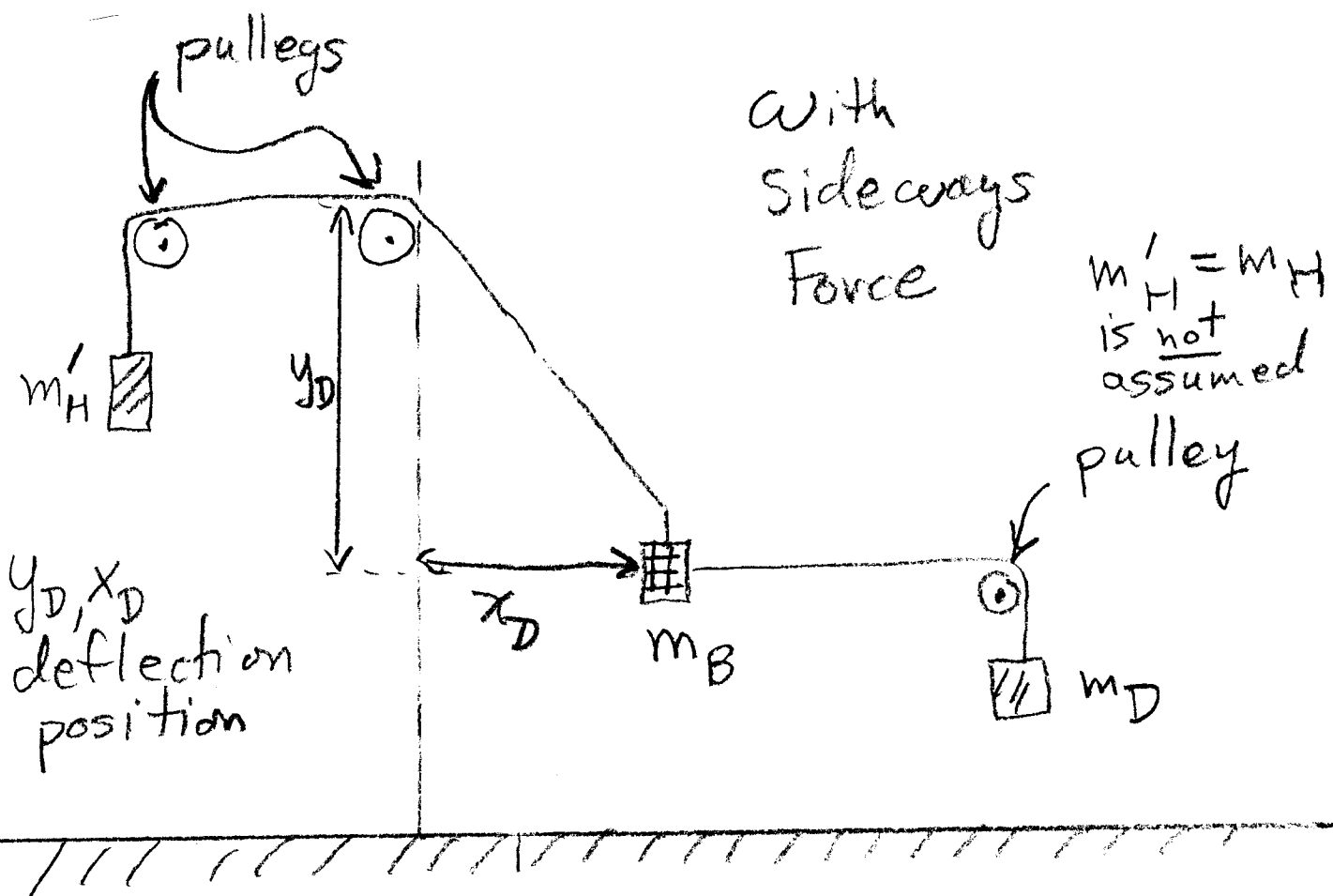
Finally you should compare the calculated and measured deflections. A graph of measured deflection against theoretical deflection is appropriate. Did your calculations match measurement?



Start
 No sideways
 force
 $m_B \approx 0.2 \text{ kg}$ good.

← undeflected vertical

Table



With
 Sideways
 Force

$m'_H = m_H$
 is not
 assumed

pulley

y_D, x_D
 deflection
 position

Table

Support rods not shown