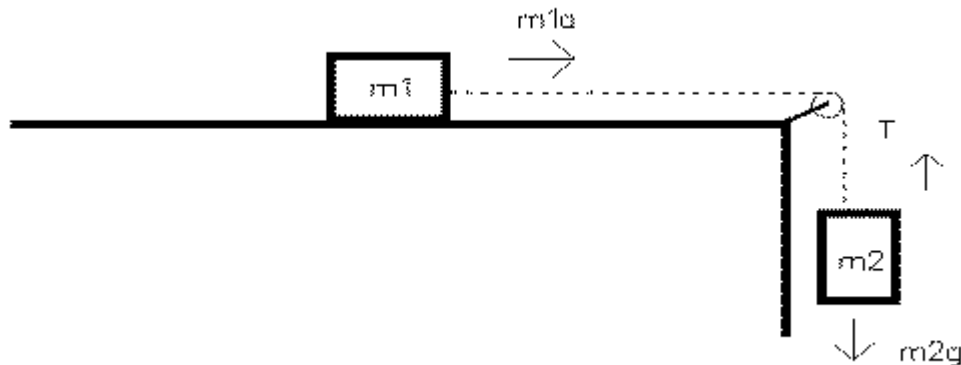


NEWTON'S SECOND LAW

THEORY: As you know by now, Isaac Newton was a great physicist who derived $F = m \cdot a$. This means a system of masses will undergo acceleration when subjected to a force, in this case a weight hanging off the lab bench. The system of masses means all the mass that moves due to the applied force. In this lab we will examine specifically the consequences of $F = m \cdot a$.

Consider the standard connected masses diagram below:



The force which causes the system to move is the force of gravity on m_2 , the hanging mass. Gravity causes no motion directly in m_1 , although it does play a part in the friction between m_1 and the surface. Let the string that connects m_1 and m_2 be very light and no stretchable. This means that the accelerations for both masses is the same, and the string doesn't contribute an accelerating force. Examining all the forces on m_1 we see that the tension T in the wire equals (neglecting friction) $m_1 \cdot a$. T is the only force which causes acceleration in m_1 . On the other hand, m_2 has two forces working on it. Gravity is pulling down and tension T is pulling up. The net force on m_2 is the difference between $m_2 \cdot g$ and T . Putting these ideas together and solving for a we have:

$$a = m_2 \cdot g / (m_2 + m_1) \quad \text{equ.1}$$

We will use equation 1 to calculate the **theoretical value of a**.

Also, by knowing the distance m_2 falls, and the time of descent, one can use fundamental kinematic equations to also determine a .

$$a = 2 \cdot h / t_{\text{avg}}^2 \quad \text{equ.2}$$

We will use equation 2 above to calculate the **experimental value of a**.

Think about the consequences of making $m_1 \gg m_2$. Disregarding friction for the nonce, will m_1 ever become big enough so acceleration equals zero? Will acceleration ever equal g (9.8 m/s^2)? Will keeping the total mass constant but changing the distribution of the mass affect the acceleration? Suppose the string that connected the two masses was very heavy-how would the acceleration be affected? These are the questions you can answer by carefully observing the outcome of the experiment..

TASK:

To examine Newton's second law for connected masses.

EQUIPMENT:

- Air track
- Cart
- Pasco Interface and Photo gates
- meter stick
- foam landing pad
- masses
- 5g mass hanger
- PC and spreadsheet

PROCEDURE:

1. Set up the air track and cart as shown at the front desk.

**** Do NOT move the cart while the air is off!** Make sure once the air is on that the cart doesn't move. (The mass hanger should not be attached to the string in this step.) This means the track is level. **

2. Set the height of the hanger to a distance greater than 70 cm.
3. Mass the cart, and record this value in Kg.
4. The cart will represent m_1 and the hanging mass (the hanger plus any other mass on it) will be m_2 .

Interface and Software Initial Setup:

1. **Carefully position the photo gates so that the distance between the gates is the same distance the mass hanger falls. Use 70 cm for this distance. This is the same value that you will use for h in your calculations**
2. Connect the PASCO Interface to the computer by using the USB cord.
3. **Plug the photo gate near the blower into the digital input #1 and the other photo gate into the digital input #2 on the interface box (1/4" phone plugs).**
4. Make sure that the cart can block the photo gate and that the string is not triggering the photo gates. **You will use the leading edge of the cart to trigger the photo gates.**
5. Double Click the "PASCO Capstone" shortcut on the desktop to start the program.
6. On the left side of the screen click on the "Hardware Setup" icon that is under the tools menu. The hardware setup window will open with a picture of the interface.

7. Move your mouse cursor over Digital Input # 1 and right click. Select Photo gate from the drop down menu. A picture of a photo gate connected to the input will appear.
8. Repeat step 7 for the Digital Input # 2.
9. Click on the "Timer Setup" icon on the left side under the Tool group. The Timers Setup window will open.
10. Select "Built your own timer" from the drop down menu.
11. Select both photo gates by checking the boxes next to their names. Click next.
12. Set the timing sequence to Photo gate ch1 "Block" and Photo gate ch2 "Block" by using the pull down menus next to each photo gate name. Click next.
13. Click Finish.
14. Click the Timer Setup Icon under tools to close the window.
15. Double click the table icon that is under the displays group on the right side of the screen. A table with two columns will open.
16. On the table's left column click the "Select Measurement" button. Then select "Custom timer (s)" from the drop down menu. You are ready to start taking data.
17. Click the "Record" button (big red button) on the lower left side of the screen to start collecting data. The timer will start as soon as the cart crosses the first gate and stop when the cart crosses the second gate.
18. Click the stop button after every run. To see previous runs, click on the "Run #" button and select the run you wish to see.

Make sure that the hanger does not hit the ground before the cart has passed the second photo gate. Turn off the blower once the car passes the second gate. Your table should now display the time of travel between photo gates.

Experiment : During this part of the experiment both the values of m_1 and m_2 will change. Do NOT move the cart while the air is off!

1. Add 40 grams to your cart (use a combinations of 5 and 10 grams masses)
2. With m_1 on the air track (cart + 40 grams) and 10 grams (the mass hanger + 5 g) as m_2 , time the descent of the mass hanger **five times**. Record the time values.
3. Decrease m_1 by 5 grams and increase m_2 by 5 grams (just transfer 5 grams from the cart to the hanger). Time five descents and record all values.
4. Repeat step 3 until $m_2 = 50$ grams (remember to account for the hanger's mass). Each occasion time five descents. **Record all values.**

CALCULATIONS:

1. On a spreadsheet make columns for m_1 (Kg), m_2 (Kg), the total mass ($m_1 + m_2$) (Kg), $m_2/(m_1+m_2)$, times 1, 2, 3, 4 & 5, the average time, the experimental acceleration from

kinematics, the theoretical acceleration (our working equation), and the accelerating force ($m_2 \cdot g$). **Be sure to label all columns, and include units!**

2. Next you are going to make eight different charts using your data:

1. **Chart 1:** Using markers only, graph the experimental acceleration vs. the Mass Ratio $m_2/(m_1+m_2)$. **Add a trend line with a (0,0) intercept. Include the equation of the line.**
2. **Chart 2:** Using markers only, graph the theoretical acceleration vs. the Mass Ratio $m_2/(m_1+m_2)$. **Add a trend line with a (0,0) intercept. Include the equation of the line.**
3. **Chart 3:** Using markers only, graph the experimental acceleration vs. M1 **Add a trend line do not cross it through (0,0) intercept. Include the equation of the line.**
4. **Chart 4:** Using markers only, graph the theoretical acceleration vs. M1 **Add a trend line do not cross it through (0,0) intercept. Include the equation of the line.**
5. **Chart 5:** Using markers only, graph the experimental acceleration vs. M2 **Add a trend line with a (0,0) intercept. Include the equation of the line.**
6. **Chart 6:** Using markers only, graph the theoretical acceleration vs. M2 **Add a trend line with a (0,0) intercept. Include the equation of the line.**
7. **Chart 7:** Make a graph (**using markers only**) of the accelerating force (Y-axis) vs. the experimental acceleration (X-axis). **Add a trend line with a (0,0) intercept. Include the equation of the line.**
8. **Chart 8:** Make a graph (**using markers only**) of the accelerating force (Y-axis) vs. the theoretical acceleration (X-axis). **Add a trend line with a (0,0) intercept. Include the equation of the line.**

PERCENT ERROR:

1. Compare the slopes of chart 2 (**theoretical**) and the slope of chart 1 (**experimental**) by calculating the percent error.
2. Compare the slope of chart 8 (**theoretical**) and the slope of chart 7 (**experimental**) by calculating the percent error.