Lab 6: Force, Mass and Acceleration

Objectives:

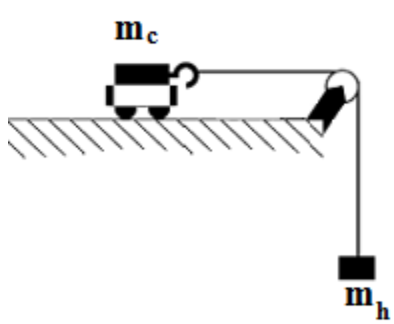
- To study Newton's Second Law, **F** = m**a**, with a constant net force
- To study Newton’s Second Law with constant mass

Equipments:

- computer-based laboratory system
- motion detector
- Real-Time physics mechanics experiment configuration files
- cart
- force probe
- ramp
- masses
- white card
- balance.

Exploration 1 Force diagrams, net force and acceleration

Consider a cart on a frictionless surface with a light string attached, hanging over a pulley, as in the picture below. Consider the situation after the hanging mass has been released from rest.



Exploration 1.1.a Draw two force diagrams – one for the cart and one for the hanging mass in the space below.

Exploration 1.1.b Does the force of the string, F_S, on the hanging mass equal the gravitational force on the hanging mass (after release from rest)? Explain.

Exploration 1.1.c If the hanging mass, m_h, after release from rest is moving, explain the motion in terms of the net force on m_h. If your explanation contradicts your answer to part 1.1.b, explain or reconsider your answer to 1.1.b.

Exploration 1.1.d If, after the hanging mass, m_h, is released from rest, the cart is moving, explain in terms of the net force on the cart. Is the net force on the cart greater than, less than or equal to $m_h g$? Explain.

Exploration 1.1.e. After the hanging mass, m_h, is released from rest, would the cart and the hanging mass move at the same acceleration? Explain.

Exploration 1.1.e. Derive an equation for the acceleration of the system of cart plus hanging mass, a, in terms of the mass of the cart, m_c, and m_h, and g.

Exploration 2 Graphs of acceleration for constant force

Exploration 2.1 Suppose the cart mass can be changed by adding masses to the cart. Sketch a graph of the acceleration plotted vs. cart mass + hanger mass in the space below based on your equation in part **1.1.e**.

Exploration 2.2 If you were to take data, measuring the acceleration of the cart for different masses added to the cart, what could you plot that would give you a straight line? What would be on the x- axis? What would be on the y- axis? What would the slope be? What physical quantity does the slope represent? Show your work and explain.

Exploration 3 Accelerating the cart with a different net force and constant total mass

Exploration 3.1 Since the surface is very low friction, it is possible to consider the cart and mass hanger as one system. What is the net force on the system? Explain.

Exploration 3.2 How could you change the net force on the system and keep the total mass of the system constant? Explain.

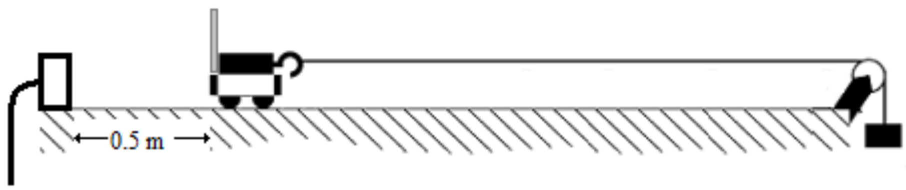
Exploration 3.3 If you were to take data, constantly changing the net force on the system, but keeping the total mass the same, what quantity could you plot vs. met force to give a straight line? Explain. Sketch the graph below.

What physical quantity does the slope of the line represent? Explain in words and equations.

Investigation 1 Acceleration with constant force

Investigation 1.1 Procedure

1) Set up the ramp, pulley, cart, string, motion detector, and force probe as shown in the following figure below. Mount the white card on the cart, so that the motion detector can recognize it.



2) Use the balance to measure the mass of the cart and the force probe together (m_c).

3) Use 20g of mass as the hanging mass (m_h).

4) Open the experimental file called "**Acceleration and Mass (L05A1-1)**" to display the axes below.

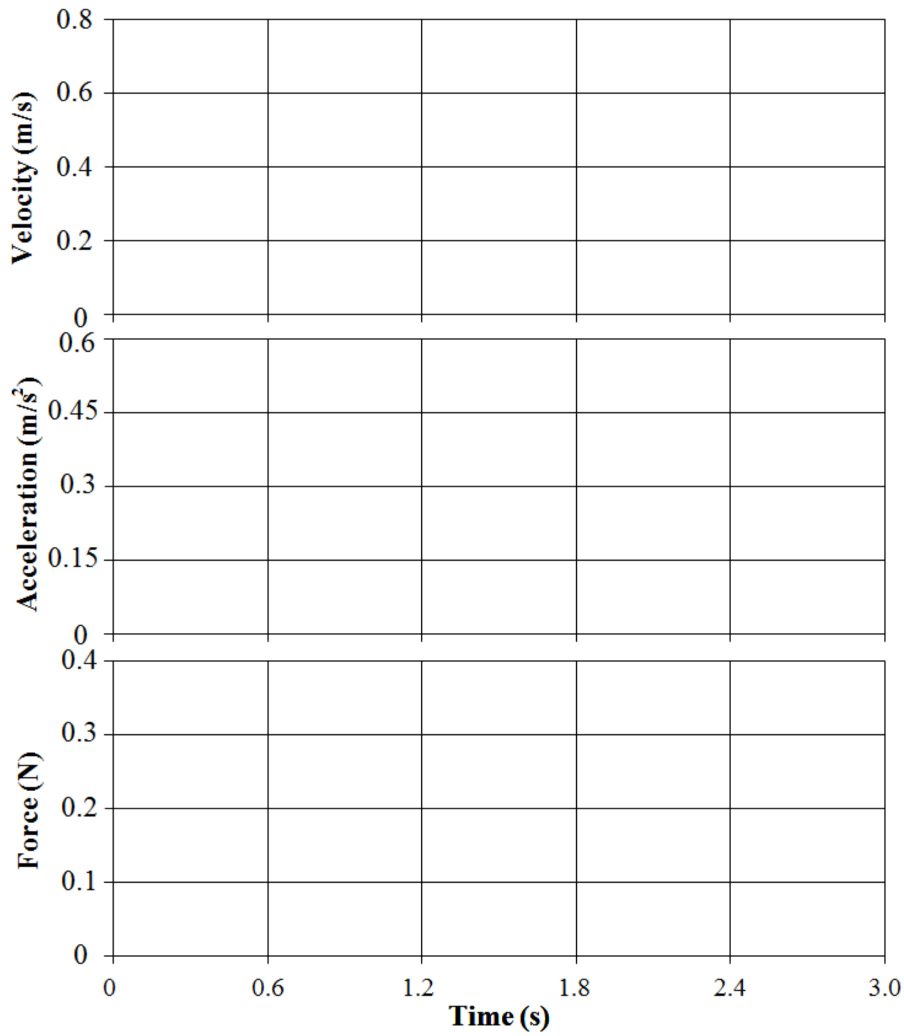
5) Calibrate the force probe with 2 N pull using one point calibration. (Click on Menu Bar → Experiment → Calibrate)

6) Zero both the force probe and the motion detector. (Click on Menu Bar → Experiment → Zero)

7) Using only the cart and the force probe, release the cart and start recording data. Store the data (Click on Menu Bar → Experiment → Store Latest Run).

8) Add 200g to the cart and repeat step (7). Keep adding masses until you reach 800g, and store the data each time (Click on Menu Bar → Experiment → Store Latest Run).

Investigation 1.2 Choose one of the sets of data that you stored and sketch the data on the graph below.



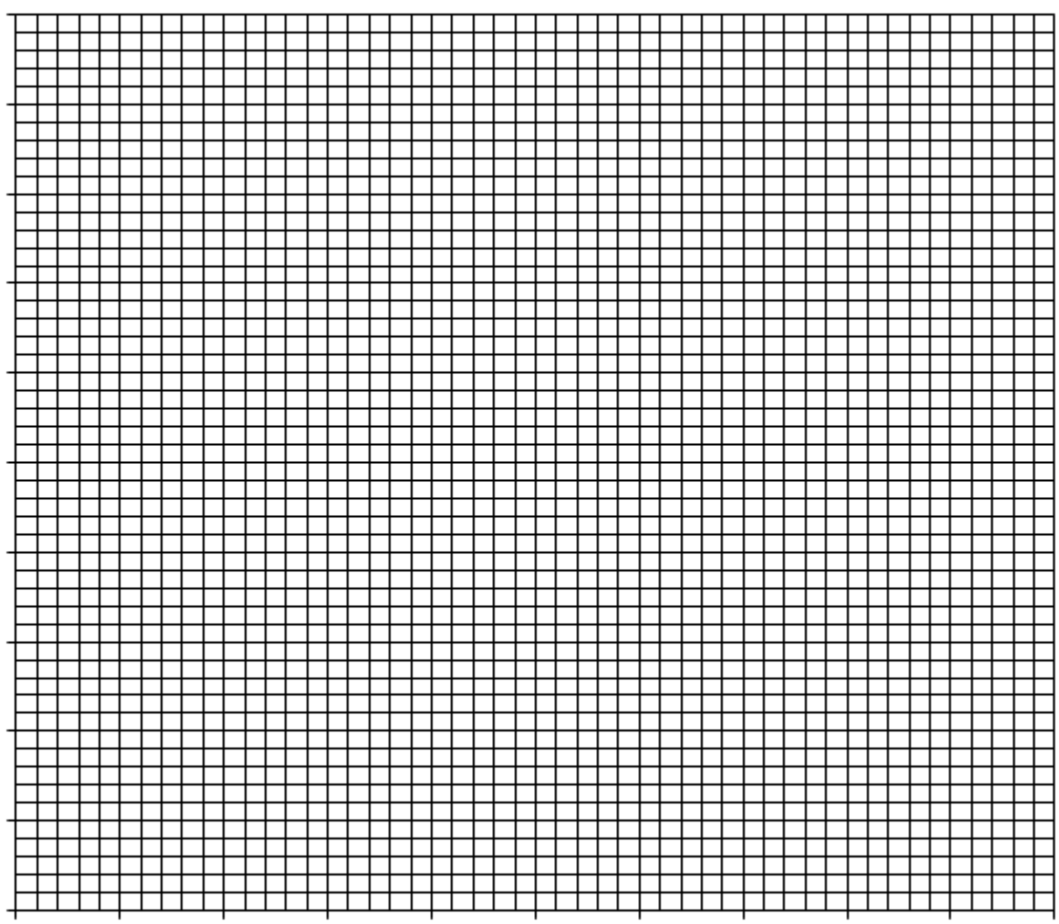
As you changed the mass, which of the graphs changed and stayed constant? Explain why they changed or stayed constant and, if they changed, briefly describe how they changed. (For example, did the slope increase, decrease or remain the same? Did constant values increase decrease or remain the same?)

Investigation 1.3

Find the average acceleration (a) and the average applied force in each case. Record them in the following table, along with the mass of the cart and the sum of the cart + hanger mass.

m_c (kg)	a (m/s^2)	Average applied force (N)	$m_c + m_h$ (kg)	$\frac{1}{m_c + m_h}$ $(\frac{1}{kg})$

Investigation 1.4 Choose the appropriate quantity to graph vs. the acceleration to produce a straight line. Graph the acceleration, a, vs. that quantity. Label the axes with the name of the quantity being graphed, the units and the numerical values, using an appropriate scale for each axis.



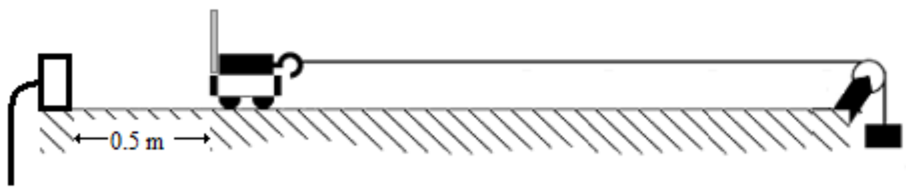
Investigation 1.5 Calculate the slope of the line, including uncertainty. Discuss an appropriate way to estimate the uncertainty in the slope.

Investigation 1.6 Remember the physical quantity represented by the slope. Compare the slope to your measured value of that quantity. Are the values in agreement within the uncertainty?

Investigation 2 Accelerating cart with different driving force and constant total mass

Investigation 2.1 Procedure

1) Set up the ramp, pulley, cart, string, motion detector, and force probe as shown in the following figure. Mount the white card on the cart, so that the motion detector can recognize it.



2) Use the balance to measure the weight of the cart and the force probe together (m_c).

3) Use 10g of mass as the hanging mass (m_h).

4) Open the experimental file called "Acceleration and Mass (L05A2-1)" to display the axes below.

5) Calibrate the force probe with 2 N pull using one point calibration. (Click on Menu Bar → Experiment → Calibrate)

6) Zero both the force probe and the motion detector. (Click on Menu Bar → Experiment → Zero)

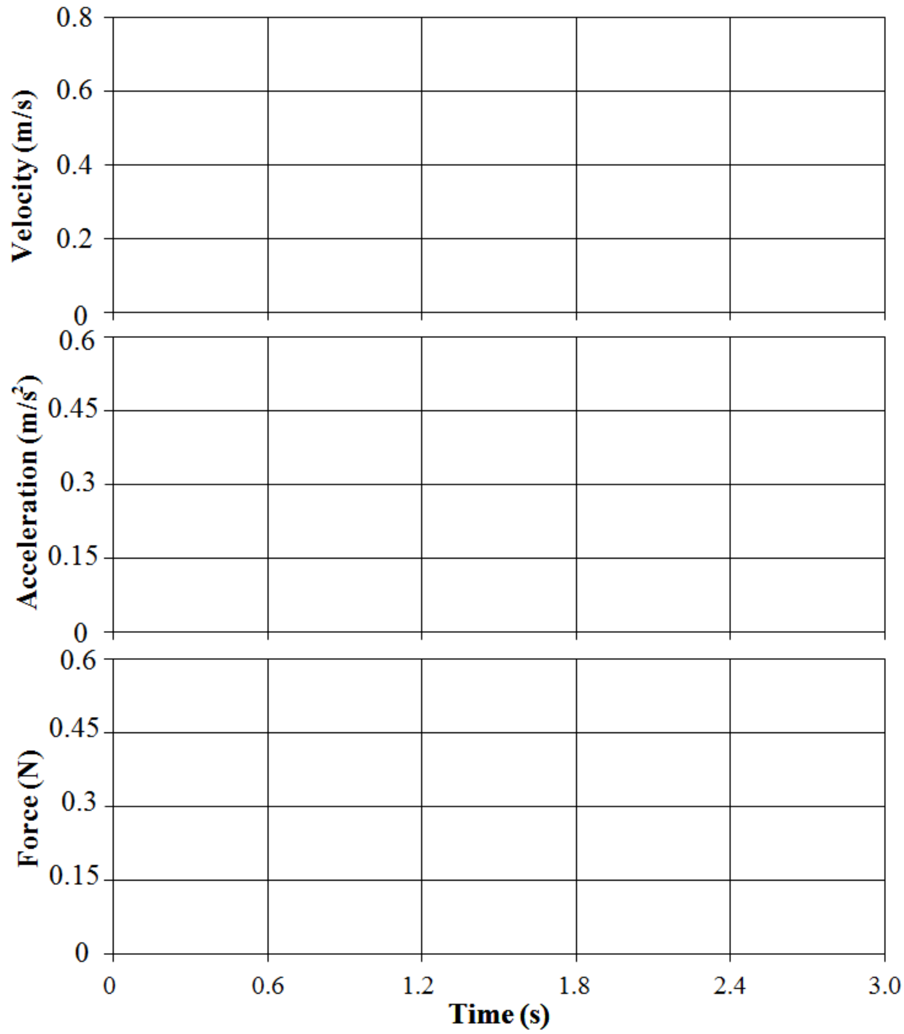
7) Add 1000g to the cart in such a way that you will be able to remove 10g at a time. With 1000g on the cart and 10g on the hangar, release the cart and start recording data. Store the data. (Click on Menu Bar → Experiment → Store Latest Run).

8) Remove 10g from the cart and put it on the hanging mass. (You will now have 990g on the cart and 20g on the hanger.) Release the cart and record and store the data.

9) Repeat step (8) three more times. The last run will have 50g on the hangar and 960g on the cart. Record and store the data each time.

Investigation 2.2

Sketch one set of the data on the following graph.

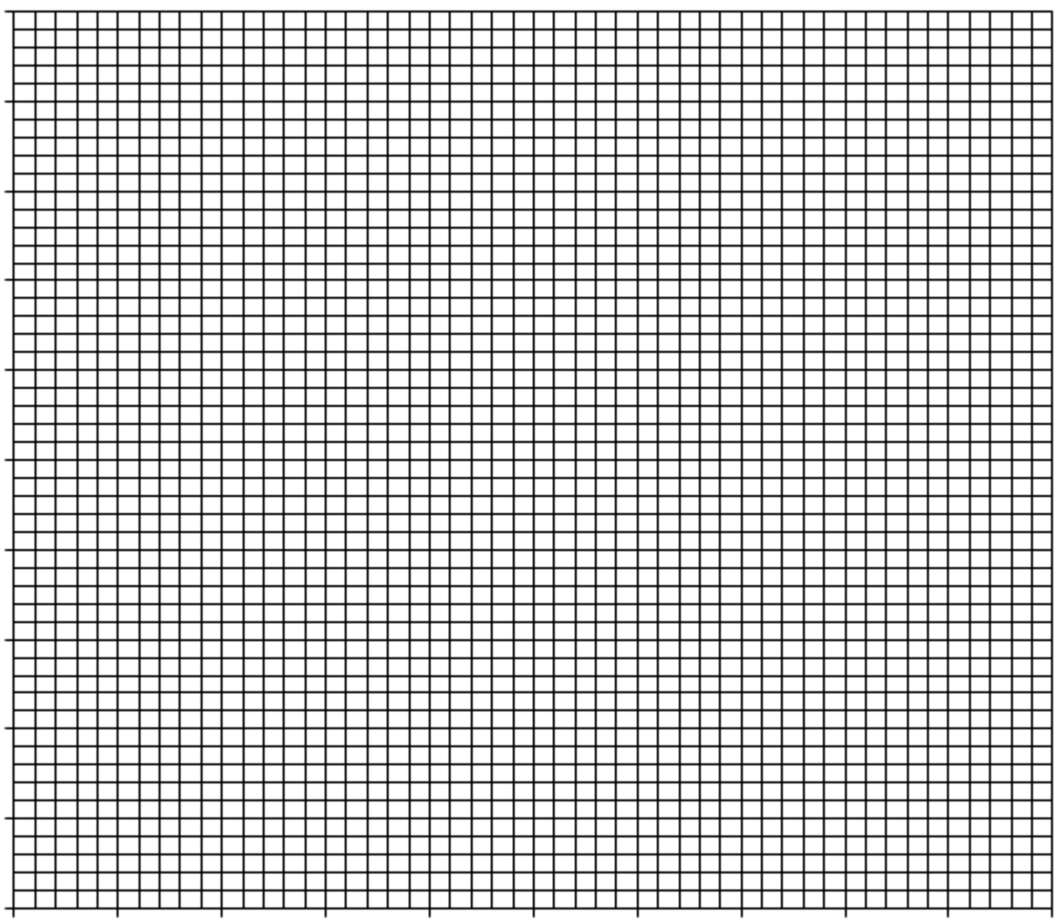


As you moved mass from the cart to the hanger, increasing the applied net force, which of the graphs changed or stayed constant? Explain why they changed or stayed constant and, if they changed, briefly describe how they changed. (For example, did the slope increase, decrease or remain the same? Did constant values increase decrease or remain the same?)

Investigation 2.3 Find the average acceleration, a, and the average applied force in each case and record them in the following table.

m_c (kg)	m_h (kg)	$m_c + m_h$ (kg)	$a\ (m/s^2)$	Average applied force (N)

Investigation 2.4 Choose the appropriate quantity to graph vs. the net applied force to produce a straight line. Graph the net force vs. that quantity. Label the axes with the name of the quantity being graphed, the units and the numerical values, using an appropriate scale for each axis.



Investigation 2.5 Calculate the slope of the line, including uncertainty. Discuss an appropriate way to estimate the uncertainty in the slope.

Investigation 2.6 Remember the physical quantity represented by the slope. Compare the slope to your measured value of that quantity. Are the values in agreement within the uncertainty?