

Name: _____

Date: _____

Newton's Second Law Prelab

Instructions: Prepare for this lab experience by answering the following questions. Note that this is a PreLab, and that PreLabs must be turned in at the start of the lab period. Time will not be given in lab to perform PreLab activities; after the start of lab activities, PreLabs will not be accepted. In the *Student Lab Handbook* (see <http://www.phy.ilstu.edu/slh/>), read the following sections and then answer the questions below. Restrict your responses only to the space provided; think carefully before you write.

- *Dimensional Analysis*
- *Physical Interpretations and Graphical Analysis*
- *Glossary of Technical Terms and Concepts (see fundamental units & derived units)*

1. Define force, mass, and acceleration and give the MKS units for each.
2. From your experiences, is acceleration proportional to the force applied on a given object?
3. From your experiences, is acceleration proportional to the mass of an object for a given force?
4. Mass is said to be arbitrarily defined in terms of the unit kilogram. What is a kilogram?
5. Are force and acceleration arbitrarily defined in the same way that mass is arbitrarily defined?
6. Are force, mass, and acceleration fundamental or derived units? Which is which? How do you know?

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Newton's Second Law Lab Guidelines

Objectives: To demonstrate experimental competence, the student will determine the...

- relationship between acceleration and force in a constant mass system
- relationship between acceleration and mass in a constant force system
- relationship between arbitrary combinations of mass, force and acceleration using dimensional analysis.
- proportionality constant, k , for the relationship derived from dimensional analysis.

I. The student will determine the relationship between acceleration and force in a constant mass system.

- a. Using a dynamics cart on a track, determine a qualitative relationship between the acceleration of that cart and the force applied to it. Hint: Don't look at the numbers, look for the trends.

Q1. Expressed in words, what is the relationship between the acceleration of the cart and the force applied to it? (Place your response to this question and all other questions on the answer sheet.)

- b. Using a dynamics cart on a track and a photogate with picket fence, determine quantitatively the algebraic relationship between acceleration and force. Be certain to hold the mass in your experimental system constant. You need not measure the mass of your system at this time.
- c. Using *Graphical Analysis*, determine the mathematical relationship between acceleration of the cart and the applied force.

Q2. What is the algebraic relationship between acceleration and applied force in this particular system?

- d. Using your control over the curve-fitting capacity of *Graphical Analysis*, determine the physical relationship between acceleration and force (e.g., if force equals zero, what should acceleration equal according to your relationship?) If the relationship is not linear, linearize it. Label the linearized output **Graph 1**. Include with your lab report.

Q3. What is the physical relationship between the acceleration and applied force in this particular system?

II. The student will determine the relationship between acceleration and mass with a constant force in a given system.

- a. Using a dynamics cart on a track, determine a qualitative relationship between the acceleration of that cart and its mass with a constant force applied to it. Note: Accelerations calculated with photogates are somewhat imprecise. Make several readings and average them.

Q4. Expressed in words, what is the relationship between the acceleration of the cart and the force applied to it? (Place your response to this question and all other questions on the answer sheet.)

- b. Using a dynamics cart on a track and either an acoustical motion detector or a photogate with picket fence, determine quantitatively the algebraic relationship between acceleration and mass. Be certain to maintain a constant force in your experimental system constant. You need not measure the force on your system at this time. Note: Accelerations calculated with photogates are somewhat imprecise. Make several readings and average them.
- c. Using *Graphical Analysis*, determine the mathematical relationship between acceleration of the cart and the mass.

Q5. What is the algebraic relationship between acceleration and mass in this particular system?

- d. Using your control over the curve-fitting capacity of *Graphical Analysis*, determine the physical relationship between acceleration and mass (e.g., if force equals zero, what should acceleration equal according to your relationship?) If the relationship is not linear, linearize it. Label the linearized output **Graph 2**.

Q6. What is the physical relationship between the acceleration and applied force in this particular system?

III. The student will determine the relationship between arbitrary combinations of mass, force and acceleration using dimensional analysis.

- a. It should be clear from the work associated with objectives I and II that acceleration is a function of force in a constant mass system, and that acceleration is a function of mass in a constant force system. Now, it is required that you find the relationship between all three variables in an arbitrary system.
 - b. Using dimensional analysis, find the relationship between a , F , and m . When responding to question 7 below, show all work.
- Q7.** Demonstrate the relationship between a , F , and m using dimensional analysis assuming from your experience that $a = f(F, m)$. Note that your theoretical relationship will contain a proportionality constant that should be labeled k .

IV. The student will find the proportionality constant, k , for the relationship derived from dimensional analysis.

- a. You now find yourself in the position of having to find a relationship between three variables using a two-dimensional graphing technique.
- Q8.** How do you propose to resolve the above problem? Hint: If a is proportional to b , and a is also proportional to g , then a must be proportional to the product of bg .
- b. Prepare your graph using suitable combinations of variables. Linearize the graph if the relationship is not linear. Find the physical relationship including the proportionality constant, k .
- Q9.** What value and units did you get for your proportionality constant?
- Q10.** The value of the proportionality constant is, by definition, 1.000. If you did not get this value, what is your percent error? Show all work.

Q11. If you achieved an error of more than 1%, explain the source of the error. Do not state human errors such as carelessness.

Q12. What is the experimentally determined relationship between a , F , and m ?