Physics 211R: Lab Report Template
Force and Motion Myths - Newton's Second Law

PRINT THESE PAGES (p. 1-2) WHEN YOU BEGIN AND INCLUDE IN YOUR REPORT

Warm-Up (Part 1): Force, Acceleration and Velocity Relationships

Q1. State the relationships between these concepts.

x ⟷ **v** ⟷ **a** ⟷ $\mathbf{F_{net}}$

Part 1A: Force, Acceleration and Velocity Relationships

Consider the following scenarios involving a block on a horizontal surface. Forces may be exerted on the block in any direction, but it never leaves the surface (so $a_z = 0$).

For each scenario, draw three arrows on each block to correspond to the direction of the velocity, acceleration, and *net* force on the object in each situation. To help distinguish the arrows, use a dashed line for velocity and be sure to label each arrow with "**v**", "**a**" or "$\mathbf{F_{net}}$". If one or more of these quantities is zero, write that above the box (e.g., "**v** = 0").

Q2. The object is at rest for more than an instant

Q3. The object is moving to the right at constant velocity

Q4. The object is moving to the left at constant velocity

Q5. The object is moving to the right and is slowing down

Q6. The object is moving to the left and is speeding up

Q7. The object is moving to the right and is speeding up

Q8. For the block below, you know the velocity at that instant (as shown below). Draw the direction of the acceleration & net force.

Q9. For the block below, you know the net force at that instant (as shown below). Draw the direction of the velocity and acceleration.

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Q10. What can you conclude about the directions of **v**, **a**, and $\mathbf{F_{net}}$ in general?

Part 1B: The One-Dimensional Kinematics Laboratory - Revisited

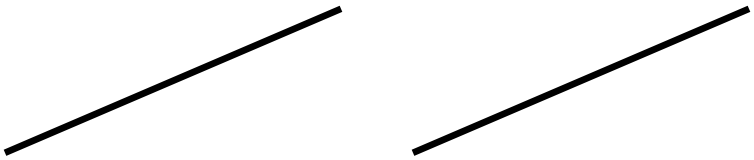
In the "One-Dimensional Kinematics" Laboratory, you had a 500 g cart roll down an inclined plane (with a small angle of incline), and then allowed it to bounce off the bottom several times. You used a motion sensor (at the top of the ramp) to record its motion. On page 2 is a velocity graph from this experiment; use it for questions 11-13.

Q11. What was the net force acting on the cart at t = 2 seconds?

Q12. What was the net force acting on the cart during its first bounce off the end of the track? (Hint: the sample rate given on the graph is important information!)

Q13. If you look very closely at the graph between 3.6 to 7.4 seconds, you will see that it's not a straight line – it has a kink in it. (You will see the same kink from 7.6 to 10 seconds, as well.) Draw a free-body diagram for the cart going up & going back down the track & use them to explain the kink in this graph.

GOING UP TRACK GOING DOWN TRACK



Check with an instructor before continuing.

Q14. To prepare yourself for the investigations you are doing today, draw a free-body diagram for the cart for the setup you will be working with in your investigations today.

Force and Motion Myths (Newton's Second Law)

Despite motion being something that we have done all our lives (or perhaps because of it), there are many "myths" out there about forces and motion. To resolve the issue once and for all, a crack team of physics students – your group! – has been assembled to test these myths and separate the valid statements from those that are just not true (busted!). And for those statements that are not correct, to come up with a statement that is correct. The four statements you have been given to investigate are:

(1) A constant (non-zero) net force causes constant velocity motion.
(2) An object's velocity is always proportional to the force acting on it at that instant.
(3) An object can move in the opposite direction of the net force acting on it.
(4) As you decrease the magnitude of the net force acting on an object in the direction of motion, the object may keep speeding up.

To test these myths, you have a cart on a level track (be sure to level it) to which you can attach a string with a hook that hangs over a pulley at the end of the track, as shown below. You can vary the weight hanging from the hook or instead attach a chain to cart. The cart has a force probe (a black box with a cable) secured to it. ***Be very careful to make sure that the cart never hits the pulley.***

You will be doing three activities:

Part 1: Warm-up: Prepare yourself for your myth-testing challenge by looking at force, velocity, and acceleration relationships, including revisiting the 1D Kinematics lab from earlier this semester.

Part 2: Myth-testing! (*The bulk of your time today will be spent on this part*.)

Part 3: Cool-down: A prediction challenge

Your challenges today all stem from the relationships among these four quantities:

Position ($\boldsymbol{x}$)
Velocity ($\boldsymbol{v}$)
Acceleration ($\boldsymbol{a}$)
Net Force ($\boldsymbol{F}_{net} = \Sigma\, \boldsymbol{F}$)

so refreshing your memory of them is a very good place to start:

Force and Motion Myths (Newton's Second Law)

Reading: HRW Chapter 5, sections 4-6.
Knight: Chapter 5, sections 4-7.

Conceptual Understanding Goals: By the end of this laboratory, you should be able to:

(1) Articulate the relationships between net force, velocity, and acceleration of a system.
(2) Be able to use free-body diagrams and Newton's Second Law to analyze the motion of objects.

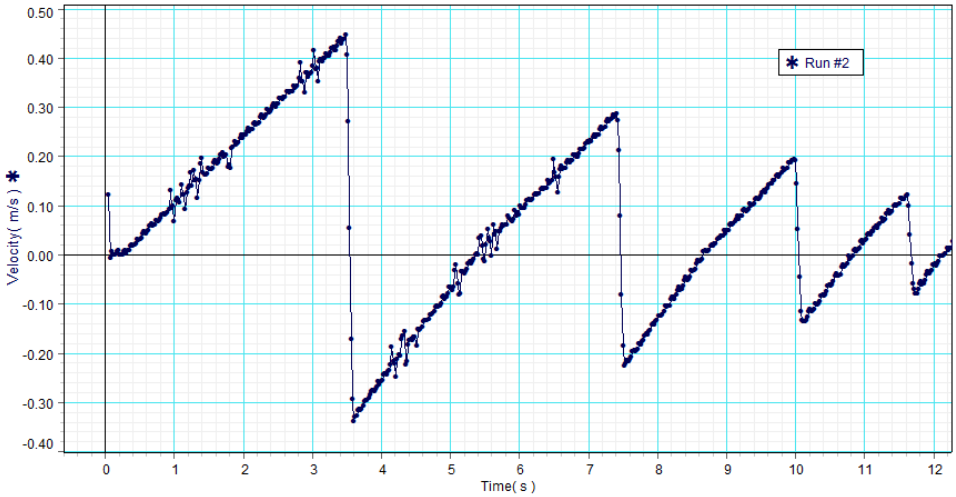
Laboratory Skill Goals: By the end of this laboratory, you should be able to:

(1) Use a force probe to measure the force acting on an object as a function of time.
(2) Design an experiment to test an idea and marshal data from the experiment to make a compelling case about the veracity of the idea.
(3) Graph experimental data in Microsoft Excel

Equipment List:

Computer with Data Studio™ and ScienceWorkshop 750 Interface
Low friction track (1.2 meter) with pulley at one end
Ultrasonic Motion Detector
500 g dynamics cart with force probe attached
String with hook at one end (for hanging masses)
String with chain at one end
Hanging mass set
Level

Graph for Questions 11-13 (50 Hz sampling rate)



Part 2: Motion Myths(?) – Busted?

The possible "myths" that you will be testing and be called upon to state whether they are true (confirmed) or false (busted) are the following:

(1) A constant (non-zero) net force causes constant velocity motion.
(2) An object's velocity is always proportional to the force acting on it at that instant.
(3) An object can move in the opposite direction of the net force acting on it.
(4) As you decrease the magnitude of the net force acting on an object in the direction of motion, the object may keep speeding up.

To test these myths, you have a cart on a level track (be sure to level it) to which you can attach a string with a hook that hangs over a pulley at the end of the track, as shown below. You can vary the weight hanging from the hook or instead attach a chain to cart. The cart has a force probe (a black box with a cable) secured to it. ***Be very careful to make sure that the cart never hits the pulley.***

Connect your motion sensor and your force probe to your ScienceWorkshop interface (motion sensor to Dig 1&2 and force probe analog port A). Then set up the probes in DataStudio (use a sampling rate of 50 Hz for both sensors).

Always zero (tare) your force meter (with NO MASS attached) before each experiment. *After you tare the first time hang a 50 g mass and check the measured force. If it does not equal 0.5 N please ask your instructor for help.*

You need to perform experiments and collect data that you can use to convincingly address the four statements above. Think strategically about what experiment you could do to test these statements and what evidence you could connect.

For each statement:

(a) Attach any relevant graphs below the appropriate statements
(b) ***Explain fully how the graphs you have provided address the statements (and what they say about the statements)!***
(c) For statements you have deemed false (busted!), write a corrected statement – what should the statement say to be correct?
(d) Explain what Newton's Second Law (and 1D kinematics) say about this statement

This activity will be graded based on the quality of the arguments you can make based on your data.

Note: The force probes may be set up to read "pulls" as negative and thus your force values may be negative.

Q15. Statement 1: A constant (non-zero) net force causes constant velocity motion

Q16. Statement 2: An object's velocity is always proportional to the force acting on it at that instant.

Q17. Statement 3: An object can move in the opposite direction of the net force acting on it.

Q18. Statement 4: As you decrease the magnitude of the net force acting on an object in the direction of motion, the object may keep speeding up.

CHECK WITH AN INSTRUCTOR AT THIS POINT

Cool-Down (Part 3): What is the mass of the cart (with force probe)?

Q19. You've been working with the cart with force probe for this lab. Using at least four different masses on the hanger, determine the average force acting on the cart and the cart's average acceleration, and put your data in the table below. (You may use any experimental runs you have already done to populate this table, but you may need to collect additional data.)

	Average Acceleration (m/s^2)	Average Force (N)
1		
2		
3		
4		
5		

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Q20. Graph your data (Force vs acceleration) in Microsoft Excel [see directions on website if you have not graphed on Excel before] using a scatter plot (showing data point and with no line connecting the points). Then do a linear fit to your data. Attach your graph below. What aspect of this graph gives you a prediction for the mass of your cart-force probe system [i.e., what parameter in the linear fit corresponds to the mass]? And what is this predicted value for the mass?

Linear fit: $y(x) = ax + b$

Q21. Now determine its mass using the scale in the room. What did you measure? Comment on how close you were and suggest any plausible reasons for differences you found (vague statements like "human error" are not acceptable responses). [If you claim that the error is friction, explain whether would change the slope or y-intercept (or both) of your Force vs Acceleration graph.]

Q22. To save time, a classmate suggests that when finding the mass of the cart, one measurement would have been sufficient. What are some arguments for or against this choice in terms of values such as responsibility in research, beneficence (a duty to help others), nonmaleficence (a duty not to harm others), fairness, loyalty to a group, respect for authority, or purity of scientific results?

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