Name:

Partner:

Block:

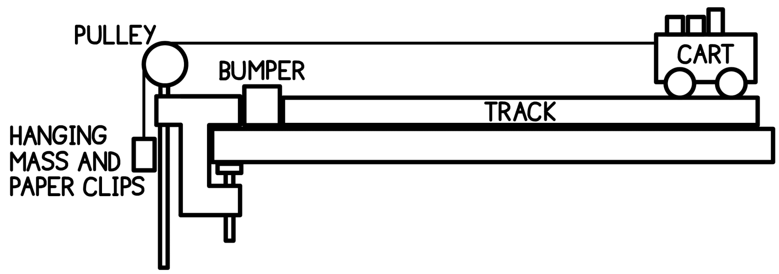
Physics 12
M. Lam

Verifying Newton's Second Law

Objective
Verify the two statements of Newton's second law:
1. the acceleration is directly proportional to the net force
2. the acceleration is inversely proportional to the mass

Equipment
cart
low-friction track
table clamp pulley
bumper (rubber stoppers)
hooked weights
paper clips
string
stopwatch
electronic balance

Apparatus



Introduction
In this lab, a cart of mass *M* will be connected to a hanging mass *m* with a string as shown in the apparatus diagram above. Starting from rest, the cart will travel a set distance *d* and the time *t* will be measured.

1. Draw a free body diagram for system consisting of the cart and hanging mass. Make the following assumptions: 1) the string and pulley are massless and 2) there is no friction at any part in the system.

2. Determine the net force on the system in terms of *M, m* and *g*.

3. Determine the acceleration of the system in terms of *d* and *t*.

Experimental Method

1. Use an electric balance to determine the mass of the cart and record this in Table 1.

2. Level the track. The cart should remain at rest and not drift to either side when placed on the track.

3. Set up the track, cart and pulley with a bumper to prevent the cart from hitting the pulley at the end of its run.

4. Add the following masses to the bed of the cart: 10 g, 50 g and two 20 g masses. You may wish to use a small amount of tape to keep the masses from falling off during the lab.

5. Attach one end of the string to the cart. Drape the string over the pulley. Position the pulley at a height such that the string is parallel to the surface.

6. Adjust the length of the string so that the longest arrangement of masses that you intend to use will not hit the floor before the cart has reached the end of its run. Tie a loop on this end of the string.

7. Hang enough paper clips onto the dangling loop in the string until the cart will just continue to move without apparent acceleration when barely nudged. This small added mass will compensate for friction in the system and will be ignored when calculating the hanging mass. The paper clips will remain attached to the loop throughout the experiment.

8. Clearly mark a point at which the cart will start. Determine the distance d that the cart will move from the starting point to the bumper block and record this distance in Table 1.

<u>Part 1: Keeping the mass of the system constant while changing the hanging mass</u>

9. Move a 10 g mass from the bed of the cart to the hanging loop and pull the cart back to the marked starting point. *Note that the total mass of the system will remain constant throughout the experiment. All the other masses should still be on the bed of the cart.*

10. Practice releasing the cart being careful not to give it any push or pull as you do so. The best way to do this is to press your finger into the table in front of the cart thereby blocking its movement. Quickly pull your finger away in the direction that the cart wants to move. At the instant you pull your finger away, start your stopwatch. Stop your stopwatch at the instant the cart arrives at the bumper. To minimize reaction time uncertainty, it is best that the person who releases the cart also does the timing.

11. Determine the average time for the cart to move through the distance d having been released from rest. Record the average of the four time trials in which you have the most confidence in Table 2.

12. Repeat for all of the masses given in the Table 2. *To change the hanging mass, transfer masses to and from the cart to keep the mass of the system constant.*

<u>Part 2: Keeping the hanging mass constant while changing the mass of the system</u>

13. Remove all masses from the cart.

14. Hang a 50 g mass from the loop. Record this mass in Table 1.

15. Determine the average time for the cart to move through the distance d having been released from rest. Record the average of the four time trials in which you have the most confidence in Table 3.

16. Add masses to the bed of the cart and repeat for all of the masses given in Table 3. *To change the cart mass, add masses not already part of the system.*

Table 1: Constants for Parts 1 and 2

Distance that cart travels *d*	
Mass of cart	
Total mass of system for Part 1	
Hanging mass for Part 2	

Table 2: Results for Part 1 in which the hanging mass is varied while the mass of the system is kept constant

Hanging mass (g)	**Net force on system (N)**	**Average time to travel distance *d* (s)**	**Acceleration of system (m/s^2)**
10			
20			
30			
40			
50			
60			

Table 3: Results for Part 2 in which the mass of the system is varied while the hanging mass is kept constant

Mass added to cart (g)	**Total mass (kg)**	**Total mass^{-1} (kg^{-1})**	**Average time to travel distance *d* (s)**	**Acceleration of system (m/s^2)**
0				
100				
200				
300				
400				
500				
600				

Analysis and Discussion

Part 1: Relationship between acceleration and net force

- Complete Table 2 by calculating the net force and acceleration of the system for each trial. **Do not use $F_{net} = ma$ when filling out the table. You cannot verify a law with circular reasoning.**
- Use Table 2 to plot a graph of acceleration (on the vertical axis) as a function of net force (on the horizontal axis).
- Comment on how the graph supports Newton's second law.
- Determine the slope of the best fit line. If graphing by hand, clearly mark the points on the line used to calculate the slope (e.g. with an ×).
- Use the slope to write an equation for the relationship between acceleration and net force. Write the equation with appropriate variables.
- Determine the theoretical value for the slope. Justify your answer.
- Compare the experimental value for the slope for the graph with the theoretical value. Determine the percent error.

Part 2: Relationship between acceleration and mass

- Complete Table 3 by calculating mass^{-1} (i.e. 1/mass) and the acceleration of the system for each trial. **Do not use $F_{net} = ma$ when filling out the table. You cannot verify a law with circular reasoning.**
- Use Table 3 to plot a graph of acceleration (on the vertical axis) as a function of total mass^{-1} (on the horizontal axis).
- Comment on how the graph supports Newton's second law.
- Determine the slope of the best fit line. If graphing by hand, clearly mark the points on the line used to calculate the slope (e.g. with an ×).
- Use the slope to write an equation for the relationship between acceleration and mass. Write the equation with appropriate variables.
- Determine the theoretical value for the slope. Justify your answer.
- Compare the experimental value for the slope for the graph with the theoretical value. Determine the percent error.

Discuss the sources of error.

Component	**Criterion**	**Weight**	**Mark**
General	*Complete word-processed lab report with proper structure and formatting*	1	
Data	*Data quality and presentation*	2	
Analysis and Discussion	*Plot of acceleration vs. net force and a statement about how the graph supports Newton's second law*	1	
	Slope of the acceleration vs. net force graph with correct units	1	
	Theoretical slope of the acceleration vs. net force graph and percent error	1	
	Plot of acceleration vs. mass^{-1} and a statement about how the graph supports Newton's second law	1	
	Slope of the acceleration vs. mass^{-1} graph with correct units	1	
	Theoretical slope of the acceleration vs. mass^{-1} graph and percent error	1	
	At least two significant sources of error	1	
TOTAL		10	