Name:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Team members:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Teacher’s Guide by Bob Bessin

**Forces and Motion Simulation Lab**

Let’s investigate the relationship between mass, force and acceleration.

![MC900391040[1]]()

**Apparatus:**

* Forces and Motion: Basics Simulation from Phet: <http://phet.colorado.edu/en/simulation/forces-and-motion-basics>
* Stopwatch

**Discussion:**

Airplanes accelerate from rest on a runway until they reach takeoff velocity. Cars accelerate from a stop sign until they reach cruising velocity. And when they come to a stop, they accelerate negatively. How do mass and force affect these accelerations? And how does friction play a role in acceleration?

In this experiment you will accelerate various objects. First, you will apply the same force to carts of different masses. Then, you will apply varying forces to the same mass. A relationship between mass and acceleration should be found. Finally, you will find the effect that friction has in these situations.

**Procedure:**

Work in pairs, one computer for each pair of students. Open up the University of Colorado, PhET "Forces and Motion" simulation

<http://phet.colorado.edu/en/simulation/forces-and-motion-basics>

Click on the Friction Tab and check all the boxes in the upper right hand corner (Forces, Sum of Forces, Values, Masses, Speed). Spend a few minutes familiarizing yourself with the controls of the simulation before you begin the lab.

**Part 1: Constant Force, Changing Mass**

* 1. Place one of the 50 kg boxes in the center of the track. Move the friction bar to “None”. Set the Applied Force box by entering 100 Newtons. You will start the force at the same time you start the stopwatch. You can do that by using the return key on the Simulation and the cursor on the stopwatch.
	2. You will allow the crate to accelerate to 40 m/s of velocity, which is full scale for the speedometer. Stop the stopwatch when the speed equals 40 m/s. Practice accelerating the carts a few times to ensure proper timing.
	3. When you get a run that you think is accurate, find the acceleration based on the change in velocity Δv and the change in time Δt (you know how to do that from Chapter 2!)
	4. Do the same procedure for masses of 100 kg (two crates), 200 kg (refrigerator) and 300 kg (fridge and two crates). Enter the results in Data Table A

Data Table A

|  |  |  |  |
| --- | --- | --- | --- |
| Mass | Push Force | Time to 40 m/s | Acceleration |
|  50 kg | 100N | 20 sec | 2 m/s/s |
| 100 kg | 100N | 40 sec | 1 m/s/s |
| 200 kg | 100N | 80 sec | 0.5 m/s/s |
| 300 kg | 100N | 120 sec | 0.33 m/s/s |

Note: Timing and accelerations may vary some. Use the values that are calculated

5. Using graph paper, make a graph of acceleration (vertical axis) vs. mass (horizontal axis). Attach the graph to this lab report.

**Analysis:**

1. Describe your graph of acceleration vs. mass. Is it a straight line or a curve?

The graph slopes downward at a decreasing rate. It is a curve (inverse function or inverse relationship).

2. How does increasing mass affect the system’s acceleration?

Increasing mass reduces the systems acceleration.

3. Using your data and graph from Steps 1-5, predict what mass on the cart would be needed to accelerate the cart by 0.75 m/s/s, using the same force. Write it here: \_\_\_133.3\_\_\_\_ kg

**Part 2: Constant Mass, Changing Force**

1. Place the 50 kg box the center of the track. Move the friction bar to “None”. Set the Applied Force box by entering 100 Newtons. Again, you will start the force at the same time you start the stopwatch.
2. Again, you will allow the crate to accelerate to 40 m/s of velocity, which is full scale for the speedometer.
3. When you get a run that you think is accurate, find the acceleration.
4. Do the same procedure for the same masses, but forces of 200N, 300N and 400N. Enter the results in Data Table B

Data Table B

|  |  |  |  |
| --- | --- | --- | --- |
| Mass | Push Force | Time to 40 m/s | Acceleration |
| 50kg | 100N | 20 sec | 2 m/s/s |
| 50kg | 200N | 10 sec | 4 m/s/s |
| 50kg | 300N | 12.5 sec | 6 m/s/s |
| 50kg | 400N |  5 sec | 8 m/s/s |

Note: again timing may vary, but should be consistent.

5. Using graph paper, make a graph of acceleration (vertical axis) vs. force (horizontal axis). Attach the graph to this lab report.

**Analysis:**

1. Describe your graph of acceleration vs. force. Is it a straight line or a curve?

The change in acceleration due to changing force has the same slope at all points. It is a line.

2. How does increasing force affect the system’s acceleration?

Increasing force increases the system’s acceleration.

3. Find the slope of the graph. What does the slope represent? It is 50 Newton sec/meter, which is the mass of the system.

**Part 3: Friction**

1. Place the 50 kg box in the center of the track. Move the friction bar to “Lots”. Set the Applied Force box by entering 350 Newtons. Again, you will start the force at the same time you start the stopwatch.
2. Again, you will allow the crate to accelerate to 40 m/s of velocity, which is full scale for the speedometer.
3. When you get a run that you think is accurate, find the acceleration.
4. Do the same procedure for the same masses and friction, but force of 450N. Enter the results in Data Table C

Data Table C

|  |  |  |  |
| --- | --- | --- | --- |
| Mass | Push Force | Time to 40 m/s | Acceleration |
| 50 kg | 350N |  |  |
| 50 kg | 450N |  |  |

Time to 40m/s and acceleration will vary depending upon the level of friction chosen. In all cases the acceleration will be more for a 450N push force.

**Analysis:**

1. What force on the 50kg masses with no friction (Table B) gives the same acceleration as with 350 N and lots of friction (Table C)? What force on the 50kg masses with no friction gives the same acceleration as with 450 N and lots of friction? I have designed the numbers to come up with a net force with friction that is compatible with the push forces in Table B. Students should be able to find compatible accelerations.

2. How much do you think the force of friction must be? Why?

Students should notice that the net force gives the same acceleration, regardless of whether there is friction or not. So combinations of push and friction forces need to combine as vectors to the same net force for the accelerations to be the same. They should be able to find the force of friction based on two situations with the same acceleration, then finding the difference in the push forces between them.

**Conclusion:**

Write a short conclusion of what you have learned from this experiment.

Acceleration is proportional to the net force applied to a system, and inversely proportional to the mass of the system.

Net force is the vector combination of all forces imposed on a system, and according to Newton’s Second Law, is a factor in the acceleration of a system. One force is does not determine the acceleration of a system, but only the vector combination of all forces on that system.