Newton’s Second Law of Motion Lab

**Purpose** To determine the relationship between the force applied to an object and the motion produced by the force.

**Materials** ~2 m Track ~1.3 m length of string Pulley

20 g, 50 g, 100 g Masses Meter Stick Motion Car

Stop Watch Calculator Mass Balance

<http://somup.com/crhTrDqXN4> (0:17)

Motion cart

Mass

Pulley Unit

1.3 m string

# Procedures

1. Set up the apparatus as shown in the diagram. Set up the ~2-meter track so it has a bumper restraint so the car cannot roll off the track.

2. You will need to raise the height of the track/table (using books, blocks, etc.) so that the end of the track overhanging the lab counter is over 1 meter off the floor (use the meter stick to measure). The mass should fall 1 meter from the pulley to the floor.

3. CAREFULLY tie a **HALF** KNOT using one end of the 1.3 m length of string to the “bumper” on the motion car. DO NOT TIE A FULL KNOT.

4. Place the motion cart on track/table. Do NOT let the cart roll off the end of the track!

5. The object is to have the motion car accelerate beyond the 100 cm (1 m) mark on the track/table. We will get it to accelerate by dropping the various masses 1 meter.

6. Attach the pulley unit to the end of the track/table. The screw should be on the underside of the track.

7. Obtain the 20-gram mass and attach it to the string by the pulley so that it will fall and pull the car. This should just clear the pulley unit. The mass needs to fall a distance of 1 meter.

8. When ready time how long it takes for the car to travel 100 cm (or 1 m) … AS SOON AS IT REACHES THE BUMPER AT THE END OF THE TRACK.

9. Repeat with the 20 g mass two more times for a total of three trials.

10. REPEAT the procedures for the 50 g mass.

11. REPEAT the procedures for the 100 g mass.

12. When finished with all the trials, measure the mass of the car. (*Place the car upside down on the mass balance so it doesn’t roll off*.)

**Calculations and Data**

1. SHOW WORK with UNITS for all calculations.

2. Convert all the masses into kilograms.

3. Convert the masses of all the objects into force (Newton’s) by multiplying by 10.

BE SURE TO INCLUDE UNITS

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 20 g Mass | Distance | Time | Calculate Acceleration  a = 2d/t2 | Acceleration |
| Trial 1 | 1 m |  |  |
| Trial 2 |  |
| Trial 3 |  |
| AVERAGE |  |

Use the AVERAGE TIME to calculate the acceleration of the motion cart using the 20 g mass.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **50 g** **Mass** | Distance | Time | Calculate Acceleration  a = 2d/t2 | Acceleration |
| Trial 1 | 1 m |  |  |
| Trial 2 |  |
| Trial 3 |  |
| AVERAGE |  |

Use the AVERAGE TIME to calculate the acceleration of the motion cart using the 50 g mass.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **100 g Mass** | Distance | Time | Calculate Acceleration  a = 2d/t2 | Acceleration |
| Trial 1 | 1 m |  |  |
| Trial 2 |  |
| Trial 3 |  |
| AVERAGE |  |

Use the AVERAGE TIME to calculate the acceleration of the motion cart using the 100 g mass.

# Measuring Mass

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Lightest Mass | 2nd Lightest | Heaviest Mass | Motion Cart |
| Mass in g |  |  |  |  |
| Mass in kg |  |  |  |  |
| Force (N) |  |  |  |  |

**Enrichment**:

5. What do you notice between the acceleration you calculated using the time trials versus the acceleration you calculated using the force applied?

6. Prepare a graph of the data you calculated in the first part of this experiment. Plot the acceleration produced on the motion cart (*using the time trials*) as the dependent variable. Plot the force applied (“accelerating force”) to the motion cart as the independent. Label your graph: “Newton’s Second Law of Motion.” Draw a straight, best fit line for slope.

# Calculating Acceleration

|  |  |  |  |
| --- | --- | --- | --- |
|  | Force Applied (N) | Mass of Motion Cart (kg) | Acceleration of motion cart |
| Lightest mass |  |  |  |
| 2nd Lightest mass |  |  |
| Heaviest mass |  |  |

Copy the force applied in N from the previous chart into the chart above. Use the following equation to calculate the acceleration produced based on the mass you used.

acceleration = Force Applied (N) / Mass of the motion cart (kg) a = f / m

Lightest mass 2nd Lightest mass Heaviest mass

**Conclusions and Questions**

1. What happens to the acceleration of the motion cart as the force applied to it increases?

2. What happens to the velocity of the motion cart as the force applied to it increases?

3. Why did you have to convert the masses into kilograms?

4. If the force applied to the motion cart apparatus was 0.5 N, what would be its acceleration? SHOW WORK

**Enrichment**:

5. What do you notice between the acceleration you calculated using the time trials versus the acceleration you calculated using the force applied?

6. Prepare a graph of the data you calculated in the first part of this experiment. Plot the acceleration produced on the motion cart (*using the time trials*) as the dependent variable. Plot the force applied (“accelerating force”) to the motion cart as the independent. Label your graph: “Newton’s Second Law of Motion.” Draw a straight, best fit line for slope.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

**Final Summary**

# ANSWERS Calculations and Data

BE SURE TO INCLUDE UNITS

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Lightest Mass | Distance | Time | Calculate Acceleration  a = 2d/t2 | Acceleration |
| Trial 1 | 1 m | 2.3 s | 0.4 m/s2 |
| Trial 2 | 2.2 s |
| Trial 3 | 2.1 s |
| AVERAGE | 2.2 s |

Use the AVERAGE TIME to calculate the acceleration of the motion cart using the

a = 2d/t2 = 2 (1 m)/(2.2 s)2

= 0.4 m/s2

lightest mass. SHOW WORK to the right and then place your answer in the chart above.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **2nd Lightest** **Mass** | Distance | Time | Calculate Acceleration  a = 2d/t2 | Acceleration |
| Trial 1 | 1 m | 1.4s | 1.0 m/s2 |
| Trial 2 | 1.5s |
| Trial 3 | 1.4 s |
| AVERAGE | 1.4 s |

Use the AVERAGE TIME to calculate the acceleration of the motion cart using the 2nd lightest mass. SHOW WORK to the right and then place your answer in the chart above.

a = 2d/t2 = 2 (1 m)/(1.4 s)2

= 1.0 m/s2

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Heaviest Mass** | Distance | Time | Calculate Acceleration  a = 2d/t2 | Acceleration |
| Trial 1 | 1 m | 1.0 s | 1.7 m/s2 |
| Trial 2 | 1.1 s |
| Trial 3 | 1.1 s |
| AVERAGE | 1.1 s |

Use the AVERAGE TIME to calculate the acceleration of the motion cart using the next heaviest mass. SHOW WORK to the right and then place your answer in the chart above.

a = 2d/t2 = 2 (1 m)/(1.1 s)2

= 1.7 m/s2

# Measuring Mass

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Lightest Mass | 2nd Lightest | Heaviest Mass | Motion Cart |
| Mass in g | 20 g | 50 g | 100 g | 500 g |
| Mass in kg | 0.02 kg | 0.05 kg | 0.1 kg | 0.5 kg |
| Force (N) | .2 N | .5 N | 1 N | 5 N |

* Convert all your masses from grams into kilograms in the chart above
* Calculate the force applied by the masses in each case by multiplying the mass in kg by 10.

# Calculating Acceleration

|  |  |  |  |
| --- | --- | --- | --- |
|  | Force Applied (N) | Mass of Motion Cart (kg) | Acceleration of motion cart |
| Lightest mass | 0.2 N | 0.5 kg | 0.4 m/s2 |
| 2nd Lightest mass | 0.5 N | 1.0 m/s2 |
| Heaviest mass | 1.0 N | 2.0 m/s2 |

Copy the force applied in N from the previous chart into the chart above. Use the following equation to calculate the acceleration produced based on the mass you used.

acceleration = Force Applied (N) / Mass of the motion cart (kg) a = f / m

Lightest mass 2nd Lightest mass Heaviest mass

a = f/m

= 0.2 N / 0.5 N

= 0.4 m/s2

a = f/m

= 0.5 N / 0.5 N

= 1.0 m/s2

a = f/m

= 1.0 N / 0.5 N

= 2.0 m/s2

**Conclusions and Questions**

1. What happens to the acceleration of the motion cart as the force applied to it increases?

*As the force applied to the motion cart in this lab increases, the acceleration also increases. We observed this when the force increased from 0.2 N to 1.0 N, the acceleration increased from 0.4* m/s2 *to 2.0* m/s*2.*

2. What happens to the velocity of the motion cart as the force applied to it increases?

*As the force applied to the motion cart in this lab increases, the velocity also increases. Velocity is distance divided by time (v = d/t). The distance the motion cart traveled remained constant (~1 m), but the time decreased with added force (more mass). This was directly observed in the lab. As more mass was added, the downward force (weight) increased, and the motion cart traveled faster down the track. Velocity is a component of acceleration. In fact, acceleration is a change in velocity. Since We observed that when the force increased from 0.2 N to 1.0 N, the acceleration increased from 0.4* m/s2 *to 2.0* m/s*2, we can say that the velocity changed accordingly. If the acceleration increased, velocity must also have increased.*

3. Why did you have to convert the masses into kilograms?

*In this lab, we converted the masses from grams to kilograms so that we could use the metric unit of force, Newtons. The masses were part of the downward force (weight W = mg) pulling the cart down the track. This lab is about Newton's 2nd law which deals with force, mass and acceleration and to be consistent, kilograms are a multiple of 10 from Newtons. For instance, the 20 grams mass is actually 0.02 kilograms, representing a force of 0.2 N.*

4. If the force applied to the motion cart apparatus was 0.5 N, what would be its acceleration? SHOW WORK

*If the force applied to the motion cart (mass = 0.5 kg) was 0.5 N, the resulting acceleration would be 1.0 m/s/s. This is determined by the equation: a = f/m, derived from f = ma (Newton's 2nd law). a = f/m = 0.5 N / 0.5 kg = 1.0 N/kg = 1.0 m/s/s.*

**Enrichment**:

5. What do you notice between the acceleration you calculated using the time trials versus the acceleration you calculated using the force applied?

*The acceleration calculated using time trials was similar to the acceleration using the force applied. We observed this because our accelerations using time trials were 0.4 m/s2, 1.0 m/s2, and 1.7 m/s2, respectively as compared to 0.4 m/s2 ,1.0 m/s2, and 2.0 m/s2, respectively. We can see that 0.4 m/s2, 1.0 m/s2 are the same, and the last accelerations (1.7 m/s2 and 2.0 m/s2 are similar).*

6. Prepare a graph of the data you calculated in the scone part of this experiment. Plot the acceleration produced on the motion cart (*using the force applied*) as the dependent variable. Plot the force applied (“accelerating force”) to the motion cart as the independent variable. Label your graph: “Newton’s Second Law of Motion.”

Force (N) versus Acceleration (m/s/s)

2.0

X

1.0 N, 2.0 m/s/s

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1.5 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1.0 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | X  0.4 N, 1.0 m/s/s |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| a  m/s/s |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 0.5 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| X  0.2 N, 0.4 m/s/s |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 0 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

0

0.5

1.0

Force applied (N)

1. Use the full graph whenever possible.
2. The vertical and horizontal axis should be labeled in equal increments.
3. Be sure to label axis and put units.
4. Be sure to title the graph.
5. The line should be a “best fit” line representing the plotted points.

**Final Summary**

*This lab involved Newton's 2nd Law of motion which states that the force applied to an object is related to the object's mass and acceleration. We can express Newton's 2nd law mathematically with f = ma.*

*As the force applied to the motion cart in this lab increases, the acceleration also increases. We observed this when the force increased from 0.2 N to 1.0 N, the acceleration increased from 0.4* m/s2 *to 2.0* m/s*2.*

*As the force applied to the motion cart in this lab increases, the velocity also increases. Velocity is distance divided by time (v = d/t). The distance the motion cart traveled remained constant (~1 m), but the time decreased with added force (more mass). Velocity is a component of acceleration. In fact, acceleration is a change in velocity. Since We observed that when the force increased from 0.2 N to 1.0 N, the acceleration increased from 0.4* m/s2 *to 2.0* m/s*2, we can say that the velocity changed accordingly. If the acceleration increased, velocity must also have increased.*

*In this lab, we converted the masses from grams to kilograms so that we could use the metric unit of force, Newtons. This lab is about Newton's 2nd law which deals with force, mass and acceleration and to be consistent, kilograms are a multiple of 10 from Newtons. For instance, the 20 grams mass is actually 0.02 kilograms, representing a force of 0.2 N.*

*Possibly errors include human error as well as equipment error. For instance, groups may have used the wrong masses; others may have not time accurately; still others may have not calculated accurately. The height of the track may not have been sufficient to yield good results. For the graph, students may not have used a straight edge for the best fit line to represent the plotted points.*