**Lab Investigation: Newton’s Second Law**

**Part A**

Purpose: to determine how the acceleration of a cart depends on the net force acting on the cart if its total mass is constant.

Hypothesis:

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| If the net force acting on a cart increases while total mass remains constant, the acceleration will…\_\_\_\_\_\_\_\_\_\_\_\_\_because |

Procedure:

1. Open the “Forces Lab” simulation at <http://mattcraig.space/forces/index.html>

2. Select pulley and v-t graph.

2. Place any three masses on the cart. Run the simulation. Record the relevant information in the table provided.

3. Move one of the masses from your cart to be hanging over the side of the table with the 0.2 kg mass that was originally there. Run the simulation. Show the velocity-time graph and record the relevant information in the table provided.

4. Move another one of the masses from your cart to be with the hanging masses. Run the simulation. Show the velocity-time graph and record the relevant information in the table provided.

5. Move the last mass from your cart to be with the hanging masses. Run the simulation. Run the simulation. Show the velocity-time graph and record the relevant information in the table provided.

Results:

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| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Mass of cart (including masses sitting on cart)  (kg) | Total Hanging mass  (kg) | Total overall mass  (kg) | Initial speed (m/s) | Final speed  (m/s) | Time (s) | Experimental Acceleration (m/s2)  (a = Δv/t) | Fnet (N)  (i.e., the Force of gravity on the hanging mass)  Fg = mg | Expected acceleration (m/s2)  (Fnet/mtotal) |
|  |  |  | 0 |  |  |  |  |  |
|  |  |  | 0 |  |  |  |  |  |
|  |  |  | 0 |  |  |  |  |  |

Analysis:

1. Draw an FBD for the hanging mass. (Use the computer or insert a hand drawn image)

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2. Draw an FBD for the cart. (Use the computer or insert a hand drawn image)

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3. Considering the direction of motion to be the positive direction, write an equation expressing which forces add up to determine the net force on each of the following. (The first one is done for you)

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| The hanging mass: Fnethanging mass = Fghanging mass - Ft |
| The cart: Fnetcart = |
| The system: Fnetsystem = |

3. Construct a graph of net force (y-axis) versus acceleration (x-axis). You may either do this by hand and insert the image, or you can use a program like Google Sheets to create a scatterplot with a line/curve of best fit and take a screen capture of your result and insert it here. (There are plenty of tutorials available if you’d like to start building this skill.)

Whether your graph is done by hand or computer, it must apply all of the conventions learned in class (title, labels, units)

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4. Describe the shape of the graph of net force (y-axis) versus acceleration (x-axis). What does this result tell you about the relationship between net force and acceleration?

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5. What is the slope of this graph? (If graphing using the computer, use the function that gives you the equation of the line to get the slope value. If working by hand, show your method below). What does this slope represent?

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Conclusion:

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| As the net force on a system increases while its total mass remains constant, the acceleration of the system will |

**Part B**

Purpose: to determine how the acceleration of a cart depends on the mass of a system when the net force acting on the system is constant.

Hypothesis:

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| If the mass of a system of objects increases while the net force on the system remains constant, the acceleration will \_\_\_\_\_\_\_\_\_\_\_\_\_ because |

Procedure:

1. Open the simulation at <http://mattcraig.space/forces/index.html>

2. Select pulley and v-t graph.

2. Place any three masses on the cart. Run the simulation. Record the relevant information in the table provided.

3. Remove one of the masses from your cart. Run the simulation. Show the velocity-time graph and record the relevant information in the table provided.

4. Remove another one of the masses from your cart. Run the simulation. Show the velocity-time graph and record the relevant information in the table provided.

5. Remove the last mass from your cart. Run the simulation. Show the velocity-time graph and record the relevant information in the table provided.

Results:

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Mass of cart (including masses sitting on cart)  (kg) | Total Hanging mass  (kg) | Total overall mass  (kg) | Initial speed (m/s) | Final speed  (m/s) | Time (s) | Experimental Acceleration (m/s2)  (a = Δv/t) | Fnet (N)  (i.e., the Force of gravity on the hanging mass) | Expected acceleration (m/s2)  (Fnet/mtotal) |
|  | 0.2 |  | 0 |  |  |  | 2.0 |  |
|  | 0.2 |  | 0 |  |  |  | 2.0 |  |
|  | 0.2 |  | 0 |  |  |  | 2.0 |  |

Analysis:

1. Construct a graph of acceleration (y-axis) versus mass (x-axis). Take an image or screen capture (depending on your method of producing the graph) of your graph and insert it here.

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2. Describe the shape of your graph. What does this tell you about the relationship between acceleration and mass?

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3. Construct a graph of acceleration (y-axis) versus the reciprocal of mass (x-axis). Take an image or screen capture of your result and insert it here.

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4. What is the slope of this graph? What does the slope of this graph represent?

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Conclusion:

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| As the mass of a system increases while the net force on the system remains constant, the acceleration of the system will \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ |

**Part C**

Purpose: to determine how friction will affect the acceleration of the cart-pulley system.

Hypothesis: *Highlight the word(s) you believe best describe what you expect to happen.*

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| If the cart experiences friction as it is pulled along the surface, the net force on the system will (increase, decrease, stay the same) and the acceleration of the system will (increase, decrease, stay the same). |

Procedure:

Arrange your set-up with the exact same set-up as you had in your last row of Part A but insert some friction into the situation by adjusting the slider for friction at the bottom of the screen.

Results:

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| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Number on the friction slider | Mass of cart (including masses sitting on cart)  (kg) | Total Hanging mass  (kg) | Fg (N) on the hanging mass  Fg = mg | Total overall mass  (kg) | Initial speed (m/s) | Final speed  (m/s) | Time (s) | Experimental Acceleration (m/s2)  (a = Δv/t) |
|  |  |  |  |  |  |  |  |  |

Analysis:

1. What do you notice about the experimental acceleration in this situation with friction versus the acceleration you observed for this set up without friction in part A? Is this what you expected?

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2. Use the theory you have been practicing throughout this unit to determine the coefficient of friction between the cart and the surface for the situation you created. Include the necessary FBDs and clear communication of all steps. (Note: I would categorize this as a higher level, multi-step problem.)

Insert an image of your completed work below.

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Conclusion:

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