Phys1111: Changes in Energy and Momentum

Name:

Group Members:

Date:

TA’s Name:

Learning Objectives:

1. Understanding the relationship between force, distance and changes in kinetic energy.
2. Understanding the relationship between force, time and changes in momentum.
3. Understanding the relationship between force and work.
4. Understanding the relationship between force and impulse.

Apparatus: Aluminum track, track legs, smart cart with cart fan, two cart stops, and four 100g masses.

Part A: Predictions

Before setting up the equipment, consider the situation shown above (call this case #1). The cart (mass \( m \)) starts from rest a distance \( d \) from the cart stop. The fan is used since it provides a \textit{constant force} as the cart moves to the right and collides with the cart stop. Just before the collision the cart is moving with velocity \( v_f \).

1. Identify the forces on the cart when the fan is running. Then draw the free body diagram for the cart. Indicate the direction of the net force and acceleration next to the free body diagram.

\begin{itemize}
\item \textbf{List of Forces}
\end{itemize}

\begin{itemize}
\item \textbf{net force vector}
\item \textbf{acceleration vector}
\end{itemize}
2. Draw your prediction for the velocity vs. time graph for case #1.

<table>
<thead>
<tr>
<th>Velocity (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (s)</td>
</tr>
</tbody>
</table>

3. If mass is added to the cart and the experiment is repeated (call this case #2), will the time it takes to travel to the cart stop be shorter, longer, or the same as it will be for case #1 when there was no added mass? Explain your reasoning.

4. For case #2 (with added mass), will the velocity just before it hits the cart stop be smaller, larger, or the same as it will be for case #1 (no added mass)? Explain your reasoning.

5. On the graph in Question 2, also predict the velocity vs. time curve for case #2 (with added mass). Make sure the scales for time and velocity are the same as for your first prediction so that the graphs can be compared. Make sure you indicate which graph is case #1 or case #2 (maybe use a dashed line for case #2).

6. Predict how the final momentum of the cart (just before it strikes the cart stop) will compare in the two cases? That is, will the cart have more or less or the same momentum in case #1 with no added mass than in case #2 with added mass? Explain why you think that’s true.

7. Predict how the final kinetic energy of the cart (just before it strikes the cart stop) will compare in the two cases? That is, will the cart have more, less, or the same kinetic energy in case #1 with no added mass than it does in case #2 with added mass? Explain why you think that’s true.
Part B: Constant Force Acting Over the Same Distance

Equipment Set-up: Now you are going test out your predictions. Set up the aluminum track on the table and make sure the track is level. Set one of the cart stops at 100 cm mark and the other close to the other end. Attach the fan to the cart.

Determine the total mass of cart and cart fan. \( m = \) _______________

Experiment: Launch the CAPSTONE software, open one window display, and set it up to capture velocity vs. time data. Switch on the smart cart and connect to the PASCO software. Change the number of decimal places to 3 as you have done in the previous experiments. Hold the cart with the edge closest to the cart stop at the 40 cm mark while you turn the fan on to its lower setting. Start recording data and then let go of the cart. Stop recording data just after the cart strikes the cart stop. We want the cart to travel 60 cm from the time it is released to when it strikes the cart stop.

8. Does your prediction in Question 2 for the velocity graph for case #1 agree with your data? Explain.

9. From your velocity vs. time graph, determine the velocity of the cart just before the collision with the cart stop. Also determine the time interval it took to travel 60 cm, that is, find the time when the cart is released and the time when it strikes the cart stop and determine the time difference, \( \Delta t \). Make sure your signs and units are correct.

\[ v_f = \] _______________ \hspace{1cm} \[ \Delta t = \] _______________

10. Use your data to determine the change in kinetic energy ( \( K = \frac{1}{2}mv^2 \) ) of the cart during its travel from rest to the point that it struck the cart stop.

\[ \Delta K = \] _______________

Show your calculations below:
11. Make a table in Excel like the one below and enter your data for this first run. Then repeat the experiment with mass added to the cart in 100g increments using the 100g masses provided. Use formula entry and the fill down operation to complete the kinetic energy and momentum columns.

*Do not delete any of the data from runs because you will use them again later.*

<table>
<thead>
<tr>
<th>Table 1: Same Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>m (kg)</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

(maximum mass = Cart with fan mass + 400 g)

12. If the force provided by the fan was the same for each run, how does the work done by that force compare from one run to another? Make sure that you use the definition of work in your explanation (\( W = Fd\cos\theta \) where \( \theta \) is the angle between the force vector and the displacement vector).

13. If the force and distance are the same for each run with a different mass, then the work done by the fan is the same in each run. Looking at your table and your answer to Question 12, does this result in approximately the same change in kinetic energy?

14. Do your results support the Work-Kinetic Energy Theorem: \( W = \Delta K \)? Explain.
Part C: Constant Force Acting for the Same Amount of Time

15. We are going to use the data you already collected in Capstone to investigate the momentum change for a force acting for a certain time. Look at your results in Table 1 and choose a time interval, \( \Delta t \), that is smaller than the time of travel for your quickest run.

\[ \Delta t = \text{________________________} \]

Then for your first run (case #1 with no added mass) use your data to determine the change in momentum \( (P = mv) \) of the cart during its travel from rest until the chosen time interval has passed.

\[ \Delta P = \text{________________________} \]

Show your calculations below:

16. Then look back at your data to determine the velocity of the cart for that time interval after the release time for each run. You can view the data from all the runs using the menus in Capstone. Make a table in Excel like the one below and calculate values for changes in momentum, \( P \), using a formula and the fill down operation. **Remember that the time intervals start when the cart is released from rest.**

<table>
<thead>
<tr>
<th>Table 2: Same Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>( m ) (kg)</td>
</tr>
<tr>
<td>:-------------:</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

17. If the force provided by the fan was the same for each run and we have chosen the same time interval, how does the impulse from that force compare from one run to another? Make sure that you use the definition of impulse \( (\vec{J} = \vec{F}_{avg} \Delta t) \) in your explanation.
18. Looking at your results in Table 2, is the change in momentum the same (or nearly the same) for each of the runs?

19. Do your results support the Impulse-Momentum Theorem: $\vec{J} = \Delta \vec{P}$? Explain.

**Part D: Conclusions**

20. What do you conclude about the relationship of work and changes in kinetic energy? Use your data to support your conclusion.

21. What do you conclude about the relationship of impulse and changes in momentum? Use your data to support your conclusion.