Impulse and Momentum

Name:

Group Members:

Date:

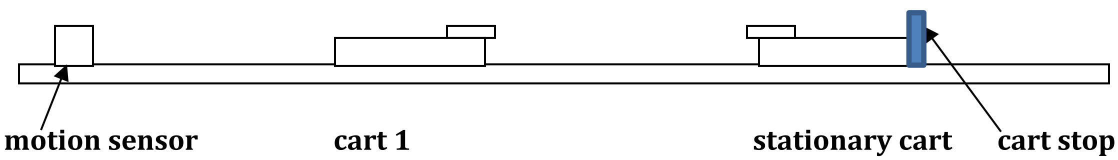
TA's Name:

Learning Objectives:

1. Understanding force vs time curves for a collision.
2. Calculating impulse using force vs. time curves.
3. Understanding the relationship between impulse and momentum.
4. Applying conservation of momentum for inelastic collisions.

Apparatus: Aluminum track, track legs, two carts, cart stop, motion sensor, two force sensors, USB link, PASCO interface, and small black rectangular cart masses.

Part A: Collision of a moving cart with a fixed cart



Consider the set up shown above. Cart 1 (mass m_1) moves to the right and collides with the stationary cart 2 (mass m_2). Just before the collision cart 1 is moving with velocity v_{xi}.

1. What are the magnitude and direction of the momentum of cart 1 *before* the collision? Use an arrow to indicate the direction.

   Magnitude of $\overrightarrow{p_{1i}}$ = $|\overrightarrow{p_{1i}}|$ = Direction of $\overrightarrow{p_{1i}}$:

2. If the cart bounces back with velocity v_{xf}, what are the magnitude and direction of the momentum of cart 1 *after* the collision?

   Magnitude of $\overrightarrow{p_{1f}}$ = $|\overrightarrow{p_{1f}}|$ = Direction of $\overrightarrow{p_{1f}}$:

3. What are the magnitude and direction of the change in momentum of cart 1?

   Magnitude of $\overrightarrow{\Delta p_1}$ = $|\overrightarrow{\Delta p_1}|$ = Direction of $\overrightarrow{\Delta p_1}$:

4. What is the direction of impulse on the moving cart?
   To the right or to the left, indicate with an arrow:
5. What is the direction of the impulse on the stationary cart?
   To the right or to the left, indicate with an arrow:

6. Now sketch the behavior you expect to see for the velocity vs. time curve for cart 1. One the other graph, sketch your predictions for the force vs. time curves for cart 1 and cart 2 during the collision on the other graph.

7. Does the area under the force vs. time graph represent any meaningful physical quantity? If yes, explain.

8. **Equipment Set-up:** Now you are going test out your predictions in real life. Set up the aluminum track on the table and make sure the track is level. Attach force sensors to each cart and attach the motion sensor to the track. Mount the cart stop near the far end of the track.

   Determine the mass of cart 1 and cart 2 with their force sensors attached.

   m_1 = ___________________ m_2=__________________________

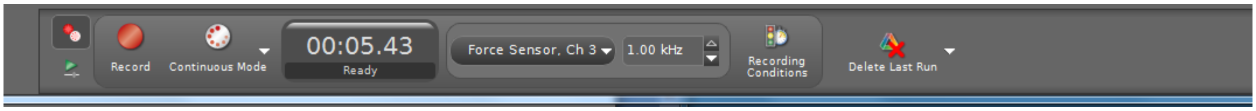
Next we need to set up the sensors and software for our data acquisition.

a. Connect both force probes and the motion sensor to the computer through the PASCO interface.

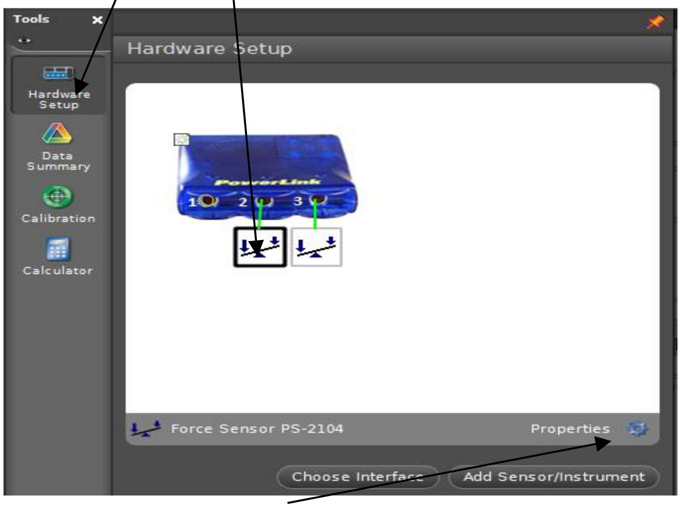
b. Open CAPSTONE software and choose two displays. One will be for velocity and the other will be for forces.

c. On the Y axis of one graph select force measurement. Use “Add similar measurements” to add the second force sensor to the same graph. Identify which channel corresponds to the force sensor on cart 1.

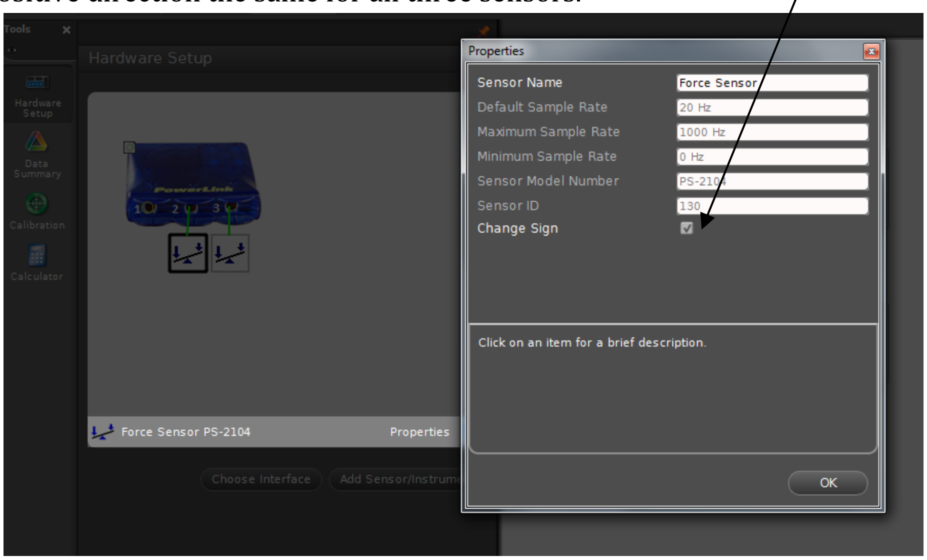
d. Change the sampling rate of force sensors to 1.0 kHz. Do this for both channels selecting the channel first and then the sampling rate. See the picture below. Change the sampling rate for the motion sensor to 100 Hz.



e. Select the force sensor attached to cart 1, the moving cart, by clicking the hardware setup as shown in the picture below.



f. Then select "Properties" and change the sign of that sensor to be negative. By doing that, we have made the positive direction the same for all three sensors.



g. Just as you did last week, set the number of decimal places to 3 for each variable by choosing *Data Summary* on the left side menu bar and selecting the *Properties* for each measurement then selecting *Numerical Format*. After changing *Number of Decimal Places* to 3, click OK and proceed to the *Properties* for the next variable. See instructor if you need help with this.

h. Click on "Recording Conditions" then "Stop Condition." Select "Time Based" and set the time to 3.0 seconds.

Experiment: Now use the CAPSTONE software to measure collision forces as a function of time for each cart and the velocity vs. time for cart 1. Be sure to zero both force sensors before each data run. Let cart 1 move and collide with cart 2. (Actually the two force sensors should collide to measure the force on each cart from the other). The motion sensor will measure the velocity of the moving cart before, during, and after the collision. Arrange the graphs in Capstone so that you can view the force on each cart, and the velocity of cart 1 before and after the collision. **Copy your graphs of velocity and force and paste them to a Word document.**

9. Do your predictions for the force and velocity graphs in Question 6 agree with your data? Explain.

10. From your velocity vs. time graph, determine the velocity of cart 1 just before the collision and the velocity just after the collision. Make sure your signs and units are correct.

    v_{xi} = ____________________________

    v_{xf} = ____________________________

11. Determine the momentum of cart 1 just before and just after the collision. Again make sure your signs and units are correct.

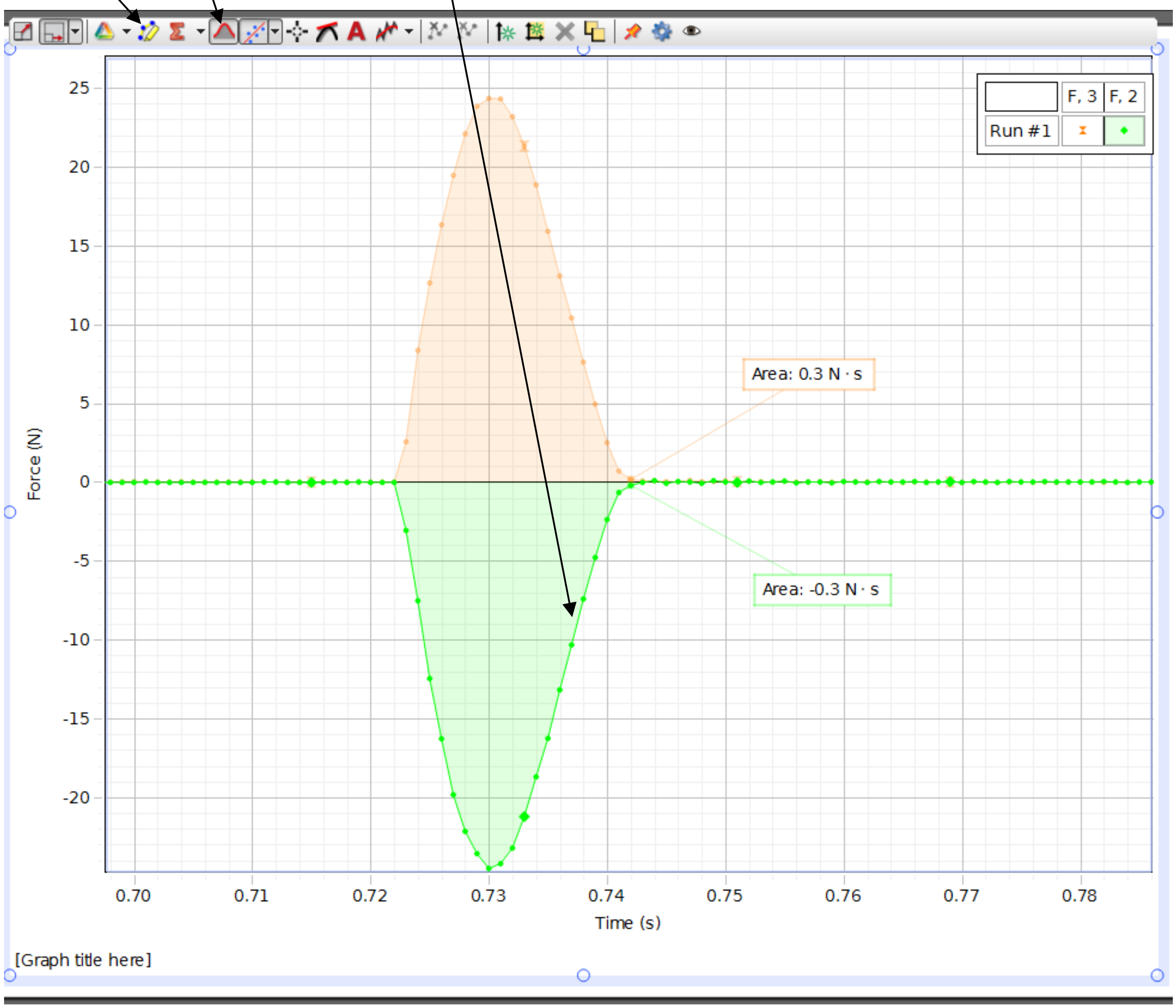
    p_{xi} = ____________________________

    p_{xf} = ____________________________

12. Determine the change in momentum of cart 1. Watch signs and units.

    Δp_x = ____________________________

13. Using the area under the tool curve, find the area under the force vs. time curve for cart 1.
To find the area, first select which graph you want by clicking on a point on the graph. Then click on the area under graph tool. The area will be displayed as shown for the selected graph. If needed, you can use the highlight tool to select a portion of the graph which you want to calculate the area under.



Area under force vs. time curve for cart 1 = ____________________________

14. What is the impulse on cart 1 as determined from your data? Remember units.

15. What are the units of impulse? Are these units equivalent to the units for momentum?

16. What is the relationship between the change in momentum of cart 1 which you found in Question 12 and the impulse on cart 1 which you found in Question 14?

17. Looking now at the force vs. time graphs for cart 1 and cart 2, how does the force on cart 1 from cart 2 compare with the force on cart 2 from cart 1?

18. How do you think these two forces should be related and why?

19. Now use the area tool to determine the area under the force vs. time curve for cart 2.

    Area under force vs. time curve for cart 2 = ______________________________

20. Comparing the results of Question 13 and Question 19, is the impulse on cart 1 from cart 2 approximately the same as the impulse on cart 2 from cart 1?

21. Will these impulses always have that relationship? Why or why not?

Part B: Collision of two movable carts

22. Now move the cart stop to the very end of the track and remove the force sensors from the two carts. Determine the mass of cart 1 and cart 2 with their force sensors removed.

    m_1 = ____________________ m_2=____________________________

23. Make sure carts are facing so that Velcro strips can stick together when they collide. Keep an extra 250g of mass on the cart 2 which starts at rest. Practice giving an initial velocity to cart 1 while cart 2 starts at rest so that after the collision both carts move as a combined object with mass $m_1 + m_2$. What is the type of collision now you are practicing with two carts?

24. Change the sampling rate for the motion sensor to 25 Hz. Now make at least 4 collisions with different combinations of mass by adding or removing small black rectangular masses from one cart or the other. From the motion sensor data determine the velocity of cart 1 just before the collision (v_{xi}) and velocity of the combined system of two carts just after the collision (v_{xf}). From this data calculate the momentum of the system just before (P_{xi}) and just after the collision (P_{xf}). Record your data and calculated momenta below. **Copy the velocity vs. time graph for one of your collisions to your Word document.**

m_1 (kg)	v_{xi} (m/s)	P_{xi} (kg m/s)	m_1+m_2 (kg)	v_{xf} (m/s)	P_{xf} (kg m/s)

25. Looking at your results, for each run how does the momentum of the system before the collision compare to the momentum of the system after the collision? Are they nearly the equal?

26. Do you expect the momentum of cart 1 to be conserved in this collision? Why or why not?

27. Do you expect the momentum of cart 2 to be conserved in this collision? Why or why not?

28. Do you expect to have the total momentum of the carts ($p_{1x} + p_{2x}$) to be conserved in this collision? Why or why not?

29. Can you conclude that the momentum of the system conserved in this experiment?

Instructions on how to submit the graphs:

1. Open a word document and type the names of all present group members.
2. Paste labeled graphs of velocity and forces vs. time from Part A.
3. Paste labeled graph of velocity vs. time for one collision from Part B.
4. Pay attention to formatting of the word document so you don't waste paper.
5. Print your word document and attach to the lab write-up.