## Experimental Design

**PART A:** Edit Dominique's procedure for length and clarity. Cross out any unnecessary statements, change the order of statements, correct statements for errors, or write new sentences if necessary.

1. ~~Gather all materials.~~
2. Record the mass of the cart.
3. ~~Plug in both the motion detector and the force sensor.~~
4. ~~Check that each device is working.~~
5. ~~Secure the motion detector to the ring stand.~~
6. ~~Attach the cardboard target to the cart so that it can be "seen" by the motion sensor.~~
7. ~~Align the motion sensor with the target cardboard.~~
8. ~~Create a data table in your notebook.~~
9. ~~Set the motion sensor to record in cart mode.~~ maybe??
10. Begin recording force and motion data with the computer.
11. Give the cart a push toward the force sensor and away from the motion detector.
12. After the cart collides with the force sensor and has bounced back, stop recording force and motion data.
13. Determine the impulse. need more!
14. Repeat steps 9–12 with different initial pushes to reduce error.
15. ~~Clean up the lab station and put away all materials.~~

Don't forget this step!! (Always have)

2. Record the mass of the Cart

10. Begin recording force + motion data w/ the Computer

11. Give the cart a push towards the force sensor + away from the motion dectector

12. After the cart collides w/ the force sensor + has bounced back, stop recording force + motion data

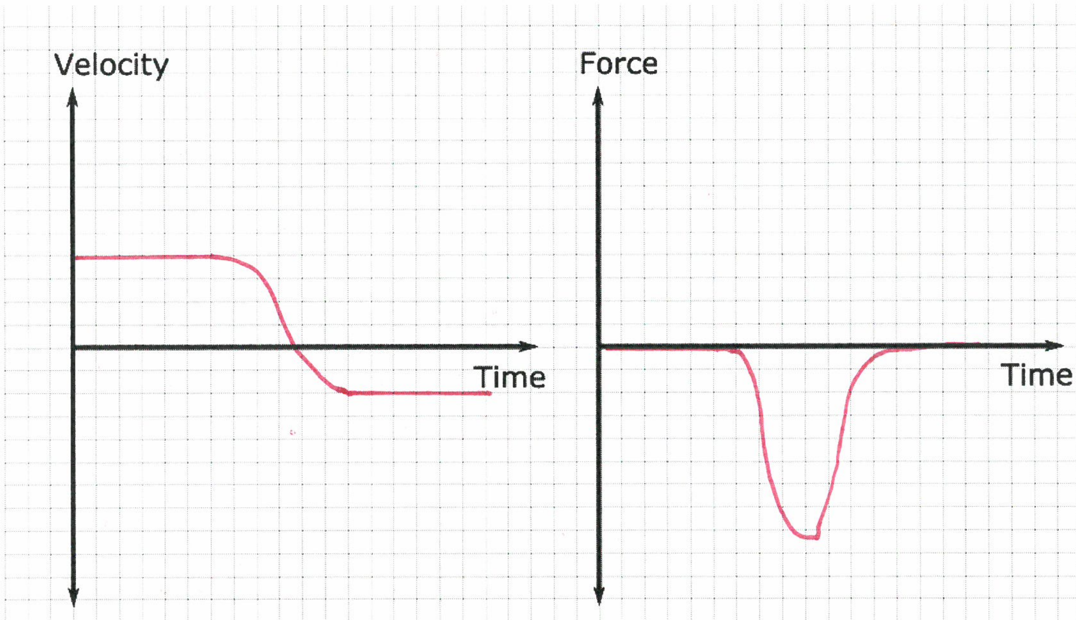
13 Determine the impulse by analyzing the force vs time graph created by the force sensor. The area under the force vs time graph will be the impulse. ← graphical way ✓

Impulse is also equal to $mv_f - mv_i$, so by looking at velocity vs time graph, using $V_i$ + $V_f$ of cart the impulse can be calculated ← math way ✓

14 Repeat steps 10-13 with different initial pushes to reduce error

## Using Representations

**PART B:** Sketch a graph of what the velocity as a function of time and the force as a function of time should look like for the time just before the collision to just after the collision.




## Data Analysis

**PART C:** Explain how these representations can be used to determine the impulse given to the cart during the collision. Explain how you could determine the impulse given to the cart from each graph.

Impulse = ΔP = mΔV on the Velocity VS time graph
· Record the carts initial + final V
· measure mass of cart

Impulse is also equal to Area under the Force VS time graph

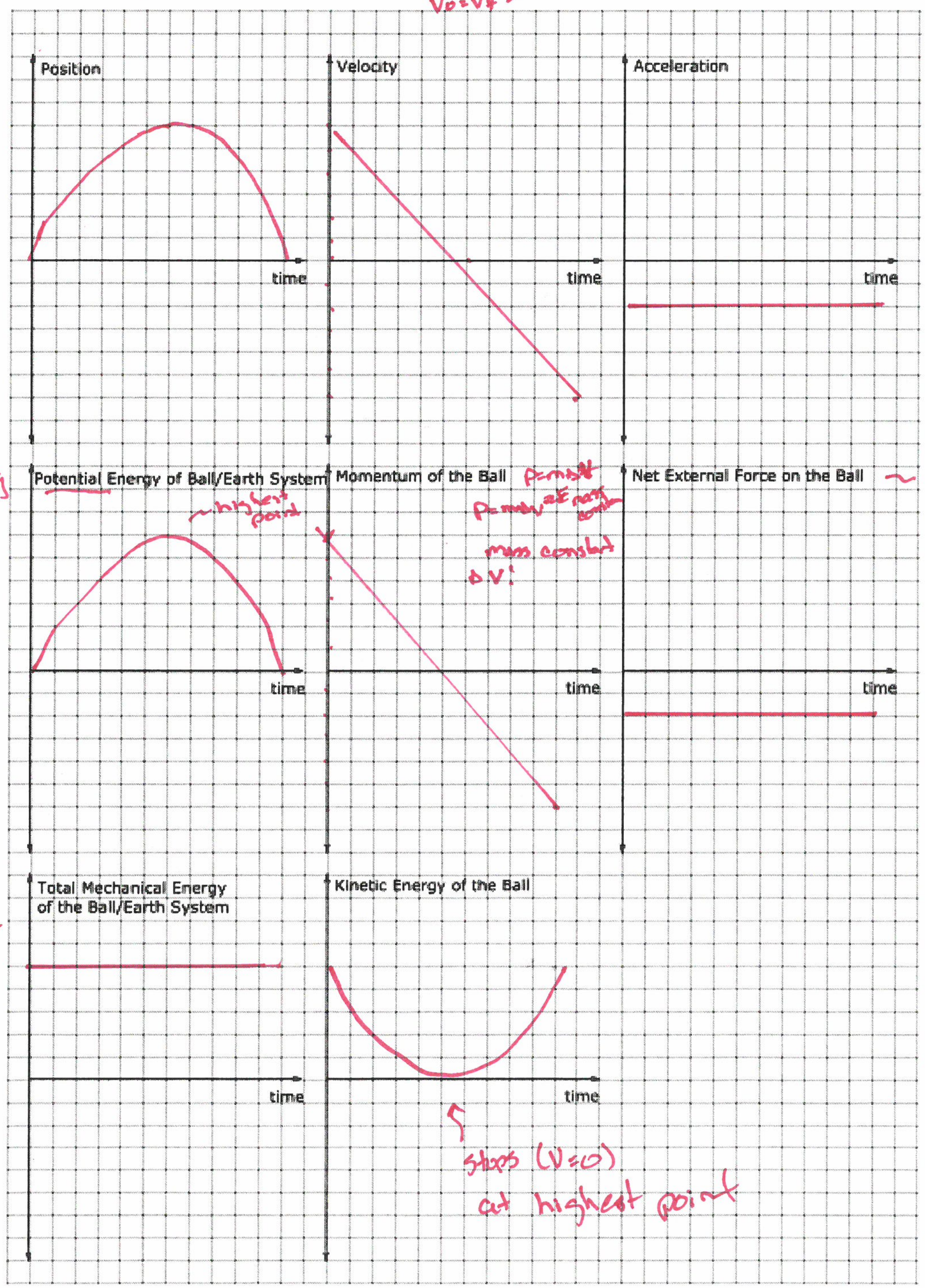
**NAME** ______________________ **DATE** Key

## Scenario

*A ball is thrown straight up into the air with an initial speed $v_0$. After a few seconds, it returns to the height from which it was thrown. Air resistance is negligible.*

## Using Representations

**PART A:** Sketch the following graphs as functions of time for the time the ball is in the air.



Key

## Data Analysis

**PART B:** The following sentences discuss the relationships between these graphs and the physical ideas they represent. Fill in the blanks.

1. The slope of the position vs. time graph is equal to Average Velocity.
2. The slope of the velocity vs. time graph is equal to Average acceleration.
3. The area under the acceleration vs. time curve is equal to the Change in Velocity.
4. The area under the velocity vs. time curve is equal to the Change in distance,
5. The graph of momentum vs. time is the same shape as the Velocity vs. time graph because momentum is equal to mass times Velocity.
6. The net force graph vs. time is the same shape as the acceleration vs. time graph because the net force is equal to mass x Acceleration. F=ma
7. The slope of the momentum vs. time graph is equal to Net average External force.
8. The area under the curve of the net external force vs. time graph is equal to Δ in P or Impulse.
9. The potential energy vs. time graph is the same shape as the Vertical position vs. time graph because the potential energy is equal to mgh.
10. The kinetic energy vs. time graph is related to the Velocity vs. time graph because the kinetic energy is equal to $\frac{1}{2}mV^2$.
11. The total mechanical energy graph is Constant because it represents the sum of the KE vs. time and the Ug (Potential E) vs. time graphs. Also, there are no external forces on the system, so there is no work done. Therefore, the total mechanical energy is Constant.

$\frac{Position}{time}$ = Velocity

$\frac{V}{t}$ = acc

$\frac{acc}{t}$ = V

$\frac{V}{t}$ = $\frac{m/s}{s}$ = m distance

P=F·Δt

$\frac{P}{t}$ = F

P=

NAME ______________________ DATE Key

## Scenario

*Angela and Carlos have identical masses* M *and stand on identical light carts with bearings with negligible friction. Carlos holds a heavy ball of mass* m. *At time* $t = 0$, *Carlos throws the ball so that it has a horizontal component of velocity* $v$ *while a projectile. At time* $t = T$, *Angela catches the ball at the same height from which it was thrown.*


## Argumentation

**PART A:** Which student moves with faster speed for time $t > T$? Explain your reasoning *qualitatively* without manipulating equations.

Carlos has a faster speed for $t > T$. Because orginal p of system (Ball, Carlos, Angela) is zero. The final p must also be zero

Carlos throw's Ball to Right. Ball momentum (mV) is Right
Carlos P (MV) is Left, equal in magnitude

The momentum of Ball (mv) has to be shared Btwn Ball & Angela
∴ Angela has smaller speed than Carlos

## Quantitative Analysis

**PART B:** Derive expressions for $v_{fA}$ and $v_{fC}$, Angela and Carlos's final speeds for time $t > T$ in terms of $M$, $m$, and $v$.

Carlos $m_c$ Ball $M_b$

| | |
|---|---|
| $\Delta P_x = \emptyset$ | System is Carlos and ball. There are no net horizontal external forces, so the momentum of the system is conserved. |
| $m V_{ic}^{\,0} + M V_{i Ball}^{\,0} = m V_{fc} + M V_{f Ball}$ | Initially, Carlos and the ball are at rest, so their initial momentum is zero, so their final momentum must also be zero. |
| $V_{fc} = \frac{-M V_{f Ball}}{m_{Carlos}}$ | Equation for $v_{fC}$ in terms of $M$, $m$, and $v$. |
| $\Delta P = \emptyset$ | For the second part of the problem, the system is the ball and Angela. There are no net horizontal external forces, so the momentum of the system is conserved. |
| $m V_{f Ball} + M V_{iA}^{\,0} = (M+m) V_{fA}$ | Initially, Angela is at rest and the ball has momentum $mv$, which means that the final momentum must also equal $mv$. After the collision, the ball and Angela have a new velocity $v_{fA}$. |
| $V_{fA} = \frac{m V_{f Ball}}{(M+m)}$ | Equation for $v_{fA}$ in terms of $M$, $m$, and $v$. |

$V_{iA}$ = initial Angela

## Data Analysis

**PART C:** Explain how your expressions in Part B support your reasoning in Part A.

Carlos speed $V_{fc} = \frac{-mV_{f\,Ball}}{M_{carlos}}$ Angela's $V_{fA} = \frac{mV_{f\,Ball}}{(M+m)}$

The denominator in Angela's equation is larger, ∴ $V_{fc} > V_{fa}$

**PART D:** Let $E_1$ be the mechanical energy of the Angela-Carlos-ball system for $t < 0$, let $E_2$ be the mechanical energy of this system for $0 < t < T$, and let $E_3$ be the mechanical energy of this system for $t > T$. Rank these energies from highest to lowest and explain your reasoning.

$t<0$ $0<t<t$ $t>T$

$E_i$ $E_2$ $E_3$

Highest energy $E_2 > E_3 > E_1$ Lowest energy

For $E_1$, @ $t<0$ the system has NO ME ← zero

$E_2$, a lot of ME due to work Carlos does on Ball $W = \Delta KE$

$E_3$ a loss of ME energy due to inelastic collision of Angela & Ball

Checklist

____ I answered the question directly.

____ I stated a law of physics that is always true.

____ I connected the law or laws of physics to the specific circumstances of the situation.

____ I used physics vocabulary (energy, mass, momentum, conservation, velocity, time).

$t<0$ $E_i = 0$

$0<t<t$

$E_2$ $W = \Delta KE$

$t>T$

$E_3$ - inelastic collision, Angela + Ball
Loss of ME

NAME ____________________ DATE Key

## Scenario

*Blake is given two carts of unequal masses, $m$ and $M$, and a long track that ensures both carts travel in a straight line with no noticeable friction. He also has access to other commonly available equipment. The carts do NOT have any way to connect together when they come into contact. He asks three questions:*

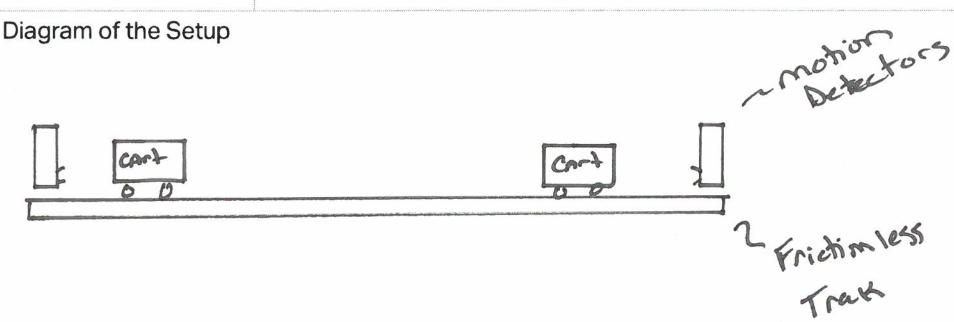
1. *When the two carts collide, is the total momentum of the system conserved?*
2. *When the two carts collide, is the mechanical energy of the two-cart system conserved?*
3. *When the two carts collide, is the force $m$ exerts on $M$ equal to the force that $M$ exerts on $m$?*

## Experimental Design

**PART A:** Outline a procedure that Blake could follow to make measurements that could be used to answer all three questions above. Give each measurement a meaningful algebraic symbol and state with what equipment each measurement is made. Draw a labeled diagram showing each piece of equipment being used.

| What Needs to Be Measured and Algebraic Symbols | Procedure: |
|---|---|
| Velocity as a function of time<br>V vs t | • measure mass of Each Cart<br>• Put Carts on either End of a Track, with motion Detector Set at Either End<br>• Set motion Detector to record Velocity as a function of time<br>• Push Carts toward each other & start motion detector<br>• Graph Velocity as a function of time for each Cart |

Labeled Diagram of the Setup



## Data Analysis

**PART B:**

i. Explain how the measurements made in Part A can be used to answer question 1.

① The mass has Been measured for Carts
② If momentum conserved $p_i = p_f$
③ Motion Detector records velocity as function of Time
Record $V_i$ + $V_f$ of Both Carts

④ $m_1 V_i + m_2 V_i = m_1 V_f + m_2 V_f$

ii. Explain how the measurements made in Part B can be used to answer question 2.

① The mass has Been measured for carts
② If KE conserved in the Collision $KE_i = KE_f$
③ Motion Detector create graph V vs t.
④ Use Velocity Before + After collisions of Graph + enter into eqn to check for equality

$\frac{1}{2}m_1 V_i^2 + \frac{1}{2}m_2 V_i^2 = \frac{1}{2}m_1 V_f^2 + \frac{1}{2}m_2 V_f^2$

iii. Explain how the measurements made in Part A can be used to answer question 3.

Acceleration is the slope of the line on Velocity vs time graph.
mass of each cart ~~x~~ its acceleration is equal in each case
then the force of M on m is equal to m on M

NAME ______________________ DATE Key

## Scenario

*A dart launcher fires a dart so fast that the speed cannot be measured by any direct method. Angela wishes to determine the speed with which the dart is fired. After being fired, the dart will embed itself into a wooden block. She already knows the mass* m *of the dart.*

## Experimental Design

**PART A:** Angela has access to the equipment listed below. Mark the space next to each piece of equipment that she could use in an experiment to determine the dart's speed.

__X__ Meterstick ______ Stopwatch ______ String __X__ Electronic balance

__X__ Cart with frictionless bearings and light wheels (that the wood block can be attached to)

__X__ Track (that allows the cart to travel in a straight line with no noticeable friction)

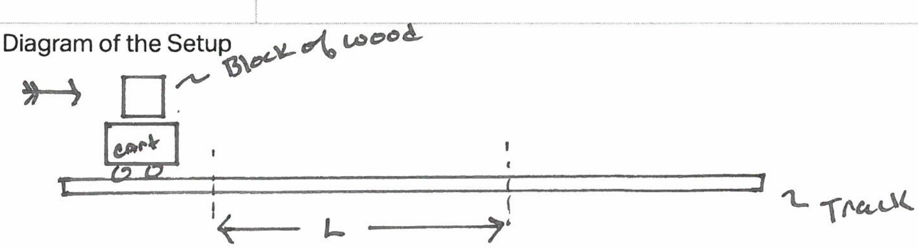
______ Hooks (that can be connected to the ceiling of the classroom or the block)

__X__ Camera (that can take video that can be replayed frame by frame with time codes indicated on each frame)

**PART B:** Outline a procedure that Angela could follow to use the equipment that you marked above to make measurements that could be used to calculate the firing speed of the dart. Give each measurement a meaningful algebraic symbol. Draw a labeled diagram of the experimental setup.

| What Needs to Be Measured and Algebraic Symbols | Procedure: |
|---|---|
| mass Cart - $m_c$<br>mass Block - $M_B$<br>-use Electronic scale<br>Length - L - using measuring stick<br>Time for Cart to travel, Distance L, using Camara | • Attach Block to Cart, $Mass_T = M_c + M_B$<br>• Measure distance L<br>• Set Block/cart on frictionless Track<br>• Start Camara<br>• Launch Dart<br>• From Video, determine t to travel distance L<br>• Repeat several times ← don't forget this Step |

Labeled Diagram of the Setup



## Data Analysis

**PART C:** Explain how the measurements can be used to calculate the speed with which the dart is fired from the gun. As part of your explanation, show symbolic equations that measurements must be plugged into and solved to arrive at your conclusion.

Find: $V_i = ?$

There are NO external forces on the system of dart, Block, Cart

$\therefore \quad p_i = p_f$

Only Dart has initial momentum

After they collide, the dart, Block, cart will have same $V_f$

$$m_D V_{iDart} = V_f (m_B + m_D + m_C)$$

$V_f$ can be determine By $\frac{L}{\Delta t}$

$$\therefore \quad V_{iDART} = \frac{V_f (m_B + m_D + m_C)}{m_D}$$

CAN sub in $V_f = \frac{L}{\Delta t}$