Key

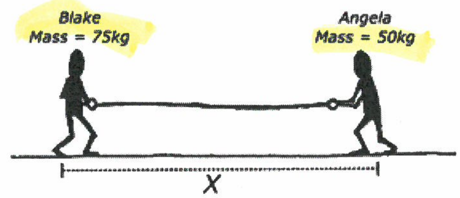
Workbook |

Unit 5 - Momentum

NAME ____________________ **DATE** Key

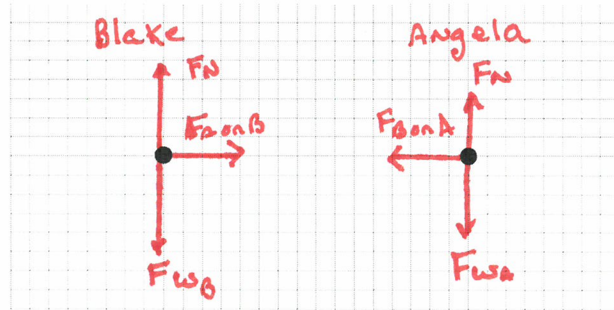
Scenario

Two students, Blake and Angela, stand on a smooth icy surface, a distance x apart and pull on opposite ends of a rope to pull themselves together. They each hold tightly onto the rope, which has negligible mass. Angela pulls on the rope with a constant force, so that she and Blake approach each other and meet. The system includes both students and the rope.



Using Representations

PART A: The dots to the right represent the two students. Draw free-body diagrams showing and labeling the forces (not components) exerted on each student. Draw the relative lengths of all vectors to reflect the relative magnitudes of all the forces.



Data Analysis

PART B: From the following four statements about the situation above, place a check mark next to the statement if it is completely true and provide justification. If it is partly true, correct the statement, and if it is false, cross out the statement and provide justification.

Angela is pulling
But Both move (No friction)
Blake 75kg vs Her 50kg

_____ A. ~~Only Angela moves relative to the ice.~~

Rope has Negligible mass ∴ No force Needed to Accelerate rope

Forces on 2 ends of the rope treated as a force pair.
Since both students move Relative to the ice, the center of mass Remains at Rest Reative to the Ice.

✓ B. The magnitude of Angela's acceleration is ~~less~~ more than the magnitude of Blake's acceleration.

$F_B = F_A$

$m_B a_B = m_A a_A$

$a_B = \frac{m_A}{m_B} a_A$ → $a_B = \frac{50}{75} a_A$

$a_B = .67 a_A$

Blakes acceleration is less than Angela's

_____ C. Just before they meet, Blake's speed is less than Angela's speed.

Since Blakes $a_B = .67 a_A$, & they will Both have same Δt Blakes velocity will be slower

_____ D. While the students are moving, their momentum vectors have equal magnitude and ~~direction~~. opposite direction

They have equal momentum's $\Delta p_A = \Delta p_B$
But oppositie directions. momentum is a vector
So it has mag & direction

Argumentation

PART C: Where do the two students meet?

The students meet at the Center of MASS of the system.

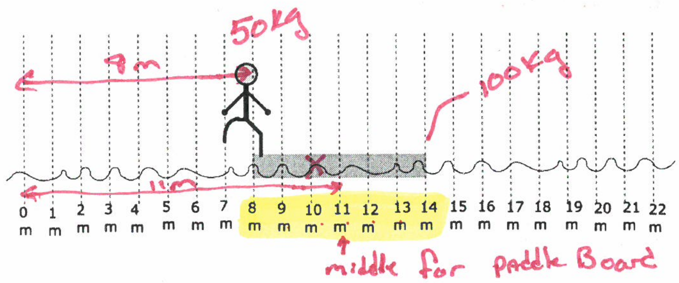
Justify your answer in a few short sentences. You do not need to do any calculations to determine where they meet.

They each move w/ Rates proportional to their MASS due to conservation of momentum.

This means that the COM where they meet will be in Between the 2 student's initial positions but closer to the larger student.

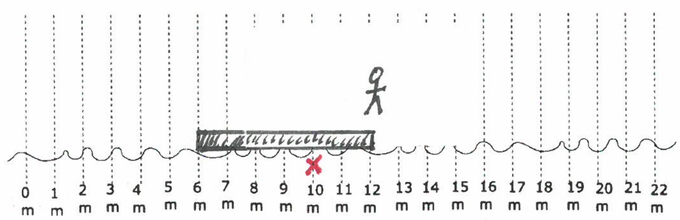
PART D: Carlos ($m = 50$ kg) stands on the far-left edge of a 100 kg stand-up paddle board. The board is 6 m long as shown in the diagram below and slides across the surface of the water with negligible friction. On the diagram, show the location of the student-board center of mass. Then draw what the system will look like after Carlos walks to the other end of the board. On this second diagram, mark the location of the student-board center of mass.

$X_{cm} = \frac{m_1 x_1 + m_2 x_2 + \text{etc}\ldots}{\text{Total mass}}$



$X_{cm} = \frac{50\text{kg}(8\text{m}) + 100\text{kg}(11\text{m})}{50\text{kg} + 100\text{kg}}$

$X_{cm} = 10\text{cm}$



Briefly explain how you made your second drawing. How did you know where to set the board? Give an explanation in terms of external forces and center-of-mass concepts.

The Net external force on system is Zero.
∴ No change in the position of the Center of MASS

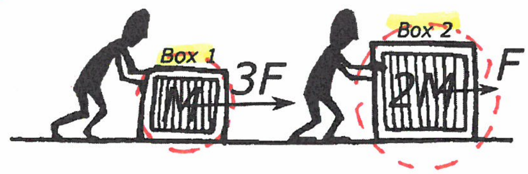
So as Student moves to far end, Board COM will shift to keep COM at same location

NAME ______________________ DATE __________

Scenario

time & force tells me, Impulse!

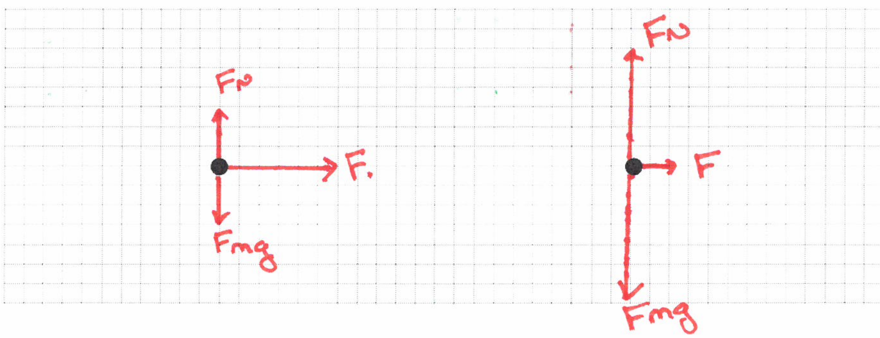
Two different boxes are pushed from rest on a frictionless surface for a time t*, with differing forces.*



Using Representations

PART A: Identify the box system by circling the objects inside the system with a dotted circle.

PART B: The dots below represent the two boxes. Draw free-body diagrams showing and labeling the forces (not components) exerted on each box. Draw the relative lengths of all vectors to reflect the relative magnitudes of all the forces. Identify the external forces.



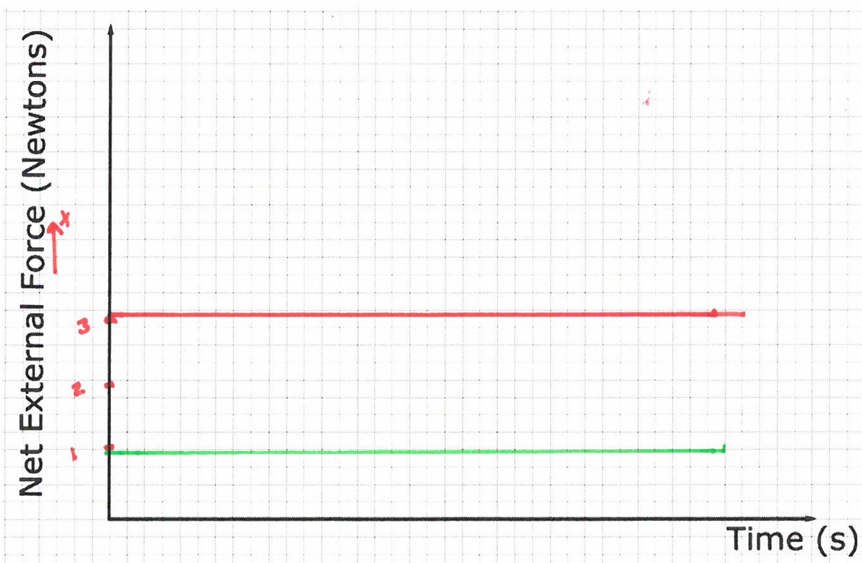
Forces that are external to the system include: FN - Normal, Fmg = gravitational Force F - Applied By Person

PART C: Sketch a graph of the net external force vs. t for each box on the same axis by using two different colors and providing a key.

Box 1 - 3F

Box 2 - 1F

* Same Δt



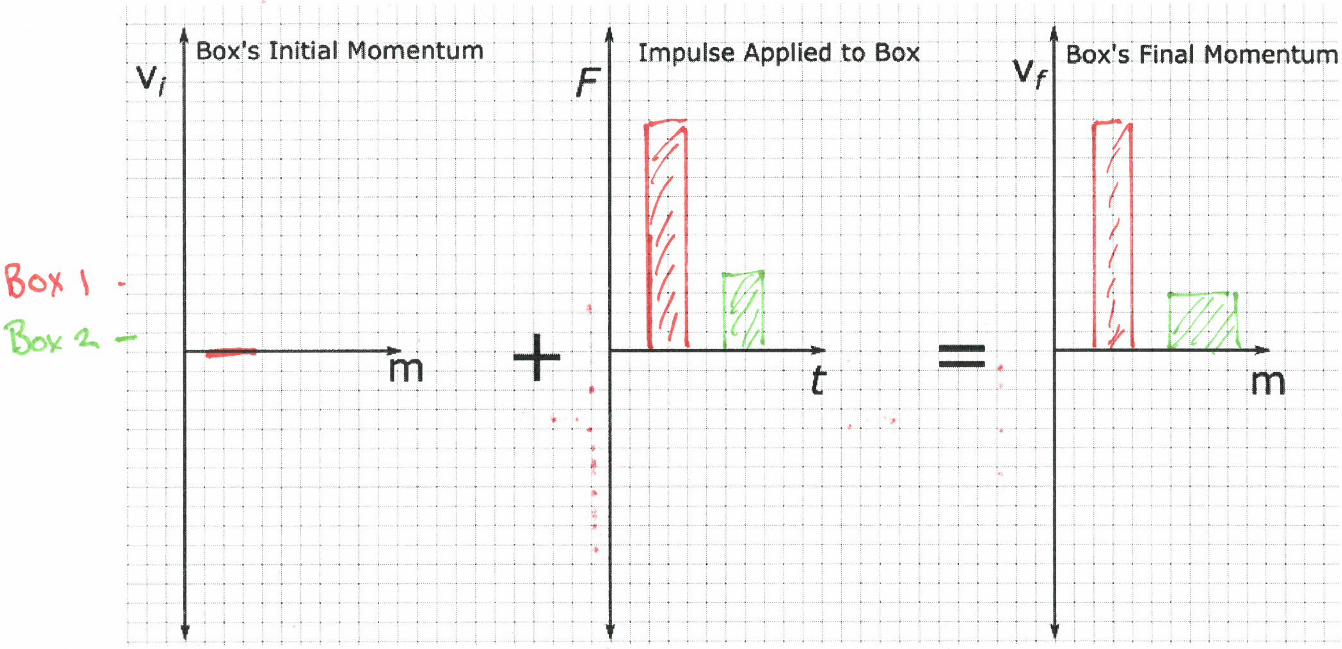
Quantitative Analysis

PART D: Using the equation for the area of a rectangle, $A = bh$, write two equations, one with words and one with units, for the area of the rectangle between the net external force vs. time line and the x-axis on the graph created in Part C.

Area (Impulse) = Net forces * time   N·s = N×Sec

The area under a net external force vs. time graph represents the Impulse or Δ in momentum ______. (Hint: Check units!)

PART E: Re-represent the data above by creating a momentum diagram for each box on the same set of axes by using two different colors and providing a key. (A momentum diagram represents the momentum of an object or system by showing the mass of the object as the width of bar on the chart, and the velocity of the object as the height of the bar. $J = F\Delta t$ t same $\Delta p = mv$



Argumentation

3F, m

PART F: Is the work done on the first box while speeding up greater than, less than, or the same as the work done on the second box while speeding up?

F, 2m

✓ Greater than ________ Less than ________ Same

$W = \Delta KE = \frac{1}{2}m(V_f^2 - V_i^2)$ Rest V_i

$W = \frac{1}{2}mv_f^2$ Box 1, m 3F Box 2 2m, F

$F = ma$ $tF = 2mV$

Box 1 will have a $F = m\frac{v}{t}$ $\frac{tF}{2m} = V$ × t same

much larger KE $\frac{t3F}{m} = V$

∴ Greater W

Box 1 faster!

PART G: Is the impulse given to the first box while speeding up greater than, less than, or the same as the impulse given to the second box while speeding up? Justify your ranking.

✓ Greater than ________ Less than ________ Same

$J = F\Delta t$, Both Boxs Same time

Box 1 3F

vs

Box 2 F

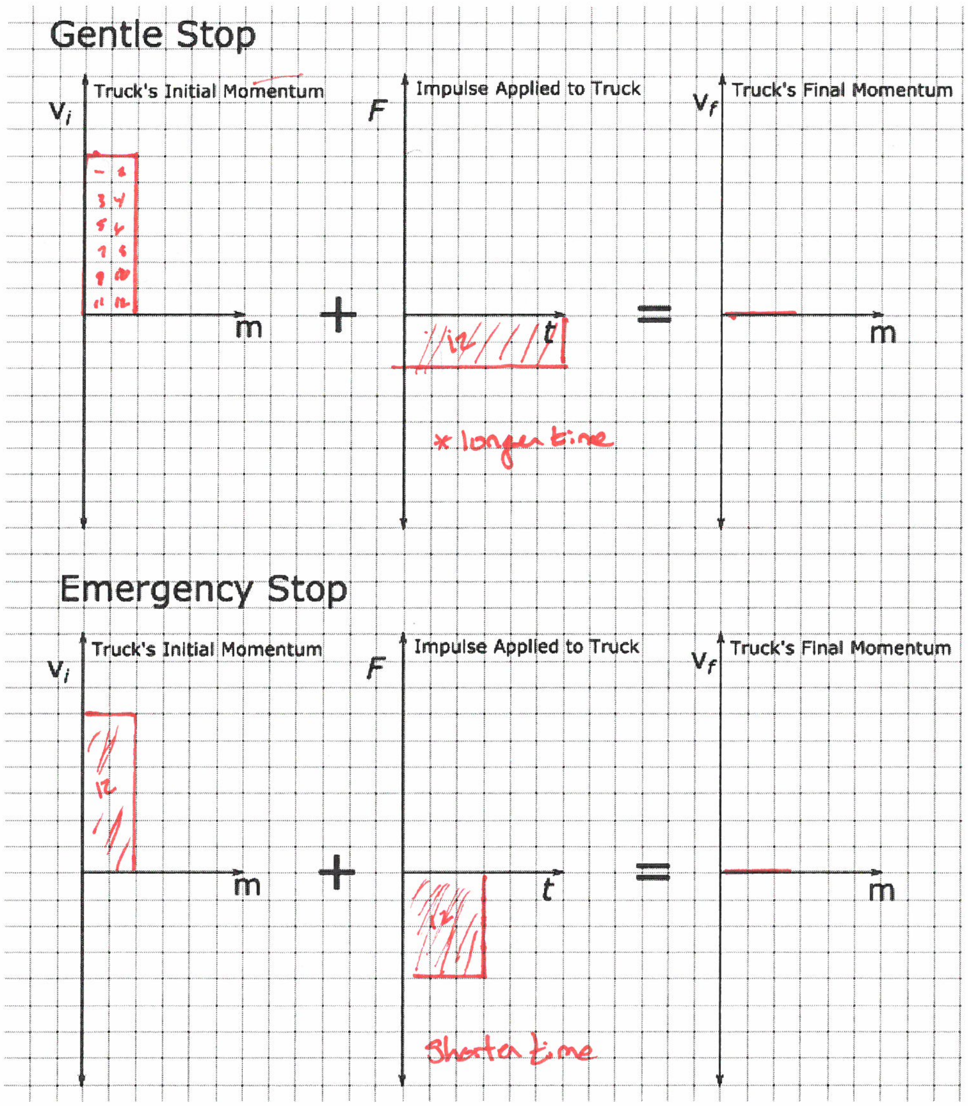
NAME ______________________ DATE Key

Scenario

A truck has a mass of M and initially moves with a speed of v_0. Consider two cases: The truck makes a "gentle" stop, and the truck makes an "emergency" stop.

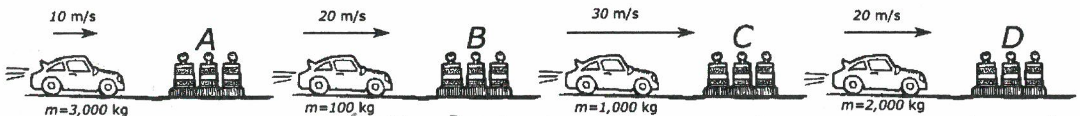
Using Representations

PART A: Show on the diagrams what a "gentle" stop and an "emergency" stop might look like.



Argumentation

A car company tests its safety features by crashing cars into barriers in its testing facility. The cars are all the same size and shape but are moving at different speeds and have different masses. Assume that the barriers are all identical and exert the same constant force.



(10)3000 = 30,000　　(20)(100) = 2,000　　30(1000) = 30,000　　20(2000) = 40,000

PART B: Rank the time it takes the cars to stop if the barriers apply the same constant force.

Longest time D > A = C > B Shortest time

Justify your ranking in a few short sentences.

$F\Delta t = m\Delta V$　　$V_f = 0$ for all cars ∴ final momentum = 0

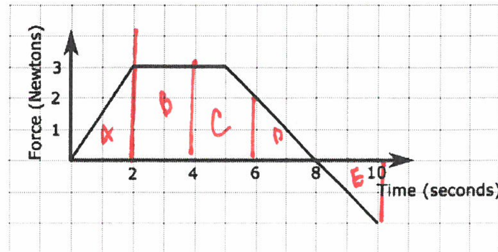
$\Delta t = \frac{mV_i}{F}$ ~ same　　F = force by barrier same all cars

final momentum is the same for all cars, so Δ momentum depends upon initial momentum p = mv.

NAME ________________ **DATE** Key

Scenario

A 10 kg box, initially at rest, moves along a smooth horizontal surface. A horizontal force is applied to the box. The magnitude of the force changes as a function of time as shown. Take the positive direction to be to the right.



Data Analysis

PART A: Rank the magnitude of the impulse applied to the box by the force during each 2-second interval indicated below:

A. 0–2 seconds B. 2–4 seconds C. 4–6 seconds D. 6–8 seconds E. 8–10 seconds

Greatest impulse B>C>A>D=E Smallest impulse

PART B: Write a few sentences justifying your reasoning. Use words like speed, velocity, acceleration, time, force, momentum, and impulse.

Impulse is equal to the area under the force vs time Graph

So the larger the area greater the magnitude of the Impulse

Using Representations

PART C: Re-represent the data given in the force vs. time graph in Part A as a momentum vs. time graph for the same 10 kg box.

Step 1: Identify the equation that relates force and momentum.

$F\Delta t = \Delta p$

Step 2: How can momentum be found from a force vs. time graph?

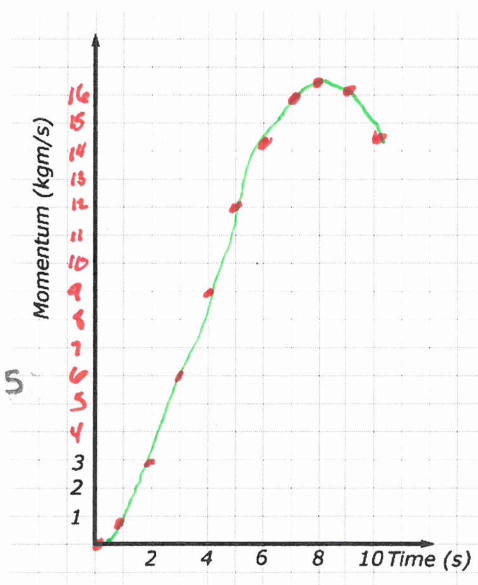
Change in momentum is equal to the area under force vs time graph

Step 3: Plot the momentum as a function of time. (Make a table if you need to.)

m= 10 kg

p = m·v

time (s)	Momentum (kg·m/s)
0	0
1	$\frac{1}{2}bh = \frac{1}{2}(1)(1.8) = 0.9$
2	$\frac{1}{2}bh = \frac{1}{2}2(3) = 3$
3	$3 + bh = 3+(1)(3) = 6$
4	$6 + bh = 6+(1)(3) = 9$
5	$9 + bh = 9+(1)(3) = 12$
6	$12 + bh + \frac{1}{2} = 12.5+(1)(2) = 14.5$
7	$14.5 + 1 + \frac{1}{2} = 16$
8	$16 + \frac{1}{2} = 16.5$
9	$16.5 - \frac{1}{2} = 16$
10	$16 - 1.5 = 14.5$



Quantitative Analysis

Use the graph above to calculate the velocity of the box after 10 seconds.

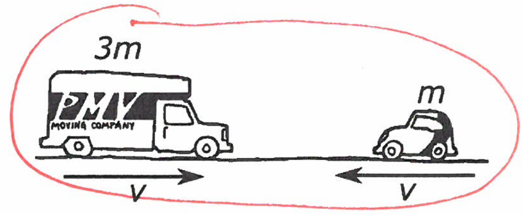
For each line in the calculation, explain what was done mathematically. The first line is done for you.

$\Delta\vec{p} = m\Delta\vec{v}$	The change in momentum is equal to the mass times the change in velocity.
$P_f - P_i = mv_f - mv_i$	The Δ in momentum is equal to the final momentum - the intial momentum
$P_f - P_i^{0} = mv_f - mv_i^{0}$ $14.5\,kg \cdot m/s = 10\,kg\ V_f$	The final momentum (graph) was equal to 14.5 kg.m/s + the initial momentum is zero (at Rest)
$V_f = 14.5\ m/s$	The velocity of the Box after 10 seconds

NAME ______________________ DATE Key

Scenario

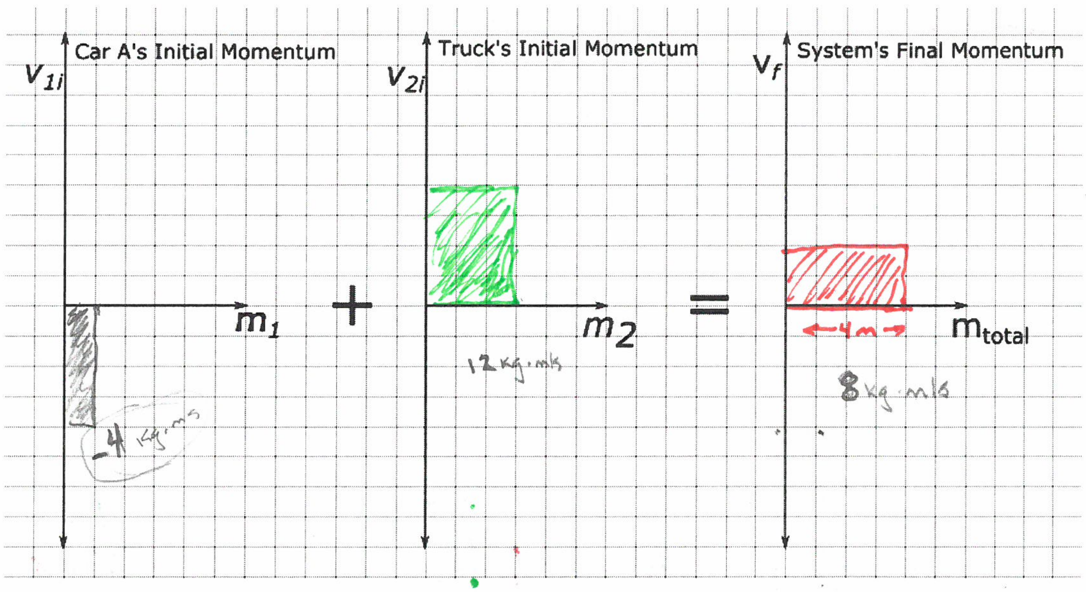
A toy car of mass m and a toy truck with a mass 3m travel in opposite directions at identical speeds. The truck moves to the right and the car moves to the left. The two toys collide and stick together.



Using Representations

PART A: Identify the system by drawing a dotted circle around the truck and the car.

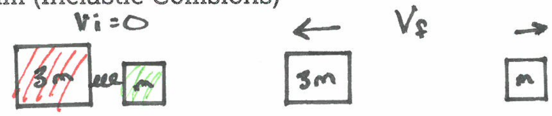
PART B: Diagram the situation.



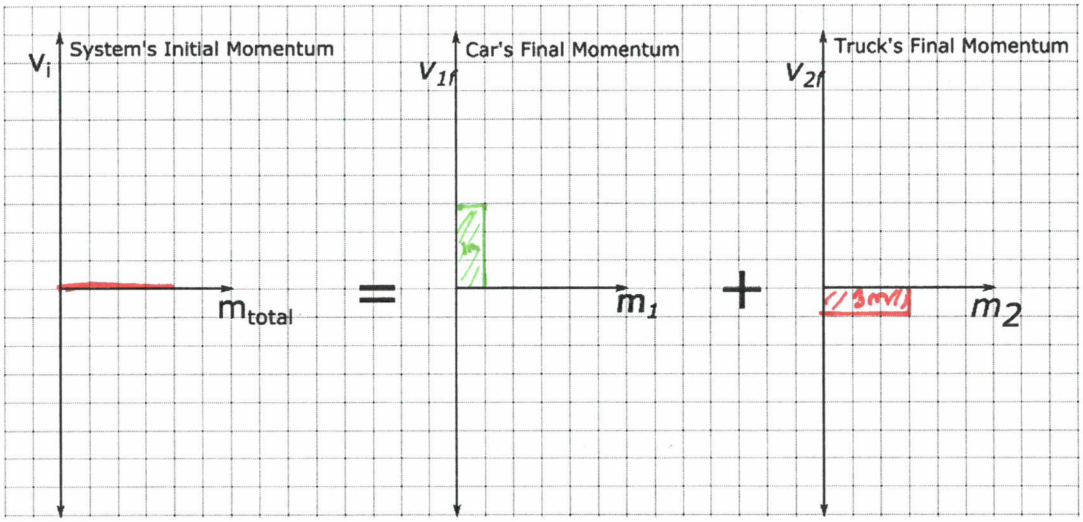
In which direction will they be traveling after the they collide? Explain and justify your answer.

The initial momentum of the system (Both Vechiles) is positive (Right). The Final momentum of the system must be equal ∴ positive (To Right)

5.E Conservation of Momentum (Inelastic Collisions)

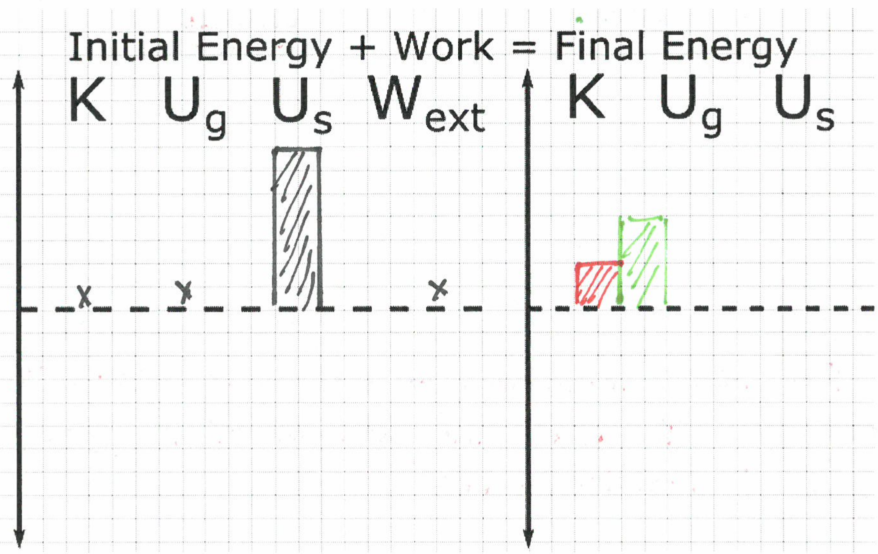


PART C: The toy car and truck are now pressed together with an ideal spring compressed between them. They are then released from rest. Diagram the momentum before and after the explosion as well as the energy before and after the explosion.



p = mv

- V, going left



Car (m)

Truck (3m)

$KE = \frac{1}{2}mv^2$

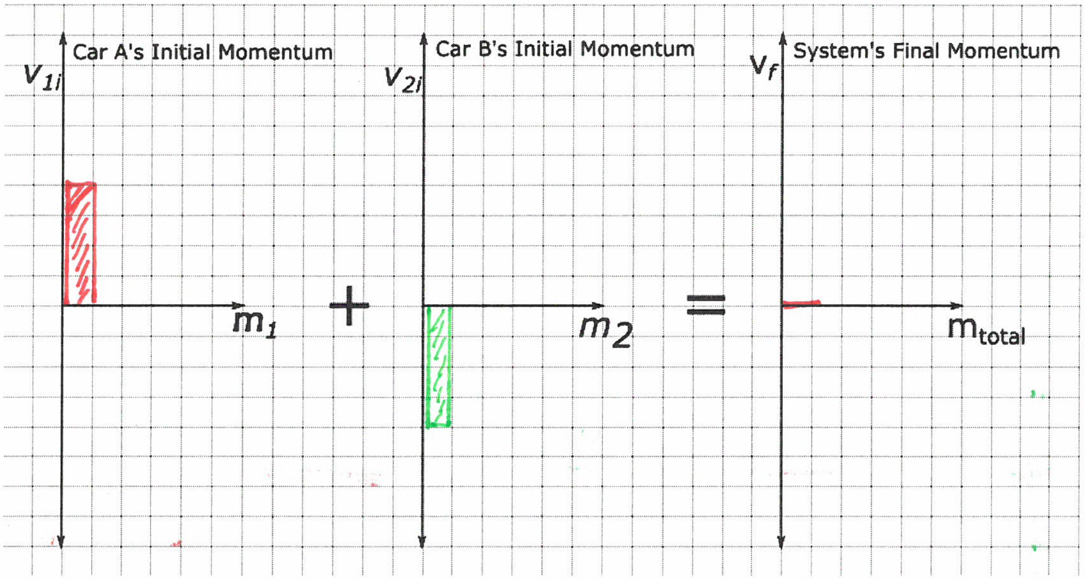
$KE = \frac{1}{2}mv^2$

$KE = \frac{1}{2}3mv^2$

$(\frac{3}{2})$

KEY

PART D: If there were instead two identical toy cars traveling in opposite directions at identical speeds, how would the momentum diagram change, and what direction would they be traveling after the collision? Explain and justify your answer.



Before Collisions

Total momentum = 0

Because 2 Toy cars
- Same mass
- Same velocity
- opposite direction

After Collision

Total momentum must equal Initial momentum

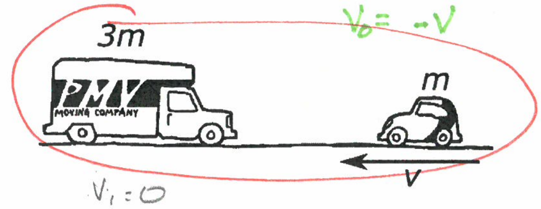
∴ $p_f = 0$

No F_{net}

NAME ______________________ DATE Key

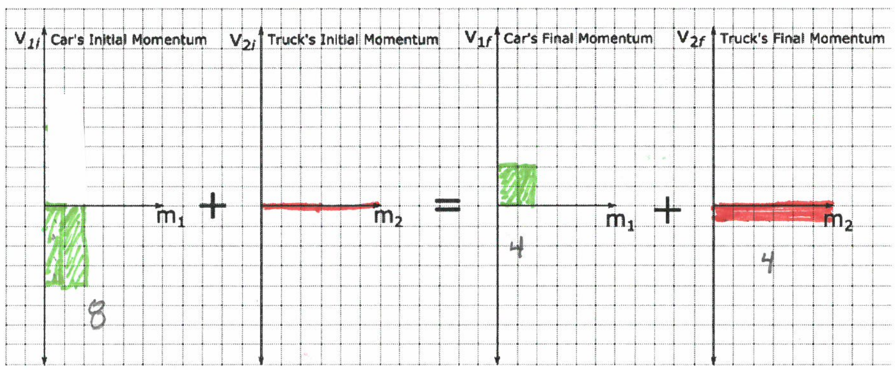
Scenario

A toy car is pushed with a speed v toward a toy truck initially at rest. The car bounces back off the truck so that the car's final speed is $\frac{v}{2}$ in the opposite direction. Consider the system to be the car and the truck.



Using Representations

PART A: Sketch a momentum diagram for the car and truck before and after the collision.



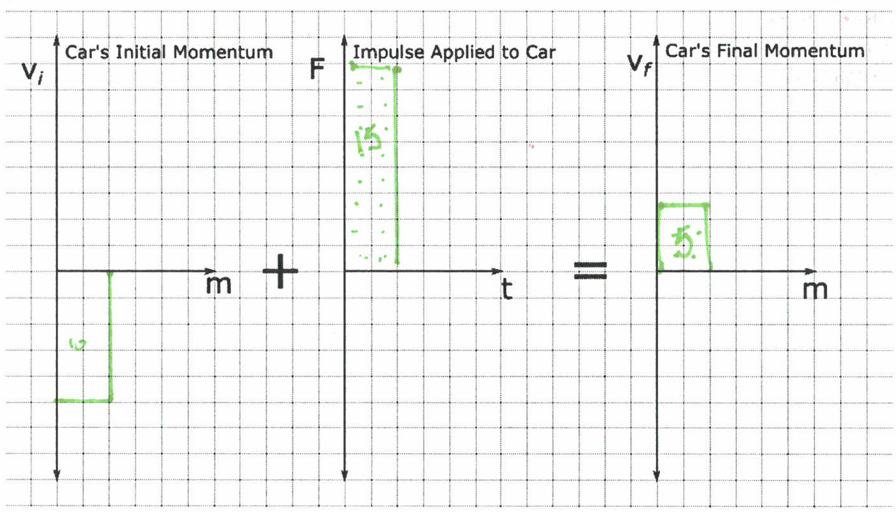
After

$p_i = p_f$

$-mv_c + 3mv_T = \frac{v}{2}m - 3mv_T$

How does the situation change if we consider the system to only contain the car?

PART B: Sketch a momentum diagram for the collision for the car-only system.



$-Vm$ $1.5Vm$ $\frac{V}{2}m$

Just picked "10"

$-10 + 15 = 5$

$FT = m\Delta V$
$= m(V_f - V_i)$
$= m(+\frac{V}{2} - (-V_i))$
$FT = 1.5Vm$

Data Analysis

PART C: In the laboratory, a ball is dropped onto a force-sensing platform several times, each time hitting a different surface (foam, feathers, clay, etc.). The momentum of the ball changes by the same amount in each trial; in each trial, the average scale reading is F, and the time of collision t are measured. What quantities would need to be graphed to exhibit a straight-line relationship?

Justify your answer in a few sentences.

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 (momentum, mass, energy, force, velocity, speed, time).

$V_i = 0$

Trials
1 foam
2 feathers
3 clay

Sensor
↓
measure
Force

$\Delta p = F_{net} \Delta t$

Since the balls p changes by the same amount in each Trial and $\Delta p = F_{net} \Delta t$, the eqn can be $F_{net} = \frac{\Delta p}{\Delta t}$. If the F_{net} is graphed vs $\frac{1}{\Delta t}$. The slope would Be equal to Δp

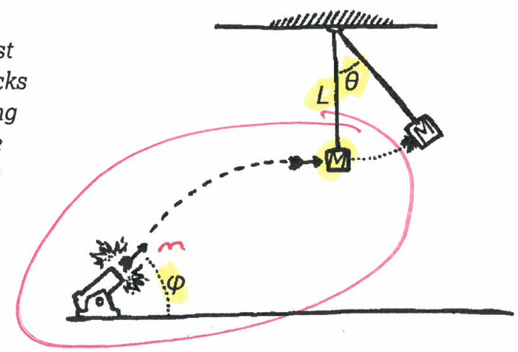
If we graphed the ball's change in momentum v's Impact time the slope would Be equal to the average force on the object.

This would Allow us to see that objects in collisions w/ greater changes in momentum experience greater average stopping forces

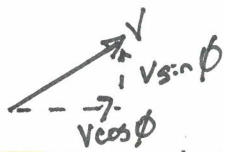
NAME ____________________ DATE Key

Scenario

A small dart of mass m is launched at an angle phi (ϕ) above the horizontal with initial speed v_0. At the moment it reaches the highest point in its path and is moving horizontally, it collides with and sticks to a wooden block of mass M that is suspended at the end of a string of negligible mass. The center of the block is a distance L below the pivot point of the string. The block and dart then swing up until the string makes an angle theta (θ) with the vertical as shown at the right. Air resistance is negligible.

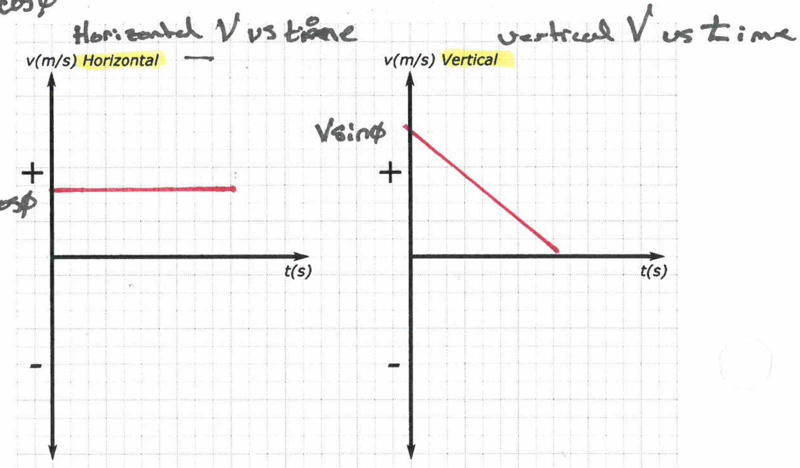


Using Representations



PART A:

i. Sketch a horizontal and a vertical velocity vs. time graph from the time the dart is launched to the time it hits the block.



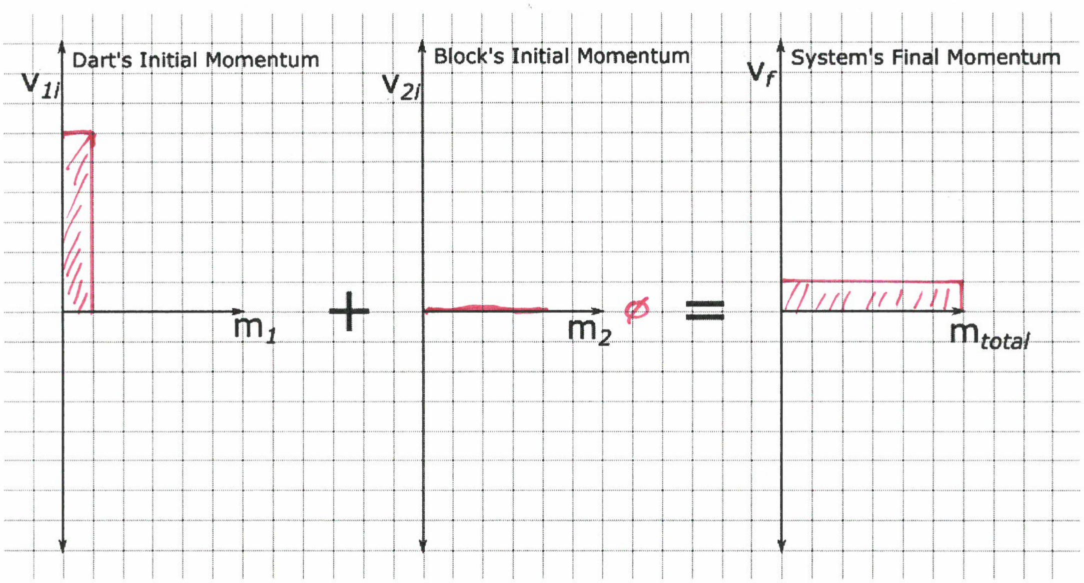
ii. Determine the speed of the dart just before it strikes the block. Your answer should only include v_0, Φ, θ, L, and physical constants.

v = Vcos ϕ

PART B:

i. Identify the system by circling both the dart and the box with a dotted circle. Arrow, Block Earth

ii. Sketch a momentum diagram for the system from just before to just after the dart collides with the block.



Note # of Squares "filled" must Be equal Initial p = final p

Δp = mV

Argumentation

PART C: In a second experiment, a dart with a greater mass is launched at the same speed and angle. The dart collides with and sticks to the same wooden block. Would the angle theta (θ) that the dart and block swings to increase, decrease, or stay the same? In a clear, coherent paragraph-length response, that ***may*** also contain figures and/or equations, justify your choice.

✓ Increase ____ Decrease ____ Stay the same

If the mass of Dart Increase, the Initial momentum also increase ($p = \underline{m}v$)

There are NO net external horizontal forces (friction, heat loss etc)
so $p_{initial} = p_{final}$

The KE_i of Arrow higher ($KE = \frac{1}{2}mv^2$)
(same speed, But m↑)

∴ post collision KE ↑, which means that the Block/dart system can swing higher ∴ Larger Angle

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 compared the situation (stated what was the same in all cases).

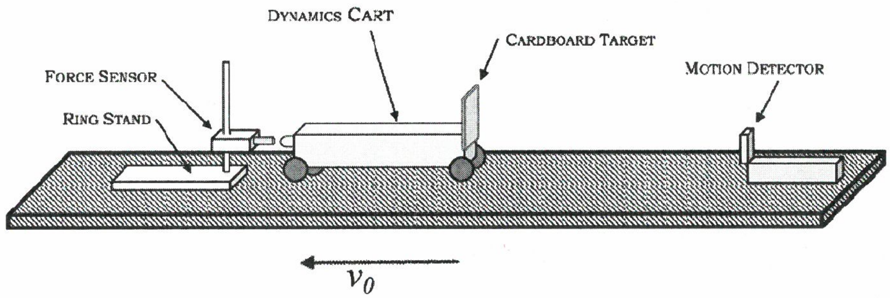
____ I contrasted the situations (stated what was different in all cases).

____ I used physics vocabulary (momentum, mass, energy, force, velocity, speed, potential, kinetic, time).

NAME ______________________ DATE ____________

Scenario

Carlos and Dominique have been challenged to design an experiment to determine the impulse given to a cart as it collides with a barrier using two different mathematical or graphical ways. Dominique sketches the following diagram of the laboratory setup and writes the procedure below.



Materials: computer, force sensor, motion sensor, cart, cardboard target, mass balance