NAME: ____________ AP PHYSICS 1 DATE: ____________

MOMENTUM DAY 4: COLLISION STATIONS LAB

LAB GOAL

Test momentum conservation across **four different collision types**. Rotate through stations (~10 min each). Predict before you measure!

CORE EQUATIONS

Momentum: $\vec{p} = m\vec{v}$

Conservation: $\Sigma\vec{p}_i = \Sigma\vec{p}_f$

Inelastic: Objects stick → KE lost

Elastic: Objects bounce → KE conserved

% difference: $\%\,\text{diff} = \frac{|p_f - p_i|}{|p_i|} \times 100\%$ (should be small if momentum is conserved)

STATION OVERVIEW

1	2	3	4
Inelastic	**Elastic**	**Explosion**	**Ballistic**
Carts stick	Carts bounce	Spring release	Pendulum

PRE-LAB PREDICTIONS

PREDICT **Station 1: Inelastic (Stick)**

Cart A (0.5 kg) at 0.6 m/s hits stationary Cart B (0.5 kg). They stick together.

Predict the final velocity of the combined carts: $v_f =$ ________ m/s

Show work:

PREDICT **Station 2: Elastic (Bounce)**

Cart A (0.5 kg) at 0.8 m/s hits stationary Cart B (0.5 kg). Equal masses, elastic collision.

What happens to the velocities? (Describe qualitatively):

PREDICT **Station 3: Explosion**

Two carts start at rest, spring releases. Cart A = 0.5 kg, Cart B = 1.0 kg.

If Cart B moves at 0.3 m/s right, predict Cart A's velocity: $v_A =$ ________ m/s

Show work:

STATION 1: INELASTIC COLLISIONS (STICK)

SETUP

- Attach Velcro or clay so carts stick on contact
- Cart A moves; Cart B starts at rest
- Try different mass combinations (equal, 2:1, 1:2)

DATA **Inelastic Trials**

Trial	m_A (kg)	m_B (kg)	v_{Ai} (m/s)	v_f (m/s)	p_{before}	p_{after}	% diff
1							
2							
3							

$v_{Bi} = 0$ for all trials. Remember: $p_{\text{after}} = (m_A + m_B) \cdot v_f$

STATION 2: ELASTIC COLLISIONS (BOUNCE)

SETUP

- Use magnetic or spring bumpers so carts bounce
- Cart A moves; Cart B starts at rest
- Try equal masses first, then unequal

DATA **Elastic Trials**

Trial	m_A	m_B	v_{Ai}	v_{Af}	v_{Bf}	p_{before}	p_{after}	% diff
1								
2								
3								

ANALYSIS **Equal Mass Elastic Pattern**

For equal-mass elastic collisions with one cart at rest, what pattern do you notice?

STATION 3: EXPLOSION (SPRING RELEASE)

SETUP

- Place two carts together with spring plunger between them
- Both carts start at rest (total initial momentum = 0)
- Trigger the spring release; carts fly apart
- Try different mass ratios

DATA Explosion Trials

Trial	m_A (kg)	m_B (kg)	v_{Af} (m/s)	v_{Bf} (m/s)	p_A	p_B
1						
2						
3						

Use + for right, – for left. If momentum is conserved, $p_A + p_B = 0$.

ANALYSIS Mass-Velocity Relationship

Compare the velocity ratio $\frac{v_A}{v_B}$ to the mass ratio $\frac{m_B}{m_A}$. What do you find?

STATION 4: BALLISTIC PENDULUM

SETUP

- Projectile collides with pendulum bob (inelastic collision)
- Combined mass swings upward
- Measure swing height to find velocity after collision
- *Details: see instructor*

DATA Ballistic Pendulum

Mass of projectile m_p = ________ kg
Mass of pendulum m_{bob} = ________ kg
Swing height h = ________ m

Combined mass M = ________ kg
Velocity after collision v_f = ________ m/s
Projectile velocity v_p = ________ m/s

CALC Two-Step Analysis

Step 1 (Energy): Use $v_f = \sqrt{2gh}$ to find velocity just after collision.
Step 2 (Momentum): Use $m_p v_p = M v_f$ to find projectile's initial velocity.

ANALYSIS & REFLECTION

1 Momentum Conservation Summary

For which station(s) was momentum conserved? Use your % difference values as evidence.

Station	Conserved? (Y/N)	Evidence (typical % diff)
1. Inelastic		
2. Elastic		
3. Explosion		
4. Ballistic		

2 Energy Comparison

Pick ONE inelastic trial and ONE elastic trial. Calculate K_{before} and K_{after} for each.

Inelastic Trial ___:

K_i = _______ J

K_f = _______ J

% lost = _______

Elastic Trial ___:

K_i = _______ J

K_f = _______ J

% lost = _______

Where does the "missing" energy go in inelastic collisions?

3 Newton's 3rd Law Connection

During any collision, how does the impulse on Cart A compare to the impulse on Cart B?

$\vec{J}_A$ vs $\vec{J}_B$: ____

Explain using Newton's 3rd Law:

4 Ballistic Pendulum: Why Two Steps?

Why can't you use energy conservation for the collision, but you CAN use it for the swing?

Key Takeaway: Momentum is *always* conserved in isolated collisions. Kinetic energy is only conserved in elastic collisions.

Homework — Crash Zone Design Challenge:
Tomorrow we test crash zones with force plates! Build a crumple zone or padding system at home using materials like foam, cardboard, paper, straws, tape, etc. Your goal: *maximize energy dissipation* to reduce peak force. Materials that crumple, compress, or deform are working well — that energy is being dissipated instead of transferred to the "passenger." Use soft, lightweight, contained materials only (foam, cardboard, paper, tape); no glass, sharp pieces, or loose fragments.