Laboratory Investigation S1:

Momentum in Sports Physics

Experimental Overview

Key Concept:
Momentum is the product of an object's mass and velocity, expressed mathematically as:

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

In this investigation, you'll analyze the momentum of sports equipment in motion, connecting classroom physics to real-world athletics. By capturing slow-motion video of sports equipment in action, you'll discover how mass and velocity combine to create the dynamic interactions we see in sports.

Investigation Strategy

Choose a sport where an object's momentum plays a crucial role. Excellent choices include:

- A Frisbee catch
- A soccer ball being kicked
- A volleyball serve
- A basketball jump shot
- A Badminton serve

Consider which motion will be easiest to capture clearly on video while also being safe to measure.

Materials and Equipment

- Smartphone with video capability (120fps or higher recommended but not needed)
- Electric balance (accurate to at least 0.1g)
- Measuring tape or meter stick
- Your chosen sports equipment
- Spreadsheet software

- Ruler (for measuring distances on video playback)
- Reference object of known size (for video scale calibration)

Safety Considerations

Safety Protocol

Before beginning your investigation:

- Choose a safe, open area appropriate for your sport
- Ensure no people or valuable objects are in the path of your sports equipment
- Follow all standard safety procedures for your chosen sport
- Have a spotter present during measurements and filming
- Secure loose clothing and remove jewelry that could interfere with movement

Experimental Procedure

Part 1: Mass Measurement

1. Use the electric balance to measure your sports object's mass in kilograms
2. Record this value with appropriate significant figures
3. Measure and record any relevant dimensions of your object

Part 2: Velocity Analysis

1. Place your reference object (of known size) in the same plane as your intended motion
2. Record your sports action in slow motion (try to keep the camera perpendicular to the motion)
3. Repeat for at least 5 measurements
4. Transfer the video to a computer for analysis

Video Analysis

1. Count the total frames for your object's motion
2. Note your camera's frame rate (frames per second)
3. Use your reference object to establish scale in the video

4. Measure the distance your object travels
5. Calculate velocity using:

$$v = \frac{\text{distance}}{\text{time}} = \frac{\text{distance}}{\text{number of frames/frames per second}}$$

Sample Calculation

Let's analyze a basketball free throw:
Given:

- Distance traveled: 4.2 meters (from player to hoop)
- Number of frames: 30 frames
- Camera frame rate: 240 frames per second

Time interval = $\frac{30 \text{ frames}}{240 \text{ frames/second}} = 0.125$ seconds
Velocity = $\frac{4.2 \text{ meters}}{0.125 \text{ seconds}} = 33.6$ meters/second
If the basketball's mass is 0.62 kg, its momentum would be:
Momentum = $0.62 \text{ kg} \times 33.6 \text{ m/s} = 20.8 \text{ kg} \cdot \text{m/s}$
Note: This example illustrates why precision in measurement is crucial - small errors in distance or frame counting can significantly affect your final momentum calculation.

Data Collection

Record your measurements in this format:

Measurement	Value	Units
Object Mass		kg
Distance Traveled		m
Frame Count		frames
Time Interval		s
Calculated Velocity		m/s
Calculated Momentum		kgm/s

Video Recording Best Practices

- Use the highest frame rate available
- Keep the camera steady (tripod recommended)
- Ensure good lighting
- Position the camera perpendicular to the motion
- Include a reference object of known size in the frame
- Record multiple trials

Analysis Questions

1. How does your object's momentum compare to other sports? Research typical values for comparison.
2. What factors might affect the accuracy of your measurements?
3. How might air resistance impact your results?
4. Why is momentum important in your chosen sport?
5. How could your measurement technique be improved?

Additional Insights

Consider how momentum conservation applies in your sport. For example, in a collision between a bat and baseball, total momentum is conserved even as it transfers between objects. How does this principle manifest in your chosen sport?

Optional Extension: Compare the momentum of different techniques in your sport (e.g., different types of serves in tennis or different types of kicks in soccer).

Assessment Rubric

Emerging

Description: Beginning to grasp fundamental momentum concepts and video analysis methods, requiring significant guidance.
Skills and Abilities:

- Can identify basic lab equipment and follow safety protocols with supervision
- Understands the basic momentum equation ($\vec{p} = m\vec{v}$) but struggles to apply it
- Can record mass measurements and frame counts but needs help with calculations
- Has difficulty converting video measurements to real-world velocities
- Requires assistance with video recording and analysis techniques

Developing

Description: Shows growing understanding of momentum principles and video analysis techniques, but needs support applying them.
Skills and Abilities:

- Sets up video recording equipment with some assistance, following safety guidelines
- Records mass and video data systematically but may have inconsistent significant figures
- Can perform basic velocity calculations from frame counts with support
- Makes simple momentum calculations but may struggle with units
- Creates basic data tables but needs help organizing multiple trials
- Recognizes the relationship between mass and velocity in momentum but has difficulty explaining it

Proficient

Description: Demonstrates solid comprehension of momentum concepts and video analysis methods, working independently with minimal support.
Skills and Abilities:

- Independently sets up video recording equipment and conducts trials safely
- Records precise measurements with appropriate units and significant figures
- Correctly analyzes video footage to determine velocities
- Calculates momentum values accurately with consistent units
- Creates clear data tables with all required measurements
- Identifies common sources of experimental error in video analysis
- Makes meaningful connections between calculated momentum and sports performance

Extending

Description: Shows advanced understanding and analytical capability, exploring momentum concepts beyond basic requirements.
Skills and Abilities:

- Designs improvements to video analysis procedure to enhance accuracy
- Considers advanced factors like air resistance and rotation in analysis
- Provides sophisticated comparison of momentum values across different sports
- Makes insightful connections between momentum conservation and game strategies
- Proposes creative extensions to investigate related concepts like impulse
- Analyzes how different techniques in their chosen sport affect momentum values
- Critically evaluates limitations of video analysis methods and suggests improvements