A Puck Moves 2.35 M/s In A -22.0 Direction. A Hockey Stick Pushes It For 0.215 S, Changing Its Velocity

Introduction

A puck moves 2.35 m/s in a -22.0° direction. A hockey stick pushes it for 0.215 seconds, changing its velocity. This scenario involves fundamental principles of physics, including motion, forces, and impulse. Understanding how the puck's velocity changes during the push requires analyzing the forces involved, the impulse imparted, and the resulting acceleration. This article explores these concepts in depth, providing a comprehensive understanding of the dynamics at play in this hockey scenario.

Understanding the Initial Conditions

Initial Velocity of the Puck

The puck's initial velocity is given as 2.35 m/s in a -22.0° direction. The negative sign indicates the direction relative to a reference axis, often taken as the positive x-axis. To analyze the motion, it's essential to resolve this velocity into its components:

- **Horizontal component (vx):** $v_{x} = v \cos \theta$
- **Vertical component (vy):** $v_{y} = v \sin \theta$

where $v = 2.35\, \text{m/s}$ and $\theta = -22.0^\circ$. Calculating these components yields:

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v_x = 2.35 × cos(-22.0°) ≈ 2.35 × 0.9272 ≈ 2.177 m/s
v_y = 2.35 × sin(-22.0°) ≈ 2.35 × (-0.3746) ≈ -0.882 m/s
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Significance of the Direction

The negative y-component indicates the puck is moving downward relative to the reference axis, while the positive x-component suggests forward motion. Understanding this initial state is crucial for analyzing how the push affects the puck's velocity.

Analyzing the Force and Impulse Applied by the Hockey Stick

What is Impulse?

Impulse is a measure of the change in momentum of an object when a force is applied over a period of time. It is given by:

- **Impulse (J):** $J = F \times \Delta t$
- **Change in momentum:** $\Delta p = m \times \Delta v$

The impulse-momentum theorem states that:

$$J = \Delta p = m \times \Delta v$$

where m is the mass of the puck, Δv is the change in velocity, and J is the impulse imparted by the force during the push.

Estimating the Force Exerted by the Hockey Stick

While the exact force depends on the mass of the puck and the change in velocity, the force can be estimated if the mass of the puck is known. For a typical hockey puck with a mass approximately 0.16 kg, we can proceed with calculations assuming this value.

Calculating the Impulse

Given the push duration $\Delta t = 0.215\, \text{s}$, the impulse can be expressed as:

$$J = F_{avg} \times \Delta t$$

where F_{avg} is the average force during the push. The change in velocity (Δv) can be determined once the final velocity is known or assumed, which leads us into the next sections.

Determining the Change in Velocity

Final Velocity of the Puck

The problem indicates that the hockey stick's push changes the puck's velocity, but does not specify the final velocity directly. To analyze, we consider the general case where the impulse affects both magnitude and direction of the velocity vector.

Approach to Calculating Final Velocity

1. Calculate the initial momentum components: $p_{x,i} = m v_x$, $p_{y,i} = m v_y$.
2. Determine the impulse components in x and y directions. If the force is applied in a specific direction, resolve the impulse accordingly.
3. Calculate the final momentum components: $p_{x,f} = p_{x,i} + J_x$ and $p_{y,f} = p_{y,i} + J_y$.
4. Compute the final velocity components: $v_{x,f} = p_{x,f} / m$, $v_{y,f} = p_{y,f} / m$.

Assuming a Pure Force Application in a Specific Direction

If the push is applied purely in the direction of the puck's initial velocity, then the change in velocity will be along that same line. Alternatively, the force could be applied at an angle, changing the direction as well as the magnitude of velocity.

Example Calculation: Force Applied in the Same Direction

Suppose the force is applied in the same direction as the initial velocity (i.e., along the x-axis). Then:

$$J_x = F_{avg} \times \Delta t$$

The change in the x-component of momentum is:

$$\Delta p_x = m \times \Delta v_x$$

which implies:

$$\Delta v_x = J_x / m$$

Similarly, the final velocity in x-direction becomes:

$$v_{x,f} = v_{x,i} + \Delta v_x$$

Given these, the final speed and direction can be recalculated to understand how the puck's motion has changed.

Calculating the Magnitude and Direction of the Final Velocity

Final Velocity Components

Assuming a certain impulse or force, the new velocity components can be computed. For example, if the impulse adds 1.0 m/s in the x-direction, then:

$$v_{x,f} = 2.177 + 1.0 = 3.177 \text{ m/s}$$
$$v_{y,f} = -0.882 \text{ m/s (assuming no change in y-direction)}$$

Final Speed and Direction

The magnitude of the final velocity vector becomes:

$$v_f = \sqrt{v_{x,f}^2 + v_{y,f}^2}$$

The direction (angle \(\theta_f \)) relative to the x-axis is:

$$\theta_f = \arctan(v_{y,f} / v_{x,f})$$

This provides insight into how the puck's motion has been altered by the push.

Implications of the Change in Velocity

Conservation of Momentum

The total momentum before and after the push reflects the impulse imparted by the hockey stick. Since external forces are involved only during the push, the change in momentum directly relates to the force applied.

Effect on the Puck's Trajectory

Changes in velocity magnitude and direction influence the puck's subsequent path on the ice. A greater impulse results in higher speed, potentially affecting gameplay strategies.

Energy Considerations

The work done by the hockey stick translates into kinetic energy transferred to the puck. The kinetic energy after the push can be calculated as:

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KE = 0.5 × m × v_f^2
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and compared to initial kinetic energy to evaluate the efficiency of the force applied.

Conclusion

The scenario of a puck moving initially at 2.35 m/s in a -22.0° direction and being pushed for 0.215 seconds demonstrates core physics principles such as velocity components, impulse, and force. By resolving the initial velocity into components, calculating the impulse imparted, and determining the resulting change in velocity, we gain a comprehensive understanding of the dynamics involved. This analysis not only provides insight into the physics of hockey but also exemplifies fundamental concepts applicable across various motion-related contexts.

Frequently Asked Questions

What is the initial velocity of the puck before the hockey stick pushes it?

The initial velocity of the puck is 2.35 m/s in the -22.0° direction.

How long does the hockey stick apply force to the puck?

The hockey stick pushes the puck for 0.215 seconds.

What factors determine the change in the puck's velocity during the push?

The change in velocity depends on the applied force, the duration of the push, and the puck's mass, according to Newton's second law.

How can we calculate the impulse delivered to the puck during the push?

Impulse is calculated as the change in momentum, which equals the force applied multiplied by the time of application, or $\Delta p = F\ \Delta t$.

What is the significance of the puck's initial velocity direction in analyzing its motion?

The initial velocity direction helps determine the vector components of the puck's motion and how the applied force affects its trajectory and speed.

Additional Resources

A puck's motion is a fundamental aspect of ice hockey physics, demonstrating key principles of mechanics,

momentum, and impulse. In this detailed analysis, we examine a scenario where a puck initially moves at 2.35 m/s in a specific direction and is subsequently acted upon by a hockey stick, which applies a force over a brief interval of time, resulting in a change in its velocity. This situation provides an excellent case study for understanding how forces influence motion, how impulses work, and the underlying physics that govern everyday sports activities like hockey.

Introduction to the Scenario

Understanding the physical principles behind a hockey puck's motion involves analyzing initial conditions, the forces applied, and the resulting changes in velocity. In this case, the puck starts with an initial velocity of 2.35 meters per second in a specified direction, which we'll denote as the negative or positive axis for clarity. Then, a hockey stick exerts a push lasting 0.215 seconds, altering the puck's velocity.

This scenario encapsulates fundamental physics concepts such as Newton's laws of motion, impulse-momentum theorem, and force analysis. It also lends itself to exploring the magnitude and direction of forces involved, the effect of brief but forceful interactions, and the implications for game strategies and equipment design.

Initial Conditions and Kinematic Overview

Initial Velocity of the Puck

The puck's initial velocity is given as 2.35 m/s in a certain direction, which we'll assume as the positive x-axis for simplicity. This initial velocity sets the puck in motion, and understanding its initial state is critical for subsequent calculations.

- Magnitude: 2.35 m/s
- Direction: Let's define this as the positive x-direction for clarity.

Significance of the Initial State

The initial velocity determines the puck's momentum before contact with the hockey stick. This momentum is given by:

$$p_{initial} = m \times v_{initial}$$

where m is the mass of the puck, typically around 0.17 kg for standard ice hockey pucks. Knowing the mass allows precise calculations of momentum and force effects.

Force Application by the Hockey Stick

Duration of Force Application

The hockey stick applies a force to the puck for 0.215 seconds. Although brief, this interval is sufficient to produce a significant change in velocity due to the high magnitude of forces involved in sports.

Change in Velocity

While the problem states that the stick "pushes it for 0.215 s, changing its velocity," it implies a change from the initial velocity $v_{initial}$ to a new velocity v_{final}. The exact final velocity is not specified but can be inferred through impulse calculations once the force magnitude is known or estimated.

Force and Impulse Relationship

The core principle connecting force, time, and change in momentum is the impulse-momentum theorem:

$$J = \Delta p = F_{avg} \times \Delta t$$

where:
- J is the impulse,
- Δp is the change in momentum,
- F_{avg} is the average force,
- $\Delta t = 0.215$ seconds.

Understanding this relationship allows us to analyze how the force applied over this specific interval changes the puck's velocity.

Mathematical Analysis of the Motion

Calculating the Change in Momentum

The change in momentum is directly related to the change in velocity:

$$\Delta p = m \times (v_{final} - v_{initial})$$

Assuming the mass m of the puck is 0.17 kg,

$$\Delta p = 0.17 \times (v_{final} - 2.35)$$

Without the final velocity, we can express the impulse needed to produce a certain velocity change once the force is known or estimated.

Estimating the Force Applied

Suppose we have an estimate for the change in velocity or the final velocity; then, the average force during the push can be calculated as:

$$F_{avg} = \frac{\Delta p}{\Delta t}$$

For example, if the puck's velocity increases to 5.0 m/s after the push:

$$\Delta p = 0.17 \times (5.0 - 2.35) = 0.17 \times 2.65 = 0.4505 \, \text{kg·m/s}$$

$$F_{avg} = \frac{0.4505}{0.215} \approx 2.095 \, \text{N}$$

This indicates the average force exerted by the hockey stick is roughly 2.1 Newtons in the direction of the push.

Note: The actual final velocity depends on the force magnitude and direction; the above is an example assuming an increase to 5.0 m/s.

Directionality of the Force and Motion

Vector Considerations

The initial velocity and the force applied are vector quantities. The direction of the push determines whether the puck accelerates in the same or opposite direction as its initial motion.

- If the force is in the same direction as the initial velocity, the puck speeds up.
- If in the opposite direction (e.g., a backward push), the puck slows down or even reverses direction.

In this scenario, since the problem states that the puck's velocity is changed, it's vital to specify whether the push is in the same or opposite direction. For simplicity, assume the push is in the same direction, increasing the puck's speed.

Implications for Game Play

In actual hockey play, players aim to maximize the force applied during the brief contact to increase puck speed or control its trajectory. The directionality of the force is crucial for strategic plays — whether to accelerate the puck towards the goal, pass to teammates, or slow down opponents.

Impact of the Force on Velocity and Motion

Changes in Velocity

Using the impulse-momentum theorem, the change in velocity is directly related to the applied impulse:

$$ \Delta v = \frac{J}{m} $$

where $J = F_{avg} \times \Delta t$.

Given the earlier example, if the force is approximately 2.1 N, then:

$$ J = 2.095 \times 0.215 \approx 0.45 \, \text{kg·m/s} $$

and

$$ \Delta v = \frac{0.45}{0.17} \approx 2.65 \, \text{m/s} $$

Adding this to the initial velocity:

$$ v_{final} = v_{initial} + \Delta v \approx 2.35 + 2.65 = 5.0 \, \text{m/s} $$

This calculation confirms that a relatively modest force applied over a short duration can significantly accelerate the puck.

Repercussions on Puck Trajectory

A change in velocity alters the puck's trajectory and kinetic energy. The kinetic energy before and after the push can be compared:

$$ KE = \frac{1}{2} m v^2 $$

- Initial KE:

$$ KE_{initial} = 0.5 \times 0.17 \times (2.35)^2 \approx 0.5 \times 0.17 \times 5.52 \approx 0.469\, \text{J} $$

- Final KE (assuming $v_{final} = 5.0\, \text{m/s}$):

$$ KE_{final} = 0.5 \times 0.17 \times 25 = 2.125\, \text{J} $$

Thus, the puck's kinetic energy increases substantially, enhancing its capacity to travel further and faster, impacting gameplay.

Additional Factors and Real-World Considerations

Friction and Air Resistance

While the ideal physics calculations assume a frictionless environment, real-world ice hockey involves friction from the ice surface and air resistance. These forces gradually decelerate the puck, requiring continuous force application for sustained speed.

- Friction: The puck's interaction with ice, characterized by a low coefficient of friction, still causes energy loss over distance.
- Air resistance: Although minimal at hockey puck speeds, it still influences the puck's deceleration over long distances.

In the context of the brief force application described, these factors are secondary but become significant over longer periods or distances.

Material and Equipment Factors

The efficiency of force transfer depends on equipment factors such as:

- Hockey stick material: Flexibility and stiffness influence how force is transmitted.
- Puck surface: The condition and surface texture affect how force is applied and how energy is conserved or lost.
- Player technique: The angle and speed of the stick push determine the effectiveness of force transfer.

Conclusion: Insights and Implications

This detailed examination of a puck's motion under a brief but forceful push underscores the profound influence of impulse and force on sports dynamics. The scenario exemplifies how even a fraction of a second of contact with a hockey stick can dramatically change a puck's velocity, direction, and energy state.

From a physics

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