A Boy Of Mass 60 Kg And A Girl Of Mass 40 Kg Are Together And At Rest On A Frozen Pond And Push Each

A Boy Of Mass 60 Kg And A Girl Of Mass 40 Kg Are Together And At Rest On A Frozen Pond And Push Each

Understanding the physics behind everyday interactions can be both fascinating and educational. Imagine a scenario where a boy weighing 60 kg and a girl weighing 40 kg are standing together on a frozen pond, initially at rest. When they decide to push each other, what happens? How do their masses influence their movements? What principles of physics come into play? This comprehensive guide explores these questions in detail, providing insights into Newton's laws of motion, conservation of momentum, force interactions, and practical implications.

Fundamental Concepts Involved in the Scenario

Before diving into the specifics of the interactions between the boy and girl, it's essential to understand the core physical principles that govern such situations.

Newton's Laws of Motion

Newton's laws form the foundation of classical mechanics and are vital in analyzing the scenario:

1. **First Law (Inertia):** An object remains at rest or in uniform motion unless acted upon by an external force.
2. **Second Law:** The acceleration of an object is directly proportional to the net force acting upon it and inversely proportional to its mass (F = ma).
3. **Third Law:** For every action, there is an equal and opposite reaction.

Conservation of Momentum

In an isolated system where external forces are negligible (like a frozen pond), the total momentum remains constant. When the boy and girl push against each other, they exert equal and opposite forces, resulting in changes in their velocities but conserving the total momentum.

Friction and External Forces

While the ice is assumed to be frictionless for ideal analysis, real ice has some friction. However, for simplicity, we consider a nearly frictionless surface to focus on the core mechanics.

Analyzing the Push: Step-by-Step Breakdown

To understand what occurs when the boy and girl push each other, consider the following:

Initial Conditions

- Both are at rest: initial velocities $v_{boy} = 0$ and $v_{girl} = 0$.
- The system's total initial momentum: $p_{initial} = 0$.

Action: The Push

- They exert forces on each other for a certain duration.
- The forces are equal in magnitude and opposite in direction (by Newton's third law).
- The push causes both to accelerate in opposite directions.

Final State

- After the push, they move apart with velocities v_{boy} and v_{girl}.
- Since no external horizontal forces act, total momentum remains zero:

$$
m_{boy} \times v_{boy} + m_{girl} \times v_{girl} = 0
$$

This equation implies:

$$
v_{boy} = - \frac{m_{girl}}{m_{boy}} \times v_{girl}
$$

The negative sign indicates opposite directions.

Calculating Velocities Post-Push

Given the masses:

- $m_{boy} = 60\,kg$
- $m_{girl} = 40\,kg$

Suppose the boy pushes the girl, imparting a certain velocity v_{girl}, then the boy's velocity v_{boy} will be:

$$
v_{boy} = - \frac{40}{60} \times v_{girl} = - \frac{2}{3} v_{girl}
$$

Or, equivalently, if the girl moves with velocity v_{girl}, the boy moves with:

$$
v_{boy} = - \frac{2}{3} v_{girl}
$$

The ratio depends directly on their masses; the lighter girl will end up moving faster than the boy, but in the opposite direction.

Example Calculation

Assuming the girl gains a velocity of 1 m/s:

- The boy's velocity becomes:

$$
v_{boy} = - \frac{2}{3} \times 1\,m/s = - 0.666\,m/s
$$

- The negative sign indicates movement in the opposite direction to the girl's.

Implications of the Mass Difference

The difference in masses significantly influences the resulting velocities:

1. **Velocity Distribution:** The lighter girl moves faster than the heavier boy after the push.
2. **Distance Covered:** Assuming equal push durations and forces, the girl will cover a larger distance in the same time.
3. **Balance of Forces and Motion:** The heavier boy's inertia resists acceleration more, resulting in smaller velocity change compared to the girl.

Real-World Factors Affecting the Motion

While the ideal physics calculations assume a frictionless surface and no external forces, real-world conditions introduce additional factors:

Frictional Resistance

- Ice has some friction, which opposes motion.
- The coefficient of friction affects how easily they can slide.
- Increased friction reduces their velocities after the push.

Air Resistance

- For short distances, air resistance is negligible but can influence the motion slightly over longer periods.

Force Duration and Push Strength

- The magnitude and duration of the applied force determine the final velocities.
- A stronger or longer push results in higher velocities.

Direction and Angle of Push

- If pushes are not perfectly aligned, the motion will have components in different directions.
- For simplicity, consider only horizontal pushes.

Energy Considerations

The push involves transferring energy from the boy and girl to their kinetic energy:

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

Total initial energy is zero, as both are at rest. Energy is imparted during the push:

$$
KE_{total} = \frac{1}{2} m_{boy} v_{boy}^2 + \frac{1}{2} m_{girl} v_{girl}^2
$$

Given the velocities are related, the total kinetic energy can be expressed in terms of one velocity:

$$
KE_{total} = \frac{1}{2} m_{boy} \left(\frac{2}{3} v_{girl}\right)^2 + \frac{1}{2} m_{girl} v_{girl}^2
$$

This energy comes from the force exerted during the push.

Summary of Key Points

- When a boy and girl push each other on a frictionless surface, they accelerate in opposite directions due to Newton's third law.
- Their velocities are inversely proportional to their masses; the lighter person moves faster.
- Conservation of momentum ensures the total system momentum remains zero if external forces are

negligible.

- Real-world factors like friction, force duration, and push strength influence the actual velocities achieved.
- The energies involved are transferred into their kinetic energies, causing movement.

Practical Applications and Educational Insights

Understanding this scenario provides valuable educational insights:

1. **Physics Education:** Demonstrates conservation of momentum and Newton's laws.
2. **Sports and Games:** Explains how mass and force influence movement dynamics in activities like rowing, pushing sports, or ice skating.
3. **Engineering and Safety:** Helps in designing systems where forces and masses interact, emphasizing safety considerations in pushing or pulling objects.
4. **Everyday Life Observation:** Explains why lighter objects or persons tend to move faster when pushed with the same force.

Conclusion

The interaction between a boy weighing 60 kg and a girl weighing 40 kg on a frozen pond showcases fundamental physics principles in action. Their push results in opposite movements governed by Newton's third law and conservation of momentum. The lighter girl accelerates more, illustrating how mass influences velocity in reciprocal interactions. While idealized models assume frictionless surfaces and uniform force application, real-world conditions add complexity but do not negate these fundamental principles. Understanding such scenarios enhances our comprehension of motion, force interactions, and energy transfer—cornerstones of physics that explain many everyday phenomena.

Keywords for SEO Optimization:

- Newton's laws of motion
- Conservation of momentum
- Push and reaction forces
- Physics of pushing objects
- Motion on ice
- Mass and velocity relationship
- Frictionless surface physics
- Force and acceleration
- Real-world physics examples
- Understanding momentum transfer

Frequently Asked Questions

What happens when a boy and girl push each other while standing on a frozen pond?

They exert equal and opposite forces on each other, causing both to move in opposite directions due to Newton's Third Law.

How do their masses affect their movements when pushing each other on the ice?

The boy, being heavier (60 kg), will accelerate less than the girl (40 kg) because acceleration is inversely proportional to mass, assuming equal force is applied.

Will the ice break when they push each other, and why?

It depends on the force they exert; if the force exceeds the ice's breaking strength, the ice may crack or break. Their combined force and the ice's thickness determine this.

If both push with the same force, who will move faster on the ice?

The girl, having less mass, will accelerate more and thus move faster in the opposite direction compared to the boy.

How can the principle of conservation of momentum be applied to their pushing scenario?

Since they start at rest, the total momentum before and after pushing remains zero; as they push each other, their momenta are equal in magnitude and opposite in direction, balancing out.

Additional Resources

A Boy Of Mass 60 Kg And A Girl Of Mass 40 Kg Are Together And At Rest On A Frozen Pond And Push Each

In the fascinating realm of classical mechanics, the seemingly simple act of two individuals pushing against each other on a frictionless surface opens up a window into fundamental principles such as Newton's Third Law, conservation of momentum, and the dynamics of motion. Imagine a scenario where a boy weighing 60 kg and a girl weighing 40 kg stand still on a frozen pond—an icy, frictionless surface—and simultaneously push each other away. At first glance, it seems straightforward, but a deeper analysis reveals intricate details about forces, motion, and energy transfer that make this scenario a perfect case study for understanding fundamental physics.

Understanding the Scenario: Setting the Stage

The Context and Assumptions

In this scenario, two individuals—one boy of mass 60 kg and one girl of mass 40 kg—are initially at rest on a perfectly frictionless, ice-covered pond. They simultaneously push against each other with equal and opposite forces. Several assumptions simplify the analysis:

- Frictionless Surface: The pond is perfectly frozen, eliminating any frictional forces.
- Equal and Opposite Forces: Based on Newton's Third Law, the forces each exerts on the other are equal in magnitude and opposite in direction.
- No External Forces: External forces like gravity (vertically) are balanced and do not influence horizontal motion, which is the focus here.
- Initial Rest State: Both start at rest, meaning initial velocities are zero.
- Simultaneity: Both push at the same time with a certain force magnitude.

This scenario is a classic illustration of Newtonian mechanics, specifically focusing on action-reaction pairs and conservation laws.

Fundamental Principles at Play

Newton's Third Law of Motion

Newton's Third Law states: For every action, there is an equal and opposite reaction. When the boy pushes on the girl, she pushes back with an equal force. These forces are internal to the system, meaning they do not change the overall momentum of the combined system of both individuals.

Conservation of Momentum

In the absence of external forces, the total momentum of the system remains constant. Since initially both are at rest, the total initial momentum is zero. Therefore, after they push each other, the sum of their momenta must still be zero:

$$ p_{boy} + p_{girl} = 0 $$

which implies:

$$ m_{boy} v_{boy} + m_{girl} v_{girl} = 0 $$

This relation is fundamental in analyzing their subsequent motion.

Analyzing the Motion: Step-by-Step Breakdown

Initial Conditions

Initially:

- Velocities: $v_{boy} = 0$, $v_{girl} = 0$

- Total momentum: 0

Action of the Push

When they push:

- The boy exerts a force F on the girl.
- The girl exerts an equal and opposite force $-F$ on the boy.
- These forces act for a certain duration Δt.

Resultant Velocities

Applying Newton's Second Law:

$$F = m \times a$$

and the impulse-momentum theorem:

$$F \times \Delta t = m \times \Delta v$$

Thus,

- For the boy:

$$F \times \Delta t = m_{boy} \times v_{boy}$$

- For the girl:

$$F \times \Delta t = m_{girl} \times v_{girl}$$

Given the equal and opposite nature of forces:

$$m_{boy} \times v_{boy} = - m_{girl} \times v_{girl}$$

which confirms their velocities are in opposite directions and related through their masses.

Quantitative Analysis: Calculating Final Velocities

Deriving Velocity Expressions

From the impulse relations:

$$v_{boy} = \frac{F \times \Delta t}{m_{boy}}$$

$$v_{girl} = - \frac{F \times \Delta t}{m_{girl}}$$

The negative sign indicates they move in opposite directions.

Using the conservation of momentum:

$$ m_{boy} v_{boy} + m_{girl} v_{girl} = 0 $$

Substituting:

$$ m_{boy} \times \frac{F \times \Delta t}{m_{boy}} + m_{girl} \times \left(- \frac{F \times \Delta t}{m_{girl}} \right) = 0 $$

which simplifies to:

$$ F \times \Delta t - F \times \Delta t = 0 $$

confirming the consistency of the analysis.

Expressing Velocities

The magnitudes of velocities after pushing:

$$ |v_{boy}| = \frac{F \times \Delta t}{60} $$

$$ |v_{girl}| = \frac{F \times \Delta t}{40} $$

Since v_{girl} is negative relative to v_{boy}, their velocities are:

$$ v_{boy} = \frac{F \times \Delta t}{60} \quad \text{(say, to the right)} $$

$$ v_{girl} = - \frac{F \times \Delta t}{40} \quad \text{(to the left)} $$

Momentum and Energy Considerations

Final Velocities and Momentum Balance

Suppose the force and contact duration Δt are known, then:

- The boy moves to the right with velocity:

$$ v_{boy} = \frac{F \times \Delta t}{60} $$

- The girl moves to the left with velocity:

$$ v_{girl} = - \frac{F \times \Delta t}{40} $$

The total momentum after pushing:

$$ p_{total} = (60) \times v_{boy} + (40) \times v_{girl} $$

Plugging in the velocities:

$$ p_{total} = 60 \times \frac{F \times \Delta t}{60} + 40 \times \left(- \frac{F \times \Delta t}{40} \right) = F \times \Delta t - F \times \Delta t = 0 $$

which confirms total momentum remains zero, consistent with initial conditions.

Energy Considerations

While momentum is conserved, kinetic energy after pushing is:

$$KE = \frac{1}{2} m_{boy} v_{boy}^2 + \frac{1}{2} m_{girl} v_{girl}^2$$

Substituting:

$$KE = \frac{1}{2} \times 60 \times \left(\frac{F \times \Delta t}{60} \right)^2 + \frac{1}{2} \times 40 \times \left(\frac{F \times \Delta t}{40} \right)^2$$

Simplify:

$$KE = \frac{1}{2} \times 60 \times \frac{(F \times \Delta t)^2}{3600} + \frac{1}{2} \times 40 \times \frac{(F \times \Delta t)^2}{1600}$$

$$KE = \frac{60}{2} \times \frac{(F \times \Delta t)^2}{3600} + \frac{40}{2} \times \frac{(F \times \Delta t)^2}{1600}$$

$$KE = 30 \times \frac{(F \times \Delta t)^2}{3600} + 20 \times \frac{(F \times \Delta t)^2}{1600}$$

$$KE = \frac{30}{3600} (F \times \Delta t)^2 + \frac{20}{1600} (F \times \Delta t)^2$$

$$KE = \frac{1}{120} (F \times \Delta t)^2 + \frac{1}{80} (F \times \Delta t)^2$$

Adding:

$$KE = \left(\frac{1}{120} + \frac{1}{80} \right) (F \times \Delta t)^2$$

Find common denominator:

$$\frac{2}{240} + \frac{3}{240} = \frac{5}{240} = \frac{1}{48}$$

Thus,

$$KE = \frac{1}{48} (F \times \Delta t)^2$$

This kinetic energy originates from the work done during the push, which is equivalent to the force times the displacement of each person during the push.

Implications of the Scenario: Insights and Real-World Analogies

Behavior of the System

The key takeaway is that both individuals will move in opposite directions with velocities inversely proportional to their masses:

- The lighter girl will attain a higher velocity than the boy for the same force and duration.
- The total momentum remains zero,

A Boy Of Mass 60 Kg And A Girl Of Mass 40 Kg Are Together And At Rest On A Frozen Pond And Push Each

A Boy Of Mass 60 Kg And A Girl Of Mass 40 Kg Are Together And At Rest On A Frozen Pond And Push Each

Related Articles

- A 250 G Pork Chop Has Approximately 4400 J Of Chemical Energy. To Produce The Pork Chop, The Pig Had
- A Firm Has The Production Function Q=F(K,L)=K1/2L1/4, Where K>0 And L>0. It Chooses Its Inputs
- A New Member Of Your Team Is Visually Impaired. He's Having A Hard Time Reading His Computer Screen.

Back to Home