A 15-kg Child Slides Down A 2.5m-high Playground Slide. She Starts From Rest And Her Speed At The Bottom

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When a child slides down a playground slide, a fascinating interplay of physics principles unfolds. Consider a typical scenario where a 15-kg child begins her descent from a height of 2.5 meters, starting from rest, and we want to determine her speed at the bottom of the slide. This situation involves concepts such as gravitational potential energy, kinetic energy, and the conservation of energy. In this article, we explore these principles in detail, providing a comprehensive understanding of what happens during her slide and how to calculate her speed at the bottom.

Understanding the Physics Behind the Slide

To analyze the child's descent, we need to understand the fundamental physics concepts involved. Primarily, this involves the transformation of potential energy into kinetic energy as she slides down.

Gravitational Potential Energy (GPE)

- Defined as the energy stored due to an object's position above the ground.
- Calculated using the formula: GPE = m × g × h
- Where:
- m = mass of the object (15 kg in this case)
- g = acceleration due to gravity (~9.8 m/s²)
- h = height above the ground (2.5 meters)

Kinetic Energy (KE)

- The energy an object possesses due to its motion.
- Calculated using: KE = ½ × m × v²
- Where:
- m = mass of the object
- v = velocity at a specific point (here, at the bottom of the slide)

Conservation of Mechanical Energy

- In an ideal situation without friction or air resistance, the total mechanical energy remains constant.
- The initial potential energy at the top converts entirely into kinetic energy at the bottom.

Calculating the Child's Speed at the Bottom of the Slide

Assuming no energy losses due to friction or air resistance, we can use the conservation of energy principle to find her speed at the bottom.

Step 1: Calculate the Initial Gravitational Potential Energy

Since the child starts from rest at height $h = 2.5$ meters:
- GPE = $m \times g \times h$
- GPE = 15 kg × 9.8 m/s² × 2.5 m
- GPE = $15 \times 9.8 \times 2.5$
- GPE = 15×24.5
- GPE = 367.5 Joules

Step 2: Equate GPE to Kinetic Energy at the Bottom

- GPE at the top = KE at the bottom
- 367.5 J = ½ × 15 kg × v^2

Step 3: Solve for v (velocity at the bottom)

- $367.5 = 7.5 \times v^2$
- $v^2 = 367.5 / 7.5$
- $v^2 = 49$
- $v = \sqrt{49}$
- $v = 7$ m/s

Therefore, the child's speed at the bottom of the slide is approximately 7 meters per second.

Real-World Factors Affecting the Child's Speed

While the above calculation provides an idealized estimate, real-world conditions often introduce factors that can affect the actual speed.

Friction and Resistance

- Friction between the child's clothing and the slide surface dissipates some energy as heat.
- Air resistance also opposes motion, reducing the child's speed slightly compared to the ideal calculation.

Slide Incline and Surface Texture

- The angle and surface roughness of the slide influence how efficiently energy is transferred.
- A steeper or smoother slide allows for higher speeds, closer to the ideal estimate.

Starting Position and Motion

- If the child begins from a position other than rest or pushes herself down, initial kinetic energy changes.
- For this scenario, starting from rest simplifies the calculation.

Additional Considerations

Beyond calculating the velocity, understanding safety and physics principles helps ensure children enjoy playgrounds safely.

Safety Guidelines for Playground Slides

- Ensure slides are well-maintained and free of obstructions.
- Use appropriate sliding techniques, such as sitting upright.
- Supervision helps prevent injuries related to improper use.

Physics Education Opportunities

- Playground slides are excellent tools for teaching physics concepts.
- They demonstrate energy transformation, the effects of friction, and the importance of safety measures.

Summary of Key Points

- The child's initial potential energy is calculated based on her mass and height.
- Assuming no energy losses, all potential energy converts into kinetic energy at the bottom.
- The child's speed at the bottom is approximately 7 meters per second.
- Real-world factors like friction and surface texture influence actual speed.
- Understanding these physics principles promotes safer and more educational playground experiences.

Conclusion

The simple act of sliding down a playground slide encompasses fundamental physics concepts such as energy conservation and motion dynamics. Calculating the child's speed at the bottom illustrates how potential energy transforms into kinetic energy, providing insight into real-world physics applications. Whether for educational purposes or safety considerations, understanding these principles enhances the appreciation of everyday phenomena like children enjoying playgrounds safely and confidently.

Frequently Asked Questions

What is the speed of the child at the bottom of the slide?

Using energy conservation, the child's speed at the bottom is approximately 7 m/s.

How is the child's potential energy at the top related to her kinetic energy at the bottom?

The potential energy at the top converts entirely into kinetic energy at the bottom, neglecting friction and air resistance.

What is the initial potential energy of the child at the top of the slide?

The initial potential energy is calculated as $mgh = 15\ \text{kg} \times 9.8\ \text{m/s}^2 \times 2.5\ \text{m} = 367.5$ Joules.

What assumptions are made in calculating the child's speed at the bottom?

Assumptions include no energy loss due to friction or air resistance, and that the slide is frictionless.

If friction were considered, how would it affect the child's speed at the bottom?

Friction would reduce the total energy transfer, resulting in a lower speed at the bottom compared to the ideal case.

What is the significance of starting from rest in this problem?

Starting from rest means initial kinetic energy is zero, simplifying the energy conservation calculation to potential converting into kinetic.

How would the child's speed change if the height of the slide increased?

Increasing the height would increase potential energy, leading to a higher speed at the bottom.

Can this problem be analyzed using Newton's second law instead of energy conservation?

Yes, but energy conservation provides a more straightforward calculation for speed in this context; Newton's laws would involve calculating acceleration and velocity at each point.

Additional Resources

A 15-kg Child Slides Down A 2.5m-high Playground Slide. She Starts From Rest And Her Speed At The Bottom is a classic physics problem that beautifully illustrates the principles of energy conservation and kinematics. It provides an excellent real-world application of fundamental physics concepts, making it a popular choice for educators and students alike to understand how potential energy transforms into kinetic energy during motion. This scenario not only helps in grasping theoretical concepts but also emphasizes safety considerations and physical intuition when engaging with playground equipment.

Understanding the Scenario

This problem involves a child, mass 15 kg, starting from rest at the top of a slide that is 2.5 meters high. The key questions revolve around determining her speed at the bottom of the slide, understanding the energy transformations involved, and considering factors that might affect the outcome.

The Basic Setup

- Mass of the child (m): 15 kg
- Height of the slide (h): 2.5 meters
- Initial velocity (u): 0 m/s (starts from rest)
- Final velocity at the bottom (v): to be determined
- Gravity (g): 9.8 m/s²

This setup assumes an idealized situation where factors like friction, air resistance, and any other dissipative forces are initially neglected for simplicity.

Physics Principles Involved

Conservation of Mechanical Energy

The core principle here is the conservation of mechanical energy, which states that in the absence of non-conservative forces like friction, the total mechanical energy remains constant throughout the motion.

Mathematically:

Initial Potential Energy (PE): $PE_{initial} = m \times g \times h$

Initial Kinetic Energy (KE): $KE_{initial} = 0$ (since starting from rest)

Final Energy at the Bottom: $KE_{final} = \frac{1}{2} m v^2$

Since energy is conserved:

$$ m g h = \frac{1}{2} m v^2 $$

Simplifying:

$$ v = \sqrt{2 g h} $$

This equation allows us to determine the child's speed at the bottom, assuming no energy losses.

Calculating the Child's Speed at the Bottom

Using the simplified formula:

$$ v = \sqrt{2 \times 9.8\, \text{m/s}^2 \times 2.5\, \text{m}} $$

Calculations:

$$ v = \sqrt{49} = 7\, \text{m/s} $$

This means that, in an ideal environment, the child would reach a speed of approximately 7 meters per second at the bottom of the slide.

Significance of this Speed

- Kinetic energy at the bottom:

$$ KE = \frac{1}{2} \times 15\, \text{kg} \times (7\, \text{m/s})^2 = 0.5 \times 15 \times 49 = 367.5\, \text{J} $$

This energy indicates how much work the child's body does to accelerate from rest to that speed.

Real-World Considerations

While the idealized calculation provides a useful estimate, real-world factors influence the actual speed and safety.

Friction and Air Resistance

In practice, the slide's surface introduces friction, which opposes motion and reduces the child's final speed. Similarly, air resistance, although minimal at these speeds, still plays a role.

- Frictional forces depend on the slide's material, surface smoothness, and the child's clothing.
- Impact on speed: Friction dissipates some of the energy as heat, meaning the actual speed at the bottom would be less than 7 m/s.

Safety Implications

- High speeds: Reaching 7 m/s (~25 km/h) is quite fast for a child, raising safety concerns.
- Design considerations: Playground slides are often designed with gentle inclines or with friction-enhancing surfaces to limit speed and reduce injury risk.
- Protective features: Handrails, bumpers, and cushioned landing areas help mitigate injury from falls or high impact.

Energy Losses and Efficiency

- In real scenarios, energy losses mean the child's kinetic energy is less than the potential energy initially stored.
- The efficiency of the slide affects the actual speed and safe use.

Features and Characteristics of Playground Slides

Understanding the physics behind sliding can also shed light on the design features of playground equipment.

Features

- Incline angle: Determines how quickly potential energy converts to kinetic energy.
- Surface material: Smooth, slippery surfaces minimize friction and increase speed.
- Length of the slide: Longer slides can allow for higher speeds if the incline remains steep.
- Safety features: Curved sides, barriers, and soft landing zones are incorporated to minimize injury.

Pros of well-designed slides

- Provide fun and exercise for children
- Encourage physical development and coordination
- Help children learn about physics concepts intuitively

Cons and safety concerns

- Excessive heights or steep inclines can lead to dangerous speeds
- Poorly maintained surfaces increase friction unpredictably
- Inadequate safety features increase injury risk

Impact of Mass and Size

While the problem specifies a 15-kg child, the physics principles are independent of mass in idealized conditions, meaning:

- Speed at the bottom: remains the same regardless of mass, assuming no friction.
- Kinetic energy: scales linearly with mass; a heavier child has more kinetic energy at the same speed.

Implications:

- Larger or heavier children generate more impact force during a fall.
- Playground safety standards often specify maximum heights and equipment features to account for this.

Safety and Ethical Considerations

Physics education about playground slides should always be paired with safety awareness:

- Supervision: Ensures children use slides appropriately.
- Age-appropriate design: Equipment should be suitable for children's size and strength.
- Regular maintenance: Keeps surfaces smooth and secure.
- Education: Teaching children about safe sliding behavior, such as sitting upright and not climbing on sides.

Conclusion and Final Thoughts

The problem of a 15-kg child sliding down a 2.5-meter-high playground slide provides a rich context for exploring fundamental physics principles like energy conservation and kinematics. Under ideal conditions, the child would reach a speed of approximately 7 m/s at the bottom, demonstrating how potential energy transforms into kinetic energy during free fall and slide descent.

Understanding these principles helps in designing safer playground equipment, appreciating the physics of everyday activities, and fostering a sense of curiosity and scientific literacy among children and educators. Moreover, considering real-world factors such as friction, air resistance, and safety features reveals the importance of thoughtful design and responsible use of playgrounds, ensuring that fun does not come at the expense of safety.

In essence, this scenario exemplifies the intersection of physics theory with practical safety considerations, highlighting the importance of physics in everyday life and recreational activities.

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