A 23-kg Child Starts From Rest And Slides Down A Slide That Is 3.8 M High. At The Bottom Of The Slide,

A 23-kg Child Starts From Rest And Slides Down A Slide That Is 3.8 M High. At The Bottom Of The Slide, understanding the physics behind this scenario can provide valuable insights into energy conservation, acceleration, and motion dynamics. This article offers a comprehensive analysis of the child's sliding motion, exploring the principles involved, calculations of velocity and energy, and practical implications. Whether you're a student studying physics or a curious reader interested in real-world applications, this detailed guide aims to clarify the fundamental concepts and their relevance.

Understanding the Scenario: Child Sliding Down a 3.8 M High Slide

Basic Description

- A child with a mass of 23 kilograms starts from rest at the top of a slide.
- The height of the slide is 3.8 meters.
- The child slides down due to gravity, converting potential energy into kinetic energy.
- The analysis involves understanding how energy transforms during the slide and calculating the child's velocity at the bottom.

Key Concepts Involved

- Conservation of Mechanical Energy
- Gravitational Potential Energy
- Kinetic Energy
- Acceleration due to Gravity
- Frictional Forces (if considered)

Fundamental Physics Principles

Conservation of Mechanical Energy

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

Mathematically:
\[\text{Potential Energy at Top} + \text{Kinetic Energy at Top} =

\text{Potential Energy at Bottom} + \text{Kinetic Energy at Bottom} \]

Since the child starts from rest and assuming negligible friction:
\[PE_{initial} = KE_{final} \]

Where:
- \(PE = mgh \)
- \(KE = \frac{1}{2}mv^2 \)

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

Step 1: Determine the Initial Potential Energy

Using the formula:
\[PE_{initial} = m \times g \times h \]
- \(m = 23 \, \text{kg} \)
- \(g = 9.81 \, \text{m/s}^2 \)
- \(h = 3.8 \, \text{m} \)

Calculation:
\[PE_{initial} = 23 \times 9.81 \times 3.8 \]
\[PE_{initial} \approx 23 \times 37.278 \]
\[PE_{initial} \approx 857.994 \, \text{J} \]

Step 2: Determine the Final Velocity at the Bottom

Assuming no energy is lost due to friction or air resistance:
\[KE_{final} = PE_{initial} \]

\[\frac{1}{2} m v^2 = 857.994 \]

Solve for \(v \):
\[v = \sqrt{\frac{2 \times 857.994}{m}} \]
\[v = \sqrt{\frac{1715.988}{23}} \]
\[v = \sqrt{74.61} \]
\[v \approx 8.64 \, \text{m/s} \]

Result:
The child's speed at the bottom of the slide is approximately 8.64 meters per second.

Factors Affecting the Sliding Motion

Frictional Forces

In real-world scenarios, friction between the child's clothing and the slide surface plays a significant role. Friction opposes motion and reduces the velocity at the bottom.

Types of friction involved:
- Static friction at the start
- Kinetic friction during motion

Implications:
- The actual velocity will be less than the ideal calculation.
- The energy lost due to friction can be estimated if the coefficient of kinetic friction is known.

Coefficient of Friction and Energy Loss

Suppose the coefficient of kinetic friction (μ_k) between the child's clothing and slide surface is 0.1.

Work done against friction:

$$W_{friction} = \mu_k \times m \times g \times d$$

Where d is the length of the slide.

- To estimate d, assume the slide length is slightly longer than the height due to the incline angle.

Note: The actual slide length and friction coefficient are needed for precise calculations.

Calculating the Slide Length and Incline Angle

Estimating the Length of the Slide

If the slide makes an angle θ with the horizontal, the length L of the slide relates to the height h:

$$L = \frac{h}{\sin \theta}$$

Assuming a typical slide angle of 30°:

$$\sin 30° = 0.5$$

$$L = \frac{3.8}{0.5} = 7.6 \, \text{m}$$

Thus, the approximate slide length is 7.6 meters.

Impact of Friction on Final Velocity

The work done against friction:

$$W_{friction} = \mu_k \times m \times g \times L$$

$$W_{friction} = 0.1 \times 23 \times 9.81 \times 7.6$$

$$ W_{friction} \approx 0.1 \times 23 \times 74.556 $$
$$ W_{friction} \approx 0.1 \times 1713.6 $$
$$ W_{friction} \approx 171.36 \, \text{J} $$

Adjusted kinetic energy at the bottom:
$$ KE_{adjusted} = PE_{initial} - W_{friction} $$
$$ KE_{adjusted} \approx 858 - 171.36 $$
$$ KE_{adjusted} \approx 686.64 \, \text{J} $$

Adjusted velocity:
$$ v = \sqrt{\frac{2 \times 686.64}{23}} $$
$$ v = \sqrt{\frac{1373.28}{23}} $$
$$ v = \sqrt{59.7} $$
$$ v \approx 7.73 \, \text{m/s} $$

Conclusion:
Accounting for friction, the child's velocity at the bottom decreases to approximately 7.73 m/s.

Safety Considerations and Practical Implications

Ensuring Safe Sliding Speeds

Understanding the physics allows for designing safe playground equipment:
- Slide height: Should be appropriate for the age group.
- Surface material: Should minimize friction to prevent excessive speed.
- Incline angle: Should balance fun and safety.
- Surface friction: Proper materials can control the child's velocity.

Estimating Impact Forces

The impact force when the child reaches the bottom depends on deceleration upon stopping or hitting a safety pad.

Simplified estimation:
- If the child comes to a stop over a distance s, then the average force F:
$$ F = \frac{m v^2}{2 s} $$

For example, if the child is stopped over 0.2 meters:
$$ F = \frac{23 \times (7.73)^2}{2 \times 0.2} $$
$$ F = \frac{23 \times 59.7}{0.4} $$
$$ F = \frac{1373.1}{0.4} $$
$$ F \approx 3432.75 \, \text{N} $$

This high force emphasizes the need for cushioning and safety features.

Conclusion: The Physics Behind a Child Sliding Down a Playground Slide

This analysis demonstrates how fundamental physics principles can be applied to understand and predict the motion of a child sliding down a slide. Starting from potential energy, the child's velocity at the bottom can be estimated using energy conservation, considering factors like friction and slide incline. These calculations are crucial for designing safe playground equipment, understanding impact forces, and promoting safe play environments.

Key takeaways:
- Without friction, the child's velocity at the bottom is approximately 8.64 m/s.
- Real-world factors such as friction reduce this speed.
- Safety considerations include controlling slide angle, surface material, and ensuring proper cushioning.
- Physics principles provide essential insights into playground safety design.

By applying these concepts, manufacturers, parents, and educators can ensure children enjoy fun and safe sliding experiences while understanding the science that makes it possible.

Frequently Asked Questions

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

The potential energy is given by $PE = mgh$, so $PE = 23\ kg \times 9.8\ m/s^2 \times 3.8\ m \approx 855.32$ Joules.

Assuming no friction, what is the child's speed at the bottom of the slide?

If there is no energy loss, the child's speed at the bottom is found using $KE = PE$: $v = \sqrt{(2gh)} \approx \sqrt{(2 \times 9.8 \times 3.8)} \approx 8.65\ m/s$.

How does friction affect the child's speed at the bottom of the slide?

Friction reduces the mechanical energy, so the child's speed at the bottom will be less than the theoretical 8.65 m/s, depending on the frictional force.

What is the work done by friction during the slide?

Work done by friction equals the initial potential energy minus the actual kinetic energy at the bottom. If friction is present, $W_{friction} = PE - KE$ at the bottom.

How can the angle of the slide influence the child's acceleration?

A steeper slide (larger angle) increases the component of gravitational force along the slide, leading to greater acceleration and higher speed at the bottom.

What energy conservation principles apply in this scenario?

The total mechanical energy is conserved if no friction or other forces do work; potential energy converts into kinetic energy as the child slides down.

How would adding friction change the child's final velocity at the bottom?

Adding friction would decrease the final velocity since some energy is dissipated as heat, resulting in a speed lower than the frictionless case.

If the child starts from rest, what is their initial kinetic energy at the top?

Since the child starts from rest, the initial kinetic energy is zero, KE = 0 Joules.

What safety considerations are important when designing a slide of this height?

Safety considerations include ensuring a smooth surface to reduce friction and injury risk, appropriate slide angle, soft landing area at the bottom, and structural stability to prevent accidents.

Additional Resources

Child Sliding Down a 3.8-Meter High Slide: An In-Depth Exploration of Physics and Safety

---

Introduction

Imagine a cheerful 23-kg child at the top of a playground slide, ready to descend from a height of 3.8 meters. This simple yet fascinating scenario offers an excellent opportunity to delve into the principles of physics, energy conservation, forces at play, and safety considerations. Understanding the mechanics behind such a movement can enhance our appreciation for playground safety and design, as well as deepen our grasp of fundamental physics concepts.

Fundamental Physics Concepts Involved

Before analyzing the child's descent in detail, it's important to understand the core physics principles involved:

1. Gravitational Potential Energy (GPE)

- Defined as the energy stored due to an object's position relative to the ground.
- Calculated by the formula:
$$ GPE = m \times g \times h $$
where:
- m = mass of the object (23 kg in this case)
- g = acceleration due to gravity (~9.81 m/s²)
- h = height from which the object starts (3.8 m)

2. Kinetic Energy (KE)

- The energy an object possesses due to its motion.
- Given by:
$$ KE = \frac{1}{2} m v^2 $$
where v is the velocity.

3. Conservation of Mechanical Energy

- In an ideal, frictionless scenario, the total mechanical energy remains constant:
$$ GPE_{initial} + KE_{initial} = GPE_{final} + KE_{final} $$
- Since the child starts from rest, initial KE is zero, and potential energy converts into kinetic energy as the child slides down.

4. Friction and Air Resistance

- Real-world scenarios involve energy losses due to:
- Friction between the child and the slide
- Air resistance
- These factors reduce the child's final speed and energy efficiency.

Calculating the Child's Potential and Kinetic Energy

Let's perform some calculations to quantify the energies involved:

1. Initial Gravitational Potential Energy

\[
GPE_{initial} = m \times g \times h = 23\, \text{kg} \times 9.81\, \text{m/s}^2 \times 3.8\, \text{m}

$$
GPE_{initial} \approx 23 \times 9.81 \times 3.8 \approx 23 \times 37.278 \approx 857.09\, \text{J}
$$

This indicates that the child starts with approximately 857 Joules of potential energy.

2. Final Kinetic Energy at the Bottom of the Slide

Assuming negligible energy loss:

$$
KE_{final} \approx GPE_{initial} \approx 857\, \text{J}
$$

3. Final Velocity at the Bottom

Using the kinetic energy formula:

$$
v = \sqrt{\frac{2 \times KE}{m}} = \sqrt{\frac{2 \times 857}{23}} \approx \sqrt{\frac{1714}{23}} \approx \sqrt{74.52} \approx 8.63\, \text{m/s}
$$

Thus, ideally, the child would reach a speed of approximately 8.63 meters per second at the bottom of the slide.

Real-World Factors Affecting Motion

While the calculations assume an ideal, frictionless environment, real-world scenarios involve various factors that influence the child's descent:

1. Friction Between the Child and the Slide

- The contact surface introduces resistance, converting some mechanical energy into heat.
- Material of the slide (plastic, metal, wood) affects friction levels.
- Clothing and body contact areas also influence friction.

2. Air Resistance

- As the child accelerates, air molecules exert a force opposing motion.
- Usually minimal at lower speeds but becomes more significant at higher velocities.

3. Incline and Slide Geometry

- The inclination angle and length of the slide influence acceleration and velocity.

- Steeper and longer slides typically result in higher speeds.

4. Safety and Comfort Considerations

- Speed must be regulated for safety.
- Surfaces are often designed to optimize fun while minimizing injury risk.

Energy Losses and Efficiency

Given the real-world factors, the actual kinetic energy at the bottom will be less than the ideal 857 Joules:

- Estimate of energy losses:
Typically, friction and air resistance may account for 10–30% of energy losses, depending on conditions.
- Effective energy at bottom:
$$ KE_{actual} \approx 0.7 \times 857 \approx 600\, \text{J} $$
- Resulting velocity:
$$
v \approx \sqrt{\frac{2 \times 600}{23}} \approx \sqrt{\frac{1200}{23}} \approx \sqrt{52.17} \approx 7.23\, \text{m/s}
$$

This provides a more realistic picture: the child might reach approximately 7.2 meters per second at the bottom.

Safety Dynamics and Impact Considerations

Understanding the physics isn't just academic; it directly impacts safety:

1. Impact Velocity and Injury Risk

- Higher velocities increase the risk of injury if the child hits the bottom or other obstacles.
- Proper cushioning or landings zones are critical.

2. Force of Impact

- The force experienced during impact depends on deceleration.
- Using the impulse-momentum theorem:
$$
F \times \Delta t = m \times \Delta v
$$
where:
- F = impact force
- Δt = the duration of impact
- Δv = change in velocity during impact

- Longer deceleration times (like cushioned mats) reduce force.

3. Design Implications for Playgrounds

- Slopes should be designed to prevent excessive speeds.
- The surface material at the bottom should absorb impact.
- Regular maintenance to ensure smoothness and reduce friction unpredictability.

Additional Factors: Mass, Acceleration, and Energy Transfer

While the child's mass (23 kg) influences the energy calculations, it's crucial to recognize:

- Acceleration during descent:
- Governed by the component of gravity along the incline, minus frictional resistance.
- Effect of mass:
- In ideal physics, mass cancels out when calculating acceleration, meaning all objects accelerate equally under gravity in a vacuum.
- However, in real scenarios, mass can influence the effect of friction; heavier children may experience slightly different dynamics.

Practical Applications and Engineering Insights

Understanding these principles informs several practical aspects:

1. Playground Slide Design

- Length, steepness, and surface material are chosen to balance fun and safety.
- Incorporating gentle slopes reduces speed and injury risk.
- Surface padding at the bottom absorbs impact energy.

2. Material Selection

- Smooth, low-friction materials (like plastic composites) facilitate a safe, controlled slide.
- Textured surfaces can increase friction for safety but may reduce speed.

3. Safety Regulations

- Many countries have standards specifying maximum heights, angles, and surface materials for playground equipment.

- Regular inspections ensure compliance and safety.

Conclusion

The scenario of a 23-kg child sliding down a 3.8-meter high slide encapsulates a rich interplay of physics principles — from gravitational potential energy to kinetic energy, and from ideal conservation laws to real-world frictional losses. While the ideal calculations suggest the child could reach speeds over 8 meters per second, practical considerations like friction and air resistance lower this speed, typically to around 7 meters per second or less.

Understanding these dynamics is vital not only for appreciating the science behind playground fun but also for ensuring safety. Proper design, material choice, and maintenance can harness these physics principles to create playground experiences that are both exhilarating and secure. As we continue to explore the mechanics of sliding, we gain insights that help us optimize playground safety and enhance children's enjoyment, all grounded in a solid understanding of physics.

In summary:

- The child's potential energy at the top is approximately 857 Joules.
- Idealistic physics predicts a maximum speed of about 8.6 m/s at the bottom.
- Real-world factors reduce this speed to roughly 7.2 m/s.
- The forces involved during impact necessitate safety measures like cushioned landings.
- Thoughtful design grounded in physics ensures the thrill of sliding remains safe and enjoyable for children.

Final thoughts:
Playground slides are a perfect example of applied physics in everyday life, illustrating how fundamental concepts like energy conservation and forces influence safety and fun. Recognizing these principles helps engineers, designers, and caregivers create environments that foster joyful, secure

A 23 Kg Child Starts From Rest And Slides Down A Slide That Is 3 8 M High At The Bottom Of The Slide

A 23 Kg Child Starts From Rest And Slides Down A Slide That Is 3 8 M High At The Bottom Of The Slide

Related Articles

- A Quick Review Of The Auditory System A. The Middle Ear Consists Of Three Bones That Amplify The Sound
- A 23-year-old Man (weighing 70 Kg) Is Brought To A&E After He Collapsed On The Hour While Playing
- A 4-month European 60-strike Call On Stock X Is Selling For 8. The Share Price Is 64. The Continuously

Back to Home