A 0.0780 Kg Lemming Runs Off A 5.36 M High Cliff At 4.84 M/s. What Is Its Kinetic Energy When It's 2.00

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Introduction

Imagine a tiny lemming, weighing just 0.0780 kilograms, suddenly leaping off a cliff that stands 5.36 meters tall. As it plummets downward, its speed increases due to gravity, transforming potential energy into kinetic energy. At some point during its fall, the lemming reaches a certain velocity, and understanding its kinetic energy at different moments can reveal fascinating insights into the physics of motion and energy conservation.

In this article, we will analyze the scenario of the lemming's fall from the cliff, specifically focusing on calculating its kinetic energy when it has descended to a point where its height is 2.00 meters above the ground. We will explore the principles of physics involved, including gravitational potential energy, kinetic energy, and energy conservation, along with step-by-step calculations to determine the kinetic energy at that point.

The Physics of Falling Objects: An Overview

Before diving into calculations, it's essential to understand the fundamental physics principles that govern the motion of falling objects.

Gravitational Potential Energy

An object elevated at a height h possesses potential energy relative to the ground, given by:

$$
PE = mgh
$$

where:
- m is the mass of the object,
- g is the acceleration due to gravity ($\approx 9.81\, m/s^2$),
- h is the height above the reference point (usually ground level).

Kinetic Energy

As the object falls, its potential energy decreases and converts into kinetic energy:

$$
KE = \frac{1}{2} mv^2
$$

where:

- v is the velocity of the object.

Conservation of Mechanical Energy

In the absence of air resistance and other dissipative forces, the total mechanical energy remains constant:

$$
PE_{initial} + KE_{initial} = PE_{final} + KE_{final}
$$

Since the lemming starts from rest (initial velocity is given as 4.84 m/s, but we will verify if this makes sense in context), and falls freely, we consider the initial potential energy at the top and the kinetic and potential energy at the point of interest.

Scenario Details and Data

Let's break down the given information:

- Mass of lemming, m: 0.0780 kg
- Initial height (top of the cliff), $h_{initial}$: 5.36 m
- Initial velocity at the edge of the cliff, $v_{initial}$: 4.84 m/s
- Velocity at the point when height is 2.00 m, v_{final}: to be determined
- Height at the point of interest, h_{final}: 2.00 m

Step-by-Step Calculation of the Lemming's Kinetic Energy at 2.00 Meters Height

Step 1: Confirm the initial conditions

The problem states that the lemming is running off the cliff at 4.84 m/s, which suggests it is not merely dropping but actively running off the edge with this initial velocity. This detail affects the energy calculations because the lemming has an initial kinetic energy at the cliff's edge.

Step 2: Calculate initial total mechanical energy

At the initial moment (at the top of the cliff), the total mechanical energy ($E_{initial}$) combines potential and kinetic energy:

$$
E_{initial} = PE_{initial} + KE_{initial}
$$

$$
PE_{initial} = m g h_{initial}
$$

$$
KE_{initial} = \frac{1}{2} m v_{initial}^2
$$

Plugging in the values:

$$
PE_{initial} = 0.0780\, kg \times 9.81\, m/s^2 \times 5.36\, m
$$

$$
PE_{initial} \approx 0.0780 \times 9.81 \times 5.36 \approx 4.101\, J
$$

$$
KE_{initial} = \frac{1}{2} \times 0.0780\, kg \times (4.84\, m/s)^2
$$

$$
KE_{initial} = 0.039 \times 23.4256 \approx 0.915\, J
$$

Total initial energy:

$$
E_{initial} \approx 4.101 + 0.915 \approx 5.016\, J
$$

Step 3: Determine the potential energy at 2.00 meters

At the point where the lemming is 2.00 meters above ground:

$$
PE_{final} = m g h_{final} = 0.0780 \times 9.81 \times 2.00
$$

$$
PE_{final} \approx 0.0780 \times 19.62 \approx 1.530\, J
$$

Step 4: Apply conservation of energy to find kinetic energy at 2.00 meters

Assuming no air resistance:

$$
E_{initial} = PE_{final} + KE_{final}
$$

$$
KE_{final} = E_{initial} - PE_{final} = 5.016\, J - 1.530\, J = 3.486\, J
$$

Therefore, the kinetic energy of the lemming when it is 2.00 meters above the ground is approximately 3.486 Joules.

Calculating the Velocity at 2.00 Meters

To find the velocity at this point, use the kinetic energy formula:

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

Rearranged to solve for v:

$$
v = \sqrt{\frac{2 KE}{m}}
$$

Plugging in the known values:

$$
v = \sqrt{\frac{2 \times 3.486}{0.0780}} = \sqrt{\frac{6.972}{0.0780}} \approx \sqrt{89.46} \approx 9.46\, m/s
$$

The lemming's velocity when it is 2.00 meters above ground is approximately 9.46 m/s.

Additional Insights and Context

Energy Transformation During Fall

This scenario illustrates the fundamental physics principle that potential energy decreases as the object falls, while kinetic energy increases correspondingly, assuming no energy losses:

- At the top (initial point): Max potential energy, initial kinetic energy.
- During fall: Potential energy decreases, kinetic energy increases.
- At 2.00 meters: Kinetic energy is roughly 3.486 Joules, with a velocity close to 9.46 m/s.

Why Is the Initial Velocity Important?

The initial velocity of 4.84 m/s at the edge of the cliff suggests the lemming isn't just dropped but runs off with some speed. This initial kinetic energy contributes significantly to the total energy during the fall and affects the velocity and kinetic energy at lower heights.

Real-World Considerations

In real-world situations, factors like air resistance would dissipate some energy, leading to a slightly lower velocity and kinetic energy at lower heights. However, for theoretical calculations, ignoring air resistance provides a good approximation of the physics involved.

Summary of Key Findings

Parameter	Value
Mass of lemming	0.0780 kg
Height of cliff	5.36 m
Initial velocity	4.84 m/s
Height at point of interest	2.00 m
Potential energy at initial point	~4.101 Joules
Total initial energy	~5.016 Joules
Potential energy at 2.00 m	~1.530 Joules
Kinetic energy at 2.00 m	~3.486 Joules

| Velocity at 2.00 m | ~9.46 m/s |

Conclusion

The physics of a lemming falling off a cliff reveals fascinating insights into energy conservation and motion. By carefully analyzing the initial conditions and applying fundamental principles, we calculated that the lemming's kinetic energy when it is 2.00 meters above the ground is approximately 3.486 Joules. Its velocity at this point reaches about 9.46 m/s, demonstrating how potential energy converts into kinetic energy during free fall.

Understanding these calculations not only enhances our grasp of classical mechanics but also highlights the importance of energy conservation principles in real-world physics scenarios. Whether analyzing small creatures or larger objects, these fundamental concepts remain universally applicable, providing a foundation for physics education and scientific exploration.

References

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Frequently Asked Questions

What is the initial kinetic energy of the lemming when it runs off the 5.36 m high cliff?

The initial kinetic energy is calculated using $KE = (1/2)\ m\ v^2$. Here, $KE = 0.5 \times 0.0780\ kg \times (4.84\ m/s)^2 \approx 0.5 \times 0.0780 \times 23.4256 \approx 0.914$ Joules.

How much potential energy does the lemming have at the top of the cliff?

Potential energy at the top is $PE = mgh = 0.0780\ kg \times 9.8\ m/s^2 \times 5.36\ m \approx 0.0780 \times 9.8 \times 5.36 \approx 4.096$ Joules.

What is the total mechanical energy of the lemming at the top of the cliff?

Total mechanical energy = potential energy + kinetic energy at the top = 4.096 J + 0.914 J ≈ 5.01 Joules.

What is the velocity of the lemming when it is 2.00 meters above the ground?

Using conservation of energy, KE + PE = constant. Potential energy at 2.00 m: PE = 0.0780 kg × 9.8 m/s^2 × 2.00 m ≈ 1.53 Joules. Total energy is 5.01 J, so kinetic energy at 2.00 m: KE = 5.01 J – 1.53 J ≈ 3.48 Joules.

What is the lemming’s speed when it is 2.00 meters above the ground?

Velocity v = √(2 × KE / m) = √(2 × 3.48 J / 0.0780 kg) ≈ √(89.23) ≈ 9.45 m/s.

How does the lemming's kinetic energy change as it falls from the top to 2.00 meters above the ground?

The kinetic energy increases from approximately 0.914 Joules at the top to about 3.48 Joules at 2.00 meters, reflecting the conversion of potential energy into kinetic energy during the fall.

What assumptions are made in calculating the lemming's kinetic energy at 2.00 meters?

Assumptions include neglecting air resistance and other forces, assuming conservation of mechanical energy, and that the lemming falls freely under gravity.

How would air resistance affect the lemming's kinetic energy at 2.00 meters?

Air resistance would cause some energy loss, resulting in a kinetic energy slightly less than the calculated 3.48 Joules, and a speed slightly lower than 9.45 m/s.

Additional Resources

Kinetic Energy: Unveiling the Dynamics of a Lemming's Leap from Cliff to Ground

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Introduction

In the fascinating world of physics, understanding the energy transformations that occur during motion provides critical insights into the natural behaviors of animals and objects alike. Today, we delve into a captivating scenario involving a tiny creature—the lemming—whose leap from a cliff offers an excellent case study for exploring kinetic energy, potential energy, and the fundamental principles governing motion. This article meticulously examines the problem: A 0.0780 kg lemming runs off a 5.36 m high cliff at 4.84 m/s. What is its kinetic energy when it is 2.00 meters above the ground?

By dissecting this problem step-by-step, employing physics formulas, and considering energy conservation principles, we aim to provide an exhaustive understanding suitable for enthusiasts and students alike. Whether you're interested in animal biomechanics or physics problem-solving, this analysis offers a comprehensive perspective.

Setting the Scene: The Physics of a Lemming's Leap

Imagine a small lemming perched at the edge of a 5.36-meter-high cliff. It begins its descent with an initial horizontal velocity of 4.84 m/s—perhaps motivated by curiosity, escape, or instinct. As it falls, its energy shifts from potential energy stored due to height to kinetic energy associated with its motion.

This scenario is a classic example of the conservation of mechanical energy: assuming negligible air resistance and other dissipative forces, the total mechanical energy remains constant throughout the fall. This principle allows us to connect the lemming’s energy at different points during its descent, providing the foundation for calculating its kinetic energy at any given height.

Fundamental Concepts and Formulas

Before diving into calculations, it's crucial to understand the core physics concepts involved:

1. Potential Energy (PE)

- Definition: The stored energy an object possesses due to its position relative to a reference point (usually ground level).
- Formula:

$$
PE = m \times g \times h
$$

where:
- m = mass of the lemming (kg)
- g = acceleration due to gravity (~9.81 m/s²)
- h = height above ground (m)

2. Kinetic Energy (KE)

- Definition: The energy an object possesses due to its motion.
- Formula:

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

where:
- m = mass (kg)
- v = velocity (m/s)

3. Energy Conservation

- Principle:

$$
\text{Total Mechanical Energy at initial point} = \text{Total Mechanical Energy at any other point}
$$

$$
PE_{initial} + KE_{initial} = PE_{final} + KE_{final}
$$

- Application: Since no external work or energy loss is considered, the sum remains constant.

Step 1: Establishing Initial Conditions

The lemming starts its descent from the top of the cliff:

- Mass (m): 0.0780 kg
- Initial height ($h_{initial}$): 5.36 m
- Initial velocity ($v_{initial}$): 4.84 m/s, directed horizontally (assuming no initial vertical component)

Note: The initial velocity is horizontal, meaning it has no vertical component at the start. Its initial kinetic energy is based solely on this horizontal speed.

Step 2: Calculating Initial Energies

Let's quantify the initial potential and kinetic energies:

Initial Potential Energy ($PE_{initial}$):

$$
PE_{initial} = m \times g \times h_{initial} = 0.0780\,kg \times 9.81\,m/s^2 \times 5.36\,m
$$

$$
PE_{initial} \approx 0.0780 \times 9.81 \times 5.36 \approx 0.0780 \times 52.56 \approx 4.098\,\text{J}
$$

Initial Kinetic Energy ($KE_{initial}$):

$$
KE_{initial} = \frac{1}{2} m v_{initial}^2 = 0.5 \times 0.0780\,kg \times (4.84\,m/s)^2
$$

$$
KE_{initial} = 0.039 \times 23.4256 \approx 0.039 \times 23.43 \approx 0.914\,\text{J}
$$

Total Mechanical Energy at the start (E_{total}):

$$
E_{total} = PE_{initial} + KE_{initial} \approx 4.098 + 0.914 = 5.012\,\text{J}
$$

This total energy remains conserved throughout the fall.

Step 3: Determining the Vertical Velocity Component at 2.00 m

As the lemming descends, its vertical velocity component increases due to acceleration under gravity, while the horizontal component remains constant (assuming no air resistance).

Horizontal velocity (v_x):

$$
v_x = 4.84\,m/s \quad (\text{constant throughout the fall})
$$

Vertical velocity (v_y):

- It starts at zero vertical velocity (since initial velocity is purely horizontal).
- It increases as the lemming falls, according to:

$$
v_y = g \times t
$$

But since we don't have the time directly, we can find v_y using energy considerations.

Step 4: Using Energy Conservation to Find Velocity at 2.00 m Height

At any point during the fall, the total mechanical energy remains 5.012 J.

At height $h = 2.00\,m$:

- Potential energy (PE_{h}):

$$
PE_{h} = m \times g \times h = 0.0780 \times 9.81 \times 2.00 \approx 0.0780 \times 19.62 \approx 1.530\,\text{J}
$$

- Remaining energy converts into kinetic energy, which has both horizontal and vertical components:

$$
KE_{h} = E_{total} - PE_{h} = 5.012 - 1.530 = 3.482\,\text{J}
$$

Note: Since horizontal velocity remains unchanged, the horizontal kinetic energy (KE_x) is:

$$
KE_x = \frac{1}{2} m v_x^2 = 0.5 \times 0.0780 \times (4.84)^2 \approx 0.914\,\text{J}
$$

This is the initial horizontal KE, which remains constant.

The vertical kinetic energy (KE_y) at this point is:

$$
KE_y = KE_{h} - KE_x = 3.482 - 0.914 = 2.568\,\text{J}
$$

Step 5: Calculating Vertical Velocity at 2.00 m

From KE_y, the vertical velocity component at this point:

$$
KE_y = \frac{1}{2} m v_{y}^2
$$

$$
v_{y} = \sqrt{\frac{2 KE_y}{m}} = \sqrt{\frac{2 \times 2.568}{0.0780}}
$$

$$
v_{y} = \sqrt{\frac{5.136}{0.0780}} \approx \sqrt{65.87} \approx 8.12\,m/s
$$

Thus, the vertical component of velocity when the lemming is 2.00 meters above ground is approximately 8.12 m/s.

Step 6: Total Velocity at 2.00 meters

The total velocity (v_{total}) combines horizontal and vertical components:

$$
v_{total} = \sqrt{v_x^2 + v_y^2} = \sqrt{(4.84)^2 + (8.12)^2}
$$

$$
v_{total} = \sqrt{23.4256 + 66.05} = \sqrt{89.48} \approx 9.46\,m/s
$$

This comprehensive velocity indicates how fast the lemming is moving just before impact, blending both horizontal motion and the acceleration-induced vertical speed.

Step 7: Calculating Kinetic Energy at 2.00 m

Finally, the kinetic energy when the lemming is 2.00 meters above the ground is:

$$
KE_{final} = \frac{1}{2} m v_{total}^2 = 0.5 \times 0.0780 \times (9.46)^2
$$

$$
KE_{final} = 0.039 \times 89.66 \approx 3.49\,\text{J}
$$

\]

This value aligns with the earlier energy partitioning and confirms the calculations.

Summary and Insights

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