A 72 Kg Stunt Woman Jumps From A 29 M High Roof And Lands On A Ledge 18 M High. What Is Her Change In

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Introduction

Stunt performances often involve precise calculations of physics principles, particularly energy transformations and motion dynamics, to ensure safety and realism. When a stunt woman jumps from a significant height and lands on a ledge at a lower elevation, understanding the change in her physical state requires analyzing various factors like gravitational potential energy, kinetic energy, and the effects of impact forces. This article provides an in-depth exploration of her change in energy, velocity, and momentum during this daring stunt, with step-by-step calculations and explanations.

Understanding the Scenario

Basic Details

- Mass of the stunt woman (m): 72 kg
- Initial height (h_1): 29 meters (height of the roof)
- Ledge height (h_2): 18 meters
- Difference in height (Δh): 11 meters
- Gravity (g): 9.81 m/s²

The stunt involves her jumping from the roof, descending under gravity, and landing safely on the ledge. During this process, her energy states change significantly, from potential energy at the start to kinetic energy just before landing, and then dissipate upon impact.

Calculating Her Initial Potential Energy

Potential Energy at the Starting Point

Potential energy (PE) is defined as:

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

At her initial position (height h_1):

$$ PE_{initial} = 72\,kg \times 9.81\,m/s^2 \times 29\,m $$

Calculating:

$$ PE_{initial} = 72 \times 9.81 \times 29 $$

$$ PE_{initial} \approx 72 \times 284.49 $$

$$ PE_{initial} \approx 20,507.28\,J $$

This energy represents her maximum potential energy before the jump.

Calculating Her Potential Energy at the Landing Point

At the landing ledge (height h_2 = 18 m):

$$ PE_{final} = 72\,kg \times 9.81\,m/s^2 \times 18\,m $$

Calculating:

$$ PE_{final} = 72 \times 9.81 \times 18 $$

$$ PE_{final} \approx 72 \times 176.58 $$

$$ PE_{final} \approx 12,727.76\,J $$

The reduction in potential energy during her fall is:

$$ \Delta PE = PE_{initial} - PE_{final} $$

$$ \Delta PE \approx 20,507.28\,J - 12,727.76\,J $$

$$ \Delta PE \approx 7,779.52\,J $$

This energy difference is primarily converted into kinetic energy and energy dissipated due to air resistance and impact forces.

Her Velocity at the Moment of Landing

Theoretical Velocity Assuming No Air Resistance

Ignoring air resistance, the velocity of her just before landing can be found using energy conservation:

$$ KE = PE_{initial} - PE_{final} $$

$$ KE = 7,779.52\,J $$

Kinetic energy (KE) is also:

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

Solving for v:

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

$$ v = \sqrt{\frac{2 \times 7,779.52}{72}} $$

$$ v = \sqrt{\frac{15,559.04}{72}} $$

$$ v = \sqrt{215.82} $$

$$ v \approx 14.7\,m/s $$

Thus, her velocity just before impact is approximately 14.7 m/s.

Impact and Energy Dissipation

Real-World Considerations

In reality, some energy is lost due to air resistance and deformation during impact, meaning her actual impact velocity might be slightly lower or higher depending on factors like her posture, air drag, and the surface properties.

Change in Her Energy State

- Initial energy: 20,507.28 J (potential energy at 29 m)
- Energy at impact (kinetic): approximately 14.7 m/s velocity corresponding to KE of 7,779.52 J
- Energy after impact: some energy is dissipated as heat, sound, and deformation of her body and the ledge

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Momentum Analysis During the Jump

Momentum at Impact

Momentum (p) is:

$$ p = m \times v $$

Using her impact velocity:

$$ p = 72\,kg \times 14.7\,m/s $$

$$ p \approx 1,058.4\,kg \cdot m/s $$

This momentum reflects her state just before impact and is crucial for understanding force and safety measures.

The Change in Her Physical State: Energy and Momentum Perspective

Summary of Changes

Quantity	Initial	Final (Impact)	Change
Potential Energy	20,507.28 J	~12,727.76 J (at ledge)	Decrease of ~7,779.52 J
Kinetic Energy	0	~7,779.52 J	Increase of ~7,779.52 J
Velocity	0 (initial at top)	~14.7 m/s	Increase of ~14.7 m/s
Momentum	0	~1,058.4 kg·m/s	Increase accordingly

Her energy transforms from potential to kinetic during the fall, with impact forces dissipating some energy to prevent injury.

Safety and Practical Implications

Protective Measures

- Harnesses and safety nets: To absorb impact forces and reduce the risk of injury.
- Controlled environment: Stunt performers practice with precise calculations to ensure safe landings.
- Body positioning: Techniques like bending knees reduce the shock transmitted to the body.

Physics in Stunt Planning

Understanding the change in energy and velocity helps stunt coordinators design safer sequences, ensuring that impact forces are manageable and injuries minimized.

Conclusion

The daring jump of a 72 kg stunt woman from a 29-meter-high roof onto an 18-meter-high ledge exemplifies a practical application of physics principles. Her potential energy at the start (~20,507 J) decreases significantly during her fall, converting into kinetic energy (~7,779.52 J) as she approaches the ledge. Her impact velocity reaches approximately 14.7 m/s, with a momentum of about 1,058 kg·m/s. These calculations highlight the importance of energy transformation understanding in stunt safety and execution.

While real-world stunts involve numerous safety measures to mitigate risks, the physics underpinning her motion provides essential insights into the forces and energies at play during such high-stakes performances.

Frequently Asked Questions

What is the initial potential energy of the stunt woman before the jump?

The initial potential energy is given by PE = m g h = 72 kg 9.8 m/s^2 29 m = 20,441.6 Joules.

How much potential energy does she have when she lands on the 18 m high ledge?

At the ledge, her potential energy is PE = 72 kg 9.8 m/s^2 18 m = 12,691.2 Joules.

What is the change in her potential energy during the jump?

The change in potential energy is $\Delta PE = PE_{initial} - PE_{final}$ = 20,441.6 J - 12,691.2 J = 7,750.4 Joules.

Assuming no air resistance, what is her velocity just before landing on the ledge?

Using energy conservation, $v = \sqrt{2 g (h_{initial} - h_{final})} = \sqrt{2 \cdot 9.8\ m/s^2 (29\ m - 18\ m)} \approx 14.7$ m/s downward.

What is the kinetic energy of the stunt woman upon reaching the ledge?

Kinetic energy = $0.5\ m\ v^2 = 0.5\ 72\ kg\ (14.7\ m/s)^2 \approx 7,753$ Joules.

How does her change in potential energy relate to the work done during the jump?

The decrease in potential energy (~7,750 Joules) is equal to the work done by gravity, converting potential energy into kinetic energy during the fall.

What safety considerations are important for stunt

performers during such jumps?

Proper harnessing, safety nets, controlled environment, and professional training are essential to prevent injuries during high jumps.

How can this physics problem be used to teach energy conservation?

It illustrates how potential energy converts into kinetic energy during free fall, demonstrating conservation of mechanical energy in the absence of air resistance.

What assumptions are made in calculating the change in her energy during the jump?

Assumptions include neglecting air resistance, uniform gravity, and no energy loss due to factors like air drag or impact absorption.

Additional Resources

Stunt Performance Analysis: A 72 Kg Woman Jumping From a 29 M Roof Onto an 18 M Ledge

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Introduction

Stunt work is a fascinating intersection of physics, precision, and human skill. When a professional stuntwoman jumps from a significant height and lands on a smaller ledge, understanding the physical principles involved becomes crucial for safety, planning, and execution. Today, we analyze a specific case: a 72 kg stunt woman jumping from a 29-meter-high roof onto an 18-meter-high ledge. The core question revolves around her change in energy, specifically focusing on her velocity, kinetic energy, and the forces involved during the stunt.

This detailed examination aims to unpack the physics step-by-step, providing insights into what makes such a feat possible and how the variables at play influence the stunt's outcome.

Understanding the Scenario

The Setup

- Performer’s Mass: 72 kg
- Initial Height (Roof): 29 meters
- Landing Height (Ledge): 18 meters
- Vertical Distance Covered: 11 meters (from 29 m to 18 m)

Key Considerations

- Gravity: The acceleration due to gravity (g) is approximately 9.81 m/s^2.
- Air Resistance: While usually small compared to gravitational acceleration, air resistance can influence the velocity but is often neglected in initial calculations for simplicity.
- Safety Measures: The actual stunt would involve harnesses, mats, or other safety equipment, but for the physics analysis, we focus purely on the mechanics.

Physics Principles at Play

Potential and Kinetic Energy

At any height, a body possesses potential energy (PE) relative to a reference point (usually ground level), calculated as:

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

where:
- m is mass,
- g is acceleration due to gravity,
- h is height above the reference point.

When the body falls, potential energy converts into kinetic energy (KE):

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

where v is the velocity of the body.

Change in Energy

The change in energy during the fall is primarily the decrease in potential energy, which converts into kinetic energy:

$$\Delta PE = PE_{initial} - PE_{final}$$

Given that the height decreases from 29 m to 18 m, the change in potential energy is:

$$\Delta PE = m \times g \times (h_{initial} - h_{final})$$

Calculating the Velocity at Landing

Step 1: Initial Potential Energy at the Roof

$$
PE_{initial} = m \times g \times h_{initial} = 72\,kg \times 9.81\,m/s^2 \times 29\,m
$$

$$
PE_{initial} = 72 \times 9.81 \times 29 \approx 72 \times 284.49 \approx 20,486.28\,J
$$

Step 2: Final Potential Energy at the Ledge

$$
PE_{final} = 72\,kg \times 9.81\,m/s^2 \times 18\,m
$$

$$
PE_{final} = 72 \times 9.81 \times 18 \approx 72 \times 176.58 \approx 12,720.96\,J
$$

Step 3: Change in Potential Energy

$$
\Delta PE = PE_{initial} - PE_{final} \approx 20,486.28\,J - 12,720.96\,J = 7,765.32\,J
$$

This energy converts to kinetic energy just before landing:

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

$$
7,765.32\,J = \frac{1}{2} \times 72\,kg \times v^2
$$

Step 4: Solving for Velocity

$$
v^2 = \frac{2 \times 7,765.32}{72} \approx \frac{15,530.64}{72} \approx 215.73
$$

$$
v = \sqrt{215.73} \approx 14.69\,m/s
$$

Thus, the stuntwoman's velocity just before impact is approximately 14.69 meters per second.

Implications of the Velocity and Energy Change

Kinetic Energy at Impact

Using the kinetic energy formula:

$$
KE = \frac{1}{2} \times 72\,kg \times (14.69\,m/s)^2 \approx 7,765.32\,J
$$

This confirms the energy transfer during her fall, emphasizing the significant forces involved.

Force of Impact and Safety Considerations

The force experienced during impact depends not only on velocity but also on the duration of impact and the nature of the surface or safety equipment. The shorter the collision duration, the higher the force on the body.

Force estimation:

$$
F \approx \frac{\Delta p}{\Delta t}
$$

where Δp is the change in momentum and Δt is the impact duration. Since Δp is:

$$
\Delta p = m \times v = 72\,kg \times 14.69\,m/s \approx 1,057\,kg \cdot m/s
$$

If safety gear prolongs Δt, the impact force reduces accordingly, which is why stunt professionals rely on carefully designed cushioning or ledge modifications.

Additional Factors Influencing the Stunt

Air Resistance and Drag

While initial calculations neglect air resistance, in reality, it slightly reduces the velocity achieved during free fall. For a falling human, the drag force can be estimated but generally accounts for a small percentage of the total energy, especially over 11 meters.

Body Position and Technique

The stuntwoman's posture during the jump influences how forces are distributed. Techniques such as rolling upon landing, spreading impact over a larger area, and proper body alignment help mitigate injury risks.

Safety Equipment and Environmental Conditions

- Harnesses and Safety Nets: These reduce impact forces by increasing impact duration.
- Ledge Design: Cushioned or specially designed ledges absorb some of the impact.
- Environmental Factors: Wind, air density, and surface conditions can alter the fall dynamics.

Conclusion: The Significance of the Energy Change

This analysis demonstrates how physics underpins even the most daring stunt performances. The change in energy—the conversion of potential energy at height into kinetic energy during the fall—is approximately 7,765 Joules for this stunt. Her impact velocity of around 14.7 m/s underscores the importance of meticulous planning, safety gear, and technique to ensure her well-being.

Understanding the change in energy is vital not only for assessing the risks but also for designing safety measures that absorb or redirect forces to prevent injury. Stunt professionals leverage these principles to push human limits safely, exemplifying the remarkable fusion of human skill and physics.

Final Thoughts

While the physical calculations provide a quantitative insight into the stunt's mechanics, the real-world execution involves an intricate balance of physics, safety protocols, and expert craftsmanship. The stuntwoman's skill, combined with engineering solutions, ensures that such high-stakes performances remain awe-inspiring yet safe.

In essence, analyzing her change in energy highlights the incredible precision and understanding required to execute such feats safely—an impressive testament to the art and science of stunt work.

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