A Firefighter Of Mass 78 Kg Slides Down A Vertical Pole With An Acceleration Of 3.0 M/s2 . Find The Friction

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When a firefighter descends a vertical pole, understanding the forces at play is essential both for safety and efficiency. The problem of calculating the frictional force involved in such a scenario provides a fascinating insight into classical mechanics, specifically Newton's laws of motion and the concept of friction. In this article, we will delve into the physics behind the motion of a firefighter sliding down a pole, explore how to determine the frictional force, and understand the factors influencing this force.

Understanding the Scenario

Imagine a firefighter with a mass of 78 kg who is descending a vertical pole. The firefighter is not simply falling freely; instead, they slide down with a certain acceleration, which in this case is 3.0 meters per second squared (m/s^2). The key question is: what is the frictional force resisting the firefighter's slide?

This scenario involves several forces:

- Gravitational Force (Weight): The force due to gravity acting downward, calculated as $W = m \times g$.
- Normal or Frictional Force: The resistive force opposing the motion, which includes static or kinetic friction depending on the situation.
- Net Force: The resultant of these forces that causes acceleration.

Let's analyze these forces in detail.

Fundamental Concepts and Equations

To find the frictional force, we need to understand Newton's second law of motion:

$$F_{net} = m \times a$$

where:

- F_{net} is the net force acting on the object,
- m is the mass of the object,
- a is the acceleration.

In the context of the firefighter sliding down:

- The downward force is due to gravity: $W = m \times g$,
- The upward resistive force is the frictional force F_f.

Since the firefighter is accelerating downward, the net force is:

$$F_{net} = W - F_f$$

Applying Newton's second law vertically:

$$m \times a = m \times g - F_f$$

Rearranged to solve for the frictional force:

$$F_f = m \times g - m \times a$$

This formula allows us to calculate the frictional force if we know the mass, acceleration, and acceleration due to gravity.

Calculating the Frictional Force

Let's plug in the known values:

- Mass $m = 78\,kg$,
- Acceleration $a = 3.0\, m/s^2$,
- Gravitational acceleration $g = 9.8\, m/s^2$.

Calculating the weight:

$$W = m \times g = 78 \times 9.8 = 764.4\, N$$

Calculating the resistive force (friction):

$$F_f = W - m \times a = 764.4 - 78 \times 3.0 = 764.4 - 234 = 530.4\, N$$

Therefore, the frictional force opposing the firefighter's slide is approximately 530.4 Newtons.

This value indicates that the frictional force plays a significant role in controlling the descent, preventing the firefighter from accelerating freely under gravity.

Understanding the Role of Friction in Such Situations

Friction acts as a resistive force that moderates the speed of descent. It is influenced by several factors:

- Surface roughness: The texture of both the pole and the firefighter's gear.
- Type of friction: Static or kinetic. In this case, since sliding occurs, kinetic friction is relevant.
- Normal force: The perpendicular component of the contact force, which in vertical sliding is primarily the weight of the firefighter.

In real-world applications, firefighters often use safety harnesses and controlled sliding mechanisms that involve friction to regulate their descent speed. The calculation above highlights the importance of understanding frictional forces for designing safe evacuation procedures.

Factors Affecting Friction in Vertical Descents

Several factors can alter the magnitude of friction during a firefighter's descent:

Surface Material and Texture

- Smooth, polished poles offer less friction, increasing speed.
- Rough or textured poles increase friction, slowing descent.

Gear and Equipment

- The material and condition of the firefighter’s gear influence the frictional interaction.
- Use of gloves or specialized clothing can modify the coefficient of friction.

Sliding Mechanisms

- Devices such as descenders or friction plates are used to control the rate of descent by adjusting friction.

Practical Implications and Safety Measures

Understanding the physics of sliding and friction is critical for ensuring safety during rescue operations. Properly calibrated equipment that accounts for the expected frictional forces allows firefighters to control their descent reliably.

Key safety considerations include:

- Regular inspection of gear and pole surface conditions.
- Training on using safety devices that modulate friction.
- Designing rescue protocols that consider the maximum expected frictional forces.

Conclusion

Calculating the frictional force in the scenario of a firefighter sliding down a pole involves understanding the interplay between weight, acceleration, and resistive forces. By applying Newton's second law, we found that the frictional force resisting the firefighter's descent is approximately 530.4 Newtons. This value underscores the vital role of friction in controlling descent speed and ensuring safety during rescue operations. Recognizing how various factors influence friction can help in designing better safety equipment and protocols, ultimately saving lives.

In summary:

- The net downward force causes acceleration.
- Friction opposes the motion, reducing acceleration.
- Calculations based on known parameters enable precise determination of frictional forces.
- Proper management of these forces is essential for safe vertical descents.

Understanding these principles not only enhances safety but also provides valuable insights into classical mechanics applications in real-world scenarios.

Frequently Asked Questions

What is the mass of the firefighter in the problem?

The mass of the firefighter is 78 kg.

What is the acceleration of the firefighter sliding down the pole?

The acceleration is 3.0 m/s^2.

How do you determine the force of friction acting on the firefighter?

The force of friction can be found using Newton's second law: $F_{friction} = m(g - a)$, where g is gravity (9.8 m/s^2).

What is the net force acting on the firefighter during the slide?

The net force is $F_{net} = m a = 78 \text{ kg } 3.0 \text{ m/s}^2 = 234 \text{ N}$.

How to calculate the gravitational force on the firefighter?

The gravitational force is $F_{gravity} = m g = 78 \text{ kg } 9.8 \text{ m/s}^2 = 764.4 \text{ N}$.

What is the magnitude of the frictional force in this scenario?

The frictional force is F_friction = F_gravity - F_net = 764.4 N - 234 N = 530.4 N.

Why is the acceleration less than g in this problem?

Because the friction opposes the motion, reducing the net acceleration below g.

Can the friction force be greater than the weight of the firefighter?

No, the maximum static friction cannot exceed the normal force, which in this case is less than or equal to the weight; here, it is approximately 530.4 N.

What assumptions are made in solving this problem?

Assumptions include neglecting air resistance, assuming the pole is vertical, and that the only forces are gravity, friction, and the net force causing acceleration.

How does the coefficient of kinetic friction relate to the problem?

The coefficient of kinetic friction μ can be calculated using F_friction = μ N, where N is the normal force (equal to weight here). In this case, μ = F_friction / (m g) = 530.4 N / 764.4 N ≈ 0.695.

Additional Resources

A Firefighter Of Mass 78 Kg Slides Down A Vertical Pole With An Acceleration Of 3.0 M/s^2: Find The Friction

When considering a firefighter of mass 78 kg sliding down a vertical pole with an acceleration of 3.0 m/s^2, it becomes crucial to analyze the forces at play. This problem involves understanding the interplay of gravity, friction, and the resultant acceleration. Such analysis not only provides insight into the physics involved but also highlights the importance of friction in real-world safety and operational scenarios. Whether you're a student preparing for exams or a professional seeking clarity on force dynamics, this detailed guide offers a comprehensive breakdown of how to determine the frictional force acting on the firefighter during his descent.

Understanding the Physical Scenario

Imagine a firefighter gripping a vertical pole. When he begins to slide downward, gravity pulls him downward, but the frictional force opposes this motion. The question is: how much frictional force is present if the firefighter slides down with a known acceleration?

Key parameters:
- Mass of firefighter (m): 78 kg

- Acceleration during slide (a): 3.0 m/s^2
- Acceleration due to gravity (g): 9.8 m/s^2 (standard value)

The primary forces acting on the firefighter are:
- Weight (W): acts downward, W = m g
- Frictional force (F_f): acts upward (opposing the slide)
- Normal force (N): in this scenario, since the pole is vertical, the normal force is equivalent to the normal contact between the firefighter and the pole, primarily contributing to the friction.

Step-by-Step Breakdown of the Physics

1. Free Body Diagram
Visualizing the forces helps in setting up the equations:
- Downward: Weight (W = m g)
- Upward: Frictional force (F_f)

Since the firefighter is sliding down with acceleration a, Newton's second law applies in the vertical direction:

$$ \text{Net force} = m \times a $$

which simplifies to:

$$ \sum F = m a $$

2. Setting Up the Equation

The net force acting downward is the difference between the weight and the frictional force:

$$ W - F_f = m a $$

Rearranged to find the frictional force:

$$ F_f = W - m a $$

Where:
- $W = m \times g$
- a is given as 3.0 m/s^2

3. Calculating the Weight

Plugging in the values:

$$ W = 78\, \text{kg} \times 9.8\, \text{m/s}^2 = 764.4\, \text{N} $$

4. Computing the Frictional Force

Using the net force equation:

$$F_f = 764.4\, \text{N} - (78\, \text{kg} \times 3.0\, \text{m/s}^2)$$

$$F_f = 764.4\, \text{N} - 234\, \text{N} = 530.4\, \text{N}$$

Thus, the frictional force acting on the firefighter is approximately 530.4 N.

Deeper Insights: Is This the Total Friction?

Yes, in this context, the frictional force is the total contact force that opposes the downward motion. Given the scenario, the friction acts upward along the pole to reduce the net downward acceleration from gravity.

The Role of Normal Force and Friction Coefficient

While the calculation above gives the magnitude of the frictional force, understanding what this force depends on requires examining the coefficient of friction (μ):

$$F_f = \mu N$$

In this case:
- N is the normal force exerted by the firefighter on the pole.
- Since the pole is vertical, the normal force is primarily due to the firefighter's grip and contact pressure, which is often close to the weight component perpendicular to the contact surface.

However, because the surface is vertical, the normal force can be approximated as the contact force exerted by the firefighter’s grip, which is difficult to directly measure. For simplicity and in many textbook problems, it’s often assumed that the normal force equals the weight component perpendicular to the contact surface. But since the pole is vertical, the normal force is more about the grip force, which must balance the normal component, which is zero in pure vertical contact.

Therefore, the friction here is acting along the surface of contact, and the key to understanding the friction coefficient would involve additional data about the grip (normal force) if needed.

Practical Applications and Real-World Significance

Understanding the forces involved in such a scenario has practical implications:

- Safety Design: Ensuring that the frictional force is sufficient to control the descent of firefighters and prevent accidents.
- Equipment Development: Designing poles and gripping equipment with optimal friction characteristics.
- Training and Protocols: Educating firefighters on how grip and friction influence descent speeds and safety.

Summary of Key Calculations

Parameter	Value	Explanation
Mass of firefighter	78 kg	Given
Gravitational force $W = m \times g$	764.4 N	Calculated
Acceleration a	3.0 m/s²	Given
Frictional force F_f	530.4 N	Calculated as $W - m a$

Final Thoughts

Determining the friction acting on a firefighter sliding down a pole with a known acceleration involves fundamental physics principles involving Newton's laws. By carefully analyzing the forces, especially the balance between gravity and friction, we can deduce the magnitude of the frictional force. This not only exemplifies classical mechanics but also underscores the importance of friction in safety-critical situations. For engineers, safety professionals, and students, mastering such calculations is essential for designing safer systems and understanding the dynamics of motion in everyday and emergency scenarios.

In conclusion, when a firefighter of mass 78 kg slides down a vertical pole with an acceleration of 3.0 m/s², the frictional force opposing his descent is approximately 530.4 N. This force plays a vital role in controlling the slide and ensuring safety during rapid descents, emphasizing the importance of frictional forces in practical physics applications.

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