A 33-N Force Is Applied To A 7-kg Object To Move It With A Constant Velocity Of 6.3 M/s Across A Level

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When analyzing the motion of objects in physics, understanding the relationship between applied forces, mass, and velocity is crucial. In this scenario, a 33-newton (N) force is applied to a 7-kilogram (kg) object to move it across a level surface at a constant velocity of 6.3 meters per second (m/s). This situation offers an excellent opportunity to explore fundamental concepts such as Newton's second law, friction, and the dynamics of constant velocity motion. This article will delve into these core principles, providing a comprehensive understanding of how forces interact with mass to produce motion—or maintain it.

Understanding the Scenario: Force, Mass, and Velocity

The Basic Setup

In this scenario, the object with a mass of 7 kg is being pulled or pushed across a flat, level surface with a force of 33 N. The goal is to understand what this force accomplishes, especially considering the object moves at a steady velocity of 6.3 m/s. The key points are:
- The object has a mass of 7 kg.
- The applied force is 33 N.
- The object moves at a constant velocity of 6.3 m/s.
- The surface is level, meaning gravitational potential energy is not changing due to elevation.

Significance of Constant Velocity

Moving at a constant velocity implies that the acceleration of the object is zero. According to Newton's first law, an object will continue in its state of motion unless acted upon by an external force. Therefore, the forces acting on the object are balanced.

Applying Newton's Laws to the Situation

Newton's Second Law: F = ma

The second law states that the net force acting on an object equals its mass times its acceleration:
$$ F_{net} = m \times a $$
Since the object moves at a constant velocity, its acceleration $a = 0$, and thus the net force must

also be zero:
$$ F_{net} = 0 $$

Forces Acting on the Object

Considering the forces involved:
- Applied Force (F_a): 33 N, directed horizontally to move the object.
- Frictional Force (F_f): Opposes the motion, acts opposite to the applied force.
- Normal Force (N): Upward force exerted by the surface.
- Gravitational Force (Weight, W): Downward force due to gravity, $W = m \times g$.

Since the object moves at a steady velocity, the sum of forces in the horizontal direction is zero:
$$ F_{a} - F_{f} = 0 $$
which simplifies to:
$$ F_{f} = F_{a} = 33\, \text{N} $$

This indicates that the frictional force resisting the motion is exactly 33 N.

Understanding Friction in the Scenario

Types of Friction

The primary frictional force resisting motion on a level surface is kinetic friction, which occurs when the object is sliding.

Calculating the Frictional Force

The kinetic friction force F_f can be calculated using:
$$ F_f = \mu_k \times N $$
where:
- μ_k is the coefficient of kinetic friction.
- N is the normal force, which on a level surface equals the weight:
$$ N = m \times g $$
- g is acceleration due to gravity ($\approx 9.81\, \text{m/s}^2$).

Given:
$$ N = 7\, \text{kg} \times 9.81\, \text{m/s}^2 = 68.67\, \text{N} $$

Since the applied force equals the kinetic friction:
$$ 33\, \text{N} = \mu_k \times 68.67\, \text{N} $$
$$
\Rightarrow \mu_k = \frac{33}{68.67} \approx 0.48
$$

Thus, the coefficient of kinetic friction between the object and the surface is approximately 0.48, indicating a moderate level of friction.

Implications of the Force and Motion

Why Is a Force of 33 N Sufficient?

Because the applied force balances the kinetic friction, the net force is zero, resulting in zero acceleration. Therefore, the object maintains its constant velocity of 6.3 m/s.

Energy Considerations

- Work Done by the Force: The work W done by the applied force over a displacement d is:
$$W = F \times d \times \cos{\theta}$$
where θ is the angle between force and displacement. Assuming the force acts horizontally:
$$W = 33\, \text{N} \times d$$
- Power Delivered: The power P (rate of work) when moving at constant velocity:
$$P = F \times v = 33\, \text{N} \times 6.3\, \text{m/s} \approx 208\, \text{W}$$
This power is used to overcome friction; no net energy is accumulated in acceleration.

Practical Applications and Real-World Examples

Using Force to Maintain Constant Speed

Understanding these principles is vital in various fields like transportation, manufacturing, and robotics. For example:
- Designing conveyor belts requires calculating the force needed to move objects at specific speeds, considering friction.
- Automotive engineers analyze engine power and braking forces to control vehicle speed.

Calculating Forces in Similar Situations

Applying the same principles:
- To move heavier objects at the same speed, larger forces are needed, or surfaces with lower friction coefficients are preferred.
- To increase speed without increasing force, reducing friction or using more efficient mechanisms is essential.

Summary and Key Takeaways

- When a 33 N force moves a 7 kg object at a constant velocity of 6.3 m/s across a level surface, the net force is zero.
- The force counteracts kinetic friction, which in this case has an approximate coefficient of 0.48.
- Newton's second law confirms that no acceleration occurs during this motion.
- Energy transfer primarily involves overcoming friction, with power output around 208 W.
- Practical applications of these principles are widespread in engineering, transportation, and physics

research.

Understanding the interplay between applied forces, friction, and motion not only explains everyday phenomena but also underpins technological advancements and efficient system designs. By mastering these concepts, engineers and physicists can optimize systems for performance, safety, and energy efficiency—making the study of forces and motion a cornerstone of modern science and engineering.

Frequently Asked Questions

What is the primary reason a 33-N force can move a 7-kg object at constant velocity across a level surface?

Because the applied force of 33 N balances the opposing kinetic friction force, resulting in zero net acceleration and constant velocity.

How can we determine the coefficient of kinetic friction between the object and the surface?

Using the formula: coefficient of kinetic friction $\mu = F_{friction}$ / normal force. Since the normal force equals the weight (mg), $\mu = (F_{applied}) / (mg)$.

What is the magnitude of the kinetic friction force acting on the object?

Since the object moves at constant velocity, the kinetic friction force is equal to the applied force, which is 33 N.

How does the applied force relate to the object's weight?

The applied force (33 N) is less than the object's weight (approximately 68.6 N), indicating that frictional force is a significant factor in motion across the surface.

What is the coefficient of kinetic friction between the object and the surface?

$\mu = F_{friction}$ / normal force = 33 N / (7 kg × 9.8 m/s^2) ≈ 0.48.

Would increasing the applied force result in acceleration if it exceeds the frictional force?

Yes, applying a force greater than the kinetic friction would produce a net force, causing the object to accelerate.

If the object is moved at a constant velocity, what does this imply about the net force acting on it?

It implies that the net force is zero; the applied force balances the kinetic friction force.

What additional information would be needed to calculate the work done by the force in moving the object?

The distance moved by the object and the direction of the force relative to the displacement are needed to calculate work done.

Additional Resources

Force Analysis and Motion Dynamics of a 7-kg Object Moving at Constant Velocity Under a 33-N Applied Force

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In the realm of classical mechanics, understanding the interplay between applied forces and motion is essential for designing and analyzing real-world systems—from industrial machinery to everyday objects. Today, we delve into a detailed examination of a specific scenario: applying a 33-newton force to a 7-kilogram object to move it across a level surface at a constant velocity of 6.3 meters per second. This case study not only illustrates fundamental principles of physics but also provides insights into the forces at work, the nature of friction, and the conditions necessary for maintaining uniform motion.

Understanding the Scenario: Basic Parameters and Assumptions

Before delving into the physics, it’s vital to clarify the parameters and assumptions:

- Object mass (m): 7 kg
- Applied force (F_applied): 33 N
- Desired constant velocity (v): 6.3 m/s
- Surface: Level (horizontal) and assumed to be flat and uniform
- Environment: No acceleration, implying steady-state motion
- Friction: Present, opposing the motion, characterized by the coefficient of kinetic friction (μ_k)
- Gravity (g): 9.81 m/s^2

This scenario resembles a typical problem in dynamics involving kinetic friction and steady motion, often encountered in engineering and physics education.

Fundamentals of Motion at Constant Velocity

Newton's First Law and Equilibrium

When an object moves at a constant velocity, it indicates that net force equals zero according to Newton's First Law. This means that all the forces acting along the direction of motion balance out:

$$ \sum F_x = 0 $$

In our case, this includes:

- The applied force $F_{applied}$ (forward)
- The kinetic friction force $F_{friction}$ (backward)

Since the velocity is steady, the sum of forces in the horizontal direction is zero:

$$ F_{applied} - F_{friction} = 0 $$
$$ F_{applied} = F_{friction} $$

Given that the applied force is 33 N, the kinetic friction force must also be 33 N to maintain constant velocity.

Analyzing the Frictional Force

What Is Kinetic Friction?

Kinetic friction is the resistive force acting opposite to the direction of motion when two surfaces slide against each other. It's characterized by the coefficient of kinetic friction μ_k, a dimensionless value that depends on the nature of the surfaces involved (e.g., rubber on concrete, metal on metal, etc.).

The kinetic friction force is given by:

$$ F_{friction} = \mu_k \times N $$

where N is the normal force.

Calculating the Normal Force

On a level surface, the normal force N balances the weight of the object:

$$N = m \times g$$
$$N = 7\, \text{kg} \times 9.81\, \text{m/s}^2$$
$$N = 68.67\, \text{N}$$

This normal force acts perpendicular to the surface, counteracting gravity.

Determining the Coefficient of Kinetic Friction μ_k

Given that the applied force equals the kinetic friction force:

$$F_{friction} = 33\, \text{N}$$

and

$$F_{friction} = \mu_k \times N$$

we can solve for μ_k:

$$\mu_k = \frac{F_{friction}}{N} = \frac{33\, \text{N}}{68.67\, \text{N}} \approx 0.48$$

Implication: The coefficient of kinetic friction between the object and the surface is approximately 0.48—a moderate value typical for certain rubber or plastic surfaces sliding on a similar material.

Implications of the Force Application and Constant Velocity

Force Requirements for Maintaining Motion

The analysis confirms that to maintain constant velocity, the applied force must exactly counteract the kinetic friction. Any increase in applied force beyond 33 N would accelerate the object, while any decrease would cause deceleration due to unbalanced frictional forces.

Key takeaways:

- The applied force of 33 N is precisely tuned to overcome kinetic friction.
- The system is in dynamic equilibrium, with no acceleration.

- The coefficient of kinetic friction is about 0.48, which influences the ease of movement.

Energy Considerations

While not explicitly asked, energy transfer is a relevant aspect:

- The work done by the applied force per second (power) is:

$$P = F_{applied} \times v = 33\, \text{N} \times 6.3\, \text{m/s} \approx 207.9\, \text{W}$$

- This energy compensates for the energy lost to friction, which manifests as heat at the contact surfaces.

Exploring Variations and Practical Considerations

Changing Surface Conditions

If the surface or materials change, μ_k may vary, impacting the force needed:

- Smoother surfaces or lubricated contacts reduce μ_k, decreasing the required force.
- Rougher surfaces or sticky materials increase μ_k, necessitating higher applied force.

Impact of External Factors

- Inclined surfaces: Would introduce gravitational components along the slope, requiring additional force.
- Surface wear or contamination: Can alter friction coefficients, affecting the force balance.

Design Implications for Real-World Systems

Understanding these force dynamics is crucial in:

- Designing conveyor belts, rollers, and trolleys: Ensuring motors or manual efforts match the necessary force.
- Automotive engineering: Calculating braking forces and fuel efficiency.
- Robotics: Planning for actuation forces to achieve desired motion profiles.

Summary and Final Remarks

In conclusion, the scenario of applying a 33 N force to a 7 kg object to keep it moving at 6.3 m/s across a level surface exemplifies key principles of classical mechanics:

- Steady, constant velocity implies zero net force.
- Friction plays a crucial role, with the kinetic friction coefficient approximately 0.48 in this case.
- The applied force must precisely balance the kinetic friction to maintain motion without acceleration.

This case underscores the importance of understanding force interactions, frictional forces, and energy considerations in practical applications. Whether designing machinery, optimizing transportation systems, or studying fundamental physics, such analyses form the backbone of effective engineering and scientific problem-solving.

Note: The actual coefficient of kinetic friction can vary based on surface materials and environmental factors. For more precise applications, empirical measurements are recommended.

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