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A stalled vehicle is being pushed up a hill at constant velocity by three people. The net force on the vehicle in this scenario is a fundamental aspect of Newtonian physics, illustrating the balance of forces involved in motion and equilibrium. This article explores the forces at play, the principles governing the situation, and the implications of pushing a vehicle at constant velocity uphill.

Understanding the Situation: The Basics

The Setup

Imagine a vehicle that has stalled on a slope, and three individuals are working together to push it uphill. Despite the effort exerted by the pushers, the vehicle moves at a steady, constant velocity. This indicates that the acceleration of the vehicle is zero, and the forces acting upon it are in a specific equilibrium.

Key Concepts in Physics

- **Newton's First Law:** An object at constant velocity experiences no net force.
- **Newton's Second Law:** The net force acting on an object equals its mass times its acceleration (F = ma).
- **Friction and Resistance:** Forces opposing the motion, including rolling resistance and kinetic friction.
- **Component of Gravitational Force:** The portion of the weight acting parallel to the incline.

Analyzing the Forces Acting on the Vehicle

Forces Involved

Several forces influence the motion (or lack thereof) of the vehicle as it is pushed uphill:

1. **Gravity (Weight):** The downward force due to gravity, which can be resolved into components parallel and perpendicular to the slope.
2. **Normal Force:** The support force exerted by the surface perpendicular to the incline.
3. **Applied Force:** The combined force exerted by the three individuals pushing the vehicle.
4. **Frictional and Resistive Forces:** Including rolling resistance and possibly air resistance, opposing the motion.

Resolving the Gravitational Force

The weight of the vehicle (W) acts vertically downward. On an inclined plane, this force can be broken into:

- **Parallel component:** $W \sin \theta$, which acts down the slope.
- **Perpendicular component:** $W \cos \theta$, which acts perpendicular to the surface.

Here, θ represents the angle of the incline.

Conditions for Constant Velocity

Equilibrium of Forces

If the vehicle moves at a constant velocity, its acceleration is zero. According to Newton's second law, the net force must also be zero:

Net Force $(F_{net}) = 0$

This implies that the sum of all forces in the direction of motion balances out:

- The total applied force exerted by the pushers.
- The sum of opposing forces, primarily the component of gravity pulling the vehicle downhill and the resistive forces.

Mathematical Representation

Let’s define:

- $\mathbf{F_{push}}$: Total force exerted by the three people combined.
- $\mathbf{F_{resist}}$: Sum of resistive forces such as friction and the downhill component of gravity.

Since the vehicle moves at constant velocity:

$\mathbf{F_{push} = F_{resist}}$

Calculating the Net Force

Determining the Resistive Forces

- **Component of gravity:** $W \sin \theta$
- **Frictional force:** Typically modeled as μN, where μ is the coefficient of kinetic friction, and N is the normal force ($W \cos \theta$).

Total Resistive Force

The total resistive force can be expressed as:

$F_{resist} = W \sin \theta + \mu W \cos \theta$

where $W = m g$ (mass times acceleration due to gravity)

Force Applied by Pushers

Given that the vehicle is moving at constant velocity, the combined force exerted by the three people must exactly counteract F_{resist}. If we denote:

- **$F_{individual}$**: The force exerted by each person (assuming equal effort)
- **F_{total}**: Sum of all three forces

then:

$$F_{total} = 3 \times F_{individual} = F_{resist}$$

Implications and Real-World Considerations

Effect of Incline and Surface Conditions

The slope angle (θ) significantly impacts the magnitude of the gravitational component. Steeper slopes increase $W \sin \theta$, demanding greater force from the pushers. Similarly, rougher surfaces with higher μ values increase resistive forces.

Distribution of Effort

In practical scenarios, the three people may exert different forces depending on their strength and positioning. The total force needed to maintain constant velocity remains the same as long as the sum of their efforts equals the resistive forces.

Energy and Work Considerations

- Although the vehicle moves at constant velocity, work is still performed by the pushers against resistive forces.
- The power output of the pushers is related to the force they exert and the velocity:

$$P = F_{push} \times v$$

where v is the velocity. Since v is constant, the power remains steady during the push.

Conclusion: The Net Force on the Vehicle

In the scenario where a stalled vehicle is being pushed uphill at constant velocity by three individuals, the net force acting on the vehicle is zero. This is a direct consequence of Newton's first law, which states that an object moving at a constant velocity experiences no net force. The forces exerted by the pushers precisely balance the forces resisting motion, including the component of gravity along the incline and frictional forces.

Understanding this equilibrium is crucial in physics, as it illustrates how forces must balance to maintain steady motion. It also emphasizes the importance of force calculation and analysis in real-world situations, such as moving heavy objects uphill, designing vehicles, or analyzing forces in mechanical systems.

Ultimately, the net force being zero signifies that the pushers are doing just enough work to counteract resistive forces without causing acceleration. The scenario underscores the fundamental principle that constant velocity corresponds to a state of dynamic equilibrium where all forces are balanced.

Frequently Asked Questions

What is the net force acting on a vehicle being pushed uphill at constant velocity?

The net force acting on the vehicle is zero because at constant velocity, the forces are balanced, meaning the push exactly counteracts the component of gravity pulling the vehicle downhill.

Why do three people pushing a stalled vehicle uphill at constant velocity not accelerate it?

Because the combined force exerted by the three people equals the gravitational component pulling the vehicle downhill, resulting in zero acceleration and a net force of zero.

What role does friction play in the scenario of pushing a vehicle uphill at constant velocity?

Friction opposes the motion and must be overcome by the push; at constant velocity, the combined force from the push and friction equals the component of gravity, resulting in a net force of zero.

How does the weight of the vehicle affect the forces involved when pushing it uphill?

The weight determines the component of gravitational force acting downhill; a heavier vehicle exerts a larger force that must be balanced by the push to maintain constant velocity.

If the vehicle starts to accelerate while being pushed uphill, what does that imply about the net force?

It implies that the net force is no longer zero; the combined pushing force exceeds the downhill component of gravity plus friction, causing acceleration.

How can the force exerted by each person be calculated when pushing a vehicle uphill at constant velocity?

Total force required equals the component of gravity plus friction; dividing this total by three gives the approximate force each person needs to exert, assuming equal effort.

What is the significance of the statement 'net force on the vehicle is zero' in this context?

It indicates that the vehicle is moving at a constant velocity with no acceleration, meaning the total forces acting on it are balanced.

Additional Resources

A Stalled Vehicle Is Being Pushed Up A Hill At Constant Velocity By Three People. The Net Force On The

In the world of physics, understanding forces and motion is fundamental to analyzing everyday situations. One such scenario involves a stalled vehicle being pushed uphill at a steady pace by three individuals. While it might seem straightforward—people pushing to move a car—the underlying physics reveals a nuanced interplay of forces. This article explores the mechanics behind this situation, focusing on the net force acting on the vehicle, the roles of the individuals pushing, and the principles that govern constant velocity motion on an inclined plane.

Understanding the Scenario: Pushing a Vehicle Up a Hill

Imagine a vehicle that has stalled halfway up a hill. Three people are positioned around it, exerting force to push it forward. The car moves steadily uphill without accelerating or decelerating, indicating that its velocity remains constant. To analyze this, we need to consider the forces acting on the vehicle and how they balance to produce this uniform motion.

Key points to note:

- The vehicle is stationary relative to the ground in the direction of the hill's incline—meaning it's moving at a constant velocity uphill.
- The three people are applying force collectively to push the car.
- External forces like gravity, friction, and possibly air resistance act on the vehicle.

Forces Acting on the Vehicle

To comprehend the net force, it is essential to identify all the forces acting on the vehicle:

1. Gravitational Force (Weight)

- Acts vertically downward.
- Magnitude: $W = mg$, where m is the mass of the vehicle, and g is acceleration due to gravity (~9.81 m/s^2).

2. Normal Force

- Perpendicular to the surface of the hill.
- Balances the component of the weight perpendicular to the incline.
- Magnitude: $N = mg \cos \theta$, where θ is the angle of the hill.

3. Component of Gravity Along the Incline

- Acts to pull the vehicle downhill.
- Magnitude: $F_g = mg \sin \theta$.

4. Frictional Force

- Resists the motion of the vehicle.
- Depends on the coefficient of kinetic friction μ_k and the normal

force.
- Magnitude: $F_f = \mu_k N = \mu_k mg \cos \theta$.

5. External Push (Applied Force)

- The collective force exerted by the three people.
- Denote this as F_{push}.

6. Air Resistance

- Usually small but can be considered depending on conditions.
- Opposes motion and can be included as F_{air}.

Summarizing, the net force F_{net} along the incline is given by:

$$
F_{net} = F_{push} - (F_g + F_f + F_{air})
$$

Constant Velocity and the Net Force

The key observation is that the vehicle moves uphill at a constant velocity. According to Newton’s First Law, when an object moves with constant velocity, the net force acting on it is zero.

Mathematically:

$$
F_{net} = 0
$$

This implies:

$$
F_{push} = F_g + F_f + F_{air}
$$

In other words, the combined pushing force exactly balances all the resistive forces acting against the vehicle's motion.

Calculating the Forces: An Example

Suppose the vehicle has a mass $m = 1500\,kg$, the hill makes an angle $\theta = 10^\circ$, the coefficient of kinetic friction $\mu_k = 0.3$, and air resistance is negligible for simplicity.

Step 1: Calculate the gravitational component along the incline:

$$
F_g = mg \sin \theta = 1500 \times 9.81 \times \sin 10^\circ
$$

$$
\sin 10^\circ \approx 0.1736
$$

$$
F_g \approx 1500 \times 9.81 \times 0.1736 \approx 1500 \times 1.702 \approx 2553\,N
$$

Step 2: Calculate the normal force:

$$
N = mg \cos \theta = 1500 \times 9.81 \times \cos 10^\circ
$$

$$
\cos 10^\circ \approx 0.9848
$$

$$
N \approx 1500 \times 9.81 \times 0.9848 \approx 1500 \times 9.66 \approx 14,490\,N
$$

Step 3: Determine the frictional force:

$$
F_f = \mu_k N = 0.3 \times 14,490 \approx 4347\,N
$$

Step 4: Sum of resistive forces:

$$
F_{resist} = F_g + F_f \approx 2553 + 4347 = 6900\,N
$$

Step 5: Determine the pushing force:

Since the vehicle moves at constant velocity,

$$
F_{push} = F_{resist} = 6900\,N
$$

This is the total force the three people need to exert collectively to maintain the vehicle's steady uphill motion.

Distribution of the Push and Human Effort

While the net force calculation provides the magnitude of the force required, understanding how three people coordinate their effort is equally crucial.

- Equal Contribution: If all three push with equal force, each must exert approximately $6900\,N / 3 \approx 2300\,N$.
- Practical Considerations: Human strength varies, and pushing forces are often less than what the calculations suggest because of factors like fatigue, technique, and safety.

Note: The actual force exerted by humans is typically less than the idealized calculated force because real-world factors like partial contact, pushing angles, and dynamic adjustments come into play.

Why the Net Force Is Zero in This Scenario

The core principle that explains the steady movement is Newton’s First Law: an object continues in its state of motion unless acted upon by a net external force. Since the vehicle maintains a constant velocity uphill:

- The pushing force from the humans exactly cancels out the sum of forces resisting motion.
- The net force is zero, indicating a dynamic equilibrium.

This equilibrium state is crucial in many practical applications, from vehicle towing to engineering design, emphasizing that maintaining constant velocity requires precise balance between driving and resistive forces.

Implications and Broader Context

Understanding the net force in this scenario has several broader implications:

- Energy Efficiency: The effort exerted by the pushers correlates directly with overcoming resistive forces; more friction or steeper inclines demand greater effort.
- Safety and Feasibility: In real-world situations, pushing a vehicle uphill at constant velocity without acceleration is feasible only if the collective force matches resistive forces.
- Design Considerations: Engineers designing vehicles or systems that move on inclines consider these forces to optimize performance and safety.

Conclusion

The scenario of three people pushing a stalled vehicle uphill at constant velocity encapsulates fundamental principles of physics. The key takeaway is that when an object moves at a steady speed, the net force acting on it is zero. In this case, the combined effort of the pushers precisely balances the components of gravity and friction resisting the vehicle's motion. By dissecting the forces involved, we gain a clearer understanding of how humans can exert just enough force to counteract natural resistances, enabling smooth, controlled movement on inclined surfaces. This analysis not only illuminates the physics behind everyday tasks but also underscores the importance of force balance in engineering and safety considerations across numerous fields.

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