12) A Horizontal Force Of 200 N Is Applied To Move A 55-kg Cart (initially At Rest) Across A 10 M Level

12) A Horizontal Force Of 200 N Is Applied To Move A 55-kg Cart (initially At Rest) Across A 10 M Level

When analyzing the motion of objects under the influence of applied forces, physics provides a robust framework to understand the dynamics involved. In this scenario, a horizontal force of 200 newtons is applied to a 55-kilogram cart that begins at rest and is moved across a level surface of 10 meters. This situation involves concepts such as force, mass, acceleration, friction, and work-energy principles, all of which are essential to accurately describe the cart's motion.

This comprehensive guide will explore the problem step-by-step, examining the forces acting on the cart, calculating the acceleration, determining the velocity after moving 10 meters, and understanding the work done by the applied force. Whether you're a physics student or simply curious about real-world applications, this detailed analysis will clarify how force influences motion in practical scenarios.

Understanding the Basic Concepts

Before delving into calculations, it's crucial to review the fundamental physics principles that govern the motion of the cart.

Newton's Second Law of Motion

- States that the acceleration (a) of an object is directly proportional to the net force (Fnet) acting on it and inversely proportional to its mass (m):

Fnet = m × a

- Rearranged to find acceleration:

a = Fnet / m

Frictional Forces

- Friction opposes the motion of the object and depends on the coefficient of kinetic friction (μk) and the normal force (N).
- For a level surface, normal force is equal to the weight of the object:

$$N = m \times g$$

- The frictional force (Ffriction) is:

$$Ffriction = \mu k \times N$$

Work and Energy

- The work done by the applied force converts into kinetic energy of the cart, provided energy losses like friction are considered.
- Work (W) is:

$$W = F \times d \times \cos(\theta)$$

where θ is the angle between the force and direction of motion ($0°$ for purely horizontal force).

Step-by-Step Solution

This section will guide through the calculation process, considering all relevant forces and energy considerations.

1. Identify Known Quantities

- Applied force, Fapplied = 200 N
- Mass of cart, m = 55 kg
- Distance to move, d = 10 m
- Initial velocity, u = 0 m/s (at rest)
- Gravitational acceleration, g ≈ 9.8 m/s2
- Coefficient of kinetic friction, μk (assumed or provided) — typically between 0.1 and 0.3 for many surfaces

Note: Since μk is not specified, we'll assume a typical value of 0.2 for demonstration purposes.

2. Calculate the Normal Force (N)

On a level surface, the normal force equals the weight of the cart:

- $N = m \times g = 55 \text{ kg} \times 9.8 \text{ m/s}^2 = 539 \text{ N}$

3. Determine the Frictional Force ($F_{friction}$)

Using the assumed coefficient:

- $F_{friction} = \mu_k \times N = 0.2 \times 539 \text{ N} \approx 107.8 \text{ N}$

This is the force opposing the applied force.

4. Calculate the Net Force (F_{net})

Since the applied force opposes friction:

- $F_{net} = F_{applied} - F_{friction} = 200 \text{ N} - 107.8 \text{ N} \approx 92.2 \text{ N}$

The net force is what accelerates the cart forward.

5. Compute the Acceleration (a)

Using Newton's second law:

- $a = F_{net} / m = 92.2 \text{ N} / 55 \text{ kg} \approx 1.677 \text{ m/s}^2$

This acceleration indicates how quickly the cart speeds up.

6. Find the Final Velocity after Moving 10 M

Use the kinematic equation:

$v2 = u2 + 2a\ d$

Where:

- $u = 0$ m/s (initial velocity)
- $a \approx 1.677$ m/s2
- $d = 10$ m

Plugging in the values:

$v2 = 0 + 2 \times 1.677 \times 10 \approx 33.54$

$v = \sqrt{33.54} \approx 5.79$ m/s

Thus, the cart reaches approximately 5.79 meters per second after moving 10 meters.

7. Calculate the Work Done by the Applied Force

Since the force acts in the same direction as the displacement:

$W = Fapplied \times d = 200\ N \times 10\ m = 2000$ Joules

This work input contributes to increasing the cart's kinetic energy and overcoming friction.

8. Determine the Kinetic Energy (KE) at 10 M

The kinetic energy at the end:

$KE = (1/2) \times m \times v2 = 0.5 \times 55\ kg \times (5.79\ m/s)2 \approx 0.5 \times 55 \times 33.54 \approx 923.2$ Joules

This value is less than the work done because some energy is dissipated overcoming friction.

9. Energy Considerations and Efficiency

- The work done by the applied force (2000 J) is partly converted into kinetic energy (~923 J) and partly lost as thermal energy due to friction (~107.8 N × 10 m ≈ 1078 J).

- Total energy loss:

Work done - KE ≈ 2000 J - 923 J ≈ 1077 J, which aligns with the work done against friction.

Implications and Real-World Applications

Understanding the dynamics of moving objects under applied forces has numerous practical applications:

Engineering and Design

- Designing transportation systems where forces are optimized to minimize energy consumption.
- Engineering carts, conveyor belts, and similar machinery with efficient friction management.

Physics Education

- Demonstrating fundamental principles like Newton's laws and work-energy theorem through real-world problems.

Energy Efficiency and Cost

- Recognizing how friction impacts energy expenditure and how reducing friction can significantly improve efficiency.

Safety and Handling

- Calculating forces and accelerations helps in designing safe handling procedures for heavy loads.

Additional Considerations and Variations

The above calculations are based on certain assumptions. Real-world scenarios may involve additional factors:

Variable Friction Coefficients

- Different surfaces or conditions (wet, oily, rough) alter μk.

Inclined Surfaces

- Moving the cart uphill introduces additional gravitational components, affecting the net force and work calculations.

Varying Applied Force

- If the applied force varies over time, more complex calculus or simulation models are necessary.

Rolling Resistance and Air Drag

- For high speeds or different objects, these forces become significant.

Acceleration Phases

- If the force is not constant or if the initial push is different, the acceleration profile changes accordingly.

Summary

In this scenario, applying a 200 N force to a 55-kg cart on a level surface results in a net force of approximately 92.2 N after overcoming friction. This force causes an acceleration of about 1.677 m/s2. After moving 10 meters, the cart reaches a velocity of approximately 5.79 m/s, with about 923 Joules of kinetic energy gained. The work done by the applied force totals 2000 Joules, with a significant portion used to overcome friction, highlighting the importance of frictional considerations in motion analysis.

Understanding these principles enables engineers, students, and enthusiasts to predict and optimize the movement of objects in various contexts, ensuring efficiency and safety in design and application.

Keywords: physics, force, motion, friction, acceleration, work-energy theorem, Newton's laws, dynamics, level surface, applied force,

Frequently Asked Questions

What is the acceleration of the 55-kg cart when a 200 N horizontal force is applied?

Using Newton's second law, acceleration $a = F/m = 200\text{ N} / 55\text{ kg} \approx 3.64\text{ m/s}^2$.

How long does it take for the cart to reach the end of the 10-meter track?

Using the equation $s = ut + 0.5at^2$ with initial velocity $u = 0$, $s = 10$ m, and $a \approx 3.64\text{ m/s}^2$, time $t \approx 2.35$ seconds.

What is the final velocity of the cart after moving 10 meters?

Using $v^2 = u^2 + 2as$, with $u=0$, $a\approx3.64\text{ m/s}^2$, $s=10$ m, the final velocity $v \approx 8.54$ m/s.

If friction is present with a coefficient of kinetic friction μk = 0.1, what is the net acceleration of the cart?

Friction force = μk normal force = 0.1 (55 kg 9.8 m/s^2) ≈ 53.9 N. Net force = 200 N - 53.9 N ≈ 146.1 N, so acceleration $a \approx 146.1\text{ N} / 55\text{ kg} \approx 2.66\text{ m/s}^2$.

What work is done by the applied force to move the cart 10 meters?

Work done $W = \text{force} \times \text{distance} \times \cos(0°) = 200\text{ N} \times 10\text{ m} = 2000$ Joules.

If the applied force is removed after reaching the end of the 10-meter track, what will be the velocity of the cart then?

Assuming no friction, the velocity at the end of 10 meters is approximately 8.54 m/s, calculated earlier. With friction, the velocity would be lower depending on energy lost.

Additional Resources

Introduction to Force and Motion: An In-Depth Analysis of Moving a Heavy Cart

When it comes to understanding the fundamentals of physics, particularly Newtonian mechanics, few concepts are as essential as force and motion. Whether you're a student, engineer, or simply a curious mind, grasping how forces influence movement is vital. Today, we delve into a practical scenario: applying a horizontal force to move a heavy cart across a level surface. Specifically, we'll analyze the case where a 200 N force is applied to move a 55-kg cart over a distance of 10 meters from rest.

This detailed examination will not only clarify the physics involved but also serve as a comprehensive guide to understanding how forces work in real-world situations. We'll explore concepts like net force, acceleration, work, and energy transfer, all tailored to this specific case.

Understanding the Scenario: Key Parameters and Basic Concepts

Before diving into calculations, it’s essential to grasp the fundamental parameters of the scenario:

- Applied Force (Fapp): 200 N (horizontal)
- Mass of the Cart (m): 55 kg
- Initial Velocity (u): 0 m/s (initially at rest)
- Distance to Cover (d): 10 meters
- Surface: Level (horizontal, implying no incline)
- Friction: Assumed to be present unless specified otherwise

This scenario presents a classic problem involving Newton’s second law, work-energy principle, and forces like friction that oppose the motion.

Analyzing the Forces at Play

1. The Applied Force

The primary force in this scenario is the 200 N applied horizontally. Its role is to overcome any resistive forces and accelerate the cart.

2. Frictional Force

On a level surface, friction acts opposite to the direction of motion. The force of kinetic friction (Ffric) can be calculated using:

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

where:
- μ_k is the coefficient of kinetic friction (depends on surface and material)
- N is the normal force, which equals the weight of the cart on a level surface: $N = m \times g$

Assuming the coefficient of kinetic friction μ_k is known or can be estimated based on typical surface conditions.

Example assumption:
- $\mu_k = 0.3$ (a common value for rubber on concrete)

Calculations:
$$ N = 55\,kg \times 9.8\,m/s^2 = 539\,N $$
$$ F_{fric} = 0.3 \times 539\,N \approx 161.7\,N $$

This resistive force must be overcome by the applied force to initiate motion and maintain movement.

Net Force and Acceleration

1. Determining if the Cart Accelerates

The net force (F_{net}) acting on the cart is:

$$ F_{net} = F_{app} - F_{fric} $$

Using the assumed friction:

$$ F_{net} = 200\,N - 161.7\,N = 38.3\,N $$

Since $F_{net} > 0$, the cart will accelerate forward.

2. Calculating Acceleration

Applying Newton’s second law:

$$ a = \frac{F_{net}}{m} = \frac{38.3\,N}{55\,kg} \approx 0.697\,m/s^2 $$

This positive acceleration indicates the cart speeds up as it moves across the surface.

Work and Energy Considerations

1. Work Done by the Applied Force

Work (W) is the energy transferred by a force over a distance:

$$ W = F \times d \times \cos{\theta} $$

For horizontal motion, $\theta = 0^\circ$, so:

$$ W_{app} = 200\,N \times 10\,m = 2000\,J $$

This work contributes to increasing the cart’s kinetic energy and overcoming friction.

2. Work Done Against Friction

Friction opposes the motion, doing negative work:

$$ W_{fric} = - F_{fric} \times d = -161.7\,N \times 10\,m = -1617\,J $$

This represents energy lost to resistive forces.

3. Net Work and Change in Kinetic Energy

The net work done on the cart is:

$$ W_{net} = W_{app} + W_{fric} = 2000\,J - 1617\,J = 381\,J $$

According to the work-energy theorem:

$$ \Delta KE = W_{net} $$

Initial kinetic energy ($KE_{initial}$) is zero since the cart starts at rest:

$$ KE_{final} = \frac{1}{2} m v^2 $$

Calculating the final velocity after 10 meters:

$$
v = u + a t
$$

But we need to find v after moving 10 meters under constant acceleration.

Using the kinematic equation:

$$
v^2 = u^2 + 2 a d
$$

$$
v^2 = 0 + 2 \times 0.697\,m/s^2 \times 10\,m = 13.94\,m^2/s^2
$$

$$
v \approx \sqrt{13.94} \approx 3.73\,m/s
$$

Final kinetic energy:

$$
KE_{final} = \frac{1}{2} \times 55\,kg \times (3.73\,m/s)^2 \approx 0.5 \times 55 \times 13.94 \approx 383\,J
$$

This closely matches the work calculation (381 J), confirming energy conservation.

Implications for Practical Applications

The analysis reveals several important points relevant for practical applications such as material handling, vehicle design, and robotics:

- Efficiency: The actual energy used to accelerate the cart is slightly less than the work done by the applied force, due to frictional losses.
- Force Requirements: To move heavier loads or surfaces with higher friction coefficients, the applied force must increase proportionally.
- Speed Control: The acceleration rate depends on the net force; adjusting the applied force allows for controlled acceleration.
- Energy Management: Understanding work and energy transfer helps optimize power consumption in mechanical systems.

Additional Factors and Real-World Variations

While the above analysis provides a solid theoretical foundation, real-world scenarios often involve additional complexities:

- Variable Friction: Surface conditions may change, affecting the friction coefficient.
- Rolling Resistance: If the cart has wheels, rolling resistance may be more relevant than kinetic friction.
- Inclines or Declines: Slopes alter normal force and, consequently, frictional forces.
- Dynamic Forces: Sudden accelerations or decelerations involve additional forces and possibly vibrations.
- Material Properties: The composition of the cart and surface influences the coefficients of friction and energy transfer.

Understanding these factors allows engineers and scientists to design more efficient systems, predict performance accurately, and troubleshoot issues effectively.

Summary and Key Takeaways

- Applying a 200 N force to a 55-kg cart over 10 meters on a level surface results in a net force of approximately 38.3 N after overcoming friction.
- The cart accelerates at about 0.697 m/s^2, reaching a final speed of around 3.73 m/s after 10 meters.
- The work done by the applied force (2000 J) exceeds the energy lost to friction (~1617 J), resulting in a net increase in the cart’s kinetic energy (~381 J).
- Understanding the interplay between applied force, friction, work, and energy transfer is crucial for designing efficient mechanical systems.

This detailed exploration underscores the importance of physics principles in real-world applications, providing insights that extend beyond academic exercises into practical engineering and operational contexts. Whether in manufacturing, transportation, or robotics, mastering these concepts empowers professionals to optimize performance and innovate effectively.

12 A Horizontal Force Of 200 N Is Applied To Move A 55 Kg Cart Initially At Rest Across A 10 M Level

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