A 1.75 Kg Book Is Sliding Along A Rough Horizontal Surface. At Point A It Is Moving At 3.46 M/s, And

A 1.75 Kg Book Is Sliding Along A Rough Horizontal Surface. At Point A It Is Moving At 3.46 M/s, And Understanding the physics behind the motion of objects on surfaces is fundamental in both academic and real-world applications. When a book of mass 1.75 kg slides along a rough horizontal surface, various physical principles come into play, including Newton's laws of motion, frictional forces, and energy conservation. This article explores the dynamics involved in such a scenario, analyzing what happens as the book slides, how to calculate relevant physical quantities, and the implications of frictional forces on the motion of the book.

Introduction to the Problem

Imagine placing a 1.75 kg book on a rough horizontal table. The book is initially moving at a speed of 3.46 m/s at a point designated as Point A. The key questions that arise in this scenario include:

- What is the nature of the forces acting on the book?
- How does friction influence the book's motion?
- What is the distance traveled before the book comes to rest?
- How can we calculate the work done by friction?
- What energy transformations occur during the sliding process?

This scenario provides a practical example of how physics principles such as kinetic friction, work-energy theorem, and acceleration are interconnected.

Understanding Friction and Its Role

Friction plays a pivotal role in the motion of objects on surfaces. In this case, the surface is rough, implying a significant frictional force that opposes the motion of the book.

Types of Friction Involved

The primary type of friction acting here is kinetic friction, which acts when two surfaces slide against each other.

- **Kinetic Friction**: The force resisting the relative motion of the sliding book.

The force of kinetic friction ($F_{friction}$) can be calculated using:

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

where:
- μ_k is the coefficient of kinetic friction (depends on the surfaces involved),
- N is the normal force, which, on a horizontal surface, equals the weight of the book ($N = mg$).

Normal Force Calculation

Given the mass $m = 1.75 \text{ kg}$ and acceleration due to gravity $g = 9.81 \text{ m/s}^2$:

$$N = mg = 1.75 \times 9.81 = 17.1675 \text{ N}$$

The actual magnitude of the frictional force depends on μ_k, which varies with the surface materials.

Analyzing the Book's Motion

The initial velocity of the book at Point A is given as 3.46 m/s. As the book slides, the kinetic friction opposes its motion, causing it to decelerate until it comes to a stop.

Work-Energy Principle

The work-energy theorem states that the work done by all forces equals the change in the object's kinetic energy:

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

Since only friction does work (assuming no other forces like air resistance), and it opposes motion:

$$ W_{friction} = - \text{Friction Work} $$

Initially, the kinetic energy is:

$$ KE_{initial} = \frac{1}{2} m v^2 = \frac{1}{2} \times 1.75 \times (3.46)^2 $$

Calculating:

$$ KE_{initial} = 0.875 \times 11.97 \approx 10.48 \text{ Joules} $$

When the book stops, its kinetic energy becomes zero:

$$ KE_{final} = 0 $$

Thus, the work done by friction equals the loss of initial kinetic energy:

$$ W_{friction} = -10.48 \text{ Joules} $$

Calculating the Distance Traveled Before Coming to Rest

To find how far the book slides before stopping, we can use the work-energy principle or kinematic equations.

Using Work-Energy Approach

The work done by friction is:

$$ W_{friction} = F_{friction} \times d $$

Rearranging:

$$ d = \frac{W_{friction}}{F_{friction}} $$

Given that:

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

and

$$ W_{friction} = -10.48 \text{ Joules} $$

If μ_k is known, the distance d can be calculated directly.

Example Calculation (Assuming $\mu_k = 0.3$)

First, calculate $F_{friction}$:

$$ F_{friction} = 0.3 \times 17.1675 \approx 5.15 \text{ N} $$

Then, the distance:

$$ d = \frac{10.48}{5.15} \approx 2.04 \text{ meters} $$

This indicates the book will slide approximately 2.04 meters before coming to rest, assuming $\mu_k = 0.3$.

Implications of Friction Coefficient and Surface Material

The coefficient of kinetic friction (μ_k) significantly influences the distance traveled.

- **Higher μ_k**: Leads to greater frictional force, shorter sliding distance, quicker stop.
- **Lower μ_k**: Less friction, longer sliding distance, slower deceleration.

Common μ_k values for different surface-material combinations:

- Wood on wood: 0.2 - 0.4
- Rubber on concrete: 0.6 - 0.85
- Plastic on rough surface: 0.3 - 0.5

Understanding these helps in designing surfaces and materials to control sliding behavior, which is useful in manufacturing, transportation, and sports.

Energy Transformations During Sliding

The process involves a transformation of energy forms:

1. **Kinetic Energy** at the initial point (Point A): The energy due to the book's motion.
2. **Work Done by Friction**: Converts kinetic energy into heat, dissipating energy into the environment.
3. **Thermal Energy**: Increased temperature at the contact surface due to frictional heat.

This energy transformation explains why objects slow down and eventually stop without any external force actively pulling or pushing.

Real-World Applications of Sliding and Friction Principles

Understanding how objects slide and stop is crucial across multiple fields:

- **Automotive Design**: Engineers optimize tire-road friction to improve safety and fuel efficiency.
- **Sports Engineering**: Design of shoes and surfaces to maximize or minimize sliding.
- **Robotics**: Controlling wheel and track friction for precise movement.
- **Material Science**: Developing surfaces with desired frictional properties for industrial applications.

Conclusion

The sliding of a 1.75 kg book along a rough horizontal surface exemplifies fundamental physics principles, including the role of kinetic friction, work-energy relationships, and energy dissipation. By analyzing the initial velocity, mass, and surface properties, we can predict the distance traveled before the book comes to rest. This understanding not only aids in solving physics problems but also informs practical applications in engineering, safety, and material design. Recognizing the interplay of forces and energy transformations helps in creating systems and environments that effectively manage sliding behavior, contributing to technological advancements and safer designs.

Keywords: physics, sliding object, kinetic friction, work-energy principle, energy transformation, coefficient of friction, motion analysis, rough surface, deceleration, distance calculation

Frequently Asked Questions

What is the initial kinetic energy of the 1.75 kg book moving at 3.46 m/s?

The initial kinetic energy is KE = 0.5 m v^2 = 0.5 1.75 kg $(3.46 \text{ m/s})^2 \approx$ 10.46 Joules.

How does the rough surface affect the book's motion?

The rough surface exerts a frictional force opposite to the book's motion, causing it to slow down and eventually stop.

If the coefficient of kinetic friction is 0.2, what is the work done by friction as the book slides?

Work done by friction = frictional force distance. Without the distance, we can't compute the exact work, but the frictional force is μ m g = 0.2 1.75 kg 9.8 $\text{m/s}^2 \approx$ 3.43 N.

How much energy is lost due to friction as the book slides?

The energy lost equals the work done by friction, which reduces the book's initial kinetic energy from approximately 10.46 Joules to zero when it stops.

What is the acceleration of the book due to friction?

Using F_friction = μ m g = 3.43 N, acceleration a = F / m = 3.43 N / 1.75 kg ≈ 1.96 m/s^2 (opposite to motion).

How long will it take for the book to come to rest assuming constant

deceleration?

Time $t = v / a = 3.46$ m/s / 1.96 m/s^2 ≈ 1.77 seconds.

What is the distance traveled by the book before coming to rest?

Using $s = v\ t - 0.5\ a\ t^2$, s ≈ 3.46 m/s 1.77 s - 0.5 1.96 m/s^2 (1.77 s)^2 ≈ 3.07 meters.

If the surface becomes frictionless, what would happen to the book's motion?

Without friction, the book would continue sliding indefinitely at the initial velocity of 3.46 m/s unless acted upon by other forces.

How can the initial velocity of the book be increased to travel further on the rough surface?

Increasing the initial velocity (more initial kinetic energy) will allow the book to slide farther before coming to rest, assuming the same friction coefficient.

Additional Resources

A 1.75 Kg Book Is Sliding Along A Rough Horizontal Surface. At Point A It Is Moving At 3.46 M/s, And This intriguing scenario offers a rich ground for exploring fundamental concepts in physics, particularly Newtonian mechanics and the effects of friction on moving objects. The scenario involves a book with a mass of 1.75 kg sliding across a rough horizontal surface, initially moving at a velocity of 3.46 m/s at point A. Analyzing this setup provides insights into the forces at play, energy transformations, and the eventual stopping of the object due to friction. In this comprehensive review, we will delve into the physics principles involved, examine the factors influencing the motion, and explore practical implications and real-world applications of such scenarios.

Understanding the Basic Physics of the Sliding Book

Mass and Initial Conditions

The mass of the book, 1.75 kg, is a critical parameter because it determines the gravitational force acting on the object and influences the kinetic energy it possesses at the start. The initial velocity of 3.46 m/s indicates that the book has a certain amount of kinetic energy that will be gradually dissipated due to resistive forces. The initial conditions set the stage for a classic problem in dynamics: how long and how far will the book slide before coming to rest?

Forces Acting on the Book

When the book slides on a rough horizontal surface, several forces are at play:

- Weight (W): The gravitational force, $W = mg$, where $m = 1.75 \, \text{kg}$, and $g \approx 9.8 \, \text{m/s}^2$.
- Normal Force (N): The support force exerted by the surface, typically equal in magnitude to the weight in the absence of vertical acceleration.
- Frictional Force (F_f): The resistive force opposing the motion, which is crucial in this scenario. It depends on the coefficient of kinetic friction μ_k and the normal force: $F_f = \mu_k N$.

Understanding these forces helps to model the deceleration process accurately.

Role of Friction in the Motion of the Book

Types of Friction and Their Effects

Friction is the primary factor causing the book to eventually stop. The two main types are:

- Static Friction: Acts when the book is at rest relative to the surface; not relevant once the book is in motion.
- Kinetic (Sliding) Friction: Acts when the book slides; it opposes the motion and reduces the kinetic energy.

In this scenario, kinetic friction is central to analyzing the deceleration. The magnitude of kinetic friction depends on the coefficient μ_k, which varies based on the materials in contact.

Coefficient of Kinetic Friction (μ_k)

The value of μ_k determines how quickly the book slows down. Typical values for common materials are:

- Wood on rough wood: μ_k around 0.3 - 0.5

- Paper on a rough surface: μ_k around 0.4 - 0.6
- Plastic on concrete: μ_k around 0.4 - 0.7

The precise value impacts the deceleration rate and stopping distance. For example, if $\mu_k = 0.4$, the frictional force can be calculated as:

$$
F_f = \mu_k \times N = \mu_k \times m g
$$

which directly influences how quickly the book loses its initial velocity.

Energy Considerations and Deceleration Analysis

Kinetic Energy of the Book

At point A, the book's kinetic energy (KE) is given by:

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

Substituting the known values:

$$
KE = \frac{1}{2} \times 1.75 \times (3.46)^2 \approx 1.75 \times 5.996 \approx 10.493 \, \text{J}
$$

This energy is gradually dissipated as thermal energy due to friction.

Work-Energy Principle

The work done by friction equals the change in kinetic energy:

$$
W_{friction} = - \text{Frictional work} = - F_f \times d
$$

where d is the stopping distance. Since the work done by friction equals the initial kinetic energy:

$$
F_f \times d = KE
$$

Substituting $F_f = \mu_k m g$:

$$
\mu_k m g \times d = \frac{1}{2} m v^2
$$

which simplifies to:

$$
d = \frac{\frac{1}{2} m v^2}{\mu_k m g} = \frac{\frac{1}{2} v^2}{\mu_k g}
$$

Notice that the mass cancels out, indicating that the stopping distance depends only on initial velocity, the coefficient of kinetic friction, and gravity.

For example, with $\mu_k = 0.4$:

$$
d = \frac{0.5 \times (3.46)^2}{0.4 \times 9.8} \approx \frac{0.5 \times 11.97}{3.92} \approx \frac{5.985}{3.92} \approx 1.53\, \text{meters}
$$

This estimates that the book will slide approximately 1.53 meters before coming to rest.

Real-World Factors and Practical Implications

Surface Roughness and Material Variability

In real-world scenarios, surface roughness and material heterogeneity influence the coefficient of friction. Variations in texture, moisture, dirt, and surface wear can significantly alter the deceleration rate. For example:

- A smoother surface reduces μ_k, increasing the stopping distance.

- A dusty or oily surface can decrease friction further, possibly leading to longer slide distances.

Understanding these factors is vital for applications where precise control of motion is required.

Energy Dissipation and Heat Generation

The kinetic energy lost during sliding is converted into heat due to friction. Although usually negligible for small objects, in high-speed or prolonged sliding, heat can impact material properties or cause wear. For the book scenario:

- The heat generated is proportional to the work done by friction, approximately 10.5 Joules, which is minimal but conceptually important.

Impacts in Engineering and Design

Studying such simple systems informs various engineering applications:

- Designing brake systems where controlled friction slows vehicles.
- Creating non-slip surfaces to ensure safety.
- Developing materials with tailored friction coefficients for specific purposes.

Additional Factors Influencing the Motion

Initial Velocity and External Disturbances

The initial velocity of 3.46 m/s provides a specific starting kinetic energy. Changes in initial speed will proportionally affect the stopping distance. External disturbances, such as vibrations or additional forces, could also influence the motion.

Inclination and External Forces

Although the scenario specifies a horizontal surface, slight inclinations or external forces (like wind or pushes) can modify the analysis. For a perfectly horizontal surface, gravity acts vertically, and the analysis remains straightforward.

Rolling vs. Sliding Friction

If the book were to roll rather than slide, rolling friction—much lower than sliding friction—would be relevant. This significantly increases the distance traveled before stopping, illustrating the importance of the mode of motion.

Summary of Key Insights

- The initial kinetic energy of the book is approximately 10.5 Joules, derived from its mass and initial velocity.
- The primary resistive force is kinetic friction, which depends on the coefficient μ_k.
- The estimated stopping distance, assuming $\mu_k=0.4$, is roughly 1.53 meters.
- Variations in surface properties, material types, and external factors can significantly alter the motion's dynamics.
- Understanding these principles is essential in designing systems involving motion on surfaces, from simple objects like books to complex machinery.

Pros and Cons of Analyzing Such a Scenario

Pros:
- Provides a fundamental understanding of friction and energy dissipation.
- Demonstrates the practical application of physics principles in everyday life.
- Helps predict and control motion in engineering design.
- Reinforces the importance of material properties and surface conditions.

Cons:
- Simplifies complex real-world interactions by assuming uniform friction and no other forces.
- Does not account for air resistance or other external factors.
- Assumes a constant coefficient of friction, which may vary in real scenarios.
- Limited to idealized conditions; actual experiments may show deviations.

Conclusion

Analyzing the motion of a 1.75 kg book sliding along a rough horizontal surface at an initial speed of 3.46 m/s offers a vivid illustration of core physics concepts

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