

A 0.60-kg Block Initially At Rest On A Frictionless, Horizontal Surface Is Acted Upon By A Force Of 7.0

A 0.60-kg Block Initially At Rest On A Frictionless, Horizontal Surface Is Acted Upon By A Force Of 7.0 Newtons, and understanding its motion involves exploring fundamental principles of physics such as Newton's laws of motion, acceleration, and the work-energy theorem. This article provides a comprehensive overview of the scenario, including detailed explanations, relevant calculations, and practical applications to help readers grasp the concepts involved.

Understanding the Basic Scenario

The Setup

In this scenario, a small block with a mass of 0.60 kilograms is placed on a frictionless, horizontal surface. Being frictionless means there is no resistive force opposing the motion of the block. Initially, the block is at rest, meaning its initial velocity is zero. A constant force of 7.0 Newtons is then applied to the block.

Key Parameters

- Mass of the block (m): 0.60 kg
- Initial velocity (u): 0 m/s
- Force applied (F): 7.0 N
- Surface: Frictionless, horizontal
- Time of application (t): To be determined based on the context or problem requirements

Fundamental Concepts Involved

Newton's Second Law of Motion

This law states that the acceleration of an object is directly proportional to the net force acting upon it and inversely proportional to its mass:

$$a = \frac{F}{m}$$

\]

Where:

- a is the acceleration (m/s^2)
- F is the net force (N)
- m is the mass (kg)

In our case, since the surface is frictionless and only one force acts on the block, the net force is 7.0 N.

Calculating the Acceleration

Using Newton's second law:

$$a = \frac{7.0 \text{ N}}{0.60 \text{ kg}} \approx 11.67 \text{ m/s}^2$$

This high acceleration indicates that the block will gain speed rapidly once the force is applied.

Kinematic Equations for Motion

Since the initial velocity is zero and the acceleration is constant, the following kinematic equations can be used:

- Velocity after time t :

$$v = u + at$$

- Displacement after time t :

$$s = ut + \frac{1}{2} a t^2$$

Given that $(u = 0)$:

$$v = at$$

$$s = \frac{1}{2} a t^2$$

Calculating Velocity and Displacement Over Time

Velocity After a Given Time

Suppose the force is applied for 3 seconds:

$$v = 11.67 \frac{\text{m}}{\text{s}} \times 3 \text{ s} = 35.01 \frac{\text{m}}{\text{s}}$$

This implies the block reaches a speed of approximately 35 m/s after 3 seconds of force application.

Displacement After a Given Time

Using the same 3-second interval:

$$s = \frac{1}{2} \times 11.67 \frac{\text{m}}{\text{s}} \times (3 \text{ s})^2 = 0.5 \times 11.67 \times 9 = 52.52 \text{ meters}$$

The block travels roughly 52.5 meters in 3 seconds under this force.

Work-Energy Theorem and Kinetic Energy

Work Done by the Force

The work done on the block by the applied force is:

$$W = F \times s$$

Using the displacement calculated:

$$W = 7.0 \text{ N} \times 52.52 \text{ m} \approx 367.64 \text{ J}$$

This work translates into an increase in the kinetic energy of the block.

Kinetic Energy of the Block

The kinetic energy after 3 seconds is:

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

Calculating:

$$KE = 0.5 \times 0.60 \, \text{kg} \times (35.01 \, \text{m/s})^2 \approx 0.3 \times 1225.7 \approx 367.7 \, \text{J}$$

This matches the work done, illustrating the work-energy theorem: the work done on an object equals its change in kinetic energy.

Implications and Practical Applications

Understanding Motion in Physics

This scenario exemplifies fundamental physics principles that are crucial in various fields, including engineering, automotive design, aerospace, and biomechanics. Understanding how forces influence motion helps in designing systems that can efficiently accelerate or decelerate objects.

Real-World Applications

- Vehicle Dynamics: Calculating acceleration and velocity for vehicles on frictionless surfaces or in controlled environments.
- Robotics: Designing robotic arms or moving parts with specified acceleration profiles.
- Material Testing: Applying known forces to test the response of materials and objects.

Advanced Considerations

Effect of Varying Force or Additional Factors

While this scenario considers a constant force on a frictionless surface, real-world situations often involve varying forces, friction, air resistance, or other resistive forces. These factors modify the acceleration and overall motion:

- Friction: Would oppose motion and reduce acceleration.
- Variable Forces: Changing forces over time require calculus-based approaches for precise analysis.
- Inclined Planes: Introducing angles modifies the net forces and accelerations due to gravity components.

Energy Conservation in More Complex Systems

In the absence of non-conservative forces like friction, total mechanical energy (kinetic + potential) remains conserved. In our frictionless case, the work done by the force directly converts into kinetic energy.

Summary and Key Takeaways

- Applying Newton's second law allows us to determine the acceleration of a mass under a known force.
- The velocity and displacement of the object can be calculated for any given time using kinematic equations.
- The work done by the force equals the increase in the kinetic energy of the object, exemplifying the work-energy theorem.
- Understanding these principles is fundamental in physics and engineering, with practical applications in designing and analyzing real-world systems.

Conclusion

A 0.60-kg block on a frictionless, horizontal surface subjected to a 7.0 N force experiences significant acceleration, leading to rapid increases in velocity and displacement over time. By applying Newton's laws and energy principles, we can accurately predict its motion and understand the underlying physics. This foundational knowledge is vital for students, engineers, and scientists working in fields that involve dynamics and motion analysis.

If you seek further information or specific calculations related to different forces, surfaces, or initial conditions, exploring advanced mechanics topics or consulting physics textbooks can deepen your understanding of motion principles.

Frequently Asked Questions

What is the acceleration of a 0.60-kg block when a 7.0 N force is applied on a frictionless surface?

The acceleration can be found using Newton's second law: $a = F/m = 7.0 \text{ N} / 0.60 \text{ kg} \approx 11.67 \text{ m/s}^2$.

How far does the 0.60-kg block move after 3 seconds under the applied force?

Using the equation $s = ut + (1/2)at^2$, with initial velocity $u=0$, $s = 0 + (1/2)(11.67 \text{ m/s}^2)(3 \text{ s})^2 \approx 52.5 \text{ meters}$.

What is the velocity of the block after 3 seconds of applying the force?

Velocity after time $t = at = 11.67 \text{ m/s}^2 \times 3 \text{ s} \approx 35.0 \text{ m/s}$.

If the force remains constant, what is the work done on the block after 3 seconds?

Work done, $W = \text{force} \times \text{distance} = 7.0 \text{ N} \times 52.5 \text{ m} \approx 367.5 \text{ Joules}$.

What is the kinetic energy of the block after 3 seconds?

Kinetic energy, $KE = (1/2)mv^2 = 0.5 \times 0.60 \text{ kg} \times (35.0 \text{ m/s})^2 \approx 367.5 \text{ Joules}$.

Additional Resources

A 0.60-kg Block Initially At Rest On A Frictionless, Horizontal Surface Is Acted Upon By A Force Of 7.0 N

Introduction

The study of Newtonian mechanics provides foundational insights into the motion of objects under various forces. Among the classic problems, analyzing the behavior of a mass under an applied force on an idealized frictionless surface offers clarity into fundamental principles such as Newton's second law. This article investigates the case of a 0.60-kg block initially at rest on a frictionless, horizontal surface being acted upon by a 7.0 N force. We will explore the kinematic and dynamic aspects, deriving key quantities such as acceleration, velocity, and displacement over time, and discuss the implications within broader physical contexts.

Fundamental Assumptions and Physical Setup

Before delving into calculations, it is crucial to outline the core assumptions that define this problem:

- Mass of the block (m): 0.60 kg
- Initial velocity (v_0): 0 m/s (initially at rest)
- Applied force (F): 7.0 N
- Surface characteristics: Frictionless and horizontal
- Time duration: Variable, depending on the specific analysis

The absence of friction simplifies the analysis, as the only horizontal force acting on the block is the applied force. This setup provides an idealized scenario that aligns with classical physics principles, allowing for straightforward application of Newton's second law.

Dynamics of the System

Calculating the Acceleration

According to Newton's second law:

$$F = m \times a$$

where:

- F is the net external force,
- m is the mass of the object,
- a is the acceleration.

Given the data:

$$a = \frac{F}{m} = \frac{7.0 \text{ N}}{0.60 \text{ kg}} \approx 11.67 \text{ m/s}^2$$

This high acceleration reflects the direct proportionality between force and acceleration, emphasizing that even moderate forces can produce significant accelerations on small masses in ideal conditions.

Implications of the Acceleration

- The constant acceleration indicates that the velocity of the block increases linearly with time.
- The absence of friction ensures no energy loss, meaning the kinetic energy of the block increases solely due to the work done by the applied force.

Kinematic Analysis

Velocity as a Function of Time

Since the initial velocity ($v_0 = 0$) and acceleration (a) is constant, the velocity at any time (t) is given by:

$$v(t) = v_0 + a t = 0 + 11.67t$$

where t is in seconds.

Displacement as a Function of Time

The displacement $x(t)$, measured from the starting point, follows:

$$x(t) = v_0 t + \frac{1}{2} a t^2 = 0 + \frac{1}{2} \times 11.67 t^2 = 5.835 t^2$$

This quadratic relationship indicates that displacement increases rapidly as time progresses, highlighting the importance of acceleration in dictating motion.

Quantitative Examples

To illustrate the dynamics, consider the following specific time points:

Time (s)	Velocity (m/s)	Displacement (m)
1	11.67	5.84
2	23.34	23.34
3	35.01	52.52
4	46.68	93.36

These values demonstrate the rapid increase in velocity and displacement, underpinning the importance of initial conditions and applied forces in motion analysis.

Energy Considerations

Since the surface is frictionless, all work done by the force translates into kinetic energy:

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

At time t :

$$KE(t) = \frac{1}{2} \times 0.60 \text{ kg} \times (11.67 t)^2 = 0.30 \times 136.17 t^2 = 40.85 t^2$$

The work-energy theorem states:

$$W = \Delta KE$$

The work done by the force over time t is:

$$W = F \times x(t) = 7.0 \times 5.835, \quad t^2 = 40.845, \quad t^2$$

which matches the kinetic energy at any instant, confirming the consistency of the analysis.

Limitations and Real-World Considerations

While this idealized model offers clear insights, real-world scenarios involve additional factors:

- Friction: Real surfaces exhibit frictional forces, which oppose motion and reduce acceleration.
- Air Resistance: For small objects moving at high speeds, drag may influence dynamics.
- Force Duration: In practice, forces may vary over time, complicating the analysis.
- Mass Distribution: The assumption of a point mass neglects rotational effects or internal mass distribution.

The model's simplicity makes it ideal for educational purposes but must be adapted when applying to physical systems.

Broader Implications and Applications

Understanding the motion of a mass under a constant force has diverse applications:

- Vehicle Dynamics: Accelerating cars or trains on frictionless tracks.
- Spacecraft Propulsion: Analyzing motion in space where gravitational and frictional forces are minimal.
- Robotics: Designing systems where precise control of motion in frictionless or low-friction environments is needed.
- Material Testing: Evaluating responses of small samples to applied forces in laboratory settings.

Furthermore, the principles demonstrated here underpin more complex systems involving variable forces, rotational motion, and non-conservative forces.

Conclusion

The investigation into a 0.60-kg block initially at rest on a frictionless, horizontal surface subjected to a 7.0 N force exemplifies core concepts in classical mechanics. The straightforward application of Newton's second law yields an acceleration of approximately 11.67 m/s², resulting in linearly increasing velocity and quadratic displacement over time. These fundamental

insights serve as building blocks for more intricate analyses involving energy conservation, real-world frictional forces, and dynamic systems.

This problem underscores the elegance of Newtonian physics in describing motion with clarity and precision, providing a foundational understanding crucial for both theoretical exploration and practical engineering applications.

References

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