

A 335 Kg Box Is Pulled 10.00 M Up A 30° Frictionless, Inclined Plane By An External Force Of 5475 N That

A 335 Kg Box Is Pulled 10.00 M Up A 30° Frictionless, Inclined Plane By An External Force Of 5475 N That presents a classic physics problem involving forces, motion, and energy considerations. Analyzing such a scenario provides insight into fundamental principles like Newton's laws, work-energy theorem, and the role of inclined planes in mechanical systems. This comprehensive exploration will delve into the problem's specifics, calculations, and broader implications, making it an informative resource for students and enthusiasts alike.

Understanding the Scenario

Problem Restatement

The problem involves a heavy box, weighing 335 kg, being pulled along a frictionless inclined plane that is inclined at 30 degrees to the horizontal. The box is moved a distance of 10.00 meters up the incline by applying an external force of 5475 N. Key points to consider include:

- Mass of the box: 335 kg
- Distance traveled along the incline: 10.00 meters
- Incline angle: 30 degrees
- External force applied: 5475 N
- Friction: none (frictionless surface)
- Goal: Analyze the motion, work done, and energy transfer involved

Fundamental Concepts Involved

Newton's Laws of Motion

Newton's second law states that the acceleration of an object is proportional to the net force acting upon it and inversely proportional to its mass:

$$F_{\text{net}} = m \cdot a$$

In this context, understanding the forces at play—applied force, component of gravitational force, and the resulting acceleration—is crucial.

Work-Energy Theorem

The work-energy principle states that the work done by all forces acting on an object results in a change in its kinetic energy:

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

Since the surface is frictionless, the primary work inputs are from the external force and the gravitational component.

Inclined Plane Dynamics

An inclined plane modifies how gravity acts on the object, splitting the gravitational force into components parallel and perpendicular to the surface:

- Parallel component: $F_{g,\text{parallel}} = m g \sin \theta$
- Perpendicular component: $F_{g,\text{perp}} = m g \cos \theta$

where g is acceleration due to gravity ($\approx 9.81 \text{ m/s}^2$) and θ is the incline angle.

Calculations and Analysis

1. Calculating the Gravitational Force and Its Components

The weight of the box:

$$W = m \times g = 335 \text{ kg} \times 9.81 \text{ m/s}^2 \approx 3288.35 \text{ N}$$

Component along the incline:

$$F_{g,\text{parallel}} = W \sin 30^\circ = 3288.35 \text{ N} \times 0.5 \approx 1644.18 \text{ N}$$

Component perpendicular to the incline:

$$F_{g,\text{perp}} = W \cos 30^\circ = 3288.35 \text{ N} \times \frac{\sqrt{3}}{2} \approx 2849.9 \text{ N}$$

Since the surface is frictionless, the perpendicular component doesn't affect the motion directly, but it influences normal force and possible normal reactions.

2. External Force and Its Effect

The external pulling force:

$$F_{\text{ext}} = 5475 \text{ N}$$

This force acts along the incline, pulling the box upward.

3. Net Force and Acceleration

Net force along the incline:

$$F_{\text{net}} = F_{\text{ext}} - F_{g,\parallel}$$

$$F_{\text{net}} = 5475 \text{ N} - 1644.18 \text{ N} \approx 3830.82 \text{ N}$$

Using Newton's second law:

$$a = \frac{F_{\text{net}}}{m} = \frac{3830.82 \text{ N}}{335 \text{ kg}} \approx 11.44 \text{ m/s}^2$$

The box accelerates up the incline at approximately 11.44 m/s^2 .

4. Work Done by External Force

Work done by the external force over 10 meters:

$$W_{\text{ext}} = F_{\text{ext}} \times d \times \cos 0^\circ = 5475 \text{ N} \times 10 \text{ m} = 54,750 \text{ J}$$

Since the force is in the direction of motion, the cosine term is 1.

5. Kinetic Energy at the End of the Motion

Assuming the box starts from rest, the work-energy theorem states:

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

Total work done by all forces:

$$W_{\text{total}} = W_{\text{ext}} - W_{\text{gravity}}$$

where:

$$W_{\text{gravity}} = F_{g,\parallel} \times d = 1644.18 \text{ N} \times 10 \text{ m} = 16,441.8 \text{ J}$$

Thus,

$$\text{W}_{\text{net}} = 54,750 \text{ J} - 16,441.8 \text{ J} = 38,308.2 \text{ J}$$

The increase in kinetic energy:

$$\text{KE}_{\text{final}} = 38,308.2 \text{ J}$$

Using kinetic energy formula:

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

solving for v :

$$v = \sqrt{\frac{2 \times \text{KE}}{m}} = \sqrt{\frac{2 \times 38,308.2}{335}} \approx \sqrt{228.76} \approx 15.14 \text{ m/s}$$

Therefore, the box reaches a speed of approximately 15.14 m/s after moving 10 meters up the incline.

Broader Implications and Real-World Applications

Engineering and Mechanical Design

Understanding forces on inclined planes is vital in designing ramps, slides, and conveyor systems. Calculating the work and energy involved helps optimize efficiency and safety.

Physics Education

Such problems serve as excellent teaching tools to demonstrate the application of Newton's laws, energy conservation, and the effects of different forces in real-world scenarios.

Industrial and Construction Settings

Employing inclined planes and external forces efficiently can reduce effort and energy consumption in moving heavy loads, leading to cost savings and enhanced safety.

Additional Considerations

Effect of Friction

In this problem, the surface is frictionless, simplifying calculations.

Introducing friction would complicate the analysis, requiring calculation of frictional force and its impact on work and energy.

Variable Forces and Real-World Dynamics

In practical situations, forces might vary, and factors like air resistance, material deformation, and non-uniform acceleration come into play, necessitating more complex models.

Safety and Mechanical Limits

Applying forces near or beyond mechanical limits can cause damage or failure. Proper engineering ensures force application remains within safe parameters.

Conclusion

Analyzing the problem of pulling a 335 kg box up a frictionless inclined plane with a force of 5475 N reveals a wealth of physics principles at work. From calculating components of gravitational force to determining acceleration, work done, and final velocity, the scenario exemplifies core concepts in classical mechanics. This analysis not only illuminates the physics involved but also underscores the importance of precise calculations for practical engineering and design applications. Whether used for educational purposes or real-world problem-solving, understanding how external forces interact with gravity and motion is fundamental to mastering mechanics.

Frequently Asked Questions

What is the primary purpose of pulling a 335 kg box up a 30° inclined plane with a force of 5475 N?

The primary purpose is to move the box to a higher elevation efficiently by overcoming gravitational and other resistive forces using an external force.

How much work is done by the external force in pulling the box 10 meters up the incline?

The work done is calculated by multiplying the force by the distance along the incline: $W = 5475 \text{ N} \times 10.00 \text{ m} = 54,750 \text{ Joules}$.

What is the component of gravitational force acting

along the inclined plane for the box?

The component of gravity along the incline is $m g \sin(30^\circ) = 335 \text{ kg} \times 9.8 \text{ m/s}^2 \times 0.5 \approx 1643.3 \text{ N}$.

Is the external force of 5475 N sufficient to move the box at a constant velocity up the incline?

Yes, since the applied force exceeds the component of gravitational force along the incline, the box can be moved upward, potentially at a constant or accelerating pace depending on other conditions.

What is the acceleration of the box if the external force is 5475 N and the incline is frictionless?

First, find the net force: $F_{\text{net}} = \text{applied force} - \text{component of gravity} = 5475 \text{ N} - 1643.3 \text{ N} \approx 3831.7 \text{ N}$. Then, acceleration $a = F_{\text{net}} / m \approx 3831.7 \text{ N} / 335 \text{ kg} \approx 11.44 \text{ m/s}^2$.

How does the angle of the incline (30°) affect the effort needed to pull the box up?

The 30° angle determines the component of gravity acting along the incline; a steeper angle increases this component, making it harder to pull, while a gentler slope reduces the effort needed.

What assumptions are made in calculating the work done on the box?

Assumptions include a frictionless incline, constant external force, no additional resistive forces, and that the force acts along the direction of motion.

Could the external force of 5475 N be used to accelerate the box faster up the incline?

Yes, since the force exceeds the gravitational component, it can accelerate the box; the acceleration depends on the net force after overcoming gravity.

What would be the effect if there was friction between the box and the incline?

Friction would oppose the motion, requiring a greater external force to move the box at the same speed, and would reduce the net acceleration if the applied force remains the same.

Additional Resources

A 335 Kg Box Is Pulled 10.00 M Up A 30° Frictionless, Inclined Plane By An External Force Of 5475 N That

In the realm of classical mechanics, understanding the forces at play when moving objects along inclined surfaces is fundamental. Such knowledge not only enriches our comprehension of everyday phenomena but also underpins engineering applications ranging from construction to transportation. Recently, a scenario has captured interest: a hefty 335-kilogram box is being pulled up a frictionless incline of 30°, covering a distance of 10 meters under the influence of an external force of 5475 newtons. This seemingly straightforward situation offers a profound opportunity to explore the intricate interplay of forces, work, and energy transfer. In this article, we delve into the physics behind this problem, dissecting the forces involved, calculating the work done, and examining the implications of the motion.

Understanding the Scenario: The Basics

Before diving into calculations, it's essential to clarify the components of the problem:

- Mass of the Box (m): 335 kg
- Distance Moved Along the Incline (d): 10.00 m
- Inclination Angle (θ): 30°
- External Force (F): 5475 N
- Friction: None (frictionless surface)

The core question centers around how much work is performed by the external force to move the box up the incline and what the resulting motion entails. To analyze this, we need to understand the forces acting on the box and how they relate to the displacement.

Forces Acting on the Box: An In-Depth Analysis

In a frictionless inclined plane scenario, the primary forces acting on the box are:

1. Gravity (Weight):

- Acts vertically downward with magnitude $(W = mg)$.
- For the given mass:

$$W = 335 \, \text{kg} \times 9.81 \, \text{m/s}^2 \approx 3289.35 \, \text{N}$$

2. Normal Force (N):

- Acts perpendicular to the surface of the incline.
- Balances the component of gravity perpendicular to the incline but does not do work since it acts normal to displacement.

3. External Force (F):

- Applied along the incline to pull the box upward.
- Magnitude given as 5475 N.

4. Component of Gravity Along the Incline:

- The component of the weight acting down the incline:

$$W_{\parallel} = W \sin \theta$$

- Calculated as:

$$W_{\parallel} = 3289.35 \text{ N} \times \sin 30^\circ = 3289.35 \text{ N} \times 0.5 \approx 1644.68 \text{ N}$$

Summary of forces along the incline:

Force	Magnitude	Direction	Effect
External Force	5475 N	Upward along the incline	Pulls the box upward
Gravity component	~1644.68 N	Downward along the incline	Resists upward motion

Since the incline is frictionless, the normal force does not influence the horizontal work calculations beyond balancing the perpendicular component of gravity.

Calculating the Net Force and Acceleration

The net force acting along the incline determines the acceleration of the box. Applying Newton's second law:

$$F_{\text{net}} = m a$$

where

$$F_{\text{net}} = F_{\text{external}} - W_{\parallel}$$

Plugging in the numbers:

$$F_{\text{net}} = 5475 \text{ N} - 1644.68 \text{ N} = 3830.32 \text{ N}$$

$$F_{\text{net}} = 5475\text{ N} - 1644.68\text{ N} = 3829.32\text{ N}$$

Thus,

$$a = \frac{F_{\text{net}}}{m} = \frac{3829.32\text{ N}}{335\text{ kg}} \approx 11.44\text{ m/s}^2$$

This significant acceleration indicates the box is rapidly speeding up as it moves upward.

Implication: The external force is more than sufficient not only to overcome gravity but to accelerate the box significantly along the incline.

Work Done by the External Force

Work is a measure of energy transfer, defined as:

$$W = F \times d \times \cos \phi$$

where:

- (F) is the magnitude of the force,
- (d) is the displacement,
- (ϕ) is the angle between the force and displacement vectors.

In this case, since the external force acts along the incline and the displacement is along the same line, $(\phi = 0^\circ)$, and $(\cos 0^\circ = 1)$.

Calculating the work:

$$W_{\text{external}} = 5475\text{ N} \times 10\text{ m} = 54,750\text{ J}$$

This is the total energy input by the external force during the movement.

Note: This energy contributes to:

- Increasing the kinetic energy of the box,
- Increasing its gravitational potential energy (height gain),
- Overcoming gravitational resistance.

Work and Energy: Connecting the Dots

Since the surface is frictionless, the work-energy theorem states that the work done by all forces equals the change in the kinetic energy of the system:

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

Given that the external force has done 54,750 J of work, part of this energy increases the box's kinetic energy and part elevates its gravitational potential energy.

Calculating the Height Gained and Kinetic Energy

Step 1: Determine the vertical height gained (h):

The vertical component of the displacement:

$$h = d \sin \theta = 10 \text{ m} \times 0.5 = 5 \text{ m}$$

Step 2: Calculate the change in gravitational potential energy (GPE):

$$\Delta U = m g h = 335 \text{ kg} \times 9.81 \text{ m/s}^2 \times 5 \text{ m} \\ \approx 16,442.68 \text{ J}$$

Step 3: Determine the kinetic energy at the top:

The work done by the external force contributes to both potential energy increase and kinetic energy:

$$\text{Initial KE} = 0 \quad (\text{assuming starting from rest})$$

$$\text{Final KE} = W_{\text{external}} - \Delta U = 54,750 \text{ J} - 16,442.68 \text{ J} \\ \approx 38,307.32 \text{ J}$$

Step 4: Find the final velocity:

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

$$v = \sqrt{\frac{2 \times KE}{m}} = \sqrt{\frac{2 \times 38,307.32}{335}} \\ \approx \sqrt{228.62} \approx 15.14 \text{ m/s}$$

The box reaches the top of the incline moving at approximately 15.14 meters per second.

Summarizing the Results

- Work done by external force: 54,750 Joules
- Vertical height gained: 5 meters
- Increase in gravitational potential energy: approximately 16,443 Joules
- Kinetic energy at the top: approximately 38,307 Joules
- Final velocity: approximately 15.14 m/s

Key insight: The lion's share of the work input accelerates the box to a high speed, with a significant portion translating into kinetic energy rather than merely raising the object.

Implications and Real-World Applications

Understanding the dynamics of pulling objects up inclined planes has practical significance across multiple industries. For example:

- Construction: Lifting heavy materials on inclined scaffolds.
- Transportation: Designing efficient ramps and loading mechanisms.
- Robotics: Programming autonomous systems to move loads efficiently.

The calculations show that applying a force substantially higher than the component of gravity ensures rapid movement, but also requires energy management to prevent structural or mechanical failures due to high accelerations.

Moreover, the absence of friction simplifies analysis but also highlights the importance of friction in real-world scenarios where energy losses are common. Incorporating friction would reduce the net force and work efficiency, necessitating more power to achieve similar results.

Conclusion: Physics in Action

The scenario of a 335 kg box being pulled up a frictionless 30° incline with a 5475 N force exemplifies fundamental principles of physics. It underscores how forces translate into energy, dictating motion and height gain. The detailed calculations reveal that a substantial external force accelerates the box to impressive speeds, with the work input partitioned into gravitational potential energy and kinetic energy. These insights are not just academic; they inform engineering design, safety considerations, and energy efficiency in practical applications. As we continue

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