A Student Pushes A 51.5 Kilogram Bookshelf Across A Smooth Floor With A Net Force Of 67 N. What Is The

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Understanding the dynamics of objects in motion is fundamental in physics, especially when analyzing forces and their effects on objects. In this context, a student is pushing a 51.5-kilogram bookshelf across a smooth floor, applying a net force of 67 N. This scenario prompts us to explore critical questions about the motion of the bookshelf, such as its acceleration, the force components involved, and the implications of the forces at play. This comprehensive guide aims to elucidate these concepts in detail, providing clarity and insights into the physics behind the scene.

Fundamental Concepts in Force and Motion

Before delving into calculations and specific analyses, it is essential to revisit key physics principles related to forces and motion.

Newton's Second Law of Motion

Newton's second law states that:
- The net force acting on an object is directly proportional to its acceleration.
- Mathematically: $F = m \times a$, where:
- F is the net force (in newtons, N)
- m is the mass of the object (in kilograms, kg)
- a is the acceleration (in meters per second squared, m/s^2)

Friction on Smooth Surfaces

- When a surface is "smooth," it implies minimal or negligible friction.
- However, in real-world scenarios, there may still be some frictional force present, which opposes the motion.
- For the purposes of this analysis, if the floor is considered perfectly smooth, the frictional force can be assumed negligible.

Analyzing the Scenario

Given data:
- Mass of bookshelf, $m = 51.5$ kg
- Net force applied, $F_{net} = 67$ N

- Floor surface: smooth (negligible friction)

The primary goal is to determine the acceleration of the bookshelf under these conditions.

Calculating the Acceleration

Using Newton's second law:
- $a = F / m$

Plugging in the known values:
- $a = 67 \text{ N} / 51.5 \text{ kg}$

Performing the calculation:
- $a \approx 1.3 \text{ m/s}^2$

This means the bookshelf accelerates at approximately 1.3 meters per second squared as a result of the applied net force.

Understanding the Forces Acting on the Bookshelf

While the net force is given, it’s helpful to understand the individual forces involved.

Applied Force ($F_{applied}$)

- The force exerted by the student on the bookshelf.
- For a smooth floor, this force is primarily responsible for overcoming inertia and any residual friction.

Frictional Force ($F_{friction}$)

- In an ideal scenario with a perfectly smooth surface, friction is negligible.
- If friction exists, it opposes the applied force.
- The net force is the vector sum of all forces:

$$F_{net} = F_{applied} - F_{friction}$$

Since the problem states a net force of 67 N, this may include the applied force minus any opposing forces.

Normal Force (F_{normal})

- The force exerted by the floor upward on the bookshelf.
- Equal in magnitude to the weight if the surface is horizontal and friction is negligible.

Weight of the Bookshelf (W)

- Calculated by:

$W = m \times g$, where $g \approx 9.8\ m/s^2$

$W = 51.5\ kg \times 9.8\ m/s^2 \approx 505.7\ N$

This weight acts downward and is balanced by the normal force upward.

Implications of the Force Analysis

Knowing the acceleration and forces involved allows us to explore further questions related to the scenario.

1. What is the Applied Force?

- If the net force is 67 N and friction is negligible:

$F_{applied} \approx 67\ N$

- If frictional forces exist, the applied force would need to be greater than 67 N to achieve this net force.

2. How Long Does it Take to Reach a Certain Speed?

- To determine the time to reach a specific velocity, use the basic kinematic equation:

$v = a \times t$

For example, to reach 3 m/s:

$t = v / a = 3\ m/s / 1.3\ m/s^2 \approx 2.3$ seconds

3. How Much Work Is Done in Moving the Bookshelf?

- Work (W) is defined as:

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

Where:
- d is the distance moved
- θ is the angle between force and displacement

- Assuming force is applied in the direction of motion, $\cos\theta = 1$.
- For a displacement of, say, 5 meters:

$W = 67\ N \times 5\ m = 335$ Joules

Practical Applications and Real-World Relevance

Understanding the mechanics of pushing objects like bookshelves has practical significance in various fields.

1. Ergonomics and Safety

- Knowing the force required to move heavy objects helps in designing ergonomic tools and procedures to prevent injuries.

2. Material Handling and Logistics

- Calculations of force and acceleration inform the development of equipment such as dollies and carts to facilitate movement.

3. Design of Furniture and Fixtures

- Engineers consider force dynamics to ensure stability and ease of movement.

Additional Considerations and Complexities

While the simplified analysis provides valuable insights, real-world scenarios often involve additional factors.

1. Friction and Surface Conditions

- Even a "smooth" floor may present some friction, requiring greater applied force.

2. Air Resistance

- At low speeds, air resistance is negligible but becomes relevant at higher velocities.

3. Human Factors

- The force a person can exert varies based on strength, fatigue, and technique.

Summary and Key Takeaways

- The acceleration of the bookshelf under the given force is approximately 1.3 m/s^2.
- Assuming negligible friction, the applied force is about 67 N.
- The weight of the bookshelf is approximately 505.7 N.
- The physics principles involved, primarily Newton's second law, are fundamental in analyzing motion.
- Practical considerations include safety, ergonomics, and material handling strategies.

Final Remarks

Understanding the forces at play when moving objects helps in designing safer, more efficient systems for handling heavy items. Whether in daily life or industrial settings, applying physics principles such as Newton's laws enables accurate predictions of motion and force requirements. The scenario of a student pushing a bookshelf illustrates core concepts that are applicable across numerous fields, including engineering, physics education, and ergonomics.

By mastering these principles, students and professionals can better analyze and solve real-world problems involving force, motion, and energy.

Frequently Asked Questions

A student pushes a 51.5 kg bookshelf across a smooth floor with a net force of 67 N. What is the acceleration of the bookshelf?

Using Newton's second law, acceleration $a = F / m = 67 \text{ N} / 51.5 \text{ kg} \approx 1.30 \text{ m/s}^2$.

What does the net force of 67 N tell us about the motion of the bookshelf?

It indicates that the bookshelf is accelerating in the direction of the applied force, with an acceleration of approximately 1.30 m/s^2.

If the floor is smooth, what forces are acting on the bookshelf besides the applied force?

The main opposing force is likely friction, but since the floor is smooth, the frictional force is minimal or negligible, allowing the net force to cause acceleration.

How would the acceleration change if the net force applied

was increased to 100 N?

The acceleration would increase proportionally: a = 100 N / 51.5 kg ≈ 1.94 m/s^2.

What is the significance of the bookshelf's mass in calculating acceleration?

The mass determines how much the force will accelerate the object; a larger mass results in less acceleration for the same net force.

If the student wanted to stop the bookshelf, what force must they exert?

They would need to exert a force equal in magnitude and opposite in direction to the net force (67 N) to bring it to rest, assuming friction remains negligible.

What assumptions are made in calculating the acceleration of the bookshelf in this scenario?

Assumptions include that the floor is perfectly smooth with negligible friction and that the net force of 67 N is the only horizontal force acting on the bookshelf.

Additional Resources

Friction

In the realm of physics, the concept of friction is fundamental to understanding how objects interact with surfaces. It plays a crucial role in everyday activities, from walking to pushing furniture, and is particularly significant when analyzing forces in practical scenarios—such as a student attempting to move a bookshelf. This article delves into the scenario where a student pushes a bookshelf weighing 51.5 kilograms across a smooth floor with a net force of 67 newtons, exploring the underlying physics principles, calculating the relevant forces, and providing insights into the role of friction.

Understanding the Scenario

Imagine a student standing in a classroom, attempting to move a bookshelf that is quite heavy—51.5 kg in mass. The floor beneath is described as smooth, which suggests minimal surface roughness but does not eliminate friction entirely. The student applies a force, resulting in a net force of 67 N, and we aim to analyze what this net force implies about the forces at play, especially the frictional force opposing the motion.

Key Data:
- Mass of bookshelf, \(m = 51.5\, \text{kg} \)

- Net force applied, $F_{net} = 67\, \text{N}$
- Assume the floor is smooth, but not frictionless
- Gravitational acceleration, $g = 9.8\, \text{m/s}^2$

Breaking Down the Forces Involved

To understand the physics, we must analyze all the forces acting on the bookshelf:

1. Gravitational Force (Weight)

The force due to gravity acting downward is calculated as:

$$
F_{gravity} = m \times g = 51.5\, \text{kg} \times 9.8\, \text{m/s}^2 = 505.7\, \text{N}
$$

This force acts vertically downward and is balanced by the normal force exerted by the floor.

2. Normal Force

The normal force, F_{normal}, is the reactive force exerted by the floor perpendicular to its surface. Under normal circumstances (no vertical forces aside from gravity and the normal force), it equals the weight:

$$
F_{normal} = F_{gravity} = 505.7\, \text{N}
$$

3. Applied Force

The student applies a force F_{push} to move the bookshelf horizontally. The net force is the vector sum of this applied force and the opposing force of friction:

$$
F_{net} = F_{push} - F_{friction}
$$

Calculating the Frictional Force

Given the net force and knowing the other forces, we can determine the frictional force.

1. Understanding the Net Force

The net force is the difference between the applied force and the frictional force:

$$
F_{net} = F_{push} - F_{friction}
$$

Assuming the student applies just enough force to overcome static friction and start moving the bookshelf, and then continues to push with a force that results in a net force of 67 N, we can analyze further.

2. Friction in Motion (Kinetic Friction)

If the bookshelf is moving at a constant velocity, the forces are balanced, and the net force would be zero. However, since a net force of 67 N is applied, the bookshelf is accelerating.

Using Newton's second law:

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

where a is the acceleration of the bookshelf.

Rearranged:

$$
a = \frac{F_{net}}{m} = \frac{67\, \text{N}}{51.5\, \text{kg}} \approx 1.3\, \text{m/s}^2
$$

This indicates the bookshelf accelerates at approximately 1.3 m/s^2.

3. Estimating the Frictional Force

Knowing the applied force F_{push}, we can write:

$$
F_{push} = F_{friction} + F_{net}
$$

But since F_{push} is not explicitly given, we need to infer it using the normal force and the nature of the surface.

Determining Frictional Characteristics

Frictional force depends on the nature of the surfaces in contact. Typically, static friction resists initial motion, and kinetic friction opposes motion once an object is sliding.

1. Coefficient of Kinetic Friction (\(\mu_k \))

The kinetic friction force is given by:

\[
F_{friction} = \mu_k \times F_{normal}
\]

Where:
- \(\mu_k \) is the coefficient of kinetic friction (dimensionless)
- \(F_{normal} \) is the normal force

Assuming the surface is smooth but still has some friction, \(\mu_k \) would be relatively low but non-zero.

2. Calculating the Frictional Force

Given the normal force:

\[
F_{normal} = 505.7\, \text{N}
\]

And the net force:

\[
F_{net} = 67\, \text{N}
\]

The applied force:

\[
F_{push} = F_{friction} + F_{net}
\]

If the student is pushing with just enough force to produce the net force (which is typical in physics problems), then the applied force is:

\[
F_{push} = F_{friction} + 67\, \text{N}
\]

Without knowing \(F_{push} \), we infer that:

\[
F_{push} = \text{force exerted by the student}
\]

But, given the problem's data, it’s more insightful to find the coefficient of kinetic friction:

\[

$$
\boxed{
\mu_k = \frac{F_{friction}}{F_{normal}}
}
$$

And since:

$$
F_{friction} = F_{push} - F_{net}
$$

The key is to determine F_{push}.

Practical Insights and Implications

This scenario illustrates several important principles that are relevant not only in physics classrooms but also in real-world applications:

1. The Role of Surface Smoothness

A "smooth floor" suggests low friction, but it does not eliminate it. The residual frictional force can still be significant relative to the applied force.

2. Effectiveness of Applied Force

Applying a force of 67 N to move a 51.5 kg bookshelf with an acceleration of 1.3 m/s^2 demonstrates how even relatively modest forces can produce noticeable acceleration when friction is low. For comparison:

- An average adult can exert roughly 300-400 N of force in a push or pull.
- The force used here (67 N) is well within human capabilities, highlighting how physics governs everyday interactions.

3. Friction's Impact on Movement

Friction acts as a resistive force. The lower the coefficient of kinetic friction (μ_k), the easier it is to move heavy objects. Conversely, high friction requires more force, which can be taxing or impractical.

4. Energy and Work Considerations

Moving the bookshelf involves doing work against the frictional force:

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

where d is the distance moved. Understanding the magnitude of $F_{friction}$ helps in estimating the energy expenditure involved in such tasks.

Final Thoughts: What Is The?

Given the initial question—"What is the" (implying perhaps "What is the frictional force?" or "What is the coefficient of friction?")—we can summarize:

1. Estimating Frictional Force

Assuming the applied force F_{push} is just enough to produce the net force of 67 N and that the normal force is approximately 505.7 N, the frictional force can be estimated as:

$$
F_{friction} = F_{push} - F_{net}
$$

If, for simplicity, we assume the applied force is roughly equal to the normal force (which is a rough approximation), then:

$$
\boxed{
F_{friction} \approx 505.7\, \text{N} - 67\, \text{N} = 438.7\, \text{N}
}
$$

However, this overestimates the force required because in reality, the applied force is likely less than the normal force. A more precise calculation would require the actual applied force.

2. Coefficient of Kinetic Friction

Using the estimated $F_{friction}$:

$$
\mu_k = \frac{F_{friction}}{F_{normal}} \approx \frac{438.7\, \text{N}}{505.7\, \text{N}} \approx 0.87
$$

A coefficient of approximately 0.87 indicates relatively high friction, which is unlikely on a smooth floor—this suggests the initial assumption might be overestimated. Realistically, typical coefficients of kinetic friction for smooth floors and wood or similar surfaces range from 0.2 to 0.4.

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