

A 65-kg Student Is In An Elevator Moving Downward With Constant Velocity. He Uses A Bathroom Scale To

A 65-kg Student Is In An Elevator Moving Downward With Constant Velocity. He Uses A Bathroom Scale To determine his apparent weight, an everyday scenario that illustrates fundamental principles of physics related to forces, motion, and acceleration. Understanding what happens in this situation provides valuable insights into concepts such as weight, normal force, and the effects of motion on perceived weight. In this article, we will explore the physics behind this scenario in detail, explaining the underlying principles, calculations, and real-world applications.

Understanding the Scenario: The Student in the Elevator

Imagine a student with a mass of 65 kilograms standing on a bathroom scale inside an elevator. The elevator is moving downward at a constant velocity. The student is curious about the reading on the scale, which indicates his apparent weight. To analyze this situation, we need to understand the concepts of weight, normal force, and the implications of constant velocity motion.

Key Concepts and Definitions

Mass and Weight

- Mass: The amount of matter in an object, measured in kilograms (kg). In this case, the student's mass is 65 kg.
- Weight: The force exerted by gravity on an object, calculated as the product of mass and acceleration due to gravity (approximately 9.8 m/s^2 on Earth).

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$$W = m \times g$$

\]

For the student:

\[

$$W = 65 \text{ kg} \times 9.8 \text{ m/s}^2 = 637 \text{ N}$$

\]

So, the true weight of the student is approximately 637 newtons (N).

Normal Force and Apparent Weight

- Normal Force (N): The force exerted by a surface supporting an object. The bathroom scale measures this force.
- Apparent Weight: The normal force exerted by the scale, which may differ from the true weight depending on acceleration.

Constant Velocity and Its Effect on Forces

- Moving at constant velocity means the elevator has zero acceleration ($a = 0$). According to Newton's second law, when acceleration is zero, the net force on the object is zero.

Analyzing the Situation: Moving Downward at Constant Velocity

Since the elevator moves downward at a constant velocity, the key points are:

- No acceleration: The elevator's velocity is steady; it is neither speeding up nor slowing down.
- Net force on the student: Zero, because there's no change in the velocity.
- Normal force: The force the scale exerts on the student, which the scale displays as weight.

Calculating the Normal Force

In this scenario, because the elevator moves at constant velocity:

$$\text{Net force} = 0$$

Applying Newton's second law in the vertical direction:

$$\begin{aligned}\text{Net force} &= N - W = 0 \\ N &= W\end{aligned}$$

Therefore, the normal force (the scale reading) equals the true weight of the student:

$$N = 637 \text{ N}$$

\]

Implication: The student's apparent weight is the same as his actual weight, approximately 637 N.

What Happens When the Elevator Accelerates?

While in this specific scenario, the elevator moves at a constant velocity, it's instructive to explore what occurs if the elevator accelerates upward or downward.

Elevator Accelerating Upward

- The normal force increases because the elevator must accelerate the student upward.
- The apparent weight becomes greater than the true weight:

\[

$$N = m(g + a)$$

\]

- The student feels heavier, and the scale shows a higher reading.

Elevator Accelerating Downward

- The normal force decreases because the elevator accelerates downward.
- The apparent weight becomes less than the true weight:

\[

$$N = m(g - a)$$

\]

- The student feels lighter, and the scale reading drops accordingly.

Real-World Applications and Significance

Understanding the physics of elevator motion and apparent weight has practical applications in various fields:

Designing Elevator Systems

- Engineers consider the forces involved when designing elevators, ensuring safety during acceleration and deceleration.
- The maximum load limits are based on the normal force calculations.

Analyzing Forces in Transportation

- Similar principles apply to other forms of transportation, like amusement park rides, where acceleration affects perceived weight.

Medical and Scientific Measurements

- Devices measuring weight, such as scales used in space or in accelerating vehicles, account for these forces to ensure accurate readings.

Key Takeaways and Summary

- When a student in an elevator moves downward at constant velocity, his apparent weight (as measured by the bathroom scale) remains equal to his actual weight.
- The normal force exerted by the scale matches the gravitational force acting on the student.
- Variations in acceleration alter the normal force, making the person feel heavier or lighter, which is crucial in understanding the physics of non-inertial frames.

Conclusion

The scenario of a 65-kg student in an elevator moving downward at constant velocity exemplifies fundamental physics principles, particularly Newton's laws of motion. It demonstrates that in the absence of acceleration, the apparent weight equals the actual weight. This understanding is not only academically interesting but also practically significant in designing safe transportation systems and understanding everyday phenomena involving forces and motion.

By grasping the concepts of normal force, weight, and acceleration, students and professionals alike can better interpret the forces at play in various real-world situations, from riding elevators to designing complex mechanical systems.

Frequently Asked Questions

What does the bathroom scale read when the elevator is moving downward at constant velocity?

The scale reads the student's actual weight, which is 65 kg multiplied by gravity (approximately 637.25 N), because there is no acceleration involved.

Why does the scale show the normal weight during downward constant velocity movement?

Because at constant velocity, there is no acceleration, so the normal force (scale reading) equals the student's weight, according to Newton's first law.

If the elevator accelerates downward, how would the scale reading change?

The scale would read less than the student's actual weight, decreasing by the amount of the downward acceleration.

Does the scale reading differ when the elevator is moving downward at constant velocity versus accelerating downward?

Yes, during constant velocity, the reading equals the actual weight, but during acceleration downward, the reading decreases due to the additional downward acceleration.

What is the significance of constant velocity in this scenario?

Constant velocity means no acceleration, so the normal force from the scale matches the student's weight, providing an accurate reading.

Can the student tell if the elevator is moving at constant velocity just by using the scale?

No, because the scale reads the same as when stationary, so the student cannot determine if the elevator is moving at constant velocity without other cues.

If the elevator were moving upward at constant velocity, what would the scale read?

It would read the same as the student's actual weight, about 637.25 N, since there is no acceleration.

What physics principle explains the scale reading during downward motion?

Newton's second law and the concept of normal force explain that during constant velocity, the normal force equals the gravitational force, resulting in a normal reading.

How does understanding elevator motion help in real-world physics applications?

It illustrates how forces and acceleration affect apparent weight, which is important in designing safety features and understanding motion in various transport systems.

Additional Resources

A 65-kg Student Is In An Elevator Moving Downward With Constant Velocity. He Uses A Bathroom Scale To

Imagine stepping onto a bathroom scale, expecting to see your usual weight reading, only to find it appears slightly different. This common scenario becomes a fascinating exploration into the principles of physics—particularly Newtonian mechanics—when a person is in an elevator moving with constant velocity. It may seem straightforward at first glance, but beneath the surface lies a nuanced understanding of forces, acceleration, and how they influence our perception of weight.

In this article, we delve into the physics behind such situations, explaining how the forces acting on the student and the scale interplay, and what the scale reading reveals about the elevator's motion. From the fundamental concepts of weight and normal force to the implications of constant velocity and the physics of elevators, our goal is to present a comprehensive, reader-friendly exploration that makes these concepts accessible without sacrificing technical accuracy.

Understanding the Scenario: The Student and the Elevator

Let's set the scene: a student weighing 65 kilograms is standing inside an elevator. The elevator is descending, but crucially, it is doing so at a constant velocity—meaning it is neither accelerating nor decelerating. The student steps onto a bathroom scale, which is essentially a device designed to measure the normal force exerted on the object (or person) resting on it.

At first glance, one might think that the student's weight remains unchanged regardless of the elevator's motion. After all, weight is simply mass times acceleration due to gravity ($W = m g$). However, the reading on the bathroom scale depends not only on the student's weight but also on the normal force exerted by the scale, which can vary depending on the elevator's acceleration.

Fundamental Concepts: Force, Mass, Weight, and Normal Force

Mass and Weight

- Mass (m): The amount of matter in an object, measured in kilograms (kg). In this case, the student's mass is 65 kg.
- Weight (W): The force due to gravity acting on an object, calculated as:

$$W = m g$$

where $g \approx 9.81 \text{ m/s}^2$ (standard acceleration due to gravity).

- Calculating the student's weight:

$$W = 65 \text{ kg} \cdot 9.81 \text{ m/s}^2 \approx 637.65 \text{ N}$$

This is the “true weight” of the student under normal conditions on Earth's surface.

Normal Force and Scale Reading

- Normal Force (N): The force exerted by a surface supporting an object. When standing on a bathroom scale, it exerts an upward normal force equal in magnitude to what the scale reads.
- Scale Reading: The force the scale exerts on the student, which is equal to the normal force (N). The scale translates this force into a weight reading, often in pounds or kilograms.

The Role of Elevator Motion: Constant Velocity vs. Acceleration

The key factor influencing the scale reading is the elevator's acceleration.

- Constant Velocity: When the elevator moves at a steady speed—either upward or downward—the acceleration is zero.
- Accelerating or Decelerating: When the elevator accelerates (speeding up or slowing down), the normal force experienced by the student changes, affecting the scale reading.

In our scenario, the elevator is moving downward at a constant velocity, which implies:

- The acceleration $(a = 0) \text{ m/s}^2$.
- No net change in the forces acting on the student due to acceleration.

This is a critical point because, in physics, the apparent weight (what the scale reads) depends on the normal force, which can vary during acceleration but remains equal to the true weight during uniform motion.

Analyzing the Forces in the Scenario

Forces Acting on the Student

- Gravity (Weight): Acts downward with a force $(W = m g)$.
- Normal Force (N): Acts upward from the scale.

Since the elevator moves downward at a constant velocity, the net force on the student is zero, and the forces balance:

$$[N = W]$$

This means the normal force exerted by the scale on the student is equal to the student's weight.

Implication for the Scale Reading

- Because the normal force equals the student's weight during constant velocity descent, the scale will display a reading corresponding to the true weight.
- In practical terms, the scale will show approximately 65 kg (or the equivalent in pounds, depending on the measurement units), the same as if the student were standing still on a stationary surface.

What Changes When the Elevator Accelerates?

Although the current scenario involves constant velocity, it's instructive to consider what would happen if the elevator were accelerating or decelerating.

Accelerating Downward

- Acceleration: $(a < 0)$ (downward).
- Effect: The normal force decreases because the student is "falling" faster than the scale supports.
- Scale Reading: The scale would register a value less than 65 kg, making the student feel lighter.

Accelerating Upward

- Acceleration: $(a > 0)$ (upward).
- Effect: The normal force increases, and the student feels heavier.
- Scale Reading: The scale would show a number greater than 65 kg.

The general relationship between the forces during acceleration is:

$$[N = m(g + a)]$$

where (a) is positive for upward acceleration and negative for downward acceleration.

The Physics in Mathematical Terms

The dynamics of the situation can be summarized with Newton's second law:

$$\sum \vec{F} = m \vec{a}$$

In the case of constant velocity downward:

- $\vec{a} = 0$
- $\sum \vec{F} = 0$

Thus:

$$\vec{N} - \vec{W} = 0 \Rightarrow \vec{N} = \vec{W}$$

which confirms that the scale reads the student's true weight.

If the elevator accelerates downward:

$$\vec{N} = m(\vec{g} + \vec{a})$$

and if upward:

$$\vec{N} = m(\vec{g} - \vec{a})$$

This formula underpins many physics problems involving elevators and apparent weight.

Practical Implications and Real-World Applications

Understanding how forces and acceleration influence perceived weight has several practical applications beyond simple elevator rides:

- **Design of Safety Systems:** Elevators are engineered with precise control over acceleration to ensure passenger safety and comfort.
- **Calibration of Scales:** Knowing how acceleration affects scale readings allows manufacturers to calibrate scales for various conditions.
- **Physics Education:** Demonstrating these principles helps students grasp Newtonian mechanics through tangible examples.

Real-World Examples and Misconceptions

Many people mistakenly believe that the weight measurement changes during constant velocity motion, but physics clarifies that:

- During constant velocity, the apparent weight remains unchanged.
- Only during acceleration or deceleration does the apparent weight differ

from the true weight.

This knowledge helps in understanding phenomena such as:

- The sensation of lighter or heavier feeling during elevator rides (which actually occur during acceleration).
- The design of amusement park rides that create the sensation of weightlessness or increased weight.

Conclusion: The Scale Reading in the Given Scenario

Returning to our initial scenario:

> A 65-kg student is in an elevator moving downward with constant velocity. He uses a bathroom scale to measure his weight.

The key takeaway is that the scale will display approximately 65 kg, matching the student's actual weight. Since the elevator is moving at a steady speed, no acceleration is present, and the forces balance out perfectly.

This seemingly simple situation exemplifies fundamental physics principles: the relationship between force, acceleration, and perceived weight. It demonstrates that our everyday experiences—such as standing on a scale in an elevator—are governed by the same laws that scientists have studied for centuries.

Understanding these principles enriches our appreciation of the physics behind routine activities and enhances our ability to analyze more complex systems involving motion, forces, and acceleration. Whether riding an elevator or designing mechanical systems, these concepts form the backbone of classical mechanics and continue to influence technology and safety standards worldwide.

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