A 550 N Physics Student Stands On A Bathroom Scale In An 850 Kg (including The Student) Elevator That

Introduction

A 550 N Physics Student Stands On A Bathroom Scale In An 850 Kg (including The Student) Elevator That is a fascinating scenario that combines fundamental principles of physics, including Newtonian mechanics, gravity, normal force, and acceleration. Such a situation is common in physics problems designed to understand the forces at play during elevator motion, as well as the effects of acceleration on apparent weight. This article explores the various aspects of this scenario, analyzing how the elevator's movement influences the readings on the bathroom scale and what physics principles are involved.

Understanding the Basic Setup

Key Components of the Scenario

- **Person's weight:** 550 N
- **Mass of the elevator (including the student):** 850 kg
- **Bathroom scale:** Measures the normal force exerted by the person due to contact with the scale
- **Elevator:** Can accelerate upward, downward, or move at constant velocity

Assumptions and Simplifications

1. The scale and the person are in contact without slipping.
2. The elevator's motion is along a vertical axis.
3. Air resistance and other external forces are negligible.
4. The person is standing still relative to the elevator's surface.

5. The gravitational acceleration is standard, $g = 9.8\, \text{m/s}^2$.

Calculating the Person’s Mass and Weight

From Weight to Mass

The person's weight is given as 550 N. Using the relation:

Weight (W) = mass (m) × gravity (g)

Rearranged to find the mass:

$$m = W / g = 550\, \text{N} / 9.8\, \text{m/s}^2 \approx 56.12\, \text{kg}$$

This indicates the person’s mass is approximately 56.12 kg.

Total Mass of the Elevator System

Including the person, the total mass of the elevator system is known as 850 kg. Therefore, the mass of the elevator alone is:

$$m_{elevator} = 850\, \text{kg} - 56.12\, \text{kg} \approx 793.88\, \text{kg}$$

Forces Acting on the Person in the Elevator

Gravity and Normal Force

- **Gravity (Weight):** Acts downward, with magnitude $W = 550\, \text{N}$.
- **Normal Force (N):** Exerted by the scale, acts upward.

Effect of Elevator’s Motion

The actual force the person experiences depends on the elevator's acceleration:

1. If the elevator is at rest or moving at constant velocity, the normal

force equals the person's weight (550 N).

2. If the elevator accelerates upward, the normal force increases, making the person feel heavier.

3. If the elevator accelerates downward, the normal force decreases, making the person feel lighter.

Analyzing Different Elevator Motions

Case 1: Elevator at Rest or Moving at Constant Velocity

In such cases, the acceleration $a = 0$. According to Newton's second law:

$$N = W = 550\, \text{N}$$

The bathroom scale reads the actual weight of the person, 550 N.

Case 2: Elevator Accelerating Upward

When accelerating upward with acceleration a, the net force on the person is:

Sum of forces: $N - W = m \times a$

Rearranged to find the normal force:

$$N = W + m \times a$$

Expressed in terms of known quantities:

$$N = 550\, \text{N} + 56.12\, \text{kg} \times a$$

Here, the normal force exceeds 550 N, making the person feel heavier.

Case 3: Elevator Accelerating Downward

When accelerating downward with acceleration a, the net force is:

$$N - W = - m \times a$$

Thus, the normal force becomes:

$$N = W - m \times a$$

In this case, the normal force is less than 550 N, making the person feel lighter.

Calculating Apparent Weight and Normal Force

Definition of Apparent Weight

The normal force exerted by the scale reflects the person's apparent weight, which varies with acceleration:

$$W_{app} = N$$

Examples of Apparent Weight Calculations

- Suppose the elevator accelerates upward at $a = 2\, \text{m/s}^2$:

  $$N = 550\, \text{N} + 56.12\, \text{kg} \times 2\, \text{m/s}^2 \approx 550 + 112.24 \approx 662.24\, \text{N}$$

- Suppose the elevator accelerates downward at $a = 2\, \text{m/s}^2$:

  $$N = 550 - 112.24 \approx 437.76\, \text{N}$$

Implications for the Person and the Scale

Feeling Heavier or Lighter

The person experiences a sensation of weight change depending on the elevator's acceleration. This is due to the change in the normal force exerted by the scale, which modifies the apparent weight:

- Accelerating upward makes the person feel heavier.
- Accelerating downward makes the person feel lighter.

Scale Reading and Actual Weight

The scale reading directly corresponds to the normal force \(N \). When at rest or moving uniformly, it reads 550 N. During acceleration, the reading varies accordingly, which can be used to determine the acceleration if the normal force is measured.

Additional Considerations

Elevator’s Motion and Safety

- Understanding the forces involved helps in designing safe elevator systems that can handle accelerations without causing discomfort or accidents.
- Rapid accelerations or decelerations can lead to significant variations in apparent weight, potentially affecting stability or user comfort.

Physics Applications and Real-World Relevance

- This scenario exemplifies principles used in designing accelerometers, which measure acceleration based on changes in normal force.
- It illustrates the importance of Newton’s laws in everyday life, from amusement park rides to elevator safety.

Conclusion

The scenario of a 550 N physics student standing on a bathroom scale inside an 850 kg elevator encapsulates core physics concepts involving forces, acceleration, and apparent weight. By analyzing the forces acting during different elevator motions—whether at rest, accelerating upward, or accelerating downward—we gain insight into how the normal force, and thus the scale reading, varies with acceleration. This understanding not only enriches our comprehension of Newtonian mechanics but also underscores its practical relevance in engineering and everyday experiences. Recognizing these principles allows us to predict and interpret the sensations and measurements associated with elevator motion, illustrating the profound interconnectedness of physics theory and real-world phenomena.

Frequently Asked Questions

What is the normal force exerted on the student when the elevator is at rest?

The normal force equals the student's weight, which is 550 N, since the elevator is at rest and there is no acceleration.

How does the normal force change when the elevator accelerates upward?

When the elevator accelerates upward, the normal force increases above 550 N, making the scale read a higher value than the student's actual weight.

What is the apparent weight of the student if the elevator accelerates downward at 2 m/s^2?

The apparent weight decreases and can be calculated as $N = m(g - a)$. Assuming the student's mass is approximately 55 kg (since weight is 550 N), the apparent weight is 55 kg (9.8 - 2) m/s^2 = 55 7.8 = 429 N.

How can you determine the student's mass from the scale reading when the elevator is stationary?

Divide the scale reading (550 N) by gravity (9.8 m/s^2) to find the mass: 550 N / 9.8 m/s^2 ≈ 56.1 kg.

What is the total weight of the elevator and its contents?

The total weight is the combined mass times gravity: 850 kg 9.8 m/s^2 = 8,330 N.

If the elevator is accelerating downward at 1.5 m/s^2, what will the scale read for the student?

Using $N = m(g - a)$: 55 kg (9.8 - 1.5) = 55 8.3 = approximately 456.5 N.

Why does the scale reading differ from the student's actual weight during elevator acceleration?

Because the scale measures the normal force exerted on the student, which varies with acceleration according to Newton's second law, leading to a perceived change in weight.

Additional Resources

Understanding the Physics of a 550 N Student Standing in an Elevator

When analyzing the scenario of a 550 N physics student standing on a bathroom scale inside an elevator, especially one with a mass of 850 kg (including the student), there are numerous layers of physics principles involved. This exploration delves into the forces at play, how the elevator's motion influences the readings, and the underlying physics concepts that explain these phenomena.

Introduction to the Scenario

Imagine a student with a weight of 550 N standing on a bathroom scale inside an elevator. The elevator's total mass, including the student, is 850 kg. To fully understand what the scale reads under various conditions, we need to consider:

- The student's weight and mass
- The elevator's mass and acceleration
- The forces acting on the student and the scale
- How acceleration influences apparent weight

This scenario is a classic example used to illustrate Newton's laws of motion, particularly how acceleration affects perceived weight, which is a fundamental concept in physics.

Basic Parameters and Conversions

Before diving into the physics, let's clarify some parameters and conversions:

- Student's weight (W): 550 N
- Student's mass (m_student): Calculated using $W = m \times g$

$$
m_{student} = \frac{W}{g} = \frac{550\, N}{9.8\, m/s^2} \approx 56.12\, kg
$$

- Elevator's total mass (including student): 850 kg
- Elevator's mass excluding student:

$$
m_{elevator} = 850\, kg - 56.12\, kg \approx 793.88\, kg
$$

- Gravitational acceleration (g): 9.8 m/s^2

Understanding these values provides a foundation for analyzing the forces involved.

Forces Acting on the Student

In a static situation (no acceleration):

- The weight (W) acts downward
- The normal force (N) from the scale acts upward

In equilibrium (no acceleration), these are equal:

$$
N = W = 550\, N
$$

However, when the elevator accelerates, the normal force (which is what the scale reads) changes based on the direction and magnitude of acceleration.

Effect of Elevator Motion on Apparent Weight

The key concept here is apparent weight, which is the normal force exerted by the scale. It differs from the actual weight depending on the elevator’s acceleration:

- If the elevator accelerates upward, the student experiences an increase in normal force.
- If the elevator accelerates downward, the normal force decreases.
- If the elevator moves at a constant velocity, the normal force equals the actual weight.

This behavior can be understood via Newton’s Second Law:

$$
\sum F = m \times a
$$

For the student:

$$
N - W = m_{student} \times a
$$

Rearranged:

$$
N = W + m_{student} \times a
$$

where:

- N: Normal force (scale reading)
- W: Actual weight (550 N)
- $m_{student}$: Mass of student (~56.12 kg)
- a: Acceleration of the elevator (positive upward, negative downward)

Calculating the Scale Reading Under Different Conditions

Let's analyze various scenarios:

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1. Elevator at Rest or Moving at Constant Velocity

Condition: No acceleration ($a = 0$)

$$
N = W = 550\, N
$$

Result: The scale reads 550 N, which corresponds to the student's actual weight.

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2. Elevator Accelerating Upward

Suppose the elevator accelerates upward with acceleration a_{up}. The normal force becomes:

$$
N = W + m_{student} \times a_{up}
$$

For example, if $a_{up} = 2\, m/s^2$:

$$
N = 550\, N + 56.12\, kg \times 2\, m/s^2 = 550\, N + 112.24\, N = 662.24\, N
$$

Interpretation: The student perceives a greater weight, and the scale reads approximately 662 N.

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3. Elevator Accelerating Downward

If the elevator accelerates downward with a_{down}, then:

$$
N = W - m_{student} \times a_{down}
$$

Suppose $a_{down} = 3\, m/s^2$:

$$
N = 550\, N - 56.12\, kg \times 3\, m/s^2 = 550\, N - 168.36\, N = 381.64\, N
$$

Interpretation: The student feels lighter, and the scale reads approximately 382 N.

Impact of the Elevator’s Overall Mass and System Dynamics

While the primary focus is on the student, understanding the system dynamics requires considering the entire elevator:

- The total mass: 850 kg
- The force required to accelerate the elevator depends on the combined mass and the desired acceleration:

$$
F_{total} = (m_{elevator} + m_{student}) \times a
$$

- Motor force and tension in cables: To accelerate the elevator, the motor must exert an additional force to overcome inertia and gravity.

Force Balance for the Entire Elevator System

The elevator's net force is governed by Newton's second law:

$$
F_{motor} - W_{total} = (m_{total}) \times a
$$

where:

- W_{total}: Total weight of elevator plus person

$$
W_{total} = (850\, kg) \times 9.8\, m/s^2 = 8,330\, N
$$

- F_{motor}: Force exerted by the motor via cables

Case analysis:

- To accelerate upward:

$$
F_{motor} = W_{total} + (m_{total}) \times a
$$

- To accelerate downward:

$$
F_{motor} = W_{total} - (m_{total}) \times a
$$

The tension in the cable, which influences the force acting on the student indirectly, depends on the elevator's acceleration.

Normal Force on the Student in Dynamic Conditions

The actual normal force experienced by the student is directly related to the tension in the cable and the acceleration of the elevator.

- When accelerating upward, the tension in the cable increases, leading to a higher normal force.
- When accelerating downward, the tension decreases, leading to a lower normal force.

In essence:

$$
N = T / \text{(number of contact points or support)}
$$

But in the typical scenario where the student stands on the scale, the scale measures the normal force exerted by the student, which is the reaction to the forces transmitted through the scale.

Additional Considerations

- Friction and stability: The student’s stance and the scale’s surface affect how accurately the normal force is transmitted.
- Scale calibration: Real bathroom scales are calibrated to display weight in units like pounds or kilograms, which are based on standard gravity.
- Non-uniform acceleration: If the elevator accelerates irregularly, the instantaneous readings will fluctuate accordingly.
- Safety and comfort: Rapid accelerations can cause discomfort or even a sensation of weightlessness or heaviness.

Practical Applications and Real-World Implications

Understanding these physics principles is vital in various engineering and safety contexts:

- Elevator design: Ensuring the cable tension and motor capacity can handle accelerations without compromising safety.

- Health and fitness: Accurate weight measurement under different motion states.
- Physics education: Demonstrating Newtonian mechanics with real-world examples.
- Accident analysis: Investigating sudden accelerations or decelerations in elevator systems.

Summary and Key Takeaways

- The weight of the student is approximately 550 N, corresponding to a mass of roughly 56.12 kg.
- The actual force the scale reads (the apparent weight) varies with the elevator's acceleration:
- No acceleration: 550 N
- Accelerating upward: greater than 550 N
- Accelerating downward: less than 550 N
- The total system dynamics depend on the combined mass and the acceleration profile of the elevator.
- Newton's Second Law provides the foundation for calculating forces and understanding perceived weight changes.
- Real-world factors like friction, scale calibration, and safety standards are important in practical applications.

Conclusion

Analyzing a 550 N student standing in an 850 kg elevator involves more than just knowing weights; it requires understanding how acceleration modifies perceived forces. This scenario encapsulates core physics principles, illustrating how Newton's laws govern everyday phenomena. Whether in designing elevators, calibrating scales, or understanding motion, these concepts bridge theoretical physics with practical experience, making them essential in both academia and industry.

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