A Pair Of Glasses Are Dropped From The Top Of A 32.0 M High Stadium. A Pen Is Dropped 2.00 S Later. How

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Understanding the physics behind objects falling from heights and the timing involved can be intriguing and educational. In this article, we will analyze a scenario where a pair of glasses is dropped from the top of a 32.0-meter-high stadium, followed by a pen being dropped 2.00 seconds later. We will explore the concepts of free fall, acceleration due to gravity, time of fall, and how to calculate the velocity and position of these objects at various points during their descent. Whether you're a physics student, educator, or enthusiast, this comprehensive guide provides detailed explanations and step-by-step calculations to help you grasp the underlying principles.

Understanding the Scenario: Key Facts and Assumptions

Before diving into the calculations, let's establish the key facts and assumptions:

- Initial height (h): 32.0 meters
- Gravity (g): 9.80 m/s^2 (standard acceleration due to gravity)
- Drop time of the glasses: at t = 0 seconds
- Drop time of the pen: at t = 2.00 seconds after the glasses are dropped
- Neglect air resistance: for simplicity and clarity
- Objects are dropped (initial velocity = 0): no initial push downward

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Basic Principles of Free Fall

Free fall describes the motion of an object under the influence of gravity alone, with no other forces acting upon it (like air resistance). The main equations governing free fall are:

Position Equation

$$ y(t) = y_0 + v_0 t + \frac{1}{2} g t^2 $$

Where:
- $y(t)$: position at time t
- y_0: initial position (height from the ground)
- v_0: initial velocity (zero in this case)
- g: acceleration due to gravity

- t: time elapsed since release

Velocity Equation

$$ v(t) = v_0 + g t $$

Calculating When the Glasses Hit the Ground

Let's first determine the time it takes for the glasses to reach the ground after being dropped from 32.0 meters.

Step 1: Set initial conditions

- $y_0 = 32.0\, \text{m}$
- $v_0 = 0\, \text{m/s}$

Step 2: Use position equation to find time to reach ground (y = 0)

$$ 0 = 32.0 + 0 \times t + \frac{1}{2} \times (-9.80) \times t^2 $$

Note: We take acceleration as negative because it's directed downward.

Simplify:

$$ 0 = 32.0 - 4.90 t^2 $$

$$ 4.90 t^2 = 32.0 $$

$$ t^2 = \frac{32.0}{4.90} $$

$$ t^2 \approx 6.5306 $$

$$ t \approx \sqrt{6.5306} \approx 2.56\, \text{seconds} $$

Therefore, the glasses hit the ground approximately 2.56 seconds after being dropped.

Timing of the Pen Drop and Its Impact

The pen is dropped 2.00 seconds after the glasses. This timing is critical because it means:

- The glasses have been falling for 2.00 seconds when the pen is released.
- At that moment, the glasses are already in motion.

Let's analyze the state of the glasses at the moment the pen is dropped.

Velocity of the glasses at t = 2.00 seconds

Using the velocity equation:

$$ v = v_0 + g t $$
$$ v = 0 + 9.80 \times 2.00 = 19.6\, \text{m/s} $$

The glasses are moving downward at 19.6 m/s when the pen is released.

Position of the glasses at t = 2.00 seconds

Using the position equation:
$$ y = y_0 + v_0 t + \frac{1}{2} g t^2 $$
$$ y = 32.0 + 0 \times 2.00 + \frac{1}{2} \times (-9.80) \times (2.00)^2 $$
$$ y = 32.0 - 4.90 \times 4.00 $$
$$ y = 32.0 - 19.6 = 12.4\, \text{meters} $$

At the moment the pen is dropped, the glasses are approximately 12.4 meters above the ground, moving downward at 19.6 m/s.

Analyzing the Pen's Fall

The pen is dropped 2.00 seconds after the glasses, starting from rest at the same height (assuming it is released from the same initial height as the glasses).

Time for the pen to reach the ground

Using the position equation:
$$ y = y_0 + v_0 t + \frac{1}{2} g t^2 $$
$$ 0 = 32.0 + 0 + \frac{1}{2} \times (-9.80) \times t^2 $$
$$ 4.90 t^2 = 32.0 $$
$$ t^2 = 6.5306 $$
$$ t \approx 2.56\, \text{seconds} $$

The pen takes approximately 2.56 seconds to hit the ground after being dropped.

Since the pen is dropped 2.00 seconds after the glasses, the total time from the moment of dropping the glasses until the pen hits the ground is:

$$ \text{Time from glasses drop to ground} = 2.56\, \text{s} $$
$$ \text{Time from pen drop to ground} = 2.56\, \text{s} $$
$$ \text{Time from glasses drop to pen drop} = 2.00\, \text{s} $$

Thus, the pen hits the ground approximately 0.56 seconds after the glasses have already hit the ground.

Positions and Velocities at Key Moments

Let's summarize the key moments:

1. When the glasses are dropped ($t=0$):
- Position: 32.0 m
- Velocity: 0 m/s

2. When the pen is dropped ($t=2.00$ s):
- Position: 12.4 m
- Velocity: 19.6 m/s downward

3. When the glasses hit the ground ($t \approx 2.56$ s):
- Position: 0 m
- Velocity: $v = v_0 + g t = 0 + 9.80 \times 2.56 \approx 25.1\, \text{m/s}$

4. When the pen hits the ground ($t \approx 2.56$ s):
- Same as above, since it was dropped from the same height 2.56 seconds ago.

Implications and Real-World Considerations

While the calculations above assume ideal free fall without air resistance, real-world scenarios involve air drag, which can slightly alter the fall times and velocities. For objects like glasses and pens, air resistance can have a notable effect, especially if they are lightweight or have large surface areas.

Key points to consider:

- Air resistance slows objects down, increasing their time to reach the ground.
- The shape and mass of objects influence how air resistance affects them.
- In educational contexts, neglecting air resistance simplifies calculations and helps understand fundamental physics principles.

Practical Applications and Related Concepts

Understanding the physics of falling objects has broad applications across various fields:

- Safety Engineering: Designing barriers and safety measures to prevent injury from falling objects.
- Sports Physics: Analyzing projectile motion in sports like basketball or soccer.
- Aerospace Engineering: Calculating re-entry velocities and descent times for spacecraft.
- Science Education: Demonstrating fundamental physics principles through real-world experiments.

Summary and Key Takeaways

- Dropping objects from a height involves understanding free fall, acceleration due to gravity, and initial conditions.
- The time it takes for an object to reach the ground from a certain height can be calculated using kinematic equations.
- When multiple objects are dropped at different times, their relative positions and velocities depend on the elapsed time since each was released.
- In ideal free fall, neglecting air resistance, the time to reach the ground from 32.0 meters is approximately 2.56 seconds.
- Dropping an object 2.00 seconds after another means the first object has already fallen significantly and is moving downward at nearly 20 m/s when the second object is released.

FAQs

1. **How long does it take for an object to fall from a 32-meter height?**