An Object Is Dropped From A Bridge. A Second Object Is Thrown Downward 1.0 S Later. They Both Reach The

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Introduction

Understanding the motion of objects under gravity is a fundamental concept in physics, particularly in the study of kinematics. When analyzing scenarios such as an object being dropped from a height or thrown downward, it is essential to consider factors like initial velocity, acceleration due to gravity, and time. This article explores a specific problem where an object is dropped from a bridge, and a second object is thrown downward one second later. We will examine their motion, calculate key parameters such as velocities and positions at various moments, and interpret the results.

Problem Overview

Imagine a scene where an object (Object A) is released from rest from the top of a bridge. One second after Object A is released, a second object (Object B) is thrown downward with an initial velocity. Both objects are subjected to the acceleration due to gravity, which we'll assume to be approximately 9.8 m/s^2 near Earth's surface.

The key questions we aim to answer include:
- How long does each object take to reach the water or ground below?
- What are their velocities upon impact?
- How do their motions compare given the different initial conditions?

Fundamentals of Free Fall and Projectile Motion

Basic Concepts

Before diving into calculations, let's review some core concepts:
- Gravity (g): The acceleration due to gravity is approximately 9.8 m/s^2 downward.
- Initial velocity (u): The velocity of an object at the start of observation.
- Displacement (s): The change in position, which in vertical motion is often measured downward as positive.
- Time (t): Duration of the object's motion.

Relevant Equations

The following equations govern the motion of objects under constant acceleration:

1. Velocity at time t:

$$
v = u + g t
$$

2. Displacement after time t:

$$
s = u t + \frac{1}{2} g t^2
$$

3. Velocity as a function of displacement:

$$
v^2 = u^2 + 2 g s
$$

Analyzing the Motion of the Two Objects

Let's define the parameters:
- Height of the bridge: H meters (unknown in this case; we'll see if calculations depend on it).
- Time when Object A is released: $t = 0$.
- Time when Object B is released: $t = 1.0\, \text{s}$.

Motion of Object A (Dropped from Rest)
Object A is released from rest, so:
- Initial velocity $u_A = 0$.
- At time t, its displacement $s_A(t)$:

$$
s_A(t) = \frac{1}{2} g t^2
$$

- Its velocity at time t:

$$
v_A(t) = g t
$$

Motion of Object B (Thrown Downward)
Object B is thrown downward with an initial velocity u_B at $t = 1.0\, \text{s}$. For times $t \geq 1.0\, \text{s}$:
- Initial velocity at $t = 1.0\, \text{s}$:

$$
u_B
$$

- Displacement from the point of release:

$$
s_B(t) = u_B (t - 1.0) + \frac{1}{2} g (t - 1.0)^2
$$

- Its velocity at time t:

$$
v_B(t) = u_B + g (t - 1.0)
$$

Position of Both Objects Relative to the Ground
Assuming the ground is at $y = 0$ and the bridge is at height H:

- For Object A:
$$
y_A(t) = H - s_A(t) = H - \frac{1}{2} g t^2
$$
- For Object B:
$$
y_B(t) = H - s_B(t) = H - \left[u_B (t - 1.0) + \frac{1}{2} g (t - 1.0)^2 \right]
$$

The objects reach the ground when their respective $y(t) = 0$.

Calculating Time to Reach the Ground
For Object A:
$$
0 = H - \frac{1}{2} g t_A^2 \Rightarrow t_A = \sqrt{\frac{2H}{g}}
$$

For Object B:
$$
0 = H - \left[u_B (t_B - 1) + \frac{1}{2} g (t_B - 1)^2 \right]
$$
Note: $t_B \geq 1.0\, \text{s}$.

Case Study: Specific Values and Calculations

Suppose the height of the bridge is $H = 45\, \text{m}$, and Object B is thrown downward with an initial velocity $u_B = 5\, \text{m/s}$.

Time for Object A to Reach the Ground
$$
t_A = \sqrt{\frac{2 \times 45}{9.8}} \approx \sqrt{\frac{90}{9.8}} \approx \sqrt{9.18} \approx 3.03\, \text{s}
$$
Thus, Object A hits the ground approximately 3.03 seconds after being dropped.

Time for Object B to Reach the Ground
Set $y_B(t) = 0$:
$$
0 = 45 - \left[5 (t - 1) + \frac{1}{2} \times 9.8 \times (t - 1)^2 \right]
$$
Simplify:
$$
5 (t - 1) + 4.9 (t - 1)^2 = 45
$$
Define $\Delta t = t - 1$:
$$
4.9 (\Delta t)^2 + 5 \Delta t - 45 = 0
$$

Solve the quadratic:

$$
4.9 (\Delta t)^2 + 5 \Delta t - 45 = 0
$$

Using quadratic formula:

$$
\Delta t = \frac{-5 \pm \sqrt{(5)^2 - 4 \times 4.9 \times (-45)}}{2 \times 4.9}
$$

Calculate discriminant:

$$
25 - 4 \times 4.9 \times (-45) = 25 + 882 = 907
$$

$$
\sqrt{907} \approx 30.13
$$

Compute roots:

$$
\Delta t = \frac{-5 \pm 30.13}{9.8}
$$

Two solutions:
- $\Delta t = \frac{-5 + 30.13}{9.8} \approx \frac{25.13}{9.8} \approx 2.56\, \text{s}$
- $\Delta t = \frac{-5 - 30.13}{9.8} \approx \frac{-35.13}{9.8} \approx -3.59\, \text{s}$ (discard negative time)

Since $t = \Delta t + 1$:

$$
t_B = 2.56 + 1 = 3.56\, \text{s}
$$

Result: Object B hits the ground approximately 3.56 seconds after Object A was released, which is about 0.53 seconds later.

Velocities Upon Impact
- Velocity of Object A at impact:

$$
v_A = g t_A = 9.8 \times 3.03 \approx 29.7\, \text{m/s}
$$

- Velocity of Object B at impact:

$$
v_B = u_B + g (t_B - 1) = 5 + 9.8 \times 2.56 \approx 5 + 25.09 = 30.09\, \text{m/s}
$$

Observation: Both objects have nearly the same impact velocity, despite different initial conditions.

Implications and Real-World Applications

Understanding the motion of objects dropped or thrown from heights has numerous practical applications, including:
- Safety Engineering: Designing barriers or safety measures on bridges and tall structures.
- Ballistics and Projectile Analysis: Calculating impact velocities and times for projectiles.
- Parachuting and Skydiving: Estimating descent times and velocities.
- Video Game Physics: Simulating realistic object motion under gravity.

Factors Affecting the Motion
While the above calculations assume ideal conditions (no air resistance), real-world scenarios involve:
- Air resistance and drag forces affecting falling objects.
- Variations in gravitational acceleration with altitude (negligible for small heights).
- Wind and environmental factors.

How to Perform Similar Calculations
For practitioners or students analyzing similar problems:
1. Determine initial conditions (velocity, height).
2

Frequently Asked Questions

How do the initial velocities of the two objects affect the time they reach the ground?

The first object, dropped freely, starts with zero initial velocity, while the second is thrown downward after 1.0 second, giving it an initial downward velocity. The second object typically reaches the ground sooner because of this initial speed, despite being released later.

What is the significance of the 1.0 second delay between dropping the two objects?

The 1.0 second delay means the first object has a head start in falling, but the second object's initial downward velocity can compensate for this delay, potentially allowing it to catch up or reach the ground simultaneously depending on the initial speed thrown downward.

If both objects reach the ground at the same time, what does this tell us about the initial velocity of the second object?

It indicates that the second object was given a sufficient initial downward velocity to make up for the delay, allowing both objects to reach the ground simultaneously despite the delayed start.

How can we determine the initial velocity needed for the second object to reach the ground at the same time as the

first?

By applying kinematic equations, considering the time delay and the acceleration due to gravity, we can calculate the initial velocity required for the second object to reach the ground simultaneously with the first.

What real-world applications involve understanding the timing of objects dropped or thrown downward?

This principle is crucial in fields like ballistics, parachute deployment, rescue operations, and designing safety systems where timing and initial velocities impact the outcome of falling objects.

Additional Resources

An Object Is Dropped From A Bridge. A Second Object Is Thrown Downward 1.0 S Later. They Both Reach The Bottom: An In-Depth Analysis of Free Fall and Projectile Motion

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Introduction: Understanding the Scenario

Imagine a scenario where two objects are released from a bridge over a river or canyon. The first object is simply dropped from rest, while the second object is intentionally thrown downward with some initial velocity exactly one second after the first. As both objects fall under the influence of gravity, they eventually reach the bottom, perhaps a riverbed or a rocky surface. The question arises: at what times do they reach the bottom, how do their velocities compare, and what physical principles govern their behavior? This scenario provides a rich context for exploring fundamental concepts in physics—namely, free fall, initial velocities, acceleration due to gravity, and the timing of objects in motion. Through this analysis, we aim to unravel the detailed mechanics behind their trajectories, velocities, and the effects of initial conditions on their motion.

Fundamental Principles of Motion in Free Fall

Gravity and Acceleration

Gravity acts as a constant acceleration on objects near Earth's surface, approximately 9.8 m/s^2 downward. This acceleration influences objects regardless of their initial velocity, provided air resistance is negligible—a common simplifying assumption in classical mechanics.

Key Equations of Motion

The motion of objects under gravity can be described using the kinematic equations:

1. Velocity as a function of time:

$v = v_0 + g t$

where:
- v is the velocity at time t,
- v_0 is the initial velocity,
- g is acceleration due to gravity (≈ 9.8 m/s^2).

2. Displacement as a function of time:

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

where:
- y is the position after time t,
- y_0 is the initial position.

These equations are crucial for analyzing the motion of both objects from the moment they are released or thrown.

Detailed Analysis of the Falling Objects

Initial Conditions and Assumptions

To create a clear picture, let's define specific parameters:

- The height of the bridge (initial position y_0) is H meters above the bottom.
- The first object is released from rest at $t=0$, with initial velocity $v_{0,1} = 0$.
- The second object is thrown downward with an initial velocity $v_{0,2}$ at $t=1.0$ second.
- Air resistance is neglected, and $g = 9.8\, \text{m/s}^2$.

These assumptions simplify calculations and focus on core physics principles.

Object 1: Dropped from Rest

Equation of motion:

$y_1(t) = H - \frac{1}{2} g t^2$

Since it starts from rest at height H, its velocity at time t is:

$v_1(t) = -g t$

(negative sign indicates downward direction).

The time t_f when the first object reaches the bottom (height zero) is:

$$
0 = H - \frac{1}{2} g t_f^2
$$

$$
t_f = \sqrt{\frac{2H}{g}}
$$

Implication: The first object reaches the bottom after time t_f, which depends solely on the initial height H.

Object 2: Thrown Downward After 1 Second

Initial conditions:

- At $t = 1\, \text{s}$, the object is given an initial velocity $v_{0,2}$.
- Prior to $t=1\, \text{s}$, the object remains at the top, not in motion.

Equation of motion after release:

For $t \geq 1\, \text{s}$:

$$
y_2(t) = y_{2}(1) + v_{0,2} \times (t - 1) - \frac{1}{2} g (t - 1)^2
$$

Since the object is at height H at $t=1\, \text{s}$:

$$
y_{2}(1) = H - \frac{1}{2} g (1)^2 = H - 4.9
$$

The velocity of object 2 immediately after release (at $t=1\, \text{s}$):

$$
v_{2}(1) = v_{0,2}
$$

The total time taken for object 2 to reach the bottom depends on its initial velocity $v_{0,2}$. The time $t_{2, \text{bottom}}$ when $y_2(t) = 0$:

$$
0 = H - 4.9 + v_{0,2} (t - 1) - 4.9 (t - 1)^2
$$

This is a quadratic in $(t - 1)$:

$$
-4.9 (t - 1)^2 + v_{0,2} (t - 1) + (H - 4.9) = 0
$$

Define $\tau = t - 1$, then:

$$
-4.9 \tau^2 + v_{0,2} \tau + (H - 4.9) = 0
$$

Multiplying through by -1:

$$
4.9 \tau^2 - v_{0,2} \tau - (H - 4.9) = 0
$$

Solve for τ:

$$
\boxed{
\tau = \frac{v_{0,2} \pm \sqrt{v_{0,2}^2 + 4 \times 4.9 \times (H - 4.9)}}{2 \times 4.9}
}
$$

The physically relevant solution is the positive root, giving the time after $t=1\, \text{s}$ when the second object hits the bottom.

Comparative Analysis and Timing

When Do Both Objects Reach the Bottom?

- The first object reaches the bottom at:

$$
t_{1,\text{bottom}} = t_f = \sqrt{\frac{2H}{g}}
$$

- The second object reaches the bottom at:

$$
t_{2,\text{bottom}} = 1 + \tau
$$

where

$$
\tau = \frac{v_{0,2} + \sqrt{v_{0,2}^2 + 4 \times 4.9 \times (H - 4.9)}}{9.8}
$$

This illustrates that the second object's arrival time depends critically on its initial velocity $v_{0,2}$. For example:

- If $v_{0,2} = 0$, the second object is simply dropped at $t=1\, \text{s}$, and its time to reach the bottom becomes:

$$
\tau = \frac{\sqrt{0 + 4.9 \times 2H}}{9.8} = \frac{\sqrt{9.8 H}}{9.8} = \frac{\sqrt{H/1}}{\sqrt{1}} = \sqrt{\frac{H}{9.8}}
$$

- The total time after the start:

$$
t_{2,\text{bottom}} = 1 + \sqrt{\frac{H}{9.8}}
$$

which is less than t_f if $v_{0,2}$ is large and negative (a strong downward throw), causing the second object to reach the bottom earlier.

Velocity Analysis at Impact

The impact velocities are essential for understanding the potential damage or energy transfer.

- Object 1: Impact velocity:

$$
v_1(t_f) = -g t_f = -\sqrt{2 g H}
$$

- Object 2: Velocity at impact:

$$
v_2(t) = v_{0,2} - g (t - 1)
$$

At impact time $t_{2,\text{bottom}}$:

$$
v_2 = v_{0,2} - g \tau
$$

These velocities determine the kinetic energy upon impact:

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

which is relevant for assessing safety, damage potential, or energy transfer.

Real-World Applications and Implications

Engineering and Safety Considerations

Understanding the timing and velocities of objects in free fall is vital for designing safety measures such as barriers or nets on bridges. Engineers need to calculate the maximum speed of falling debris or objects to ensure protective structures are adequately rated.

Physics Education and Experimentation

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