# A Book Is Thrown Upward From Height 10.m And Lands With A Velocity Of -17.50m/s. What Was Its Initial

**A Book Is Thrown Upward From Height 10.m And Lands With A Velocity Of -17.50m/s. What Was Its Initial** velocity? This intriguing question involves fundamental principles of physics, particularly kinematics and motion under gravity. Understanding the initial velocity of an object thrown upward from a certain height requires analyzing the motion's parameters, including displacement, velocity, acceleration, and time. In this comprehensive article, we will explore the physics behind this problem, derive relevant equations, and demonstrate step-by-step calculations to determine the initial velocity. Whether you're a student preparing for exams or a physics enthusiast seeking clarity, this guide will provide clear explanations and practical insights into solving such motion problems.

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## Understanding the Problem: Key Concepts and Parameters

Before delving into calculations, it's essential to clarify the problem's parameters and the physics concepts involved.

### Given Data

- Initial height from which the book is thrown, $h_0 = 10\, \text{m}$
- Final velocity just before hitting the ground, $v_f = -17.50\, \text{m/s}$ (negative indicating downward direction)
- Acceleration due to gravity, $g = 9.81\, \text{m/s}^2$

### What is being asked?

- To find the initial velocity $v_0$ with which the book was thrown upward from the height of 10 meters.

### Assumptions and Conditions

- Air resistance is neglected for simplicity.
- The motion occurs in a uniform gravitational field.
- The upward direction is considered positive; downward is negative.
- The motion starts at height $h_0 = 10\, \text{m}$ with initial velocity $v_0$.
- The book lands at the ground level, i.e., height $h_f = 0\, \text{m}$.

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## Fundamental Equations of Kinematics

The problem involves vertical motion under constant acceleration due to gravity. The key kinematic equations are:

1. Velocity as a function of time:
$$v = v_0 + g\,t$$

2. Displacement as a function of time:

$$ h = h_0 + v_0 t - \frac{1}{2} g t^2 $$

3. Velocity in terms of displacement:
$$ v^2 = v_0^2 + 2 g (h - h_0) $$

Since we know the initial height, final velocity, and gravity, the third equation is particularly useful for finding the initial velocity without explicitly solving for time.

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# Step-by-Step Solution to Find the Initial Velocity

To determine $v_0$, we analyze the motion from the point of throw to the moment just before landing.

## Step 1: Set Known Values

- Initial height: $h_0 = 10\, \text{m}$
- Final height: $h_f = 0\, \text{m}$
- Final velocity: $v_f = -17.50\, \text{m/s}$
- Acceleration due to gravity: $g = 9.81\, \text{m/s}^2$

## Step 2: Use the Kinematic Equation

The equation relating velocities and displacement:
$$ v_f^2 = v_0^2 + 2 g (h_f - h_0) $$

Rearranged for $v_0$:
$$ v_0^2 = v_f^2 - 2 g (h_f - h_0) $$

Plugging in the known values:
$$ v_0^2 = (-17.50)^2 - 2 \times 9.81 \times (0 - 10) $$
$$ v_0^2 = 306.25 - 2 \times 9.81 \times (-10) $$
$$ v_0^2 = 306.25 + 196.2 $$
$$ v_0^2 = 502.45 $$

Taking the square root:
$$ v_0 = \pm \sqrt{502.45} $$
$$ v_0 \approx \pm 22.43\, \text{m/s} $$

Since the book was thrown upward, the initial velocity is positive:
$$ v_0 \approx +22.43\, \text{m/s} $$

Result: The initial velocity of the book was approximately +22.43 meters per second.

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# Interpreting the Result: Physical Insights

Understanding what this initial velocity means in the context of the problem provides valuable physics insights.

## Key Points

- The positive sign indicates the throw was upward.
- The magnitude (~22.43 m/s) reflects a relatively strong upward throw.
- The downward final velocity of -17.50 m/s shows the book gained speed during fall, passing through the initial height and descending to the ground.

## Additional Observations

- The initial velocity exceeds the final velocity in magnitude, illustrating energy transfer from initial kinetic energy to potential energy and vice versa.
- The maximum height reached by the book can be calculated if desired, showing how high the book traveled before descending.

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# Calculating the Maximum Height Reached

To find the maximum height, we analyze the motion from the initial throw until the velocity becomes zero at the peak.

## Step 1: Use velocity at maximum height

At maximum height, $v = 0\, \text{m/s}$. Applying the equation:
$$v^2 = v_0^2 - 2g(h_{max} - h_0)$$

Rearranged:
$$h_{max} = h_0 + \frac{v_0^2}{2g}$$

Substituting $v_0 = 22.43\, \text{m/s}$:
$$h_{max} = 10 + \frac{(22.43)^2}{2 \times 9.81}$$
$$h_{max} = 10 + \frac{503.5}{19.62}$$
$$h_{max} = 10 + 25.66$$
$$h_{max} \approx 35.66\, \text{m}$$

Interpretation: The book reaches approximately 35.66 meters above the ground before descending.

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# Time of Flight and Other Considerations

While the primary goal was to find the initial velocity, understanding the total time of flight and the motion's dynamics enriches the analysis.

## Time to reach maximum height:

$$v = v_0 - g t_{up}$$
At maximum height, $v=0$:
$$0 = 22.43 - 9.81 t_{up}$$
$$t_{up} = \frac{22.43}{9.81} \approx 2.29\, \text{s}$$

Total time to land (assuming symmetric ascent and descent):

- Time to fall from maximum height to ground:
$$ h_{max} = 35.66\, \text{m} $$
$$ h_{max} = \frac{1}{2} g t_{down}^2 $$
$$ t_{down} = \sqrt{\frac{2 h_{max}}{g}} = \sqrt{\frac{2 \times 35.66}{9.81}} \approx 2.70\, \text{s} $$

- Total flight time:
$$ T_{total} = t_{up} + t_{down} \approx 2.29 + 2.70 = 4.99\, \text{s} $$

This comprehensive timing helps in understanding the motion's duration.

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## Practical Applications and Real-World Implications

Understanding such kinematic problems isn't just academic; they have practical applications in various fields:

- Sports Science: Calculating projectile velocities for athletes' throws or jumps.
- Engineering: Designing drop tests and safety mechanisms considering impact velocities.
- Aerospace: Analyzing the motion of objects thrown in gravitational fields or under specific initial conditions.
- Education: Teaching students the application of physics equations in real-world contexts.

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## Summary and Key Takeaways

- The initial velocity of the book was approximately +22.43 m/s.
- The problem utilized the kinematic equation relating velocities, displacement, and acceleration.
- The maximum height reached was about 35.66 meters.
- The total time of flight was roughly 5 seconds.
- Neglecting air resistance simplifies calculations but in real-world scenarios, air drag can significantly influence motion.

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## Conclusion

Determining the initial velocity of an object thrown upward from a height involves applying core principles of physics and kinematics. By carefully analyzing the known parameters—initial height, final velocity, and gravitational acceleration—and employing the appropriate equations, we can accurately calculate the initial velocity. This problem exemplifies the power of classical mechanics in solving real-world motion questions, providing insights into energy transfer, motion dynamics, and the fundamental laws governing the physical universe.

Understanding these concepts equips students, engineers, and enthusiasts with the tools to analyze diverse motion scenarios, from sports trajectories to space

# Frequently Asked Questions

## What is the initial velocity of the book when it was thrown upward from a height of 10 m if it lands with a velocity of -17.50 m/s?

Using the equation $v^2 = u^2 + 2gh$, where $v = -17.50$ m/s, $g = 9.8$ m/s$^2$, and $h = 10$ m, the initial velocity $u$ is approximately 8.90 m/s upward.

## How do you calculate the initial velocity of an object thrown upward when given the final velocity and height?

You can use the kinematic equation $v^2 = u^2 + 2gh$ and solve for $u$: $u = \pm\sqrt{(v^2 - 2gh)}$, considering the sign conventions for direction.

## What assumptions are made in calculating the initial velocity in this problem?

Assumptions include constant acceleration due to gravity (9.8 m/s$^2$), no air resistance, and that upward is positive.

## Why is the final velocity negative in this problem?

The negative sign indicates that the velocity is directed downward at the moment it lands, assuming upward is positive.

## If the object lands with a velocity of -17.50 m/s from a height of 10 m, what is the maximum height reached?

The maximum height can be found by calculating the height at the point where the velocity becomes zero; using $u$ and initial velocity, the max height is approximately 13.37 meters.

## How does gravity affect the initial velocity calculation in this scenario?

Gravity accelerates the object downward, influencing the velocity change over the height, and is incorporated through the term $2gh$ in the kinematic equation.

## Can the initial velocity be negative in this problem? Why or why not?

No, because the initial velocity is upward, it should be positive; negative velocities indicate downward motion, which is not the initial direction here.

## What is the significance of the height of 10 meters in calculating the initial velocity?

The height of 10 meters is the starting point from which the object was thrown, and it affects the velocity change during the motion.

## How would air resistance affect the calculation of the initial velocity in real-world scenarios?

Air resistance would oppose the motion, reducing the velocity and making the actual initial velocity different

from the ideal calculation; it would require more complex modeling.

### What formula relates the final velocity, initial velocity, acceleration, and displacement in this problem?

The relevant formula is $v^2 = u^2 + 2as$, where v is final velocity, u is initial velocity, a is acceleration due to gravity, and s is displacement (height).

## Additional Resources

Understanding the Dynamics of an Object Thrown Upward from a Height of 10 Meters

When analyzing the motion of objects under gravity, physics offers a well-established framework through the equations of uniformly accelerated motion. The problem of determining the initial velocity of an object thrown upward from a certain height, based on its final velocity and other known parameters, is a classic example that combines kinematic equations, energy principles, and an understanding of free-fall motion. In this detailed review, we will dissect the problem: An object is thrown upward from a height of 10 meters and lands with a velocity of -17.50 m/s. Our goal is to find its initial velocity.

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## Problem Breakdown and Assumptions

Before diving into calculations, it's essential to clarify the problem parameters and assumptions:

- Initial height ($h_0$): 10 meters
- Final velocity (v): -17.50 m/s (negative sign indicates downward motion upon landing)
- Acceleration due to gravity (g): 9.8 $m/s^2$ (standard value on Earth)
- Initial velocity (u): Unknown (what we need to find)
- Time of flight: Not explicitly required, but may be useful.
- Air resistance: Neglected for simplicity, assuming ideal projectile motion.
- Coordinate system: Upward is positive; downward is negative.

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## Understanding the Motion: Key Concepts

The motion of the object can be divided into phases:

1. Upward motion from initial throw: Starting at height 10 m with initial velocity u.
2. Reaching the maximum height: When velocity becomes zero.
3. Descent: Falling down from the maximum height to the ground level (or final point).

The core physics principles involved include:

- Kinematic equations for uniformly accelerated motion.
- Conservation of energy (if approached from an energy perspective).
- Sign conventions: Upward positive, downward negative.

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## Step 1: Establishing the Known Quantities and Equations

The main equation governing the vertical motion of the object is:

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

Where:
- $v$ is the final velocity at a certain position.
- $u$ is the initial velocity.
- $a$ is acceleration (here, $-g = -9.8\, \text{m/s}^2$, since gravity acts downward).
- $s$ is the displacement from the starting point.

Given the problem, the key is to find the initial velocity $u$, knowing the final velocity $v$, initial height $h_0$, and the acceleration.

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## Step 2: Establishing the Displacement and Final Position

The object starts at a height of 10 meters and lands at ground level or some other reference point. The problem states the final velocity when it lands is -17.50 m/s.

- Assumption: The object lands at ground level (height = 0 meters).
- If the object lands at a different height, the calculation would need to account for that.

- Displacement from starting point to landing:

$$s = \text{final height} - \text{initial height}$$
$$s = 0\, \text{m} - 10\, \text{m} = -10\, \text{m}$$

The negative sign indicates downward movement from the initial point to the final point.

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## Step 3: Applying Kinematic Equation

Using the equation:

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

Substitute the known quantities:

$$(-17.50)^2 = u^2 + 2 \times (-9.8) \times (-10)$$

Calculations:

- $v^2 = 17.50^2 = 306.25$
- $2 a s = 2 \times (-9.8) \times (-10) = 2 \times 98 = 196$

Thus,

$$306.25 = u^2 + 196$$

Solve for $u^2$:

$$u^2 = 306.25 - 196 = 110.25$$

Now, take the square root:

$$u = \pm \sqrt{110.25} = \pm 10.5\, \text{m/s}$$

Since the object was thrown upward initially, the initial velocity must be positive:

$$u = +10.5\, \text{m/s}$$

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## Step 4: Verifying the Result with Additional Kinematic Checks

To ensure the correctness of this initial velocity, we can perform a secondary check:

- Maximum height reached during the motion:

Using the initial velocity:

$$v_{max} = 0\, \text{m/s}$$ (at the peak)

- From the kinematic equation:

$$v_{max}^2 = u^2 - 2 g h_{max}$$

Rearranged:

$$h_{max} = \frac{u^2}{2g}$$

Plugging in $u = 10.5\, \text{m/s}$:

$$h_{max} = \frac{(10.5)^2}{2 \times 9.8} = \frac{110.25}{19.6} \approx 5.62\, \text{m}$$

- Total maximum height from ground level:

Since the object starts at 10 meters, the maximum height above ground:

$$H_{total} = 10\, \text{m} + h_{max} \approx 10 + 5.62 = 15.62\, \text{m}$$

- Time to reach maximum height:

$$v = u - g t_{up} \Rightarrow 0 = 10.5 - 9.8 t_{up} \Rightarrow t_{up} = \frac{10.5}{9.8} \approx 1.07\, \text{s}$$

- Time to fall from maximum height to ground:

Total time to land:

$$t_{total} = t_{up} + t_{down}$$

- Displacement during descent:

From maximum height (15.62 m) to ground (0 m):

$$ s_{down} = -15.62\, \text{m} $$

- Velocity upon landing:

Using:

$$ v = v_{max} + g t_{down} $$

But since the object is falling from rest at the maximum height, it accelerates for:

$$ v_{final}^2 = v_{max}^2 + 2 g h_{max} $$

Alternatively, use:

$$ v_{final} = - \sqrt{v_{max}^2 + 2 g h_{max}} $$ (negative sign indicates downward velocity)

Calculate:

$$ v_{final} = - \sqrt{0^2 + 2 \times 9.8 \times 15.62} $$

$$ v_{final} = - \sqrt{0 + 2 \times 9.8 \times 15.62} $$

$$ v_{final} = - \sqrt{305.88} \approx -17.50\, \text{m/s} $$

This matches perfectly with the given final velocity in the problem, confirming our initial velocity estimate.

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## Summary of Findings

The detailed analysis confirms:

- The initial velocity $u$ with which the object was thrown upward from 10 meters is approximately 10.5 m/s.

- The upward throw allows the object to reach a maximum height of about 15.62 meters above ground, then descend, gaining speed under gravity until it hits the ground with a velocity of approximately -17.50 m/s.

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## Additional Considerations and Real-World Factors

While the calculations assume ideal conditions, real-world scenarios might introduce complexities:

- Air resistance: Would slow the ascent and affect the velocity upon landing, generally leading to a lower landing speed than predicted.
- Measurement errors: Slight inaccuracies in velocity measurement can influence initial velocity calculations.
- Gravity variations: Slight differences in gravity based on location.

However, in controlled physics problems, neglecting air resistance provides a sufficiently accurate estimate, and the calculations above stand as a robust solution.

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## Conclusion

In conclusion, by applying fundamental kinematic equations and carefully analyzing the motion phases, we find that the initial velocity of the object was approximately 10.5 m/s upward. This initial velocity allowed the object to reach a certain maximum height before descending and landing with a velocity of -17.50 m/s from a height of 10 meters. This problem exemplifies the power of classical mechanics in solving real-world motion scenarios and highlights the importance of sign conventions and displacement considerations in kinematic analysis.

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