A Rock Is Thrown Straight Up From The Top Of A Bridge That Is 75 Ft High With An Initial Velocity Of

A Rock Is Thrown Straight Up From The Top Of A Bridge That Is 75 Ft High With An Initial Velocity Of a specific initial speed, presenting a fascinating physics problem that combines concepts of kinematics, gravity, and projectile motion. This scenario offers an excellent opportunity to explore the principles of motion, analyze the path of an object under gravity, and understand how initial velocity impacts the trajectory of a thrown object. Whether you're a student studying physics or an enthusiast curious about the mechanics of motion, this comprehensive article covers all aspects of this interesting problem, providing detailed explanations, mathematical derivations, and practical applications.

Understanding the Scenario

Before delving into the physics, let’s clarify the scenario:

- A rock is thrown vertically upward from the top of a bridge.
- The height of the bridge is 75 feet above the ground.
- The initial velocity of the throw is a specific value (e.g., 20 ft/sec, 50 ft/sec, etc.).
- Gravity acts downward with an acceleration of approximately 32.2 ft/sec^2.
- The goal is to analyze the motion: determine how high the rock goes, how long it stays in the air, and when it hits the ground.

This problem is a classic example of one-dimensional kinematics, which involves analyzing motion along a single axis—in this case, vertical motion under gravity.

Fundamental Concepts in Vertical Motion

To understand the trajectory of the thrown rock, it’s essential to grasp some key physics concepts:

Kinematic Equations

The primary equation used for constant acceleration motion (such as gravity) is:

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

Where:
- $y(t)$ is the height at time t,
- y_0 is the initial height,
- v_0 is the initial velocity,

- a is the acceleration (gravity, in this case).

Variables in the Scenario

- Initial height, $y_0 = 75$ ft.
- Initial velocity, v_0 (variable depending on the throw).
- Acceleration due to gravity, $a = -32.2$ ft/sec^2 (negative because it opposes the upward motion).

Key Outcomes to Determine

- The maximum height reached by the rock.
- Total time the rock spends in the air before hitting the ground.
- The velocity of the rock at different points in time.
- The effect of different initial velocities on the trajectory.

Analyzing the Motion of the Thrown Rock

Let’s break down the analysis step-by-step, considering an example initial velocity and then generalizing for different values.

Calculating the Time to Reach Maximum Height

At maximum height, the velocity becomes zero ($v = 0$). Using the velocity equation:

$$v = v_0 + a t$$

Setting $v = 0$:

$$0 = v_0 - 32.2 t_{max}$$

$$t_{max} = \frac{v_0}{32.2}$$

This gives the time to reach the peak of the trajectory.

Maximum Height Achieved

Using the position equation:

$$y_{max} = y_0 + v_0 t_{max} + \frac{1}{2} a t_{max}^2$$

Substitute t_{max}:

$$ y_{max} = 75 + v_0 \left(\frac{v_0}{32.2} \right) + \frac{1}{2} (-32.2) \left(\frac{v_0}{32.2} \right)^2 $$

Simplify:

$$ y_{max} = 75 + \frac{v_0^2}{32.2} - \frac{v_0^2}{2 \times 32.2} $$

$$ y_{max} = 75 + \frac{v_0^2}{32.2} - \frac{v_0^2}{64.4} $$

Combine the terms:

$$ y_{max} = 75 + v_0^2 \left(\frac{1}{32.2} - \frac{1}{64.4} \right) $$

Calculate the difference:

$$ \frac{1}{32.2} - \frac{1}{64.4} = \frac{2}{64.4} - \frac{1}{64.4} = \frac{1}{64.4} $$

So,

$$ y_{max} = 75 + \frac{v_0^2}{64.4} $$

This shows the maximum height depends on the initial velocity squared.

Time to Hit the Ground

To find the total time T when the rock hits the ground ($y=0$), solve the quadratic equation:

$$ 0 = y_0 + v_0 t + \frac{1}{2} a t^2 $$

Plugging in known values:

$$ 0 = 75 + v_0 t - 16.1 t^2 $$

Rearranged as:

$$ -16.1 t^2 + v_0 t + 75 = 0 $$

Use the quadratic formula:

$$ t = \frac{-v_0 \pm \sqrt{v_0^2 - 4 \times (-16.1) \times 75}}{2 \times -16.1} $$

Simplify:

$$ t = \frac{-v_0 \pm \sqrt{v_0^2 + 4 \times 16.1 \times 75}}{-32.2} $$

Calculate discriminant:

$$ D = v_0^2 + 4 \times 16.1 \times 75 $$

Once you have v_0, you can compute the roots and select the positive time value.

Impact of Initial Velocity on the Trajectory

The initial velocity plays a crucial role in determining the behavior of the thrown rock:

- Higher initial velocity results in a higher maximum height and longer time in the air.
- Lower initial velocity results in a shorter flight time, with the object possibly falling back quickly.
- Zero initial velocity (if the rock is dropped) would mean the object simply falls from 75 ft.

Practical Examples

Let’s analyze specific cases:

Example 1: Initial velocity of 20 ft/sec

- $v_0 = 20$ ft/sec
- $t_{max} = 20 / 32.2 \approx 0.62$ sec
- $y_{max} = 75 + (20)^2 / 64.4 \approx 75 + 400 / 64.4 \approx 75 + 6.21 \approx 81.21$ ft

Total time to hit ground:

- Discriminant:

$$D = 400 + 4 \times 16.1 \times 75 = 400 + 4 \times 16.1 \times 75$$

$$D = 400 + 4 \times 1207.5 = 400 + 4830 = 5230$$

- Roots:

$$t = \frac{-20 \pm \sqrt{5230}}{-32.2}$$

$$t = \frac{-20 \pm 72.33}{-32.2}$$

Taking the positive root:

$$t = \frac{-20 + 72.33}{-32.2} = \frac{52.33}{-32.2} \approx -1.62 \text{ (discard negative)}$$

$$t = \frac{-20 - 72.33}{-32.2} = \frac{-92.33}{-32.2} \approx 2.87 \text{ sec}$$

Thus, the total time in the air is approximately 2.87 seconds.

Example 2: Initial velocity of 50 ft/sec

Repeat the calculations to see how higher initial velocity extends the flight time and height.

Applications and Real-World Implications

Understanding the physics of throwing objects from heights has numerous real-world applications:

- Engineering and Construction: Calculating the trajectory of projectiles or debris.
- Sports: Analyzing the motion of balls in basketball, baseball, or golf.
- Safety: Assessing potential fall zones and impact points.
- Physics Education: Demonstrating principles of motion and gravity.

Designing Experiments and Simulations

Using the equations and methods outlined, students and engineers can design experiments or computer simulations to predict projectile paths, optimize initial velocities, and ensure safety measures.

Factors Affecting the Motion Beyond Ideal Conditions

While the above analysis assumes ideal conditions, real-world factors can influence the motion:

- Air resistance slows down the projectile, reducing maximum height and flight time.
- Wind can alter the trajectory.
- The shape and mass of the rock affect how air resistance impacts motion.

Accounting for Air Resistance

Including air resistance complicates calculations,

Frequently Asked Questions

What is the initial velocity needed for a rock thrown straight up from a 75 ft high bridge to reach a specific maximum height?

To determine the initial velocity, you need to know the maximum height you want to reach. Using the kinematic equation $v^2 = u^2 + 2as$, where $v=0$ at the maximum height, $a=-32$ ft/sec² (acceleration due to gravity), and s is the height difference, you can solve for u (initial velocity). For example, to reach 150 ft total height, initial velocity $u = \sqrt{(2\ 32 \text{ ft/sec}^2\ 75 \text{ ft})} \approx 69.28$ ft/sec.

How long does it take for a rock thrown straight up from a 75 ft high bridge with an initial velocity of 50 ft/sec to reach its highest point?

The time to reach the highest point is $t = u / g$, where $u=50$ ft/sec and $g=32$ ft/sec². So, $t = 50 / 32 \approx 1.56$ seconds.

What is the maximum height reached by a rock thrown upwards from a 75 ft high bridge with an initial velocity of 40 ft/sec?

The maximum height above the bridge is given by $s = u t - (1/2) g t^2$. First, find the time to reach maximum height: $t = u / g = 40 / 32 \approx 1.25$ seconds. Then, height above the bridge: $s = 40 1.25 - 0.5 32 (1.25)^2 \approx 50 - 25 = 25$ ft. Total height above ground: 75 ft + 25 ft = 100 ft.

If a rock is thrown straight up from the top of a 75 ft high bridge with an initial velocity of 60 ft/sec, how long will it take to hit the ground?

The total time until the rock hits the ground can be found by solving the quadratic equation for vertical motion: $y = y_0 + u t - (1/2) g t^2$, where $y=0$ (ground level), $y_0=75$ ft, $u=60$ ft/sec. Solving $0 = 75 + 60 t - 16 t^2$ gives $t \approx 0.52$ seconds (upward journey) plus the time to fall back down. Using quadratic formula, total time is approximately 4.7 seconds.

Additional Resources

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Introduction

In the realm of physics and engineering, understanding the motion of objects under the influence of gravity is fundamental. A classic problem involves analyzing the trajectory of a projectile launched vertically from a certain height with an initial velocity. This scenario has practical implications—from designing safety barriers to understanding natural phenomena. This article delves into a detailed investigation of the motion of a rock thrown straight upward from the top of a bridge, which is 75 feet high, with a specified initial velocity. We aim to explore the kinematic equations involved, the potential maximum height reached, the time to reach that height, and the total time before the rock hits the ground.

The Scenario in Focus

Suppose a rock is thrown vertically upward from the top of a bridge that stands 75 feet above the ground. The initial velocity of the throw, denoted as v_0, is given—let’s assume for this analysis that $v_0 = 20\, \text{ft/sec}$. The problem involves understanding the rock’s motion under Earth's gravity, which exerts a constant acceleration downward, approximately $g = 32\, \text{ft/sec}^2$.

The key questions we seek to answer include:
- What is the maximum height the rock reaches?
- How long does it take to reach that height?
- When does the rock hit the ground?
- What is the total time of flight?

To systematically analyze these questions, we begin with the fundamental equations of motion.

Fundamental Kinematic Equations

The motion of the rock can be modeled using the basic kinematic equations for uniformly accelerated motion:

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

where:
- $h(t)$ is the height at time t,
- $h_0 = 75\, \text{ft}$ is the initial height,
- $v_0 = 20\, \text{ft/sec}$ is the initial velocity,
- $g = 32\, \text{ft/sec}^2$ is the acceleration due to gravity,
- t is the time in seconds.

Determining the Maximum Height

The maximum height occurs when the upward velocity reduces to zero due to gravity. Using the velocity-time relation:

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

At the peak:

$$
v(t_{max}) = 0 \implies 0 = v_0 - g t_{max}
$$

which yields:

$$
t_{max} = \frac{v_0}{g} = \frac{20\, \text{ft/sec}}{32\, \text{ft/sec}^2} \approx 0.625\, \text{sec}
$$

\]

Maximum Height Calculation:

Plugging t_{max} into the position equation:

$$
h_{max} = h_0 + v_0 t_{max} - \frac{1}{2} g t_{max}^2
$$

$$
h_{max} = 75 + 20 \times 0.625 - \frac{1}{2} \times 32 \times (0.625)^2
$$

Calculations:

- $20 \times 0.625 = 12.5$
- $\frac{1}{2} \times 32 = 16$
- $(0.625)^2 = 0.390625$
- $16 \times 0.390625 = 6.25$

Thus:

$$
h_{max} = 75 + 12.5 - 6.25 = 81.25\, \text{ft}
$$

Interpretation: The rock reaches a maximum height of approximately 81.25 feet above the ground, about 6.25 feet above the bridge.

Time to Reach the Maximum Height

As previously calculated, the time to reach maximum height is:

$$
t_{max} \approx 0.625\, \text{seconds}
$$

This relatively short duration reflects the initial velocity's influence on the ascent phase.

When Does the Rock Hit the Ground?

The total time of flight depends on when the height $h(t)$ becomes zero, i.e., when the rock reaches the ground level.

Set $h(t) = 0$:

$$
0 = 75 + 20 t - 16 t^2
$$

Rearranged as a quadratic in t:

$$
-16 t^2 + 20 t + 75 = 0
$$

Dividing through by -1 for simplicity:

$$
16 t^2 - 20 t - 75 = 0
$$

Applying the quadratic formula:

$$
t = \frac{20 \pm \sqrt{(-20)^2 - 4 \times 16 \times (-75)}}{2 \times 16}
$$

Calculations:

- Discriminant:

$$
(-20)^2 - 4 \times 16 \times (-75) = 400 + 4800 = 5200
$$

- Square root of discriminant:

$$
\sqrt{5200} \approx 72.11
$$

Therefore, the solutions are:

$$
t = \frac{20 \pm 72.11}{32}
$$

The two roots:

1. $t = \frac{20 + 72.11}{32} \approx \frac{92.11}{32} \approx 2.878\, \text{sec}$
2. $t = \frac{20 - 72.11}{32} \approx \frac{-52.11}{32} \approx -1.629\, \text{sec}$

Since negative time is non-physical in this context, the relevant solution is:

$$
t_{impact} \approx 2.878\, \text{seconds}
$$

\]

Conclusion: The rock will hit the ground approximately 2.88 seconds after being thrown.

Total Flight Duration and Impact Dynamics

The total time in flight from release to impact is approximately 2.88 seconds. During this interval, the rock ascends to its peak at around 0.625 seconds, then descends back to ground level.

Additional Considerations

Effect of Varying Initial Velocities

The initial velocity v_0 significantly influences the maximum height and flight time:

Initial Velocity v_0 (ft/sec)	Max Height (ft)	Time to Max Height (sec)	Total Time of Flight (sec)
10	78.125	0.3125	2.07
20	81.25	0.625	2.88
30	86.875	0.9375	3.66
40	94	1.25	4.45

This demonstrates a quadratic relationship between initial velocity and maximum height, while flight duration increases roughly with the initial velocity.

Impact of Air Resistance

While this analysis assumes a vacuum, real-world scenarios involve air resistance, which reduces maximum height and prolongs descent. Incorporating drag models complicates calculations but is essential for precise predictions—especially in safety-critical applications.

Practical Implications and Safety Considerations

Understanding the physics of objects thrown from heights is crucial in engineering, safety assessments, and accident reconstructions. For instance, if a person throws a rock from a bridge, knowing the impact time and height helps evaluate potential hazards to pedestrians below.

In civil engineering, such analysis informs the design of barriers and protective measures. For example, ensuring that objects thrown from bridges cannot reach vehicles or pedestrians requires careful consideration of initial velocities and trajectories.

Summary of Key Findings

- Maximum height: Approximately 81.25 feet above the ground.
- Time to reach maximum height: About 0.625 seconds.
- Impact time: Approximately 2.88 seconds after release.
- Height at impact: Ground level (0 feet).

Conclusion

Analyzing the motion of a rock thrown vertically from a bridge height involves applying fundamental physics principles, particularly kinematic equations under constant acceleration. The initial velocity plays a pivotal role in determining the maximum height and total flight time. While simplified models neglect air resistance for clarity, they provide valuable insights into projectile motion and its practical applications.

Understanding these dynamics not only satisfies academic curiosity but also supports real-world engineering and safety decisions. Future investigations could incorporate factors like air resistance or lateral motion to develop more comprehensive models, further bridging theoretical physics with practical engineering.

References

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This comprehensive analysis provides a clear understanding of the motion of a projectile launched from a significant height, combining theoretical rigor with

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