A 90-g Apple Is Falling From A Tree.a. What Is The Impulse That Earth Exerts On It During The First 0.50

A 90-g Apple Is Falling From A Tree. What Is The Impulse That Earth Exerts On It During The First 0.50 Seconds?

Introduction

Understanding the concept of impulse in physics provides insight into the forces acting on objects during motion, especially during events like free fall. When a 90-gram apple detaches from a tree and begins to fall under Earth's gravity, it experiences a force exerted by the planet. The question here is: during the initial 0.50 seconds of its fall, what is the magnitude and nature of the impulse that Earth exerts on the apple?

This article explores the physics behind the apple's fall, focusing on the concept of impulse, the forces involved, and the calculations necessary to determine the impulse during the first half-second of free fall. We will analyze the problem step by step, considering relevant formulas, assumptions, and real-world considerations.

Understanding the Key Concepts

What Is Impulse?

Impulse is a fundamental concept in physics that relates to the change in momentum of an object when a force is applied over a period of time. It is defined as:

- **Impulse (J)** = Force (F) × Time interval (Δt)
- Or equivalently, the change in momentum: **J = Δp**

Where:
- *Impulse* is measured in Newton-seconds (N·s).
- *Force* is measured in Newtons (N).
- *Time interval* is measured in seconds (s).
- *Momentum (p)* is mass × velocity.

Understanding impulse helps us analyze how forces change an object's momentum over specified time intervals.

Forces Acting on the Falling Apple

During free fall, the primary force acting on the apple is gravity, which exerts a downward force equal to:

$$
F_g = m \times g
$$

Where:
- m is the mass of the apple.
- g is the acceleration due to gravity (~9.8 m/s^2).

In an idealized scenario, neglecting air resistance, the force exerted by Earth on the apple is simply the weight of the apple, which remains constant during the fall.

Analyzing the Problem Step by Step

Step 1: Convert the Mass to Kilograms

Since SI units are standard in physics calculations:

$$
m = 90\, \text{g} = 0.090\, \text{kg}
$$

Step 2: Calculate the Force Earth Exerts on the Apple

The force due to gravity (Earth's force on the apple):

$$
F_g = m \times g = 0.090\, \text{kg} \times 9.8\, \text{m/s}^2 = 0.882\, \text{N}
$$

This force acts downward, and in the absence of air resistance, it remains constant during the initial phase of fall.

Step 3: Determine the Acceleration and Velocity After 0.50 Seconds

Since the apple is in free fall:

- Acceleration $a = g = 9.8\, \text{m/s}^2$
- Initial velocity $u = 0\, \text{m/s}$ (assuming it starts from rest)

Using kinematic equations:

$$
v = u + a \times t
$$

$$
v = 0 + 9.8\, \text{m/s}^2 \times 0.50\, \text{s} = 4.9\, \text{m/s}
$$

So, after 0.50 seconds, the apple's velocity is approximately 4.9 m/s downward.

Step 4: Calculate the Change in Momentum (Δp)

Momentum is given by:

$$
p = m \times v
$$

Initial momentum:

$$
p_{initial} = 0\, \text{kg·m/s}
$$

Final momentum after 0.50 seconds:

$$
p_{final} = 0.090\, \text{kg} \times 4.9\, \text{m/s} = 0.441\, \text{kg·m/s}
$$

Change in momentum:

$$
\Delta p = p_{final} - p_{initial} = 0.441\, \text{kg·m/s} - 0 = 0.441\, \text{kg·m/s}
$$

This change in momentum is directly related to the impulse exerted by Earth:

$$
J = \Delta p = 0.441\, \text{kg·m/s}
$$

Note: The impulse exerted by Earth during this interval equals the change in the apple's momentum, assuming negligible air resistance and no other forces.

Implication of the Force and Impulse in Real-World Context

Force During the Fall

The force exerted by Earth is approximately 0.882 N downward, which remains essentially constant during free fall. Because this force is sustained over the interval, the impulse can also be calculated as:

$$
J = F \times \Delta t = 0.882\, \text{N} \times 0.50\, \text{s} = 0.441\, \text{N·s}
$$

This aligns perfectly with the change in momentum calculated earlier, confirming the physical consistency.

Role of Air Resistance

In real-world scenarios, air resistance opposes the motion of the falling apple, slightly reducing the net acceleration from g. For simplicity, this analysis neglects air resistance, but in practice:

- The actual impulse exerted by Earth may be slightly less.
- The velocity after 0.50 seconds would be slightly less than 4.9 m/s.
- The force exerted by Earth remains close to the weight, but the net force experienced by the apple would be reduced due to air drag.

Summary of Key Calculations

1. Mass of apple: 0.090 kg

2. Force due to gravity: 0.882 N
3. Velocity after 0.50 s: 4.9 m/s
4. Change in momentum: 0.441 kg·m/s
5. Impulse exerted by Earth: 0.441 N·s

Conclusion

The impulse exerted by Earth on the apple during the first 0.50 seconds of its fall is approximately 0.441 Newton-seconds. This impulse corresponds to the change in the apple's momentum due to the gravitational force acting over that period. The understanding of impulse in this context emphasizes how continuous forces produce measurable changes in an object's motion and highlights the interconnectedness of force, time, and momentum in classical mechanics.

While the idealized calculations assume no air resistance, real-world factors could slightly alter the precise values. Nevertheless, the fundamental physics principles remain the same, illustrating the power of impulse analysis in understanding motion under gravity.

Frequently Asked Questions

What is the impulse exerted by Earth on a 90-g apple during the first 0.50 seconds of its fall?

The impulse is equal to the change in momentum of the apple during that time. Assuming gravity is constant, impulse = mass × acceleration due to gravity × time = 0.09 kg × 9.8 m/s² × 0.50 s = 0.441 kg·m/s downward.

How do you calculate the impulse exerted on an object falling under gravity?

Impulse is calculated as the product of the average force exerted and the time over which it acts, or equivalently, as the change in momentum. For free fall under gravity, impulse = mass × change in velocity.

Is the impulse exerted by Earth during the first 0.50 seconds equal to the weight of the apple times

the time?

Yes, since the force of gravity (weight) is approximately constant during free fall, impulse = weight × time = m × g × t, which equals 0.441 kg·m/s downward.

What assumptions are made when calculating the impulse during the apple's fall?

Assumptions include that air resistance is negligible, gravity remains constant during the fall, and the apple starts from rest at the initial moment considered.

How does the impulse relate to the change in the apple’s momentum during its fall?

Impulse is directly equal to the change in momentum of the apple. Since the apple starts from rest, the impulse equals its momentum after 0.50 seconds.

If the apple's velocity after 0.50 seconds is about 4.9 m/s downward, what is the impulse exerted during this time?

Impulse = mass × change in velocity = 0.09 kg × 4.9 m/s = 0.441 kg·m/s downward, consistent with the calculation based on gravity.

How does the impulse exerted by Earth compare to the force of gravity acting on the apple?

The impulse over 0.50 seconds (about 0.441 kg·m/s) corresponds to the force of gravity acting over that time. Since force × time = impulse, the average force during fall is approximately 9.8 N, matching the weight of the apple.

Can the impulse exerted by Earth during the first 0.50 seconds be considered constant?

Yes, because the force of gravity remains constant during free fall, so the impulse exerted over that time interval is consistent and can be calculated using the product of weight and time.

Why is understanding impulse important in analyzing the apple’s fall from the tree?

Understanding impulse helps quantify the effect of forces over time on the apple's momentum change, illustrating how gravity accelerates the apple and how forces interact during the fall process.

Additional Resources

A 90-g Apple Is Falling From A Tree.a. What Is The Impulse That Earth Exerts On It During The First 0.50 Seconds?

Understanding the physics behind a falling apple may seem straightforward, yet it opens the door to exploring fundamental concepts such as forces, impulses, and motion. In this article, we delve into the detailed analysis of the impulse exerted by Earth on a 90-gram apple during its initial half-second of free fall. This exploration is not only a fascinating exercise in classical mechanics but also provides insights into how forces influence motion in everyday phenomena.

Introduction to the Problem

The scenario involves a small apple weighing 90 grams, which is equivalent to 0.09 kilograms, falling freely from a tree. The question centers on determining the impulse exerted by Earth on the apple during the first 0.50 seconds of its fall.

Impulse, defined as the change in momentum of an object, is a pivotal concept in physics that links forces to motion. It is mathematically expressed as:

$$ J = \Delta p = F \times \Delta t $$

where:
- J is the impulse,
- Δp is the change in momentum,
- F is the average force applied,
- Δt is the time duration over which the force acts.

In free fall, assuming negligible air resistance, the force exerted by Earth is primarily the gravitational force. Hence, analyzing the impulse involves understanding the gravitational force and the change in momentum over the specified period.

Fundamental Concepts

What Is Impulse?

Impulse measures the effect of a force acting over a finite time interval. It provides a direct link between forces and changes in an object's momentum. In the context of the apple falling:

- The apple initially has zero velocity (if dropped from rest).
- As it falls, gravity accelerates it downward.
- The impulse exerted by Earth during the fall causes its momentum to change from zero to some value at the end of the interval.

Momentum and Its Change

Momentum (p) is the product of mass and velocity:

$$p = m \times v$$

- At the start (assuming dropped from rest), $v_i = 0$, so initial momentum $p_i = 0$.
- After time t, the velocity is $v = v_f$.
- The change in momentum (Δp) during the period is:

$$\Delta p = m \times v_f - 0 = m \times v_f$$

The impulse exerted during this time equals this change in momentum.

Analyzing the Fall of the Apple

Initial Conditions

- Mass of apple, $m = 0.09\, \text{kg}$
- Initial velocity, $v_i = 0\, \text{m/s}$
- Duration considered, $\Delta t = 0.50\, \text{s}$

Assuming the apple is released from rest, it begins to accelerate downward under gravity.

Acceleration Due to Gravity

- Standard acceleration due to gravity, $g = 9.81\, \text{m/s}^2$

In the absence of air resistance, the apple accelerates uniformly downward with this acceleration.

Velocity After 0.50 Seconds

Using kinematic equations for uniformly accelerated motion:

$$ v_f = v_i + g \times t $$

Plugging in the values:

$$ v_f = 0 + 9.81\, \text{m/s}^2 \times 0.50\, \text{s} = 4.905\, \text{m/s} $$

Thus, after half a second, the apple's velocity is approximately 4.905 m/s downward.

Change in Momentum

The change in momentum:

$$ \Delta p = m \times v_f = 0.09\, \text{kg} \times 4.905\, \text{m/s} \approx 0.44145\, \text{kg·m/s} $$

This value represents the impulse exerted by Earth on the apple over the 0.50 seconds.

Calculating the Impulse

Given the assumptions, the impulse exerted by Earth during the first 0.50 seconds is approximately 0.44145 kg·m/s downward.

This calculation is based on the idealized case where air resistance is neglected. In real-world scenarios, air drag would slightly reduce the acceleration and final velocity, resulting in a slightly lower impulse.

Role of Air Resistance and Real-World Factors

While the calculations above provide a good approximation, considering additional forces such as air resistance is essential for a comprehensive understanding.

Effects of Air Resistance

- Air drag opposes the motion of the falling apple.
- It reduces the acceleration slightly below g.
- The net acceleration becomes:

$$ a_{net} = g - a_{drag} $$

- The terminal velocity is reached when the drag force balances the weight.

Implications for Impulse Calculation

- With air resistance, the velocity after 0.50 seconds would be less than 4.905 m/s.
- Consequently, the impulse exerted would be less than the idealized 0.44145 kg·m/s.

However, for small objects like an apple over short durations, this effect is minor, and the approximation remains valid for most practical purposes.

Additional Considerations

Force Exerted by Earth During the Fall

- In free fall, the force exerted by Earth is approximately equal to the weight:

$$ F_{gravity} = m \times g = 0.09\, \text{kg} \times 9.81\, \text{m/s}^2 \approx 0.883\, \text{N} $$

- This force acts downward throughout the 0.50 seconds.

Impulse as the Product of Force and Time

- Since gravity acts constantly (assuming negligible air resistance), the average force during the fall is roughly the weight.
- The impulse over 0.50 seconds:

$$ J = F_{avg} \times \Delta t \approx 0.883\, \text{N} \times 0.50\, \text{s} = 0.4415\, \text{N·s} $$

which aligns with the momentum change calculation.

Pros and Cons of the Simplified Model

Pros:

- Provides a clear understanding of the fundamental physics involved.
- Uses straightforward calculations based on known constants.
- Suitable for educational purposes and basic analysis.

Cons:

- Ignores air resistance and other minor forces.
- Assumes the apple is dropped from rest without initial velocity.
- Assumes constant gravity, which may vary slightly with altitude.

Features and Significance of the Analysis

- Demonstrates how impulse relates directly to momentum change.
- Highlights the importance of force and time in motion analysis.
- Reinforces the concept that gravity exerts a constant force during free fall.
- Serves as a foundation for more complex analyses involving air resistance and other forces.

Conclusion

The impulse exerted by Earth on a 90-gram apple during its first 0.50 seconds of free fall is approximately 0.4415 kg·m/s downward. This value results from the change in the apple's momentum as it accelerates under gravity from rest. While simplified by neglecting air resistance, this analysis captures the core physics principles that govern everyday phenomena like falling objects. Understanding these concepts not only enriches our comprehension of motion but also underscores the elegant relationships between forces, momentum, and impulse that underpin classical mechanics.

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In summary:

- The initial impulse is equal to the change in momentum, which is \( m
\times v_f \).
- The velocity after 0.50 seconds is about 4.905 m/s.
- The impulse exerted by Earth during this period is roughly 0.4415 kg·m/s.
- Real-world factors like air resistance slightly modify this value but do
not fundamentally alter the primary physics involved.

This detailed analysis exemplifies how fundamental physics principles
manifest in simple, everyday events, illustrating the elegance and utility of
classical mechanics in understanding our physical world.
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