A Bus Speeds Up From 5 M/s To 15 M/s In 20 Seconds. How Far Did It Go During The 20 Seconds? (use KE1

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Understanding how far a bus travels during its acceleration phase is a fundamental concept in physics, especially when analyzing motion. When a bus accelerates from an initial speed of 5 meters per second (m/s) to a final speed of 15 m/s over a period of 20 seconds, it provides an excellent example to explore the principles of kinematics, energy, and motion equations. In this article, we will examine how to calculate the distance traveled during this acceleration, applying key concepts from KE1 (Kinetic Energy 1) and fundamental physics equations.

Understanding the Motion: Key Concepts

Before diving into calculations, it’s important to understand the core concepts involved in this problem:

Uniform Acceleration

- The bus accelerates uniformly from its initial velocity to its final velocity.
- This means its acceleration remains constant throughout the 20 seconds.

Initial and Final Velocities

- Initial velocity, $u = 5\,\text{m/s}$
- Final velocity, $v = 15\,\text{m/s}$

Time of Acceleration

- Total time taken for acceleration, $t = 20\,\text{seconds}$

Objective

- Find the total distance traveled, s, during this acceleration.

Applying Kinematic Equations to Find Distance

The core of the solution lies in applying the kinematic equations for uniformly accelerated motion. When acceleration is constant, the following equations govern the motion:

$$
v = u + at
$$
$$
s = ut + \frac{1}{2}at^2
$$
$$
v^2 = u^2 + 2as
$$

Where:
- u = initial velocity
- v = final velocity
- a = acceleration
- s = distance traveled
- t = time taken

Step 1: Calculate the acceleration (a)

Using the first equation:
$$
a = \frac{v - u}{t}
$$
Substituting the known values:
$$
a = \frac{15\, \text{m/s} - 5\, \text{m/s}}{20\, \text{s}} = \frac{10\, \text{m/s}}{20\, \text{s}} = 0.5\, \text{m/s}^2
$$

Step 2: Calculate the total distance traveled (s)

Using the second equation:
$$
s = ut + \frac{1}{2}at^2
$$

Plugging in the values:
$$
s = (5\, \text{m/s})(20\, \text{s}) + \frac{1}{2}(0.5\, \text{m/s}^2)(20\, \text{s})^2
$$

Calculating each term:
- First term: $5 \times 20 = 100\, \text{m}$
- Second term:
$$
\frac{1}{2} \times 0.5 \times 400 = 0.25 \times 400 = 100\, \text{m}
$$

Adding both:
$$
s = 100\, \text{m} + 100\, \text{m} = 200\, \text{m}
$$

Result: The bus traveled 200 meters during the 20 seconds of acceleration.

Understanding the Energy Aspect (KE1)

The problem also relates to the concept of kinetic energy (KE1), which provides insight into the energy transformations during acceleration.

Kinetic Energy at Initial and Final Speeds

- Initial kinetic energy:
$$
KE_{initial} = \frac{1}{2} m u^2
$$
- Final kinetic energy:
$$
KE_{final} = \frac{1}{2} m v^2
$$

Since the mass m cancels out when comparing energy changes, the change in kinetic energy per unit mass can be expressed as:

$$
\Delta KE = \frac{1}{2} (v^2 - u^2)
$$

Substituting the velocities:

$$
\Delta KE = \frac{1}{2} (15^2 - 5^2) = \frac{1}{2} (225 - 25) = \frac{1}{2} \times 200 = 100\, \text{J/kg}
$$

This shows that per kilogram of mass, 100 joules of kinetic energy are gained during the acceleration.

Implication for Distance Traveled

The energy gained during acceleration manifests as an increase in the bus's kinetic energy, which correlates with the work done by the engine. The work-energy principle states:

$$
Work = \Delta KE

\]

Since work is also related to force and displacement:

$$
Work = F \times s
$$

Given the constant acceleration, the average force F_{avg} can be written as:

$$
F_{avg} = m \times a
$$

Thus, the total work done:

$$
W = F_{avg} \times s = m \times a \times s
$$

Matching this with the change in kinetic energy:

$$
\frac{1}{2} m v^2 - \frac{1}{2} m u^2 = m \times a \times s
$$

Dividing both sides by m:

$$
\frac{1}{2} (v^2 - u^2) = a \times s
$$

Rearranged to find s:

$$
s = \frac{\frac{1}{2} (v^2 - u^2)}{a}
$$

Plugging in the values:

$$
s = \frac{100}{0.5} = 200\, \text{m}
$$

This confirms our earlier calculation using kinematic equations.

Practical Implications and Real-World Considerations

While the theoretical calculation gives the exact distance, real-world factors such as air resistance, friction, and variations in acceleration can influence actual measurements. However, for physics problems and engineering purposes, these ideal calculations provide a solid foundation.

Key Takeaways:
- The bus travels 200 meters during the 20 seconds of acceleration.
- The acceleration is constant at 0.5 m/s^2.
- The change in kinetic energy per unit mass during acceleration is 100 joules.
- The problem exemplifies the relationship between work, energy, and motion.

Summary

In summary, when a bus accelerates from 5 m/s to 15 m/s over 20 seconds, it covers a distance of approximately 200 meters. This calculation integrates fundamental physics principles, including kinematic equations and energy considerations, illustrating how motion, force, and energy interplay during acceleration. Such analyses are invaluable in fields ranging from vehicle design to physics education, providing a comprehensive understanding of motion dynamics.

Final note: Always consider real-world factors for practical applications, but in the realm of theoretical physics, the calculations above accurately describe the bus's journey during its acceleration phase.

Frequently Asked Questions

How do you calculate the distance traveled by the bus when it accelerates from 5 m/s to 15 m/s over 20 seconds?

You can use the formula for average velocity during acceleration: average velocity = (initial velocity + final velocity) / 2. Then, multiply the average velocity by the time to find the distance: distance = average velocity × time. Here, distance = [(5 + 15)/2] × 20 = 10 × 20 = 200 meters.

What is the initial velocity of the bus in this problem?

The initial velocity of the bus is 5 meters per second.

What is the final velocity of the bus after 20 seconds?

The final velocity of the bus is 15 meters per second.

What is the average velocity of the bus during the acceleration?

The average velocity is (initial velocity + final velocity) / 2 = (5 + 15) / 2 = 10 meters per second.

How long did the bus accelerate from 5 m/s to 15 m/s?

The bus accelerated over a duration of 20 seconds.

Using KE1, how is kinetic energy related to the bus's acceleration in this problem?

While KE1 primarily involves energy calculations, in this context, understanding kinetic energy (KE = ½ m v^2) helps relate the change in the bus's speed to its kinetic energy, illustrating how the energy increases as the bus speeds up from 5 m/s to 15 m/s.

What is the total distance traveled by the bus during the 20 seconds?

The bus traveled a total of 200 meters during the 20 seconds.

Additional Resources

A Bus Speeds Up From 5 M/s To 15 M/s In 20 Seconds. How Far Did It Go During The 20 Seconds? (use KE1)

Understanding how far a vehicle travels during acceleration is a fundamental concept in physics, especially in kinematics. In this detailed guide, we'll analyze the problem where a bus speeds up from 5 meters per second (m/s) to 15 m/s over a period of 20 seconds. This scenario is a classic example of uniformly accelerated motion and provides an excellent opportunity to explore the key principles involved, including calculating acceleration, average velocity, and total displacement. By the end of this article, you'll be equipped to approach similar problems with confidence and clarity.

Understanding the Problem

Let's first restate the problem clearly:

- Initial velocity (u): 5 m/s
- Final velocity (v): 15 m/s
- Time taken (t): 20 seconds
- Question: How far did the bus travel during this period?

This problem involves a bus that accelerates uniformly from a starting speed to a higher speed. The key terms here are initial velocity, final velocity, acceleration, time, and displacement (distance traveled).

Fundamental Concepts in Kinematics

Before diving into calculations, it’s beneficial to review some core concepts:

1. Uniformly Accelerated Motion

- When an object accelerates at a constant rate, its motion can be described using basic kinematic equations.
- The key variables are:
- u: initial velocity
- v: final velocity
- a: acceleration
- t: time
- s: displacement (distance traveled)

2. Acceleration

- Acceleration is the rate of change of velocity with respect to time.
- For uniform acceleration:

$$
a = \frac{v - u}{t}
$$

3. Average Velocity

- When acceleration is constant, the average velocity (v_{avg}) during the time interval is:

$$
v_{avg} = \frac{u + v}{2}
$$

4. Displacement During Acceleration

- The total displacement during constant acceleration can be calculated as:

$$
s = v_{avg} \times t
$$

- Alternatively, using the initial velocity and acceleration directly:

$$
s = ut + \frac{1}{2} a t^2
$$

Step-by-Step Solution Approach

Let's now systematically approach the problem.

Step 1: Calculate the acceleration

Given the initial and final velocities and the time:

$$
a = \frac{v - u}{t} = \frac{15\, \text{m/s} - 5\, \text{m/s}}{20\, \text{s}} = \frac{10\, \text{m/s}}{20\, \text{s}} = 0.5\, \text{m/s}^2
$$

Interpretation: The bus accelerates at a rate of 0.5 meters per second squared.

Step 2: Find the average velocity

$$
v_{avg} = \frac{u + v}{2} = \frac{5\, \text{m/s} + 15\, \text{m/s}}{2} = \frac{20\, \text{m/s}}{2} = 10\, \text{m/s}
$$

Interpretation: The bus's average speed during the acceleration period is 10 meters per second.

Step 3: Calculate the total distance traveled

Using the average velocity:

$$
s = v_{avg} \times t = 10\, \text{m/s} \times 20\, \text{s} = 200\, \text{meters}
$$

Alternatively, using the kinematic equation:

$$
s = ut + \frac{1}{2} a t^2
$$

Plugging in the known values:

$$
s = 5\, \text{m/s} \times 20\, \text{s} + \frac{1}{2} \times 0.5\, \text{m/s}^2 \times (20\, \text{s})^2
$$

$$
s = 100\, \text{m} + 0.25\, \text{m/s}^2 \times 400\, \text{s}^2
$$

$$
s = 100\, \text{m} + 100\, \text{m} = 200\, \text{meters}
$$

Both methods agree that the bus traveled 200 meters during the 20 seconds of acceleration.

Additional Insights and Considerations

1. Uniform Acceleration Assumption

This calculation assumes the bus accelerates uniformly. Real-world factors such as engine performance, road conditions, and driver behavior can cause acceleration to vary. However, for most physics problems, this simplified model provides a good approximation.

2. Displacement During Different Phases

If the problem involved multiple phases (e.g., constant acceleration, constant speed, deceleration), the calculation would be broken into parts. Here, since the entire 20 seconds is acceleration, the calculation remains straightforward.

3. Graphical Representation

Plotting the velocity-time graph:

- The graph is a straight line from 5 m/s to 15 m/s over 20 seconds.
- The area under the curve represents the displacement, which forms a trapezoid.

Summary of Key Results

Quantity	Calculation	Result
Acceleration	$a = (v - u)/t$	0.5 m/s^2
Average velocity	$(u + v)/2$	10 m/s
Distance traveled	$s = v_{avg} \times t$	200 meters

Practical Applications and Real-World Relevance

Understanding how to compute distance traveled during acceleration has practical applications:

- Transport Planning: Estimating travel distances during acceleration phases.
- Vehicle Dynamics: Designing buses and cars for optimal acceleration profiles.
- Safety Analysis: Determining stopping distances and reaction times.
- Sports Science: Analyzing athletes' acceleration and sprint distances.

Final Thoughts

The problem of a bus accelerating from 5 m/s to 15 m/s over 20 seconds illustrates fundamental principles of kinematics. By calculating the acceleration, average velocity, and then the total displacement, we demonstrate a clear and methodical approach to solving motion problems. These skills are essential not only in academic contexts but also in real-world engineering, transportation planning, and physics research.

Remember, always verify whether the acceleration is uniform and whether the problem's assumptions align with real-world conditions. With practice, solving such kinematic problems becomes intuitive, providing valuable insights into the motion of objects around us.

In summary, during the 20 seconds of acceleration, the bus traveled 200 meters. This calculation hinges on understanding the relationships between initial and final velocities, acceleration, and displacement—core concepts that form the backbone of classical mechanics.

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