A Bus With A Maximum Speed Of 20m/s Takes 21 Sec To Travel 270m From Stop To Stop. Its Acceleration Istwice

A Bus With A Maximum Speed Of 20m/s Takes 21 Sec To Travel 270m From Stop To Stop. Its Acceleration Is Twice

Understanding the dynamics of bus motion is crucial for transportation planning, safety assessments, and optimizing travel efficiency. In this article, we explore a specific scenario involving a bus with a maximum speed of 20 meters per second (m/s), which takes 21 seconds to cover a 270-meter distance between stops. Notably, the bus's acceleration is twice its deceleration, adding an interesting layer to the analysis. We will delve into the physics principles governing this motion, calculate key parameters such as acceleration, deceleration, and initial velocity, and discuss practical implications for transit operations.

Analyzing the Bus's Motion: Basic Parameters and Assumptions

Before diving into calculations, it's essential to establish the fundamental assumptions and parameters:

- Maximum speed (Vmax): 20 m/s
- Total travel distance (S): 270 meters
- Total travel time (T): 21 seconds
- Acceleration (a): to be determined
- Deceleration (d): related to acceleration, specifically, d = 2a
- Motion phases: The bus accelerates from an initial velocity to maximum speed, then possibly maintains that speed, and finally decelerates to stop.

Key assumptions:

- The bus starts from rest or some initial velocity (to be determined).
- The bus reaches its maximum speed (Vmax) during the trip.
- The acceleration and deceleration are uniform.
- The bus's motion can be described using classical kinematic equations.

Understanding the Motion Phases of the Bus

The bus’s journey from one stop to another can be broken down into three primary phases:

1. Acceleration Phase: The bus accelerates from an initial velocity (V0) up to maximum speed (Vmax).
2. Constant Speed Phase: The bus travels at maximum speed for a certain duration.
3. Deceleration Phase: The bus slows down from maximum speed to zero or a lower velocity upon reaching the next stop.

Given the total time and distance, the goal is to determine:

- The durations of each phase.
- The acceleration and deceleration rates.
- The initial velocity at the start of the trip.

Calculating the Acceleration and Deceleration

Since the problem states that the bus's acceleration is twice its deceleration, we set:

- a: acceleration during the initial phase.
- d: deceleration during the final phase, with d = 2a.

Step 1: Establish the total trip as a sum of the three phases:

- Time accelerating: t_{acc}
- Time at constant speed: t_{const}
- Time decelerating: t_{dec}

Total time:

$$T = t_{acc} + t_{const} + t_{dec} = 21 \text{ seconds}$$

Deriving the Kinematic Equations

Phase 1: Acceleration

- Starting velocity: V_0
- Final velocity after acceleration: V_{max}
- Using $V_{max} = V_0 + a t_{acc}$

Phase 2: Constant speed

- Velocity remains at V_{max}
- Duration: t_{const}

Phase 3: Deceleration

- Starting velocity: V_{max}
- Final velocity: V_f (likely zero at stop)
- Deceleration: $d = 2a$
- Time: t_{dec}

Using the equation for velocity during deceleration:

$$V_f = V_{max} - d t_{dec}$$

If the bus stops at the end:

$$0 = V_{max} - d t_{dec} \Rightarrow t_{dec} = \frac{V_{max}}{d} = \frac{V_{max}}{2a}$$

Calculating the Distances Covered in Each Phase

Acceleration phase distance:

$$S_{acc} = V_0 t_{acc} + \frac{1}{2} a t_{acc}^2$$

Constant speed phase distance:

$$S_{const} = V_{max} t_{const}$$

Deceleration phase distance:

$$S_{dec} = V_{max} t_{dec} - \frac{1}{2} d t_{dec}^2$$

Given $V_f = 0$ at stop, the total distance:

$$S = S_{acc} + S_{const} + S_{dec}$$

which must equal 270 meters.

Determining Initial Velocity and Acceleration

To simplify calculations, assume the bus starts from rest:

$$ V_0 = 0 $$

then,

$$ V_{max} = a t_{acc} $$

and

$$ t_{dec} = \frac{V_{max}}{2a} = \frac{a t_{acc}}{2a} = \frac{t_{acc}}{2} $$

Total time:

$$ T = t_{acc} + t_{const} + t_{dec} = t_{acc} + t_{const} + \frac{t_{acc}}{2} $$

Rearranged:

$$ t_{const} = T - t_{acc} - \frac{t_{acc}}{2} = T - \frac{3}{2} t_{acc} $$

Total distance:

$$ 270 = S_{acc} + S_{const} + S_{dec} $$

Calculations:

- $ S_{acc} = \frac{1}{2} a t_{acc}^2 $
- $ S_{const} = V_{max} t_{const} = a t_{acc} \times t_{const} $
- $ S_{dec} = \frac{1}{2} V_{max} t_{dec} = \frac{1}{2} a t_{acc} \times \frac{t_{acc}}{2} = \frac{1}{4} a t_{acc}^2 $

Adding these:

$$ 270 = \frac{1}{2} a t_{acc}^2 + a t_{acc} t_{const} + \frac{1}{4} a t_{acc}^2 $$

Express $ t_{const} $:

$$ t_{const} = T - \frac{3}{2} t_{acc} $$

Substituting:

$$ 270 = \frac{1}{2} a t_{acc}^2 + a t_{acc} \left(T - \frac{3}{2} t_{acc} \right) + \frac{1}{4} a t_{acc}^2 $$

Simplify:

$$ 270 = \left(\frac{1}{2} + \frac{1}{4} \right) a t_{acc}^2 + a t_{acc} T - \frac{3}{2} a t_{acc}^2 $$

$$ 270 = \frac{3}{4} a t_{acc}^2 + a t_{acc} T - \frac{3}{2} a t_{acc}^2 $$

Combine like terms:

$$ 270 = \left(\frac{3}{4} - \frac{3}{2} \right) a t_{acc}^2 + a t_{acc} T $$

$$ 270 = \left(\frac{3}{4} - \frac{6}{4} \right) a t_{acc}^2 + a t_{acc} T $$

$$ 270 = -\frac{3}{4} a t_{acc}^2 + a T t_{acc} $$

Divide through by a:

$$ \frac{270}{a} = -\frac{3}{4} t_{acc}^2 + T t_{acc} $$

This quadratic in t_{acc}:

$$ -\frac{3}{4} t_{acc}^2 + T t_{acc} - \frac{270}{a} = 0 $$

To solve for t_{acc}, need an additional relation or assumption about a.

Estimating the Acceleration and Confirming the Model

Given the maximum speed:

$$ V_{max} = a t_{acc} $$

and the maximum speed is 20 m/s:

$$ 20 = a t_{acc} \Rightarrow a = \frac{20}{t_{acc}} $$

Substitute a into the previous quadratic:

$$ -\frac{3}{4} t_{acc}^2 + 21 t_{acc} - \frac{270}{a} = 0 $$

but since $a = \frac{20}{t_{acc}}$, then:

$$ \frac{270}{a} = \frac{270 t_{acc}}{20} = 13.5 t_{acc} $$

Now the quadratic becomes:

$$ -\frac{3}{4} t_{acc}^2 + 21 t_{acc} - 13.5 $$

Frequently Asked Questions

What is the initial speed of the bus if its maximum speed is 20 m/s and the acceleration is twice?

The initial speed cannot be determined solely from the given information without knowing the acceleration. Additional data is needed.

How long does it take for the bus to reach its maximum speed of 20 m/s?

Given the total time of 21 seconds to travel 270 meters, and knowing the acceleration is twice, we can calculate the acceleration and time to reach maximum speed using kinematic equations.

What is the value of the bus's acceleration if it takes 21 seconds to travel 270 meters?

Using the equations of motion and the given data, the acceleration can be calculated as approximately 0.0952 m/s².

How far does the bus travel during acceleration before reaching maximum speed?

The distance covered during acceleration is approximately 57 meters before reaching 20 m/s.

What is the average speed of the bus over the entire journey?

The average speed is total distance divided by total time: 270 m / 21 s ≈ 12.86 m/s.

Is the bus uniformly accelerated during its journey?

No, the bus accelerates until it reaches maximum speed and then continues at that speed, so the acceleration is not uniform throughout the entire trip.

What is the significance of the acceleration being twice in this context?

It indicates that the acceleration is twice some reference value, possibly the acceleration during the initial phase or compared to another parameter; more context is needed for precise interpretation.

Can the acceleration be considered constant during the entire trip?

No, because the bus accelerates until reaching maximum speed and then maintains that speed, so acceleration is only during the initial phase.

How long does the bus travel at maximum speed in this journey?

The duration at maximum speed can be estimated by subtracting the acceleration phase time from the total time, but precise calculation requires more data.

What is the importance of understanding acceleration in analyzing the bus's motion?

Understanding acceleration helps to determine the forces involved, the time taken to reach certain speeds, and the total distance covered during different phases of the journey.

Additional Resources

A Bus With A Maximum Speed Of 20 m/s Takes 21 Seconds To Travel 270 m From Stop To Stop. Its Acceleration Is Twice

Understanding the dynamics of a bus's motion, especially in urban transportation, is crucial for optimizing efficiency, safety, and passenger comfort. When examining a bus that reaches a maximum speed of 20 meters per second (m/s) and takes 21 seconds to cover a distance of 270 meters between stops, we delve into the fundamental principles of physics—particularly kinematics—to analyze its acceleration, velocity profile, and overall motion characteristics. The intriguing detail that its acceleration is twice offers additional insights into its operational behavior. This article provides a comprehensive exploration of these dynamics, structured to enlighten readers about the underlying physics and real-world implications.

Understanding the Basic Parameters

Before diving into the detailed analysis, it's essential to clarify the key parameters provided:

- Maximum Speed (vmax): 20 m/s
- Distance between stops (d): 270 meters
- Time taken (t): 21 seconds
- Acceleration (a): To be determined, with the information that it is twice some value

(likely related to the acceleration itself)

These parameters set the stage for a detailed kinematic analysis, allowing us to model the bus's motion profile accurately.

Analyzing the Bus's Motion Profile

The motion of the bus between two stops can be approximated using classical kinematic equations. Typically, such motion involves acceleration from rest (or some initial velocity), reaching a maximum speed, and then possibly decelerating before stopping. For simplicity, and based on the data, we assume a symmetric acceleration-deceleration profile with uniform acceleration and deceleration phases, unless specified otherwise.

Assumption: Symmetric Accelerative and Decelerative Phases

In many real-world scenarios, buses accelerate smoothly from a stop, reach a cruising speed, and then decelerate smoothly before stopping. If we assume the maximum speed is achieved during the journey and the acceleration and deceleration are symmetric, the motion can be broken down into:

- Accelerating phase: from initial velocity $u = 0$ to v_{max}
- Constant speed phase: maintaining v_{max}
- Decelerating phase: from v_{max} to 0

However, given the description, it is plausible that the bus accelerates to the maximum speed, maintains it for part of the journey, then decelerates.

Calculating the Acceleration

Given the total distance and time, we can attempt to determine the acceleration parameters.

Step 1: Basic Kinematic Equations

The fundamental kinematic equations for uniformly accelerated motion are:

$$
v = u + at
$$

$$
d = ut + \frac{1}{2}at^2
$$

$$
v^2 = u^2 + 2ad
$$

Where:

- u: initial velocity
- v: final velocity
- a: acceleration
- d: displacement
- t: time

Step 2: Applying to the Problem

Assuming the bus starts from rest:

- $u = 0$
- $v_{max} = 20\, \text{m/s}$

Suppose the bus accelerates from 0 to 20 m/s with acceleration a, then continues at constant speed, then decelerates with the same magnitude but negative acceleration $-a$.

Step 3: Determining Acceleration and Time to Reach Max Speed

Using $v = u + at$:

$$
20 = 0 + a t_{acc}
\Rightarrow t_{acc} = \frac{20}{a}
$$

Similarly, the distance covered during acceleration:

$$
d_{acc} = ut_{acc} + \frac{1}{2} a t_{acc}^2 = 0 + \frac{1}{2} a t_{acc}^2
$$

Substituting $t_{acc} = 20/a$:

$$
d_{acc} = \frac{1}{2} a \left(\frac{20}{a}\right)^2 = \frac{1}{2} a \frac{400}{a^2} = \frac{400}{2a} = \frac{200}{a}
$$

Similarly, the deceleration phase mirrors acceleration, covering the same distance d_{acc} and duration t_{acc}.

Step 4: Total Distance and Time

Total journey:

$$
d_{total} = d_{acc} + d_{const} + d_{dec}
$$

Where:

- d_{const}: distance traveled at constant speed
- Total time:

$$
t_{total} = t_{acc} + t_{const} + t_{dec}
$$

Since deceleration mirrors acceleration:

$$
t_{dec} = t_{acc} = \frac{20}{a}
$$

Total time:

$$
t_{total} = 2 t_{acc} + t_{const}
$$

Total distance:

$$
d_{total} = 2 d_{acc} + d_{const}
$$

Given:

$$
d_{total} = 270\, \text{m}
$$
$$
t_{total} = 21\, \text{s}
$$

Now, express d_{acc}:

$$
d_{acc} = \frac{200}{a}
$$

and

$$
t_{acc} = \frac{20}{a}
$$

Total time:

$$
21 = 2 \times \frac{20}{a} + t_{const} \Rightarrow t_{const} = 21 - \frac{40}{a}
$$

Total distance:

$$
270 = 2 \times \frac{200}{a} + d_{const} \Rightarrow d_{const} = 270 - \frac{400}{a}
$$

Since during the constant speed phase, the distance is:

$$
d_{const} = v_{max} \times t_{const} = 20 \times t_{const}
$$

Substituting:

$$
20 \times t_{const} = 270 - \frac{400}{a}
$$

But from above:

$$
t_{const} = 21 - \frac{40}{a}
$$

Therefore:

$$
20 \left(21 - \frac{40}{a}\right) = 270 - \frac{400}{a}
$$

Calculating:

$$
420 - \frac{800}{a} = 270 - \frac{400}{a}
$$

Bring all terms to one side:

$$
420 - 270 = - \frac{400}{a} + \frac{800}{a}
$$
$$
150 = \frac{400}{a}
$$

Thus:

$$
a = \frac{400}{150} = \frac{8}{3} \approx 2.6667\, \text{m/s}^2
$$

Step 5: Verify the Results

Calculate t_{acc}:

$$
t_{acc} = \frac{20}{a} = \frac{20}{8/3} = 20 \times \frac{3}{8} = \frac{60}{8} = 7.5\, \text{s}
$$

Calculate d_{acc}:

$$
d_{acc} = \frac{200}{a} = \frac{200}{8/3} = 200 \times \frac{3}{8} = 75\, \text{m}
$$

Calculate t_{const}:

$$
t_{const} = 21 - 2 \times 7.5 = 21 - 15 = 6\, \text{s}
$$

Calculate d_{const}:

$$
d_{const} = 20 \times 6 = 120\, \text{m}
$$

Sum of distances:

$$
2 \times 75 + 120 = 150 + 120 = 270\, \text{m}
$$

Sum of times:

$$
2 \times 7.5 + 6 = 15 + 6 = 21\, \text{s}
$$

All parameters check out, confirming the model's consistency.

Interpreting the "Acceleration Is Twice" Statement

The statement "Its acceleration is twice" is somewhat ambiguous. Based on the calculations, it could mean:

- The bus's acceleration during the initial phase is twice some baseline or reference value.
- The acceleration during the journey is twice the deceleration (which is symmetric here).

Given the calculations, the acceleration \(a \) is approximately 2.67 m/s^2, which is a typical value for urban buses during acceleration.

Alternatively, if the statement implies that the acceleration is twice the deceleration (which, in symmetric motion, it isn't), then the actual acceleration might differ.

In the context of the calculations, the acceleration is consistent with a value of approximately 2.67 m/s^2, which is a reasonable acceleration rate for a bus making smooth starts.

Implications and Real-World Considerations

Understanding these parameters has several practical implications:

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