

4. A Car, Initially Traveling East With A Speed Of 5.0 M/s, Is Accelerated Uniformly At 2.0 M/s² East

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Understanding the motion of a car under uniform acceleration is fundamental in physics and essential for designing safety systems, analyzing vehicle dynamics, and improving driving strategies. In this article, we explore the scenario where a car initially moves eastward at a speed of 5.0 meters per second (m/s) and experiences a steady acceleration of 2.0 meters per second squared (m/s²) directed eastward. Through detailed analysis, we will examine the concepts of uniform acceleration, displacement, velocity, and the implications for real-world driving situations.

Fundamentals of Uniform Acceleration

What Is Uniform Acceleration?

Uniform acceleration occurs when an object's velocity changes at a constant rate over time. In the context of vehicular motion, this means the car's speed increases or decreases uniformly, and the acceleration vector remains constant in both magnitude and direction.

Mathematically, uniform acceleration is described by equations derived from kinematics:

- Final velocity: $v = v_0 + a t$
- Displacement: $s = v_0 t + \frac{1}{2} a t^2$
- Velocity as a function of displacement: $v^2 = v_0^2 + 2 a s$

Where:

- v_0 = initial velocity
- v = final velocity after time t
- a = acceleration
- s = displacement along the motion path

Understanding these equations allows us to predict the car's position and speed at any given time during uniform acceleration.

Scenario Breakdown: Initial Conditions and Acceleration

Initial Conditions

- Initial velocity, $(v_0) = 5.0 \text{ m/s}$ (eastward)
- Direction: East
- The initial speed indicates the car is already moving eastward at a moderate pace.

Acceleration Details

- Acceleration, $(a) = 2.0 \text{ m/s}^2$ (eastward)
- This positive acceleration means the car's speed increases at a constant rate in the eastward direction.

Analyzing the Motion

Velocity as a Function of Time

Using the first kinematic equation:

$$v = v_0 + a t$$

Substituting known values:

$$v(t) = 5.0 \text{ m/s} + (2.0 \text{ m/s}^2) t$$

This equation tells us that after any time (t) , the car's velocity in the eastward direction will be the initial velocity plus twice (t) .

Displacement Calculation

Displacement (s) after time (t) :

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

Substituting the values:

$$s(t) = 5.0 \text{ m/s} t + \frac{1}{2} \times 2.0 \text{ m/s}^2 t^2 = 5.0 t + t^2$$

The displacement depends quadratically on time, indicating the car's position changes increasingly

rapidly as time progresses.

Velocity and Displacement Over Time

For specific time intervals:

Time (seconds)	Velocity (m/s)	Displacement (m)
0	5.0	0
1	7.0	6.0
2	9.0	14.0
3	11.0	24.0
4	13.0	36.0

This table illustrates how the car’s speed and position evolve over time with constant eastward acceleration.

Practical Implications and Real-World Applications

Acceleration in Driving Contexts

Understanding uniform acceleration is crucial for various driving scenarios:

- Accelerating onto highways: Vehicles often accelerate at a steady rate to match traffic speed safely.
- Braking and deceleration: Similar principles apply when decelerating uniformly but with negative acceleration.
- Vehicle safety systems: Modern cars use sensors to monitor acceleration and prevent unsafe conditions like skidding or rollover.

Safety Considerations

- Controlled acceleration: Maintaining a consistent acceleration ensures comfort and safety for passengers.
- Reaction time: Drivers need to account for the time it takes to accelerate, which impacts stopping distances and collision avoidance.
- Road design: Engineers consider typical acceleration and deceleration rates when designing ramps, curves, and signage.

Calculations for Specific Scenarios

Time to Reach a Certain Speed

Suppose the driver wants to know how long it takes to reach a speed of 15.0 m/s:

$$v = v_0 + a t$$

Rearranged:

$$t = \frac{v - v_0}{a}$$

Plugging in:

$$t = \frac{15.0 \, \text{m/s} - 5.0 \, \text{m/s}}{2.0 \, \text{m/s}^2} = \frac{10.0}{2.0} = 5.0 \, \text{seconds}$$

It takes 5 seconds for the car to accelerate from 5.0 m/s to 15.0 m/s eastward.

Displacement During Acceleration to a Certain Speed

The distance traveled during this time:

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

$$s = 5.0 \, \text{m/s} \times 5.0 \, \text{s} + \frac{1}{2} \times 2.0 \, \text{m/s}^2 \times (5.0 \, \text{s})^2 = 25 + 25 = 50 \, \text{meters}$$

The car covers 50 meters while accelerating from 5.0 m/s to 15.0 m/s eastward.

Graphical Representation of Motion

Visualizing the car's motion can enhance understanding:

- Velocity vs. Time graph: A straight line with a slope of 2.0 m/s², starting at 5.0 m/s.
- Displacement vs. Time graph: A parabola opening upwards, reflecting increasing displacement over time.

These graphs can be used to analyze vehicle behavior during acceleration phases and predict future positions.

Conclusion

The scenario of a car initially traveling east at 5.0 m/s and uniformly accelerating eastward at 2.0 m/s² encapsulates fundamental principles of kinematics. By applying the core equations, we can determine the car's velocity and displacement at any moment, which has significant implications for driver safety, vehicle control, and roadway design. Understanding uniform acceleration helps drivers anticipate vehicle behavior, optimize acceleration and deceleration strategies, and ensure safe navigation through various driving conditions. Whether in everyday driving or in the development of automotive safety systems, mastering these concepts is essential for engineers, drivers, and safety professionals alike.

Frequently Asked Questions

What is the initial velocity of the car in the given scenario?

The initial velocity of the car is 5.0 m/s towards the east.

What is the acceleration of the car during the motion?

The car is uniformly accelerated at 2.0 m/s² towards the east.

How can we calculate the velocity of the car after a certain time?

The velocity after time t can be calculated using $v = u + at$, where u is initial velocity, a is acceleration, and t is time.

What is the significance of uniform acceleration in this scenario?

Uniform acceleration means the car's velocity increases at a constant rate, simplifying calculations of its speed at any given time.

How far does the car travel after 3 seconds of acceleration?

Using the equation $s = ut + 0.5at^2$, the distance traveled is $s = (5.0)(3) + 0.5(2.0)(3)^2 = 15 + 0.5(2)(9) = 15 + 9 = 24$ meters.

What will be the car's velocity after 4 seconds?

Using $v = u + at$, the velocity after 4 seconds is $v = 5.0 + (2.0)(4) = 5.0 + 8.0 = 13.0$ m/s east.

If the acceleration was reversed (towards the west), how

would that affect the car's motion?

The car would decelerate while moving east, eventually coming to a stop and then moving west if the acceleration continued, reversing its direction.

Additional Resources

A Car, Initially Traveling East With A Speed Of 5.0 M/s, Is Accelerated Uniformly At 2.0 M/s² East is a classic physics problem that offers rich insights into the principles of motion, acceleration, and kinematics. This scenario provides a practical example to understand how an object's velocity changes over time under uniform acceleration, and it serves as a foundational concept in mechanics. Analyzing this problem involves exploring initial conditions, calculating key parameters like final velocity and displacement, and understanding the implications of uniform acceleration in real-world applications such as vehicle motion.

Introduction to Uniform Acceleration and the Scenario

Before diving into calculations and analysis, it's essential to understand what uniform acceleration entails. Uniform acceleration refers to a change in velocity at a constant rate over a period of time. In the given scenario, a car initially moving east at 5.0 m/s experiences a steady acceleration of 2.0 m/s² east. This means the car's velocity increases by 2.0 meters per second every second in the eastward direction.

This simplified model serves as an idealized case to understand fundamental physics concepts, but it also mirrors real-world situations such as a vehicle speeding up on a highway or an object sliding down an inclined plane with constant acceleration due to gravity. The problem prompts us to consider key questions: How long does it take for the car to reach a certain velocity? What is the distance traveled during this acceleration? How does the motion evolve over time?

Understanding Initial Conditions and Kinematic Equations

Initial Velocity and Direction

The initial velocity (v_0) is given as 5.0 m/s east. In physics, direction is crucial, and since the acceleration is also eastward, the motion is straightforwardly one-dimensional along the east-west axis.

Acceleration

The acceleration (a) is 2.0 m/s^2 east, indicating that each second, the velocity increases by 2.0 m/s in the eastward direction. This constant acceleration is a key assumption that simplifies calculations using kinematic equations.

Key Kinematic Equations

The core equations for uniformly accelerated motion in one dimension are:

- Final velocity:

$$v = v_0 + a t$$

- Displacement:

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

- Velocity squared relation:

$$v^2 = v_0^2 + 2 a s$$

These equations enable us to analyze how the velocity and displacement change over time, given initial conditions and constant acceleration.

Calculating the Final Velocity Over Time

Suppose we want to determine how fast the car is moving after a certain period. For example, after 3 seconds:

$$v = v_0 + a t = 5.0 \text{ m/s} + (2.0 \text{ m/s}^2)(3 \text{ s}) = 5.0 + 6.0 = 11.0 \text{ m/s}$$

This calculation shows that after 3 seconds, the car's velocity increases from 5.0 m/s to 11.0 m/s eastward.

Implications:

- The car accelerates relatively quickly, nearly doubling its initial speed in just a few seconds.

- The uniform acceleration makes the velocity increase linear with time, simplifying predictions.

Time to Reach Specific Velocities

An important aspect of motion analysis involves determining the time needed to reach a particular velocity. For instance, what is the time required for the car to reach 15.0 m/s?

Using the velocity equation:

$$v = v_0 + a t \rightarrow t = \frac{v - v_0}{a}$$

Plugging in the values:

$$t = \frac{15.0 \, \text{m/s} - 5.0 \, \text{m/s}}{2.0 \, \text{m/s}^2} = \frac{10.0}{2.0} = 5 \, \text{s}$$

Key Takeaways:

- It takes 5 seconds for the car to accelerate from 5.0 m/s to 15.0 m/s.
- The linear relationship between velocity and time under uniform acceleration allows straightforward predictions.

Displacement and Distance Traveled During Acceleration

Calculating displacement helps us understand how far the car travels during the acceleration period. Using the displacement formula:

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

For the 3-second interval:

$$s = (5.0 \, \text{m/s})(3 \, \text{s}) + \frac{1}{2}(2.0 \, \text{m/s}^2)(3 \, \text{s})^2$$

$$s = 15.0 + 0.5 \times 2.0 \times 9 = 15 + 9 = 24 \, \text{m}$$

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Interpretation:

- The car travels 24 meters eastward during the first 3 seconds of acceleration.
- The displacement increases quadratically with time because of the (t^2) term, meaning the object covers more ground each successive second.

Graphical Representation of Motion

Visualizing the motion through graphs enhances understanding:

- Velocity-Time Graph:

- A straight line with slope $(a=2.0, \text{m/s}^2)$, starting at 5.0 m/s.
- After 5 seconds, velocity reaches 15.0 m/s.

- Displacement-Time Graph:

- A parabola, illustrating increasing displacement over time.
- The steepness increases as the velocity grows.

These graphs help in understanding the continuous change in velocity and displacement, emphasizing the uniform acceleration's effects.

Features, Pros, and Cons of Uniform Acceleration

Features:

- Motion equations are linear, allowing easy calculation of velocity and displacement.
- Provides clear relationships between variables like time, velocity, and displacement.
- Useful in modeling real-world scenarios where forces are constant.

Pros:

- Simplifies analysis of dynamic systems.
- Facilitates prediction of future states of motion.
- Easy to visualize and interpret through graphs.

Cons:

- Assumes constant acceleration, which is rarely the case in real environments.

- Ignores external factors like friction, air resistance, or changing forces.
- Limited to idealized one-dimensional motion.

Real-World Applications and Implications

Understanding uniform acceleration is fundamental in vehicle dynamics, sports science, and engineering. For example:

- Vehicle Acceleration: Analyzing how quickly a car can reach a certain speed helps in designing engines and safety features.
- Safety and Braking: Similar equations are used to determine stopping distances and braking times.
- Physics Education: Serves as a basis for teaching more complex motion scenarios involving non-uniform forces.

In the context of the given scenario, such analysis could inform decisions about acceleration limits, fuel consumption, or safety protocols when increasing vehicle speed.

Conclusion

The problem of a car initially traveling east at 5.0 m/s and uniformly accelerating eastward at 2.0 m/s² encapsulates core principles of kinematics and motion analysis. It demonstrates how velocity evolves linearly over time, how displacement accumulates quadratically, and how such models can be applied to real-world situations. By understanding the fundamental equations, their implications, and their limitations, students and engineers can better interpret motion data, design safer vehicles, and develop more effective control systems. While the idealized assumptions of uniform acceleration simplify calculations, practical applications must also consider external forces and factors, adding complexity to real-world motion analysis. Nevertheless, mastering these basic concepts forms the foundation for more advanced studies in physics and engineering disciplines.

Key Takeaways:

- Uniform acceleration results in linear increases in velocity and quadratic increases in displacement.
- Calculation of time, velocity, and displacement is straightforward using basic kinematic equations.
- Graphical representations aid in visualizing motion.
- Understanding these principles is essential for designing and analyzing systems involving motion.

By exploring this scenario comprehensively, we gain not only theoretical insights but also practical skills applicable across many technological and scientific fields.

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