

Multiple Choice: A Car With A Mass Of 825 Kg Moves Along The Roadway At A Speed Of 15 M/s To The East.

Multiple Choice: A Car With A Mass Of 825 Kg Moves Along The Roadway At A Speed Of 15 M/s To The East. This scenario provides an excellent opportunity to explore fundamental concepts in physics, particularly Newtonian mechanics, energy transfer, and motion analysis. Understanding how to analyze such situations is essential for students, engineers, and enthusiasts interested in vehicle dynamics and the principles governing motion. In this comprehensive article, we will delve into the physics of moving vehicles, examine the forces involved, and explore various related topics that deepen our understanding of the motion of cars on roadways.

Understanding the Scenario

Basic Details of the Car's Motion

The scenario involves a car with a mass of 825 kilograms moving steadily at a velocity of 15 meters per second towards the east. This data provides the foundation for analyzing the car's kinetic energy, momentum, and the forces acting upon it.

- Mass of the car (m): 825 kg
- Speed of the car (v): 15 m/s
- Direction: East

Such parameters are typical in physics problems that demonstrate the principles of motion. The car's constant velocity implies that the net force acting on it in the horizontal direction is zero, according to Newton's First Law of Motion.

Fundamental Concepts Involved

Kinetic Energy and Momentum

The moving car possesses kinetic energy and momentum, which are key concepts in analyzing its motion.

- Kinetic Energy (KE): The energy due to the motion of the object.

$$KE = \frac{1}{2} m v^2$$

Substituting the given values:

$$KE = \frac{1}{2} \times 825 \, \text{kg} \times (15 \, \text{m/s})^2 = 412.5 \times 225 = 92,812.5 \, \text{J}$$

So, the car has approximately 92,812.5 joules of kinetic energy.

- Momentum (p): The quantity of motion, calculated as:

$$p = m v$$
$$p = 825 \, \text{kg} \times 15 \, \text{m/s} = 12,375 \, \text{kg} \cdot \text{m/s}$$

This momentum indicates how difficult it would be to stop the car rapidly.

Forces Acting on the Car

In steady motion, the forces acting on the car primarily include:

- Driving force (engine torque): propels the car forward.
- Frictional force: acts opposite to motion, including rolling resistance and air resistance.
- Normal force: perpendicular to the roadway, balancing the weight.
- Gravity: acts downward, balanced by the normal force.

Assuming steady, constant velocity, the net horizontal force is zero, meaning the driving force balances resistive forces.

Analyzing the Dynamics of the Car

Newton's Laws in Action

Applying Newton's Second Law:

$$\begin{aligned} & \left[\right. \\ & F_{\text{net}} = m a \\ & \left. \right] \end{aligned}$$

Since the car moves at a constant velocity, acceleration $(a = 0)$, so:

$$\begin{aligned} & \left[\right. \\ & F_{\text{net}} = 0 \\ & \left. \right] \end{aligned}$$

This implies that the forward driving force from the engine equals the resistive forces.

Work and Power

- Work done: If the car accelerates or decelerates, work is done by or against the forces.
- Power: The rate at which work is done, related to the engine's power output.

For steady motion, the power delivered by the engine compensates exactly for the energy lost to resistive forces.

Energy Considerations

Kinetic Energy and Energy Conservation

Since the car's speed is constant, the kinetic energy remains unchanged unless external forces act to alter its velocity.

- Energy input: The engine supplies energy to maintain motion against resistive forces.
- Energy losses: Due to air drag, rolling resistance, and other dissipative effects.

If the car accelerates, its kinetic energy increases, requiring additional energy input. Conversely, during braking, kinetic energy is transferred to other forms of energy, such as heat.

Power Required to Maintain Speed

The power needed depends on resistive forces:

[

$$P = F_{\text{resistance}} \times v$$

]

Where $(F_{\text{resistance}})$ includes:

- Air resistance: proportional to the square of speed.
- Rolling resistance: proportional to the weight of the vehicle.

Understanding these forces helps in designing efficient engines and vehicle aerodynamics.

Implications for Road Safety and Design

Stopping Distance and Safety

Knowing the momentum and kinetic energy allows engineers and drivers to estimate the stopping distance. The basic relation:

$$d = \frac{v^2}{2a}$$

where (a) is the deceleration rate. For example, if a driver applies brakes with a deceleration of 6 m/s^2 , the stopping distance from 15 m/s :

$$d = \frac{(15)^2}{2 \times 6} = \frac{225}{12} = 18.75 \text{ meters}$$

This calculation is vital for assessing safe driving distances and designing road safety features.

Fuel Efficiency and Environmental Impact

Driving at constant speed with minimal resistive forces maximizes fuel efficiency. Understanding the

physics behind vehicle motion informs strategies to reduce emissions and improve sustainability.

Related Topics and Advanced Analysis

Energy Transfer and Powertrain Efficiency

Investigate how engine efficiency affects the energy transfer from fuel to motion, including losses due to transmission and aerodynamic drag.

Effects of Inclines and Road Conditions

Analyzing how changes in road slope or surface conditions impact the forces and energy requirements for maintaining or changing speed.

Vehicle Dynamics and Stability

Understanding how mass distribution, tire grip, and suspension influence the car's ability to maneuver safely at various speeds.

Conclusion

Analyzing a car moving at a constant speed along a roadway involves multiple fundamental physics principles, including Newton's laws, energy conservation, and force analysis. The scenario with an 825 kg car traveling at 15 m/s east provides a practical context for understanding kinetic energy, momentum, and the forces involved in vehicle motion. Such analyses are crucial for designing safer, more efficient vehicles, optimizing road safety measures, and advancing transportation technology. Whether in academic settings or real-world applications, mastering these concepts allows us to better understand and improve the way vehicles operate on our roads.

Keywords: vehicle dynamics, kinetic energy, momentum, forces in motion, road safety, energy transfer, physics of cars, steady motion, resistive forces, energy efficiency

Frequently Asked Questions

What is the momentum of the car moving at 15 m/s to the east?

The momentum is calculated as mass times velocity: $825 \text{ kg} \times 15 \text{ m/s} = 12,375 \text{ kg}\cdot\text{m/s}$ to the east.

If the car accelerates to 20 m/s eastward, what is the change in its momentum?

The change in momentum is $(825 \text{ kg} \times 20 \text{ m/s}) - (825 \text{ kg} \times 15 \text{ m/s}) = 16,500 \text{ kg}\cdot\text{m/s} - 12,375 \text{ kg}\cdot\text{m/s} = 4,125 \text{ kg}\cdot\text{m/s}$ eastward.

What force would be required to bring this car to a stop in 5 seconds from its current speed?

Using $F = \Delta p / \Delta t$, where $\Delta p = 12,375 \text{ kg}\cdot\text{m/s}$ (initial momentum) and $\Delta t = 5 \text{ s}$, $F = 12,375 / 5 = 2,475 \text{ N}$ directed westward.

If the car's velocity is doubled to 30 m/s east, what is its kinetic energy?

Kinetic energy is $(1/2) \times \text{mass} \times \text{velocity squared}$: $0.5 \times 825 \text{ kg} \times (30 \text{ m/s})^2 = 0.5 \times 825 \times 900 = 371,250 \text{ Joules}$.

How much work is done to accelerate the car from 15 m/s to 30

m/s?

Work done equals the change in kinetic energy: $(1/2) \times 825 \text{ kg} \times (30^2 - 15^2) = 0.5 \times 825 \times (900 - 225) = 0.5 \times 825 \times 675 = 278,437.5 \text{ Joules}$.

If the car travels 100 meters at 15 m/s, how long does it take?

Time taken is distance divided by speed: $100 \text{ m} / 15 \text{ m/s} \approx 6.67 \text{ seconds}$.

What is the kinetic energy of the car at its initial speed of 15 m/s?

Kinetic energy = $0.5 \times 825 \text{ kg} \times (15 \text{ m/s})^2 = 0.5 \times 825 \times 225 = 92,812.5 \text{ Joules}$.

Additional Resources

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Introduction

In the realm of physics and automotive dynamics, understanding the motion of vehicles provides crucial insights into their energy, momentum, and the forces acting upon them. Today, we delve into a scenario involving a car with a mass of 825 kg moving along a roadway at a speed of 15 meters per second toward the east. This analysis is not just about basic kinematics; it encompasses concepts like momentum, kinetic energy, force interactions, and the implications of these physical quantities in real-world driving situations.

This comprehensive exploration aims to dissect the various facets of this scenario, providing clarity and a deeper understanding of the underlying physics. Whether you are a student, an engineering enthusiast, or a curious reader, this article offers an expert-level review of how the fundamental

principles come into play in everyday vehicular motion.

Understanding the Basic Parameters

Before diving into complex calculations and concepts, let's thoroughly understand the given parameters:

- Mass of the car (m): 825 kg
- Speed of the car (v): 15 m/s
- Direction: Toward the east

These parameters form the foundation for all subsequent analysis, and their precise interpretation is essential.

Fundamental Concepts in Vehicle Dynamics

To analyze the scenario effectively, we need to revisit some core physics principles:

2.1 Momentum

Definition: Momentum (p) is a vector quantity, representing the product of an object's mass and its velocity:

$$p = mv$$

$$p = m \times v$$

\]

Significance: Momentum indicates how much motion an object has and how difficult it is to stop or change its direction.

2.2 Kinetic Energy

Definition: Kinetic energy (KE) is the energy a body possesses due to its motion:

\[

$$KE = \frac{1}{2} m v^2$$

\]

Significance: It reflects the work needed to accelerate the vehicle from rest to its current speed, relevant in collision analysis and energy efficiency.

2.3 Force and Acceleration

Newton's Second Law: The net force acting on the vehicle causes acceleration:

\[

$$F_{\text{net}} = m \times a$$

\]

Implication: Knowing the current velocity, if an external force is applied, the vehicle's acceleration or deceleration can be predicted.

Calculating the Vehicle's Momentum

2.1 Momentum Magnitude

Applying the formula:

$$p = m \times v = 825 \, \text{kg} \times 15 \, \text{m/s} = 12,375 \, \text{kg} \cdot \text{m/s}$$

Interpretation: The car has a momentum of 12,375 kg·m/s directed eastward. This value indicates the quantity of motion and is instrumental in understanding collision dynamics and braking requirements.

2.2 Directionality

Since the velocity vector points east, the momentum vector also points east. This directional aspect is crucial when analyzing interactions with other objects or forces, such as friction or external pushes.

Calculating the Kinetic Energy

2.1 Kinetic Energy Value

Using:

$$KE = \frac{1}{2} \times 825 \, \text{kg} \times (15 \, \text{m/s})^2$$

\[

$$KE = 0.5 \times 825 \times 225 = 0.5 \times 185,625 = 92,812.5, \text{J}$$

\]

Interpretation: The vehicle possesses approximately 92,813 joules of kinetic energy. This energy must be dissipated during braking or collision to bring the vehicle to rest, highlighting the importance of braking system design and safety considerations.

Implications of the Vehicle's Motion in Real-World Contexts

Understanding these fundamental quantities informs various practical scenarios:

2.1 Braking Distance and Deceleration

Given the kinetic energy, the braking distance depends on the deceleration rate:

\[

$$d = \frac{v^2}{2a}$$

\]

Alternatively, considering the work-energy principle:

\[

$$\text{Work done by brakes} = \text{Initial KE} \Rightarrow F_{\text{brake}} \times d = KE$$

\]

This shows that the higher the initial kinetic energy, the longer the stopping distance unless the braking force increases.

2.2 Impact in Collisions

The momentum value indicates how much force is required to change the vehicle's motion. In a collision, the change in momentum (impulse) relates to the force exerted over time, which affects occupant safety and vehicle integrity.

Analyzing External Forces Acting on the Car

In real driving conditions, several forces influence the motion of the vehicle:

2.1 Frictional Forces

- Rolling Resistance: The force resisting rolling motion, generally proportional to the normal force.
- Air Resistance (Drag): A velocity-dependent force opposing motion, often modeled as:

$$F_{\text{drag}} = \frac{1}{2} C_d \rho A v^2$$

where:

- C_d is the drag coefficient,
- ρ is the air density,
- A is the frontal area.

2.2 Drive and Traction Forces

The engine provides a driving force to overcome resistive forces and maintain or accelerate the vehicle.

2.3 External Influences

- Inclines or declines of the roadway,
- Crosswinds,
- External pushes or pulls.

Impact: These forces determine whether the car maintains its speed, accelerates, or decelerates.

Energy Considerations and Efficiency

2.1 Conversion of Energy

The kinetic energy represents the energy stored in the moving car. Energy is lost primarily as heat in braking systems and through air resistance.

2.2 Fuel Efficiency

Maintaining a speed of 15 m/s (approximately 54 km/h) requires a certain amount of fuel energy, factoring in the energy needed to overcome resistive forces.

2.3 Safety and Performance

- Braking systems must be capable of dissipating approximately 92,813 Joules efficiently.
- Acceleration capabilities depend on the maximum force the engine can exert relative to the vehicle's mass.

Advanced Considerations in Vehicle Dynamics

Beyond straightforward calculations, several advanced topics emerge:

2.1 Momentum and Safety

- Momentum conservation: In collisions, the total momentum before and after can be analyzed to understand crash outcomes.
- Impact force: The force during a collision depends on the change in momentum and the duration of impact.

2.2 Kinetic Energy and Damage Potential

Higher kinetic energy at given speeds correlates with greater potential for damage in accidents, underscoring the importance of speed limits and safety features.

2.3 Energy Recovery Systems

Modern vehicles incorporate regenerative braking systems that convert kinetic energy into electrical energy, improving efficiency by capturing some of the vehicle's kinetic energy during deceleration.

Conclusion

This analysis of a car with a mass of 825 kg moving at 15 m/s eastward offers a comprehensive perspective on the fundamental physics that govern vehicle motion. From calculating momentum and kinetic energy to understanding the forces acting upon the vehicle, each aspect provides vital insights into vehicle performance, safety, and energy management.

Understanding these principles is essential for engineers designing safer vehicles, policymakers establishing speed regulations, and drivers aiming to comprehend the physics behind everyday travel. As vehicles continue to evolve with new technologies, the core concepts of momentum, energy, and force remain central to optimizing automotive safety and efficiency.

Final Thoughts

The scenario exemplifies how fundamental physics principles underpin real-world applications in transportation. Recognizing the magnitudes of momentum and energy involved in even modest speeds emphasizes the importance of safety measures, proper vehicle maintenance, and responsible driving. As technology advances, integrating these physics insights into vehicle design and operation continues to enhance mobility, safety, and sustainability.

End of Article

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