A 900 Kg Car Is Traveling At 20 M/s Along The Road. What Force Must Be Applied To The Car To Stop It

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Introduction

When a vehicle moves at a certain velocity, understanding the force required to bring it to a complete stop involves principles of physics, specifically Newton's laws of motion. In this scenario, a car with a mass of 900 kilograms is traveling at a speed of 20 meters per second. To determine the force necessary to stop this vehicle, we need to analyze the concepts of acceleration (or deceleration), the work-energy principle, and the related equations of motion.

Basic Concepts and Definitions

Before delving into the calculations, it’s essential to understand some fundamental physics concepts:

- **Mass (m):** The amount of matter in the object, measured in kilograms (kg). Here, m = 900 kg.
- **Velocity (v):** The speed of the object in a specific direction, measured in meters per second (m/s). Here, v = 20 m/s.

- **Acceleration (a):** The rate of change of velocity, measured in meters per second squared (m/s^2). To stop the car, the acceleration will be negative (deceleration).

- **Force (F):** The push or pull acting upon an object, measured in Newtons (N).

- **Work-Energy Principle:** The work done by the force is equal to the change in the kinetic energy of the object.

Calculating the Required Deceleration

The key to determining the force needed to stop the car is first to understand what deceleration (negative acceleration) is required.

Kinematic Equation for Uniform Deceleration

The basic equation relating initial velocity, final velocity, acceleration, and displacement is:

\vspace{0.2cm}

$v^2 = u^2 + 2as$

where:

- v = final velocity (0 m/s, since the car comes to rest)
- u = initial velocity (20 m/s)
- a = acceleration (negative in this case)
- s = stopping distance (unknown)

Assuming the goal is to find the force required to bring the car to rest within a certain stopping distance, or alternatively, to find the force given a certain deceleration, we can proceed with different approaches.

Calculating Force Using Newton’s Second Law

Newton's second law states:

$F = m \times a$

To find the force, we need to determine the deceleration (a).

Determining the Deceleration Needed

Suppose we want the car to come to a stop within a specific distance, say 50 meters, which is a typical stopping distance under good conditions.

Using the kinematic equation:

$0 = (20)^2 + 2 \times a \times 50$

$\Rightarrow 0 = 400 + 100a$

$\Rightarrow 100a = -400$

$\Rightarrow a = -4 \text{ m/s}^2$

This means the car must decelerate at 4 meters per second squared to stop within 50 meters.

Note: The negative sign indicates deceleration.

Calculating the Force Required

With the deceleration known, we can now compute the force:

$F = m \times a = 900 \text{ kg} \times (-4 \text{ m/s}^2) = -3600 \text{ N}$

The negative sign indicates the force acts opposite to the direction of motion.

Therefore, to stop the car within 50 meters, a force of approximately 3600 N must be applied in the opposite direction of travel.

Considering Different Stopping Distances

In real-world scenarios, the stopping distance can vary significantly based on factors such as road conditions, brake efficiency, and driver reaction time. Let's examine how the required force changes with different stopping distances.

Stopping Distance of 20 meters

Using the same approach:

$0 = (20)^2 + 2 \times a \times 20$

$\Rightarrow 0 = 400 + 40a$

$\Rightarrow a = -10 \text{ m/s}^2$

Force:

$F = 900 \text{ kg} \times (-10 \text{ m/s}^2) = -9000 \text{ N}$

Implication: A higher deceleration (10 m/s^2) is needed for a shorter stopping distance, requiring a larger force.

Stopping Distance of 100 meters

Similarly:

$0 = 400 + 200a$

$\Rightarrow a = -2 \text{ m/s}^2$

Force:

$F = 900 \text{ kg} \times (-2 \text{ m/s}^2) = -1800 \text{ N}$

Implication: Longer stopping distances require less deceleration and, consequently, less force.

Real-World Factors Affecting the Force Required

While the theoretical calculations provide a solid foundation, real-world conditions influence the actual force needed to stop a vehicle.

- **Road conditions:** Wet or icy roads reduce friction and may require higher forces or longer distances to stop safely.
- **Brake efficiency:** Worn brakes or poor maintenance decrease the deceleration rate.
- **Driver reaction time:** The time taken to apply brakes affects the total stopping distance.
- **Vehicle load and distribution:** Heavier loads or uneven weight distribution can alter stopping dynamics.

In practical terms, the maximum force that brakes can exert is limited by their design and condition.

Summary of Key Points

- The initial velocity of the car is 20 m/s.
- To bring the car to rest, a deceleration is necessary, which depends on the stopping distance.
- For a stopping distance of 50 meters, a deceleration of 4 m/s^2 is required, translating to a force of approximately 3600 N.
- Shorter stopping distances demand higher forces; longer distances require less.
- Real-world factors can influence the actual force needed, often necessitating safety margins.

Conclusion

To determine the force necessary to stop a moving vehicle, one must analyze the desired stopping distance, the initial velocity, and the vehicle's mass. Using the principles of kinematics and Newton’s second law, it is clear that the force required is directly proportional to the deceleration needed and the mass of the vehicle. For the specific case of a 900 kg car traveling at 20 m/s, applying approximately 3600 N of force in the opposite direction of travel will bring the vehicle to a halt within a 50-meter distance. Adjustments to this force are necessary based on the actual conditions and safety considerations in real-world driving scenarios.

Frequently Asked Questions

What is the initial velocity of the car in the problem?

The initial velocity of the car is 20 meters per second.

What is the mass of the car given in the problem?

The mass of the car is 900 kilograms.

What is the goal when applying force to the car in this scenario?

The goal is to bring the car to a complete stop, i.e., reduce its velocity to zero.

Which physics principle is used to calculate the force required to stop the car?

Newton's second law of motion, which relates force, mass, and acceleration, is used.

How do you calculate the acceleration needed to stop the car?

Using the kinematic equation, the acceleration is a = (final velocity^2 - initial velocity^2)/(2 distance), but if stopping distance is not given, a common approach is to specify a desired stop time or deceleration rate.

What additional information is needed to precisely calculate the force required to stop the car?

The stopping distance or the time over which the car should come to a stop is needed to calculate the exact force.

If the car needs to stop in 10 seconds, what is the approximate force required?

Assuming uniform deceleration over 10 seconds, the acceleration is $a = (0 - 20 \text{ m/s}) / 10 \text{ s} = -2 \text{ m/s}^2$. The force is $F = m a = 900 \text{ kg} (-2 \text{ m/s}^2) = -1800 \text{ N}$, so a force of approximately 1800 N in the direction opposite to the motion is required.

Can the force required to stop the car be calculated without knowing the stopping distance or time?

No, because force depends on the rate of deceleration, which is determined by the stopping distance or time; without these, only the relationship can be described, not the exact value.

What real-world factors could affect the actual force needed to stop the car?

Factors include road conditions, tire friction, brake efficiency, and whether the deceleration is uniform or variable.

Additional Resources

A 900 Kg Car Is Traveling At 20 M/s Along The Road. What Force Must Be Applied To The Car To Stop It

When analyzing the dynamics of a moving vehicle, understanding the forces required to bring it to a halt is fundamental, especially in safety engineering, driving strategies, and vehicle design. In this context, we examine a scenario where a car with a mass of 900 kg is traveling at a velocity of 20 meters per second (m/s), and we aim to determine the force necessary to stop it. This question involves principles from Newtonian mechanics, particularly the concepts of momentum, acceleration, and the work-energy theorem. The analysis not only reveals the magnitude of the force but also provides insight into the factors affecting stopping distances and safety considerations on the road.

Understanding the Basic Principles

Before delving into calculations, it is essential to grasp the underlying physics concepts that govern the problem.

Newton’s Second Law and Force

Newton's second law states that the force acting on an object is equal to the mass of the object multiplied by its acceleration ($F = m a$). When stopping a moving vehicle, the force applied must produce an acceleration (or deceleration) opposite to the vehicle's direction of motion.

Kinetic Energy and Work

The vehicle's kinetic energy (KE) is given by:

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

where:
- m is the mass of the vehicle (900 kg),
- v is its velocity (20 m/s).

The force applied to stop the vehicle does work equal to this initial kinetic energy, resulting in a change in the vehicle’s energy state from kinetic to zero.

Calculating the Force Needed to Stop the Car

The core of the problem involves calculating the magnitude of the force required to bring the car to a complete stop within a specified stopping distance or within a certain time frame. For simplicity, we first consider the general case of determining the force needed to decelerate the vehicle at a constant rate, assuming some stopping distance or time.

Option 1: Force Based on Stopping Distance

If the vehicle is to be stopped within a certain distance d, the work-energy principle states:

$$ \text{Work done} = \text{Change in kinetic energy} $$

Since the work done by the braking force F over distance d is:

$$ F \times d = \frac{1}{2} m v^2 $$

Rearranging gives:

$$ F = \frac{\frac{1}{2} m v^2}{d} $$

This formula indicates that the required force depends inversely on the stopping distance.

Example Calculation:
Suppose the car needs to stop within 50 meters:

$$ F = \frac{\frac{1}{2} \times 900 \times 20^2}{50} = \frac{0.5 \times 900 \times 400}{50} $$

$$ F = \frac{180,000}{50} = 3,600\, \text{N} $$

This means a braking force of approximately 3,600 Newtons is needed to stop the car within 50 meters.

Option 2: Force Based on Time to Stop

Alternatively, if the vehicle is to be stopped within a specific time t, the required acceleration a can be found from the kinematic equation:

$$ v = a t \Rightarrow a = \frac{v}{t} $$

Using Newton's second law:

$$ F = m a = m \frac{v}{t} $$

Example Calculation:
If the car must stop in 5 seconds:

$$ a = \frac{20}{5} = 4\, \text{m/s}^2 $$

$$ F = 900 \times 4 = 3,600\, \text{N} $$

Again, the force required is approximately 3,600 N, matching the previous example when the stopping distance is 50 meters.

Factors Influencing the Force Required

The above calculations assume idealized conditions, but several real-world factors influence the actual force needed to stop a vehicle:

Frictional Forces

Friction between tires and the road surface provides the primary braking force. The maximum available frictional force is given by:

$$ F_{friction} = \mu m g $$

where:

- μ is the coefficient of friction,
- g is acceleration due to gravity (~9.8 m/s^2).

For example, if $\mu = 0.7$ (typical for dry asphalt):

$$ F_{friction} = 0.7 \times 900 \times 9.8 \approx 6,174\, \text{N} $$

This suggests that, under ideal conditions, the maximum braking force is around 6,174 N, which is higher than the earlier calculated 3,600 N, indicating that braking is feasible without locking wheels.

Pros:

- Utilizes existing tire-road friction.
- No additional force required beyond maximum friction.

Cons:

- Limited by tire and road conditions.
- In wet or icy conditions, μ decreases, reducing maximum braking force.

Braking Efficiency and Driver Response

The actual force applied depends on the braking system efficiency and driver response time. Mechanical limitations or delayed reactions can reduce effective deceleration.

Implications for Safety and Vehicle Design

Understanding the forces involved in stopping a vehicle has broad implications:

Designing Effective Braking Systems

Modern vehicles incorporate advanced braking systems—disc brakes, anti-lock braking systems (ABS), and electronic stability controls—that maximize the effective force and prevent wheel lockup.

Features:

- ABS prevents skidding, allowing maximum friction utilization.
- Regenerative brakes in electric vehicles improve efficiency.

Pros:

- Safer stopping distances.
- Better control during emergency braking.

Cons:

- Increased complexity and maintenance costs.
- Dependence on electronic systems that can fail.

Road Conditions and Safety Margins

Road surface quality, weather conditions, and tire quality significantly impact the maximum available braking force. Drivers must anticipate these factors and maintain safe following distances.

Conclusion and Summary

Calculating the force needed to stop a 900 kg car traveling at 20 m/s involves understanding the interplay of kinetic energy, stopping distance, and deceleration. Under ideal conditions, the force required can be estimated using energy principles, resulting in approximately 3,600 N to bring the vehicle to a halt within 50 meters or 5 seconds. Real-world factors such as tire-road friction, braking system efficiency, and environmental conditions influence the actual force applied and the vehicle's stopping distance.

Key Takeaways:
- The force required is proportional to the vehicle's initial kinetic energy and inversely proportional to the stopping distance or time.
- Maximizing available friction and employing advanced braking technologies can enhance safety.
- Proper driver awareness and adherence to safe following distances are vital, given the physical limitations of stopping forces.

Understanding these principles not only aids in vehicle safety planning but also informs the design of braking systems and road safety regulations, ultimately contributing to safer travel experiences for all road users.

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