A Car Weighing 12,950 N Starts From Rest And Accelerates To 83.0 Km/h In 4 S. The Friction Force Is 1,430-n.

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Understanding the dynamics of a car's motion involves analyzing various forces and parameters such as weight, acceleration, friction, and velocity. In this comprehensive guide, we explore the scenario of a car with a weight of 12,950 N that starts from rest and accelerates to a speed of 83.0 km/h within 4 seconds, considering a friction force of 1,430 N. This case study illustrates fundamental principles of physics, including Newton's laws, force analysis, and kinematic equations, providing insights valuable for students, engineers, and automobile enthusiasts alike.

Overview of the Scenario

In this scenario, a car begins at rest and accelerates to a specified speed over a set period, with known forces acting upon it. The key parameters include:

- Weight of the Car: 12,950 N
- Initial Velocity (u): 0 m/s (rest)
- Final Velocity (v): 83.0 km/h
- Time Taken (t): 4 seconds
- Friction Force (F_f): 1,430 N

Using these parameters, we aim to determine various quantities such as the car's acceleration, the net force acting on it, the work done by forces, and the implications of friction on its motion.

Understanding the Key Parameters

1. Weight and Mass of the Car

- The weight (W) of an object is the gravitational force acting on it and is related to its mass (m) by:

$$
W = m \times g
$$

where g is the acceleration due to gravity (approximately 9.8 m/s²).

- Calculating the mass:

$$
m = \frac{W}{g} = \frac{12,950\, \text{N}}{9.8\, \text{m/s}^2} \approx 1,322.45\, \text{kg}
$$

2. Final Velocity Conversion

- The final velocity is given in km/h, which needs to be converted to m/s:

$$
v = 83.0\, \text{km/h} \times \frac{1000\, \text{m}}{1\, \text{km}} \times \frac{1\, \text{h}}{3600\, \text{s}} \approx 23.06\, \text{m/s}
$$

Calculating the Acceleration

Using Kinematic Equations

- Since the car starts from rest and reaches a final velocity in a known time, the average acceleration a can be calculated:

$$
a = \frac{v - u}{t} = \frac{23.06\, \text{m/s} - 0}{4\, \text{s}} \approx 5.77\, \text{m/s}^2
$$

Analyzing Forces Acting on the Car

1. Driving Force (Net Force)

- According to Newton's second law:

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

$$
F_{net} = 1,322.45\, \text{kg} \times 5.77\, \text{m/s}^2 \approx 7,636\, \text{N}
$$

- This net force is responsible for the acceleration of the car.

2. Frictional Force

- The problem states a friction force of 1,430 N, which opposes the motion.

3. Total Driving Force (Engine Force)

- The total force exerted by the engine (or driving system) must overcome both the friction force and provide the net force for acceleration:

$$
F_{engine} = F_{net} + F_{friction}
$$

$$
F_{engine} = 7,636\, \text{N} + 1,430\, \text{N} \approx 9,066\, \text{N}
$$

This is the minimum force required from the engine to achieve the observed acceleration.

Work-Energy Perspective

1. Work Done by the Engine

- The work done on the car equals the change in its kinetic energy:

$$
W = \Delta KE = \frac{1}{2} m v^2 - 0 = \frac{1}{2} \times 1,322.45\, \text{kg} \times (23.06\, \text{m/s})^2
$$

$$
W \approx 0.5 \times 1,322.45 \times 532.6 \approx 352,232\, \text{J}
$$

2. Work Done Against Friction

- Friction opposes the motion and does negative work:

$$
W_{friction} = - F_{friction} \times d
$$

- First, calculate the distance traveled:

$$
d = ut + \frac{1}{2} a t^2 = 0 + \frac{1}{2} \times 5.77\, \text{m/s}^2 \times (4)^2 \approx 46.2\, \text{m}
$$

- Then, work against friction:

$$
W_{friction} = - 1,430\, \text{N} \times 46.2\, \text{m} \approx -66,066\, \text{J}
$$

- The net work done by the engine accounts for both the kinetic energy gained and work against friction:

$$
W_{engine} = KE + |W_{friction}| \approx 352,232\, \text{J} + 66,066\, \text{J} \approx 418,298\, \text{J}
$$

Implications and Real-World Applications

1. Engine Power Calculation

- Power is the rate at which work is done:

$$
P = \frac{W}{t} = \frac{418,298\, \text{J}}{4\, \text{s}} \approx 104,575\, \text{W} \approx 140\, \text{hp}
$$

- This indicates the engine must deliver approximately 140 horsepower to achieve the acceleration within 4 seconds, considering friction.

2. Fuel Efficiency and Performance

- Understanding the forces involved helps in designing engines that optimize power output while minimizing fuel consumption.
- Engineers analyze similar force and work calculations to improve acceleration and handling.

3. Automotive Safety and Design

- Knowledge of acceleration and force dynamics assists in designing safety features, such as brakes and airbags, to withstand forces during sudden stops or collisions.

Summary of Key Calculations

1. **Mass of Car**: approximately 1,322.45 kg

2. **Acceleration**: approximately 5.77 m/s^2

3. **Engine Force:** approximately 9,066 N
4. **Distance Traveled:** approximately 46.2 meters
5. **Work Done by Engine:** approximately 418,298 Joules
6. **Power Required:** approximately 140 horsepower

Conclusion

This analysis of a car starting from rest and accelerating to 83.0 km/h in 4 seconds, with a known friction force, demonstrates fundamental physics concepts such as force analysis, kinematic equations, work-energy principles, and power calculations. The insights gained from such calculations are essential for automotive engineers aiming to optimize vehicle performance, safety, and fuel efficiency. Understanding how forces interact during acceleration not only enhances vehicle design but also provides a deeper appreciation of the physics governing everyday motion.

Additional Resources

- Khan Academy Physics: Forces and Newton’s Laws
- Engineering Toolbox: Kinematic Equations
- How Car Engines Work

By understanding the detailed physics behind a car’s acceleration, enthusiasts and professionals alike can appreciate the intricate balance of forces that enable smooth and efficient vehicle performance.

Frequently Asked Questions

What is the initial velocity of the car when it starts from rest?

The initial velocity of the car is 0 m/s since it starts from rest.

How can we calculate the acceleration of the car during the 4-second interval?

First, convert the final speed from km/h to m/s: 83.0 km/h = 23.06 m/s. Using the formula $a = (v - u) / t$, where $u = 0$, the acceleration is $a = 23.06 / 4 \approx 5.77$ m/s².

What is the net force acting on the car during acceleration?

Using Newton's second law, net force $F_{net} = m a$. First, find the mass: weight = m g → m = weight / g = 12,950 N / 9.8 m/s² ≈ 1322.45 kg. Then, F_{net} = 1322.45 kg 5.77 m/s² ≈ 7632 N.

How do the friction force and net force relate in this scenario?

The friction force opposes the motion. The net force accelerating the car is the total driving force minus the friction force. So, the driving force is approximately 7632 N + 1430 N = 9062 N.

What is the total work done on the car during its acceleration?

The work done is equal to the change in kinetic energy: $KE = 0.5\ m\ v^2$ = 0.5 1322.45 kg (23.06 m/s)² ≈ 351,278 Joules.

Additional Resources

Car Acceleration Analysis: From Rest to 83.0 km/h in 4 Seconds with Frictional Force Considerations

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Introduction

Understanding the dynamics of a car's motion involves analyzing various forces, accelerations, and energy conversions. In this detailed review, we examine a specific scenario: a car with a weight of 12,950 N that starts from rest, accelerates to a velocity of 83.0 km/h within 4 seconds, and faces a frictional resistance of 1,430 N. This case offers an excellent opportunity to explore fundamental principles of physics, including Newtonian mechanics, force analysis, kinematic equations, and energy considerations.

Basic Parameters and Conversions

Before delving into calculations, it is crucial to convert all given data into consistent SI units and clarify the parameters:

- Weight (W): 12,950 N
- Initial velocity (u): 0 m/s (since starting from rest)
- Final velocity (v): 83.0 km/h
- Time taken (t): 4 s
- Frictional force (F_f): 1,430 N

Conversions:

- Velocity from km/h to m/s:

$$
v = 83.0\, \text{km/h} \times \frac{1000\, \text{m}}{1\, \text{km}} \times \frac{1\, \text{h}}{3600\, \text{s}} = \frac{83.0 \times 1000}{3600} \approx 23.056\, \text{m/s}
$$

- Weight to mass:

$$
m = \frac{W}{g} = \frac{12,950\, \text{N}}{9.8\, \text{m/s}^2} \approx 1322.45\, \text{kg}
$$

Force Analysis and Free-Body Diagram

Understanding the forces acting on the car:

1. Driving Force (F_{drive}): The engine generates a force to accelerate the car forward.
2. Frictional Resistance (F_f): A retarding force of 1,430 N opposes the motion.
3. Air Resistance and Rolling Resistance: For simplicity, only the given frictional force is considered, assuming it encompasses both effects.
4. Gravity and Normal Force: Vertically balanced, with normal force equal to the weight (assuming level ground).

Free-Body Diagram:

- Forward force: F_{drive}
- Opposing force: $F_f = 1430\, \text{N}$

Net Force (F_{net}):

$$
F_{net} = F_{drive} - F_f
$$

Calculating the Acceleration

Using kinematic equations:

$$
v = u + a t
$$

Given $u=0$, $v=23.056\, \text{m/s}$, $t=4\, \text{s}$:

$$
a = \frac{v - u}{t} = \frac{23.056 - 0}{4} = 5.764\, \text{m/s}^2
$$

This is the average acceleration over the 4 seconds.

Determining the Required Driving Force

Applying Newton's second law:

$$
F_{net} = m a
$$

$$
F_{net} = 1322.45\, \text{kg} \times 5.764\, \text{m/s}^2 \approx 7621\, \text{N}
$$

Since:

$$
F_{net} = F_{drive} - F_f
$$

We find:

$$
F_{drive} = F_{net} + F_f = 7621 + 1430 = 9051\, \text{N}
$$

Implication: The engine must produce approximately 9051 N of force to accelerate the car to 83 km/h in 4 seconds against the given friction.

Power and Work Done Analysis

Work-Energy Principle:

The work done by the engine translates into the kinetic energy gained by the car minus work done against friction.

1. Kinetic Energy (KE):

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

$$
KE = 0.5 \times 1322.45 \times (23.056)^2 \approx 0.5 \times 1322.45 \times 532.4 \approx 352,529\, \text{J}
$$

2. Work done by the engine (W):

$$
W_{engine} = F_{drive} \times d
$$

To find the distance traveled during acceleration:

$$
d = u t + \frac{1}{2} a t^2 = 0 + 0.5 \times 5.764 \times 16 = 0.5 \times 5.764 \times 16 \approx 46.11\, \text{m}
$$

Thus:

$$
W_{engine} = 9051\, \text{N} \times 46.11\, \text{m} \approx 417,118\, \text{J}
$$

3. Work against friction:

$$
W_{friction} = F_f \times d = 1430\, \text{N} \times 46.11\, \text{m} \approx 65,912\, \text{J}
$$

Total work input:

$$
W_{total} = KE + W_{friction} \approx 352,529 + 65,912 = 418,441\, \text{J}
$$

Efficiency considerations: The engine's work exceeds the kinetic energy acquired because part of the work compensates for frictional losses.

Power Output and Performance

Power is the rate of work done:

$$
P = \frac{W_{total}}{t} \approx \frac{418,441}{4} \approx 104,610\, \text{W}

\approx 104.6\, \text{kW}
\]

This indicates the engine must sustain an average power output of approximately 104.6 kW during acceleration to achieve the target speed in 4 seconds.

Discussion of Real-World Factors

While the calculations provide a theoretical understanding, real-world scenarios involve additional complexities:

- Aerodynamic Drag: At 83 km/h, air resistance significantly impacts the force required. The simplified model assumes only the given frictional force, but in practice, drag force \(F_{drag} = \frac{1}{2} C_d \rho A v^2\) would contribute, increasing the power demand.

- Rolling Resistance Variability: Factors such as tire inflation, road surface, and vehicle load influence rolling resistance.

- Engine Efficiency: Not all the input power translates into propulsive force; engines have efficiency ratings often below 100%, meaning the actual power required would be higher.

- Transmission and Drivetrain Losses: Power losses in the transmission system further increase the power demand from the engine.

Implications for Vehicle Design and Performance

Understanding the forces and energy involved:

- Engine Selection: An engine capable of delivering at least 105 kW during acceleration would be necessary, considering efficiency losses.

- Braking and Safety: Rapid acceleration to high speeds requires robust braking systems and safety considerations.

- Fuel Efficiency: The energy input and power output directly influence fuel consumption; high power demands over short periods can reduce efficiency.

- Design Optimization: Aerodynamic improvements and reduced friction materials can lower the power needs, leading to better performance and fuel economy.

Conclusion

This detailed analysis of a car starting from rest and reaching 83.0 km/h in 4 seconds, with a frictional force of 1,430 N, demonstrates the interplay of forces, energy, and power in vehicle dynamics. The key takeaways include:

- The acceleration is approximately 5.764 m/s^2.
- The engine must exert a force of about 9051 N to overcome resistive forces and accelerate the vehicle.
- The power output required is roughly 104.6 kW, highlighting the significant energy involved in rapid acceleration.
- Frictional forces and other resistances play a critical role in determining the actual force and power needs.

This scenario underscores the importance of understanding physics principles for vehicle design, performance optimization, and safety considerations. It also illustrates the necessity of accounting for real-world factors such as air resistance and mechanical efficiencies to accurately predict vehicle behavior.

In summary, analyzing a vehicle's acceleration profile with given forces provides valuable insight into the energy and power demands of high-performance driving. It emphasizes the significance of force management, energy conversion, and the engineering challenges involved in achieving rapid acceleration within a short timeframe.

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