Two People Push A 2,000-kg Car To Get It Started. An Acceleration Of At Least 5.0 M/s? Is Required To

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Getting a car to start, especially when it's unresponsive or the battery is dead, often involves physical effort. Sometimes, people resort to pushing the vehicle to generate enough momentum for the engine to turn over. But how much effort is actually needed? Specifically, if two individuals are pushing a 2,000-kg car, what acceleration must they achieve to get it moving effectively? Understanding the physics behind this scenario can shed light on the forces involved and provide a clear picture of what's required to get that car rolling.

Understanding the Basics: Force, Mass, and Acceleration

Before delving into the specifics, it's important to revisit some fundamental physics concepts.

Newton's Second Law of Motion

Newton's second law states that:

$$ F = m \times a $$

where:
- F is the net force applied on the object (in newtons, N),
- m is the mass of the object (in kilograms, kg),
- a is the acceleration of the object (in meters per second squared, m/s^2).

This law helps us determine the amount of force needed to produce a specific acceleration in an object of a given mass.

Friction and Resistance

In real-world scenarios, pushing a car isn't just about overcoming inertia (the tendency of the vehicle to resist changes in its state of motion). Several resistive forces oppose movement, including:
- Static friction between the tires and the road surface,
- Rolling resistance,
- Air resistance, which is usually minimal at low speeds.

To get the car moving, the applied force must first overcome static friction. Once the car is in motion, rolling resistance becomes the primary opposition.

Calculating the Required Force and Acceleration

To determine the effort needed, we start with the basic physics equations.

Estimating the Force Necessary to Overcome Static Friction

The maximum static friction force (F_{static}) can be calculated as:

$$F_{static} = \mu_s \times N$$

where:
- μ_s is the coefficient of static friction,
- N is the normal force, which, on a flat surface, equals the weight of the car: $N = m \times g$.

Assuming typical values:
- μ_s (static friction coefficient for rubber tires on asphalt): approximately 0.7,
- g (acceleration due to gravity): 9.81 m/s^2.

Calculating F_{static}:

$$F_{static} = 0.7 \times 2000\, \text{kg} \times 9.81\, \text{m/s}^2$$
$$F_{static} = 0.7 \times 19,620\, \text{N}$$
$$F_{static} \approx 13,734\, \text{N}$$

Implication: To just start moving the car from rest, the push must produce a force exceeding approximately 13,734 N.

Determining the Acceleration Needed

Once the car begins to move, the main opposing force is rolling resistance, which is generally less than static friction. For simplicity, assume a coefficient of rolling resistance (μ_r) of about 0.015.

Rolling resistance force:

$$F_{rolling} = \mu_r \times N$$
$$F_{rolling} = 0.015 \times 19,620\, \text{N}$$
$$F_{rolling} \approx 294\, \text{N}$$

To accelerate the car at a rate a, the pushing force must overcome rolling resistance and provide the necessary acceleration:

$$F_{push} = m \times a + F_{rolling}$$

Suppose the goal is to accelerate the car at at least 5.0 m/s^2:

$$F_{push} = 2000\, \text{kg} \times 5.0\, \text{m/s}^2 + 294\, \text{N}$$
$$F_{push} = 10,000\, \text{N} + 294\, \text{N}$$

$$F_{push} \approx 10,294\, \text{N}$$

Key insight: To accelerate the car at 5.0 m/s^2, the push must generate approximately 10,294 N of force, which is less than the static friction force. Therefore, initial movement requires overcoming about 13,734 N, but once moving, an acceleration of 5.0 m/s^2 is achievable with around 10,294 N.

Can Two People Generate Such Force?

The critical question: Is it feasible for two individuals to exert such a force?

Estimating Human Pushing Capacity

Studies and practical observations suggest:
- An average person can exert a maximum pushing force of about 300-400 N in a sustained effort.
- Highly trained athletes or individuals utilizing their entire body weight and strength may reach forces of 600-800 N temporarily.

Assuming both individuals push together:

$$F_{total} = 2 \times 400\, \text{N} = 800\, \text{N}$$

Comparison:

- Required force to start moving the car: approximately 13,734 N.
- Max combined human effort: around 800 N.

This indicates that two people cannot generate enough force to overcome static friction and start the car moving under typical conditions.

Implications and Practical Considerations

- Multiple people: More individuals would be needed to generate the necessary force.
- Mechanical advantage: Using tools like a lever or a tow strap connected to a vehicle with a stronger power source can help.
- Reducing resistance: Ensuring tires are properly inflated, removing obstacles, and minimizing friction can decrease the force needed.
- Assistance from the engine: Once the car is moving, the engine can help maintain acceleration with less effort from pushers.

Alternative Methods for Starting a Stuck Car

Given the force limitations of human pushers, consider these alternatives:

- **Using a Tow Rope or Chain:** Connecting to another vehicle with a powerful engine can help generate enough force.

- **Push-Start (Bump Start):** Engaging the clutch and shifting into gear while rolling downhill or with a push can start the engine.
- **Jump-Starting:** Using jumper cables from a functional battery source.
- **Checking the Battery and Fuel System:** Ensuring the vehicle's systems are functioning properly to avoid the need for physical push-starts.

Conclusion: The Physics of Pushing a Car

In summary, while the idea of two people pushing a 2,000-kg car to get it started might seem straightforward, physics reveals the challenges involved. To achieve an acceleration of at least 5.0 m/s^2, a force of approximately 10,294 N is necessary once the car is in motion, but overcoming static friction to initiate movement requires about 13,734 N. Given typical human strength, two people are unlikely to generate enough force to start the car from rest under normal conditions.

Key takeaways:

- The initial push to overcome static friction is significantly higher than what two average individuals can exert.
- Once moving, achieving 5.0 m/s^2 acceleration is feasible with less force, but the initial movement remains the main challenge.
- Mechanical aids or additional help are often necessary for starting stubborn vehicles.

Understanding these physics principles not only helps set realistic expectations but also encourages the use of proper tools and techniques to start a vehicle efficiently and safely.

Frequently Asked Questions

What minimum force is needed to accelerate a 2000-kg car at 5.0 m/s^2?

Using Newton's second law, $F = m \times a$, the force required is 2000 kg × 5.0 m/s^2 = 10,000 N.

Why do two people need to push with a combined force of at least 10,000 N to start the car?

Because the force required to accelerate the car at 5.0 m/s^2 is 10,000 N, and two people working together must exert at least this combined force to achieve that acceleration.

How does friction affect the effort needed to push the car and get it moving?

Friction opposes the motion, so additional force beyond 10,000 N is needed to overcome static friction before achieving the desired acceleration.

If two people push equally, how much force does each need to apply to reach the required acceleration?

Each person must exert at least half of the total force, so approximately 5,000 N each, assuming equal effort and no other resistances.

What practical methods can be used to help start a heavy car without exerting such high force manually?

Using mechanical aids like a push-start or pull-start, applying a slight incline, or using a car jump-start system can reduce the manual force needed to get the car moving.

Additional Resources

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Introduction

In everyday life, many car owners and roadside assistance personnel have encountered situations where their vehicle refuses to start—be it due to a dead battery, malfunctioning starter, or other mechanical issues. Occasionally, the solution involves pushing the car to invoke a "push start" or "bump start," especially for manual transmission vehicles. While this method is common, understanding the physics behind how much force and acceleration are necessary to get a car moving from rest can clarify why certain efforts succeed or fail.

This article investigates the scenario where two people are pushing a 2,000-kg car to get it started, with a specific focus on the requirement that an acceleration of at least 5.0 m/s^2 is necessary. We will explore the fundamental physics principles involved, analyze the forces at play, and assess the practical implications for those attempting such a task.

The Physics of Pushing a Car: Fundamental Concepts

Newton’s Laws of Motion

The core principle underlying the act of pushing a vehicle is Newton's Second Law:

\[

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

where:
- F_{net} is the net force applied to the object,
- m is the mass of the object,
- a is the acceleration.

To initiate movement, the force exerted by the pushers must overcome the static friction between the tires and the ground, as well as any additional resistances such as rolling resistance.

Static vs. Kinetic Friction

- Static Friction (f_s): Acts when the object is at rest; must be overcome to start movement.
- Kinetic Friction (f_k): Acts when the object is sliding; generally less than static friction.

Pushing a stationary car involves overcoming static friction, which is usually higher than kinetic friction. The maximum static friction force is given by:

$$
f_{s_{max}} = \mu_s \times N
$$

where:
- μ_s is the coefficient of static friction,
- N is the normal force, typically equal to the weight of the car ($m \times g$).

Determining the Required Acceleration and Force

Given Data

- Car mass, $m = 2000\, \text{kg}$
- Desired acceleration, $a = 5.0\, \text{m/s}^2$
- Number of pushers: 2
- Gravitational acceleration, $g = 9.8\, \text{m/s}^2$

Calculating the Force Needed for the Desired Acceleration

Applying Newton's Second Law:

$$
F_{push} = m \times a = 2000\, \text{kg} \times 5.0\, \text{m/s}^2 = 10,000\, \text{N}
$$

This is the net force required to produce the specified acceleration.

Accounting for Frictional Resistance

To actually move the car, the force exerted by the pushers must exceed the maximum static friction:

$$
f_{s_{max}} = \mu_s \times N
$$

Assuming the normal force:

$$
N = m \times g = 2000\, \text{kg} \times 9.8\, \text{m/s}^2 = 19,600\, \text{N}
$$

Estimating Static Friction Coefficient:

Typical static friction coefficients between rubber tires and asphalt are in the range:

- Dry asphalt: $\mu_s \approx 0.7$
- Wet asphalt: $\mu_s \approx 0.4$

For this analysis, assume dry conditions:

$$
f_{s_{max}} = 0.7 \times 19,600\, \text{N} = 13,720\, \text{N}
$$

Implication: The maximum static friction force is approximately 13,720 N, which exceeds the 10,000 N needed for the desired acceleration.

Practical Force Requirements and Limitations

Total Force Exerted by Two Pushers

If two people push simultaneously, the total force they can exert is roughly:

$$
F_{total} = 2 \times F_{individual}
$$

Assuming each person can exert a maximum of approximately 600 N (a realistic estimate for a strong individual pushing horizontally), the total force:

$$
F_{total} = 2 \times 600\, \text{N} = 1,200\, \text{N}
$$

This is well below the 10,000 N required for an acceleration of 5.0 m/s^2, indicating that with typical human effort, achieving the necessary acceleration is unlikely.

Required Human Force for 5.0 m/s^2

To generate the net force required:

$$
F_{push} \geq F_{friction} + m \times a
$$

But since the static friction force must first be overcome:

$$
F_{push} \geq f_{s_{max}} + m \times a
$$

Given $f_{s_{max}} = 13,720\, \text{N}$ and $m \times a = 10,000\, \text{N}$:

$$
F_{push} \geq 13,720\, \text{N} + 10,000\, \text{N} = 23,720\, \text{N}
$$

This is far beyond what two people can exert simultaneously.

Analyzing the Feasibility of the Push Start

Is a 5.0 m/s² acceleration realistic?

- Acceleration context: An acceleration of 5.0 m/s^2 is quite high for a manual push starting from rest. For comparison, typical urban vehicle acceleration from 0 to 60 km/h (~16.7 m/s) takes about 8-10 seconds, corresponding to average accelerations around 1.7 m/s^2.

- Physically attainable acceleration: Human push force limits suggest that accelerations in the range of 0.5–1.0 m/s^2 are more realistic with two people, especially for a heavy vehicle.

Realistic Force and Acceleration

Suppose two strong pushers can exert a total force of approximately 1,200 N, as estimated:

$$
a = \frac{F_{net}}{m} = \frac{1,200\, \text{N}}{2000\, \text{kg}} = 0.6\, \text{m/s}^2
$$

This acceleration is sufficient to start moving the car, overcoming static friction, provided the force exceeds $f_{s_{max}}$.

Practical Implications and Strategies for Moving a Heavy Vehicle

Overcoming Static Friction

Given the maximum static friction force (~13,720 N), efforts to push the vehicle must:

- Increase the applied force: Use mechanical advantage (e.g., a lever, tow strap, or a vehicle with

more power).
- Reduce friction: Ensure tires are properly inflated, and the surface is dry and smooth.
- Use mechanical assistance: Employ a winch or a motorized device to generate the necessary force.

Improving Push Effectiveness

- Multiple pushers: More people can increase total force, but human limits still apply.
- Proper technique: Push from the correct position, using legs and body weight rather than just arms.
- Aligning force vectors: Push in the same direction to maximize net force.

Alternative Methods

- Rolling the vehicle: If possible, slightly tilting the car or moving it on a slight incline can leverage gravity.
- Using a helper vehicle: Towing or using a vehicle with sufficient power is often more effective.
- Mechanical aids: Portable push-start devices or electric jump starters can circumvent the need for physical pushing.

Conclusion

The scenario of two people pushing a 2,000-kg car to get it started with an acceleration of at least 5.0 m/s^2 presents significant physical challenges. Calculations reveal that achieving such an acceleration solely through manual effort is practically impossible due to the enormous force required to overcome static friction and produce the desired acceleration.

In reality, the maximum static friction force between tires and asphalt under typical conditions exceeds the force two strong individuals can exert, especially considering safety and human strength limits. Therefore, while pushing can sometimes successfully initiate movement if conditions are ideal and force is sufficient, expecting two people to accelerate a heavy vehicle at 5.0 m/s^2 is unrealistic.

Key Takeaways:

- To move a 2,000 kg car, forces on the order of 13,700 N are necessary just to overcome static friction.
- Human effort limits typically cap at around 600 N per person, making such high accelerations unfeasible.
- Practical push-start methods rely on reducing friction, mechanical advantage, or external power sources rather than purely human force.

Final remark: Understanding the physics behind vehicle movement underscores why mechanical assistance or alternative strategies are essential when attempting to move heavy objects like cars, especially when high accelerations are desired. It also highlights the importance of safety and realistic expectations in such endeavors.

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