Five properties of physics that affect your gas mileage

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Credit: John Moreno/Argonne National Laboratory

Physics is inescapable. It's everywhere, making your Frisbees fly, your toilets flush and your pasta water boil at a lower temperature at altitude. We've harnessed these forces, along with chemistry and engineering, to build a marvelous contraption called a car—but many of the same properties that allow you to fly along the freeway also affect how much gas mileage you get out of your car. We talked to Argonne transportation engineer Steve Ciatti to explore some of the forces at work in your engine when it's on the road.

1) Vapor pressure

In summer, gasoline companies produce a blend of gas with lower vapor pressure, which basically means it is less likely to evaporate. Liquids evaporate more quickly when it's hot, so in order to prevent the gasoline vapor from contributing to summer smog and ozone pollution, the U.S. Environmental Protection Agency orders companies to change the formula.

The reformulated gas is cleaner and gets slightly better mileage for your car. Why? Gas is made up of a mix of molecules—all in the same family, but some short and some long. You get energy by breaking the molecules apart. Short ones, like butane, have less energy, and they cost less (so it makes sense that a company would want to add more of them). The part the EPA cares about is that short molecules also evaporate more easily, contributing to pollution. So in summer, the EPA restricts how many short-chain molecules can be in the blend, and your mileage increases because there's more energy in the gasoline overall. Unfortunately, it also makes the gas slightly more expensive.

2) Friction

Scientists at Argonne's sister national lab, Oak Ridge, tested cars' fuel economy at speeds over 50 miles per hour. For each extra 10 mph over, you lose a little over 12 percent of your miles per gallon. That increases as you go faster. Going from 70 to 80 mph costs you 15 percent, not 12.

Depending on the make of your car, it could be more or less. Some cars dropped as much as 25 percent.

"If you're driving at a steady velocity, all the power you're using is going into overcoming friction," Ciatti explained. "That equation increases by a power of three as you increase speed. So keeping the car going at 80 mph is using eight times the power you'd be using at 40 mph."

The faster you go, the more gas you'll need to move the car over the same distance.

3) Drag coefficient

The drag coefficient of your car is basically measuring how easily air goes around it. "You want as little frontal surface area as possible. If the car is a box, that's bad," Ciatti said. (You can see the coefficients of various shapes in the sidebar).

You can demonstrate this effect yourself, Ciatti said, when you hold your arm out the window while you're driving on the highway. If you lay your hand flat, parallel to the ground, the force isn't too bad. But if you hold your palm out, facing front, exposing more surface area to the direction of travel, the force is much stronger. That's the difference drag coefficient makes.

Automakers today pay close attention to drag coefficient, designing cars so that air slips easily around them. Choosing a car with an aerodynamic front—compared with a boxier make—will mean its gas mileage tends to be better.

4) Momentum

Weighing from 1,800 pounds (Smart Cars) up to 5,000 pounds and more (SUVs), cars have a huge amount of mass, which you can use for good or ill. It takes a lot of power to get an object of that mass moving, but once it does, you can use the momentum to coast—especially during city driving, with frequent stops and starts.

"One of the worst things you as a driver can do for your mileage is jam on the gas as soon as the light turns green," Ciatti said. "The harder you accelerate, the more power you need, and that all goes to waste as soon as you hit the next red light." A savvier driver eases off the gas and relies on momentum to carry the car forward, especially if there's a red light coming up a block ahead.

"Dampening those jackrabbit starts will significantly improve your fuel efficiency," he said.

5) Rolling resistance

Remember when we said that if you're driving at a steady speed, most of the energy you're using is going to counteract friction? The tires are where that happens, and how much power it takes is dictated by a property called rolling resistance. Essentially, the softer the tire is, the more effort it will take to push it across a surface.

Why don't our cars have solid, hard tires, if that would be better for gas mileage? Harder tires are more efficient, but they provide less braking force, especially in rain and snow (because there's less friction) and they don't absorb shock as well. That's why your back might be sore after a ride in a performance car, Ciatti said; the tires on sports cars are built harder so that they can turn more crisply, but without that cushion, the ride quality is rougher. As a result, personal vehicles are engineered to balance all these factors—safety, efficiency, ride quality, durability—for everyday use.

You have some control over rolling resistance by inflating or deflating your tires. The manufacturer's recommendation takes performance, efficiency and ride handling into account; keeping your tires within that range will increase your gas mileage, Ciatti said.

Bonus! Air temperature

By far the biggest difference that air temperature makes is whether it makes you turn on the air conditioning, Ciatti said.

"The A/C is a power guzzler," Ciatti said. "Evaporating and condensing, which is what's going on in air conditioning, is horrifically power intensive." Yes, it's worse than opening the windows. Because the windows are on the sides of the car, they don't change the shape of the front of the car, which is what makes by far the largest difference in wind resistance. But you do drain engine power by running the A/C.

"Sometimes I'll turn the A/C off for a minute if I know I'll need to make a sudden acceleration, like a left-hand turn at the end of a light, because you can absolutely feel the difference in the amount of power you can get from the engine," Ciatti said.

Why is cooling a car so much more power-intensive than heating it? Engines make heat as a byproduct anyway, so the heat is "free"—just blow air past the engine coolant.

Where the rubber hits the road

The term physics properties makes it sound inevitable, but "driver behavior is a huge, huge factor in how good your gas mileage is," Ciatti said. "Jackrabbit starts, driving at extremely high speeds on the highway—those are the best ways to burn a lot of gas."

That enormous variation due to driving styles is why, when Argonne engineers and researchers test vehicles at the laboratory, they use a computer to drive the car. They set the vehicle up on a dynamometer, which is essentially a treadmill for cars, and run it while they measure everything from emissions to battery life in hybrids. "This lets us control all the variables we possibly can," Ciatti said, "and driver behavior is a big one."

Provided by Argonne National Laboratory

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