How Car Suspensions Work

When people think of automobile performance, they normally think of horsepower, torque and zero-to-60 acceleration. But all of the power generated by a piston engine is useless if the driver can't control the car. That's why automobile engineers turned their attention to the suspension system almost as soon as they had mastered the four-stroke internal combustion engine.

Car Suspension Image Gallery

Photo courtesy Honda Motor Co., Ltd.
Double-wishbone suspension on Honda Accord 2005 Coupe. See more car suspension pictures.

The job of a car suspension is to maximize the friction between the tires and the road surface, to provide steering stability with good handling and to ensure the comfort of the passengers. In this article, we'll explore how car suspensions work, how they've evolved over the years and where the design of suspensions is headed in the future.

If a road were perfectly flat, with no irregularities, suspensions wouldn't be necessary. But roads are far from flat. Even freshly paved highways have subtle imperfections that can interact with the wheels of a car. It's these imperfections that apply forces to the wheels. According to Newton's laws of motion, all forces have both magnitude and direction. A bump in the road causes the wheel to move up and down perpendicular to the road surface. The magnitude, of course, depends on whether the wheel is striking a giant bump or a tiny speck. Either way, the car wheel experiences a vertical acceleration as it passes over an imperfection.
Without an intervening structure, all of wheel's vertical energy is transferred to the frame, which moves in the same direction. In such a situation, the wheels can lose contact with the road completely. Then, under the downward force of gravity, the wheels can slam back into the road surface. What you need is a system that will absorb the energy of the vertically accelerated wheel, allowing the frame and body to ride undisturbed while the wheels follow bumps in the road.

The study of the forces at work on a moving car is called vehicle dynamics, and you need to understand some of these concepts in order to appreciate why a suspension is necessary in the first place. Most automobile engineers consider the dynamics of a moving car from two perspectives:

- **Ride** - a car's ability to smooth out a bumpy road
- **Handling** - a car's ability to safely accelerate, brake and corner

These two characteristics can be further described in three important principles - road isolation, road holding and cornering. The table below describes these principles and how engineers attempt to solve the challenges unique to each.

<table>
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<th>Principle</th>
<th>Definition</th>
<th>Goal</th>
<th>Solution</th>
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<td>Road Isolation</td>
<td>The vehicle's ability to absorb or isolate road shock from the passenger</td>
<td>Allow the vehicle body to ride undisturbed while traveling</td>
<td>Absorb energy from road bumps and dissipate</td>
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<td>Road Holding</td>
<td>The degree to which a car maintains contact with the road surface in various types of directional changes and in a straight line (Example: The weight of a car will shift from the rear tires to the front tires during braking. Because the nose of the car dips toward the road, this type of motion is known as &quot;dive.&quot; The opposite effect -- &quot;squat&quot; -- occurs during acceleration, which shifts the weight of the car from the front tires to the back.)</td>
<td>Keep the tires in contact with the ground, because it is the friction between the tires and the road that affects a vehicle's ability to steer, brake and accelerate.</td>
<td>Minimize the transfer of vehicle weight from side to side and front to back, as this transfer of weight reduces the tire's grip on the road.</td>
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<td>Cornering</td>
<td>The ability of a vehicle to travel a curved path</td>
<td>Minimize body roll, which occurs as centrifugal force pushes outward on a car's center of gravity while</td>
<td>Transfer the weight of the car during cornering from the high side of the vehicle to the</td>
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cornering, raising one side of the vehicle and lowering the opposite side.

A car's suspension, with its various components, provides all of the solutions described.

Let's look at the parts of a typical suspension, working from the bigger picture of the chassis down to the individual components that make up the suspension proper.

Car Suspension Parts

The suspension of a car is actually part of the chassis, which comprises all of the important systems located beneath the car's body.

![Basic Components of Car Suspension](image)

Chassis

These systems include:
The frame - structural, load-carrying component that supports the car's engine and body, which are in turn supported by the suspension.

The suspension system - setup that supports weight, absorbs and dampens shock and helps maintain tire contact.

The steering system - mechanism that enables the driver to guide and direct the vehicle.

The tires and wheels - components that make vehicle motion possible by way of grip and/or friction with the road.

So the suspension is just one of the major systems in any vehicle.

With this big-picture overview in mind, it's time to look at the three fundamental components of any suspension: springs, dampers and anti-sway bars.

Springs

Today's springing systems are based on one of four basic designs:

Coil springs - This is the most common type of spring and is, in essence, a heavy-duty torsion bar coiled around an axis. Coil springs compress and expand to absorb the motion of the wheels.
Leaf springs - This type of spring consists of several layers of metal (called "leaves") bound together to act as a single unit. Leaf springs were first used on horse-drawn carriages and were found on most American automobiles until 1985. They are still used today on most trucks and heavy-duty vehicles.

Torsion bars - Torsion bars use the twisting properties of a steel bar to provide coil-spring-like performance. This is how they work: One end of a bar is anchored to the vehicle frame. The other end is attached to a wishbone, which acts like a lever that moves perpendicular to the torsion bar. When the wheel hits a bump, vertical motion is transferred to the wishbone and then, through the levering action, to the torsion bar. The torsion bar then twists along its axis to provide the spring force. European carmakers used this system extensively, as did Packard and Chrysler in the United States, through the 1950s and 1960s.

Air springs - Air springs, which consist of a cylindrical chamber of air positioned between the wheel and the car's body, use the compressive qualities of air to absorb wheel vibrations. The concept is actually more than a century old and could be found on horse-drawn buggies. Air springs from this era were made from air-filled, leather diaphragms, much like a bellows; they were replaced with molded-rubber air springs in the 1930s.
Based on where springs are located on a car -- i.e., between the wheels and the frame -- engineers often find it convenient to talk about the sprung mass and the unsprung mass.

**Springs: Sprung and Unsprung Mass**

The sprung mass is the mass of the vehicle supported on the springs, while the unsprung mass is loosely defined as the mass between the road and the suspension springs. The stiffness of the springs affects how the sprung mass responds while the car is being driven. Loosely sprung cars, such as luxury cars (think Lincoln Town Car), can swallow bumps and provide a super-smooth ride; however, such a car is prone to dive and squat during braking and acceleration and tends to experience body sway or roll during cornering. Tightly sprung cars, such as sports cars (think Mazda Miata), are less forgiving on bumpy roads, but they minimize body motion well, which means they can be driven aggressively, even around corners.

So, while springs by themselves seem like simple devices, designing and implementing them on a car to balance passenger comfort with handling is a complex task. And to make matters more complex, springs alone can't provide a perfectly smooth ride. Why? Because springs are great at absorbing energy, but not so good at dissipating it. Other structures, known as dampers, are required to do this.