AUTOMOBILE DESIGNING TIPS

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Aerodynamic:

Aerodynamics is a branch of dynamics concerned with studying the motion of air, particularly when it interacts with a solid object. Aerodynamics is a subfield of fluid dynamics and gas dynamics, with much theory shared between them. Aerodynamics is often used synonymously with gas dynamics, with the difference being that gas dynamics applies to all gases.

General Aerodynamics Principles:

- Drag
- Lift/Downforce
- Drag Coefficient
- Frontal Area

Aerodynamic Devices:

- Scoops/Positive pressure intakes
- NACA Ducts
- Spoilers
- Wings

Aerodynamics Design Tips:

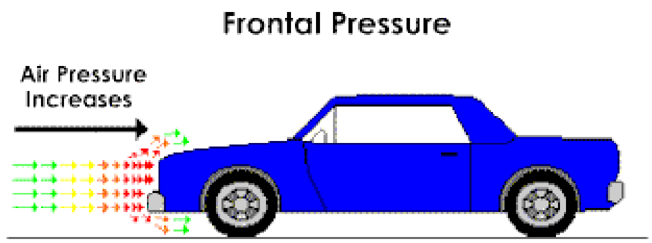
General Aerodynamic Principals:

Drag:

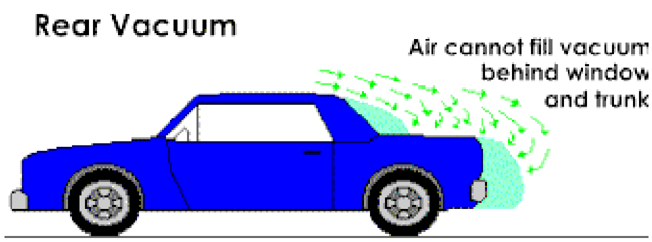
A simple definition of aerodynamics is the study of the flow of air around and through a vehicle, primarily if it is in motion. To understand this flow, you can visualize a car moving through the air. As we all know, it takes some energy to move the car through the air, and this energy is used to overcome a force called **Drag**.

Drag, in vehicle aerodynamics, is comprised primarily of two forces. **Frontal pressure** is caused by the air attempting to flow around the front of the car. As millions of air molecules approach the front grill of the car, they begin to compress, and in doing so raise the air pressure in front of the car. At the same time, the air molecules travelling along the sides of the car are at atmospheric pressure, a lower pressure compared to the molecules at the front of the car.

Just like an air tank, if the valve to the lower pressure atmosphere outside the tank is opened, the air molecules will naturally flow to the lower pressure area, eventually equalizing the pressure inside and outside the tank. The same rules apply to cars. The compressed molecules of air naturally seek a way out of the high pressure zone in front of the car, and they find it around the sides, top and bottom of the car. See the diagram below.



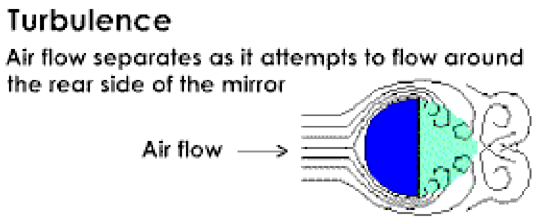
Rear vacuum (a non-technical term, but very descriptive) is caused by the "hole" left in the air as the car passes through it. To visualize this, imagine a bus driving down a road. The blocky shape of the bus punches a big hole in the air, with the air rushing around the body, as mentioned above. At speeds above a crawl, the space directly behind the bus is "empty" or like a vacuum. This empty area is a result of the air molecules not being able to fill the hole as quickly as the bus can make it. The air molecules attempt to fill in to this area, but the bus is always one step ahead, and as a result, a continuous vacuum sucks in the opposite direction of the bus. This inability to fill the hole left by the bus is technically called **Flow detachment.** See the diagram below.



Flow detachment applies only to the "rear vacuum" portion of the drag equation, and it is really about giving the air molecules time to follow the contours of a car's bodywork, and to fill the hole left by the vehicle, it's tires, it's suspension and protrusions (ie. mirrors, roll bars). If you have witnessed the Le Mans race cars, you will have seen how the tails of these cars tend to extend well back of the rear wheels, and narrow when viewed from the side or top. This extra bodywork allows the air molecules to converge back into the vaccum smoothly along the body into the hole left by the car's cockpit, and front area, instead of having to suddenly fill a large empty space.

The reason keeping flow attachment is so important is that the force created by the vacuum far exceeds that created by frontal pressure, and this can be attributed to the **Turbulence** created by the detachment.

Turbulence generally affects the "rear vacuum" portion of the drag equation, but if we look at a protrusion from the race car such as a mirror, we see a compounding effect. For instance, the air flow detaches from the flat side of the mirror, which of course faces toward the back of the car. The turbulence created by this detachment can then affect the air flow to parts of the car which lie behind the mirror. Intake ducts, for instance, function best when the air entering them flows smoothly. Therefore, the entire length of the car really needs to be optimized (within reason) to provide the least amount of turbulence at high speed. See diagram below (Light green indicates a vacuum-type area behind mirror):



Lift and Downforce:

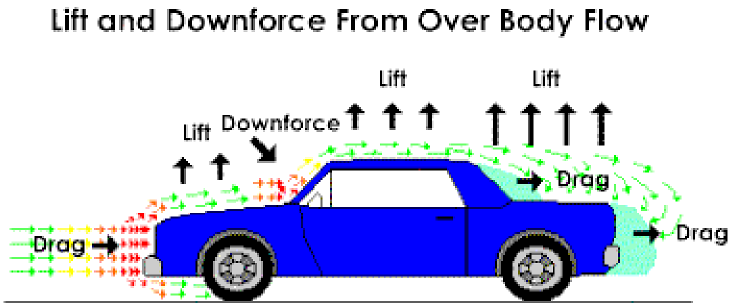
One term very often heard in race car circles is **Downforce**. Downforce is the same as the lift experienced by airplane wings, only it acts to press down, instead of lifting up. Every object travelling through air creates either a lifting or downforce situation. Race cars, of course use things like inverted wings to force the car down onto the track, increasing traction. The average street car however tends to create lift. This is because the car body shape itself generates a low pressure area above itself.

How does a car generate this low pressure area? According to Bernoulli, the man who defined the basic rules of fluid dynamics, for a given volume of air, the higher the speed the air molecules are travelling, the lower the pressure becomes. Likewise, for a given volume of air, the lower the speed of the air molecules, the higher the pressure becomes. This of course only applies to air in motion across a still body, or to a vehicle in motion, moving through still air.

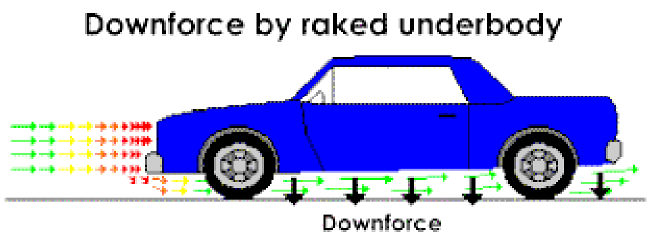
When we discussed **Frontal Pressure,** above, we said that the air pressure was high as the air rammed into the front grill of the car. What is really happening is that the air slows down as it approaches the front of the car, and as a result more molecules are packed into a smaller space. Once the air **Stagnates** at the point in front of the car, it seeks a lower pressure area, such as the sides, top and bottom of the car.

Now, as the air flows over the hood of the car, it's loses pressure, but when it reaches the windscreen, it again comes up against a barrier, and briefly reaches a higher pressure. The lower pressure area above the hood of the car creates a small lifting force that acts upon the area of the hood (Sort of like trying to suck the hood off the car). The higher pressure area in front of the windscreen creates a small (or no t so small) downforce. This is akin to pressing down on the windshield.

Where most road cars get into trouble is the fact that there is a large surface area on top of the car's roof. As the higher pressure air in front of the wind screen travels over the windscreen, it accellerates, causing the pressure to drop. This lower pressure literally lifts on the car's roof as the air passes over it. Worse still, once the air makes it's way to the rear window, the notch created by the window dropping down to the trunk leaves a vacuum, or low pressure space that the air is not able to fill properly. The flow is said to **detach** and the resulting lower pressure creates lift that then acts upon the surface area of the trunk. This can be seen in old 1950's racing sedans, where the driver would feel the car becoming "light" in the rear when travelling at high speeds. See the diagram below.



Not to be forgotten, the underside of the car is also responsible for creating lift or downforce. If a car's front end is lower than the rear end, then the widening gap between the underside and the road creates a vacuum, or low pressure area, and therefore "suction" that equates to downforce. The lower front of the car effectively restricts the air flow under the car. See the diagram below.



So, as you can see, the airflow over a car is filled with high and low pressure areas, the sum of which indicate that the car body either naturally creates lift or downforce.

Drag Coefficient:

The shape of a car, as the aerodynamic theory above suggests, is largely responsible for how much drag the car has. Ideally, the car body should:

- Have a small grill, to minimize frontal pressure.
- Have minimal ground clearance below the grill, to minimize air flow under the car.
- Have a steeply raked windshield to avoid pressure build up in front.
- Have a "Fastback" style rear window and deck, to permit the air flow to stay attached.
- Have a converging "Tail" to keep the air flow attached.
- Have a slightly raked underside, to create low pressure under the car, in concert with the fact that the minimal ground clearance mentioned above allows even less air flow under the car.

  If it sounds like we've just described a sports car, you're right. In truth though, to be ideal, a car body would be shaped like a tear drop, as even the best sports cars experience some flow detachment. However, tear drop shapes are not condusive to the area where a car operates, and that is close to the ground. Airplanes don't have this limitation, and therefore teardrop shapes work.

  What all these "ideal" attributes stack up to is called the **Drag coefficient (Cd)**. The best road cars today manage a Cd of about 0.28. Formula 1 cars, with their wings and open wheels (a massive drag component) manage a minimum of about 0.75.

If we consider that a flat plate has a Cd of about 1.0, an F1 car really seems inefficient, but what an F1 car lacks in aerodynamic drag efficiency, it makes up for in downforce and horsepower.

Frontal Area:

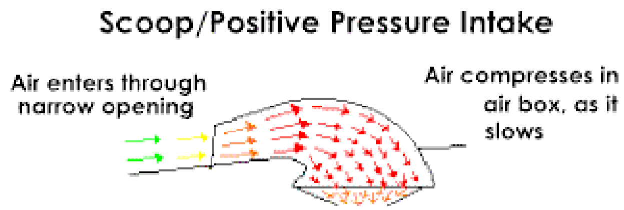
Drag coefficient, by itself is only useful in determining how "Slippery" a vehicle is. To understand the full picture, we need to take into account the frontal area of the vehicle. One of those new aerodynamic semi-trailer trucks may have a relatively low Cd, but when looked at directly from the front of the truck, you realize just how big the **Frontal Area** really is.

It is by combining the Cd with the Frontal area that we arrive at the actual drag induced by the vehicle.

Aerodynamic Devices:

Scoops:

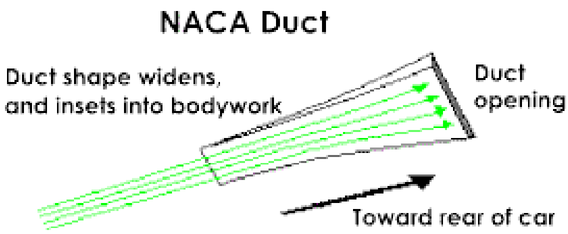
Scoops, or positive pressure intakes, are useful when high volume air flow is desireable and almost every type of race car makes use of these devices. They work on the principle that the air flow compresses inside an "air box", when subjected to a constant flow of air. The air box has an opening that permits an adequate volume of air to enter, and the expanding air box itself slows the air flow to increase the pressure inside the box.



NACA Ducts:

NACA ducts are useful when air needs to be drawn into an area which isn't exposed to the direct air flow the scoop has access to. Quite often you will see NACA ducts along the sides of a car. The NACA duct takes advantage of the **Boundary layer**, a layer of slow moving air that "clings" to the bodywork of the car, especially where the bodywork flattens, or does not accellerate or decellerate the air flow. Areas like the roof and side body panels are good examples. The longer the roof or body panels, the thicker the layer becomes (a source of drag that grows as the layer thickens too).

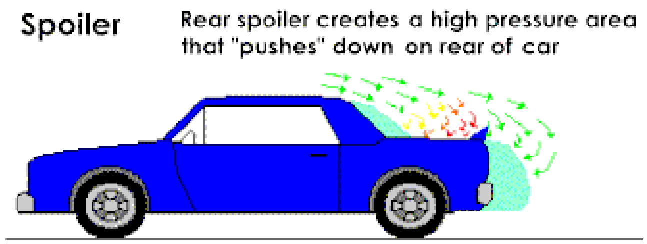
Anyway, the NACA duct scavenges this slower moving area by means of a specially shaped intake. The intake shape, shown below, drops in toward the inside of the bodywork, and this draws the slow moving air into the opening at the end of the NACA duct. Vorticies are also generated by the "walls" of the duct shape, aiding in the scavenging. The shape and depth change of the duct are critical for proper operation.



Typical uses for NACA ducts include engine air intakes and cooling.

Spoilers:

. They act like barriers to air flow, in order to build up higher air pressure in front of the spoiler. This is useful, because as mentioned previously, a sedan car tends to become "Light" in the rear end as the low pressure area above the trunk lifts the rear end of the car. See the diagram below:



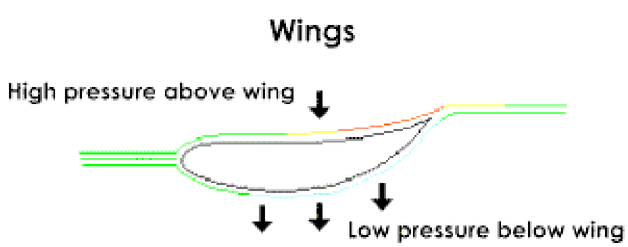
Front air dams are also a form of spoiler, only their purpose is to restrict the air flow from going under the car.

Wings:

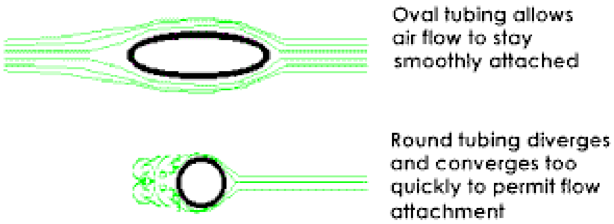
Probably the most popular form of aerodynamic aid is the wing. Wings perform very efficiently, generating lots of downforce for a small penalty in drag. Spoiler are not nearly as efficient, but because of their practicality and simplicity, spoilers are used a lot on sedans.

The wing works by differentiating pressure on the top and bottom surface of the wing. As mentioned previously, the higher the speed of a given volume of air, the lower the pressure of that air, and vice-versa. What a wing does is make the air passing under it travel a larger distance than the air passing over it (in race car applications). Because air molecules approaching the leading edge of the wing are forced to separate, some going over the top of the wing, and some going under the bottom, they are forced to travel differing distances in order to "Meet up" again at the trailing edge of the wing. This is part of Bernoulli's theory.

What happens is that the lower pressure area under the wing allows the higher pressure area above the wing to "push" down on the wing, and hence the car it's mounted to. See the diagram below:



Wings, by their design require that there be no obstruction between the bottom of the wing and the road surface, for them to be most effective. So mounting a wing above a trunk lid limits the effectiveness.



Chassis:

A **chassis**(consists of an internal framework that supports a man-made object. It is analogous to an animal's skeleton. An example of a chassis is the underpart of a motor vehicle, consisting of the frame (on which the body is mounted) with the wheels and machinery.

Vehicle chassis:

In the case of vehicles, the term chassis means the frame plus the "running gear" like engine, transmission, driveshaft, differential, and suspension. A body (sometimes referred to as "coachwork"), which is usually not necessary for integrity of the structure, is built on the chassis to complete the vehicle. For commercial vehicles chassis consists of an assembly of all the essential parts of a truck (without the body) to be ready for operation on the road.

The design of a pleasure car chassis will be different than one for commercial vehicles because of the heavier loads and constant work use.

In the case of vehicles, the term chassis means the frame plus the "running gear" like engine, transmission, driveshaft, differential, and suspension.

ACommercial vehicle manufacturers sell “chassis only”, “cowl and chassis”, as well as "chassis cab" versions that can be outfitted with specialized bodies. These include motor homes, fire engines, ambulances, box trucks, etc.

In particular applications, such as school buses, a government agency like National Highway Traffic Safety Administration (NHTSA) in the U.S. defines the design standards of chassis and body conversions.

An armoured fighting vehicle's hull serves as the chassis and comprises the bottom part of the AFV that includes the tracks, engine, driver's seat, and crew compartment. This describes the lower hull, although common usage of might include the upper hull to mean the AFV without the turret. The hull serves as a basis for platforms on tanks, armoured personnel carriers, combat engineering vehicles, etc.

Frame:

A frame is the main structure of the chassis of a motor vehicle. All other components fasten to it; a term for this is design is body-on-frame construction

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There are three types of frames :

1. Conventional frame
2. Integral frame
3. Semi-integral frame

1. Conventional frame:

It has two long side members and 5 to 6 cross members joined together with the help of rivets and bolts. The frame sections are used generally.

a. Channel Section – Good resistance to bending
b. Tabular Section – Good resistance to Torsion
c. Box Section – Good resistance to both bending and Torsion

2. Integral Frame:

This frame is used now a days in most of the cars. There is no frame and all the assembly units are attached to the body. All the functions of the frame carried out by the body itself. Due to elimination of long frame it is cheaper and due to less weight most economical also. Only disadvantage is repairing is difficult.

3. Semi – Integral Frame:

In some vehicles half frame is fixed in the front end on which engine gear box and front suspension is mounted. It has the advantage when the vehicle is met with accident the front frame can be taken easily to replace the damaged chassis frame. This type of frame is used in some of the European and American cars.

Engine:

An **engine** or **motor** is a machine designed to convert energy into useful mechanical motion.

Heat engines, including internal combustion engines and external combustion engines (such as steam engines) burn a fuel to create heat which is then used to create motion.

Electric motors convert electrical energy into mechanical motion, pneumatic motors use compressed air and others, such as clockwork motors in wind-up toys use elastic energy. In biological systems, molecular motors like myosins in muscles use chemical energy to create motion.

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$VE = \frac{3456 \times CFM}{CID \times RPM}$ volumetric efficiency

$CID = NOC \times SV$ cubic inch displacement

$CID = NOC \times 0.7854 \times BORE^2 \times STROKE$ cubic inch displacement

$CFM = \frac{CID \times RPM \times VE}{3456}$ air flow rate

$HGV = HGCT \times 0.7854 \times BORE^2$ head gasket volume

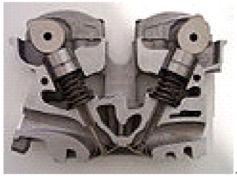
$PDV = (0.7854 \times BORE^2 \times DPD) + (VPD - VPB)$ piston deck volume

$CR = 1 + \frac{0.7854 \times BORE^2 \times STROKE}{CCV + HGV + PDV}$ compression ratio

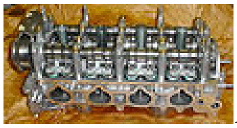
$ISH = \frac{HP}{16}$ fuel system injector size per horsepower

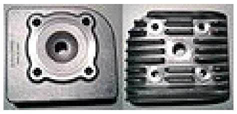
Cylinder head:

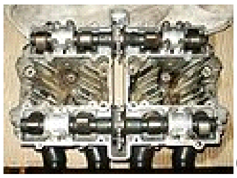
In an internal combustion engine, the **cylinder head** sits above the cylinders on top of the cylinder block. It closes in the top of the cylinder, forming the combustion chamber. This joint is sealed by a head gasket. In most engines, the head also provides space for the passages that feed air and fuel to the cylinder, and that allow the exhaust to escape. The head can also be a place to mount the valves, spark plugs, and fuel injectors


A cylinder head sliced in half showing the intake and exhaust valves, intake and exhaust ports, coolant passages, cams, tappets and valve springs.


A single overhead camshaft (SOHC) cylinder head from a HondaD15A3

. 
A double overhead camshaft (DOHC) cylinder head from a Honda K20Z3.


The bottom (left) and top (right) of a Malossi cylinder head for single-cylinder, two-stroke scooters. Hole in the middle for the spark plug, four holes for the cylinder bolt posts.


Overhead view of an air-cooled cylinder head from a SuzukiGS550 showing dual camshafts, drive sprockets and cooling fins.


The cylinder head from a GMCvan. The valves and part of the exhaust manifold are visible.

Stroke:

The **stroke** is the first stroke in a four-stroke internal combustion engine cycle. It involves the downward movement of the piston, creating a partial vacuum that draws (allows atmospheric pressure to push) a fuel/air mixture into the combustion chamber.

Compression stroke

The **compression stroke** is the second of four stages in an otto cycle or diesel cycleinternal combustion engine.

In this stage, the mixture (in the case of an Otto engine) or air (in the case of a Diesel engine) is compressed to the top of the cylinder by the piston until it is either ignited by a spark plug in an Otto engine or, in the case of a Diesel engine, reaches the point at which the fuel which has been injected spontaneously combusts, forcing the piston back down.

$$\frac{T3}{T2} = \left(\frac{V2}{V3}\right)^{\gamma-1}$$

Power stroke/Expansion Stroke

A **power stroke** is, in general, the stroke of a cyclic motor which generates force. It is used in describing mechanical engines. This force is the result of the spark plug igniting the compressed fuel-air mixture.

Exhaust stroke

The **exhaust stroke** is the fourth of four stages in a four strokeinternal combustion engine cycle. In this stage gases remaining in the cylinder from the fuel ignited during the compression step are removed from the cylinder through an exhaust valve at the top of the cylinder. The gases are forced up to the top of the cylinder as the piston rises and are pushed through the opening which then closes to allow fresh air/fuel mixture into the cylinder so the process can repeat itself.

Fuel pump:

A **fuel pump** is a frequently essential component on a car or other internal combustion engined device. Many engines do not require any fuel pump at all, requiring only gravity to feed fuel from the fuel tank through a line or hose to the engine. But in non-gravity feed designs, fuel has to be pumped from the fuel tank to the engine and delivered under low pressure to the carburetor or under high pressure to the fuel injection system. Often, carbureted engines use low pressure mechanical pumps that are mounted outside the fuel tank, whereas fuel injected engines often use electric fuel pumps that are mounted inside the fuel tank.

Mechanical pump:

Prior to the widespread adoption of electronic fuel injection, most carbureted automobile engines used mechanical fuel pumps to transfer fuel from the fuel tank into the fuel bowls of the carburetor. Most mechanical fuel pumps are diaphragm pumps, which are a type of positive displacement pump. Diaphragm pumps contain a pump chamber whose volume is increased or decreased by the flexing of a flexible diaphragm, similar to the action of a piston pump. A check valve is located at both the inlet and outlet ports of the pump chamber to force the fuel to flow in one direction only. Specific designs vary, but in the most common configuration, these pumps are typically bolted onto the engine block or head, and the engine's camshaft has an extra eccentric lobe that operates a lever on the pump, either directly or via a pushrod, by pulling the diaphragm to bottom dead center. In doing so, the volume inside the pump chamber increased, causing pressure to decrease.This allows fuel to be pushed into the pump from the tank (caused by atmospheric pressure acting on the fuel in the tank). The return motion of the diaphragm to top dead center is accomplished by a diaphragm spring, during which the fuel in the pump chamber is squeezed through the outlet port and into the carburetor. The pressure at which the fuel is expelled from the pump is thus limited (and therefore regulated) by the force applied by the diaphragm spring.

The carburetor typically contains a float bowl into which the expelled fuel is pumped. When the fuel level in the float bowl exceeds a certain level, the inlet valve to the carburetor will close, preventing the fuel pump from pumping more fuel into the carburetor. At this point, any remaining fuel inside the pump chamber is trapped, unable to exit through the inlet port or outlet port. The diaphragm will continue to allow pressure to the diaphragm, and during the subsequent rotation, the eccentric will pull the diaphragm back to bottom dead center, where it will remain until the inlet valve to the carburetor reopens.

Because one side of the pump diaphragm contains fuel under pressure and the other side is connected to the crankcase of the engine, if the diaphragm splits (a common failure), it can leak fuel into the crankcase.

The pump creates negative pressure to draw the fuel through the lines. However, the low pressure between the pump and the fuel tank, in combination with heat from the engine and/or hot weather, can cause the fuel to vaporize in the supply line. This results in fuel starvation as the fuel pump, designed to pump liquid, not vapor, is unable to suck more fuel to the engine, causing the engine to stall. This condition is different from vapor lock, where high engine heat on the pressured side of the pump (between the pump and the carburetor) boils the fuel in the lines, also starving the engine of enough fuel to run. Mechanical automotive fuel pumps generally do not generate much more than 10-15 psi, which is more than enough for most carburetors.

Decline of mechanical pumps:

As engines moved away from carburetors and towards fuel injection, mechanical fuel pumps were replaced with electric fuel pumps, because fuel injection systems operate more efficiently at higher fuel pressures (40-60psi) than mechanical diaphragm pumps can generate. Electric fuel pumps are generally located in the fuel tank, in order to use the fuel in the tank to cool the pump and to ensure a steady supply of fuel.

Another benefit of an in-tank mounted fuel pump is that a suction pump at the engine could suck in air through a (difficult to diagnose) faulty hose connection, while a leaking connection in a pressure line will show itself immediately. A potential hazard of a tank-mounted fuel pump is that all of the fuel lines are under high pressure, from the tank to the engine. Any leak will be easily detected, but is also hazardous.

Electric fuel pumps will run whenever they are switched on, which can lead to extremely dangerous situations if there is a leak due to mechanical fault or an accident. Mechanical fuel pumps are much safer, due to their lower operating pressures and because they 'turn off' when the engine stops running.

Electric pump:

In many modern cars the fuel pump is usually electric and located inside the fuel tank. The pump creates positive pressure in the fuel lines, pushing the gasoline to the engine. The higher gasoline pressure raises the boiling point. Placing the pump in the tank puts the component least likely to handle gasoline vapor well (the pump itself) farthest from the engine, submersed in cool liquid. Another benefit to placing the pump inside the tank is that it is less likely to start a fire. Though electrical components (such as a fuel pump) can spark and ignite fuel vapors, liquid fuel will not explode (see explosive limit) and therefore submerging the pump in the tank is one of the safest places to put it. In most cars, the fuel pump delivers a constant flow of gasoline to the engine; fuel not used is returned to the tank. This further reduces the chance of the fuel boiling, since it is never kept close to the hot engine for too long.

The ignition switch does not carry the power to the fuel pump; instead, it activates a relay which will handle the higher current load. It is common for the fuel pump relay to become oxidized and cease functioning; this is much more common than the actual fuel pump failing. Modern engines utilize solid-state control which allows the fuel pressure to be controlled via pulse-width modulation of the pump voltage. This increases the life of the pump, allows a smaller and lighter device to be used, and reduces electrical load.

Cars with electronic fuel injection have an electronic control unit (ECU) and this may be programmed with safety logic that will shut the electric fuel pump off, even if the engine is running. In the event of a collision this will prevent fuel leaking from any ruptured fuel line. Additionally, cars may have an inertia switch (usually located underneath the front passenger seat) that is "tripped" in the event of an impact, or a roll-over valve that will shut off the fuel pump in case the car rolls over.

Some ECUs may also be programmed to shut off the fuel pump if they detect low or zero oil pressure, for instance if the engine has suffered a terminal failure (with the subsequent risk of fire in the engine compartment).

The fuel sending unit assembly may be a combination of the electric fuel pump, the filter, the strainer, and the electronic device used to measure the amount of fuel in the tank via a float attached to a sensor which sends data to the dash-mounted fuel gauge. The fuel pump by itself is a relatively inexpensive part. But a mechanic at a garage might have a preference to install the entire unit assembly.

Turbo pump:

Many jet engines, including rocket engines use a turbopump which is a centrifugal pump usually propelled by a gas turbine or in some cases a ram-air device.

Drive system:

A **drive shaft**, **driveshaft**, **driving shaft**, **propeller shaft** (**prop shaft**), or **Cardan shaft** is a mechanical component for transmitting torque and rotation, usually used to connect other components of a drive train that cannot be connected directly because of distance or the need to allow for relative movement between them.

Drive shafts are carriers of torque: they are subject to torsion and shear stress, equivalent to the difference between the input torque and the load. They must therefore be strong enough to bear the stress, whilst avoiding too much additional weight as that would in turn increase their inertia.

To allow for variations in the alignment and distance between the driving and driven components, drive shafts frequently incorporate one or more universal joints, jaw couplings, or rag joints, and sometimes a splined joint or prismatic joint.

Front-engine, rear-wheel drive:

In front-engined, rear-drive vehicles, a longer drive shaft is also required to send power the length of the vehicle. Two forms dominate: The torque tube with a single universal joint and the more common Hotchkiss drive with two or more joints. This system became known as SystèmePanhard after the automobile company PanhardetLevassor patented it.

Most of these vehicles have a clutch and gearbox (or transmission) mounted directly on the engine with a drive shaft leading to a final drive in the rear axle. When the vehicle is stationary, the drive shaft does not rotate. A few, mostly sports, cars seeking improved weight balance between front and rear, and most commonly Alfa Romeos or Porsche 924s, have instead used a rear-mounted transaxle. This places the clutch and transmission at the rear of the car and the drive shaft between them and the engine. In this case the drive shaft rotates continuously as long as the engine does, even when the car is stationary and out of gear.

Early automobiles often used chain drive or belt drive mechanisms rather than a drive shaft. Some used electrical generators and motors to transmit power to the wheels.

Front-wheel drive:

In British English, the term "drive shaft" is restricted to a transverse shaft that transmits power to the wheels, especially the front wheels. A drive shaft connecting the gearbox to a rear differential is called a **propeller shaft**, or **prop-shaft**. A prop-shaft assembly consists of a propeller shaft, a slip joint and one or more universal joints. Where the engine and axles are separated from each other, as on four-wheel drive and rear-wheel drive vehicles, it is the propeller shaft that serves to transmit the drive force generated by the engine to the axles.

A drive shaft connecting a rear differential to a rear wheel may be called a **half shaft**. The name derives from the fact that two such shafts are required to form one rear axle.

Several different types of drive shaft are used in the automotive industry:

- One-piece drive shaft
- Two-piece drive shaft
- Slip-in-tube drive shaft

The slip-in-tube drive shaft is a new type that also helps in crash energy management. It can be compressed in the event of a crash, so is also known as a collapsible drive shaft.

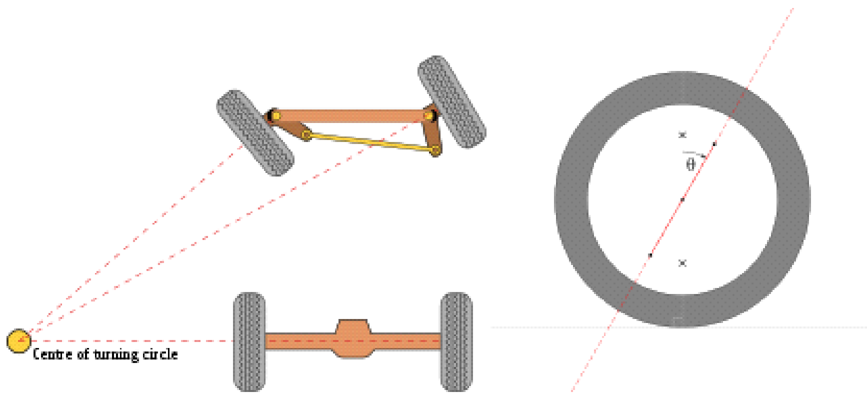
Four wheel and all-wheel drive:

These evolved from the front-engine rear-wheel drive layout. A new form of transmission called the transfer case was placed between transmission and final drives in both axles. This split the drive to the two axles and may also have included reduction gears, a dog clutch or differential. At least two drive shafts were used, one from the transfer case to each axle. In some larger vehicles, the transfer box was centrally mounted and was itself driven by a short drive shaft. In vehicles the size of a Land Rover, the drive shaft to the front axle is noticeably shorter and more steeply articulated than the rear shaft, making it a more difficult engineering problem to build a reliable drive shaft, and which may involve a more sophisticated form of universal joint.

Modern light cars with all-wheel drive (notably Audi or the Fiat Panda) may use a system that more closely resembles a front-wheel drive layout. The transmission and final drive for the front axle are combined into one housing alongside the engine, and a single drive shaft runs the length of the car to the rear axle. This is a favoured design where the torque is biased to the front wheels to give car-like handling, or where the maker wishes to produce both four-wheel drive and front-wheel drive cars with many shared components

Steering:

Steering is the term applied to the collection of components, linkages, etc. which will allow a vessel (ship, boat) or vehicle (car, motorcycle, bicycle) to follow the desired course. An exception is the case of rail transport by which rail tracks combined together with railroad switches (and also known as 'points' in British English) provide the steering function.



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Power steering:

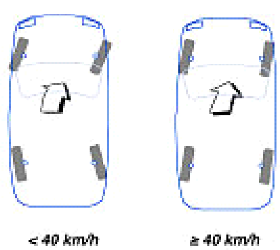
Power steering helps the driver of a vehicle to steer by directing some of the its power to assist in swivelling the steered roadwheels about their steering axes. As vehicles have become heavier and switched to front wheel drive, particularly using negative offset geometry, along with increases in tire width and diameter, the effort needed to turn the wheels about their steering axis has increased, often to the point where major physical exertion would be needed were it not for power assistance. To alleviate this auto makers have developed power steering systems: or more correctly power-assisted steering—on road going vehicles there has to be a mechanical linkage as a fail safe. There are two types of power steering systems; hydraulic and electric/electronic. A hydraulic-electric hybrid system is also possible.

A hydraulic power steering (HPS) uses hydraulic pressure supplied by an engine-driven pump to assist the motion of turning the steering wheel. Electric power steering (EPS) is more efficient than the hydraulic power steering, since the electric power steering motor only needs to provide assistance when the steering wheel is turned, whereas the hydraulic pump must run constantly.

Speed Sensitive Steering:

An outgrowth of power steering is speed sensitive steering, where the steering is heavily assisted at low speed and lightly assisted at high speed. The auto makers perceive that motorists might need to make large steering inputs while manoeuvering for parking, but not while traveling at high speed. The first vehicle with this feature was the Citroën SM with its Diravi layout although rather than altering the amount of assistance as in modern power steering systems, it altered the pressure on a centring cam which made the steering wheel try to "spring" back to the straight-ahead position. Modern speed-sensitive power steering systems reduce the mechanical or electrical assistance as the vehicle speed increases, giving a more direct feel. This feature is gradually becoming more common.

Four-wheel steering:



Four-wheel steering (or all-wheel steering) is a system employed by some vehicles to improve steering response, increase vehicle stability while maneuvering at high speed, or to decrease turning radius at low speed.

Active four-wheel steering:

In an active four-wheel steering system, all four wheels turn at the same time when the driver steers. In most active four-wheel steering systems, the rear wheels are steered by a computer and actuators. The rear wheels generally cannot turn as far as the front wheels. There can be controls to switch off the rear steer and options to steer only the rear wheel independent of the front wheels. At low speed (e.g. parking) the rear wheels turn opposite of the front wheels, reducing the turning radius by up to twenty-five percent, sometimes critical for large trucks or tractors and vehicles with trailers, while at higher speeds both front and rear wheels turn alike (electronically controlled), so that the vehicle may change position with less yaw, enhancing straight-line stability. The "Snaking effect" experienced during motorway drives while towing a travel trailer is thus largely nullified.

rab steering:

Crab steering is a special type of active four-wheel steering. It operates by steering all wheels in the same direction and at the same angle. Crab steering is used when the vehicle needs to proceed in a straight line but under an angle (i.e. when moving loads with a reach truck, or during filming with a camera dolly), or when the rear wheels may not follow the front wheel tracks (i.e. to reduce soil compaction when using rolling farm equipment).

Passive rear wheel steering:

Many modern vehicles offer a form of passive rear steering to counteract normal vehicle tendencies. For example, Subaru used a passive steering system to correct for the rear wheel's tendency to toe-out. On many vehicles, when cornering, the rear wheels tend to steer slightly to the outside of a turn, which can reduce stability. The passive steering system uses the lateral forces generated in a turn (through suspension geometry) and the bushings to correct this tendency and steer the wheels slightly to the inside of the corner. This improves the stability of the car, through the turn. This effect is called compliance understeer and it, or its opposite, is present on all suspensions. Typical methods of achieving compliance understeer are to use a Watt's Link on a live rear axle, or the use of toe control bushings on a twist beam suspension. On an independent rear suspension it is normally achieved by changing the rates of the rubber bushings in the suspension. Some suspensions will always have compliance oversteer due to geometry, such as Hotchkiss live axles or a semi-trailing arm IRS.

Passive rear wheel steering is not a new concept, as it has been in use for many years, although not always recognised as such. For example, Jaguar independent rear suspension incorporated a small amount of passive rear wheel steering since 1961.

Articulated steering:

Articulated steering is a system by which a four-wheel drive vehicle is split into front and rear halves which are connected by a vertical hinge. The front and rear halves are connected with one or more hydraulic cylinders that change the angle between the halves, including the front and rear axles and wheels, thus steering the vehicle. This system does not use steering arms, king pins, tie rods, etc. as does four-wheel steering. If the vertical hinge is placed equidistant between the two axles, it also eliminates the need for a central differential, as both front and rear axles will follow the same path, and thus rotate at the same speed. Long road trains, articulated buses, and internal transport trolley trains use articulated steering to achieve smaller turning circles, comparable to those of shorter conventional vehicles. Articulated haulers have very good off-road performance.

Rear wheel steering:

A few types of vehicle use only rear wheel steering, notably fork lift trucks, camera dollies, early pay loaders, Buckminster Fuller's Dymaxion car, and the ThrustSSC.

Rear wheel steering tends to be unstable because in turns the steering geometry changes hence decreasing the turn radius (oversteer), rather than increase it (understeer). A rear wheel steered automobile exhibits non-minimum phasebehavior.It turns in the direction opposite of how it is initially steered. A rapid steering input will cause two accelerations, first in the direction that the wheel is steered, and then in the opposite direction: a "reverse response." This makes it harder to steer a rear wheel steered vehicle at high speed than a front wheel steered vehicle.

Vehicle brake

A **vehicle brake** is a brake used to slow down a vehicle by converting its kinetic energy into heat. The basic hydraulic system, most commonly used, usually has six main stages. The brake pedal, the brake boost (vacuum servo), the master cylinder, the apportioning valves and finally the roadwheel brakes themselves.

Types of brake:

1.Friction brake

1.1 Drum brake

1.2 Disc brake

2. Electromagnetic brake

3.Air brake

Friction brake

A friction brake is a type of automotive brake that slows or stops a vehicle by converting kinetic energy into heat energy, via friction. The heat energy is then dissipated into the atmosphere. In most systems, the brake acts on the vehicle's roadwheel hubs, but some vehicles use brakes which act on the axles or transmission. Friction brakes may be of either drum or disc type.

Drum brake

A drum brake is a brake in which the friction is caused by a set of brake shoes that press against the inner surface of a rotating drum. The drum is connected to the rotating roadwheel hub.

Disc brake

The disc brake is a device for slowing or stopping the rotation of a road wheel. A brake disc (or rotor in U.S. English), usually made of cast iron or ceramic, is connected to the wheel or the axle. To stop the wheel, friction material in the form of brake pads (mounted in a device called a brake caliper) is forced mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc. Friction causes the disc and attached wheel to slow or stop.

Electromagnetic brake

Electromagnetic brakes slow an object through electromagnetic induction, which creates resistance and in turn either heat or electricity. Friction brakes apply pressure on two separate objects to slow the vehicle in a controlled manner.

Air brake:

Air brakes or more formally a **compressed air brake system** is a type of friction brake for vehicles in which compressed air pressing on a piston is used to apply the pressure to the brake pad needed to stop the vehicle. Air brakes are used in large heavy vehicles, particularly those having multiple trailers which must be linked into the brake system, such as trucks, buses, trailers, and semi-trailers in addition to their use in railroad trains.

Anti – lock braking system:

An **anti-lock braking system** (**ABS**) is an automobile safety system that allows the wheels on a motor vehicle to continue interacting tractively with the road surface as directed by driver steering inputs while braking, preventing the wheels from locking up (that is, ceasing rotation) and therefore avoiding skidding

Regenerative brake

A regenerative brake **is an energy recovery mechanism which slows a vehicle or object down by converting its kinetic energy into another form, which can be either used immediately or stored until needed. This contrasts with conventional braking systems, where the excess kinetic energy is converted to heat by friction in the brake linings and therefore wasted.**

Engine control unit (electricalsystem):

An **engine control unit (ECU)**, most commonly called the powertrain control module (PCM), is a type of electronic control unit that controls a series of actuators on an internal combustion engine to ensure the optimum running. It does this by reading values from a multitude of sensors within the engine bay, interpreting the data using multidimensional performance maps (called Look-up tables), and adjusting the engine actuators accordingly.

Control of Air/Fuel ratio:

For an engine with fuel injection, an engine control unit (ECU) will determine the quantity of fuel to inject based on a number of parameters. If the Throttle position sensor is showing the throttle pedal is pressed further down, the Mass flow sensor will measure the amount of additional air being sucked into the engine and the ECU will inject more fuel into the engine. If the Engine coolant temperature sensor is showing the engine has not warmed up yet, more fuel will be injected (causing the engine to run slightly 'rich' until the engine warms up). Mixture control on computer controlled carburetors works similarly but with a mixture control solenoid or stepper motor incorporated in the float bowl of the carburetor..

Control of ignition timing:

A spark ignition engine requires a spark to initiate combustion in the combustion chamber. An ECU can adjust the exact timing of the spark (called ignition timing) to provide better power and economy. If the ECU detects knock, a condition which is potentially destructive to engines, and "judges" it to be the result of the ignition timing being too early in the compression stroke, it will delay (retard) the timing of the spark to prevent this. Since knock tends to occur more easily at lower rpm, the ECU controlling an automatic transmission will often downshift into a lower gear as a first attempt to alleviate knock.

Control of idle speed:

Most engine systems have idle speed control built into the ECU. The engine RPM is monitored by the crankshaft position sensor which plays a primary role in the engine timing functions for fuel injection, spark events, and valve timing. Idle speed is controlled by a programmable throttle stop or an idle air bypass control stepper motor. Early carburetor-based systems used a programmable throttle stop using a bidirectional DC motor. Early TBI systems used an idle air control stepper motor. Effective idle speed control must anticipate the engine load at idle. Changes in this idle load may come from HVAC systems, power steering systems, power brake systems, and electrical charging and supply systems. Engine temperature and transmission status, and lift and duration of camshaft also may change the engine load and/or the idle speed value desired.

A full authority throttle control system may be used to control idle speed, provide cruise control functions and top speed limitation.

Control of variable valve timing:

Some engines have Variable Valve Timing. In such an engine, the ECU controls the time in the engine cycle at which the valves open. The valves are usually opened sooner at higher speed than at lower speed. This can optimize the flow of air into the cylinder, increasing power and economy.

Electronic valve control;

Experimental engines have been made and tested that have no camshaft, but have full electronic control of the intake and exhaust valve opening, valve closing and area of the valveopening.Such engines can be started and run without a starter motor for certain multi-cylinder engines equipped with precision timed electronic ignition and fuel injection. Such a static-start engine would provide the efficiency and pollution-reduction improvements of a mild hybrid-electric drive, but without the expense and complexity of an oversized starter motor.

The first production engine of this type was invented (in 2002) and introduced (in 2009) by Italian automaker Fiat in the Alfa RomeoMiTo. Their Multiair engines use electronic valve control which drastically improve torque and horsepower, while reducing fuel consumption as much as 15%. Basically, the valves are opened by hydraulic pumps, which are operated by the ECU. The valves can open several times per intake stroke, based on engine load. The ECU then decides how much fuel should be injected to optimize combustion.

For instance, when driving at a steady speed, the valve will open and a bit of fuel will be injected, the valve then closes. But, when you suddenly stamp on the throttle, the valve will open again in that same intake stroke and much more fuel will be injected so that you start to accelerate immediately. The ECU then calculates engine load at that exact RPM and decides how to open the valve: early, or late, wide open, or just half open. The optimal opening and timing are always reached and combustion is as precise as possible. This, of course, is impossible with a normal camshaft, which opens the valve for the whole intake period, and always to full lift.

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