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An Introduction to the Automobile

This chapter discusses the development of the automobile in a chronological order, the main components and sub-assemblies, and various design considerations.

Main topics :

- **Development of the Automobile**
- **General Classification of Automobiles**
- **Main Assembles of Automobile**
- **Engine Position**
- **Drive Arrangements**
- **Vehicle Design Considerations**

1.1. Development of the Automobile

The progress of means for transportation has been intimately associated with the progress of civilisation. Transportation on land has evolved from the slow moving oxcart to the high-speed automobile. A self-propelled vehicle used for transportation of goods and passengers on land is called an automobile or automotive or motor vehicle. In general, modern automobile is a complex piece of machinery performing in a safe, economical and efficient manner. It is comprised of a chassis and a body. The chassis is made up of a frame supporting body, power unit, clutch or fluid coupling, transmission system and control systems. Wheels and tyres through suspension system and axles support the frame. The power delivered by the power unit (engine) is transmitted through the clutch or fluid coupling, transmission system, and axles to the wheels. The automobile is propelled on road due to friction between the tyre and road surface. The various sub-systems are properly designed and held together for efficient functioning individually as well as a whole unit. The protection and comfort is provided by the body and the suspension system. The automobile has its limitations in regard to the load it can carry and the speed as well as the distance it can carry the load.

Construction of any vehicle requires a prime mover able to move itself, together with the vehicle structure and the pay load. Since the power needed to move the mass m at a speed V on a level surface with coefficient of friction (sliding or rolling) μ is equal to $P = m\, g\, \mu\, V$, it is easy to conclude that the minimum value of the power mass ratio of a prime mover able to move itself is

$$\frac{P}{m} = \frac{g\, \mu\, V}{\eta\, \alpha},$$

where α is the ratio between the mass of the engine and the total mass of the vehicle and η is the total efficiency of the mechanism, which transfers the power and propels the vehicle.

Prime movers with an adequate power/mass ratio were practically not available until the 19th century, and this consideration is sufficient to explain why ground vehicles with mechanical propulsion appeared only quite recently in the history of human civilization. The development of a suitable prime mover is, however, not sufficient for the construction of successful automobile. The problems related to the construction of suitable transmission, propulsion, control and guidance systems must be successfully solved as well.

Captain Nicholas Cugnot, a Frenchman is considered to be the father of the "Automobile". Steam engines were used as the power plant in first self-propelled vehicles. In 1769, the steam engine operated Cugnot's artillery tractor was first built in France. It had a three-wheeled coach. The speed of this vehicle was 5 km per hour with a cruising range of about 13 km. In 1802, the first practical steam automobile was built by Richard Trevitluck of England using a crankshaft, for the first time. In 1805, Oliver Evan's operated his Evan's Amphibian for the first time in Philadelphia, America. This vehicle was designed with four wheels and the body was in the form of a flat boat. In 1821, Julis Griffith of England built the first comfortable steam powered vehicle. Two outstanding successes in America were the Stanley Steamer and the White Steam Car, introduced in 1895 and 1902 respectively. Both of these automobiles gave excellent performance. The Stanley Steamer is credited with being the first self-propelled vehicle to attain a road speed of 160 km per hour.

The development of the internal combustion engine changed radically the history of motor vehicle production. Belgium inventor, Elenne Lenoir, in 1860, demonstrated first time, the operation of internal combustion engine. The French engineer, Beau-de-Rcohas in 1862 laid down the conditions, which must prevail in order to obtain maximum efficiency. The automobile propelled by gas engine was built in 1863 by Lenoir who drove his vehicle for about 11 km. The vehicle used a one-cylinder engine using lighting gas. In 1876, Otto embodied these principles in an actual engine. He put a new type of engine into commercial production using coal gas as the fuel and working on four-stroke cycles, known as 'Otto cycle'. Dugald Clark invented an engine in 1880 based on two-stroke cycle. And modern two-stroke engines appeared in 1891 due to Day. Gottlieb Daimler in Germany patented an internal combustion engine in 1885-86 and installed this engine in a bicycle. In 1986, Carl Benz of Germany also built a three wheeled carriage or tricycle (Fig. 1.1) propelled by an internal combustion engine working on Otto cycle. It attained a speed of 16 km per hour and produced approximately 6 kW power. Daimler's engine is the first high speed, light construction power unit producing 800 to 1000 rpm in contrast to earlier heavier gas engines, which could run at 150 to 200 rpm. Almost in the same period a Frenchman, Fernand Forest, built a four-cylinder engine and is also credited with the development of a carburettor.

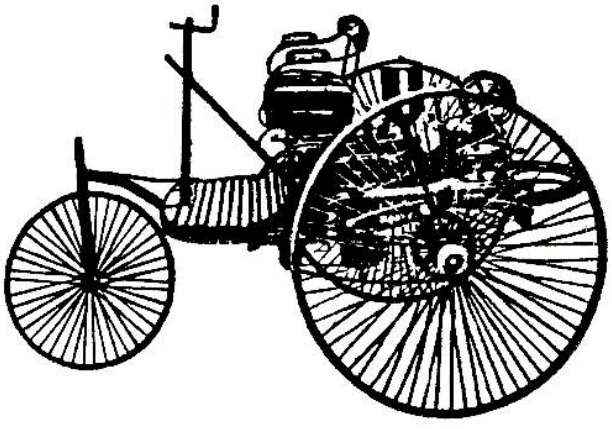


Fig. 1.1. A tricycle built by Carl Benz.

The patent rights to Dailmer's light and fast engine were granted to M.Levassor of Panhard and Levassor. This Frenchman developed entirely a new type of vehicle in 1894. The engine was placed in front of a chassis, hooked up to a clutch, a sliding gear transmission and differential. The vehicle also incorporated brake pedals and an accelerator.

Around the turn of the century, gasoline automobiles had stiff competition with steam and electric automobiles. The steam and electrically powered automobile had the advantage of an abundance of power at low speed, making a transmission unnecessary. The danger of high-pressure steam boilers and the inconvenience of recharging electric batteries reduced their popularity. On the other hand, the gasoline-powered vehicle, despite the necessity of the transmission, had the advantage of producing a large amount of power from a small quantity of fuel and the fuel required could be replenished easily and quickly.

Charles E. Duryea and his brother Frank Duryea, of Massachusetts, successfully operated the first gasoline-powered vehicle in America on 12^{th} September 1892. The vehicle was propelled by a 4-horse power (2.9 kW) gasoline motor. It was known as the "horseless bugg". In 1895, Henry Ford started the construction of the 'quadricycle', which was driven by a two-cylinder gasoline engine. In this year 300 cars were produced in USA. In the year 1900, the first front-mounted power units were constructed at Columbia. In 1901, Oldsmobile began the production of its framed curved-dash automobile. The Cadillac Company came in 1902. In 1903 the Brick Motor Company and the Ford Motor Car Company were established and the Packard Company shifted to Detroit. In this year, Cadillac produced 1,895 units and Oldsmobile 4,000 units. Brick produced 750 cars in 1905. In 1908, Ford put 20,000 vehicles of his Model T on the roads.

From the year 1900 onwards, the improved design of automobiles fully awakened the public to the greater utilities of this new form of transportation. During 1900 to 1906, the production and sales of these vehicles become a real business. In America alone, there were 121 car manufacturers. The years that followed 1906 to 1920 are considered the era of mass production and interchange-ability methods permitting lower price production. The mass production of automobiles is a masterpiece of skill and organisation. Henry Ford in America is credited with developing some of the earliest mass production methods. In England, William Morris employed similar methods in the early 1920 in order to market a low priced motorcar.

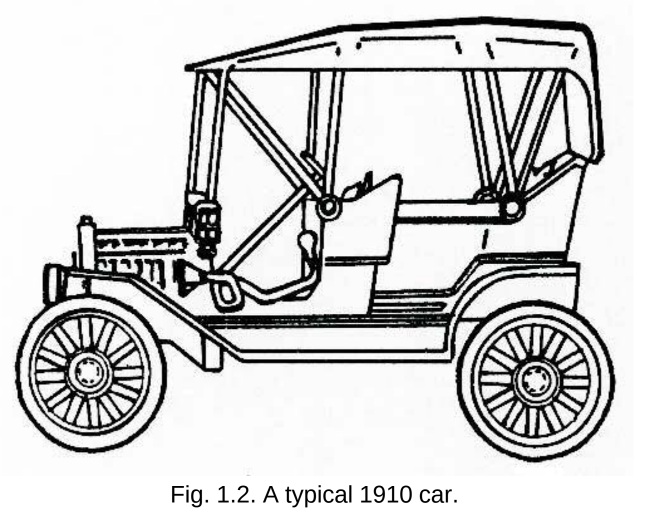


Fig. 1.2. A typical 1910 car.

With the year 1920 began the period of gradual change and refinement in the automobile design. The electric self-starter was introduced in this period. The advent of World War I (1914-18) necessitated the rapid development of the automobiles to take over the job of transport and even to serve as fighting units. After the World War I, automobile manufacturers concentrated on the refinement of power units and all automotive components for the next twenty years. The spark ignition gasoline engine was the power plant of motor vehicle. The engine made was compact, light, high speed, perfectly balanced and free from vibration, streamlined, air or water cooled, noiseless and capable of running on different fuels. The steam and electric engines were no more in use. The engine was located in the front of the chassis. The sliding gear transmission and poppet valve had established their utility for every engine design. The main changes had been the increased tyre life, replacement of rigid front axle with independent front wheel suspension, four-wheel hydraulic brakes, and increased engine compression ratios and use of stronger and cheaper materials. The internal combustion engines powered the armed services of all World Powers during World War II (1939-45).

Ackroyd-Stuart, an Englishman and Rudolf Diesel, a German developed the diesel engine around 1890. However, only in 1927 it was realised that diesel engines had some advantages over petrol engines, such as lower fuel costs, reduced maintenance costs, low fire risk and more uniform torque over a wide range of engine speeds. High thermal efficiency is the primary reason why almost all commercial vehicles in the medium to heavy range are powered by diesel engines. Despite their low output in terms of both power per litre and per kg, which translates into higher initial cost and greater bulk and weight for a given power output, diesel engines still offer lower overall cost of operation. Although the first diesel vehicle on the roads of the UK was a Mercedes lorry in 1928, the first diesel car in series production was the 1936 Mercedes 260D. In the meantime, one diesel powered vehicle, the Bentley, competed in the RAC Rally in 1932 at an average speed of 128 km/h. In mid 1970s Volkswagen fitted 1.5 litre indirect injection engine (IDI) to the Golf (Rabbit in the US). This development was really the derivative of a petrol engine. It used a toothed belt to drive both its overhead camshaft and its distribution type fuel injection pump. The engine had a specific power output of 25 kW per litre. The French manufacturers, Peugeot-Citroen and Renault, were quick to follow with some excellent diesel vehicles in the 1980s. In 1997 in the USA, there were virtually no diesel-powered cars but, with the steady rise in fuel cost and fears of a fuel shortage following the 1973 oil crisis, the market for diesel-powered vehicles expanded rapidly. By 1981, however, fuel prices were dropping again, and the demand for the diesel cars fail steeply. In Japan, the demand has increased steadily since about 1976.

In the past, the gasoline-fuelled engine has been more attractive for cars because it has offered much better acceleration and top speed. This has been because not only the specific power of the diesel engine is inferior, but also it is heavier and more bulky, and therefore adds significantly to the overall weight of the vehicle. Other factors, which have been largely offset by improvements to diesel fuels and engines over the decade in question, include unpleasant smell, noise, problems in very cold weather, etc. However, the weight problem has been greatly ameliorated by the use of turbo-charging, which can be applied to better advantage to diesel than gasoline engines.

With the increasing application of turbo-charging and other advances, specific power outputs have been improved, and engines operating over wider speed ranges and that are quieter have been developed. Furthermore, as production quantities have increased, prime costs have fallen. Exhaust smoke, often quoted as a disadvantage, can be totally eliminated by rigorous control over the adjustment of the fuelling system. Improvements in both diesel fuels and additives have helped to overcome the problems of noise, smell and cold weather operation. Consequently, objections to diesel power for cars have been rendered irrelevant. Mercedes-Benz, Peugeot and Volkswagen were the pioneers in the introduction of turbochargers to passenger car diesels. However, VW Golf introduced the most successful package on the Golf. Indeed, by the end of the decade 1980-1990, there were diesel cars on the road capable of running at 192 km/h with accelerations comparable to those of gasoline-powered cars. A good example is the 1991 Citroen XM powered by the 2.1 litre turbocharged diesel engine compared with the 2.0 litres carburettor and injection engines respectively. From the environmental viewpoint, the diesel engine emits less than a third of the HC, about 1% of the CO and 30% less CO_2 than do gasoline engines. It has, however, a tendency to emit particulates and higher proportions of NO_x. In addition to turbo-charging, the 1990s saw the wide spread adoption of many new features such as inter-cooling, exhaust gas recirculation (EGR), multi-valve cylinder head and diesel oxidation catalysts. Direct injection (DI) technology and electronic injection control were very important introductions.

In India the first motorcar was imported in 1898 and it was continued for about 50 years thereafter. Sri M Visveswaraya made an attempt for the establishment of an automobile industry in 1935 and the Government did not approve the plan. The first automobile factory in India, Hindustan Motors Limited (Calcutta) was set up in the year 1947 and then came Premier Automobiles Limited (Bombay) in 1948. They were initially producing cars. On the recommendation of the Tariff Commissions, in 1953 the Government of India discouraged the activities of assemblers, established at Bombay, Calcutta and Madras by leading foreign manufacturers, to ensure economic output of the automobiles and provided a further protection to the industry in 1956 with priority for manufacture of commercial vehicle, expansion of capacity of existing units and increased production of diesel vehicles. Both defence vehicles and civil vehicles were produced in India. By April 1971, the number of vehicles on Indian roads was above 16 lakhs. Maruti Udyog Limited, the only public undertaking company came up during 1979 in collaboration with Suzuki (Japan). Within 15 years, the Indian consumer's choice of just two cars has increased to over 30 different models, and though the number is still small compared to that in the developed market, it is rapidly expanding. Probably never in the history of the automobile industry have so many car manufacturers rushed into a country, *i.e.* India, in so little time. Electric cars are projected to soon enter mass production in India, while CNG and LPG vehicles are already proliferating due to government's anti-pollution measures. Micro cars using engine of capacities around 500 cc are expected to be introduced in India soon.

The automobile of today is the culmination of many years of pioneering research and development. It is a highly complicated machine involving numerous efficient and dependable mechanical, electrical and electronic devices. In 1996 there were over 6000 automotive suppliers in over 60 countries across the world. The automobile's golden age lies ahead for the driver and the consumer. High technology inventions such as fluorescent dashboards, computerised gears, and bonnet raindrop detectors (which automatically activate the windscreen wipers) are in offering. An aerodynamically designed body covers a network of computer controls for responding to the driver's instructions, adjusting to the road conditions, and to rescue the driver from mistakes. Many luxury cars are already using microprocessor driven colour instrument panels.

Many cars use multiplex wiring using optic-fibre cables. This carries messages from more than one instrument, which enables car makers to install more controls on the steering column. Ford is using such wiring to put 10 control buttons at driver's fingertips. A touch-sensitive dashboard display screen through which the driver is able to control radio, interior temperature and trip computer by just putting a finger to the screen has been introduced in Brick car. Computer controlled active suspensions, whose rudimentary versions have already appeared on sedans by Toyota, Nissan and Mitsubishi, are the ultimate improvement in automobile handling. By pushing a button on the dashboard on a Mitsubishi version, the driver can select either a hard mode or an automatic mode to let the vehicle decide whether a hard or soft ride is most appropriate for the driving conditions. The car automatically stiffens its suspension during hard cornering or hard braking or at high speeds and makes the suspension less stiff at low speeds. By comparing the steering wheel motions and speeds, the computer controls the pumping up and deflection of air springs and the variation of distribution of fluid within shock absorbers in Mitsubishi models in order to perform the above functions. Lotus Cars Ltd. is developing a far more refined suspension system replacing springs and shock absorbers completely with hydraulic pistons. Computers adjust the car to road irregularities and cornering forces. Programmed suspensions are being used for truly exotic effects like keeping a car level while taking a turn instead of leaning over.

Computers also help to obtain finer control over engine functions resulting in greater operating efficiency. For example, the function of opening and closing of valves is expected to be taken over from mechanical crankshafts by tiny, powerful electromagnets in General Motors vehicles. This reduces engine weight and complexity. Computers also control the valve actions and maximise engine efficiency. General Motors and Ford sedans are using computers to adjust the mixture of petrol and air keeping engine efficient even if the spark plugs wear, air filters get dirty and the quality of petrol varies. It is expected that a future car might recognise the owner or driver by his/her infrared key and open its door, adjust its climate control seat, mirrors, handling and fuel economy to suit the driver person and start the engine. Some of these features have already debuted in current cars.

1.2. General Classification of Automobiles

The different types of automobiles found on roads are presented in Chart 1.1 in a comprehensive manner. There are in general three main classifications of the various types of vehicle. They are:

(*i*) Single-unit vehicles or load carriers.

(*ii*) Articulated vehicles.

(*iii*) Heavy tractor vehicles.

Chart 1.1. Classification of vehicles.

Single-unit Vehicles or Load Carriers. These vehicles are conventional four-wheel types with two-axle design in which the front axle is a steering non-driving axle and the rear axle is the driving axle. With the advancement, many changes have been incorporated in the number of axles as well as the driving system.

Articulated Vehicles. A larger powered three-wheeler with single steering wheel in front and a conventional rear-driving axle falls in this category. It can be turned about its own tail due to the three-wheel construction and has a greater handling ability in unusual places. The coupling mechanism between semi-trailer and tractor in most of these vehicles is designed for automatic connection and coupling up. A lever is provided within the driver's approach for coupling operation. A pair of retractable wheels in front can be raised or lowered automatically along with the coupling and uncoupling operation.

Heavy-tractor Vehicles. To move heavy loads tractor or independent tractor vehicles are used. They commonly operate in pair either in tendon or as puller or pusher. The latter arrangement provides stability while descending appreciable gradients.

The digital figures like 4×2, 4×4, 6×4, etc. are commonly used in the classification of vehicles, where the first figure represents the total number of wheels and the second figure the number of driving wheels. By increasing the number of axles, the load per axle can be reduced, which protects the tyres from overloading and the road surface from damage. Wheel axles are called "live" if drive and called "dead" if non-drive. A live axle supports the payload and provides driving tractive effort, whereas a dead axle just supports the load.

1.3. Motor Car

The motorcar carries passengers in the sitting position and also accommodates their luggage. Space is also provided for the engine, the transmission system, the steering, the suspension layout, and the braking system. Finally, consideration is given to the styling of the body to meet various aesthetics and application requirements.

The light motor vehicles, designed to carry passengers and sometimes goods, are broadly classified as follows :

(*i*) Saloon car (*ii*) Coupe
(*iii*) Convertible (*iv*) Estate car
(*v*) Pick-up.

Saloon Car. Saloon cars have an enclosed compartment to accommodate a row of front and row of rear seats (Fig. 1.3) without any partition between the driver and rear-passenger seats. A separate luggage space is made either at the front or the rear, based on the location of the engine. One or two doors are provided on each side of the car, but if the car is a hatchback (Fig. 1.4), a door replaces the luggage space

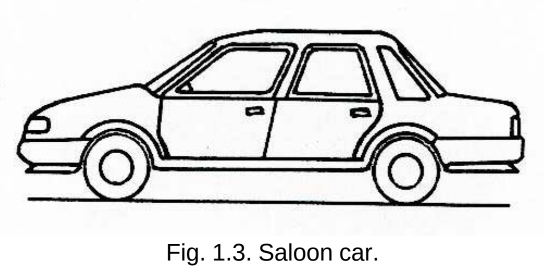


Fig. 1.3. Saloon car.

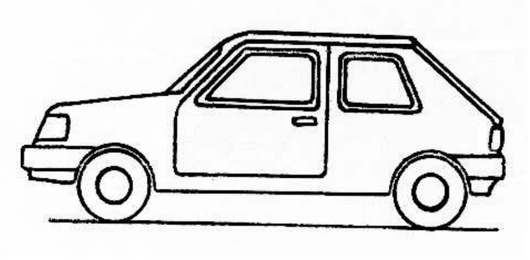


Fig. 1.4. Hatchback car.

Coupe. The couple (Fig. 1.5) is the outcome of changes is saloon-car design and has two doors, two front seats, and a hard roof. When two additional small seats are provided at the rear, the layout is known as "two-plus-two".

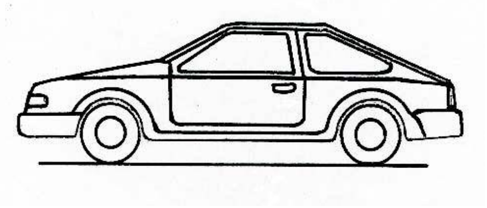


Fig. 1.5. Coupe car.

Convertible. Normally cars of this type (Fig. 1.6) have two doors and two seats, but sometimes two extra seats are also provided. Generally these have a soft folding roof and wind-up windows to make the compartment either open or closed.

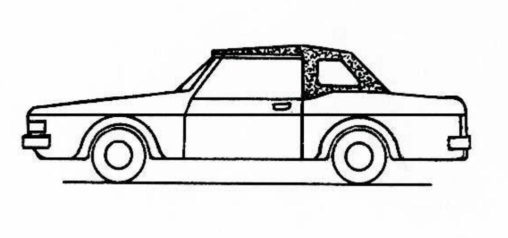


Fig. 1.6. Convertible car.

Estate Car. In this type (Fig. 1.7), the passenger roof of saloon is completely extended to the back end so that rear space is increased. For access a rear door is provided and sometimes the rear seats are designed to collapse to provide additional space for carrying goods.

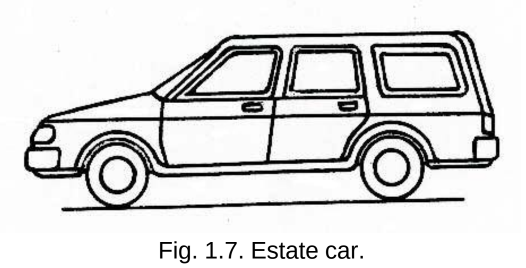


Fig. 1.7. Estate car.

Pick-up. This type of vehicle (Fig. 1.8) is generally classified as a two-door front-seating van with an open back (with or without canvas roof) to carry mixed collection of goods.

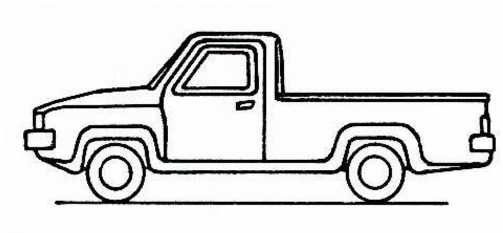


Fig. 1.8. Pick-up.

1.4. Vans

Vans are light goods vehicles used for long distances or door-to-door delivery. They have seats in the front for the driver and for only one or two passengers. The engine is usually located over or just in front of the front axle. Hinged or sliding type doors are located on each side opposite the seats. There are double doors at the rear of the van, which open outwards for easy loading. Small vans (Fig. 1.9) combine the cab and the body with integral or mono-box construction. Large vans sometimes have separate cab and body, mounted on an independent chassis frame. The rear axle may have twin road-wheels to have higher load carrying capacity.

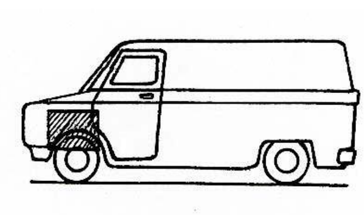


Fig. 1.9. Medium-sized van.

1.5. Coaches

Coaches (Fig. 1.10) carry passengers travelling on long distance, and hence the interior is designed to provide the best possible comfort and to minimise fatigue. Seats are located facing the front to provide passengers the benefit of looking ahead. For better visibility of passenger's large panelled windows are provided on either side extending the full length of the vehicle and across the back seats. There is a door adjacent to the driver. The passenger's doors are located opposite side of the driver's seat one towards the front and the other towards the rear. An emergency door is usually provided towards the centre on the opposite side of passenger's doors.

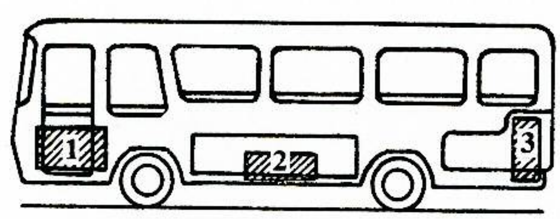


Fig. 1.10. Coach.

Most coaches have the two-axle arrangement, but sometimes an extra axle is also used at the front to have dual steering as a safety measure. As shown in the figure, engines may be mounted longitudinally is the front (position 1), or in the mid-position horizontally (position 2), or at the rear transversely (position 3). The location of the engine and transmission depends much on the length of the coach, the number of passenger seats, the luggage space, and high or low floorboard and seat-mounting requirements.

1.6. Double-decker Bus

These buses are used to transport large numbers of people having little luggage for short distances, usually in high-density traffic. The double-decker bus (Fig. 1.11) occupies the minimum amount of road space. These vehicles require a stair space for people to climb up to the upper deck (first floor).

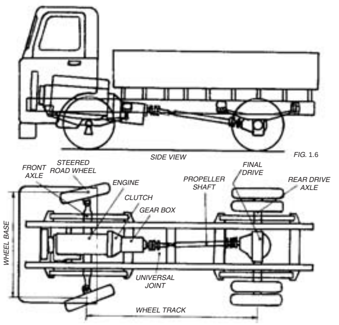


Fig. 1.11. Double-decker bus.

The ground floor of the bus is arranged for seating and standing provision of the passengers. The size and quality of seats are normally minimal due to short journeys. Visibility for passengers inside the bus is provided sufficiently so that they can see where they are and where to get off. Most modern buses have two sets of doors. Passengers can enter through the front side door and pay their fare, and can disembark by the rear side door. The engine is normally located transversely across the back of the bus or sometimes longitudinally to one side at the back.

1.7. Lorries

Commercial vehicles, used for the transportation of heavy goods, are generally referred to as lorries. These vehicles are grouped into two categories such as rigid trucks and articulated vehicles.

Rigid Trucks.

These vehicles unlike articulated vehicles are constructed to have all the axles attached to a single chassis frame. A simple truck (Fig. 1.12) has two axles and four wheels. More number of axles and wheels are added to increase load-carrying capacity.

Classification of a Rigid Truck. The number of wheel hubs and the number of drive axle hubs classifies the rigid trucks as follows:

(*a*) A four-wheeler (4 × 2) truck with two driving wheels (Fig. 1.12).

(*b*) A six-wheeler (6 × 2) truck with two driving wheels.

(*c*) A six-wheeler (6 × 4) truck with four driving wheels.

(*d*) An eight-wheeler (8 × 4) truck with four driving wheels.

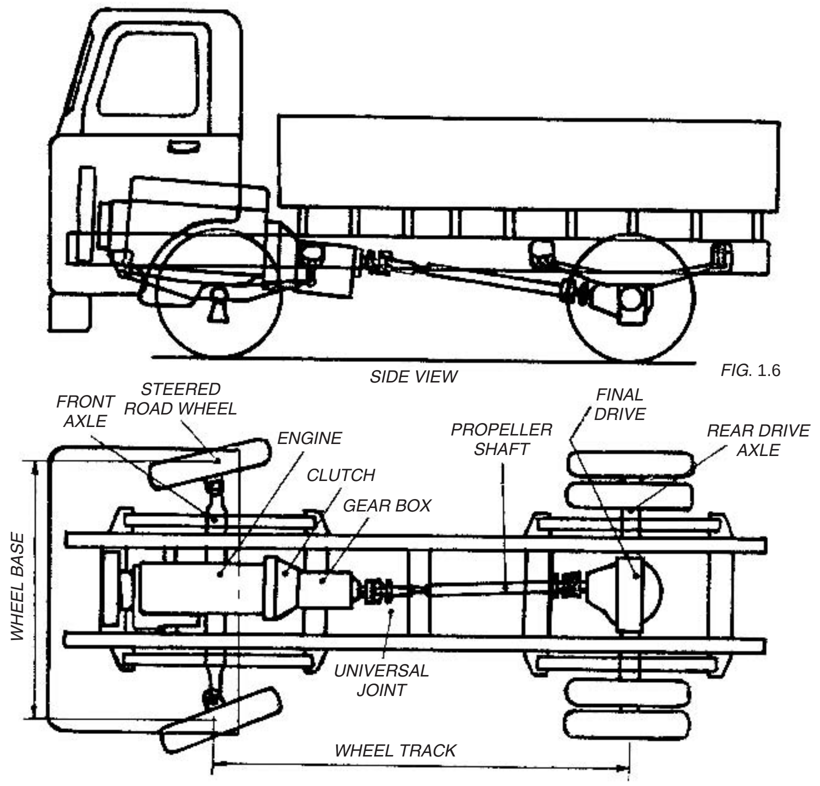


Fig. 1.12. Rigid 4 × 2 truck.

Articulated Tractor and Semi-trailer.

Articulated vehicles (Figs. 1.13) use a tractor unit for providing the propulsive power and a semi-trailer for carrying the payload. The tractor uses a short rigid chassis and two or three axles. The front axle carries the steered road-wheels, and the rear axle is the driving (live) one. The middle axle may either function as an additional drive axle or for dual steering.

The semi-trailer has a long rigid chassis with a single-axle, tandem-axle, or tri-axle layout at the rear end. All the trailer axles are dead axles. The front end of the trailer chassis is supported on the rear of the tractor chassis. At this point it is free to swivel about a pivot known as the fifth wheel coupling.

Fifth-wheel Coupling. The fifth-wheel coupling is the swivel mechanism (Fig. 1.13) used to attach the trailer to the tractor unit. It contains a turntable, fixed to the rear of the tractor unit, to support the underside front end of the trailer with a kingpin, which pivots between two half jaws. For hitching and unhitching of the trailer and the tractor, the half jaws are moved either together to secure the kingpin or apart to release it.

Classification of Articulated Vehicle. Different sizes of articulated tractor and trailer are available, which can be classified as follows.

(*i*) Four-wheeler and two-wheel trailer (rigid 4 × 2 tractor and single-axle 2 articulated trailer) (Fig. 1.13).

(*ii*) Six-wheeler tandem-drive-axle tractor and four-wheel trailer (rigid 6 × 4 tractor and tandem-axle 4 articulated trailer).

(*iii*) Six-wheeler dual-steer-axle tractor and six wheel trailer (rigid 6 × 2 tractor and tri-axle 6 articulated trailer).

Fig. 1.13. Rigid 4 × 2 tractor and single-axle 2 articulated trailers.

1.8. Main Parts of the Automobile

The modern automobile can be categorised into two distinct sub-assemblies, the body and the chassis.

The Body. The main function of the body (Fig. 1.14) is to provide comfort and protection to the passengers besides giving a good look. The body includes the passenger compartment, the trunk, the bumpers, the fenders, the radiator grill, the hood, interior trim, glass and paint. A wide variety of body styles, like two doors or four doors, sedans or hardtop, convertible or station wagons are available for each chassis model.

Fig. 1.14. A car body.

The Chassis. The chassis (Fig. 1.15) forms the complete operating unit and is capable of running with its own power. It is an assembly of a vehicle without body. The chassis includes frame, wheels, axles, springs, shock absorbers, engine, clutch, gearbox, propeller shaft and universal joints, differential and half shafts, steering, brakes and accelerator, fuel tank, storage battery, radiator, and silencer.

The engine is generally located at the front of the vehicle, followed by clutch, gear box, propeller shaft, universal joint, differential, rear axle, etc. The drive from the gearbox is transmitted through a short shaft to the front universal joint of the propeller shaft. From the propeller shaft it is conveyed to the rear wheels through a sliding splined type universal joint. The bevel gear of the short shaft is driven by the rear universal joint. This bevel gear meshes with a large bevel gear, which drives the two rear axle shafts through the differential gear.

There are two methods of body and chassis construction, the separate body and chassis construction, and the integral construction. In the separate body and chassis construction, the body is fixed to the chassis frame by means of a number of body bolts, passing through the base of the body and the frame. Pads of anti-quake or vibration materials such as rubbers are placed between the body and the frame at the bolts to prevent quakes and rattles. In the integral construction, the body and the chassis frame are combined as one eliminating the mountings. The integral construction is also called as chassis-less or unibody construction.

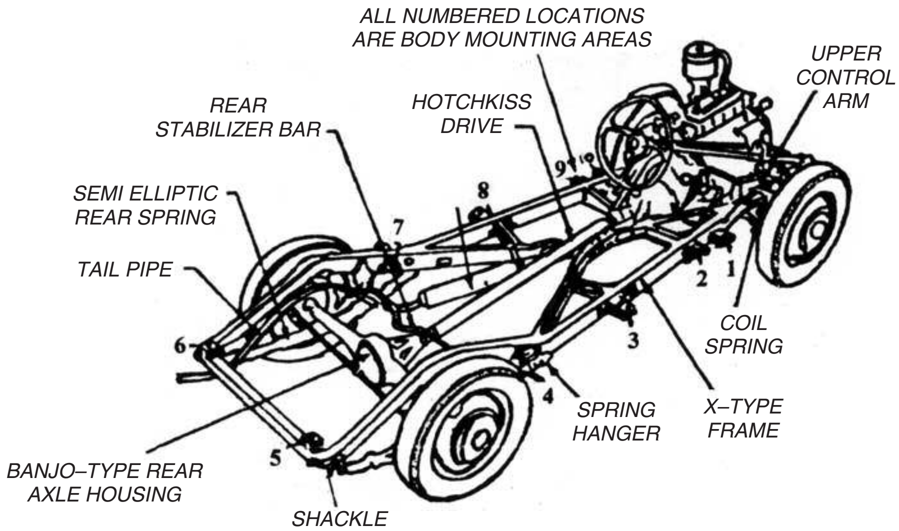


Fig. 1.15. A car chassis.

Unlike commercial vehicles, which have a separate cab attached to a chassis, car bodies are now mostly of integral construction (Fig. 1.16), which is frameless mono-box construction. These body shells are made up from pillars, rails, sills, and panels all welded together, and a reinforcing channel-section under-frame with an extended sub-frame at the front is provided to replace the chassis.

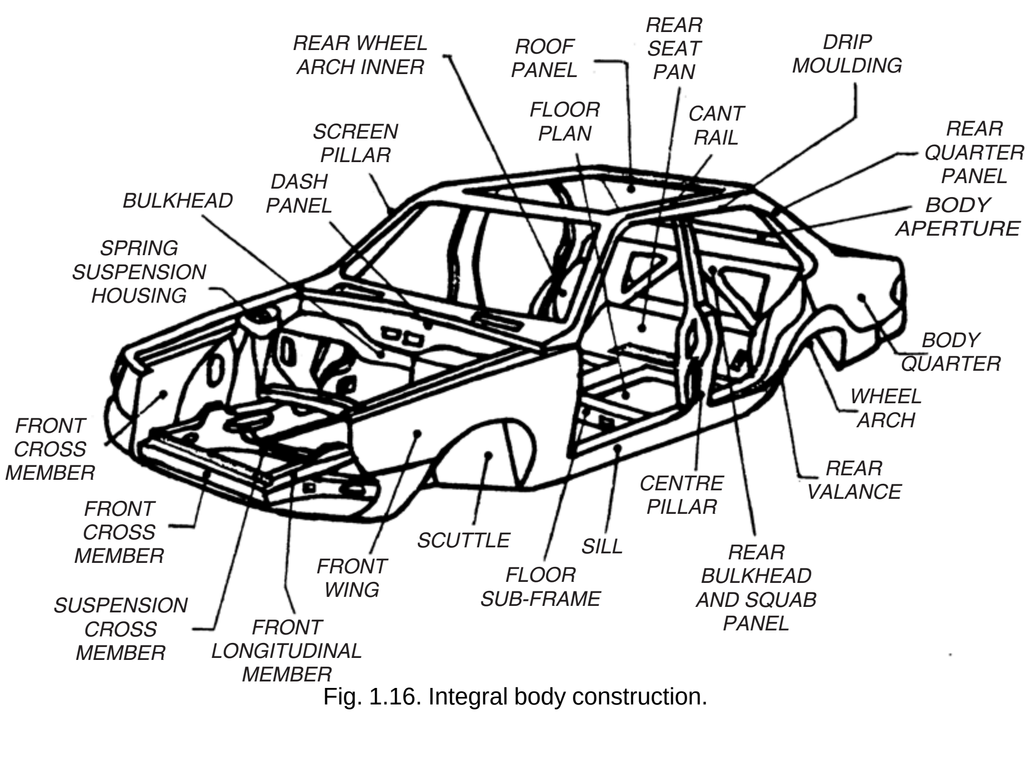


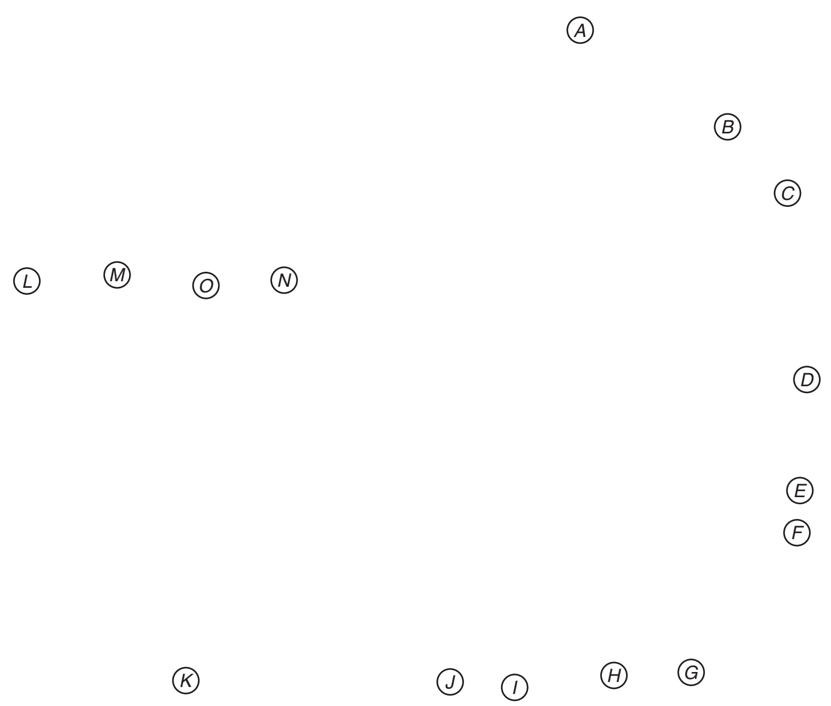
Fig. 1.16. Integral body construction.

1.9. Vehicle Assemblies

The main components of an automobile can be sub-grouped in the following assemblies (Chart 1.2).

(*i*) Engine or power plant
(*ii*) Running gear or basic structure
(*iii*) Driving system
(*iv*) Basic control system
(*v*) Electrical system
(*vi*) Accessories

Engine. The prime movers used in almost all vehicles are either gasoline (petrol) or diesel engines. Some speciality automobiles use a different type of engine. The diesel engine consumes considerably less fuel than the gasoline engine, when operated at low speeds. The rotating combustion chamber engine is gaining popularity in small cars, and its use will probably increase. Turbine engines show promise, especially in commercial vehicles. They are powerful, light weight and produce less hydrocarbons and carbons monoxide. They are ideally suited to replace diesel engines in over-the-road load carrying vehicles. Battery or electric vehicles are also being introduced to conserve fossil fuels and to minimise pollution.



A. AIR-FILTER AND SILENCER
B. OIL FILTER-CAP AND BREATHER
C. PISTON
D. DISTRIBUTOR
E. OIL PUMP
F. OIL FILTER
G. OIL SUMP
H. CAMSHAFT
I. STARTER MOTOR
J. CRANKSHAFT
K. CONNECTING ROD
L. GEAR BOX
M. CLUTCH
N. VALVE
O. FLYWHEEL

Fig. 1.17. An automobile engine with clutch and gearbox.

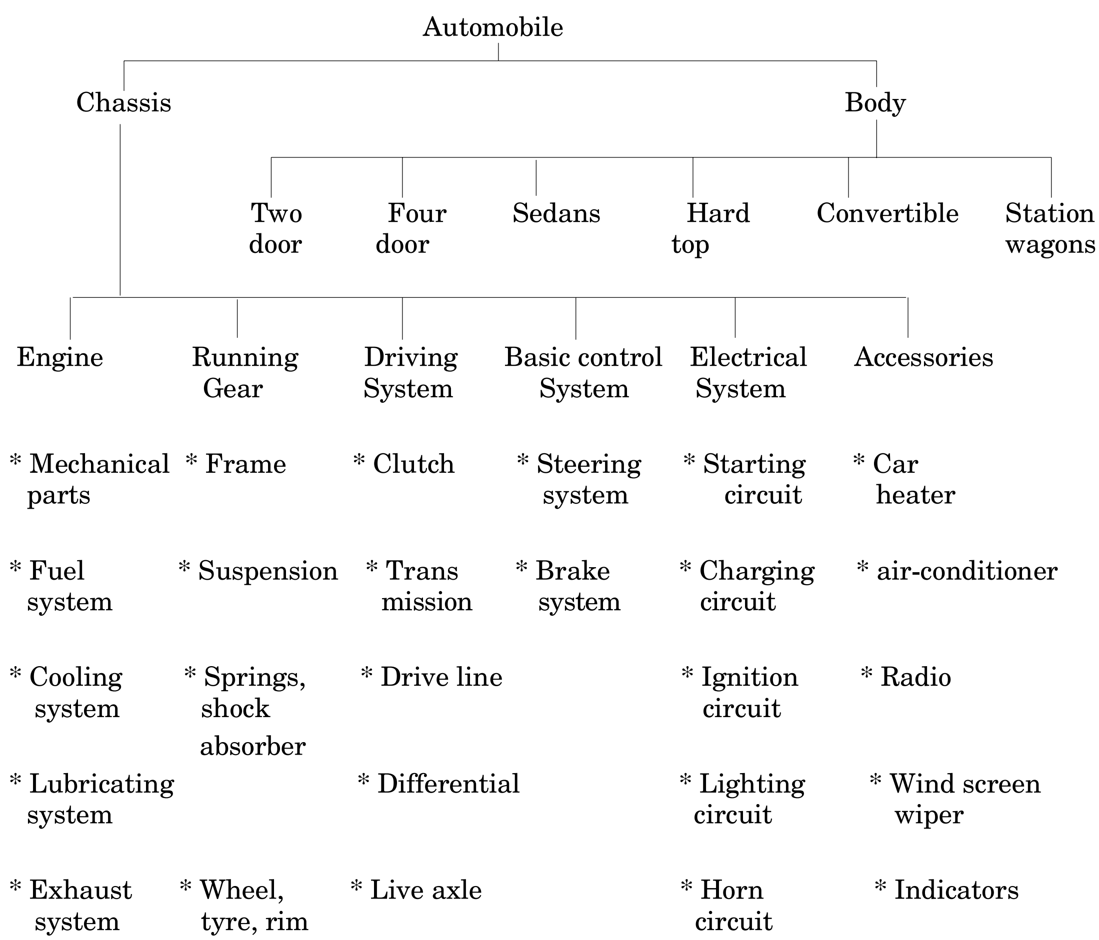
The engine is located either in the front, mid-ship or rear. Front mounted engines are more common in automobiles. The engine contains mechanical parts, fuel system, cooling system, lubricating system and exhaust system. Figure 1.17 shows an automobile engine with its clutch and gearbox. The radiator is located at the front of the engine.

Running Gear. The running gear comprises of the frame, suspension, springs, shock absorbers, wheels, rims and tyres. The tyres are the only place where the automobile touches the road. All of the engine power, steering and braking forces must operate through these tyre-to-road contact areas. Control of the vehicle is reduced or lost when the tyre does not contact the road or when skidding begins.

The suspension keeps the tyre in contact with the road as much as possible in all road conditions. The suspension system must be strong enough to resist axle twisting from high engine power and from brake reaction. The suspension system consists of springs, shock absorbers and linkages or arms.

The frame is a rigid structure that forms a skeleton to hold all the major units together. The wheels and tyre assemblies support the frame and the units are attached to it, through front and rear suspension systems so as to follow the road irregularities.

Chart 1.2. Vehicle assemblies.



Driving System. The driving system comprises of the clutch, transmission, driveline, differential and live axle. The driving system carries power to the driving wheels from the engine. A clutch or torque converter is connected to the engine crankshaft to effectively disconnect or connect the engine with the driveline.

The function of the transmission is to provide gear reduction, which produces high torque to start the automobile from rest and drive it up the steep grades. It also provides a reverse gear for backing the automobile. A propeller shaft is required to transmit the engine power to the rear axle. It has universal joints on each end to provide flexibility as the suspension position changes. A differential incorporated with a rear axle, splits the incoming power to each drive wheel. This also allows the drive wheels to turn at different speeds as they go over bumps and round corners.

Control System. The steering and braking systems form the basic control system. The steering gear controls the direction in which the front wheels are pointed. The steering systems have some parts (*i.e.* the steering gear) bolted to the frame, some parts (*i.e*. the steering column) bolted to the body and some parts closely integrated with the front suspension system.

The brake system slows down the speed of the vehicle or stops it at the driver's will. The entire brake system is located in the chassis. The brakes are mounted inside the wheels. The brake designs are either drum type or disc type. Four-wheel disc brakes are more common in use.

Electrical System. The electrical system is a part of both chassis and body. The system includes the starting, charging, ignition, lighting and horn circuit. Some electrical circuits are for engine operation, some for power transmission and others for lighting and operation of protective devices and accessories.

Accessories. Accessories are used to make driving more pleasant. They include car heater, air-conditioner, radio, windscreen wiper, indicators, etc.

1.9.1. Engine Position

Front Engine. There are a number of reasons for locating the engine at the front of a car as shown in Fig. 1.18. The large mass of an engine at the front of the car provides the driver protection in the event of a head-on collision, and engine-cooling system becomes simpler. Also the cornering ability of a vehicle becomes better due to concentration of weight at the front.

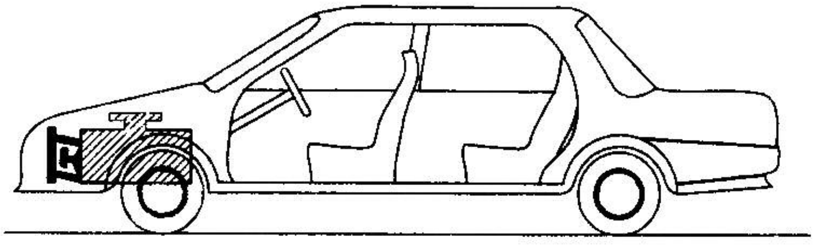


Fig. 1.18. Front-engined car.

Rear Engine. With the engines mounted at the rear of the vehicle the components like the clutch, gearbox and final drive assembly can be installed as a single unit. This arrangement requires the use of some form of independent rear suspension. Rear-engine layouts are mostly confined to small cars, as this adversely effect on the 'handling' of the car. Also it takes up a larger space in comparison to the front-engined car for carrying luggage. However, a rear-engined layout increases the load on the rear driving wheels, providing better grip on the road. Figure 1.19 presents one of the rear-engined cars. The front seats are close to the front wheels than a front-engined car, and the floor is quite flat.

Central and Mid-engine. This engine location is generally confined to sports cars because this provides both good handling and maximum traction from the driving wheels. This arrangement, however, is not convenient for everyday cars as the engine takes up space that is normally occupied by passengers. The mid-engine layout, shown in Fig. 1.20, combines the engine and transmission components in one unit.

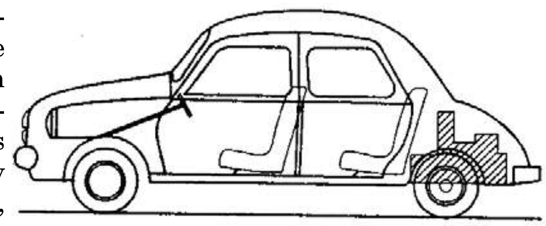


Fig. 1.19. Rear-engined car.

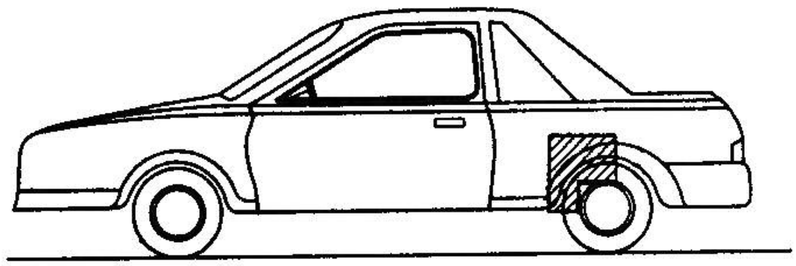


Fig. 1.20. Mid-engined car.

1.9.2. Drive Arrangements

Rear-wheel Drive. In this layout (Fig. 1.21) the rear wheels act as the driving wheels and the front wheels swivel for steering of the vehicle. The location of the main components in this arrangement makes each unit accessible. A major drawback is the protrusion of the transmission components into the passenger compartment due to which a larger bulge is produced in the region of the gearbox and a raised long tunnel down to the centre of the car floor is formed to accommodate the propeller shaft.

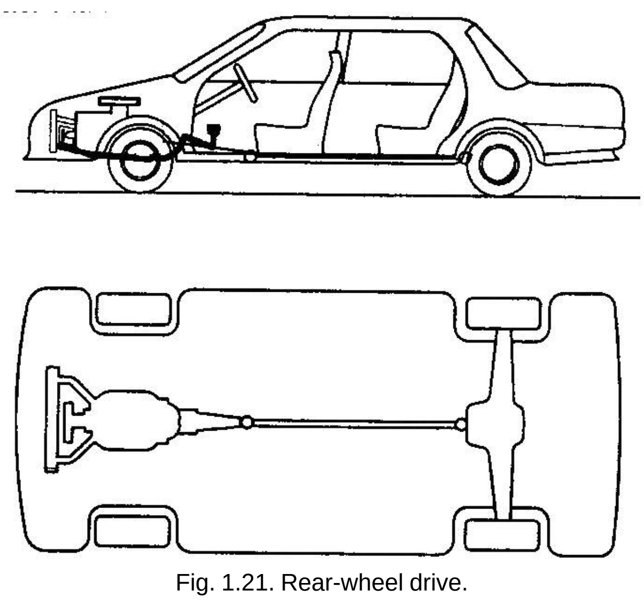


Fig. 1.21. Rear-wheel drive.

In this driving arrangement, the load transfer takes place from the front to rear of the vehicle during hill climbing or acceleration providing good traction. However, if the wheels lose adhesion, the driving wheels move the rear of the car sideways causing the car to 'snake'.

Front-wheel Drive. This layout (Fig. 1.22) is compact as the engine is mounted transversely and hence very popular for use on cars. From space considerations the length of the engine is the critical, but the use of V-type engines for larger power units has enabled to place the engine transversely. Consequently, the placement of all the main components under the bonnet (hood), and the removal of floor bulges and tunnel provide maximum space for the rear passengers. Transverse mounting of the engine also simplifies the transmission. The use of bevel-type final drive is eliminated; instead a simple reduction gear-along with a differential transmits the power through short drive shafts to the road wheels. Each drive shaft is fitted with an inner and outer universal joint. The outer joint accommodates the steering action and is specially designed to transmit the drive through a large angle. When the front wheels are used for steering, the driving force acts in the same direction as the wheel is pointing. Also the vehicle is being 'dragged' behind the front driving wheels. These features improve vehicle handling especially in slippery conditions.

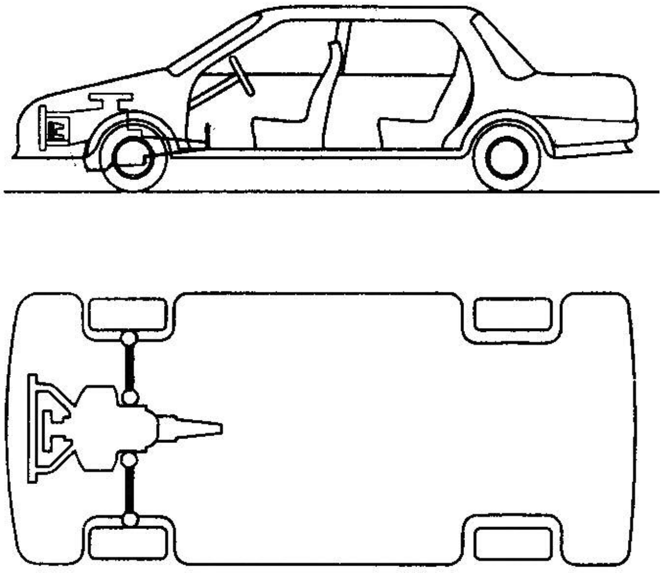


Fig. 1.22. Front-wheel drive.

Mounting the main units in one-assembly some-times makes it difficult to gain access to some parts, but this problem has largely been overcome now a days. One disadvantage is that the driving wheels have fewer grips on the road when the vehicle is accelerating and negotiating a gradient. This problem can be partly rectified by placing the engine well forward to increase the load on the driving wheels, but the car is then liable to become 'nose-heavy' causing the steering more arduous. In cases where the driver's steering effort becomes excessive, the car is often fitted with power-assisted steering.

Four-wheel Drive. This arrangement (Fig. 1.23) is safer because of distribution of the drive to all four wheels. The sharing of the load between the four wheels during acceleration reduces the risks of wheel spin specifically on slippery surfaces like snow and mud. In addition the positive drive to each wheel during braking minimizes the possibility of wheel lock-up. On an icy road or across off-highway a two-wheel-drive vehicle soon becomes non-drivable due to the loss of grip of one of the driving wheels, which causes the wheel to spin.

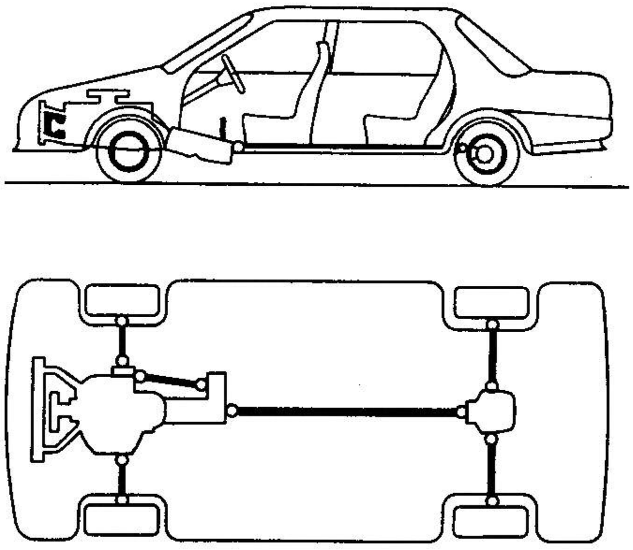


Fig. 1.23. Four-wheel drive.

1.10. Vehicle Design Considerations

Design Objective. The first thing a manufacturer must consider is the specific job the automobile should perform. Based on the requirements, different types of automobiles have been designed-such as, trucks, buses, cars, trailers, racing cars, etc.

Design Parameters. The designer of an automobile must consider the maximum required acceleration, speed, economy, load to be carried, ride and handling characteristics, size, etc. that are expected from the vehicle. The maximum limits of these features are called the design parameters. A finished automobile is a blend of all these components, one feature traded off against another, to produce the final product.

Durability. Each part of the vehicle has a specific design life, which takes into account its operating load, speed, temperature, lubrication, etc. Life of all the components together decides the time period the vehicle should operate before major service is required.

Cost. One of the best selling points is a low price. Therefore, one of the major design objectives is to lower the price without compromising the design parameters. In some cases, a large reduction in costs can be accomplished with only a slight compromise in a design objective. The cost reduction is also possible by changing the manufacturing methods or by using cheaper materials like fibreglass, plastic, etc.

Many features of the product are the result of the engineer's preference, which are usually based upon the previous satisfactory performance of the design. There is a tendency to continue those features until they become uneconomical or unpopular, or until new engineering management takes over.

1.11. Engine System

A system is consisted of a collection of interacting parts. These parts are connected together to perform a particular function, which may be complete in itself or it may form just a part of a larger system. A system may also be divided into a number of smaller systems, called sub-systems. In an engine, ignition arrangements and fuel supply layouts are two examples of systems. Along with other systems they form a larger system, named the engine or power system. A carburettor and a distributor are examples of sub-systems.

It is difficult to investigate the behaviour of a large family of mechanical components in a complete assembly, because each part responds in a different way to a given change. To simplify this study the assembly is split up unto smaller sections, so that the function of each part can be analyzed. When investigations of these parts are completed, it is possible to visualise the effect, or interaction of individual parts on the complete system.

An investigation of a system often constitutes an analysis to determine its function and a study of its behaviour to ascertain its performance. A functional study, known as a qualitative analysis, establishes the basic qualities of a system and indicates the role to be full filled by each part of the system. The manner, in which the system performs its role, and the effectiveness of a system in respect to its performance, is called a quantitative analysis. A qualitative study provides the basic information regarding the fundamental duties to be performed by each main part of a system. The quantitative analysis provides its operational details and the measurement of the effectiveness of its operation.

In a qualitative analysis, the main parts of a system are represented by blocks in a diagram indicating the function to be performed by each part. This layout in the form of blocks is a simple method commonly used in electronics to indicate the arrangement of the various sub-systems and the paths followed by the control signals in the system.

A quantitative analysis involving performance of a component is generally expressed in a mathematical equation. By comparing the equations of alternative parts, the designer is able to make an accurate, non-subjective judgment, which helps him to select the most suitable system or part for a particular application.

The representation of the performance of individual parts through mathematical equations can be extended to the complete system. The mathematical representation of particular system or sub-system is called a mathematical model. Combining the models and entering the mathematical data of individual model to a computer makes it possible to understand the overall performance. In addition to this the response of the system can also be studied, when any part of the system is altered.

A modern electronic system has to function over a wide range of parameters and conditions. With the aid of this modelling facility, if is possible to vary the signal from each subsystem and study the effect of the change on the complete system. These design enables to predict accurately the performance of a system before it is put into production and actual use. This also allows numerous alternatives and modifications, which can be tried to determine if it is possible to improve the performance or to decide on a simpler and cheaper system. Prior to the use of the computer as a design tool, the introduction of a new system required a series of practical tests on the actual components, which was time consuming.

REVIEW QUESTIONS

1. Give a brief history of the development of automobile. (1.1)
2. How has the automobile industry grown in India ? (1.1)
3. What were the types of fuel used during initial period of development of road vehicles ? (1.1)
4. What was the necessity for using diesel engine in automobiles ? (1.1)
5. Why is gasoline preferred most among all the fuels for automobiles ? (1.1)
6. How do you view an automobile of today and in future ? (1.1)
7. What is the general classification of road vehicles ? (1.2)
8. What is the classification of light motor vehicles ? (1.3)
9. What is the difference between a saloon and hatchback car ? (1.3)

10. What are the utilities of a van ? (1.4)
11. What are the differences between a coach and double-decker bus from utility view point ? (1.5, 1.6)
12. What are the differences between a rigid truck and articulated vehicle ? (1.7)
13. What is a fifth-wheel coupling referred to articulated vehicles ? (1.7)
14. What are the advantages of articulated vehicle over rigid truck ? (1.7)
15. What are the main parts of an automobile ? (1.8)
16. Explain the two methods of body and chassis construction. (1.8)
17. Describe the flow of power from the engine to the rear wheels ? (1.8)
18. Show a chart indicating the major assemblies of an automobile. (1.9)
19. Write short notes on the running gear and drive system. (1.9)
20. What is the preferred position of the engine in a car and why ? (1.9.1)
21. Discuss various drive arrangements and conclude with the best possible one. (1.9.2)
22. What are the design considerations of a vehicle ? (1.10)
23. Write short note on “design parameters”. (1.10)
24. Explain the terms system and sub-system with respect to automobile engine. (1.11)
25. What are the two types of studies required to examine a system ? (1.11)
26. What is system modelling ? (1.11)
27. What is the purpose of system modelling ? (1.11)