Participant Handbook Part I

Auto Service Technician

Skill India
कौशल भारत - कुशल भारत

सत्यमेव जयते
GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT & ENTREPRENEURSHIP

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Power Flow Systems

General Instructions to Trainee

1. Greet your instructor and the other participants when you enter the class.
2. Always be punctual for every class.
3. Be regular. Candidates who fall short of the required attendance will not be certified.
4. Inform your instructor if, for any reason, you need to miss class.
5. Pay attention to what your instructor is saying or showing.
6. If you do not understand something, put up your hand and seek clarification.
7. Make sure you do all the exercises at the end of each module in this book. It will help you understand the concepts better.
8. Practise any new skills you have learnt as many times as possible. Seek the help of your Trainer or co-participant for practice.
9. Take all necessary precautions, as instructed by your Trainer, while working with electricity and with tools.
10. Make sure you are neatly attired and presentable at all times.
11. Participate actively in all the activities, discussions and games during training.
12. Always take bath, wear clean clothes and comb your hair before you come to class.
13. The three most important words you must always remember and use in your daily conversation are **PLEASE**, **THANK YOU** and **SORRY**.

Symbols Used in This Manual

Symbol	Meaning
	Time
	Objectives
	Pre-requisite Knowledge
	Module Overview
	Theory
	Procedure
	Key Learnings
	Worksheets
	Tips
	Notes

What is an Automobile

At the end of this session you will be able to:

- state the purpose of automobiles;
- list the types of automobiles.

Session Plan	
1	Introduction
2	Purpose of an Automobile
3	Types of Automobile
4	Key Learnings
5	Worksheet

Introduction

Automobile

It comes from an ancient Greek word is *autos* meaning self, and the Latin word *mobilis* meaning movable. It is defined as a four wheeled vehicle that runs on a motor or an engine.

The internal combustion engine propels the vehicle to move using either volatile inflammable substances (petrol or diesel), or electric motors.

Purpose of an Automobile

Purpose of Automobile

Automobiles were made to transport people and goods.

Automobiles are used mainly for commercial and personal reason.

Commercial vehicles used for transporting goods.

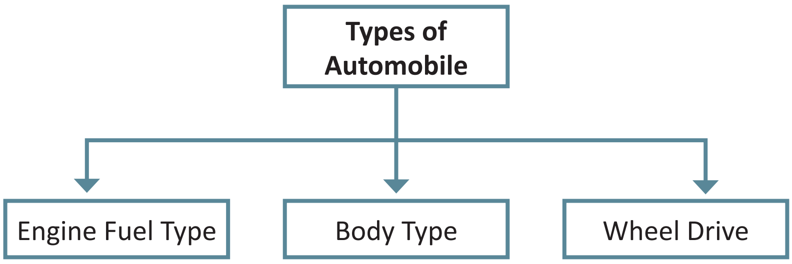
- Truck
- Semi-truck
- Vans
- Coach
- Buses
- Taxicab
- Trailers
- Box truck

Passenger vehicles used for transporting people

- Hatchbacks such as the Alto 800, Maruti Swift, Tata Indica, Hyundai i10, Nissan Micra
- Sedans such as the Hyundai Verna, Nissan Sunny, Toyota Corolla Altis, Renault Fluence
- SUVs such as Renault Koleos, Tata Safari Storme, Toyota Fortuner, Mahindra Rexton
- MPVs such Toyota Innova, Nissan Evalia, Chevrolet Tavera

Types of Automobile:

Automobile can be classified based on the following parameters:



Engine Fuel Type

- **Diesel Engine –** A vehicle that uses diesel as a fuel. It uses a mechanism wherein heat is produced by compression that burns the fuel that is injected. The energy produced is converted into mechanical motion. Example; Heavy vehicles such as trucks, buses, tractors etc.
- **Petrol Engine –** is also referred to as gasoline engines that uses petrol as fuel. Here the spark plugs are used for combustion. Example; Light vehicles such as petrol, bikes etc.
- **Electric car –** Vehicles that uses electric as fuel stored in batteries

Body Types

Automobiles can be classified based on the body types such as the hatchbacks, sedans, multipurpose vehicles MPVs, sport utility vehicles SUVs

Wheel Drive

- Two-wheel drive vehicles such as mopeds and motorcycles
- Four-wheel drive vehicles uses all the four wheels, also referred to as off-road vehicles. E.g. SUVs
- Front-wheel drive vehicles where the engine drives the front wheels e.g. hatchbacks, sedans
- Rear-wheel drive vehicles such as sports cars

Engine Layout

- Front engine, front wheel drive where the engine is placed at the front of the vehicle and drives the front wheel. E.g. hatchbacks, buses, trucks etc.
- Rear engine, front wheel drive where the engine is placed behind the rear wheels and drives the front wheel.
- Front engine, rear wheel drive where the engine is places at the front of the vehicle and drives the rear wheel drive. E.g. Grand Tourers
- Rear mid-engine, rear wheel drive where the engine is placed just in front of the rear wheels which drives the latter. E.g Lamborghini Miura, Lancia Stratos Hf , Fiat X1/9, Porsche 550 Spyder, Renault 5 Turbo, Porsche 914, Porsche Boxster

- Rear engine, rear wheel drive places both the engine and driven wheel are at the rear. E.g. Skoda 110 R Coupè
- Mid engine, front wheel drive where the engine is placed behind the front wheels and drives the front wheels. E.g. Renault 4, Renault 16, Saab Sonett mk1

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. What are the engine layouts?

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2. What are the types of Automobiles?

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Worksheet

1. Read the questions and choose the correct answers.

a. The word automobile means ______________________ .

i. self-moving ☐

ii. auto drive ☐

iii. auto car ☐

iv. all of the above ☐

Notes

Answers: What is an Automobile

Question Number	Answer
1	a. i

Evolution of Automobiles

	At the end of this session you will be able to: ◆ state the history of automobile.

Session Plan	
1	Introduction
2	Developments in Automobiles
3	Key Learnings
4	Worksheet

Introduction

History of the Automobile

It started with the steam engine automobiles that were primarily used for transporting people from one place to another. Electric vehicles were used for sometime until later when the internal combustion engine was introduced. Fuel gas was replaced by the steam engines.

There isn't a single man responsible for inventing the automobile, but it's a development and innovations of many men over a period of time that were responsible for the automobile as we know it today.

Karl Benz is known to have built the first practical use modern automobile. He built the first Motorwagen and was awarded for it.

Developments in Automobiles

17th Century to 18th Century

- In 1770-1771, Nicholas-Joseph Cugnot who was a French inventor, built the Cugnot's steam wagon. It was used by the French army to haul cannons. This was the first self-propelled vehicle and was three wheeled. It moved at a speed of 2.25 miles per hour.
- In 1801, Richard Trevithick improved the steam engine which was compact and lighter. And a carriage was attached for carrying passenger. Due to insufficient steam pressure and was of very little use.
- In 1807, François Isaac de Rivaz designed the first internal combustion engine which was used on a vehicle, this vehicle ran on hydrogen and oxygen.

19th Century

- In 1860, Jean Joseph Etienne Lenoir, a Frenchman, built the first successful two-stroke gas driven engine
- Nikolaus Otto made the four stroke petrol internal combustion engine and Rudolf diesel create a similar four stroke diesel engine
- In 1881, a French inventor Gustave Trouvé made a three wheeled automobile which was powered by electricity.
- In 1885, Karl Benz, referred to as the inventor of the first practical modern automobile built the first Motorwagen in Germany. He was awarded for the concept.
- In 1889, Panhard et Levassor build automobiles in France that introduced the four-cylinder engine
- In 1890, the four stroke cylinder, four stroke engine was built by Maybach, his design was later taken in the 1902 Mercedes-35 hp

19th Century

- In 1892, Rudolf Diesel, a German Engineer built the first diesel engine
- In 1896, Benz built the first internal-combustion flat engine. This was called the boxemotor
- In 1897, Harry J. Lawson's company made the first production of automobile in Great Britain

Electric Automobiles

- In 1828, Ányos Jedlik invented an electric motor which he used in his small tiny car model
- In 1835, Professor Sibrandus Stratingh of Netherland created a small-scale electrical car which was powered by non-rechargeable cells
- In 1838, Robert Davidson built an electric locomotive that travelled with a speed of 7 kilometers per hour
- Between 1832 to 1839, Robert Anderson invented crude electric carriage that were powered by primary (non-rechargeable)

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. List the developments in the 19th century.

____

____

____

____

2. List the events in regards to the Electric Automobiles.

Worksheet

1. Read the questions and choose the correct answers.

a. Who was known to build the first practical use modern automobile ______________ .

i. Anyos Jedlik ☐

ii. Rudolf Diesel ☐

iii. Karl Benz ☐

iv. Harry J. Lawson ☐

b. Who built the first Diesel Engine ______________ .

i. Ányos Jedlik ☐

ii. Rudolf Diesel ☐

iii. Nikolaus Otto ☐

iv. Josef Bozek ☐

Notes

Answers: Evolution of Automobiles

Question Number	Answer
1	a. iii b. ii

Indian Auto Industry

At the end of this session you will be able to:

- state the history of Indian automobile industry;
- state the major developments in Indian automobile industry.

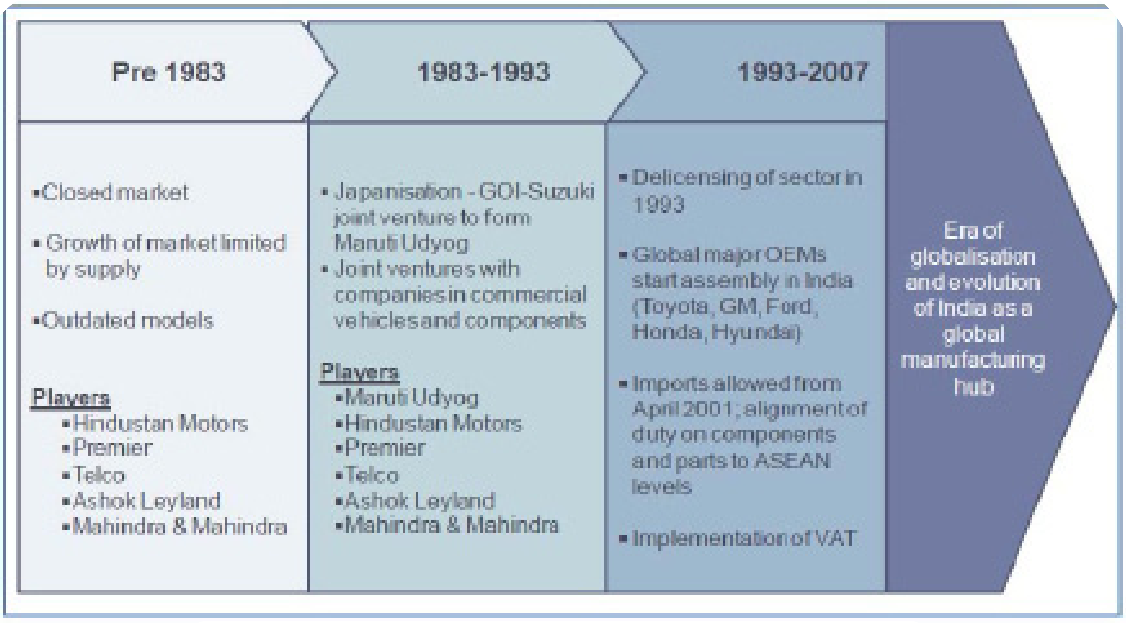
Session Plan	
1	Introduction
2	Evolution of the Indian Auto Industry
3	Indian Auto Industry segments
4	Major Developments
5	Key Learnings

Introduction

The Indian Auto Industry has had a huge growth over the years and is continuing to do so. Currently the Indian Automobile industry has over 30 Auto Original Equipment Manufactures (OEM's) that comprise of two wheelers, three wheelers, passenger vehicles, commercial vehicles.

Evolution of the Indian Auto Industry

- In 1942 Hindustan Motors was established by CK Birla Group, in 1948 the production of the iconic Ambassador was started
- In 1947 Mahindra got the license to build Jeep SUVs in India, and thus introduced the Utility Segment in India
- In the early 1980's the Indian Auto Industry had limited supply of vehicles and most of the them were outdated
- In 1983-1993, Maruti Udyog Limited entered the Indian automotive sector



Evolution of the Indian Automotive Industry
Source: IMacs analysis

The automobile industry is one of the fastest growing segments the world. In India it has grown to a extent and that makes it the 6th largest in the world in terms of passenger and commercial vehicles.

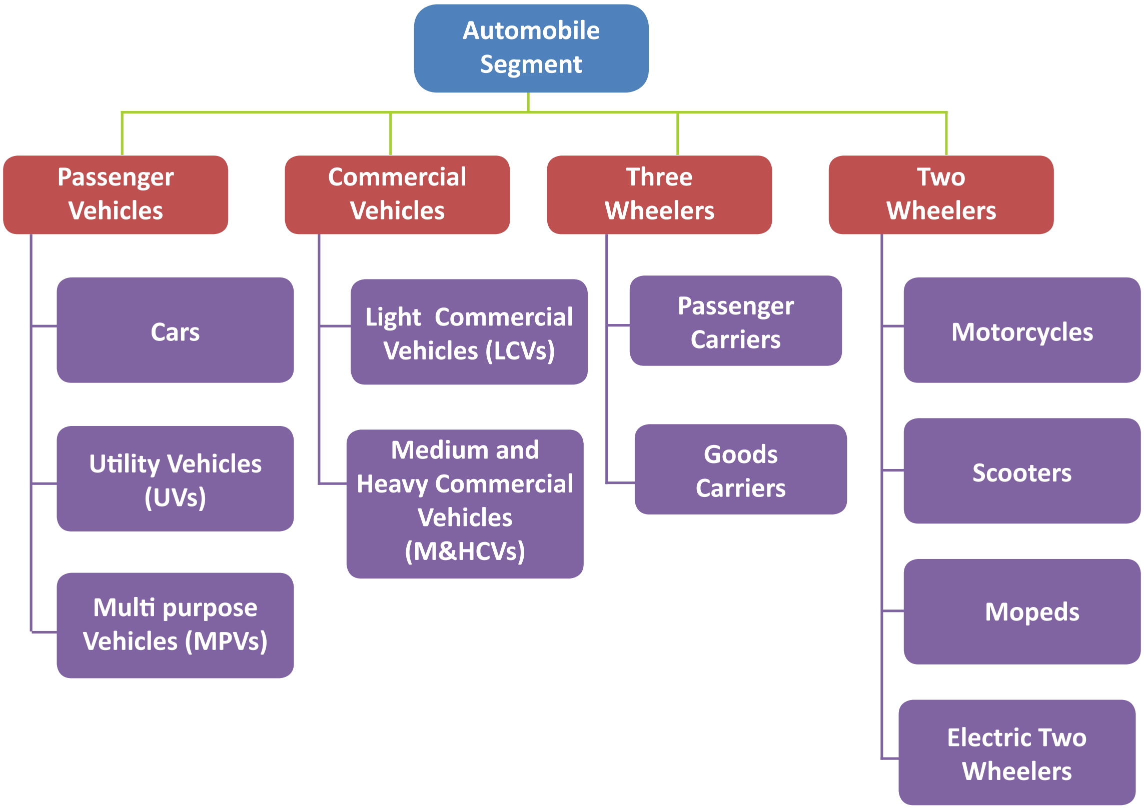
- In the last 7-8 years, the industry has grown at a CAGR of over 14%.
- In 2008-2009, the size of the automotive sector was estimated around Rs. 1,910 billion:
  - The automobile segment was estimated to be Rs. 1230 billion*
  - The auto components segment contributed around Rs. 680 billion*

Industry Size (Rs. Billion) of the Automobile & Auto Components sector

Year	Automobile Segment Size	Auto Components Segment Size	Total Industry Size
2000	423	169	592
2001	492	181	673
2002	499	213	712
2003	595	263	858
2004	662	309	971
2005	836	391	1,227
2006	974	531	1,505
2007	1,135	679	1,814
2008	1,204	724	1,928
2009	1,230	680	1,910
CAGR between 2000 - 2009	13%	17%	14%

* Source: IMacs analysis

Automobile Segment Product Categories



The Auto Industry in India is segmented on the basis of its size, mode of use and number of seating options, pricing, drive mode:

Micro

- Length normally less than 3200
- Hatchback body style
- Engine Displacement Normally up to 0.8 Litre

Mini

- Seats upto-5, Length Normally <3600 mm
- Body Style-Hatchback
- Engine Displacement Normally upto 1.0 Litre

Compact

- Seats upto-5, Length Normally between 3600 - 4000 mm
- Body Style-Sedan/Estate/Hatch/Notchback
- Engine Displacement Normally upto 1.4 Litre

Super Compact

- Seats upto-5, Length Normally between 4000 - 4250 mm
- Body Style-Sedan/Estate/Hatch/Notchback
- Engine Displacement Normally up to 1.6 Litre

Mid-size

- Seats upto-5, Length Normally between 4250 - 4500 mm
- Body Style-Sedan/Estate/Hatch/Notchback
- Engine Displacement Normally up to 1.6 Litre

Executive

- Seats upto-5, Length Normally between 4500 - 4700 mm
- Body Style-Sedan/Estate/Notchback
- Engine Displacement Normally up to 2 Litre

Premium

- Seats upto-5, Length Normally between 4700 - 5000 mm
- Body Style-Sedan/Estates
- Engine Displacement Normally up to 3 Litre

Luxury

- Seats upto-5, Length Normally Over 5000 mm
- Body Style-Sedan/Estates
- Engine Displacement Normally up to 5 Litre

Coupe

- Roadster- 2 Doors; 2/4 Seater, retractable/firm roof

Exotics

- 2 Seats, Price >Rs. 1 Crore

UV1

- Length <4400 mm
- Price Up to Rs. 15 Lakh

UV2

- Length 4400 - 4700 mm
- Price Up to Rs. 15 Lakh

UV3

- Length >4700 mm
- Price Up to Rs. 15 Lakh

UV4

- Price Between Rs. 15 to 25 Lakh

UV5

- Price > Rs.25 Lakh

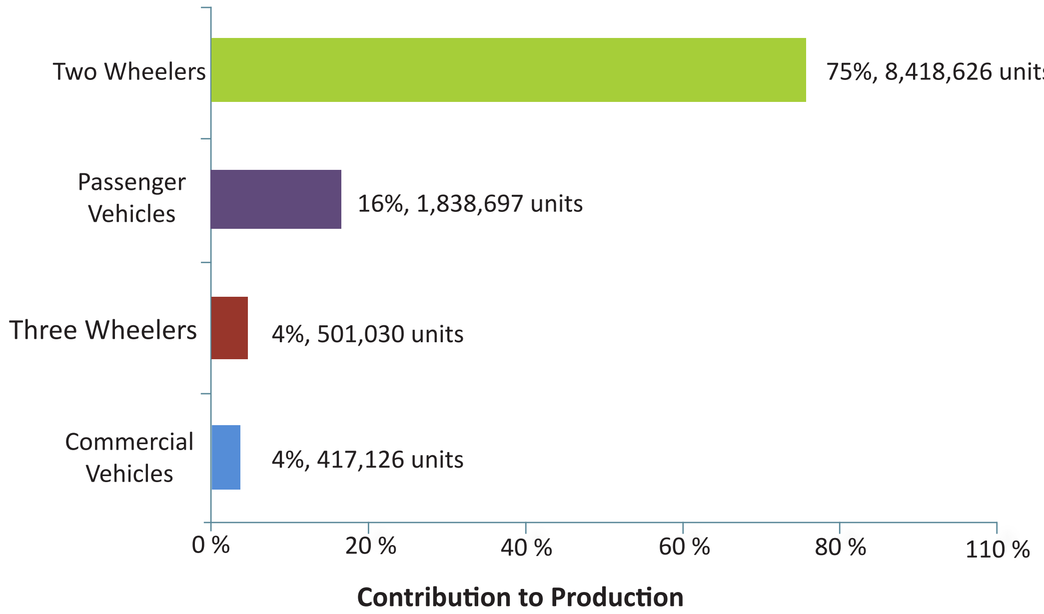
V1

- Hard tops mainly used for personal transport
- Price Up to Rs. 10 Lakh

V2

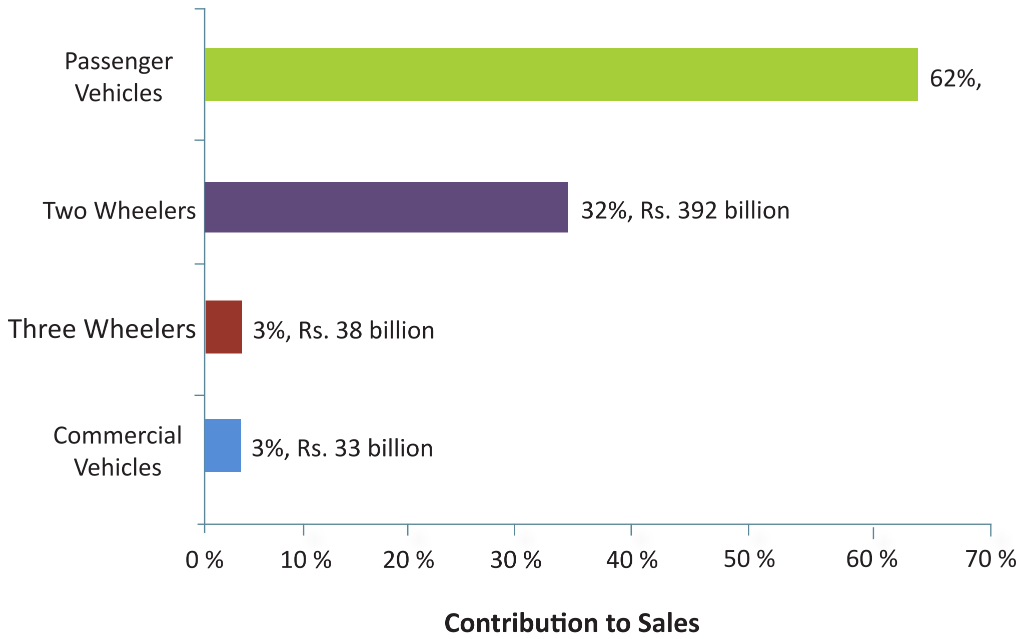
- Soft tops mainly used as Maxi Cabs
- Price UptoRs. 10 Lakh

Production of Automobiles in no of units (2008-2009)

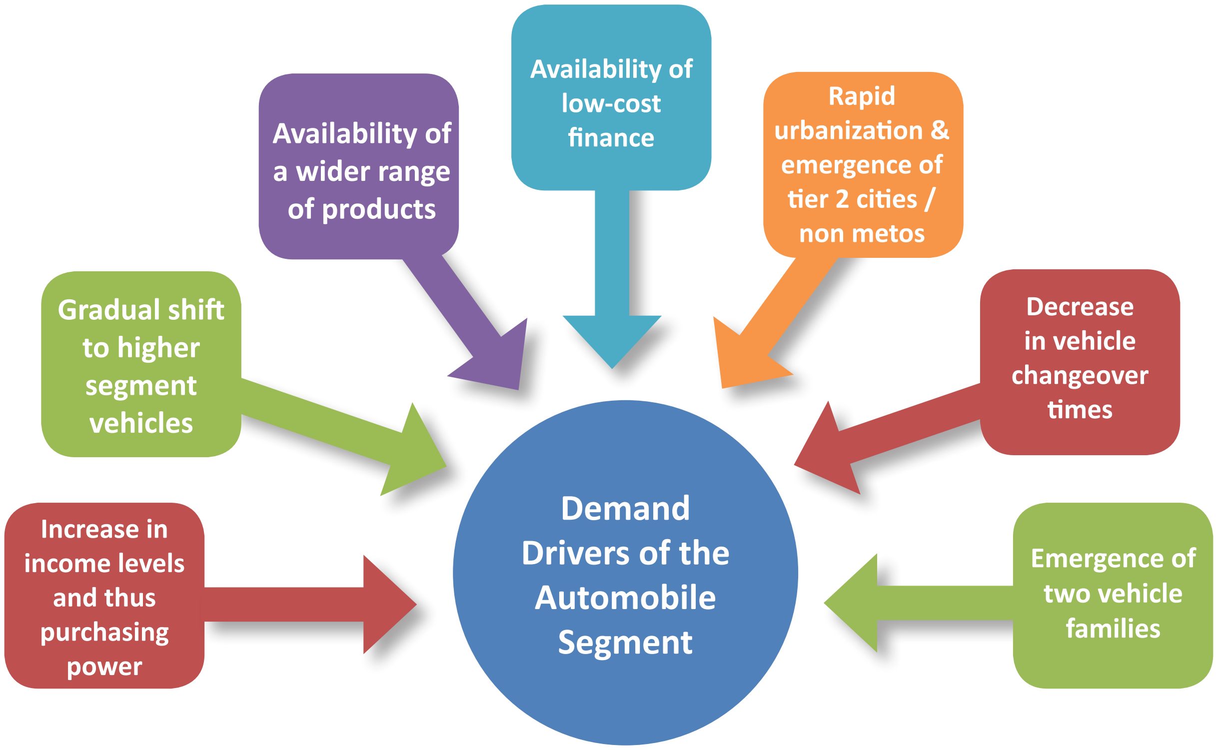


Sales of Automobiles in Rs. billion (2008-2009)

The highest selling segment is the passenger vehicles segment that has recorded a total sale of Rs. 768 billion in the year 2008 – 2009, a way ahead from the other segments.



Several factors have favored the growth of the Indian Automobile Industry. The below diagram shows the demand drivers that have helped growth in the Industry.



Opportunities

Demand drivers for automobile segment are key reasons for the rapid growth in the automobile segment.

- Increase in income levels and thus increasing in car purchases - Cars are made a ffordable to a larger section of the population. The automobile prices are reduced due to increase in production and stiff competition in the market.
- Gradual shift to higher segment passenger vehicles - The B and C segments have emerged as high growth over the last few years.
- Availability of a wider range of products for the customers.
- Availability of low-cost finance such as decline in interest rates and easy finance options.
- Emergence of tier 2 cities and non metros – More then half of the share of vehicles are sold in small cities and towns.
- Decrease in product life cycles – Purchases for replacement of existing vehicles have been increasing. This has led to reduce the timeline for the introduction of the new product.
- Emergence of two-vehicle families – Increase in income there is a growing trend of owing two vehicles by the same person. This has led to high demand of automobiles.

Challenges

There are many key risk factors that affect vehicle sales.

- Correlation with the economy – A slowdown in the economy can greatly affect the industry demand.
- Increase in input material price – Steel prices and other metal prices may lead to price hikes of the car.

- Higher inflation and increase in fuel price – Can greatly have a negative impact on the demand of automobiles as it will increase the running cost of the vehicle.
- Rise in interest rates – With increasing interest rates can affect the vehicle demand considerably.
- Low availability of skilled human resources – Lack of skilled manpower can affect the growth and development of the Indian automobile segment.

Major Developments in the auto industry

In recent years there have been many developments in the auto industry with regards to safety comfort and manufacturing and these developments are continuing to grow, particularly with more concentration on the following points.

- Alternative fuels - With the rise of petroleum consumption increasing daily, it will be hardly any time before its completely exhausted. Several auto companies are working on alternate sources of energy like; Hydrogen, fuel cells and Plug-in hybrids.
- Low consumption Maximum power - Reducing engine size, body weight and integrating features brake recuperation are some of the developments which will be common on most of the automobiles.
- Autonomous driving - Several companies have developed and are in development of cars that have Artificial Intelligence which will allow it to carry passengers around without the need for a driver. Every function from steering, braking to self parking will be all controlled by the cars ECU.

Major Developments in the Indian auto industry

India is emerging as one of the world's fastest growing passenger car markets and second largest two wheeler manufacturer in the world. It is also home for the largest motor cycle manufacturer and fifth largest commercial vehicle manufacturer.

- India is emerging as an export hub for sports utility vehicles (SUVs).
- India has become the largest base to export compact cars to Europe. Along with that, hybrid and electronic vehicles are new developments on the automobile canvas and India is one of the key markets for them.
- Global and Indian manufacturers are focussing their efforts to develop innovative products, technologies and supply chains.
- The automotive plants of global automakers in India rank among the top across the world in terms of their productivity and quality.
- Several Auto manufacturers are looking to further invest and set up plants in the country.
- Several collaborations between Indian auto manufactures and other auto companies have taken place while others are in the process of developingnew technologies and products.
- There is an emergence of non OEM service centers.

The Indian government has various initiatives to further increase and support the growth of the Auto sector in India.

- The Indian government encourages foreign investment in the automobile sector and allows 100% FDI under the automatic route.
- The government has not laid down any minimum investment criteria for the automobile industry.
- The government has made successive policy changes that allow for stronger growth in the automotive sector like:

- Automotive Mission Plan: Prepared by the Ministry of Heavy Industries and Public Enterprises, the Automotive Mission Plan aims to accelerate and sustain growth in the sector over the period 2006 to 2016. It is aimed to make India a global automotive hub, with special emphasis on the export of small cars, MUVs, two- and three-wheelers and auto components.
- National Automotive Testing and R&D Infrastructure Project: This is a USD 388.5 million initiative of the Government of India and other various state governments; it's aim is to create a state-of-art dedicated testing, validation and R&D infrastructure across the country.
- Structural advantages: Over half the country's population is in the working-age group and the economy has shown strong growth over most part of the last decade. These factors, in turn, translate into beneficial spillovers for the Indian automobile sector: 1.Indian banks provide easy finance schemes for the segment. 2.The country has low-cost, high-skilled manpower with the second-largest pool of engineering talent in the world
- Auto components: India has a strong auto components industry, it accounts for about 2% of the country's national income and registered a growth rate of 19.2% in 2009– 10. The country has emerged as an outsourcing hub for international companies such as Ford, General Motors, Daimler Chrysler, Fiat, Volkswagen and Toyota

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. List the Indian car segmentation.

2. What are the challenges faced in the Indian Auto Industry?

3. What are the initiatives taken by the Indian government to help the Indian Auto industry?

Notes

Growing Importance of After Sales Service

At the end of this session you will be able to:

- state the need for after sales service in automobile industry.

Session Plan	
1	Introduction
2	Growing importance of aftersales in the Auto Industry
3	Key Learnings

Introduction

The Auto industry has to focus on after sales as it is one on the key factors for success for an auto company.

Growing importance of aftersales in Auto Industry

The role of the companies does not end with selling the product only. In fact with the ever growing competitive market, it is completely important for every company to equally work hard in after sales. This includes product quality and sustains performance which leads to customer satisfaction.

Aftersales service should ensure that customers are happy and satisfied not with the product only but also the service the organization offers.

An excellent aftersales service promotes

- The brand of the company
- Goodwill with the existing customers
- Attract new customers

Aftersales is all about post deliver customer feed-back.

Role of Aftersales in auto-industry ensures:

- Product and service meet or exceed the customer's expectation;
- Customer believes and trust in the brand;
- A strong bond between the organization and the customer;
- Earn more customers through reference from old ones;
- Earn more revenues and profits in the market.

With the Auto sector set to increase in growth, further more there is a need for professionals like;

- Focus on Specialized rather than Generalized skills;
- Skilled labour training, motivation, management and retention;
- Customer service delivery and management;
- Marketing and customer loyalty;
- Spare parts management;
- Skills for servicing special vehicle segments like luxury vehicles and green vehicles;
- Ensuring availability of adequate numbers of skilled manpower, across different locations and different levels. Skills include not only technical skills, but also business management skills (for senior management) and customer management;
- Continuous improvement in productivity and quality, to reduce turnaround times, improve capacity utilization, reduce costs and increase customer satisfaction;
- Focus on softer aspects of customer management and innovate to retain customer loyalty.

The Passenger Car segment will see the highest level skill requirement amongst non-mechanic cadre. The need for effective customer service and service/ work order management is the highest in this segment.

There is a growing need of professionals in each of the segment:

Two Wheelers

- While, 70% of the estimated 91,0002 service centers in India cater to Two Wheelers, this is also the segment where the presence of unorganized players is much higher at an 80%. The manpower requirement per service center is lower, given the high vehicle turnaround in the service center compared to larger vehicles.

Passenger Cars

- The need for manpower requirement in the Passenger Cars segment is expected to grow by over 70% by 2015. This segment is expected to witness the highest level of skill enhancement with the emergence of the non-OEM sector.

Commercial Vehicles

- The commercial vehicles segment is expected to see the highest growth rate in the skill requirement over the next five years, with the manpower requirement in 2015 increasing by close to 80% over the existing manpower.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. What is the importance of aftersales in Auto Industry?

2. List the needs for the demand of professionals in the industry.

Notes

You and the Workshop

At the end of this session you will be able to:

- state the service process of a workshop and job card.

Session Plan	
1	Introduction
2	Technicians and Workshop
3	Identification of Place of Work
4	Reporting Structure of Organization
5	Service Process
6	Job Card
7	Key Learnings
8	Worksheet

Introduction

The technicians play an important role for the workshop profitably. A productive workforce of technically sound people will ensure customer satisfaction and retention. A proper workshop has room for different work activities. An organisation chart defines the reporting structure of the workshop. A well-defined service process ensures a smooth running of the workshop.

Technicians and Workshop

Technicians:

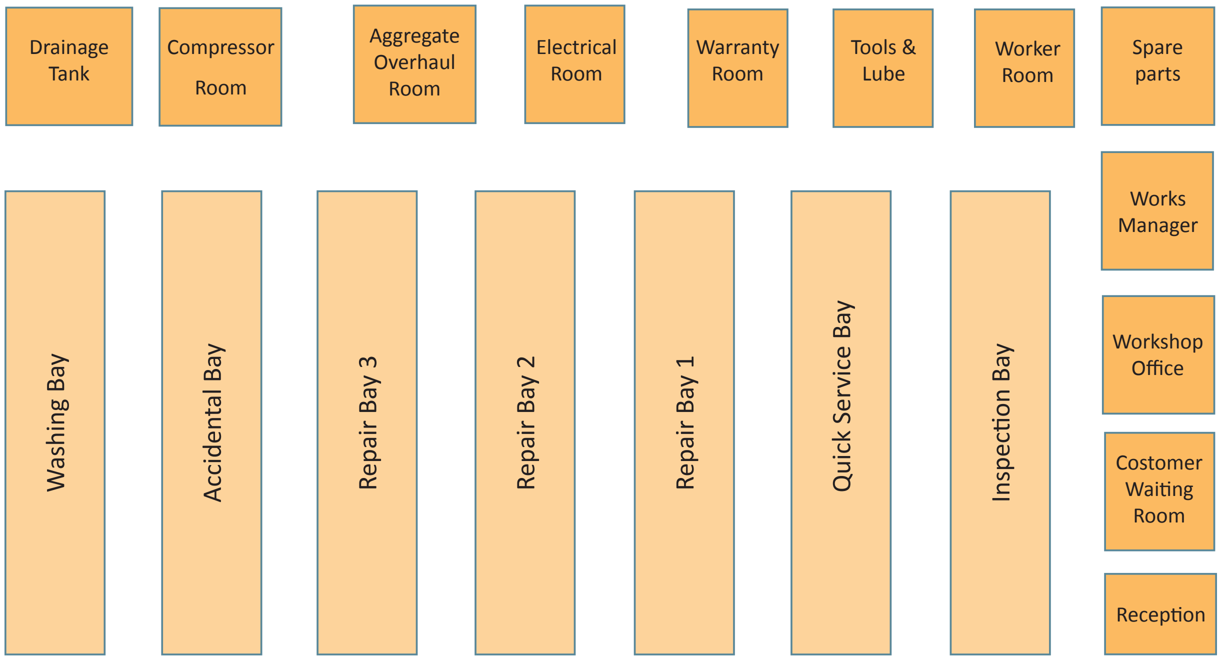
Technicians are the individuals who are mainly responsible for the workshop profitability. The success of a workshop lies in the hands of Technicians. Technicians are the only productive workforce in a workshop.If a Technician does his job correctly, the other profitability factors like customer satisfaction, customer retention, FIRFT (fix it right first time) are all automatically taken care of.However, team work is equally important to achieve all the above.

Workshop:

Workshop is the place where the actual repairs/diagnosis and maintenance of the vehicles are carried out. Following is the layout of a typical Four Wheeler workshop that we find in most of the Dealerships:

Identification of Place of Work

Layout of Workshop



Workshop Office - To ensure smooth flow of work, an administration area which is attuned to rational order processing, is extremely essential.

- Warranty Room - Racks and bins should be provided for the same. Storage space for records should also be provided.There should be adequate space for storage of failed parts
- Tool and Lube Room - An ideal locations for the tool and lube room would be in the vicinity of the lubrication bay. This would make the room easily accessible from most of the work bays ensuring that minimum time/effort is lost in issuing tools and lubricants.
- Electrical Room - The electrical room should have the tools and equipment as per the list given by specific manufacturers for electrical work.
- Engine / Aggregate Overhauling Room - The Engine/ Aggregate overhauling room should have the tools and equipment as per the requirements of workshop.
- Workers Change Room - Rooms provided to keep the belongings of workers working in the workshop.
- Compressor / Generator Room - The storage space for air compressor is used for pneumatic tools. Generator in case of workshops situated in rural areas where electricity is uncertain.
- Works Manager Room - Room required for the Head of the Workshop and Should be Located at a place where entire Workshop is Visible to Monitor the Work In Workshop.
- Customer Waiting Room - The customer waiting represents the interface between the customer and workshop operations. It should also have work in progress chart to update customer every time about their vehicle status.
- Reception - The customer should be attended quickly with the least possible delay. The service advisor should keep himself completely free for the customer.
- Inspection Bay - A bay used for initial inspection of vehicle so that further actions can be taken for any additional repair work to be carried on the vehicle.

- Quick Service Bay - Additional facilities provided to customer to carry out minor repair work at higher cost. It is provided for customers who are interested in making the vehicle repair as soon as possible.
- Repair Bay - Bay provided to carry out minor / major / paid / warranty works on the vehicle. It should be located close to overhauling room and lube room.
- Accidental Bay - Accidental repairs are the major sources of earnings for the servicing set-ups. Special Bay is provided for Accidental Vehicles so that the vehicle can be made on road at Earliest.
- Washing Bay - To carry out washing of the vehicle separate baysare providing to avoid water spreading in work locations.

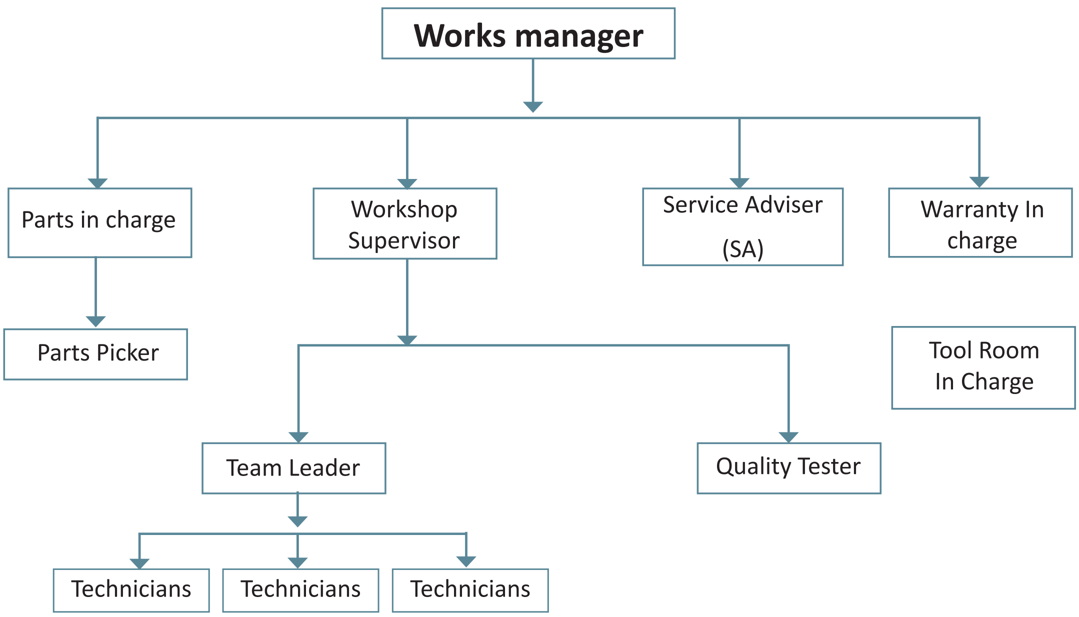
Working in Teams

Key Players of a Team:

- Managers: Hold conventional managerial responsibility and are drawn from the hierarchical culture of the organization
- Facilitators: These are neutral, objective individuals who are chosen for their process consulting skills. They may also act as arbitrators in times of conflict between managers and team players
- Team leader: These are often the department supervisors who must work with managers and facilitators and help them to shape the team.
- Team players: These are the members of the team who share a common goal or purpose. They must be trained and developed to assume the special skills and responsibilities of self-management
- Support groups: These are clusters of individuals who work with the Team supporting them with specific services required – e.g. the Human Resource, Finance and Administration departments.

Reporting Structure of Organization

Organization Chart of a Workshop



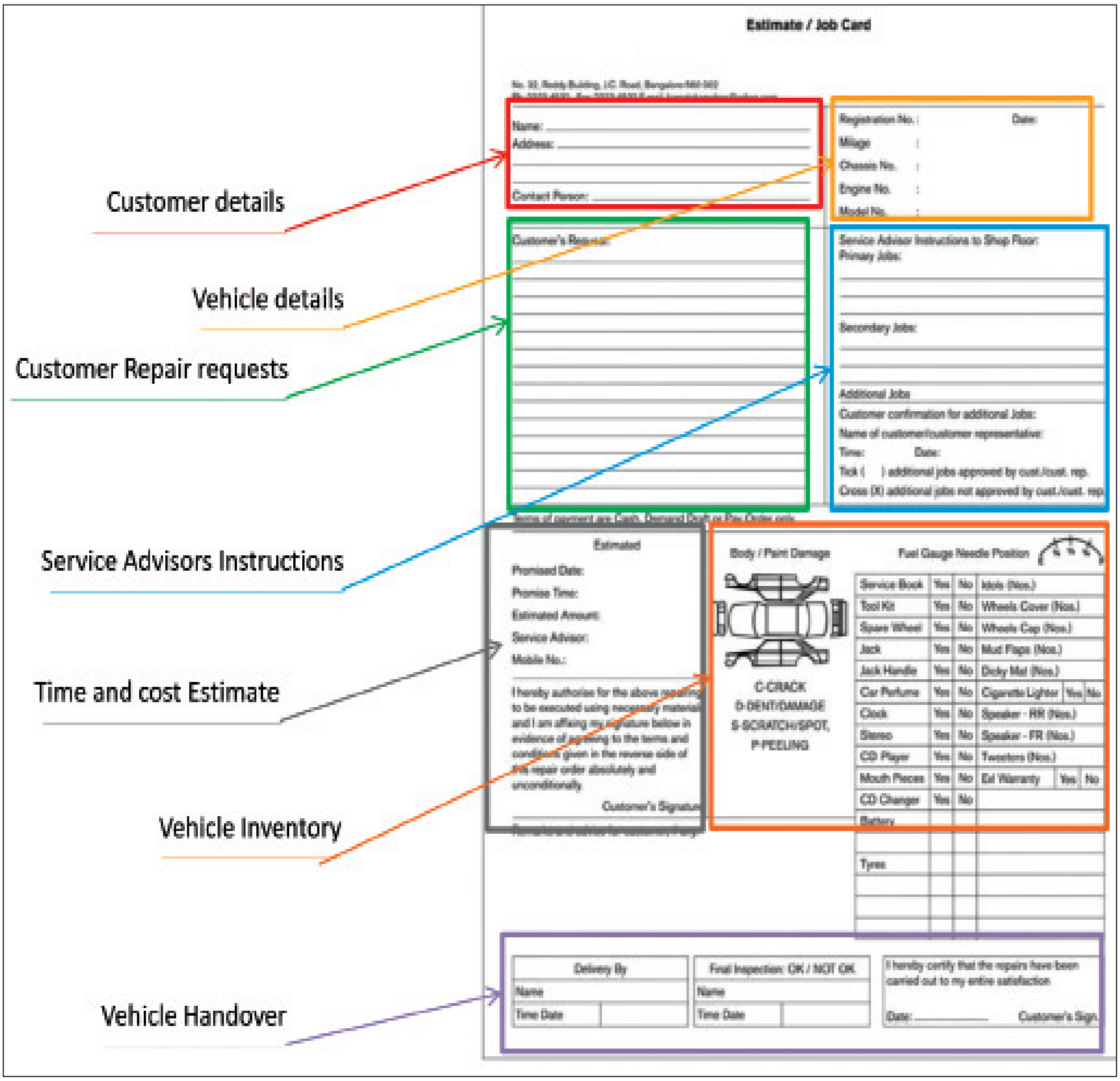
Service Process

- Vehicle Booking: In this process the appointment is taken by the service adviser from the customer for the service jobs. When the customer calls for an appointment to service his vehicle, the SA will allot time and date for him to bring his vehicle to the workshop as per the work schedule.
- Vehicle Receiving and Job Card Opening: The SA will receive booked vehicle and open a Job Order. A Job Order or a Job Card is a document which has details of the customers and the vehicle along with the jobs to be carried out on his vehicle. The customer has to ensure that his and his vehicle details are correctly entered and the jobs and his vehicle problems are correctly recorded on the Job Card before signing the JC.
- Job Allotment: The workshop Supervisor allots the jobs to the technicians as per the schedule and priority and delivery commitments.
- Work Progress: The Technician carries out the work as prescribed in the Job Order. He will intimate the supervisor if any additional job has to be done on the vehicle. An estimate of the job if required is given. On completion of the job the vehicle is sent for final inspection
- Final Inspection: The Quality Tester will perform the final inspection of the vehicle. He ensures that the job requested by the customer is carried out and the reported problems in the vehicle are solved. He sent the vehicle to washing after his inspection.
- Invoicing and Vehicle Delivery: After washing the vehicle comes to Delivery Section. The Service Adviser will prepare an invoice mean final billing of the vehicle will be done.Service adviser will inform the customer about the vehicle readiness and upon arrival of customer, the vehicle will be delivered to the customer after the bill amount is collected
- Post Service Follow up: The service adviser or the Customer Relation Executive(in some workshops) will call the customer after 3-4 days to take customer's feedback on the jobs done;

The above procedures may slightly vary depending upon the number of vehicle received and the type and size of the workshop.

Job Card

A job card is a sheet that contains details about the customer, vehicle, customer repair requests, and instructionsby service advisors, time and cost estimate, vehicle inventory and vehicle handover.



Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. What is a workshop?

2. Draw the layout of a workshop.

3. Draw the organization chart of a workshop.

4. Explain what is a job card or a job order.

Worksheet

1. *Read the questions and choose the correct answers*

a. The service adviser or the customer relation executive will call the customers after ____________ days to take customer feedback.

i. 3 - 4 ☐

ii. 4 - 5 ☐

iii. 5 - 6 ☐

iv. None of the above ☐

b. The repair bay is place that carry out ____________ on the vehicle.

i. Minor work ☐

ii. Major work ☐

iii. Warranty works ☐

iv. All of the above ☐

c. The workshop advisor allots the jobs to the ____________ as per the schedule and priority and delivery commitments.

i. Technicians ☐

ii. Parts picker ☐

iii. Service advisor ☐

iv. Tool room in charge ☐

d. The job card has details of ____________ .

i. Customer ☐

ii. Vehicle ☐

iii. Service advisor instruction ☐

iv. All of the above ☐

Notes

Answers: You and the Workshop

Question Number	Answer
1	a. i b. iv c. i d. iv

Your Role and Responsibilities as a Technician

At the end of this session you will be able to:

- state your role as a technician;
- state your responsibility as a technician.

Session Plan	
1	Introduction
2	Job Description
3	Role and Responsibility
4	Key Learnings
5	Worksheet

Introduction

Automotive service technicians should have thorough knowledge of basic automotive theories and have a practical expertise to repair and service for different types of vehicles. In addition to this, the technician should be aware of his/her responsibility and role in this job profile.

Job Description

Automotive Service Technicians generally will be employed by Vehicle Dealers of two wheelers, four wheelers and Heavy Vehicles – For Eg: Maruti, GM, Toyota, Tata, JCB etc.

These Dealerships have Service Departments in which the Aftersales activities of Maintenance and Repairs of respective vehicles will be carried out.

Role and Responsibilities of a Technician:

Role as a Technician:

- Perform Periodic Maintenance Service and related works on the vehicles he is specialized in as below:
  - Carrying out the service jobs like periodic maintenance and Pre Delivery Inspections on the vehicles using prescribed checklists
  - Performing running repairs like replacement of components of Engine, Suspension and other related aggregates of a vehicle
  - Overhauling of Vehicle aggregates like Engine, Transmission and Drivelines etc.
  - Perform diagnosis of problems in vehicles using sophisticated diagnostic tools, Service Manuals and special tools in a structured and systematic manner
  - Practice Fix it Right First Time Policy and find out the root cause of a vehicle problem
  - Ensure that the repairs/diagnosis jobs are performed within the specified Labour Time

Responsibilities as a Technician:

- Observe the rules andregulation and company policies
- Maintain discipline and work culture
- Work in Teams, respect others and being sincere
- Effective Management of Time
- Take part in the Assessments conducted by the dealerships and put in full efforts to reach higher levels his career
- Observe safety rules and personal safety inside the workshop while working on Equipment and Tools and also to ensure proper care while handling the customer vehicles
- Ensure to give maximum output in terms of Efficiency and productivity following the principles of 5S and kaizen.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. What is the role of a technician?

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2. What is the responsibility of a technician?

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Worksheet

1. *Read the questions and choose the correct answers.*

a. An automotive service technician should have through knowledge of basic ____________ theories and ____________ experience to repair and service different types of vehicles.

i. electrical, knowledge ☐

ii. automotive, practical ☐

iii. certification, driving ☐

iv. All of the above ☐

b. The dealerships have service departments that consist of aftersales activities and maintenance and repairs of respective vehicles will be carried out.

i. True ☐

ii. False ☐

Notes

Answers: Your Role and Responsibilities as a Technician

Question Number	Answer
1	a. ii b. i

Work Place Ethics and Behavioural Skills

At the end of this session you will be able to:

- state the importance of team work;
- follow work place ethics;
- work in teams.

Session Plan	
1	Introduction
2	Workplace Ethics
3	Working in Teams
4	Key Learnings
5	Worksheet

Introduction

Following the right conduct at workplace along with proper behaviour with subordinates and colleagues are important for the smooth work flow. Workplace ethics and behavioural skills can help the organization to earn maximum profit and employee satisfaction.

Workplace Ethics

Advantages of working in teams at a workplace:

- Improved productivity – successful teams develop the ability to accomplish more and faster
- Improved creativity – cross functionality, application of different minds to the task usually produces original, 'out-of-the-box' thinking
- Focus - properly tasked teams can solve intractable organizational problems

- Development – serving on a team, participating in team activity provides good developmental experience, sometimes fast-track, for team members
- Employee satisfaction – successful teams often have a good time, members also have a sense of achievement

Preconditions of high performing teams:

Purpose:

Successful teams have a clear sense of why they exist.

Objectives:

Successful teams have always translated their purpose into a series of measurable objectives.

Empowerment:

Successful teams have a strong sense of being in charge of their own destiny. They believe themselves to be accountable for what they do, that they 'carry the can', and that they are responsible for their conduct.

Support:

Teams need to be supported by the organizations, and usually be the person to whom they report. They must be buoyed up when they get miserable, reassured when they are in doubt, admired when they succeed, etc.

Characteristics of high performing teams:

Interpersonal skills

Successful teams develop the ability to work together without unproductive conflict. They do not allow differences to disrupt the achievement of the purpose or objectives.

Participation:

Successful team generates a high degree of participation among members. People contribute their views and experiences; it implies that when team members undertake to do something, they actually do it.

Decision making:

Decisions are reached with a proper evaluation of the information; the team is good at gathering all the information. All the members support the decision in practice even if there are any differences.

Creativity:

Successful teams almost always access new ideas, different ways of doing things, novel perspectives on events or circumstances.

Managing the external environment:

Good teams ensure that members interact with their outside world –usually the rest of organization. This often reduces organizational suspicion and enables a higher degree of external co-operation and fewer unwelcome surprises.

Working in Teams

Key Players of a Team:

- **Managers:** Hold conventional managerial responsibility and are drawn from the hierarchical culture of the organization
- **Facilitators:** These are neutral, objective individuals who are chosen for their process consulting skills. They may also act as arbitrators in times of conflict between managers and team players
- **Team leader:** These are often the department supervisors who must work with managers and facilitators and help them to shape the team.
- **Team players:** These are the members of the team who share a common goal or purpose. They must be trained and developed to assume the special skills and responsibilities of self-management
- **Support groups:** These are clusters of individuals who work with the Team supporting them with specific services required – e.g. the Human Resource, Finance and Administration departments.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. List down the advantages of a team in an organization.

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2. What is the role of a manager, team player, facilitators and team leader?

____

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Worksheet

1. *Read the questions and choose the correct answers.*

   a. The ______________________ are cluster of individuals who work with the supporting team with specific services required such as finance and administration departments.

      i. Managers ☐

      ii. Team Players ☐

      iii. Support groups ☐

      iv. Facilitators ☐

   b. A decision is taken after ______________________ .

      i. Proper evaluation of the information ☐

      ii. Gathering of the information by the team ☐

      iii. Support of all team members ☐

      iv. All of the above ☐

Notes

Answers: Work Place Ethics and Behavioural Skills

Question Number	Answer
1	iii
2	iv

Workshop safety

At the end of this session you will be able to:

- follow the various safety practices in an automobile workshop.

Session Plan	
1	Introduction
2	Safety Practices to be Observed
3	Key Learnings

Introduction

An automobile workshop consists of various moving components/machinery. It is necessary to take the required precaution when working to prevent component damage and injuries to human life.

Safety Practices to be Observed

Following are the most important safety practices that need to be followed when working in an automobile workshop.

Always wear a safety helmet in the workshop, especially when working under the vehicle.

- An automobile contains hard and sharp components on the under body which could hit the head and cause serious injuries.
- To prevent head injuries it is necessary to wear a safety helmet when working under the vehicle .

Hand Gloves

Wear cotton hand gloves when working or carrying out repairs or service on a vehicle.

- Due to excessive running of the engine, the engine components get heated.
- It is advisable to wear hand gloves to prevent burning of finger tips when working on heated objects especially engine components.
- The hand gloves also prevent dirtying the hands especially when working on under body components.

Wear face masks to cover your nose and mouth.

- To prevent poisonous gases from entering in to the lungs while working on engine exhaust when the engine in starting condition.
- The brake dust while carrying out brake cleaning and brake overhauling.
- Dust and dirt from under chassis and vehicle interior while cleaning /washing the vehicle.

Safety Goggles

Wear safety goggles when working under the vehicle.

- Due to excessive usage of the vehicle on various road surfaces, large amount of mud and dust collects on the under body of the vehicle.
- It is advisable to wear safety goggles when working under the vehicle to prevent dust from entering the eyes.
- It is also advisable to wear goggles when dealing with the fuel system, as fuel under pressure may spray and could enter the eyes causing injuries.
- Apart from the above, it recommended that while working on machineries such as Wheel Balancer and Grinder, goggles should be used.

Do not wear rings, watches and loose clothes when working on a vehicle.

- Avoid wearing metal watches and rings when working on a vehicle as metal could scratch the vehicle body paint and create damage.
- Since metal is a conductor of electricity it could also lead to short circuiting of the electrical circuit.
- Avoid wearing loose clothes as it gets into the moving parts of the vehicle which could cause injuries.

Boiler Suit

Keep the shop floor clean and tidy.

- Clean the shop floor once the job is complete.
- Prevent the oil from spilling on the shop floor as it could result in a slippery floor.
- Slippery floor is dangerous as it could cause injuries to life.

Wear safety shoes in the workshop

- The safety shoes consists of a metal cup covering the toes.
- It is necessary to wear safety shoes when working on the shop floor to prevent injuries to toes from heavy and sharp falling objects.

Use specific and tool for a specific job

- Use a correct tool for the specific job as usage of un appropriate tool could cause damage to components and injuries to life
- Prevent the use of wrong tool as component damaged when on the vehicle are difficult to remove
- Always use manufacturer prescribed special service tools (SST) while carrying out specific Diagnostic and overhauling jobs

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. What are the various safety practices that need to be followed in an automobile workshop?

2. Why do you need to wear safety goggles when working under the vehicle?

3. Describe safety shoes.

Notes

5S

	At the end of this session you will be able to: ◆ follow workshop standards to work safely and efficiently.

Session Plan	
1	Introduction
2	5S
3	Key Learnings
4	Worksheet

Introduction

The 5S Process, or simply "5S", is a structured program to systematically achieve total cleanliness, and standardization in the workplace. A well-organized workplace results in a safer, more efficient, and more productive operation. It boosts the morale of the workers, promoting a sense of pride in their work and ownership of their responsibilities. "5S" was invented in Japan, and stands for five (5) Japanese words that start with the letter 'S': Seiri, Seiton, Seiso, Seiketsu, and Shitsuke.

5S

Following are the most important safety practices that need to be followed when working in an automobile workshop.

Japanese Term	English Equivalent	Meaning in Japanese Context
Seiri	Tidiness	Throw away all rubbish and unrelated materials in the workplace
Seiton	Orderliness	Set everything in proper place for quick retrieval and storage
Seiso	Cleanliness	Clean the workplace; everyone should be a janitor
Seiketsu	Standardization	Standardize the way of maintaining cleanliness
Shitsuke	Discipline	Practice 'Five S' daily - make it a way of life; this also means 'commitment'

Seiri (Tidiness)

The first step of the “5S” process, seiri, refers to the act of throwing away all unwanted, unnecessary, and unrelated materials in the workplace. The idea is to ensure that everything left in the workplace is related to work. Even the number of necessary items in the workplace must be kept to its absolute minimum. Because of seiri, simplification of tasks, effective use of space, and careful purchase of items follow.

Seiton (Orderliness)

Seiton, or orderliness, is all about efficiency. This step consists of putting everything in an assigned place so that it can be accessed or retrieved quickly, as well as returned in that same place quickly. If everyone has quick access to an item or materials, work flow becomes efficient, and the worker becomes productive. The correct place, position, or holder for every tool, item, or material must be chosen carefully in relation to how the work will be performed and who will use them. Every single item must be allocated its own place for safekeeping, and each location must be labeled for easy identification of what it’s for.

Seiso (Cleanliness)

Seiso consists of cleaning up the workplace and giving it a ‘shine‘. Cleaning must be done by everyone in the organization, from operators to managers. It would be a good idea to have every area of the workplace assigned to a person or group of persons for cleaning. No area should be left un-cleaned. Everyone should see the ‘workplace’ through the eyes of a visitor - always thinking if it is clean enough to make a good impression.

Seiketsu(Standardization)

The fourth step of “5S”, or seiketsu, more or less translates to ‘standardized clean-up‘. It consists of defining the standards by which personnel must measure and maintain ‘cleanliness‘. Seiketsu encompasses both personal and environmental cleanliness. Personnel must therefore practice ‘seiketsu’ starting with their personal tidiness. Visual management is an important ingredient of seiketsu. Color-coding and standardized coloration of surroundings are used for easier visual identification of anomalies in the surroundings. Personnel are trained to detect abnormalities using their five senses and to correct such abnormalities immediately.

Shitsuke (Discipline)

The last step of “5S”, Shitsuke, means ‘Discipline. It denotes commitment to maintain orderliness and to practice the first 4 S as a way of life. The emphasis of shitsuke is elimination of bad habits and constant practice of good ones. Once true shitsuke is achieved, personnel voluntarily observe cleanliness and orderliness at all times, without having to be reminded by management.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. What do you mean by Seiton (Orderliness)?

____
____
____
____
____
____

2. Describe Shitsuke (Discipline).

____
____
____
____
____
____
____

Worksheet

1. *Read the questions and choose the correct answers.*

   a. ______________________ is the English equivalent of Seiketsu.

      i. Standardization ☐

      ii. Discipline ☐

      iii. Orderliness ☐

      iv. Tidiness ☐

Notes

Answers: 5S

Question Number	Answer
1	a. i

General Workshop Tools and Equipment

At the end of this session you will be able to:

- identify the various tools and equipments used in an automobile workshop;
- use the tools available in an automobile workshop.

Session Plan	
1	Introduction
2	Workshop Tools
3	Key Learnings
4	Worksheet

Introduction

The automobile workshop is equipped with various tools. It is necessary to understand and identify the specific tool required to perform a job.

Workshop tools

A good automobile workshop needs to have all the equipment to undertake all repairs on the vehicles. Following is a list of equipment that needs to be present at the workshop to carry all the repairs:

Screw drivers

A screw driver is a device that is used to loosen and tighten screws in a machine. The main parts of the screw driver are:

Handle

- The handle is a smooth and properly shaped end of the screw driver that gives grip when holding the screw driver
- It is usually made of hard plastic or wood

Blade

- The blade is made of hardened and tempered carbon steel or alloy for strength
- Screw drivers are specified according to the length and width of the blade

Tip

- The tip is a part of the screw driver that fits in the groove of the screw head
- The various tip design available are flat end and plus
- The various type of screw drives available are straight tip type, Philips type, offset type and ratchet type

Spanners

Spanners are also known as wrenches and are used to loosen and tighten the nuts. These are made of high tensile or alloy steel and are drop forged and hat treated. The size of the spanner is determined by the nut or bolt it fits. The different types of spanners available are:

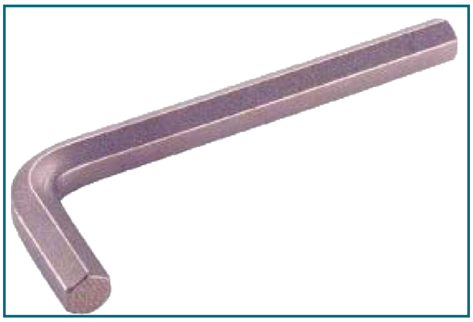
- Open ended spanners
- Ring spanner
- Combination spanners
- Socket spanners

Torque Wrench

Important nuts and bolts in an automobile need to be tightened with a specified amount torque because excessive torque may result in their breakage while with lesser torque they will come out loose during use. This is made possible by a torque wrench. It is a specialized form of a socket spanner. The pointer at any time indicated the amount of torque applied on the nut. The refined form of a torque wrench available in the market on which the torque figures are provided on the shaft of the wrench and the handle needs to be rotated to set the desired torque wrench.

Adjustable wrench

This type of wrench has one adjustable jaw. The main advantage of this wrench is to it can be adjusted to adapt to various nut and bolt sizes. The movable jaw is adjusted by rotating the adjustable screw.



Allen wrench (Allen key)

Allen keys are used to loosen or tighten screws which have a hexagonal shaped groove on their heads.

Hammers

Hammer is a tool that is used for striking operations such as denting, bending, punching reverting etc. The head and the handle form two parts of the hammer. The head is made of drop forged steel and has a hole in the centre to mount the handle. The handle is made of wood or metal pipe, longer the handle greater is the force applied. The striking part of the hammer is flat and is called the face, while the uppermost part is called the peen. Peen is shaped according to different requirement and is basically classified on the basis of the peen:

- Ball peen
- Cross peen
- Wooden.

Chisels

Chisels are basically used for cutting a metal sheet by hammering it. The basic application of the chisel in an automobile workshop is to tear open the corroded nuts or rivets in the vehicle. The body of the chisel is generally hexagonal in cross section and the cutting edge is hardened and tampered to increase toughness, stiffness and hardness.

Files

Files are used to smoothen rough surfaces and for removing small amounts of metal. The file cuts the metal during the push stroke. Files are generally classified as either single cut or double cut depending upon whether they have cuts in one direction or in both directions. Files may also be classified based on the cross-sectional shapes such as:

- Flat file
- Triangular files
- Square file
- Half round file
- Round file.

Hacksaw

Hacksaw is meant to cut metal by sawing. The hacksaw has an adjustable frame with a handle and a replaceable cutting blade. The hacksaw design is such that, it can accommodate blades of various sizes by adjusting the adjusting fly nut. The blade is thin narrow strip with teeth on one or both sides and two pin holes on each end. The blade is made of high speed steel and is available in various lengths and thicknesses.

Taps and Dies

Taps are used to cut inside threads in the metal especially pipes, while the dies are used for cutting external threads.

T-types or long handles are used to hold the taps and dies for threading.

Taper tap

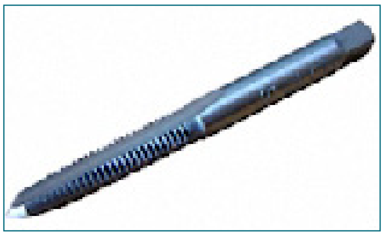
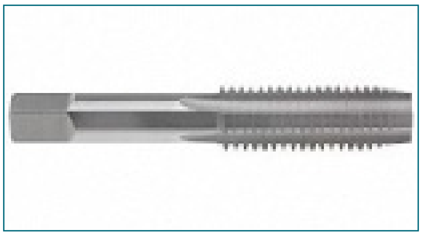
- The taper tap is used to cut threads in a hole through a metal piece.

Plug tap

- The plug tap is used to thread a hole partly for installing a plug in it.

Bottom tap

- The bottom tap is used to cut a thread in a blind hole.

		
Taper	**Plug**	**Bottom**

Drilling Machine

A drilling machine is a tool that is used to drill holes into the metal, it may be hand operated or electrically operated. The toll used for drilling is called the twist drill. The main parts of a drilling machine are the electrical unit and a drill bit. The drill bit is fitted to the drilling machine through a chuck nut. The main parts of the drill bit are shank, body and the point. The shank is fitted to the drill through the chuck nut, while the point is the conical end which does the cutting. The cutting edge is called the tip. The portion between the shank and the tip is called the body and has spiral grooves called flutes, which act as cutting edges and act as a passage for cut metal pieces to exit from the drilled hole.

Grinder

A grinder is a machine that is used to re-sharpen the edges of various tools as well as to grind sharp edges of vehicle components if necessary. It is electrically powered and has a grinding blade. Once the grinder is switched ON, the grinding blade start rotating and grinds the required surface. It advisable, not to stand on the opposite side of the grinder as fine metal chips fly in the forms of sparks and if entered the eye, could damage the eye.

Bench vice

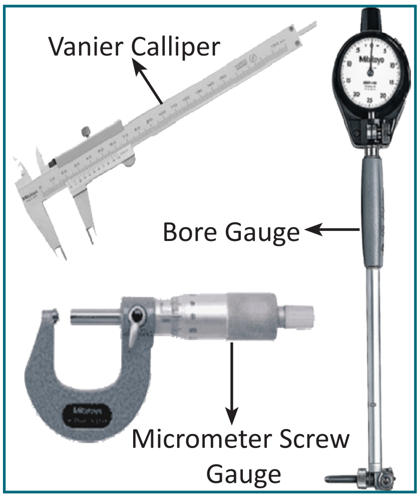
The bench vice is a stationary tool and is fixed on the work bench. It is generally used of holding metal components especially when grinding, cutting and filing. It consists of a fixed and a movable jaw. The movable jaw can be moved in and out by rotating the screw to accommodate jobs of various sizes. The jaws consist of additional jaws with threaded design to provide grip to the job when working.

Measuring tools

Tools that are used to measure component dimensions are known as measuring tools. The various tools used in an automobile workshop are:

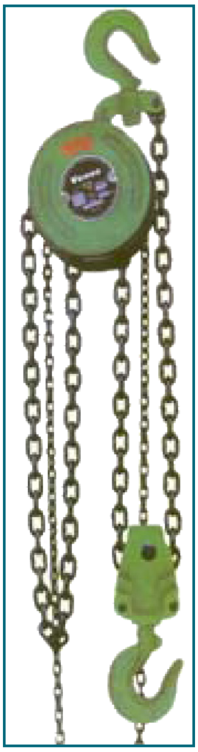
- Vanier Calliper
- Micrometer Screw Gauge
- Depth Gauge
- Bore Gauge

A VernierCalliper and micrometer is used to measure external as well as internal dimensions where the bore gauge is used to measure the inside diameter of the engine cylinder.



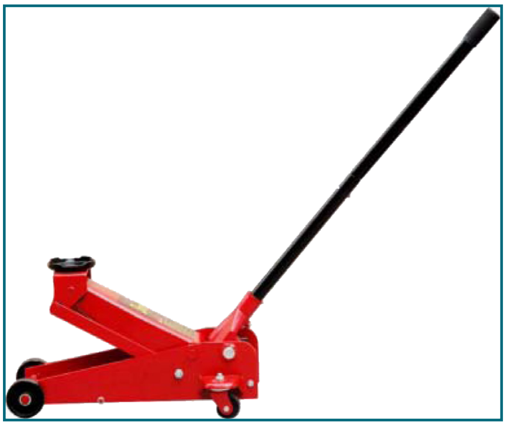
Chain Pulley Block

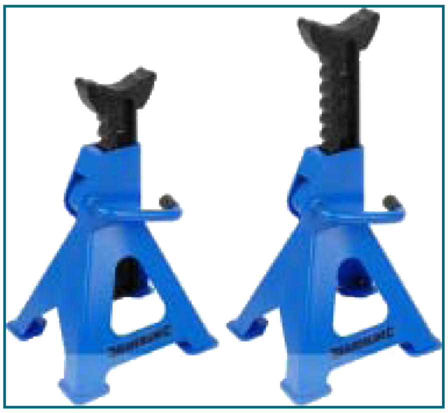
A chain pulley block is used to lift the engine out from the vehicle body or insert into the vehicle body during the overhauling process. The hook is mounted at specified locations on the engine as per manufacturer specifications.



Hydraulic Jack And Axle Stand

A hydraulic jack is used to lift the vehicle form the ground. It consists of a fluid reservoir, piston and a cylinder. The piston pumps the oil form the reservoir to the cylinder to exert pressure on the vehicle in order to lift it above the ground. To lower the vehicle one needs to open the pressure relief valve which releases the pressure and lowers the vehicle. It is advisable to rest the vehicle on axle stands once the vehicle is lifted to prevent accidental damage of the vehicle, if the hydraulic system in the jack fails.





Battery Testing and Charging Equipment

Battery equipment commonly required in an automobile workshop is as below:

- Battery charger
- Hydrometer
- Cell tester

A battery charger is a transformer that provides constant DC voltage to charge the battery. The hydrometer is used to check the specific gravity of the electrolyte in the battery at all-time which also indicates the state of charge of the battery. The battery cell tester is used to test the battery under simulated starting conditions when very heavy current is drawn.

Two Post Lift or Service Ramp

A two post lift is used to lift the vehicle fully above ground level. This system facilitates comfortable working posture especially when working under the car. It consists of arms on which the vehicle is lifted. The vehicle is lifted with a help of electric drive. The electric motor drives the arms through a screw and chain mechanism. Service ramp is a traditional way of servicing cars. In this method a pit is dug into the ground and the technician need to enter the pit to service the under body of the vehicle.

Pneumatic Gun

A pneumatic gun along with a socket spanner is used to loosen and tighten the wheel bolts. It operated on compressed air. The rotational movement can also be reversed by operating a valve on the handle.

Wheel Balancing Machine

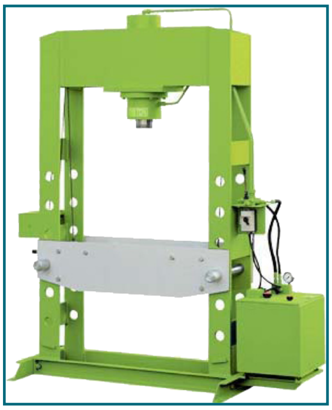
A wheel balancing machine is an electric driven machine which consists of a rotating shaft. It is used to distribute the mass of the wheel equally. Due to periodic usage the tyres tend to wear; the wear is generally uneven. The uneven wear causes the tyre imbalance, hence, to get the tyre balanced it is mounted on the wheel balancing machine and additional weights are fixed to the wheel rim.

High Pressure Washing Equipment

After servicing the vehicle, it needs to be cleaned before delivering it to the customer so that no stains of grease are left on the body paint. This is done using high pressure washing equipment. The high pressure washing equipment consists of a compressor, high pressure pipe and a high pressure washing gun. The compressor pumps water from the reservoir tank at high pressure and delivers the same to the nozzle of the gun through the high pressure pipe, which is used to clean the car along with soap solution. The water leaving the nozzle is at high pressure; hence it is advisable not to keep it close to your body as it may cause cuts and bruises.

Engine Analyzer

Engine analyzer is an engine scanning tool used in large automobile workshops to reduce time and effort in fault finding. It consists of a scanning session that is connected to the vehicle through an on-board-diagnostic port usually located under the dashboard. The defects and faults are displayed on the monitor. The faults are displayed in the form of Diagnostic Trouble Codes (DTCs). For proper explanation on the DTCs, one needs to refer to the model specific service manual.



Hydraulic Press

The hydraulic press is required for many repair jobs in an automobile where steady pressure is necessary, especially when replacing bearings. It consists of a piston that is manually operated or electrically operated by a hydraulic pump. The height of the work table can be adjusted by shifting the table to various slots provided on the side members, this help in accommodating jobs of various sizes.

Piston Ring Compressor

A spring compressor is a metal sleeve that goes over a piston to compress the rings so that the piston can be installed easily in the engine cylinder. It tightens on the piston, forcing the rings into the grooves in the piston then you tap it into the cylinder. This is a special tool that is used at the time of an engine overhaul operation.

Wheel Alignment Machine

The wheel alignment is an electronic machine that is used to set the steering geometry of the vehicle. It uses sensors, through which the steering angles are scanned. The angles are altered by adjusting the various steering components like tie-rods etc. using a spanner. It is necessary to maintain the steering geometry angles, if not done so; it will lead to pulling of the vehicle on one side resulting in uneven wear of the tyres.

Air Compressor and Pressure Gauge

The air compressor is electrically driven and is used to compress the air at high pressure and is generally located in the store room of the workshop. The compressed air is transferred to the nozzle through a long high pressure pipe which is used to inflate the flattened tyre. The pressure gauge is used to measure the inflated pressure which is generally denoted by psi (Pounds per square inch).

AC Recovery and Recharge Machine

In a single series of operations, the machine permits recovering and recycling refrigerant with no risk of release into the environment, and also permits purging the AC system of humidity and deposits contained in the oil. The machine is equipped with a built-in evaporator/ separator that removes oil and other impurities from the refrigerant recovered from the AC system and collect them in a container for that purpose. The fluid is then filtered, recycled and returned to the tank installed in the machine. The machine also permits running certain operational and leak tests on the AC system.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. Describe the wheel alignment machine

2. Describe measuring tools.

3. What is the usage of a bench vice?

Worksheet

1. Battery testing equipment consists of which of the following components?

   a. Battery charger ☐

   b. Hydrometer ☐

   c. Cell tester ☐

   d. All of the above ☐

2. Tyre pressure is denoted by ____________________.

   a. psi ☐

   b. Nm ☐

   c. Ps ☐

   d. kW ☐

Notes

Answers: General Workshop Tools and Equipment

Question Number	Answer
1	d. All of the above
2	a. psi

Anatomy of an Automobile

At the end of this session you will be able to:

- identify the various aggregates of an automobile;
- state the function of the various aggregates.

Session Plan	
1	Introduction
2	Automobile Aggregates
3	Key Learnings
4	Worksheet
5	Engine
6	Clutch
7	Gearbox/transmission
8	Transfer case
9	Propeller shaft
10	Differential
11	Axle
12	Brakes
13	Wheels
14	Suspension
15	Steering

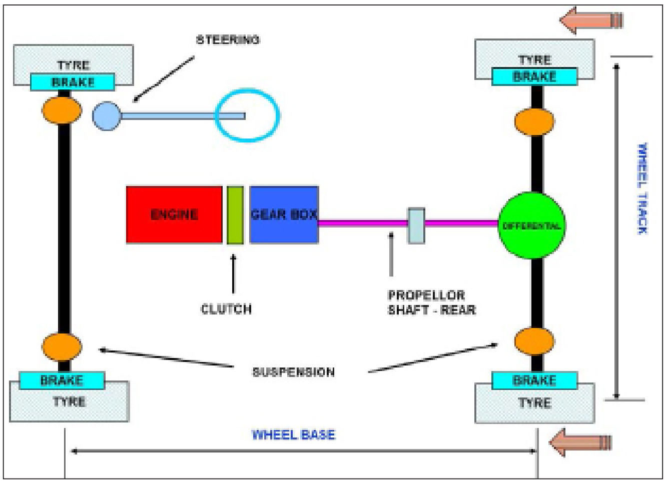
Introduction

An automobile is a carriage that is mounted on wheels. It facilitates the movement of goods or people from one place to another with minimum effort. It is made up of various systems or aggregates that combine with each other to make mobility possible.

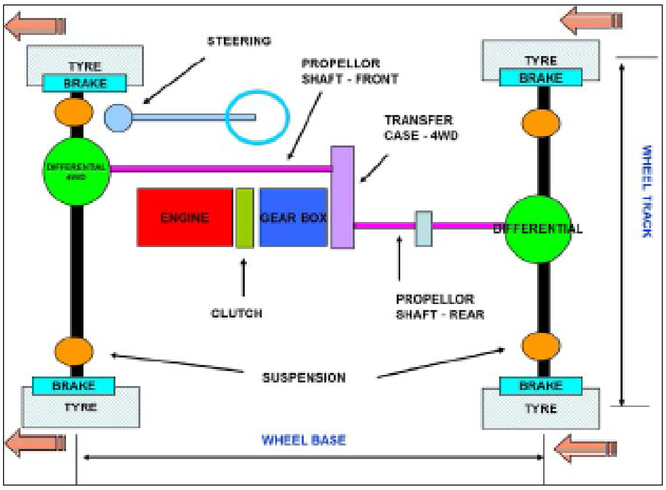
Automobile Aggregates

Below listed are the various automobile aggregates:

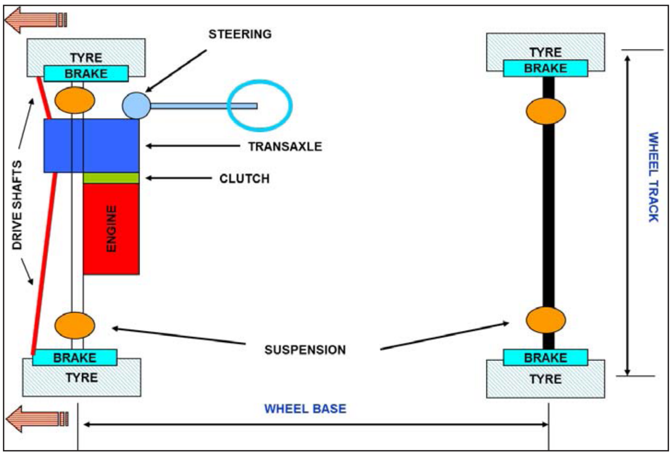
The location of each aggregate could differ based on front wheel drive, rear wheel drive or all-wheel drive.



Anatomy of An Automobile
(rear wheel drive - 2wd)



Anatomy of An Automobile
(four wheel drive)



Anatomy of An Automobile
(four wheel drive)

Engine

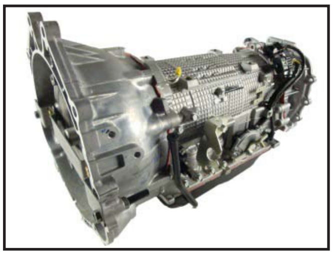
An engine is a machine that converts chemical energy into useful mechanical motion. It is also the heart of an automobile and works on petrol, diesel, CNG or LPG based on application. Engines are available in various cylinder configurations ranging from 1 to 12 cylinders.

Clutch

The clutch is a circular disc with friction material on both sides. It is situated between the engine and the transmission. Primary function of the clutch is to engage and disengage the drive from the engine to the gearbox when shifting gears.

Gearbox/Transmission

A transmission is a solid component that consists of gears of different sizes. Gears mesh up with each other to provide a controlled application of power at the road wheels to suit every load condition.



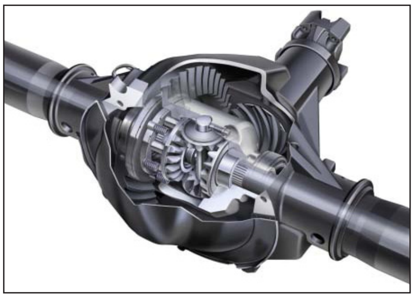
Transfer Case

A transfer case is generally seen in vehicles equipped with four wheel drive system. It is connected to the transmission and also to the front and rear axles by means of drive shafts. Its primary function is to transfer power to the front as well as the rear when the four wheel drive is engaged.

Propeller Shaft

A propeller shaft is a long tubular device that is used to connect the transmission to the rear axle in the case of a rear wheel drive vehicle. The consists of an universal joint at each end to accommodate the change in length and height when the vehicle is travelling on uneven surfaces.

Differential



A differential is a gear mechanism that is housed in the transaxle in the case of front wheel drive vehicle or in the rear axle in the case of a rear wheel drive vehicle. The main function of a differential is to differentiate the speed of the inner and outer wheels while on a turn to prevent skidding.

Axle

Axles are long tubular shafts that connect the differential to the road wheels. It consists of a splined end that is coupled with the differential and a flange at the other end that is connected to the wheel by means of bolts. These are made of high strength steel as they undergo a tremendous twisting force when transferring power to the wheels.

Brakes

Brakes are vital components in an automobile. The primary function is to reduce the speed of the vehicle in order to prevent accidents. Automobiles are generally equipped with disc brakes in the front and drum brakes at the rear.However, some automobiles are also available all four disc brakes too.

Wheels

The main components of a wheel are tyre, tube and the wheel rim. The primary function of the tyre is to provide friction to between the wheel and the road surface to move the vehicle forward, the tube holds air in itself to provide smooth operation and absorption of road shocks. The wheel rim is available as a steel disc or and alloy wheel, alloy wheels are comparatively lighter than the steel discs.

Suspension

Suspension system isolates the cabin from the road shocks to provide comfortable drives. Automobiles are generally equipped fully independent suspension setup in the front and semi-independent or non-independent suspension at the rear. Recently automobiles are also equipped with all independent set-ups too.

Steering

The steering system is combination of various components and linkages. It aids the driver in selecting the direction of motion by steering the steering wheel with minimum effort. Automobiles are equipped with hydraulic, electric and electro-mechanical or electro-hydraulic power steering systems.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. List the various automobile aggregates.

2. State the function of the following:

   a. Clutch:

   b. Brakes:

   c. Wheels:

   d. Axle:

Worksheet

1. Read the questions and tick the correct answer.

e. The primary function is to reduce the speed of the vehicle in order to prevent accidents.

   i. True ☐

   ii. False ☐

f. Which of the following is/are the different steering systems available in automobiles?

   i. Hydraulic power steering ☐

   ii. Electric power steering ☐

   iii. Electromechanical power steering ☐

   iv. All of the above ☐

Notes

Answers: Anatomy of an Automobile

Question Number	Answer
1	a. i b. iv

Common Body Types

At the end of this session you will be able to:

- identify the various automobile body styles.

Session Plan	
1	Introduction
2	Automobile Body Styles
3	Key learnings
4	Worksheet

Introduction

An automobile is available in various body styles to suit the need of every customer. Each body style has a direct impact on the number of seats or people it can carry.

Automobile Body Styles

Hatchback

A hatchback is a 2 box design. It consists of a separate engine and a passenger compartment. The boot is enclosed with the passenger compartment behind the rear seats and is ideal for single users/small families especially cities. Maximum seating capacity of a hatchback is 4-5 persons.

Sedan

A sedan is a 3 box design and is also known as a notchback. It consists of a separate engine, passenger and boot compartment and is ideal for families who need separate boot compartment. Maximum seating capacity of a sedan is 4-5 persons.

Estate

An estate is a 2 box design and is a modified version of a sedan. It consists of a separate engine and a combination of passenger plus boot compartments. The boot compartment is significantly larger and more spacious than a sedan. Maximum seating capacity of an estate is 4-5 persons.

MPV/Van

An MPV/Van is a 1 or 2 box design and is known as a Multi-Purpose Vehicle. It consists of engine, passenger and boot compartments in one box. Maximum seating capacity of a MPV/Van is 5/6/7/8 persons.

SUV

An SUV is a 2 box design. SUV means –Sports Utility Vehicle. These vehicles have large tyres, higher ground clearance. It consists of a separate engine compartment and a combination of passenger plus boot compartment. The vehicle is equipped with either 4 wheel drive as standard or as an option and is used for off-road driving. Maximum seating capacity of an SUV is 5/6/7/8

Pick-up

A pick-up is a 3 box design. These vehicles have large tyres, higher ground clearance. It consists of a separate engine, passenger and boot compartment. It is similar to SUV in terms of usage but designed for load carrying. They are either equipped with 4WD as standard or as an option. Maximum seating capacity of an SUV is 2/3/4/5/6 persons.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. What is the difference between a hatchback and a sedan?

2. What do you mean by an SUV?

Worksheet

1. *Read the questions and choose the correct answers.*

   a. An SUV is a ____________________ design.

      i. 1 box ☐

      ii. 2 box ☐

      iii. 3 box ☐

      iv. 4 box ☐

   b. A sedan is also known as a notchback.

      i. True ☐

      ii. False ☐

Notes

Answers: Common Body Styles

Question Number	Answer
1	a. ii b. i

General Automotive Terminologies

At the end of this session you will be able to:

- state the various automobile terminologies.

Session Plan	
1	Introduction
2	Automobile Terminologies
3	Key learnings
4	Worksheet

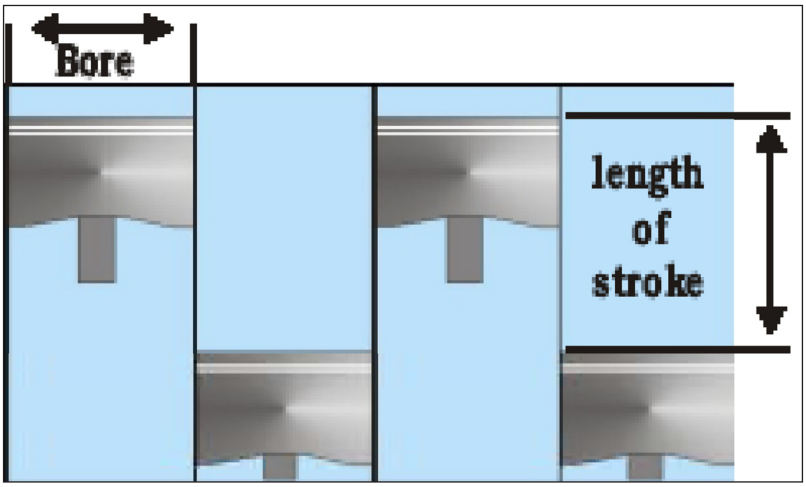
Introduction

The function of an Automobile is mainly dependent on its Engine Performance. The Engine performance is determined by measuring various parameters related to its components. These parameters have definite terminologies and are measured in specific units. The following session covers all the important terminologies – their units of measurement and the ideal way of calculating them.

Automobile Terminologies

Engine size

Engine size is the total amount of air-fuel mixture entering inside all the cylinders of the engine during once cycle; 4 strokes. It is measured in cubic centimeters (cc). It is equivalent to the displacement of all pistons, (stroke length x area of piston x no of cylinders), measured in cubic centimeters (cc) Bore length of stroke. Higher cc engine generally results in generation of higher power output.



RPM

Revolutions Per Minute (rpm) is a unit to measure rotational speed. In context of engines, it represents the number of full rotations the crankshaft (flywheel) makes in one minute. If you increase the rpm of the engine, the power output of the engine also increases. The rpm is displayed on the tachometer.

Torque

Torque is a term used to describe turning or twisting force. In automobiles, it relates to the pulling capacity of the engine. It is usually measured in pounds-per feet (Lb-ft), Newton metre (Nm) or Kilogram metre (Kgm). Higher torque at low rpm will give the vehicle good pulling power, and easy drivability.

1 Kgm = 9.8066 Nm; 1 Nm = 0.7376 Lb-ft

Power

Brake Horse Power (BHP) is the unit of measuring power, produced by an engine. Power is a measure of how quickly work can be done (moving the car). It is the actual power delivered at the flywheel of the engine .Power (BHP) of the engine depends on its torque and engine speed (RPM). The higher the BHP, the more powerful an engine is. The unit of power for automobile is KW, bhp or PS (German word: Pfederstark).

1 PS = 0.986 bhp

1 KW = 1.341 bhp = 1.3596 PS

Power to Weight Ratio

Power to weight ratio is the power the engine generates, divided by the vehicle's weight. The power-to-weight ratio is measured as bhp per tonne. Higher power indicates vehicle's capability to pull more weight and accelerate quickly (better pick-up).

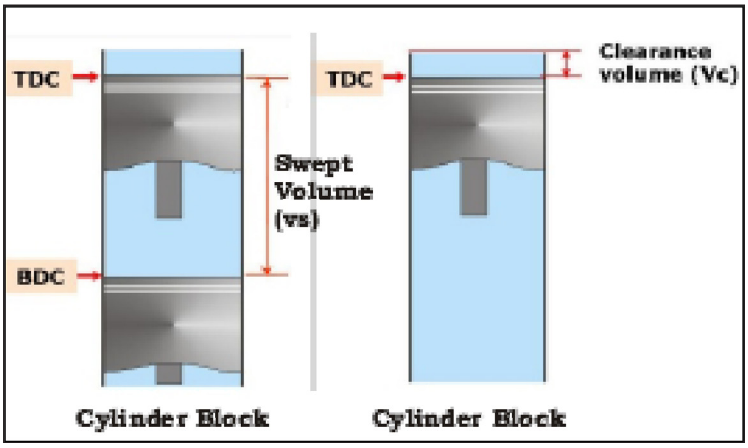
Compression Ratio

In an internal combustion engine is the ratio of the volume between the piston and the cylinder head before & after a compression stroke.

$$\frac{vs + vc}{vc} = \text{Compression Ratio}$$

vs = Volume between T.D.C TO B.D.C position.

vc = Volume above the piston when it is in the T.D.C position



Compression Ratio:

- For petrol Engine : (8 ~ 10):1
- For Diesel Engine : (15 ~ 24):1

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. Explain power to weight ratio?

____

____

____

____

2. What do you mean by engine size?

____

____

____

____

Worksheet

1. Choose the correct answers.

a. Torque is a term used to described ____________________.

i. engine size ☐

ii. horse power ☐

iii. turning or twisting force ☐

iv. none of the above ☐

b. The unit of measure rotational speed is ____________________.

i. BHP ☐

ii. RPM ☐

i. KW ☐

ii. none of the above ☐

Notes

Answers: General Automotive Terminologies

Question Number	Answer
1	a. iii b. ii

General Terms Related to Electricity

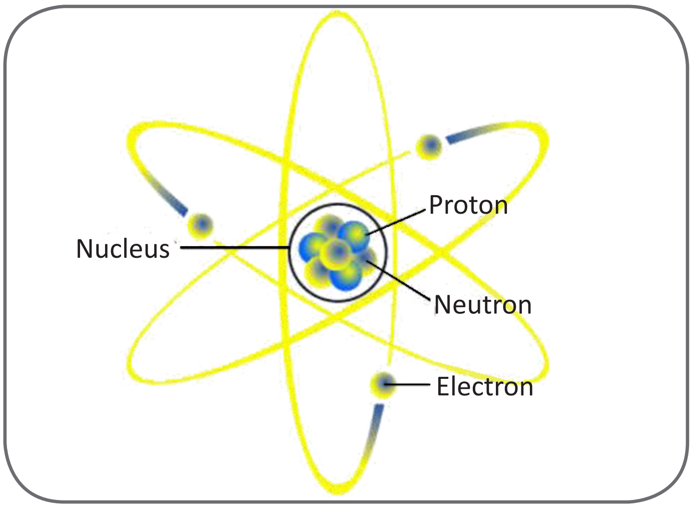
At the end of this session you will be able to:

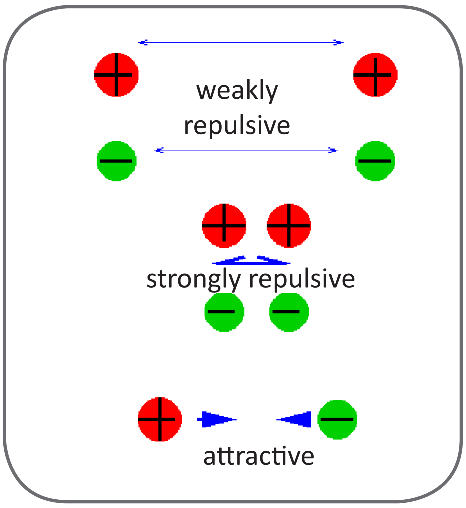
- state the various terms used in electricity;
- define resistance, voltage and current;
- define ohm's law;
- measure resistance, voltage and current using a multi-meter.

Session Plan	
1	Introduction
2	Basics of Electricity
3	Voltage
4	Current
5	Resistance
6	Ohm's Law
7	Multi-Meter
8	Key Learnings

Introduction

A basic electric circuit consists of voltage, current and resistance having its own significance in the particular circuit. Measuring each of these parameters is done using a multi-meter.





Basics of Electricity

Atom: An atom is made of three components

- Protons (positively charged)
- Electrons (negatively charged)
- Neutrons (no charge)

Nucleus: Nucleusis the central region of an atom which contains the protons and the neutrons; the electrons revolve around the orbit.

Electric Charges: These can be either positive or negative. Opposite charges will attract each other and tend to move towards each other whereas like charges always repel.

Electricity is the flow of electrons (negative charge). The basic units of electricity are:

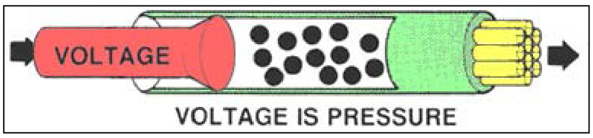
- Voltage (Denoted by 'V')
- Current (Denoted by 'I')
- Resistance (Denoted by 'R')

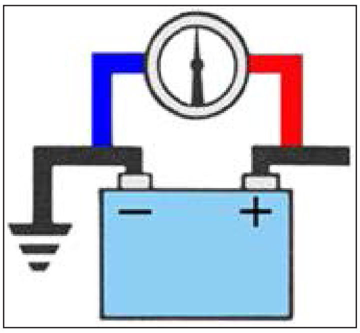
Voltage

Voltage can be described as an electrical pressure. In an automobile, the battery or generator is used to apply this pressure. The amount of pressure applied to a circuit is measured in volts. It is also known as electromotive force. The symbol forelectromotive force is E.

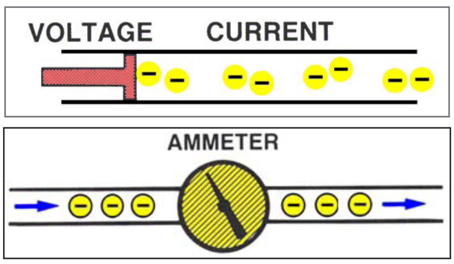
The symbol for volts is V.

A **voltmeter** is used to measure the voltage potential across or parallel to the circuit.





Current

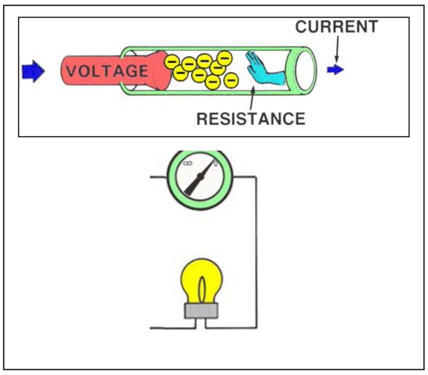


Current can be described as the rate of electron flow. It is measured in amperes. The current increases as pressure or voltage is increased – provided that circuit resistance remains constant. Another term for amperes is 'intensity of current'. The symbol for current intensity is I. The symbol for amperes is A.

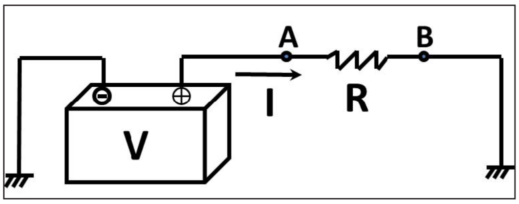
An **ammeter** measures the quantity of current flow. Ammeters are placed in series (inline) to count the electrons passing through it.

Resistance

Resistance is the force that reduces or stops the flow of electrons. It opposes voltage. Higher resistance will decrease the flow of electrons and lower resistance will allow more electrons to flow. It is measured in ohm (Ω)



Ohm's Law



Equivalent equation:
◆ $V = I \times R$
◆ $I = \frac{V}{R}$
◆ $R = \frac{V}{I}$

Ohm's law states that the current (I) in an electric circuit is inversely proportional to the resistance (R) of the circuit (when V is constant), and is directly proportional to the electromotive force (emf) in the circuit (when R is constant).

Ohm's law applies only to linear constant-current circuits.

An electric circuit has a resistance of one ohm when an applied voltage (emf) of one volt causes current at the rate of one ampere.

Multi-meter

In an electrical circuit a multi-meter is used for checking:

- voltage;
- current;
- resistance/continuity.

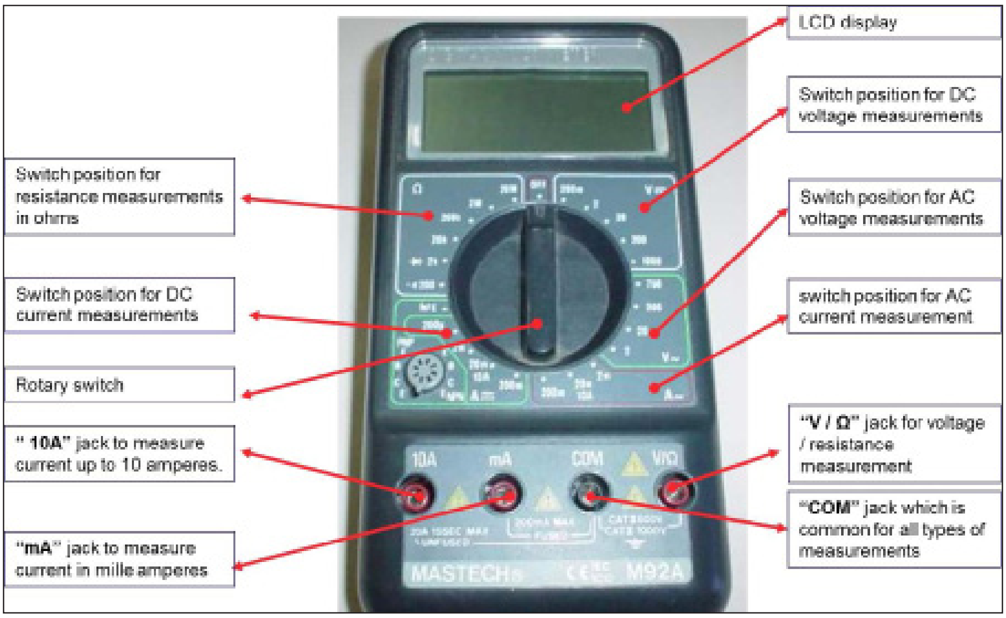
Multi-meters are available in two configurations:

- analog multi-meter;
- digital multi-meter.

Digital Multi-meter

Analog Multi-meter

Part identification of the multi-meter



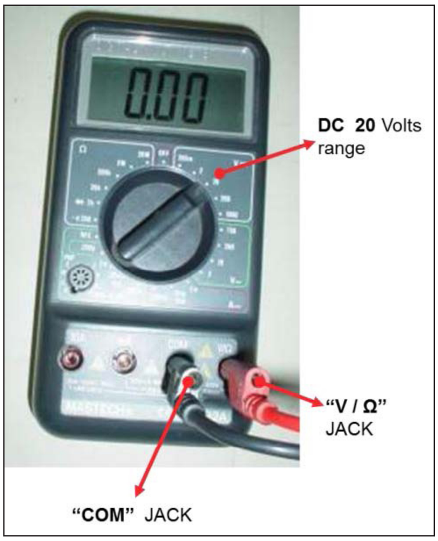
Precautions to be taken when using a multi-meter are:

- Ensure that the battery is not low. It is either "BATT" or no display on screen appears if battery is low.
- Never exceed the maximum input voltage or current limits shown beside the input jacks, if exceeded it can lead to internal circuit damage.
- Do not turn the rotary switch full circle (check manufacturer's specification).
- Become familiar with all the buttons and turn the rotary switch to proper range before operating.
- Check the condition of test leads for damage insulation and for exposed metal.
- Do not turn the rotary function switch during voltage or current measurement.
- Turn off the meter (turn rotary switch to "off") after all measurements are over.

Multi-meter setting for voltage measurement:

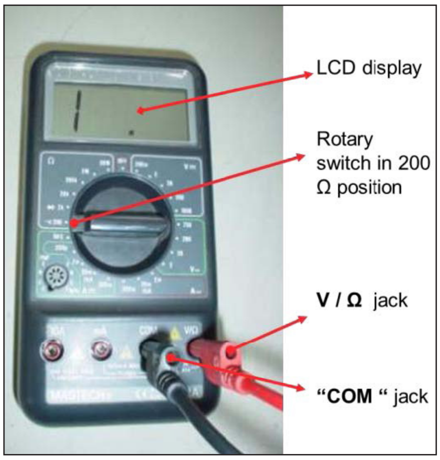
The following steps need to be followed when measuring voltage on a multi-meter:

- Connect the black test lead to "COM" jack.
- Connect the red test lead to "V" jack.
- Select the kind of voltage to be checked: AC or DC.
- Set the rotary switch to suitable voltage range.
- If the magnitude of the voltage is unknown, always start with the highest range and reduce until satisfactory reading is obtained.
- When you connect the test lead across the terminals of the component to be measured, LCD displays the measured value and also the polarity of the red test lead.
- "1" indicates meter is over loaded, then set the measuring range to higher.



Multi-meter setting for current measurement

The following steps need to be followed when measuring current on a multi-meter:

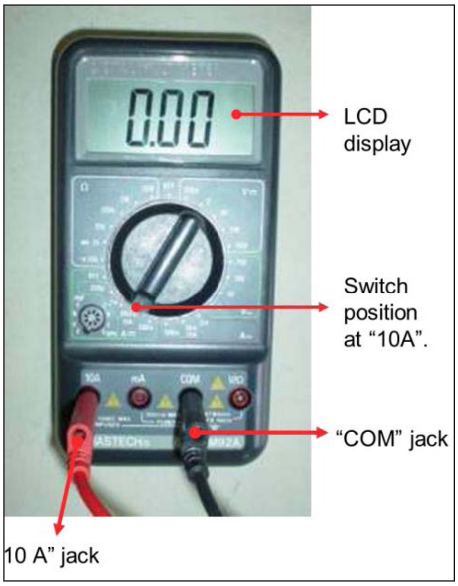


- Connect the black test lead to "COM" jack.
- If measuring current is 200mA or below, connect the red test lead to "mA" jack.
- If measuring current is 10 amps or below, connect the red test lead to "10A"jack.
- Select the kind of current to be checked, i.e. AC or DC.
- Set the rotary switch to suitable current range.
- Connect the test leads in SERIES with the component to be measured.
- LCD displays the measured value and also the polarity of the red test lead.
- If magnitude of current is unknown, always start with the highest range and reduce until satisfactory reading is obtained.

Multi-meter setting for resistance measurement

The following steps need to be followed when measuring resistance on a multi-meter:

- Connect the black test lead to "COM" jack.
- Connect the red test lead to "Ω" jack.
- Set the rotary switch to desired value range in "Ω".
- Connect the test lead across the component whose resistance has to be checked.
- If the magnitude resistance is unknown start with lowest range and increase until satisfactory reading is obtained.
- "1" indicates meter is overloaded, then set the measuring range to higher.
- When standard resistance of a component is known and after selection of suitable range shows "1", it means there is open circuit.
- "1" could also result if there is no input, i.e. the test leads are not touching the terminals of the object whose resistance is being measured.
- Make sure all objects, circuits and components to be measured for resistance are without voltage.



Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. What do you understand by voltage?

2. State Ohm's law.

3. Mention the precautions that need to be followed when using a multi-meter.

4. What are the steps that you need to follow to measure current in a circuit using a multi-meter?

Worksheet

1. Read the questions and tick the correct answer.

a. In order to measure current in a circuit using a digital multi-meter it is necessary to shift the rotary switch to ______________________ position.

- i. ohms ☐
- ii. volts ☐
- iii. ampere ☐
- iv. None of the above ☐

b. In an electrical circuit, a multi-meter is used to measure ______________________ .

- i. voltage ☐
- ii. current ☐
- iii. resistance ☐
- iv. All of the above ☐

c. Ohm's law states that the current in an electric circuit is inversely proportional to the resistance of the circuit (when V is constant), and is directly proportional to the electromotive force in the circuit (when R is constant).

- i. True ☐
- ii. False ☐

d. ______________________ is used to measure resistance in an electrical circuit.

- i. voltmeter ☐
- ii. ammeter ☐
- iii. ohmmeter ☐
- iv. None of the above ☐

Notes

Answers: General Terms Related to Electricity

Question Number	Answer
1	a. iii b. iv c. i d. iii

Conductors and Insulators

At the end of this session you will be able to:

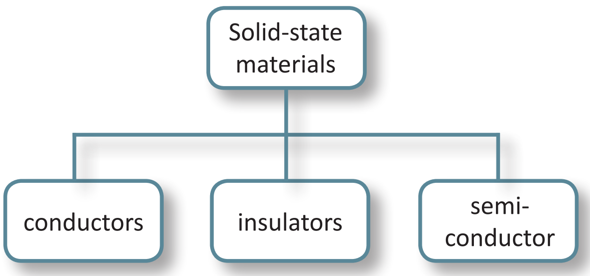
- define conductors and semiconductors;
- state the difference between conductors, insulators and semiconductors;
- describe the various application of semiconductors in automobile industry.

Session Plan	
1	Introduction
2	Conductors
3	Insulator and Semi-conductor
4	Energy Band Diagrams
5	The Differences between Insulator, Semi-Conductor and Conductor
6	Application of Semi-conductor in Automobile Industry
7	Key Learnings
8	Worksheet

Introduction

Electrical components are made of conductors, insulators and semi-conductors. In automobiles semi-conductors are used to power most of the electrical and electronic circuits.

Solid-state materials can be broadly classified into three groups:

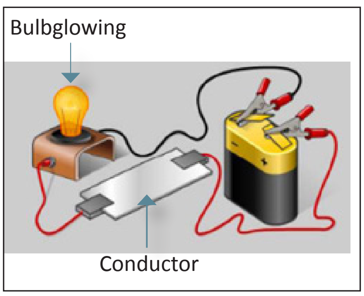


Conductors

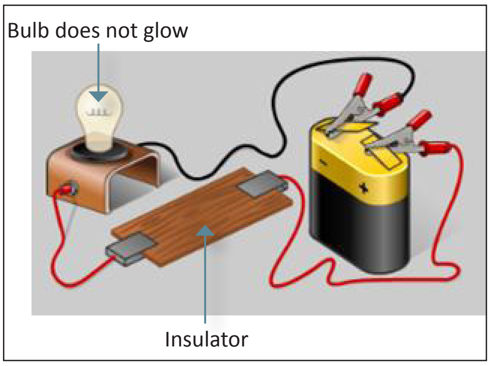
Conductors

Materials which allow the flow of electric charges (current) in one or more direction are called conductors.

Example: gold, silver, copper, iron, steel and aluminium.



Insulator and Semi-conductor



Insulator

Materials which do not allow the flow of electric charges (current) are called insulators.

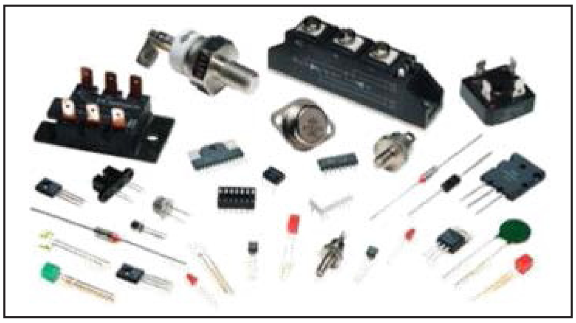
Example: Wood, plastic, cotton, paper, jute, rubber, distilled water.

Semi-conductor

There is the third kind of material called a semi-conductor. It is a man-made material in which current (electron)can or cannot flow as per the direction of flow.

Semi-conductors are used to make solid state devices.

Example: Diode, triode, transistor.



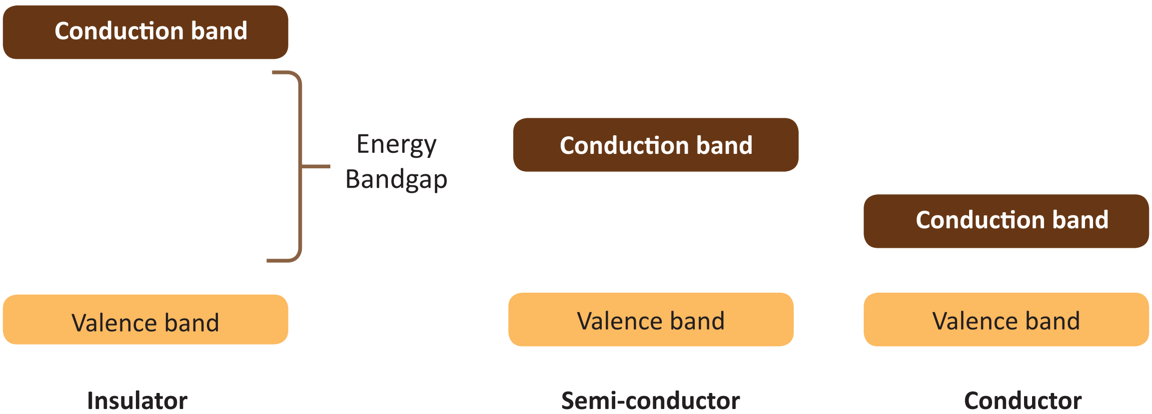
Note: They are called "solid-state" because they are solid and have no moving parts except for electrons; for example, diode and transistor.

Energy Band Diagrams

Energy band diagram: A solid is composed of ranges of energy called the energy band that an electron within the solid may have and ranges of energy called band gaps, which it may not have.

Valence band: It is the highest range of electron energies where electrons are present in absolute zero temperature.

Conduction band: It is the range of electron energies that helps to free an electron from an atom.



The Differences between Insulator, Semi-Conductor and Conductor

The main difference between these three materials; conductors, insulators and semi-conductors, depends on their conductivity property.

Insulator	Semiconductor	Conductor
◆ Impede the free flow of electrons ◆ Wide band of energy gap ◆ In the Valence band, energy level are fully occupied by electrons and conduction band are empty ◆ Here in ordinary temperature the electrons cannot get sufficient energy to jump to the conduction band to conduct electricity	◆ Has electron conductivity between conductor and insulator ◆ The energy gap is small. ◆ Both electrons and holes are energy carries ◆ upon application of an external voltage, the electrons and hole move in opposite direction to produce current flow ◆ Semiconductor has variatioon of electrical resistivity with emperature.	◆ Permits the flow of electrons easily ◆ The valence and conduction band overlap ◆ The gap is extremely thin. ◆ Electrons in the upper region of the valence band are in the conduction band itself ◆ Requires small amount of energy to promot the flow electrond to the conduction band

Application of Semi-conductors in Automobile Industry

The automotive industry has undergone a tremendous change in the past few decades. All this has been possible due to the advent of semi-conductor technology. The performance and efficiency have reached new heights.

Application of semi-conductors in automobile industry

Powertrain Control

- Engine control
- Gasoline management
- Fuel injectioni

Driver Information Systems

- Infotainment
- Telematics

Safety

- Airbags
- Electronic stability program
- Collision avoidance and adaptive cruise control

Body Electronics

- Body control module
- Seat, door and window control
- Remote control
- HVAC control
- Lightning control

Automotive Networking/Communication

- Communication systems
- Controller area network
- Local interconnect network

Chassis

- Braking systems
- Electronic power steering
- Active suspension

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. How are solid-state materials classified?

____

____

____

____

____

2. What do you mean by semi-conductors? Give examples.

____

____

____

____

____

3. Mention two basic differences between insulator, semi-conductor and conductor.

____

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____

Worksheet

1. *Read the questions and tick the correct answer.*

a. Materials which allow flow of electric charges are called ______________

   i. conductors ☐

   ii. insulators ☐

   iii. semi-conductors ☐

   iv. All of the above ☐

b. The ______________ is a man-made solid-state material.

   i. conductor ☐

   ii. insulator ☐

   iii. semi-conductor ☐

   iv. All of the above ☐

c. The ______________ is the highest range of electron energies where electrons are present in absolute zero temperature.

   i. valence band ☐

   ii. conduction band ☐

   iii. energy band gap ☐

   iv. None of the above ☐

d. Diode and transistors are called solid state materials as they have no moving parts except electrons.

   i. True ☐

   ii. False ☐

Notes

Answers: Conductors and Insulators

Question Number	Answer
1	a. i b. iii c. i d. i

Electrical Circuits

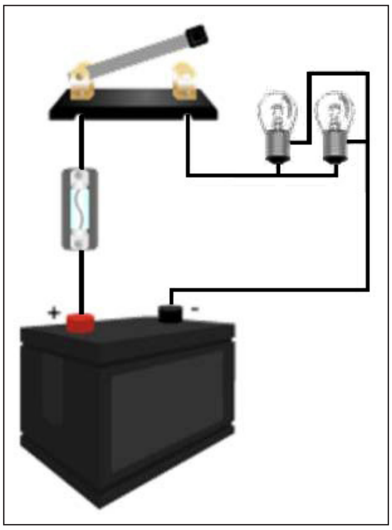
	At the end of this session you will be able to: ◆ to define the different types of electrical circuits.

Session Plan	
1	Introduction
2	Series Circuit
3	Parallel Circuit
4	Combination of Series and Parallel Circuit
5	Grounded Circuit
6	Shorted Circuit
7	Open Circuit
8	Key Learnings
9	Worksheet

Introduction

Every electrical system requires a complete circuit for it to function. A complete circuit is simply an uninterrupted path for electricity to flow from its source through all circuit components and back to the electrical source. Whenever the circuit is broken (interrupted), electricity will not flow.

Series Circuit



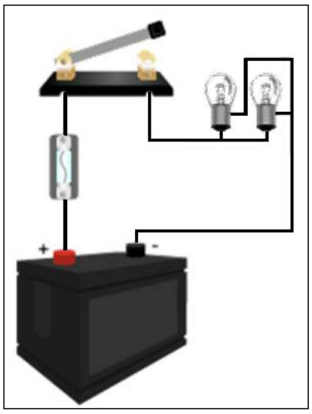
In a series circuit various components are connected one after another. Current has to travel through all components. Current is same at all points when measured using a multi-meter. The voltage is shared between components.

Example: series circuit are connected like links in a chain, if any one link fails, current to all the components is cut off. Due to this reason these circuits are not used in automobiles.

Total resistance in a series circuit is measured using the below formula:

R = R1 + R2 + R3

Parallel Circuit

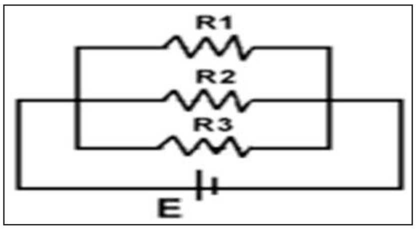


The parallel circuit has two or more paths for electrons to flow. Current in this circuit is shared between the branches.

- Sum of the current in each branch = total current
- Voltage loss is the same across all components

Example: headlight circuit; even if one headlight is burned out the other headlight will still operate.

The total resistance in a parallel circuit is measured using the formula:



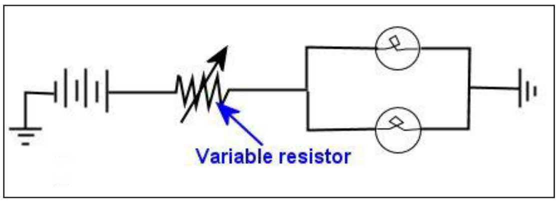
$$\frac{1}{R} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}$$

Combination of Series and Parallel Circuit

A combination of series and parallel circuit consists of some components in series and some in parallel. The power source and control or protection devices are connected in series and the loads are usually connected in parallel.

Same current flows in series portion and different currents flow in the parallel portion. Same voltage is applied to parallel portion and different voltage is applied in series portion.

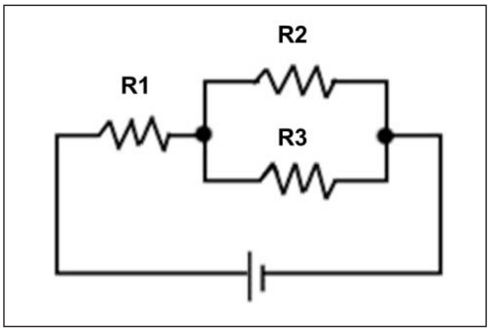
Example: Instrument panel lamp dimming circuit; here a resistor is in series with a pair of parallel light bulbs. When the resistance is low, the voltage across the bulbs are high and they illuminate brightly, and when the resistance is high, the bulbs become dim.



To calculate total resistance in a series-parallel circuit, calculate the series portion of the circuit as stated above, then calculate the parallel portion of the circuit and add to the series resistance.

Total resistance in the circuit is measured using the following formula:

$$R = R1 + \frac{1}{R2} + \frac{1}{R3}$$

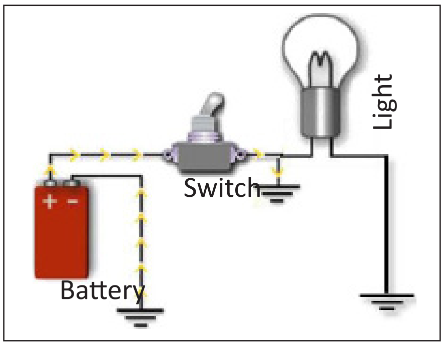


Grounded Circuit

A grounded circuit is a condition that allows current to return to ground before it has reached its intended destination.

An example of this would be a grounded taillight circuit.

If the wire leading to the taillight has an insulation breakdown allowing the wire to touch the frame or body of the vehicle, electricity will flow to the ground at this point and return directly to the battery without reaching the taillight.

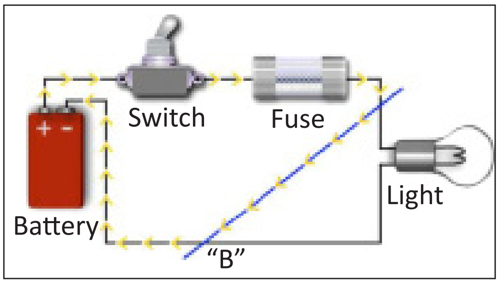


Shorted Circuits

A shorted circuit is a circuit that allows current to bypass part of the normal path.

An example of this would be a shorted coil.

Coil windings are normally insulated from each other; however, if this insulation breaks down and allows copper-to-copper contact between turns, part of the coil windings will be bypassed.



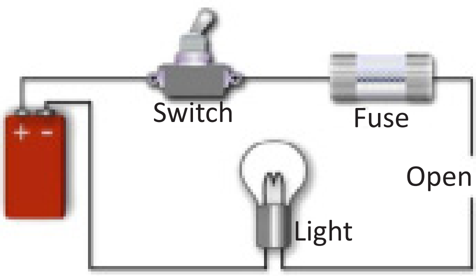
In an ignition coil primary windings, this condition would reduce the number of windings through which electricity will flow, hence reducing coil capacity.

Open Circuits

An open circuit is a circuit in which there is a break in continuity.

For electricity to be able to flow there must be a complete and continuous path, from the electrical source through the circuit and back to the electrical source.

If this path is broken (cut) it is no longer operational, therefore it acts the same as switched off.



In an ignition coil primary windings, this condition would reduce the number of windings through which electricity will flow, hence reducing coil capacity.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. What do you understand by a series circuit?

2. What do you mean by series-parallel circuit?

3. Explain the difference between a parallel and series circuit.

4. What do you mean by shorted circuit?

Worksheet

1. *Read the questions and tick the correct answer.*

   a. Which of the following is true with respect to series circuit?

      i. has a single loop for electrons to travel round

      ii. has two or more paths for electrons to flow down

      iii. sum of the current in each branch = total current

      iv. All of the above

   b. The total resistance in a parallel circuit is calculated using ____________

      i. R = R1 + R2 + R3

      ii. $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

      iii. $R = R_1 + \left(\frac{1}{R_2} + \frac{1}{R_3}\right)$

      iv. None of the above

   c. A grounded circuit is a condition that allows current to return to ground before it has reached its intended destination.

      i. True

      ii. False

   d. In a parallel circuit,voltage loss is the same across all components.

      i. True

      ii. False

Notes

Answers: Electrical Circuits

Question Number	Answer
1	a. i b. ii c. i d. i

Circuit Protection Devices

At the end of this session you will be able to:

- state the different circuit protection devices;
- describe the working and use of different circuit protection devices.

Session Plan	
1	Introduction
2	Circuit Protection Devices
3	Fuse
4	Relay
5	Capacitor
6	Diode
7	Transistor
8	Key Learnings
9	Worksheet

Introduction

Electrical circuits are likely to be damaged when there is an overflow of current or short circuit. The excess current generates heat and causes the circuit to behave like a short circuit. To prevent this from occurring the use of various circuit protection devices have been made.

Circuit Protection Devices

The circuit protection devices protect the wires and connectors from being damaged by the excess current.

The various devices used for circuit protection are:

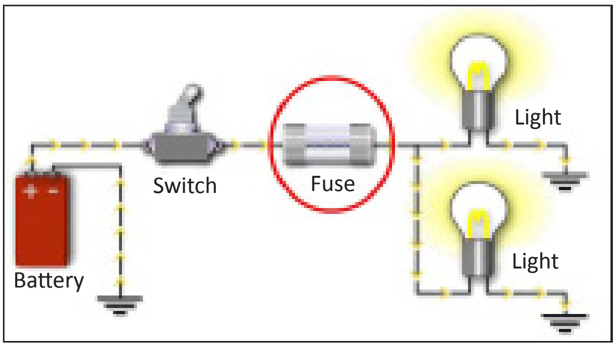
- fuse
- relay
- capacitor
- diode
- transistor

Fuse

In electronic and electrical engineering, a fuse is a type of sacrificial overcurrent protection device. It is an essential component and is a metal wire or strip that melts when too much current flows, which interrupts the circuit in which it is connected.Short circuit, overload or device failure is often the reason for excessive current.

Characteristics of Fuse

- A fuse interrupts excessive current (blows) so that further damage by overheating or fire is prevented.
- Wiring regulations often define a maximum fuse current rating for particular circuits.
- Over-current protection devices are essential in electrical systems to limit threats to human life and property damage.
- Fuses are selected to allow passage of normal current and of excessive current only for short periods.



Types of Fuse

Fuses based on their applications are broadly classified into:

- blade type fuse
- cartridge type fuse
- fuse element

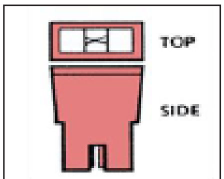
The blade fuse and fuse element are most widely used.

The blade fuse elements are of three types:

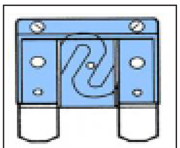
- Maxifuse
- Autofuse
- Minifuse

Blade type

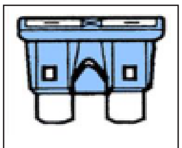
Cartridge type



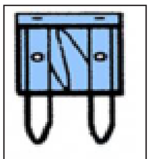
Fuse element



Maxifuse



Autofuse



Minifuse

Good fuse

Burnt fuse

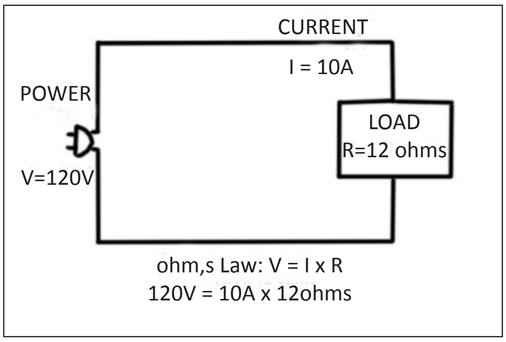
Blown fuse

Detecting a Fuse

Fuse Selection

To select a fuse the following criteria should be carried out:

- For every 20°C higher or lower in temperature in the circuit, the fuse should be re-rated higher or lower 10-15%.
- A blown fuse must be replaced by a fuse of the same rating. Placing a low rated fuse will result in a blown fuse again, and replacing with a higher rated fuse may damage the circuit.

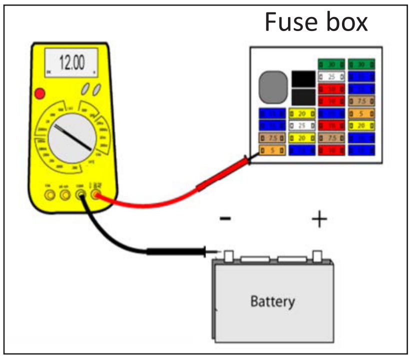


Note: *Care should be taken to correct whatever problem that may have occurred when the fuse opened in the first place before replacing the open fuse with a new fuse.*

Fuse Check

To check continuity of fuses the steps given below need to be followed:

- Use a multi-meter to check the fuse.
- Turn the ignition switch in the run position.
- Clamp the end of the negative cable of the multi-meter to a ground close to the fuse box.
- Check one end of the first fuse if it shows 12 V, the fuse is unspoiled and if it does not, remove the fuse and inspect visually.

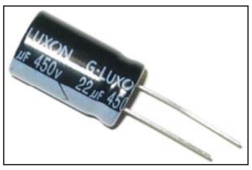


Relay

Relay is an electro-mechanical switch to switch heavy current using a small current.
To check continuity of fuses the steps given below need to be followed:

Characteristics of relay

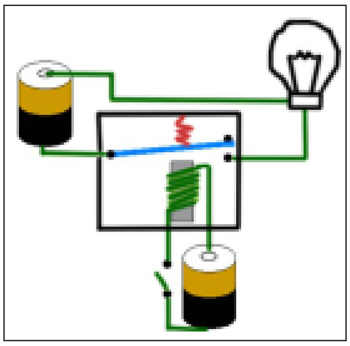
- Relays consist of a 'control' circuit and a 'controlled' circuit.
- The control circuit is an electromagnet which acts on a moving arm carrying one or more contacts.
- The moving arm opens and closes the controlled circuit.



In a simple relay the moving contact is held clear of its fixed contact by a spring.

When current flows through the winding of the electromagnet the induced magnetism attracts the arm and closes the contacts, completing the controlled circuit.

Types of Relays



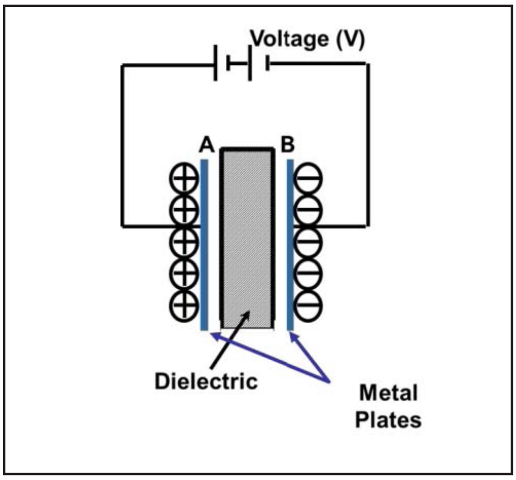
- Full size relays are cube shaped and approx. 25 mm square.
- Mini relays approx.15 mm x 20 mm x 20 mm.

Capacitor

Capacitor is an electronic component used to store electric charge. It prevents arching and is used as radio interference.

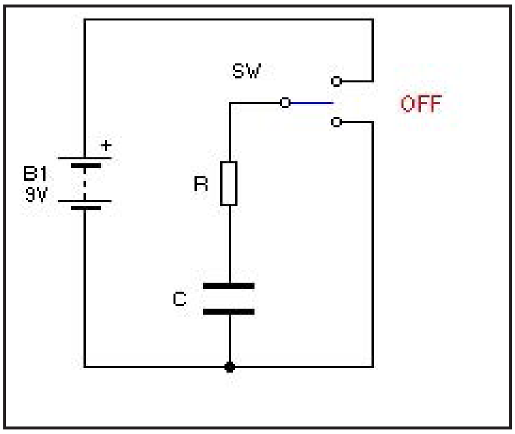
In cars, a capacitor is used in theatre dimming interior lamp,SDM and audio system.

Characteristics of Capacitor



- Electric capacitance C=Q/V
- Unit of electric capacitance : F(Farad), μF=10-6 F, PF=10-6 μF
- Electric capacitance: Proportion to – Voltage
  - area of plates
  - dielectric constant
- Inverse proportion to
  - plate spacing
  - o thickness of dielectric

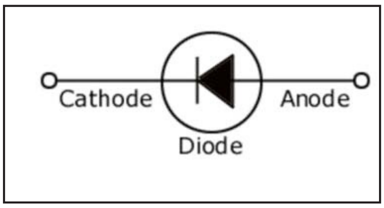
Working of Capacitor



- The capacitor is fully discharged.
- When the switch is closed the capacitor charges from the battery until it reaches the voltage of the battery.
- On pressing the reset button, the capacitor discharges.

Diode

A diode is a solid state (completely static) device that allows current to pass through itself in one direction only (within its rated capacity).



Acting as a one-way electrical check valve, it allows current to pass in one direction and blocks it in the other direction.

The silicon wafer is chemically treated to produce either a positive or negative diode.

A diode is also used to rectify (convert) alternating current (AC) to direct current (DC).

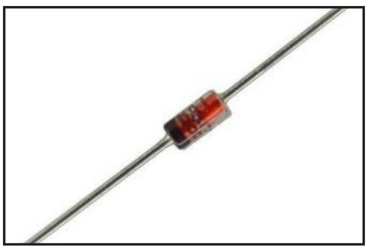
Characteristics of Diode

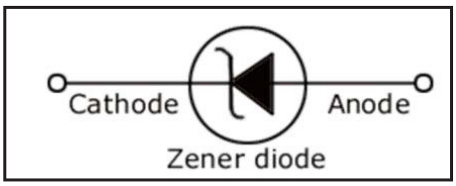
- In the compressor of a small air conditioner, a silicon diode is used which serves to protect against overloading.
- Since a diode is destroyed in the presence of excessive voltage it can be used like a fuse.
- A silicondiode does not conduct current in the direction opposite to conventional current flow. That is why it can be used as a current reversal protector. This is the case in an electronic anti-lock brake system (ABS).
- The silicon diode in an AC current rectifier causes the rectification of the alternating current, by allowing current to pass through in only one direction.

Working of a Diode

- Consider P type and N type material forming a PN junction diode.
- Free electrons from N side meets free holes in the P side at the junction. Here, the charge movement gets cancelled.
- There is a depletion region formed at the junction called depletion zone.
- A force is exerted here driving the free charge away from this zone.
- This free charge requires suitable voltage called the barrier voltage to overcome the depletion.
- Once the switch is closed the charge carriers cross the depletion zone.

Zener Diode





The zener diode is a specially designed diode that conducts current like a normal diode but will also safely conduct current in a reverse direction when reverse current reaches the specified design voltage.

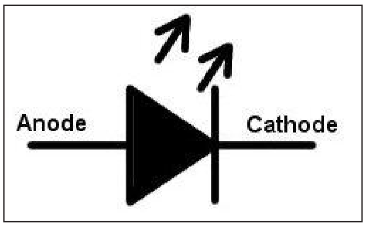
Characteristics of Zener Diode

- A zener diode can prevent reverse current if it is below design voltage, but when reverse current reaches and exceeds design voltage, the zener diode will conduct reverse current.
- This type of diode is used in control circuit such as in the field current in an alternator.

Light Emitting Diode

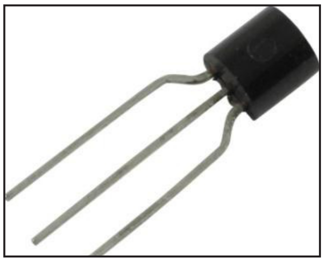
A light-emitting diode (LED) is a semi-conductor light source. LEDs are used as indicator lamps in many devices and are increasingly used for other lighting.

Characteristics of LED

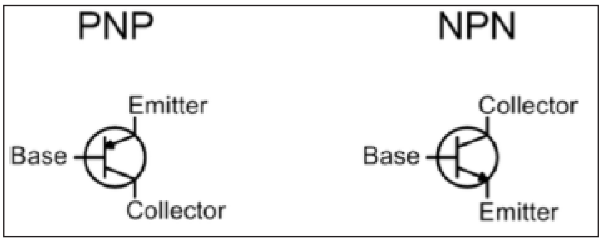


- As all diodes, it emits luminous, electromagnetic rays when current flows through it in the conduction direction.
- Since it is manufactured from special semi-conductor material, it emits a brighter light than a conventional silicon diode.
- An LED is only employed in the conventional current flow direction, just as standard diodes, and blocks current flowing in the reverse direction.
- In order to prevent LED from getting damagedby the current intensity flowing through them,current must be limited by an appropriate resistor. Due to the low power required and the high working life of approximately 100 years, LEDs are used for optical displays.

Transistor



A transistor is a solid-state switching device used to control current. It operates like a relay, except that it has no moving parts. A relatively small current is used to control a larger current. The transistor either allows current to pass or stops it.



The transistor consists of three terminals:

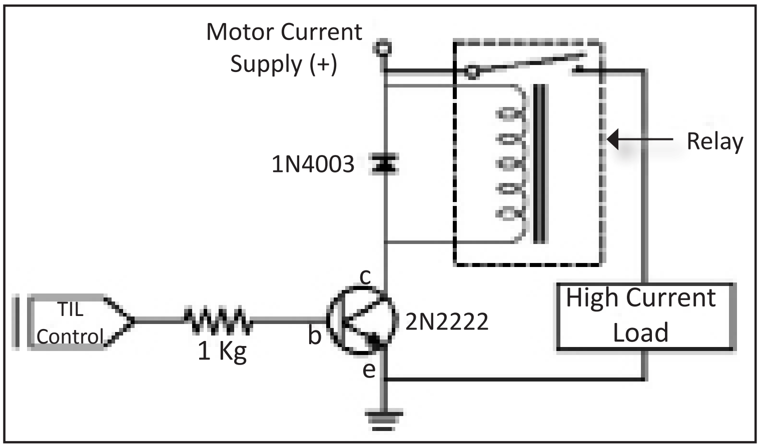
- emitter
- base
- collector

The two different transistors available are:

- PNP
- NPN

Characteristics of Transistor

Transistors can be employed as very high-performance switches because a high load current can be connected between the collector and emitter with a low control current between base and emitter.



A transistor performs the same function as a relay. It does not wear out and is therefore non-wearing. In addition to that a considerably higher switching frequency is possible, for example for fuel injection valves.

Working of Transistor

- When the base circuit of transistors is energised, a small base current is applied to the transistor collector.
- Since the emitter is closer to the collector than it is to the base, most of the current is conducted by the emitter-collector section of the transistor.
- This is caused by the fact that electricity normally follows the path of least resistance.

Transistor Check

- Switch the meter to diode test.
- With one probe held to a terminal, use the other probe on the two remaining terminals, listening for a beep on either terminal, this will identify the base.
- Leave the probe on the base, switch the meter to resistance, test the two remaining terminals.
- The one with the highest ohms reading is the emitter.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. Write down the steps to test a fuse.

____

____

____

____

2. Mention the working of a transistor.

3. Draw the symbols for diode, transistor and light emitting diode.

4. What are the cahracteristics of a LED?

Worksheet

1. Read the questions and tick the correct answer.

a. Which of the following is/are blade fuse elements?

- i. Maxifuse ☐
- ii. Autofuse ☐
- iii. Minifuse ☐
- iv. All of the above ☐

b. Capacitor in an electronic component is used to store electric charge.

i. True ☐

ii. False ☐

c. When testing a transistor using a multi-meter, the rotary switch needs to be positioned at ____________________ .

i. voltage test ☐

ii. current test ☐

iii. resistance test ☐

iv. diode test ☐

d. Which of the following is the terminals of a transistor?

i. emitter ☐

ii. base ☐

iii. collector ☐

iv. All of the above ☐

Notes

Answers: Circuit Protection Devices

Question Number	Answer
1	a. iv b. i c. iv d. iv

Working and Construction of the Engine

At the end of this session you will be able to:

- explain working and construction of an engine;
- state the different engine terminologies.

Session Plan	
1	Introduction
2	Working and Construction of an Engine
3	Basic Engine Terminologies
4	Engine Cycles
5	Key Learnings
6	Worksheet

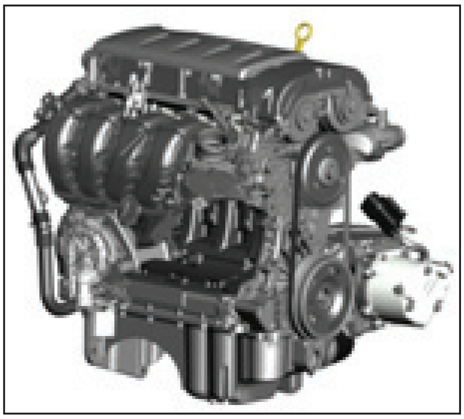
Introduction

An engine is the most important mechanical device used in automobiles. There are some basic engine terminologies that helps describe the function of an engine.

Working and Construction of an Engine

An engine is a machine designed to convert energy from one form to another to achieve useful mechanical motion. In common words it converts chemical energy of fuel to useful mechanical work.

Heat Engines or Internal Combustion Engines, which are most popularly used in Automobiles, also known as the heart of the automobile, burns fuel to create heat which in turn produces mechanical motion. The fuel used can be petrol, diesel, CNG or LPG. Some vehicles also use bio gas or ethanol /methanol based blended fuels for producing the heat energy.An engine is made up of a solid cast iron, aluminum or alloy materials which houses many components internally and externally. Some internal components of the engine are high precision items.



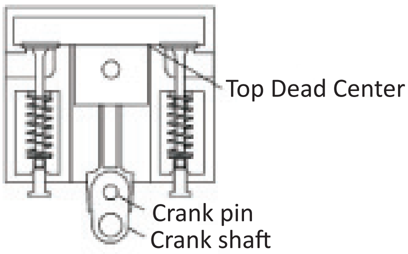
Basic Engine Terminologies

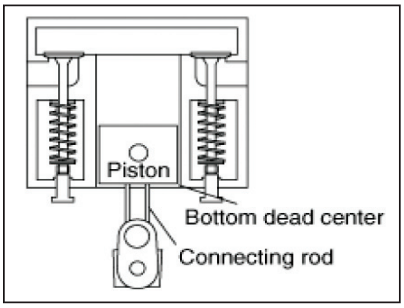
A number of terminologies are used to compare and differentiate engines. Following are some engine terminologies:

- Top dead centre
- Bottom dead centre
- Bore
- Stroke
- Clearance volume
- Piston displacement
- Engine capacity
- Compression ratio
- Power
- Indicative power
- Brake power
- Engine torque

Top Dead Centre

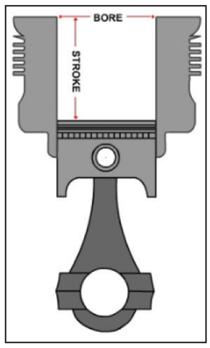
This refers to the position of the crankshaft when the piston is at the topmost position, ie: when the piston the closest to the cylinder head.





Bottom Dead Centre

This refers to the position of the crankshaft when the piston is at the lowest position, ie: when the piston the farthest to the cylinder head



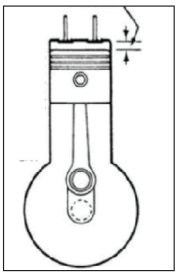
Bore

It is the internal diameter of the of the engine cylinder

Stroke

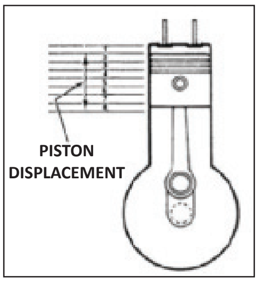
This is the distance travelled by the piston when it travels from top dead centre to the bottom dead centre.

CLEARANCE VOLUME



Clearance volume

The volume of the cylinder above the piston when it is in the top dead centre position is called clearance volume



Piston displacement

It is the volume swept by the piston in moving from top dead centre to bottom dead centre
It is also called swept volume.

Engine Capacity

It is the total piston displacement or the swept volume of all the cylinders. It is denoted by cc (cubic capacity)

Compression Ratio

This indicates the extent of which the charge (air/fuel) can be compressed. It is calculated as the ratio of volume above the piston at the bottom dead centre to the volume above the piston at the top dead centre

Power

It is the work done in a given period of time. Doing the same amount of work in a lesser time would require more power.

Indicated Power (IP)

The power developed within the engine cylinders is called indicated power. This is calculated from the area on the engine indicator diagram. It is denoted by kW (kiloWatt).

Brake Power (BP)

The power available at the crankshaft is called brake power. It is obtained by deducting various power losses like friction. Usually measured using a dynamometer and is denoted by kW, PS (Pferdestärke) or BHP (Brake Horse Power).

Engine Torque

It is described as the force of rotation acting about the crankshaft axis at any given point of time. It is denoted by Nm (Newton Metre)

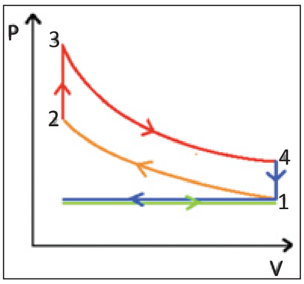
Engine Cycles

Automobiles are equipped with internal combustion engines that are used to produce the power required to move the vehicle from one place to another. The two basic cycles on which internal combustion engines work are as below:

- Otto cycle
- Diesel cycle

Otto Cycle

The Otto cycle is named after the German engineer Nicolaus Otto, who was the first person to build a working four stroke engine, a stationary engine using a coal gas-air mixture for fuel (a gas engine). The cycle consists of two adiabetics and two constant volume lines.



Process 1-2

This is the adiabatic compression of the air/fuel mixture in the cylinder, also known as the compression stroke.

Process 2-3

At this stage the air/fuel mixture is compressed at the top of the compression stroke with constant volume, also known as ignition phase.

Process 3-4

This is the adiabatic expansion of the hot gaseous mixture in the cylinder head, also known as power stroke.

Process 4-1

This is a constant-volume process in which heat is rejected from the air while the piston is at the bottom dead centre.

Diesel cycle

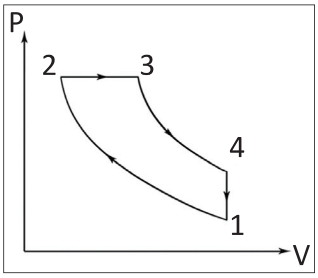
The diesel cycle is named after its inventor, Rudolph Diesel. It is similar to the Otto cycle, except in this case the combustion takes place at constant pressure.

Process 1-2

This is the adiabatic compression of the air in the cylinder, also known as the compression stroke.

Process 2-3

At this stage the air is heated at constant pressure and diesel fuel is injected into the cylinder, also known as ignition stage.



Process 3-4

This is the adiabatic expansion of the hot gaseous mixture in the cylinder head, also known as power stroke.

Process 4-1

This is a constant-volume process in which heat is rejected from the air while the piston is at the bottom dead centre.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. What is an engine? State its function in automobiles.

____

____

____

____

2. What is an engine? State its function in automobiles.

3. Explain briefly top dead centre and bottom dead centre.

4. What is an engine? State its function in automobiles.

5. What is a diesel cycle? Explain its processes briefly.

Worksheet

1. The bore of an engine is the ______________________ diameter of the engine cylinder.
   a. Internal
   b. External
   c. Both a and b
   d. None of the above
2. The term piston displacement in engine is also known as swept volume.
   a. True ☐
   b. False ☐
3. The power developed within the engine cylinders is called __________________ power.
   a. Indicated
   b. Brake
   c. Horse
   d. None of the above
4. The Otto cycle consists of two adiabetics and two constant volume lines.
   a. True ☐
   b. False ☐

Notes

Answers: Working and Construction of the Engine

Question Number	Answer
1	1. a 2. a 3. a 4. a

Classification of Engines

At the end of this session you will be able to:

- classify automobile engine based on strokes, fuel used and layout.

Session Plan	
1	Introduction
2	Engine Categories
3	Number of Strokes
4	Type of Fuel Used
5	Engine Layout
6	Fuel System
7	Key Learnings
8	Worksheet

Introduction

Automobile engines are classified based on different parameters viz. construction, fuel used and mechanical action operating them. The fuel system used in these engines can be direct or indirect injection, each having their own benefits and drawbacks.

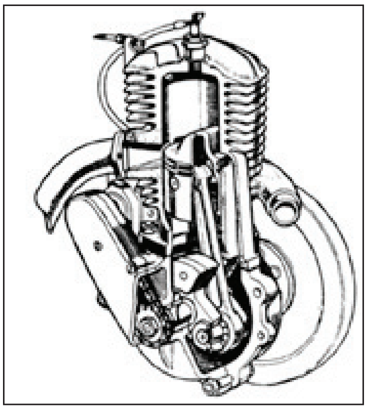
Engine Categories

An internal combustion engine is classified into various categories based on its construction, fuel used to achieve mechanical action and place of application.

Engines can be categorised on the basis of the following:

- Number of strokes
- Type of fuel used
- Engine layout.

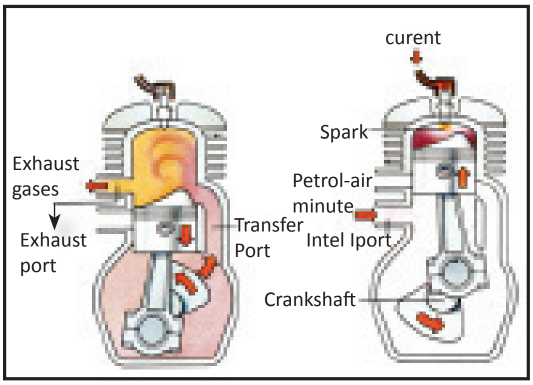
Number of Strokes



Two Stroke Engine

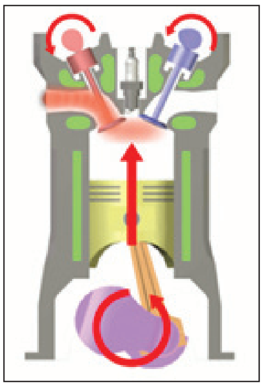
- In a two stroke engine the entire cycle is completed and power output is achieved in two strokes ie: one revolution of the crankshaft.
- A two-stroke engine provides higher power-to-weight ratio, usually in a narrow range of rotational speeds called the "power band" and have a less number of moving parts which makes it compact and significantly lighter.
- These engines were earlier used mostly in two wheelers, but now are almost obsolete.

Working

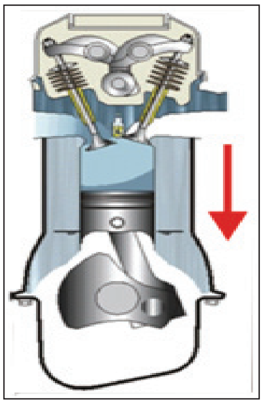


- The air/fuel mixture from the carburettor enters the cylinder when the piston moves upwards.
- The upward movement of the piston also compresses the air/fuel mixture which is ignited using a spark plug when the piston just reaches TDC.
- The ignition of air/fuel mixture generates a downward force which pushes the piston downwards.
- During the downward movement of the piston, the fresh mixture entered into the crankcase from the inlet port is compressed and pushed into the cylinder through the port by the crankshaft.
- Simultaneously the burnt gasses are also pushed out of the cylinder through the exhaust port. This process is called cross flow scavenging.

Four Stroke Engine

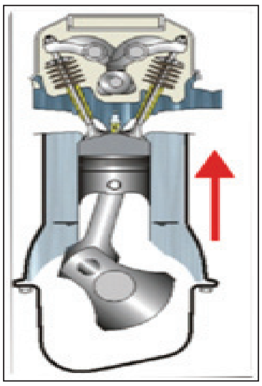


- In a four stroke engine the entire cycle is completed and power output is achieved in four strokes ie: two revolution of the crankshaft.
- The four strokes involved in producing power in this engine are:
  - Suction
  - Compression
  - Power
  - Exhaust.
- These engines are generally bulkier and consists of a single or multiple cylinders.
- They are used in all vehicles recently.



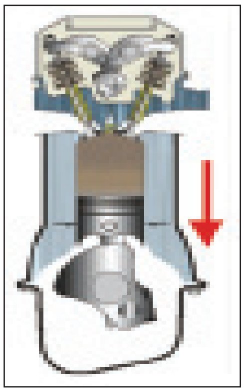
Working

- Suction or the Intake stroke is the first of the four strokes of the cycle.
- During this stroke the piston moves to BDC from TDC causing the suction inside the cylinder via the inlet valve.
- This stroke takes place during 0°-180° of crank rotation.



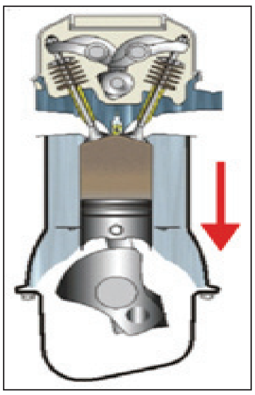
Compression Stroke

- The compression stroke is the second of the four strokes of the cycle.
- During this stroke the piston moves from BDC to TDC with both valves closed.
- The intake mixture is therefore compressed in the combustion chamber due to the upward movement of the piston.
- As the piston rises the temperature and pressure of the charge increases
- This stroke takes place during 180°-360° of crank rotation.



Power Stroke

- The intense heat and pressure generated by igniting the compressed mixture in the cylinder causes the pressure to increase rapidly, this pressure forces the piston down towards the BDC with both valves closed.
- This stroke takes place during 360°-540° of crank rotation.



Exhaust Stroke

- The exhaust stroke is the last in the cycle.
- During this stroke the piston starts moving from BDC to TDC .
- The inlet valve remains closed while the exhaust valve opens forces the burnt gases out through the exhaust.
- This stroke takes place during 540°-720° of crank rotation.

Type of Fuel Used

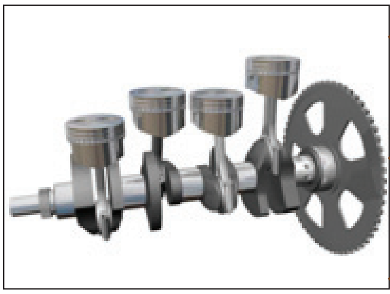
Engines used in automobiles use various fuels to generate power. Below are the most commonly fuels used in automobiles.

- **Petrol Engine:**
  - Petrol engines use gasoline or petrol as a fuel to produce heat energy required to produce power.
  - Generally petrol engines are spark ignited engines, means the fuel and air mixture is ignited by a spark plug.
- **Diesel Engines:**
  - Diesel engines use diesel as the fuel to produce the heat energy required to produce power.
  - Diesel engines are compression ignition engines in which only air is compressed and a fine diesel spray through injectors ignites the compressed air at high temperature and pressure to produce the heat energy.

Engine Layout

Automobile engines are also categorized by the layout. The most commonly used layouts are:

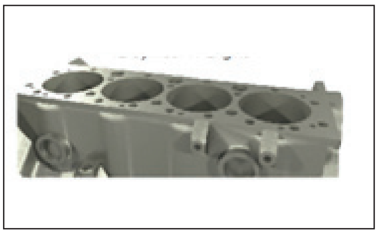
- Reciprocating type
- Rotary type.



Reciprocating Type:

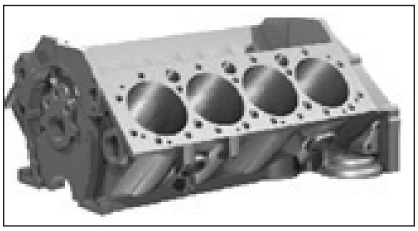
- In this type of layout, the piston moves inside the vertically arranged or horizontally arranged cylinder block in back and forth manner to complete all the strokes of an engine.
- The crankshaft is horizontally placed in the block on which the pistons and connecting rods are vertically fitted inside the cylinder block.
- All recent engines, whether two or four stroke, diesel or petrol use this type of layout.

The reciprocating type layout is further divided in the below categories:



Inline cylinders:

- The cylinders are arranged in a single line and each cylinder is adjacent to each other.
- There can be single,2,3,4 and 6 cylinder engines which can be arranged inline.

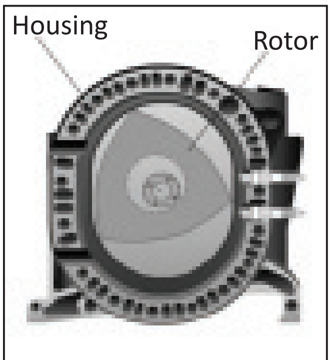


V- Type cylinders:

- As the name indicates the cylinders are arranged in a shape of " V" with a common crankshaft.
- There can be 6,8 cylinder engines in this configurations.

W- Type cylinders:

- The cylinders are arranged V type but the bores on each bank are offset to each other which are in the shape of letter " W".
- There can be 12 or more cylinder engines in this configuration.



Rotary Engine

Rotary Type:

- In this type of layout, the piston or rotor which is triangular shaped rotates inside the oval shaped housing or chamber to complete the four strokes of an engine.
- The rotor and the housings are sixed to form three working chambers of varying sizes.
- Each chamber is in different phase at same time.
- It is also known as a Wankel engine.
- The main advantage of this layout is greater power to weight ratio and is capable of sustaining a high RPM.
- This layout is prone to poor emissions and requires an extra emission system.
- Not used much in Automobile applications now.

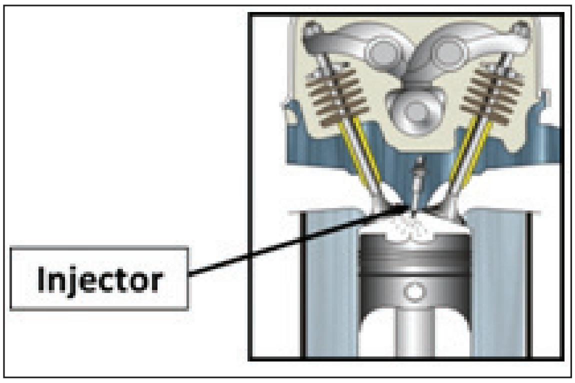
Fuel System

The fuel injection system used in automobiles is classified into two categories:

- Direct injection
- Indirect injection

Direct Injection

In a direct injection diesel engine, fuel is injected directly into the cylinder through a injector located above the engine cylinder. The advantages of this system are:



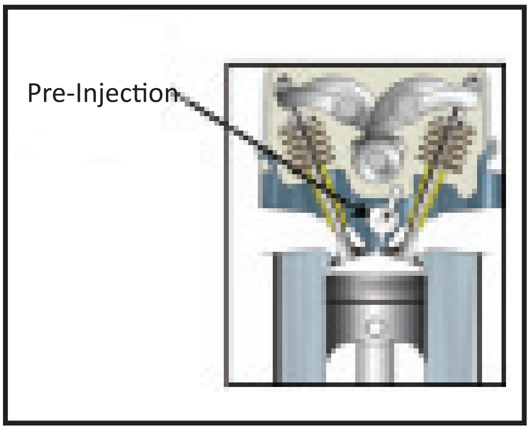
- High power
- High efficiency
- Low emissions.

However, some drawbacks of this system are:

- Higher sound levels and vibrations.

Indirect Injection

An indirect injection system is used to overcome the drawbacks of a direct injection system.



Here fuel is injected into a small pre-injection chamber which is connected to the cylinder by a narrow opening. The initial combustion takes place in this pre-chamber slowing the rate of combustion

The advantages of this are:

- Reduced sound and vibrations
- However it also has some disadvantages like:
- Less power
- Less efficiency
- More emissions

Differences between direct and indirect injection

Direct Injection	Indirect Injection
High Compression ratio	Little lower compression ratio
Higher injection pressure	Lower injection pressure
Multi Hole Injection	Single or dual hole injectors
Combustion chamber on piston	Combustion chamber in cylinder head
Stronger combustion	Relatively smoother combustion
Heavier components	Little less heavier
More Noise	Less Noise
Glow Plug can be Optional	Glow plugs are necessary

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. Explain briefly a two stroke engine.

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2. Explain briefly the working of a four stroke engine.

3. What is a reciprocating type layout in automobile engines?

4. Mention the basic difference between direct and indirect injection.

Worksheet

1. *Read the questions and choose the correct answers.*

   a. The ______________ stroke occurs during 0° - 180° of crank rotation.

      i. suction

      ii. compression

      iii. power

      iv. exhaust

b. A two-stroke engine provides higher power –to-weight ratio usually in a narrow range of rotational speeds called the ______________ band.

i. engine ☐

ii. power ☐

iii. stroke ☐

iv. none of the above ☐

c. In a four stroke engine the entire cycle is completed and power output is achieved in ___________________ revolution of the crankshaft.

i. one ☐

ii. two ☐

iii. three ☐

iv. four ☐

d. There can be more than 12 cylinder engines in a W-type cylinder configuration.

i. True ☐

ii. False ☐

Notes

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Answers: Classification of Engines

Question Number	Answer
1	a. i b. ii c. ii d. i

Working of Petrol and Diesel Engines

At the end of this session you will be able to:

- describe the working of petrol engine;
- describe the working of diesel engine;
- identify basic differences between petrol and diesel engine.

Session Plan	
1	Introduction
2	Petrol Engine
3	Diesel Engine
4	Differences between Petrol and Diesel Engines
5	Key Learnings
6	Worksheet

Introduction

Engines are broadly classified into petrol and diesel engines. Each of these engines has a particular way of operating which is different from each other.

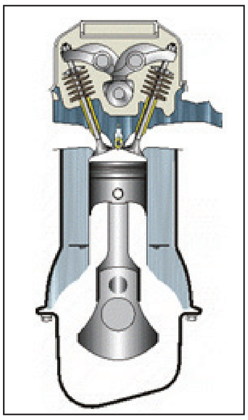
Petrol Engine

Suction Stroke

During this stroke the piston moves from TDC to BDC. The movement to the piston away from the cylinder head creates a pressure reduction below atmospheric pressure. The actual pressure reduction depends on the speed and load on the engine. This reduction of pressure sucks the air/fuel mixture (charge) into the cylinder via the intake valve till the piston reaches completely to the bottom dead centre.

Engines in which air/fuel mixture is inducted into the cylinder only due to pressure reduction are known as naturally aspirated engines.

Compression Stroke



During this stroke the piston moves from BDC to TDC. The movement to the piston along with the charge towards the cylinder head creates an increase in pressure and temperature

During this stroke both, intake and exhaust valves are closed and at the end of which the cylinder pressure will be from 8-13 bars. When the piston is just about to reach TDC, the charge is ignited using a spark plug. The ignition of charge generates heat and rapid rise in pressure which may reach to even 60 bars at full load condition.

Power Stroke

Due to the ignition of the charge, the burning gasses expand exerting pressure on the piston During this stage the force pushes the piston from TDC to BDC which is called the power stroke or expansion stroke. At the end of the power stroke the inlet valve remains closed but the exhaust valve starts opening.

Exhaust Stroke

During this stroke the piston moves from BDC to TDC. Opening of the exhaust valve at this stage allows the burnt gasses to escape or be pushed out from the cylinder. At the end of the exhaust stroke, the cylinder pressure may fall to atmospheric pressure or even lesser.

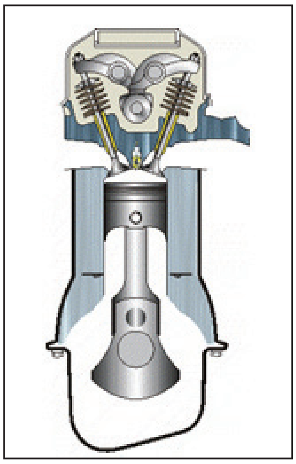
Diesel Engine

Suction Stroke

During this stroke, the piston moves from TDC to BDC. Here, only air from the atmosphere enters the cylinder unlike air and fuel mixture in the case of petrol engine. Engines in which air is inducted into the cylinder only due to pressure reduction are known as naturally aspirated engines. However, in recent times engines are also equipped with a turbocharger to force a higher volume of air into the cylinder.

Compression Stroke

During this stroke, the piston moves from BDC to TDC. The upward movement of the piston compresses the air to a ratio of 1:22 of its original volume due to both valves being closed which results in increase in air temperature. When the piston is just about to reach the TDC fuel (diesel) is injected into the cylinder with the help of an injector.



Power Stroke

During this stroke, the piston moves from TDC to BDC. The injection of fuel (diesel) in the presence of high temperature compressed air causes the fuel to self-ignite. The ignition temperature of diesel is about 400° C. The burning gasses exert pressure on the piston pushing it downwards which is called power stroke. During this process both the valves are closed. When the piston reaches BDC, the exhaust valve starts opening gradually.

Exhaust Stroke

During this stroke, the piston moves from BDC to TDC. The movement of piston from BDC to TDC pushes the exhaust gasses out of the engine cylinder. During this process the exhaust valve is open and the intake valve is closed. However, the intake valve also gradually opens just before the completion of the exhaust valve.

Differences between Petrol and Diesel Engines

Parameters	Petrol Engine	Diesel Engine
Ignition	Spark	Compression
Compression Ratio	10:1	22:1

Construction	Light	Heavy
Glow Plug	Not Available	Available
Vibrations	Less	More
Fuel Economy (km/litre)	Less	More

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. Explain the working of a suction stroke in petrol engine.

2. Explain the working of a power stroke in petrol engine.

3. Explain the working of compression stroke in diesel engine.

4. What are the major differences between petrol engines and diesel engines?

Worksheet

1. Read the questions and choose the correct answers.

a. Engines in which air/fuel mixture is inducted into the cylinder only due to pressure reduction are known as ____________ aspirated engines.

i. Artificially ☐

ii. Externally ☐

iii. Internally ☐

iv. Naturally ☐

b. In a compression stroke of a petrol engine, the ignition of charge generates heat and rapid rise in pressure which can reach ____________ bars at full load condition.

i. 40 ☐

ii. 50 ☐

iii. 60 ☐

iv. 70 ☐

c. Engines are also equipped with a ____________ to force a higher volume of air into the cylinder.

i. Turbocharger ☐

ii. Piston ☐

iii. Crank shaft ☐

iv. None of the above ☐

v. Four ☐

d. The fuel economy for diesel engine is more than petrol engine.

i. True ☐

ii. False ☐

Notes

Answers: Working of Petrol and Diesel Engine

Question Number	Answer
1	a. iv b. iii c. i d. i

Internal Components of an Engine

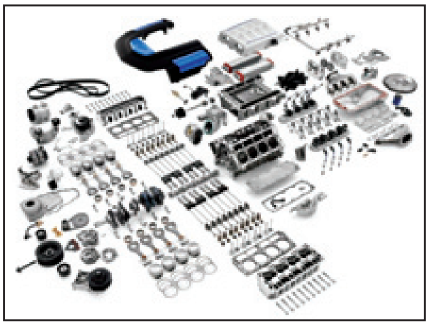
	At the end of this session you will be able to: ◆ identify the internal components of an engine; ◆ describe the construction and function of the engine components.

Session Plan	
1	Introduction
2	Internal Components of an Engine
3	Cylinder Head
4	Engine Block
5	Key Learnings
6	Worksheet

Introduction

The engine is made up of numerous components that are made of two main assemblies. These assemblies are further divided into sub-assemblies and components. Each of these components plays a vital role in the smooth functioning of the engine.

Internal Components of an Engine



An engine component can be categorized into two main assemblies namely:

- Cylinder head
- Engine block.

Each of the above main assemblies contains many different sub-assemblies and sub-components.

Cylinder Head

Cylinder Head is made of Aluminum which sits directly on the cylinder block over the pistons. It consists of internal tracts and passages for the water flow, oil path, intake and exhaust ports, and combustion chamber and so on. A gasket is also installed between the two mating surfaces of the cylinder head and cylinder block to prevent leakage.

Following are the sub components that are housed inside the cylinder head:

- Cam shaft
- Rocker Shafts
- Rocker arms
- Tappets or lifters
- Valves and springs

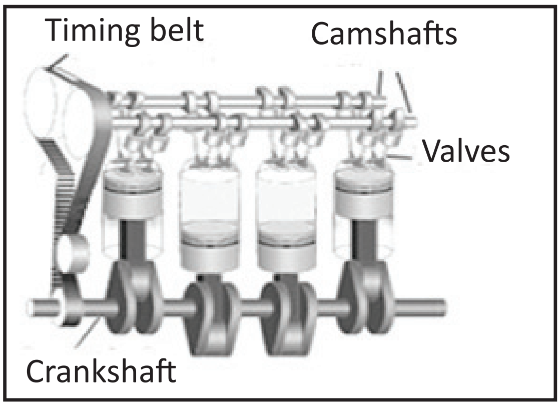
Cam Shaft

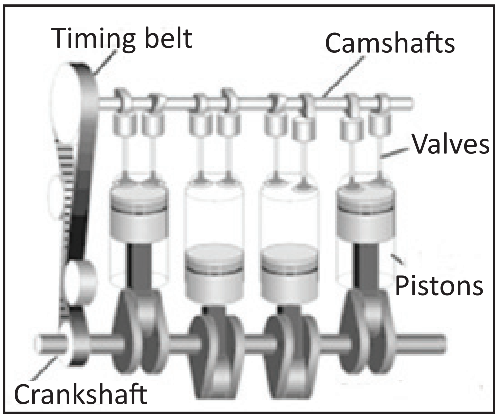
Camshaft is placed on the top of the cylinder head. Its main job is to operate and manage the inlet and exhaust valves with the help of cam lobes which are an integral part of camshaft, based on the engine cycle. Camshaft is made up of steel and attached to the crankshaft by means of belts, chain or gears. The rotational speed of the camshaft is half the speed of the crankshaft.

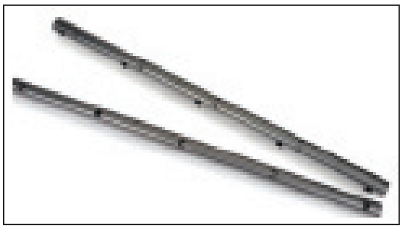
Engines can be equipped with single overhead cam shaft (SOHC) or double overhead camshaft (DOHC)

- In a SOHC configuration, both intake and exhaust valves are operated by a single camshaft
- In a DOHC configuration, the engine is equipped with separate camshafts for intake and exhaust valves.

Camshaft in some models drive the fuel pump, vacuum pump, fuel injectors etc.







Rocker Shaft:

The rocker shaft is made up of steel and usually used in SOHC mechanism. It holds the rocker arms in place which operate the inlet and exhaust valves. Separate shafts for inlet and exhaust valves.

Rocker Arms:

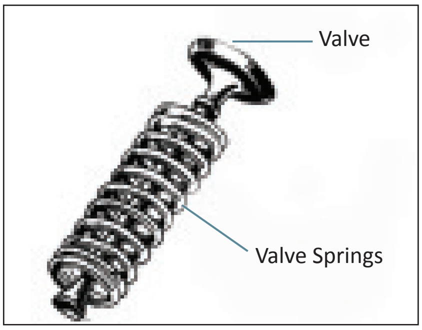
The rocker arms are made up of cast iron or steel. This will be fitted on the rocker shafts and each arm operates one valve.

Tappets or Lifters

Tappet is a projection that is mounted on a rod and gets its rotation movement from the camshaft lobes. In a cam drive mechanism it runs on the cam lobe and operates the valves.

In OHC, it transfers the linear motion to the valves through long push rods. The two types of tappets found in engines are as below:

- Mechanical Tappets – which require adjustments periodically.
- Hydraulic Tappets – or HLA (Hydraulic Lash Adjuster) which does not require adjustments.



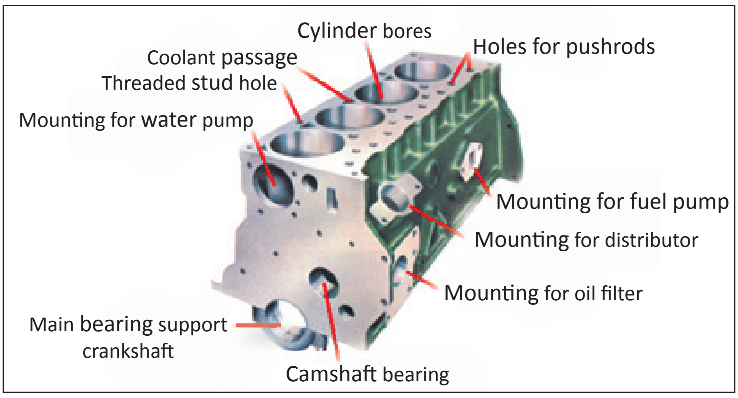
Valves and Springs

Valve is an important component in the cylinder head which opens and closes to allow the charge (Air/fuel) to enter the combustion chamber and exit in the form of exhaust gases during the exhaust stroke. The springs provide tension to the valve in-order to help it seat firmly on the valve seat, it also helps the valve to return to the closed position once the stroke is completed.

Engines are generally provided with two separate valves for the inlet and exhaust for better engine breathing.

In some vehicles there can be two each for inlet and exhaust ports (altogether 4 valves per cylinder).

Engine Block



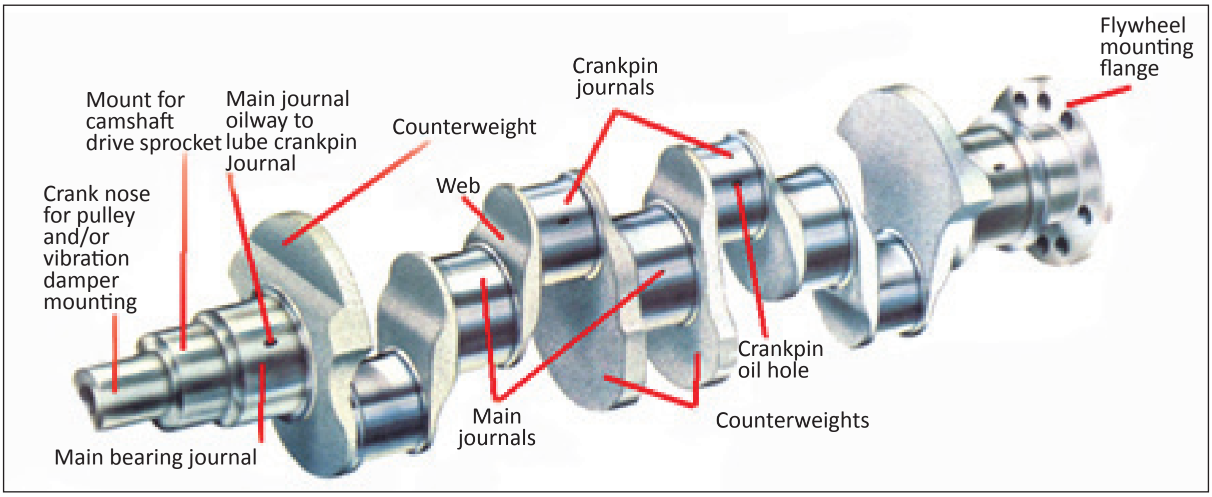
An engine block is made up of cast iron or aluminum. It is the main component of an engine as all 4 strokes or cycles are carried out in it. Like the cylinder head, engine block also has coolant passages, lubrication passages, galleries, exhaust and intake etc. machined in it. It consists of cylinder bores and provisions for the crankshaft and other sub components fitments

The Engine Block houses the following components:

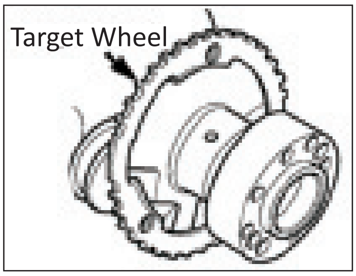
- Crankshaft assembly
- Crankshaft balancer
- Main bearings
- Connecting rod and bearings
- Piston, Piston pin and rings
- Crank case

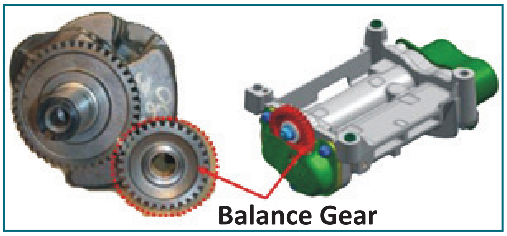
Crankshaft Assembly

The crankshaft is made of forged steel to provide a strength and is located between the engine block and the bed plate. It consists of 5 main bearing journals, the main bearing journals have oil passages cross drilled for lubrication of the connecting rod bearings



The 3rd main bearing or the center main bearing is where the thrust bearing is located, which ensures that the crankshaft has the proper axial end play. The crankshaft gear on the front end of the crankshaft drives the oil pump and crankshaft balancer. The back of the crankshaft is mounted with a target wheel to send signals to CKP (Crankshaft Position Sensor).



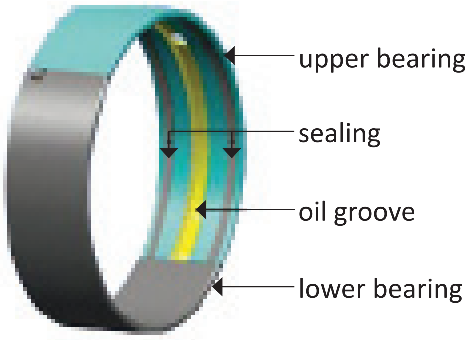


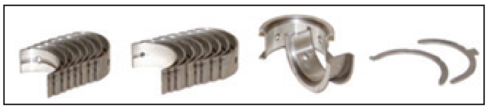
Crankshaft Balancer

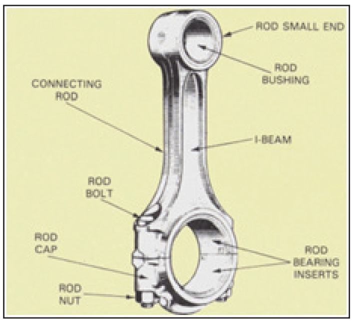
The crankshaft balancer assembly is driven by the crankshaft. The 2 balancer shafts revolve in opposite directions so that the balancer counterbalances the vibration that comes from the crank shaft assembly. It is located between the bed plate and the oil pan and is submersed in engine oil.

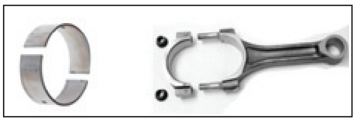
Main Bearings and Thrust Bearings

The Crankshaft is fixed to the cylinder block journal with the help of bearings to make the rotation smooth and friction free. The main bearings are of split type. One half fits (lower) into the engine block bearing journal whereas the second half (upper) fits on the top of the crank shaft journal in the bearing cap. The thrust bearing located in the centre fits into the groove made in the block.







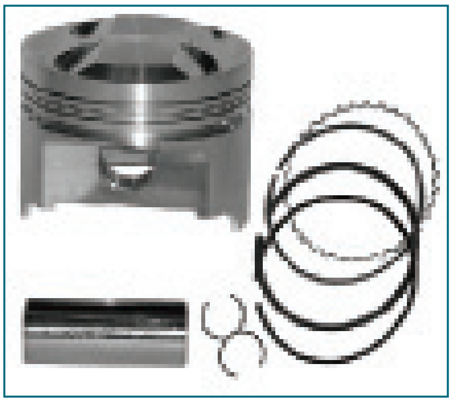


Connecting Rod and Bearing

The connecting rod is a part which connects the crankshaft to the piston so that the linear motion of the Crankshaft and piston is converted in to rotary motion of the crankshaft

Connecting rod is made up of cast iron, steel or alloys of aluminum. The small end which connects to the piston is known as gudgeon pin or wrist pin which is normally press fitted to the piston with a piston pin whereas the big end is connected to the crankshaft. The big ends have two slit bearings and are connected to the crankshaft with the help of bearing cap and bolts. The pin hole on the bearing and on the big end of connecting rod provides lubrication.

Piston, Piston Pins and Rings



The pistons are made of cast aluminum with a flat top design and piston skirts that are coated to reduce friction. Each piston uses 2 compression rings and a 3-piece oil control ring assembly. The piston pin is a full-floating design and is retained to the connecting rod by clips located in each end of the piston pin bore. The connecting rod and rod cap are positioned and aligned by a dowel pin and retained by bolts. The piston rings are of split type made up of cast iron and steel which fits in to the grove on the outer diameter of piston

Usually three in numbers and the top two are compression rings and the bottom helical one are oil rings. The piston pin is made up of steel and has two locks to keep the piston in place and connected to the connecting rod.

Crank Case or Oil Pan

The oil pan is made up of sheet metal and stores lubricating oil required for the lubrication of internal engine components. It consists of baffles (metal separators) on the lower surface to prevent oil from moving from one end to another when taking so. If oil moves from one side to another there can be possibility that the oil pump runs out of oil which could result in seizing of the engine. The oil pan acts as a covering and protecting device for the crankshaft and related components. It has an opening at the bottom to drain out oil from the crank case while replacing new oil.

The oil pan is fixed to the Engine block with the help of gaskets/seals to prevent leakage. Crank case is a component that is placed between the cylinder block and the oil pan.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. Name the two main assemblies that comprise the internal components of an engine. Describe each briefly.

2. Explain the construction of a cam shaft in an engine.

3. What are tappets or lifters?

4. What is a crankshaft assembly in an engine block?

Worksheet

1. *Read the questions and choose the correct answers.*

a. A ____________________ is also installed between the two mating surfaces of the cylinder head and cylinder block to prevent leakage.

i. Tract ☐

ii. Passage ☐

iii. Filter ☐

iv. Gasket ☐

b. The rocker arms are made of cast iron or ____________________ .

i. Steel ☐

ii. Aluminium ☐

iii. Titanium ☐

iv. Iron ☐

c. The crankshaft assembly in the engine block consist of ____________________ main bearing journals.

i. 2 ☐

ii. 4 ☐

iii. 5 ☐

iv. 10 ☐

d. The ____________________ on the lower surface of the crank case in the engine block prevents oil from moving from one end to another.

i. Baffles ☐

ii. Gasket ☐

iii. Piston rings ☐

iv. None of the above ☐

Notes

Answers: Internal Components of an Engine

Question Number	Answer
1	a. iv b. i c. iii d. i

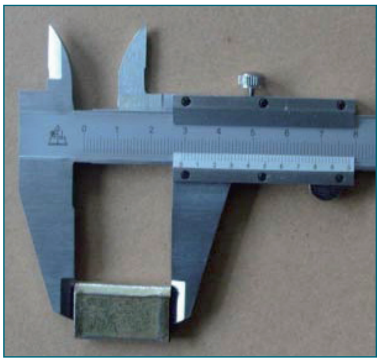
Engine Mechanical Measurements

At the end of this session you will be able to:

- list the various tools used in engine measurements;
- state the use of the tool.

Session Plan	
1	Introduction
2	Vernier Calliper
3	Micrometer
4	Bore Gauge
5	Key Learnings
6	Worksheet

Introduction



Mechanical Tools such as vernier calliper, micrometer screw gauge and bore gauge measures the dimension of an engine component and conclude whether the latter is within a serviceable limit.

An automobile is a machine made up of various units and individual components. Every component needs to function for the vehicle to operate on the road. Due to periodic usage, the components tend to wear. Hence, when carrying out periodic maintenance it is necessary to check for wear. Measuring tools are used to check various dimensions and decide if the component is between serviceable limit.

The various tools used for measuring engine components are:

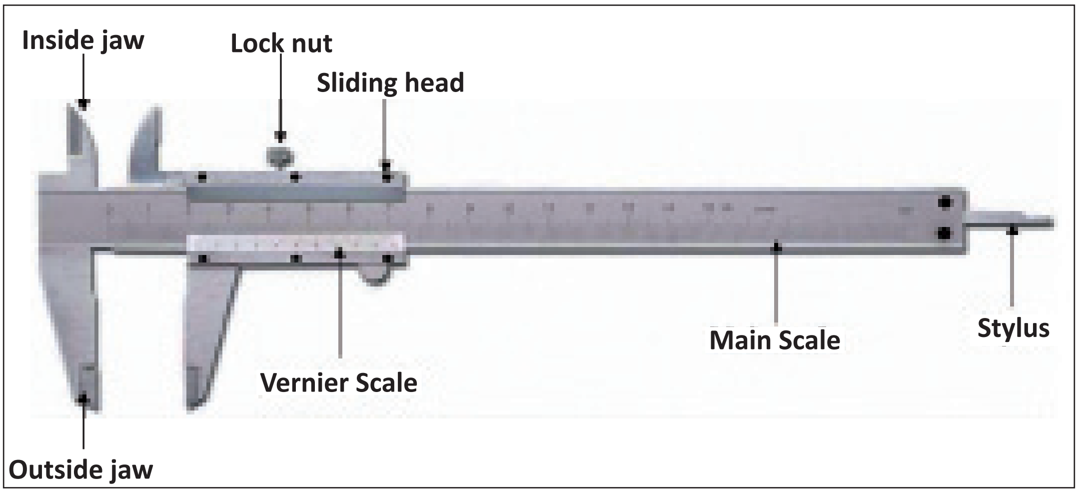
- Vernier calliper
- Micrometer
- Bore gauge

Vernier Callliper

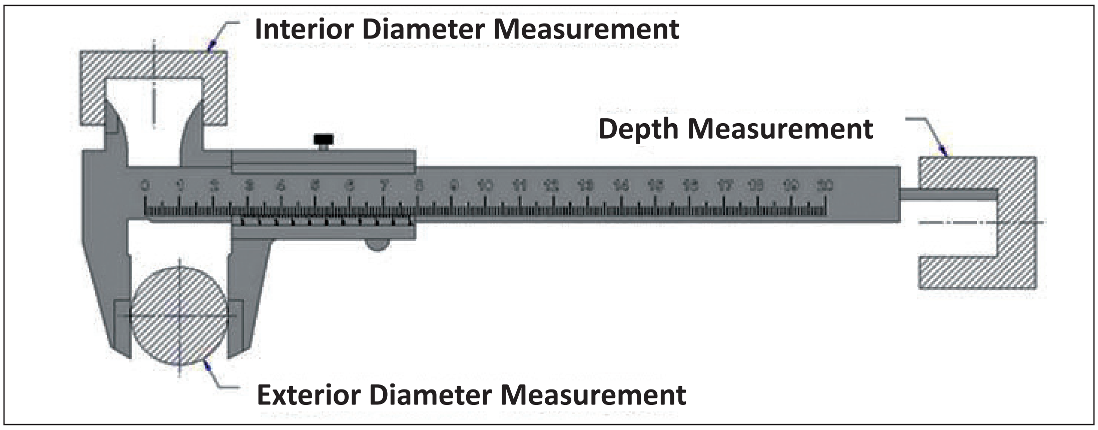
A Vernier Calliper is used to measure internal, external dimensions and depth of any mechanical component. It can measure dimensions precisely with a least count of 0.02mm ie: the lowest measurement that can be measured using the Vernier Calliper is 0.02mm.

It consists of a L shaped frame which also has the main scale and a sliding scale that slides on the main scale which has the Vernier scale. The lock nut on the vernier/sliding scale enables locking of the scale to get the perfect reading.

Stylus is provided to measure depth, internal jaws to measure internal dimensions and external jaws to measure external dimensions.



Dimension = Main scale reading + Coinciding division x Least Count



Measuring interior diameter

- Place the spring between the jaws of the Verniercalliper meant to measure exterior dimensions (usually larger in size).
- Using the thumb push the adjustable jaw by pushing the Vernier scale until it holds the spring firmly between the jaws.
- Lock the Vernier scale by tightening the screw/lock provided on the Vernier scale.
- Note the division on the main scale that is just before the left-most mark on the sliding scale (eg.14 mm).
- Carefully notice the divisions on the Vernier scale, one out of ten divisions will perfectly coincide with a division on the main scale. Note the number of division (eg. 10th division).
- Multiply the reading with the least count (eg- 10x0.02) = 0.2 mm the reading now will be 14 + 0.2 = 14.20 mm.

Measuring interior diameter

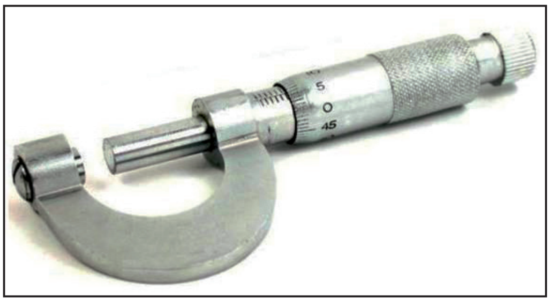
- Place the wire between the jaws of the Verniercalliper meant to measure interior dimensions (usually smaller in size).
- Follow the same steps used to measure exterior diameter to note the reading.

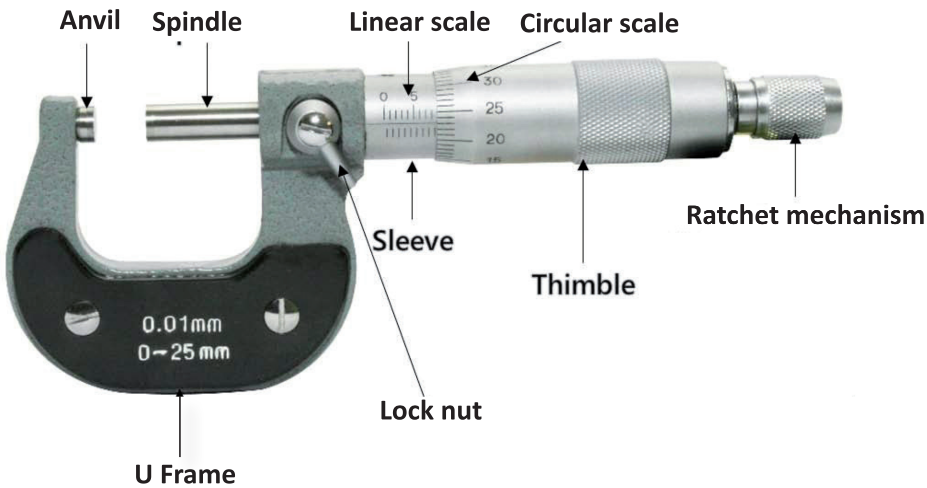
Measuring depth

- Hold the Verniercalliper vertically and place the end of the main scale on the edge of the cylinder whose depth is needed to be measured.
- Using the thumb, slide the Vernier scale outwards so that the tail attached to the Vernier scale moves out.
- Push it till the Vernier scale stops moving.

Micrometer

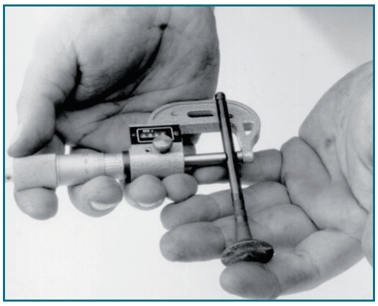
A Micrometer is to measure external dimensions. It can measure dimensions precisely with a least count of 0.01mm ie: the lowest measurement that can be measured using the Micrometer screw gauge is 0.01mm. It consists of a U shaped frame that is strong enough to prevent deflection when the component to be measured is between the anvil and the spindle. The frame is attached to the barrel which has the main scale provided on it. The thimble is a hollow tube placed over the barrel which has a circular scale provided on it. Lock nut is provided to lock the Micrometer to get the precise reading. The ratchet at the end helps rotating the barrel and the spindle. As soon as the job is firmly held between the spindle and the anvil, the ratchet starts slipping thus allowing exerting an even pressure while measuring a component.





Dimension = Linear scale reading + Circular scale reading + Zero error reading

Measurement of external diameter of valve stem using micrometer screw gauge



- Place the valve stem between the anvil and spindle end.
- Rotate the thimble until the valve stem is firmly held between the anvil and the spindle.
- Using the ratchet tighten the spindle (If the valve stem is firmly held between the anvil and spindle, the ratchet will slip).

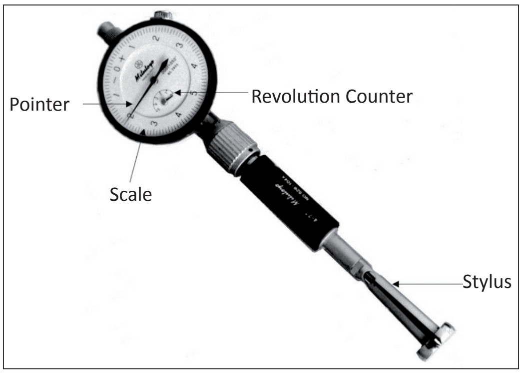
Taking a reading:

- Note the reading on the main scale provided on the sleeve (eg. 7mm).
- Note the reading on the circular scale provided on the cone of the thimble (eg. 0mm).
- Multiply the thimble reading by least count (eg- 0x 0.01) = 0 mm.
- Sum up both the readings and calculate the reading (eg. 7+0= 7mm).

Bore Gauge

A bore gauge also known as dial gauge is used to measure flatness, taper, concentricity, parallelism etc. It has a very high accuracy which is 1 micron ie: 0.001 mm. It consists of a rack that is engaged to the pinion and is connected to the stylus. The pinion is compounded with another bigger gear which in turn engages with another smaller gear. A small movement in the stylus is magnified to a high movement of the pointer by the gear train

The stylus has a linear movement whereas the pointer rotates. The stylus is brought back to its original place with the help of a spring once the measurement is done.



Measurement of engine cylinder bore using bore gauge

- Set the bore gauge to zero by attaching the measurement head that corresponds with the estimated diameter of the cylinder and adjusting the calibration knob next to the dial until it reads zero.
    - Use a ruler to take a quick measurement across the cylinder bore, if you do not know the estimated diameter of the cylinder.
- Insert the measurement head into the top of the cylinder, rocking the bore gauge back and forth slightly until the head is level across the cylinder.
- Remove and replace the measurement head with the next smallest head if the one you are using will not fit into the mouth of the bore. Repeat the process until you are able to take your measurement. Take the measurement then remove the gauge.
- Turn the measurement head to a 90-degree angle from your original measurement, and then repeat the process of taking a measurement across the top of the cylinder bore. Write down this measurement alongside the first measurement, marking both of them as being taken at Position No. 1.
- Reinsert the measurement head into the cylinder, this time taking a measurement across the cylinder at a depth of approximately 1 inch. Rock the gauge slightly to level the measurement head, then write down the measurement.

- Take another measurement at the same depth, again turning the measurement head to a position at a 90-degree angle from the first measurement. Record this measurement along with the original measurement for this depth, marking them both as being taken at Position No. 2.
- Repeat the process of taking two perpendicular measurements two more times, each time moving the gauge approximately 1 inch deeper for each set. Record each pair as being taken at positions No. 3 and No. 4, respectively.
- Remove the dial bore gaugeand then examine your recorded readings. Each set of measurements will show you the variations in the cylinder width at a given depth.
- If the readings are below the serviceable limits than replacing the cylinder liners is necessary.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. What are the tools used for measuring engine components? Explain briefly.

____

____

____

2. How can a spring whose exterior dimension needs to be measures using Vernier calliper?

____

____

____

3. What is a bore gauge? Mention its highest rate of accuracy

____

____

____

____

Worksheet

1. Read the questions and choose the correct answers.

a. The ____________________ in Vernier calliper is provided to measure depth, internal jaws to measure internal dimension.

- i. ratchet ☐
- ii. barrel ☐
- iii. stylus ☐
- iv. pinion ☐

b. The __________ can measure dimensions precisely with a least count of 0.01 mm.

- i. Micrometer ☐
- ii. Vernier Calliper ☐
- iii. Bore Gauge ☐
- iv. All of the above ☐

c. The Vernier calliper can measure dimensions precisely with a least count of ________ .

- i. 0.02 mm ☐
- ii. 0.01 mm ☐
- iii. 0.001 mm ☐
- iv. 0.003 mm ☐

d. The ____________________ is a hollow tube in a Micrometer screw gauge placed over the barrel which has a circular scale provided on it.

- i. barrel ☐
- ii. thimble ☐
- iii. anvil ☐
- iv. none of the above ☐

Notes

Answers: Engine Mechanical Measurements

Question Number	Answer
1	a. iii b. i c. i d. ii

Diagnostic Gauges

At the end of this session you will be able to:

- identify the various diagnostic gauges;
- use the gauges to diagnose defects in the engine components.

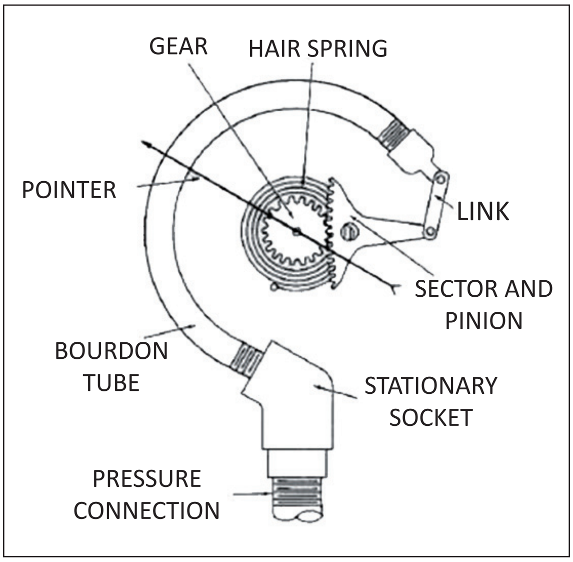
Session Plan	
1	Introduction
2	Bourdons Principle
3	Oil Pressure Gauge
4	Power Steering Fluid pressure Gauge
5	Compression Pressure Gauge
6	Coolant Pressure Tester
7	Vacuum Pump
8	Coolant Quality Tester
9	Hydrometer
10	Stethoscope
11	Key Learnings
12	Worksheet

Introduction

Some of the engine components are likely to wear after a certain period of time. One such wear can be leakages in air, fuel mixture or the fuel lines. The diagnostic gauges help to repair these amounts of leakages.

An engine operates at high pressures to produce the power required to move the vehicle. A leakage in pressure from the engine could lead to reduced performance. Due to periodic usage of the vehicle, the mechanical components wear out resulting in leakage of the compressed gasses. Different gauges are used to rectify the amount of leakage in air/fuel mixture, fuel lines etc.

Borudon Principle



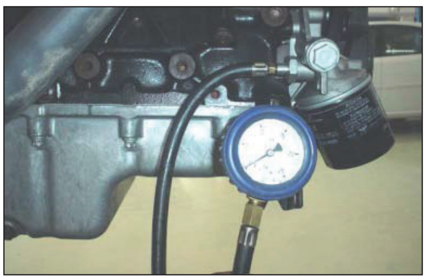
Pressure and vacuum gauges work on the Borudons principle which is a flattened tube tends to straighten or regain its circular form in cross-section when pressurized. A flattened thin-wall, closed-end tube is connected at the hollow end to a fixed pipe containing the fluid pressure to be measured. As the pressure increases, the closed end moves in an arc, and this motion is converted into the rotation of a gear by a connecting link that is usually adjustable. A small-diameter pinion gear is on the pointer shaft, so the motion is magnified further by the gear ratio. The indicator card with readings is positioned behind the pointer which indicates the desired range of pressure for variations in the behavior of the Bourdon tube itself. Differential pressure can be measured by gauges containing two different Bourdon tubes, with connecting linkages.

Fuel Pressure Gauge

The fuel pressure gauge is used to measure the pressure in developed by the fuel pump. It needs to be to be connected between fuel rail and main fuel line, as shown in the picture. Once the ignition is switched ON, the fuel pressure is indicated on the fuel gauge.


Oil Pressure Gauge

The oil pressure gauge is used to measure the pressure in developed by the oil pump. The oil pressure gauge is installed in place of the oil pressure switch using a suitable adaptor. When the engine is started, engine oil pump develops oil pressure that is indicated by the gauge. Oil pressure is checked at specific engine RPM recommended by the manufacturer.

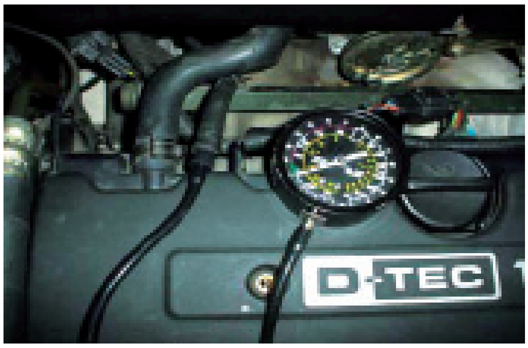
Power Steering Fluid Pressure Gauge

The power steering fluid pressure gauge is used to measure the pressure in developed by the power steering pump. It is connected in series with outlet of the power steering pump and the fluid line. To check power steering fluid pressure engine need to be started, which drives the power steering fluid pump. Power steering fluid pressure is checked in two stages.

- System pressure at specified RPM recommended by manufacturer
- Relief pressure by closing the knob on the gauge. (knob should not be kept closed for more than 5 seconds)

Vacuum Pressure Gauge

Vacuum cum pressure gauge is used to measure the engine vacuum and needs to be connected with intake manifold as shown in the picture. When the engine is cranked and started the gauge indicates the vacuum pressure. At idle speed, the needle turns anti clockwise and if the gauge reads around 450 [green line as shown in the picture] it means the health of the engine is good.



Compression Pressure Gauge

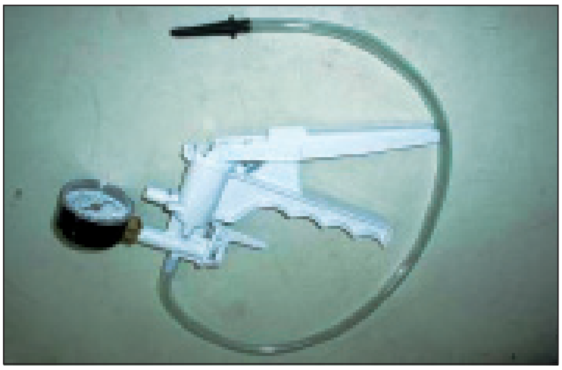
Compression gauge is used to measure the compression pressure

It is connected in place of a glow plug in the case of a diesel engine and in place of a spark plug in a petrol engine with the help of special adaptors. When the engine is cranked the gauge indicates the compression pressure.

Coolant Pressure Tester

Coolant pressure tester is used to check for leakage in coolant lines and test coolant pressure cap. It is connected either on the coolant reservoir or the radiator cap, as shown in the image. To check for leakage pressure needs to be created in the cooling line which should not exceed 1.2 Bar.

Vacuum pump



Vacuum pump is used to create vacuum pressure at any component, which works on vacuum and measure the voltage output or functional operation. For inspection of MAP sensor [as shown in the picture] the gauge needs to be connected to with sensor and by creating a vacuum pressure. The output voltage of the sensor is notified on the multimeter.

Coolant Quality Tester

Coolant quality tester is used to inspect the quality of coolant as shown in the image.

The reading of tester [boiling point of coolant] should be between 129 to 131 degree Celsius, if not it needs to be replaced.

Hydrometer

Hydrometer is used to check the specific gravity of electrolyte solution of battery.

To measure the strength of a battery, insert the hydrometer into the battery cell as shown in the image.

Specific Gravity	Rate of Charge (%)
1.270-1.280	100% (Fully Charged)
1.230 - 1.240	75%
1.190 - 1.200	50%
1.145 - 1.155	25%
1.00	0%

Stethoscope

A stethoscope is used to detect any abnormal sound from moving components of vehicle. For example Engine, AC compressor, Transmission, fuel pumps etc.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. State Bourdons Principle.

2. What is a compression gauge? How is it used as a diagnostic gauge?

____

____

____

____

____

3. What is a fuel injector tester and how is it used as diagnostic gauges?

____

____

____

____

____

4. What is a hydrometer used for?

____

____

____

____

____

Worksheet

1. *Read the questions and choose the correct answers.*

   a. The fuel pressure gauge is connected between fuel rail and ____________________ .

      i. Coolant reservoir ☐

      ii. Main fuel line ☐

      iii. Oil pump ☐

      iv. None of the above ☐

b. At idle speed, if the vacuum pressure gauge reads ______________ it means the engine is in good condition.

i. 350 ☐

ii. 450 ☐

iii. 480 ☐

iv. 500 ☐

c. While using a coolant pressure tester to check leakage, pressure should be created in the cooling line which should not exceed ____________ bar.

i. 1 ☐

ii. 1.5 ☐

iii. 1.8 ☐

iv. 1.2 ☐

d. The reading of a coolant quality tester which is the boiling point which should be between ____________ °c to ____________ °c.

i. 125, 140 ☐

ii. 129, 131 ☐

iii. 125,131 ☐

iv. 126,142 ☐

Notes

____

____

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____

____

____

Answers: Diagnostic Gauges

Question Number	Answer
1	a. ii b. ii c. iv d. ii

Introduction to Air Induction System

	At the end of this session you will be able to: ◆ state the purpose of an air induction system.

Session Plan	
1	Introduction
2	Purpose of Air Induction System
3	Components of Air Induction System
4	Working of Air Induction System
5	Key Learnings
6	Worksheet

Introduction

Atmospheric air contains oxygen content in it and since oxygen facilitates burning it needs to be supplied to the engine cylinder. The channel through which air or air/fuel mixture enters the engine cylinder is called the air induction system.

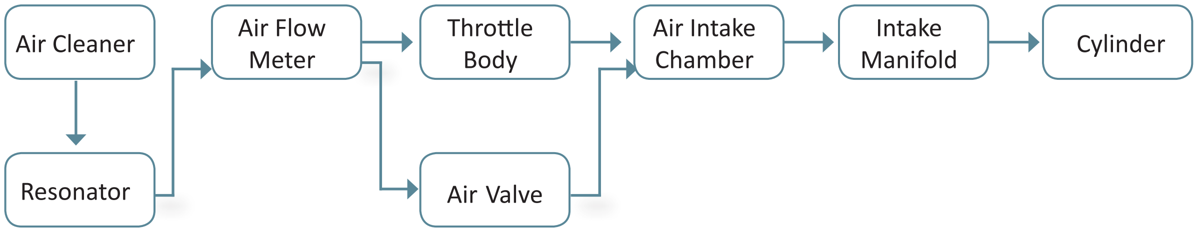
It consists of various components mechanical/electrical to measure and control the quantity and quality of the air entering the engine cylinder, each component has it unique way of operation.

Purpose of Air Induction System

The purpose of an air induction system is to filter, meter and measure the flow of air into the engine cylinder. The various components of an air induction system are:

- Air cleaner
- Resonator
- Air flow meter (Mass air flow sensor)
- Throttle body
- Air valve (Idle air control valve)
- Air intake chamber
- Intake manifold
- Cylinder

A general schematic of an air induction system is as below.



Components of Air Induction System

Air Cleaner

Air cleaner also most commonly known as an air filter. As the name implies, its main function is to clean the air that is entering the engine cylinder.

The cleaning of air entering the system prevents dust and emery particles entering the engine which could wear out the engine faster. It reduces the hissing produced by fast moving air into the cylinder and prevents the flame coming out of the cylinder when the engine back fires.

The various air cleaners used in automobiles are:

- Wet type air cleaners
- Dry type air cleaners

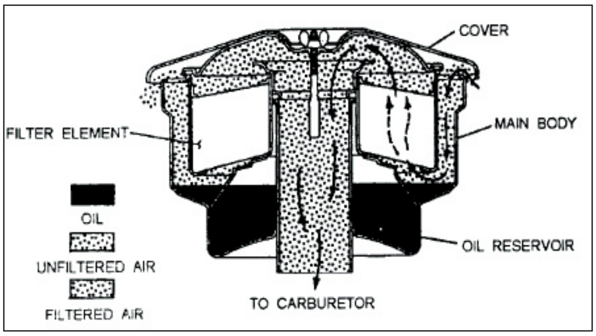


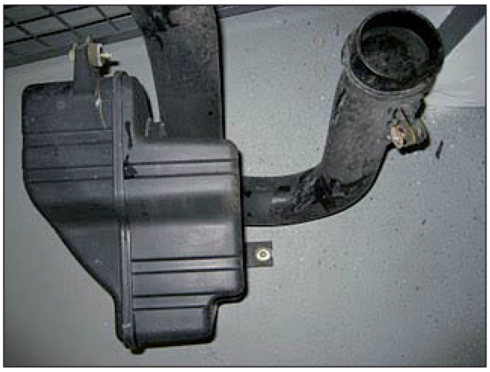
Figure 4-15,–Wet-type air filter

Air Cleaner – Wet Type Air Cleaner

In a wet type air cleaner also known as oil cleaner the filtering medium is oil as the name suggests. In this system the air enters the through an intake passage and deflects on the surface of oil in the oil tank. The dust particles in the air come in contact with the surface of oil and are trapped into the oil which settles at the base of the tank. The air then passes through the wire mesh which is also a wet type and further traps any dust particles contained in the air. The wire mesh needs to be cleaned during periodic maintenance.

Air Cleaner – Dry Type Air Cleaners

In a dry type air cleaner the filtering of air is done with the help of a corrugated paper which is in the form of ring or square shaped. The air enters the through an intake passage and passes through the paper element. The dust particles are trapped here from entering cylinder. The filter needs to be replaced during periodic maintenance.

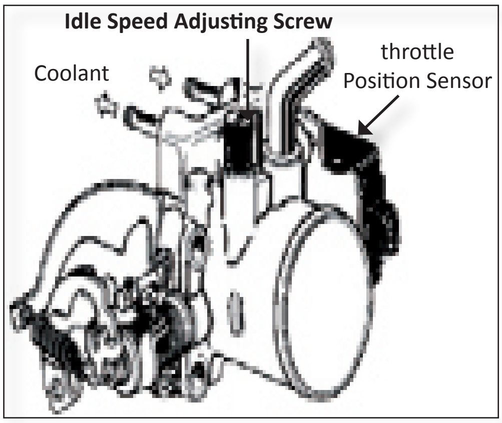


Resonator

Reduces the noise produced by the air rushing through air filter because of the engine vacuum. More the engine vacuum higher the resonance (noise).

Air Flow Meter

The air flow meter is placed in series with the air cleaner and the throttle body, ensuring the measurement of the volume of entering the engine. The air flow meter consists of a measuring plate, which is spring loaded and closed by a return spring. A potentiometer attached to the plate varies the electrical signal to the ECU as the position of the plate changes. The volume of air entering the engine is directly proportional to the amount of movement detected from the measuring plate.

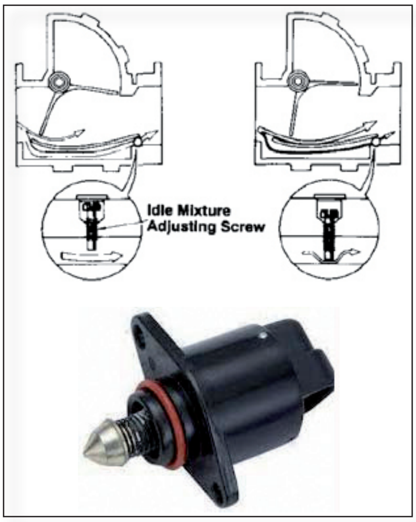


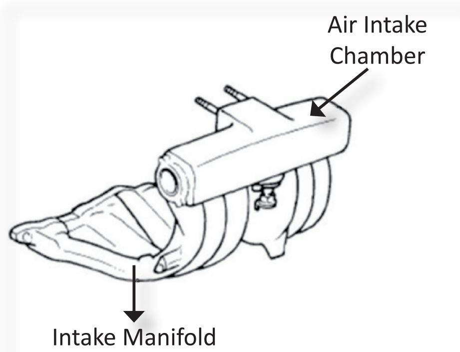
Throttle Body

The throttle body consists of the throttle valve, the idle air by-pass circuit, throttle position sensor and also houses various ported and manifold vacuum sources to operate emission devices. The throttle valve is mechanically controlled via a cable from the accelerator pedal or electrically controlled in situations where vehicle is equipped with drive by wire system. The drop in pressure during the suction stroke causes throttle plate icing. Throttle icing is prevented by the use of an engine coolant cavity located adjacent to the throttle valve.

Air Valve

The air valve also knows as an idle valve is connected in parallel with the throttle valve and comes in action only when the engine is idling. During idling, since throttle valve is fully closed no air can enter the engine; air valve bypasses the throttle valve and provides air to the engine to facilitate burning. A screw is used to adjust the amount of air that can bypass the measuring plate which is adjusted and sealed at the factory to avoid improper adjustment and tampering.In some models the screw/valve will be ECM controlled.





Air Intake Chamber and Manifold

An air intake chamber is a large metal/plastic body that is connected between the throttle body and the manifold runners. It prevents pulsations and improves the air distribution to each manifold runner. The manifold runners are long tubular pipes connecting between the air intake chamber and the cylinder head to improve air velocity at the intake valve.

Working of an Air induction System

- When the ignition is switched on and the driver presses the accelerator pedal, the throttle valve is opened via an cable or drive by wire mechanism.
- Since the first stroke is the intake stroke, the downward movement of the piston creates vacuum in the engine cylinder which sucks the atmospheric air.
- The atmospheric air may contain dust and emery particles which could damage the engine and hence needs to be cleaned before entering the system.
- The air is passed through the air cleaner which purifies the air and passes the same to the engine cylinder through the throttle body, air intake chamber and the manifold.
- During idling, the throttle valve is closed as a result of accelerator pedal not being pressed, hence calibrated amount of air by-passes the throttle valve and enters the engine cylinder to facilitate burning.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. Sketch a general schematic of an air induction system.

2. Describe an air cleaner and mention the different types of air cleaners used in automobiles.

Worksheet

1. Read the questions and tick the correct answer.

a. ______________________ causes icing of throttle plate.

i. Drop in pressure ☐

ii. Rise in pressure ☐

iii. Icing is never caused to the throttle plate ☐

iv. None of the above ☐

b. The intake manifold prevents pulsations and improves the air distribution to each manifold runner.

i. True ☐

ii. False ☐

Notes

Answers: Introduction to Air Induction System

Question Number	Answer
1	a. i b. i

Types of Air Induction System

At the end of this session you will be able to:

- identify the components of air induction system;
- describe the working of air induction system.

Session Plan	
1	Introduction
2	Types of Air Induction System
3	Key Learnings
4	Worksheet

Introduction

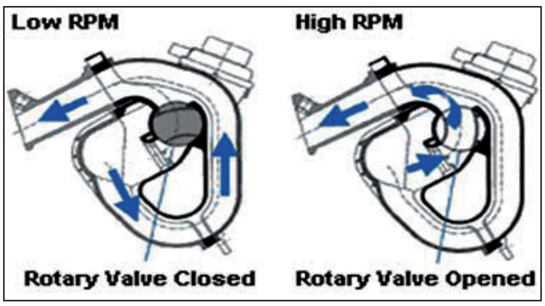
Automobile engines are generally naturally aspirated, ie: air in the engine cylinder is inducted due to natural draft. However, at high speed to generate more power more air needs to be pumped into the cylinder, this is done by using different forced induction methods in a petrol and diesel engine. Following methods are used to pump more air into the engine cylinder:

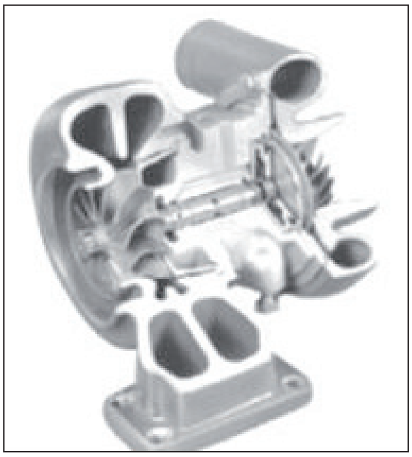
- Variable Geometry Intake System (VGIS)
- Fixed Geometry Turbocharger (FGT)
- Variable Geometry Turbocharger (VGT)

Types of Air Induction System

Variable Geometry Intake System (VGIS)

This system is used in petrol engines. It is a special type of intake manifold designed to maintain the volumetric efficiency of the engine at all speeds and is controlled by an ECM. It consists of two paths of air intake inside the VGIS unit; one activated at high speed and the other at low speed. At low speed, since less air is required for combustion, the air travels from the longer path from the air intake to the intake valve. During high speed, as more air is required for the burning of fuel, the rotary valve situated at the mid-way of the VGIS unit is opened by the force applied to the plunger by engine vacuum pressure. The opening of the rotary valve increases the amount of air entering into the cylinder increasing power output.



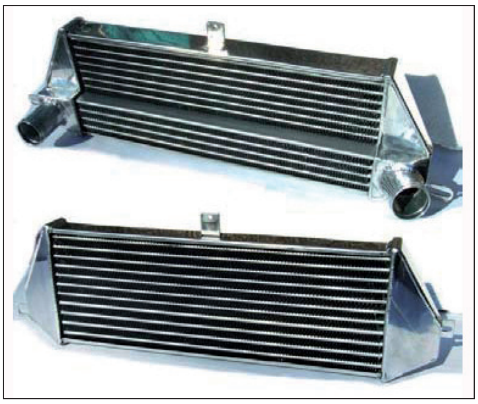


Fixed Geometry Turbocharger (FGT)

This is a simplest form of turbocharger design from a control perspective and consists of a turbine whose geometry is fixed. Turbochargers run on exhaust gasses. It consists of a turbine and a compressor mounted on a common shaft. Turbine runs by the exhaust gases leaving the engine cylinder which in turn rotates the intake compressor. The rotation of the compression forces more air into the engine cylinder to produce more power. This turbine is not functional at low speeds and is only activated at high speed. Hence the initial turbo lag can be noticed when the turbo kicks-in.

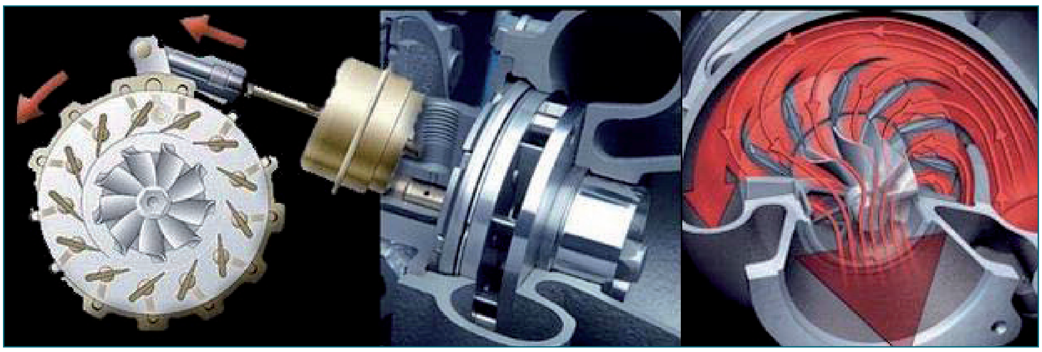
Intercooler

The charge air cooler also helps the performance of the engine. Intake air is drawn through the air cleaner and into the turbocharger compressor housing. Pressurized air from the turbocharger then flows forward through the charge air cooler located in the front of the radiator. From the charge air cooler, the air flows back into the intake manifold. However charging efficiency into the cylinder increases as compressed hot air is cooled and density of air gets higher through the charge air cooler. It brings also higher fuel efficiency as well as lower emissions. Charge air cooler which is installed in front of radiator and it makes compressed hot air cool by airflow through the radiator grill.



Variable Geometry Turbocharger (VGT)

Variable-geometry turbochargers (VGTs) are a family of turbochargers, usually designed to allow the effective aspect ratio (A:R) of the turbo to be altered as conditions change. The construction of this setup is the same as the FGT, the only difference being that the VGT consists of variable vanes in the turbocharger. The variable vanes are electrically controlled by the ECM or manually controlled by engine vacuum through a plunger as the engine speed increases or decreases to produce the required power. In this setup there is no noticeable turbo lag.



Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. Sketch a general schematic of an air induction system.

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2. Explain the VGIS system.

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Worksheet

1. *Read the questions and tick the correct answer.*

a. VGIS stands for ______________________ .

i. Variable Geographic Intake System ☐

ii. Variable Geometry Intake System ☐

iii. Vast Geometry Intake System ☐

iv. None of the above ☐

Notes

Answers: Types of Air Induction System

Question Number	Answer
1	a. ii

Introduction to Evaporative (EVAP) Emission System

	At the end of this session you will be able to: ◆ state the importance and purpose of an evaporative emission (EVAP) system; ◆ identify the components of evaporative emission system.

Session Plan	
1	Introduction
2	Introduction to Evaporative (EVAP) Emission System
3	Purposes of an EVAP system
4	Components of an EVAP system
5	Key Learnings
6	Worksheet

Introduction

The Evaporative Emission System is designed to store and purge fuel vapours that are created in the fuel system and it helps in preventing it from escaping into the atmosphere.

Introduction to Evaporative (EVAP) Emission System

- With the increasing stringent Government Rules to control the emission of Automobiles in India, the Auto manufacturers are mandatorily required to introduce Tail pipe emission Systems and EVAP System.
- When a variety of Hydrocarbons are leaked in to the atmosphere from automobiles, these substances react with air and sunlight to form smog.
- Thus the need for an EVAP system exists to eliminate air pollution and save evaporative fuel losses.

Purposes of an EVAP System

The main purpose of the EVAP System systems is;

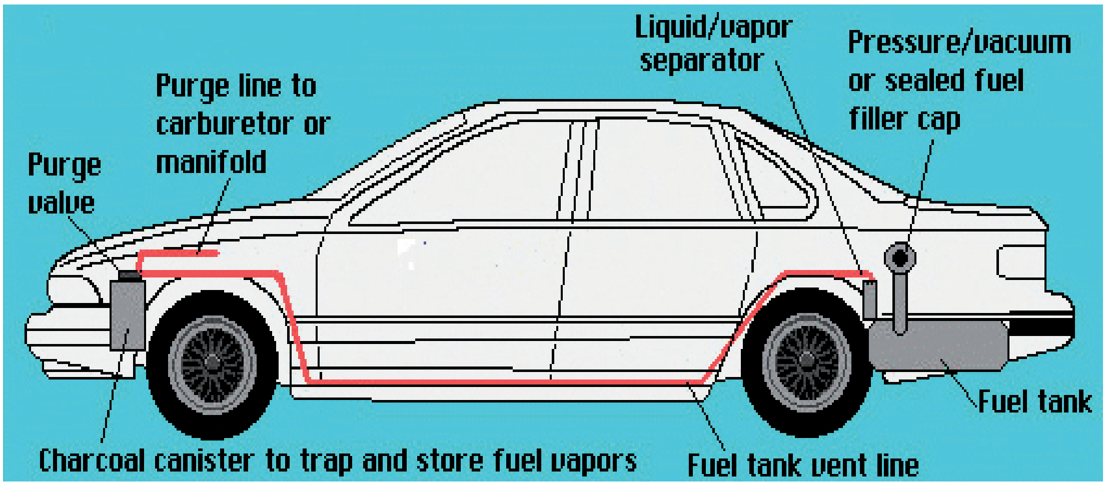
To trap and hold gasoline vapours (HC) in the fuel system and not allow them to escape into the atmosphere

- To deliver trapped vapours to the engine airflow for complete burning.
- Provide system ventilation to allow purging.
- Provide pressure relief to prevent excess pressure inside the fuel tank.

Components of an EVAP System

The main components of an EVAP system are;

- Charcoal canister
- Purge valve/purge solenoid
- Vacuum lines
- Fuel tank filler cap
- Fuel expansion tank
- Fuel tank pressure sensor
- Vent valve.



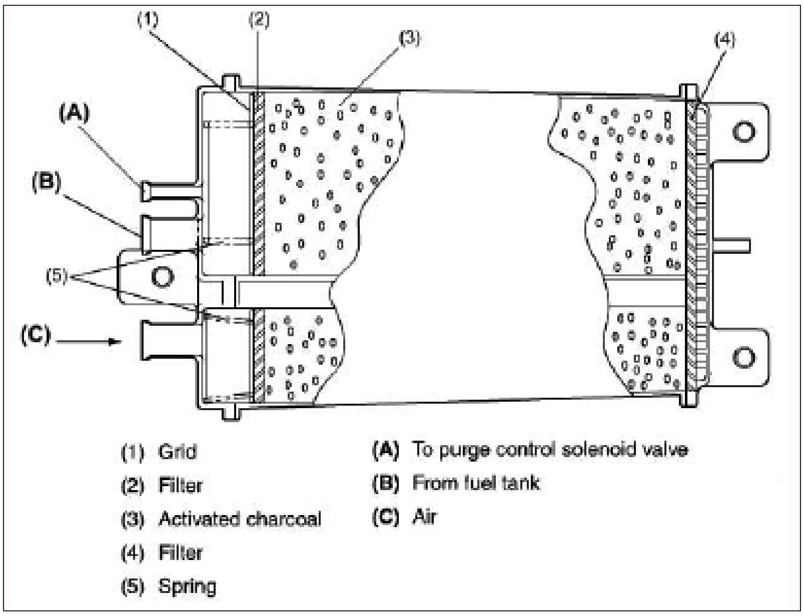
Charcoal Canister

Charcoal canister is placed in between the fuel tank & purge valve.

This canister contains activated charcoal that traps and holds the vapours and is later used for burning in the engine.

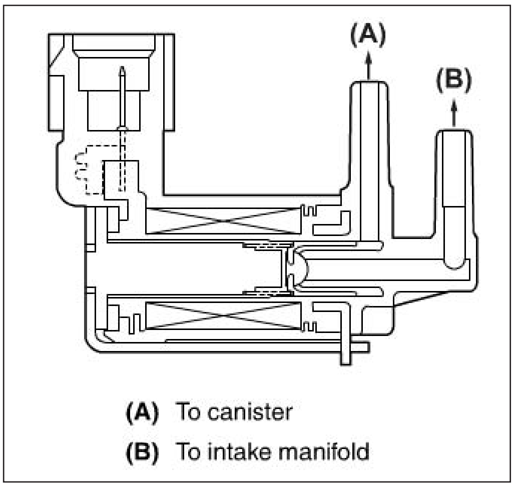
The Charcoal canister consists of the following components:

- Grid
- Filter
- Activated Charcoal
- Spring



Purge valve/purge solenoid

- The canister purge valve forms part of the emission control system
- It is situated between the canister and manifold, the purge valve is Controlled by PCM to allow canister purging during certain conditions
- Petrol vapour from the petrol tank that is stored in the carbon absorption filter, is taken to the engine through this solenoid valve.

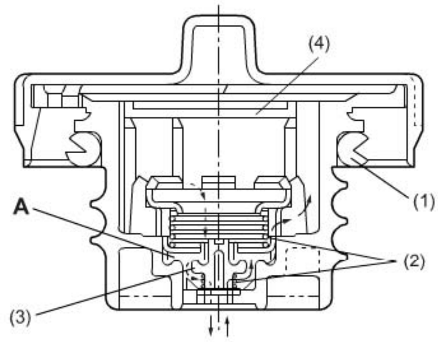


Vacuum Lines

- Connects the tank to the canister as well as to the engine manifold.

Fuel Tank Filler Cap

- Seals the fuel tank and allows for pressure relief
- Prevents excessive vacuum from collapsing the fuel tank.
- If vacuum develops in the fuel tank, the atmospheric pressure forces the spring down to open the valve; consequently outside air flows into the fuel tank, thus controlling the inside pressure.

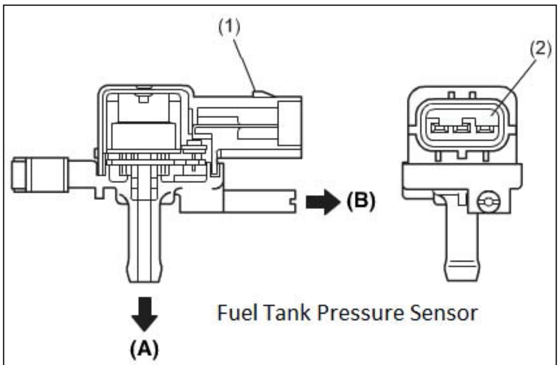


Fuel Tank Filler Cap

(1) Seal
(2) Spring
(3) Valve
(4) Filter

Fuel Tank Pressure Sensor

- Monitors the fuel tank pressure level in the tank.
- The measured pressure is converted into an electrical signal and sent to the ECM

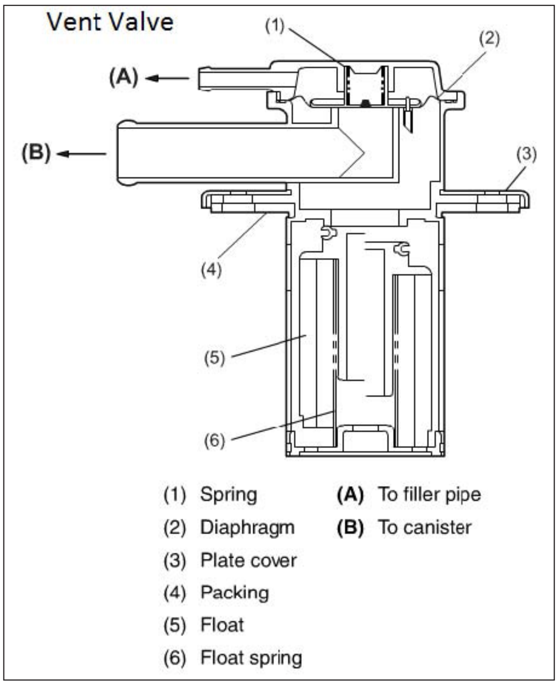


Fuel Tank Pressure Sensor

(1) Connector (A) To fuel tank
(2) Terminal (B) To fuel tank sensor control valve

Vent Valve

- Allows fresh air to enter in the system for purging.
- It is also used in the seal the system to check for leaks.
- When the fuel vapour pressure becomes higher than the atmospheric pressure and overcomes the spring force which is applied to the backside of the diaphragm, the port toward the canister is opened.
- The vent valve also has a float which rises and blocks the port toward the canister when the fuel is full.



Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. What is the purpose of the evaporative emission system?

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2. What are the components of the evaporative emission system?

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Worksheet

1. Read the questions and tick the correct answer.

a. The formation of ______________________ occurs due to the leakage of fuel vapours.

i. Clouds ☐

ii. Smog ☐

iii. Fog ☐

iv. None of the above ☐

Notes

Answers: Introduction to Evaporative Emission System

Question Number	Answer
1	a. ii

Types of EVAP System

At the end of this session you will be able to:

- state the various types of EVAP systems.

Session Plan	
1	Introduction
2	Types of EVAP System
3	Purpose of EVAP System
4	Key Learnings
5	Worksheet

Introduction

Diesel fuel isn't as volatile as compared to petrol. Due to this there is no need for evaporative emission control devices or a charcoal canister in diesel cars.

An EVAP system is of two types; both these types of EVAP system are designed to reduce emissions.

Types of EVAP System

There are mainly two types of EVAP Systems used in petrol cars:

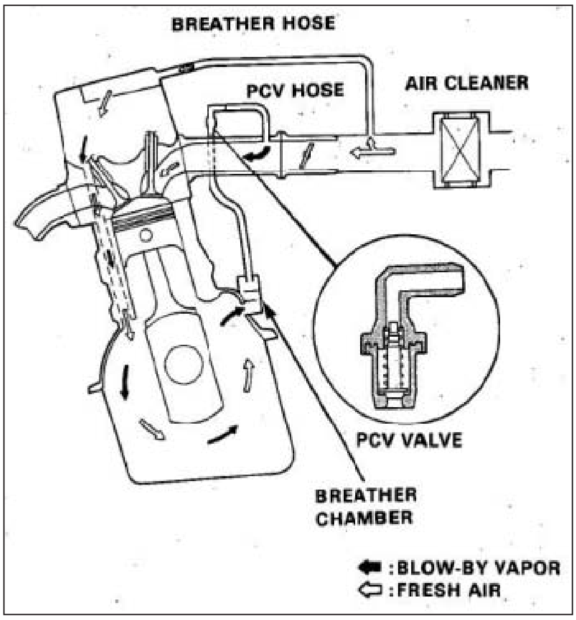
- PCV System
- Canister and Purge System

PCV System (Positive Crankcase Ventilation)

- During normal compression stroke, a small amount of gases in the combustion chamber escapes past the piston. Around 70% of these "Blowby" gases are unburned fuel.
- These blowy gases can dilute and contaminate the engine oil.
- These gases if not removed from the crank case, will create back pressure on the piston.
- Earlier days this gas was directly released in to atmosphere through a pipe, but in modern automobiles this gas is routed through proper systems back in to the intake system, so that the unburned gases are utilised again for the combustion process.

Components of PCV System:

- Crank Case oil separator
- Breather Chamber
- Breather Hose
- PCV Hose
- PCV Valve



Purpose of an EVAP System

PCV Operation:

- The primary control PCV is oil separator.
- An oil separator separates the oil from the blow-by gases and meters the flow of blow-by gas according to the manifold vacuum signal.
- The manifold vacuum draws the blow-by gases from the oil separator into the valve cover then into the intake where it is consumed by the normal combustion process.
- The volume of blow-by gas entering the intake manifold is precisely controlled in order to maintain idle quality.

Canister and Purge System:

- In this system the fuel vapours released from the fuel tank are stored in a container called "canister" through hoses and routings and are allowed to enter in the intake manifold at predetermined time with the help of purge solenoid which is operated by the Engine Control Module.
- The charcoal present in the canister absorbs the fuel vapours and stores and release once air or vacuum is applied on it.
- The purge solenoid is electrically operated switch and is placed in line between the canister and the intake manifold.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. What are the types of EVAP systems?

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2. What are the components of the evaporative emission system?

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Worksheet

1. *Read the questions and tick the correct answer.*

   a. Diesel cars have an EVAP system.

      i. True ☐

      ii. False ☐

   b. During compression stroke a small amount of unburned gases which escape past the piston are called blowby gases.

      i. True ☐

      ii. False ☐

Notes

Answers: Types of EVAP System

Question Number	Answer
1	a. ii b. i

Working of EVAP System

At the end of this session you will be able to:

- describe the working of EVAP system.

Session Plan	
1	Introduction
2	Working of EVAP System
3	Key Learnings
4	Worksheet

Introduction

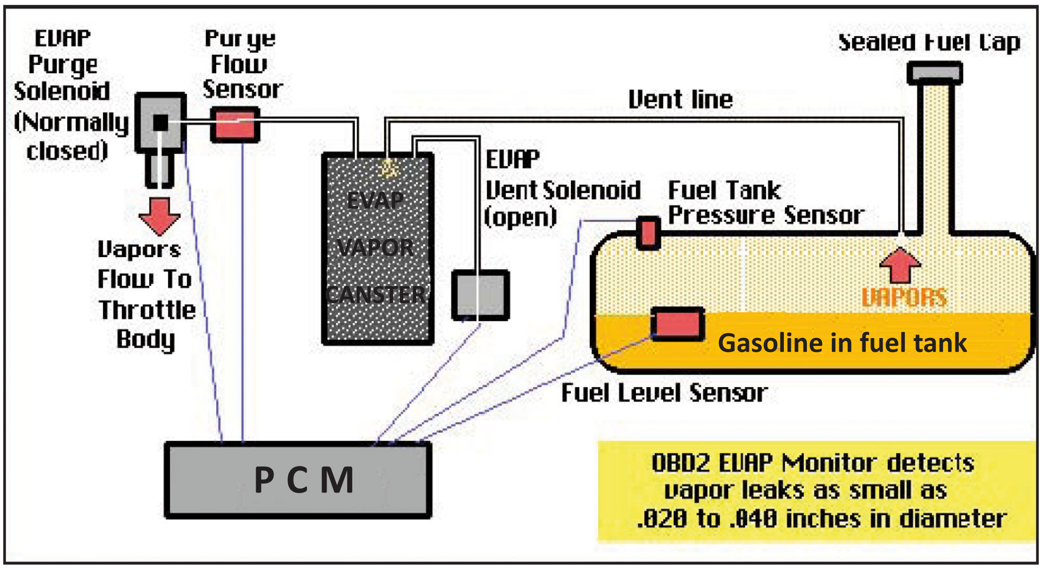
The working of the EVAP system is given here for a better understanding.

Working of EVAP System

The EVAP System is designed to reduce emissions. The EVAP system needs to work efficiently in order to prevent vapours leaking into the atmosphere and maintain stable engine performance.

Operation of EVAP

- The EVAP transfers the fuel vapours that are formed in the sealed fuel tank through a vent line to an activated carbon storage device, which is the EVAP canister.



- The EVAP canister stores the vapours until the engine is able to use the extra fuel vapour.
- When the engine is able to use the extra fuel vapour, the Purge solenoid opens and the intake air flow purges the fuel vapour from the carbon element and the vapours flow in to the throttle body and is then burnt in the normal combustion process.
- The system is required in order to detect the evaporative fuel system leaks as small as 0.040 inch between the fuel filler cap and the EVAP canister purge valve.
- The system can test the evaporative system integrity by applying a vacuum signal, ported or manifold, to the fuel tank in order to create a small vacuum.
- The powertrain control module (PCM) then monitors the ability of the system to maintain the vacuum. If the vacuum remains for a specified period of time, then there are no evaporative leaks, and a PASS is reported by the PCM.
- If a leak is detected, then the system either will not achieve a vacuum, or a vacuum cannot be maintained. Usually a fault can only be detected after a cold start with a trip of sufficient length and driving conditions to run the needed tests.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. Explain the operation of the EVAP system

Worksheet

1. *Read the questions and tick the correct answer.*

   a. The fuel vapours are stored in the ______________________ .

      i. Purge solenoid ☐

      ii. Charcoal canister ☐

      iii. Both of the above ☐

      iv. None of the above ☐

Notes

Answers: Evaporative Emission System Working

Question Number	Answer
1	a. ii

Introduction to Fuel System - Petrol

At the end of this session you will be able to:

- state the importance and purpose of a fuel system;
- state the types of fuels and its characteristics;
- describe the fuel system and its components.

Session Plan	
1	Introduction
2	Purposes of a Fuel System
3	Types of Fuels
4	Fuel Quality Check
5	Fuel System Components
6	Key Learnings
7	Worksheet

Introduction

Fuel is a vital ingredient that makes an engine run. Automobile fuels are of various types these days, and to deliver the fuel to the engine a fuel system is needed.

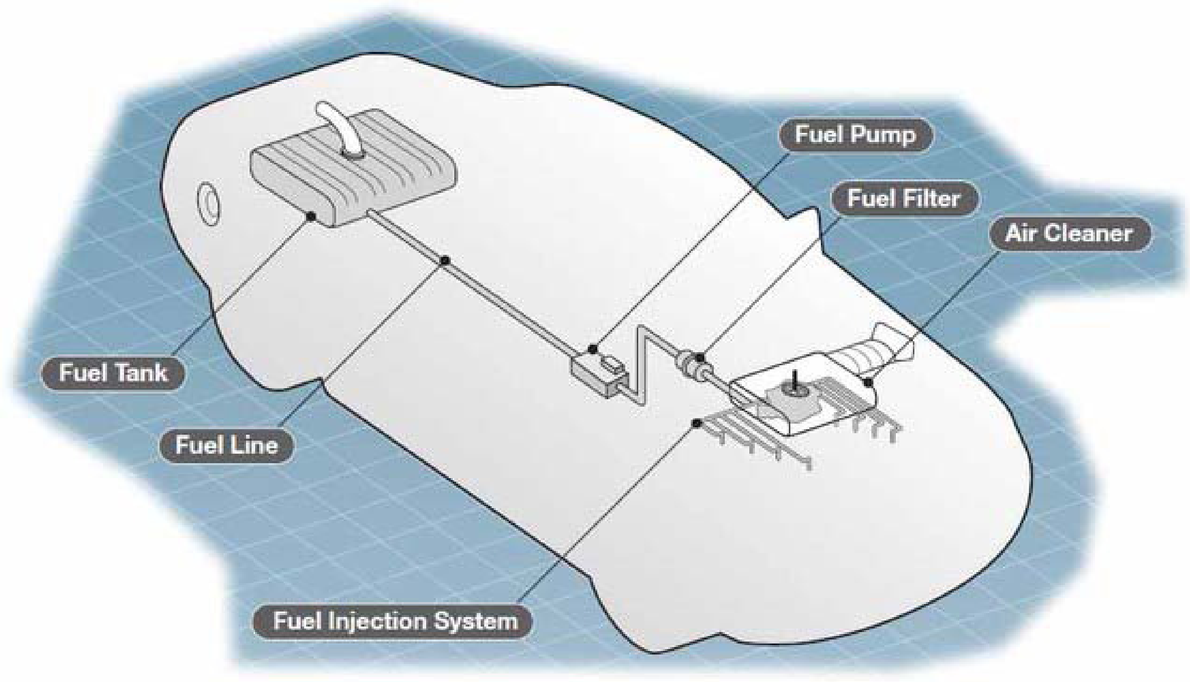
Functions of the fuel system are:

- Fuel is a necessary component to keep the engine running.
- It is stored in a tank and is always placed away from the engine cylinder.
- Hence, it needs to be transported from one place to another in specific quantity and at specific time in order to ensure perfect functioning of the engine.

Purpose of a Fuel System

The purpose of a fuel system is as below:

- Transfer the fuel from the fuel tank to the engine cylinder at specific time and in specific quantity Atomize the fuel to maintain the perfect air-fuel ratio.
- Provide pressure relief to prevent excess pressure inside the fuel tank.



Types of Fuels

Different automobiles run on various fuels based on place of application.

Automobiles may run on single fuel as well as dual fuel for eg: Petrol and CNG/LPG

The various type of fuels used on automobiles are

- Petrol (Gasoline)
- Diesel
- Liquefied Petroleum Gas (LPG)
- Compressed Natural Gas (CNG)
- Ethanol
- Bio-Diesel.

Petrol

- Gasoline or petrol is the most common fuel used in cars today
- This specialized fossil fuel is designed for four-stroke engines like the ones found in common cars
- Gasoline allows for quick starting, fast acceleration, easy combustion and quiet operation

- The hydrocarbons contained in gasoline and its production of carbon dioxide when burned contributes to pollution, smog and global warming
- Although it is the most readily available fuel, it is considered to be a temporary source of fuel because of its cost, environmental effects and limited resources

Diesel

- Diesel fuel is widely used in transport vehicles such as tractor-trailer trucks, buses, boats and trains.
- This fossil fuel is also non-renewable, like gasoline.
- Although it contributes less carbon dioxide to the environment, diesel creates more organic compounds and nitrous oxide that cause smog.
- Diesel vehicles have 30% better fuel efficiency than the average gasoline vehicles.

LPG

- Liquefied petroleum, better known as LPG, is a clean fuel alternative to gasoline that is used in common vehicles on a limited basis.
- Liquefied petroleum produces fewer toxins when burned and does not contribute to smog in the same way that diesel and gasoline doe.
- It is less expensive and more fuel efficient than gasoline.

CNG

- Petrol engines can be converted to run on compressed natural gas, or CNG.
- CNG is a clear, odorless and non-corrosive gas that can be used in liquid or gas form to run a combustion engine.
- Vehicles fitted with a CNG fuel system can be expected to produce 80 percent less ozone-forming emissions than gasoline burning cars.

Ethanol

- Ethanol is a bio-fuel alternative to gasoline that's made from the conversion of sugar cane, corn, barley and other natural products.
- Ethanol has become popular as a fuel source because in most cases it's one of the only fuels that can fuel a gasoline engine without modifications.
- Many car models can run on 100% ethanol, but it is more commonly used as an additive.

Bio-diesel

- Bio-diesel is a diesel substitute made from sugar beet, rapeseed or palm oil.
- Individuals sometimes make this substance by collecting used oil from restaurant fryers.
- Bio-diesel burns much cleaner than standard gas or diesel and produces far less carbon dioxide emissions when used.
- However, continued production of this substance may result in excessive deforestation.

Fuel Quality Check

- Due to the rise in fuel prices in the Indian market, retailers tend to adulterate the fuel to earn maximum profits. The adulterations could include fuels like kerosene.
- However, in some cars due to the damage in the fuel tank cap, water may enter into the fuel storage tank during monsoons or washing, which could cause adulteration. Water in the fuel could cause knocking.
- Hence to ensure optimum operation of the fuel system, it is necessary to use pure and unadulterated fuel.
- Checking of fuel for adulteration is done by using the following methods:
    - Filter paper test
    - Density Check.

How to check the quality of Petrol

Filter paper test

- Clean the mouth of the dispensing nozzle to ensure that there are no stains.
- Fill it in a clean glass, put a drop of petrol on the filter paper from the glass.
- The drop of fuel should evaporate in about 2 minutes without leaving a stain on the filter paper.
- If a stain is left on the filter paper, there is a possibility of adulteration.

Density Check

- Fill about 3/4th of the jar with the product taken through the nozzle of the Dispensing Unit.
- Dip the thermometer and the hydrometer in the jar and record the temperature and density as indicated.
- The actual density observed is then converted into density at 15 degree centigrade with the help of the conversion chart.
- This converted density is then compared with the density shown by the records maintained at the Retail Outlet on the basis of density recorded on delivery challans. If the difference is more than + 0.003, it indicates the possibility of adulteration.

Octane Rating

- Octane rating or octane number is a standard measure of the performance of a motor fuel.
- The higher the octane number, the more compression the fuel can withstand before detonating.
- In broad terms, fuels with a higher octane rating are used in high-compression engines that generally have higher performance.
- In contrast, fuels with lower octane numbers (but higher cetane numbers) are ideal for diesel engines.
- Use of gasoline with lower octane numbers may lead to the problem of engine knocking

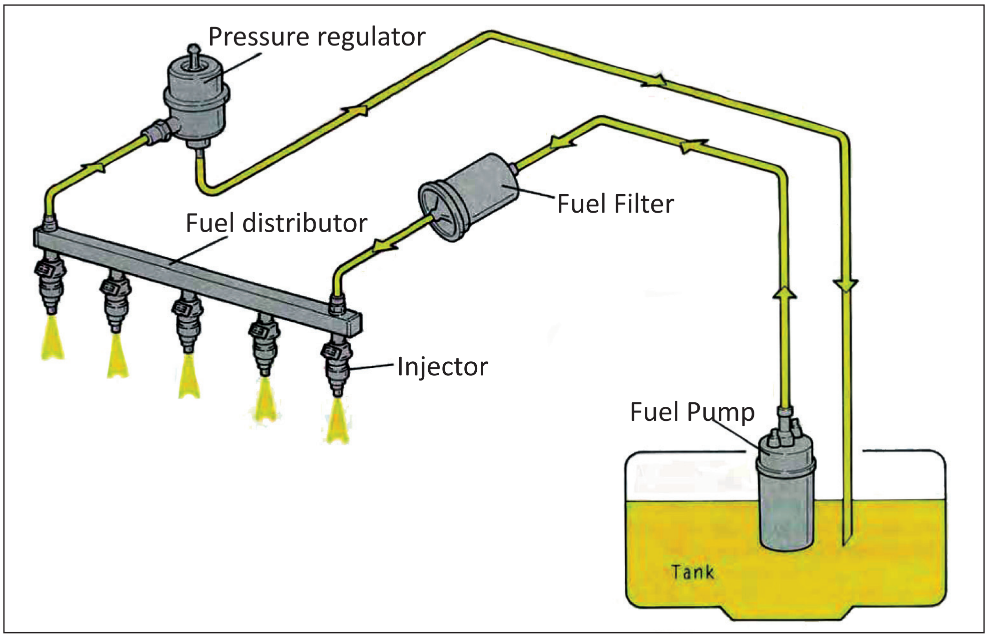
Octane Ratings

- Regular fuel – 87 octane
- Mid-grade- 89 octane
- Premium fuel – 93 octane

Fuel System Components

Fuel system in an automobile consists of various components:

- Fuel tank
- Fuel pump
- Fuel filter
- Injector
- Fuel distributer
- Pressure regulator



Fuel Tank

- All modern fuel systems are fed through a pump, so the fuel tank is usually at the rear of the chassis under the trunk compartment.
- The fuel tank stores the excess fuel until it is needed for operation of the vehicle.
- The fuel tank has an inlet pipe and an outlet pipe.

- The outlet pipe has a fitting for fuel line connection and may be located in the top or in the side of the tank.
- The lower end is about one-half inch above the bottom of the tank so that collected sediment will not be flushed out into the carburettor.
- The bottom of the tank contains a drain plug so that tank may be drained and cleaned.

Fuel Pump

- The fuel pump pumps the fuel from the fuel tank to the engine cylinder when the engine is cranked.
- The pressure at which the fuel is pumped remain the same irrespective of the engine speed.
- The fuel pump has three functions:
  - Deliver enough fuel to supply the requirements of an engine under all operating conditions.
  - Maintain enough pressure in the line between the injector and the pump to keep the fuel from boiling
  - Prevent vapor lock.
- The various types of fuel pumps available are:
  - Mechanical Fuel Pump;
  - Electric Fuel Pump;
  - Vacuum Pump.

Fuel Filter

- A fuel filter is a pad that is connected to the intake of the fuel pump.
- It traps the dust particles are any other impurities in the fuel and prevents them from entering the fuel system hence preventing damage to the fuel system.
- It is mandatory to clean the fuel filter periodically to prevent starving of fuel system from fuel.

Injector

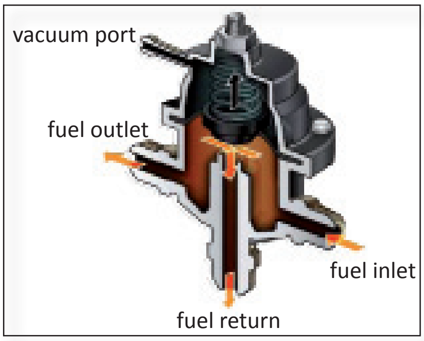
- The fuel injector is an electromechanical device that sprays and atomizes the fuel.
- The fuel injector is nothing more than a solenoid through which gasoline is metered.
- When electric current is applied to the injector coil, a magnetic field is created, which opens and closes the passage which helps in spraying pressurized fuel in the combustion chamber.

Fuel Distributor

- A fuel distributer commonly known as common rail, is a hard metal pipe that receives fuel from the fuel pump at high pressure.
- The injectors are mounted on the fuel distributer which spray the fuel in the engine cylinder.

Pressure Regulator

- A pressure regulator regulates the pressure in the fuel distributor.
- It returns the excess fuel into the fuel tank through the return pipe to prevent loss of fuel.



Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. What is the purpose of a fuel system?

____

____

____

____

____

2. What is octane rating?

____

____

____

____

____

Worksheet

1. *Read the questions and tick the correct answer.*

   a. Ethanol is a type of fuel.

      i. True ☐

      ii. False ☐

Notes

Answers: Introduction to Fuel System - Petrol

Question Number	Answer
1	a. i

Types of Fuel System - Petrol

At the end of this session you will be able to:

- state the types of a fuel system;
- describe the working of fuel systems.

Session Plan	
1	Introduction
2	Types of Fuel System
3	Carburettor System
4	Fuel Injection System
5	Key Learnings
6	Worksheet

Introduction

The fuel system ensures the accurate quantity of fuel delivery and optimum combustion in a vehicle. There are various types of fuel systems.

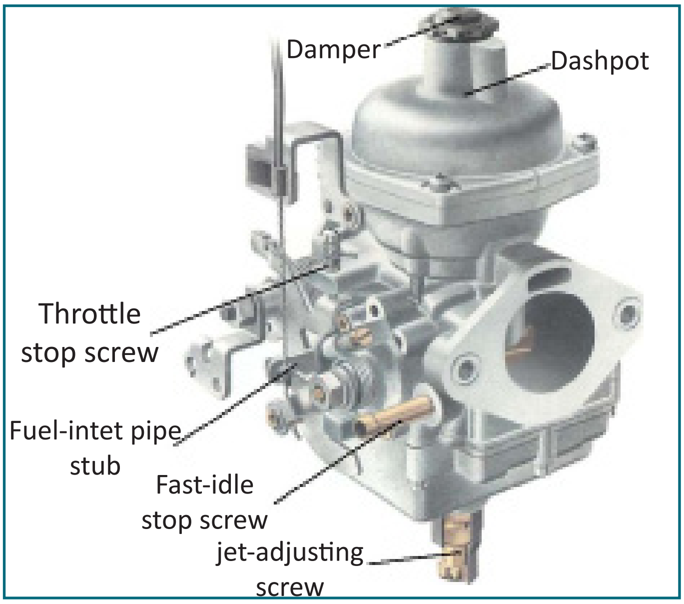
The following systems are used to feed fuel to the engine cylinder from the fuel tank:

- Carburettor system
  - Gravity system
  - Pressure system
  - Vacuum system
  - Pump system
- Fuel injection system
  - Single point fuel injection
  - Multipoint Fuel Injection
  - Gasoline direct injection

Types of Fuel System

Carburettor System

- A carburettor is a device that blends air and fuel for an internal combustion engine. It works on Bernoulli's principle: the faster air moves, the lower its static pressure, and the higher its dynamic pressure. The throttle (accelerator) linkage does not directly control the flow of liquid fuel. Instead, it actuates carburettor mechanisms which meter the flow of air being pulled into the engine. The speed of this flow and its pressure, determines the amount of fuel drawn into the airstream.



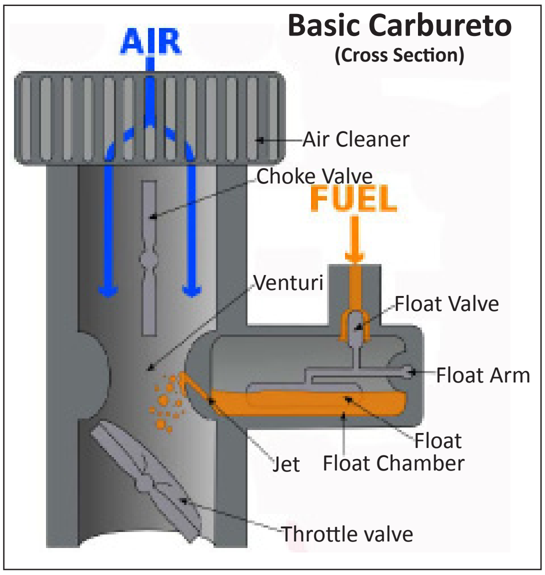
Advantages of a carburettor system are as below:

- less complex and easy to install;
- less expensive.

Limitations of this system are:

- the metering of fuel to all the cylinders at various speeds is not accurate;
- fuel tends to evaporate from the carburettor resulting in fuel losses.

Carburettor System: Working



- A carburettor consists of an open pipe through which the air passes into the inlet manifold of the engine.
- The pipe is in the form of a venturi: it narrows in section and then widens again, causing the airflow to increase in speed in the narrowest part.
- Below the venturi is a butterfly valve called the throttle valve — a rotating disc that can be turned end-on to the airflow, to hardly restrict the flow at all, or can be rotated so that it completely blocks the flow of air.
- This valve controls the flow of air through the carburettor throat and thus the quantity of air/fuel mixture the system will deliver, thereby regulating engine power and speed.
- The throttle is connected, usually through a cable or a mechanical linkage to the accelerator.
- Fuel is introduced into the air stream through small holes at the narrowest part of the venturi and at other places where pressure will be lowered when not running on full throttle.

- Fuel flow is adjusted by means of precisely calibrated orifices, referred to as jets, in the fuel path.
- When the driver presses the accelerator pedal, which controls the throttle plate an open it wider.
- As the throttle plate opens, engine suction is applied at the intake, the air is sucked into the carburettor through air filter
- As the high velocity air passes the venturi, the pressure of air drops causing the suction of fuel from float chamber.
- The in-coming air now mixes with the fuel, which in turn is supplied to engine cylinder.

Gravity System

- In this system the fuel tank is situated at the highest position from where the fuel drops into the carburettor float chamber by gravity
- The system is very simple and cheap but the rigidity of placing the fuel tank necessarily over the carburettor is a disadvantage
- This system is generally used in two wheelers

Pressure System

- In this system a uses a sealed fuel tank is used
- The pressure is created in the tank by means of engine exhaust or a separate air pump
- For starting, the pump is primed by hand
- It is under pressure thus produced that the fuel flows to the float chamber of the carburettor
- The advantage in this system is the fact that the fuel tank can be placed an any suitable location
- The disadvantage is that it can also have a pressure leak

Vacuum System

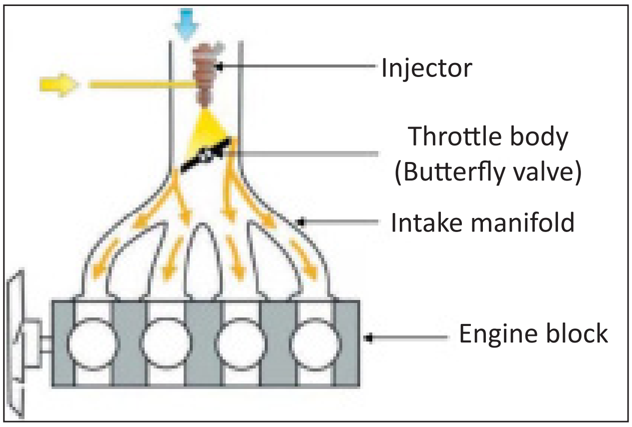
- This system is based upon the simple fact that the engine suction is used for sucking fuel from the main tank to the auxiliary tank from where it flows to the carburettor float chamber through gravity Pump system
- In this system, a steel pipe carries fuel from the fuel pump to the carburettor float chamber
- If the fuel pump used in this system is a mechanical pump, it needs to be driven by the engine camshaft, hence the fuel tank need to be situated close to the engine compartment
- However, electrically operated fuel pumps are also employed which have an advantage of placing the fuel tank away from the engine
- This system is most commonly used in cars

Fuel Injection System

In this system, fuel is injected by means of an injector nozzle unlike in the case of a carburettor system where fuel is sucked into the air stream. The mixture of air and fuel under various load and speed conditions is controlled either mechanically or now a days electronically with the help of an ECM. This system is most commonly used in modern petrol engines.

The various types of Fuel Injection Systems used in petrol cars are:

- Single point Injection;
- MPFI (Multi-Point Fuel Injection);
- Direct Injection.

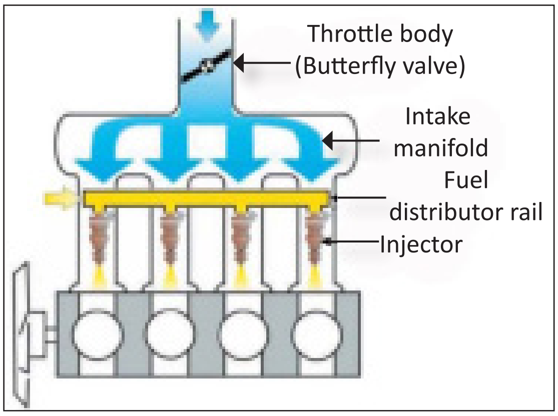


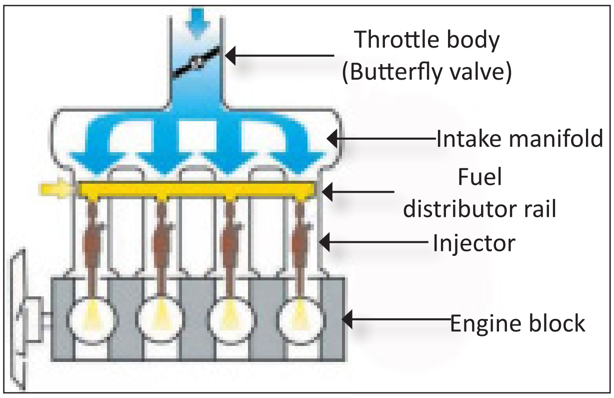
Single Point or Throttle Body Injection (TBI)

This system is a simplest fuel injection system. The carburettor in this system is replaced by a fuel injector in the intake manifold. Since the fuel passes through the intake runners, it is called a "wet manifold system". It was introduced in the 1940s in large aircraft engines (then called the pressure carburettor) and in the 1980s in the automotive world (called Throttle-body Injection). This system is less expensive as compared to other fuel injection systems.

Multi-Point Fuel Injection (MPFI)

In a MPFI system, each engine cylinder gets a dedicated injector that is mounted on the intake manifold, just before the intake valve; unlike a single injector in the case of TBI system. The fuel in this system is distributed to individual injectors with the help of a fuel distributer rail. Hence, if the engine consists of 4 cylinders, it will have 4 injectors. The positioning of the injector closer to the intake valve helps in reducing fuel losses and increasing fuel efficiency. This system is more expensive compared to single point fuel injection system.





Gasoline Direct Injection (GDI)

GDI system is very similar to a MPFI system, the only difference being the fuel is injected directly into the combustion chamber. Direct fuel injection costs more than indirect injection systems: the injectors are exposed to more heat and pressure, so more costly materials and higher-precision electronic management systems are required. However, the entire intake is dry, making this a very clean fuel injection system.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. Note the various types of fuel systems?

2. Explain direct injection.

3. Explain a carburettor.

Worksheet

1. *Read the questions and tick the correct answer.*

   a. In in-direct fuel injection system the fuel in injected in the inlet manifold.

      i. True ☐

      ii. False ☐

Notes

Answers: Types of Fuel System - Petrol

Question Number	Answer
1	a. i

Introduction to Fuel System - Diesel

At the end of this session you will be able to:

- state the importance and purpose of a diesel fuel system;
- describe the diesel fuel system and its components.

Session Plan	
1	Introduction
2	Purpose of Fuel System - Diesel
3	Fuel System Components
4	Key Learnings
5	Worksheet

Introduction

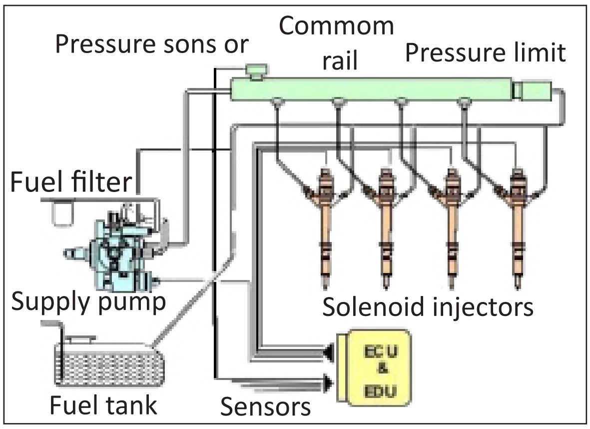
Diesel as compared to petrol is a heavier fuel. A diesel engine is much more efficient and delivers more torque. To delivery of diesel fuel has various types of systems.

Purpose of Fuel System - Diesel

The performance of diesel engines is heavily influenced by their injection system design. In fact, the most notable advances achieved in diesel engines resulted directly from superior fuel injection system designs.

The main purpose of the diesel fuel injection system is:

- To deliver fuel into the engine cylinders at extremely high pressures in order for the engine to effectively make use of the fuel
- Ensure that fuel atomizes into very small fuel particles

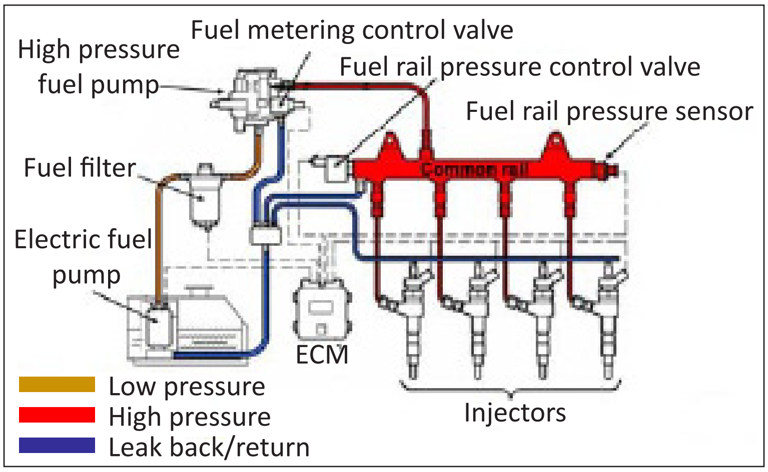


Diesel fuel injection system components come in contact to very high temperatures and materials should be selected to withstand higher stresses in order to perform for extended durations that match the engine's durability targets. Greater manufacturing precision and tight tolerances are also required for the system to function efficiently. In addition to expensive materials and manufacturing costs, diesel injection systems are characterized by more intricate control requirements. All these features add up to a system whose cost may represent as much as 30% of the total cost of the engine.

Components of Diesel Fuel Injection System

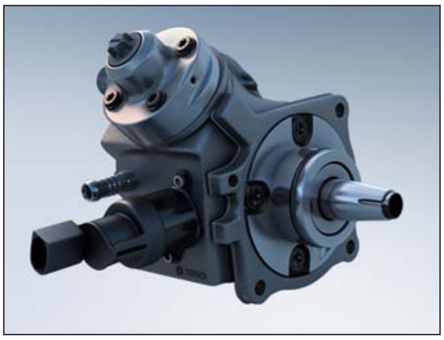
The layout of a diesel fuel system is similar to a petrol fuel injection system. It consists of the following components:

- Fuel tank
- Electric fuel pump
- Fuel filter
- High pressure fuel pump
- Fuel metering control valve
- Fuel rail pressure control valve
- Common rail
- Fuel rail pressure sensor
- Injectors
- Glow plugs



However, the following components are exclusively found only in diesel injection systems

- High pressure pump
- Fuel metering control valve
- Common rail
- Glow plugs
- Diesel injectors

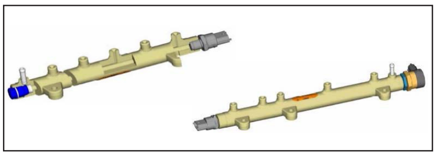


High Pressure Pump

High pressure pump is an interface between the low pressure and the high pressure side of the fuel system. The task of the high-pressure pump is to compress the fuel in the amounts required for the entire engine operating range. It constantly feeds fuel into the rail, thus maintaining the system pressure. The fact that pressure generation is not linked to engine speed means that the pressure required is already available at low engine speeds.

Fuel Metering Control Valve

The fuel metering valve is located at the back of the high pressure pump. It controls the fuel intake to the pump. IT runs on battery voltage through a signal send by the ECM. When the solenoid in the metering valve is de energised, the valve is open; low fuel volume intake to the pump. When the solenoid in the metering valve is energised, the valve is closed; high fuel volume intake to the pump.



Common rail

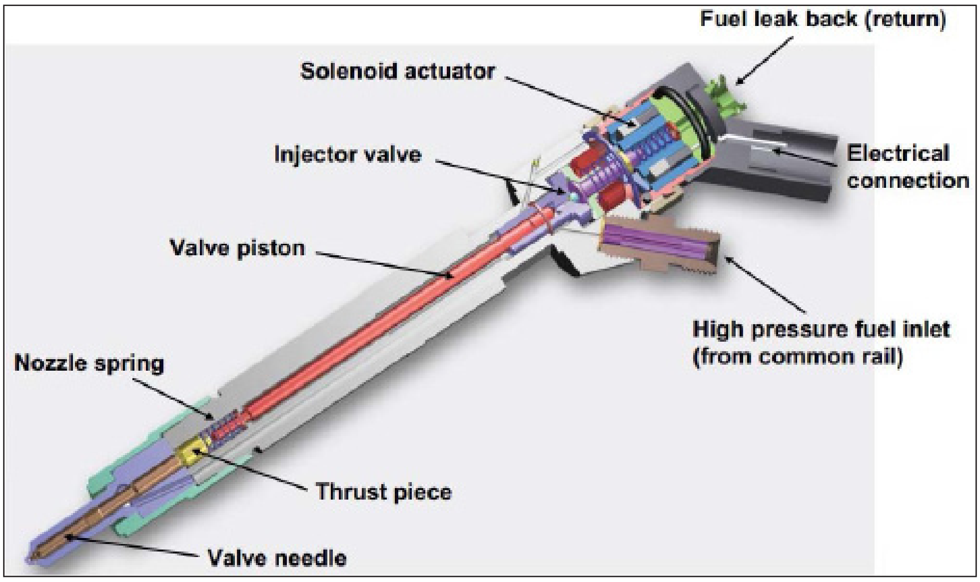
Common rail or high pressure accumulator receives fuel at high pressure from the high pressure pump. The rail stores and distributes the fuel at individual injectors. It also helps in dampening the pressure vibrations caused by the high pressure pump and the injection process. The fuel rail pressure during engine idling and running temperature condition ranges approximately from 300-400 Bar and ranges to a maximum value of 1600-2000 Bar.

Glow Plug

A glow plug is a long pencil shaped device installed on the engine block. It consists of a heating element at the end that protrudes into the engine cylinder and is electrically powered. This heating element, when electrified, heats due to its electrical resistance and begins to emit light in the visible spectrum, hence it is known as a "glow plug". Heat generated by the glow plugs is directed into the cylinders, and serves to warm the engine block immediately surrounding the cylinders. This aids in reducing the amount of thermal diffusion which will occur when the engine attempts to start.

Diesel Injectors

The injector of the Common Rail System contains the injection nozzle, a solenoid valve plus the hydraulic and electrical connections to trigger the nozzle module. An injector connected to the rail via a short high-pressure line is installed in each engine cylinder. The electro-hydraulic servo system in the injector receives control impulses from the ECM to open and close the nozzle module and is triggered by a solenoid valve. The short switching times of the solenoid permit pilot, main and secondary injections which results in efficient and clean combustion at all operating points.



Injector of the Common Rail

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. Describe a glow plug used in a diesel engine.

2. List the components that are exclusively found only in diesel injection systems?

Worksheet

1. *Read the questions and tick the correct answer.*

   a. Which of the following is the main purpose of a diesel fuel injection system?

      i. Deliver fuel into the engine cylinders at extremely high pressures in order for the engine to effectively make use of the fuel. ☐

      ii. Ensure that fuel atomizes into very small fuel particles. ☐

      iii. Evaporate the excess fuel in the injector. ☐

      iv. All of the above. ☐

Notes

Answers: Introduction to Fuel System - Diesel

Question Number	Answer
1	a. iv

Types of Fuel System - Diesel

	At the end of this session you will be able to: ◆ state the types of a fuel system; ◆ describe the working of fuel systems.

Session Plan	
1	Introduction
2	Types of Fuel System Diesel
3	Working of Fuel Systems
4	Key Learnings
5	Worksheet

Introduction

Similar to the petrol system for accurate fuel quantity delivery and optimum combustion there are a various types of disel fuel systems.

Types of Diesel Fuel Systems

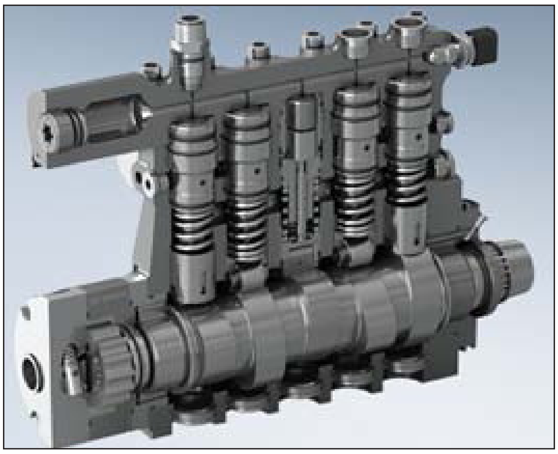
The Diesel fuel systems are mainly of:

- In-line Injection pump;
- Distributor fuel-injection pumps;
- Common Rail System.

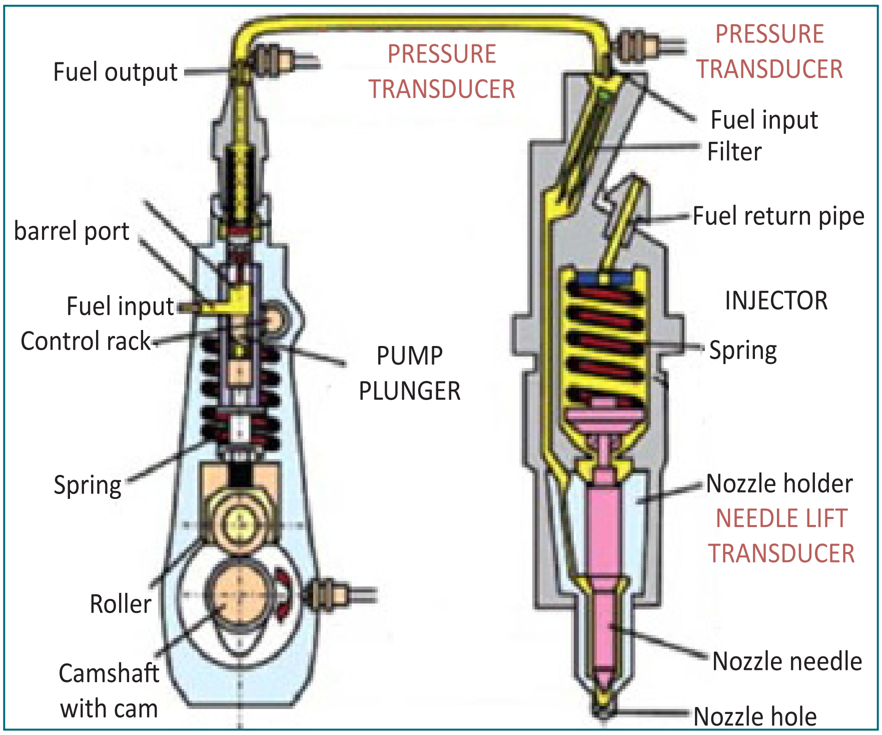
Types of Fuel System - Diesel

In-line Injection Pump

- The standard in-line injection pumps incorporate their own camshaft, and a plunger-and-barrel assembly (pumping element) for each engine cylinder.
- The number of plunger barrel assembly depends on the number of cylinders in the engine
- The injection pump's camshaft is driven by the diesel engine.
- The injected fuel quantity depends upon the swept volume of the injection-pump barrel, and maximum (pump-side) injection pressures are between 400 and 1,150 bar.



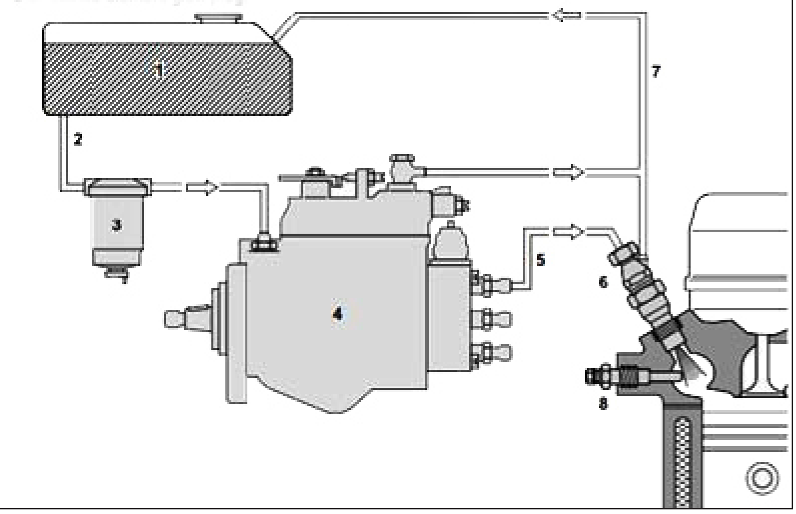
- When the camshaft rotates, it pushes the roller which in turn moves the pump plunger in an upward direction.
- The fuel which enters the barrel through the fuel input is now compressed to high pressure due to upward movement of the plunger.
- This high pressure fuel is sent to the injector which is mounted on each cylinder through a high pressure tube.
- As the high pressure fuel is forced in to the injector the spring loaded nozzle needle is lifted from its seat and thus the fuel is injected in to the cylinder.



Distributor fuel-injection Pumps

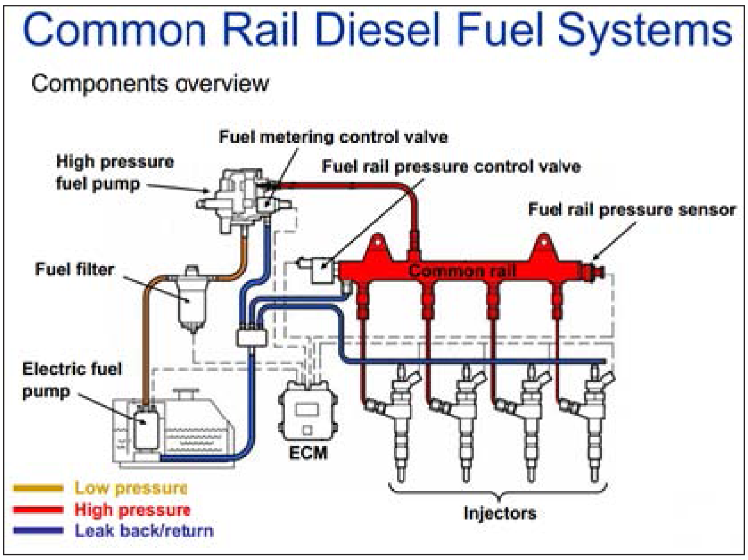
- Unlike the fuel injection pump, there is a single pumping element in this type of pump & the fuel is distributed to each cylinder by means of a rotor.
- This pump is being rotated by the engine camshaft
- The rotor has a center longitudinal passage and a set of radial holes, each equal to the number of engine cylinders.
- The delivery port is connected to a high pressure delivery lines leading to injectors on the injector cylinder.

Fuel supply and delivery in a distributor-pump fuel-injection system 1 Fuel tank, 2 Fuel line (suction pressure), 3 Fuel filter, 4 Distributor injection pump, 5 High-pressure fuel-injection line, 6 injection nozzle, 7 Fuel-return line (pressureless), 8 Sheathed element glow plug.



Common Rail System

- The Common Rail Diesel Injection System delivers a more controlled quantity of atomized fuel, which leads to better fuel economy.
- In the Common Rail system, a common reservoir of fuel under a consistent controlled pressure that is separate from the fuel injection points.
- A high-pressure pump increases the fuel pressure in the accumulator (common rail) up to 1,600 bar or 23,200 PSI.
- The injectors in the Common rail engine are being electronically controlled by the ECU.
- The ECU unit controls all the engine injection parameters including the pressure in the fuel rail and the timing and duration of injection.
- Because of a common rail system a much more accurate and high pressure fuel is being delivered which leads to better efficiency.



Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. What are the types of diesel fuel systems?

2. Explain distributor fuel-injection pumps.

3. Explain the common rail system.

Worksheet

1. *Read the questions and tick the correct answer.*

   a. The injectors in a common rail system are controlled electronically.

      i. True ☐

      ii. False ☐

Notes

Answers: Types of Fuel System - Diesel

Question Number	Answer
1	a. i

Introduction to Lubrication System

At the end of this session you will be able to:

- state the functions of a lubrication system.

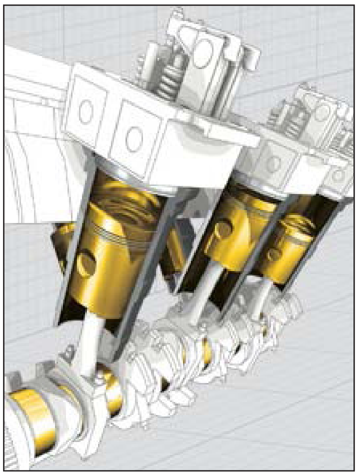
Session Plan	
1	Introduction
2	Purpose of Lubrication System
3	Function of Lubrication System
4	Key Learnings
5	Worksheet

Introduction

An automobile engine operates at very high speed and hence generated high heat. Also metal to metal contact generates friction. In order to reduce friction and reduce temperature, a lubrication system is used in automobiles.

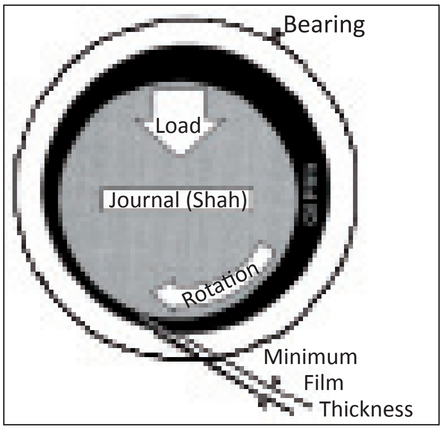
Purpose of a Lubrication System

Internal combustion engines (IC engine) operate at very high speed and temperature to produce the required power output. It also uses a number of metal components that operate in sync with each other. These components are exposed to friction due to direct metal to metal contact and hence need to be lubricated. Also as metal expands on heating, it is necessary to ensure that the components operate at an optimum temperature. A lubrication system is used in order to maintain the optimum temperature and provide lubrication. If not done so, it could lead to seizing of the engine.



Functions of a Lubrication System

The main functions of a lubrication system are as below:



Provide lubrication to moving components

- Seal gases from escaping from the engine cylinder
- Clean the moving components
- Cool and keep the moving components at the optimum temperature
- Absorb shocks

Provide lubrication to moving components

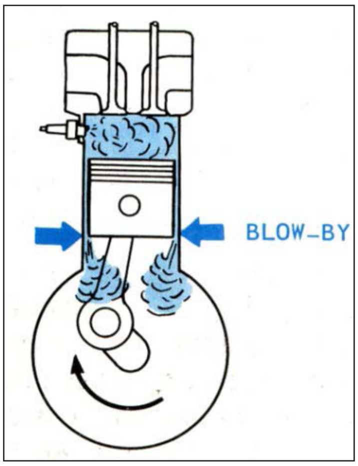
The lubrication oil reduces friction between moving components by creating a thin film (Clearance) between the moving components (Bearings and journals).

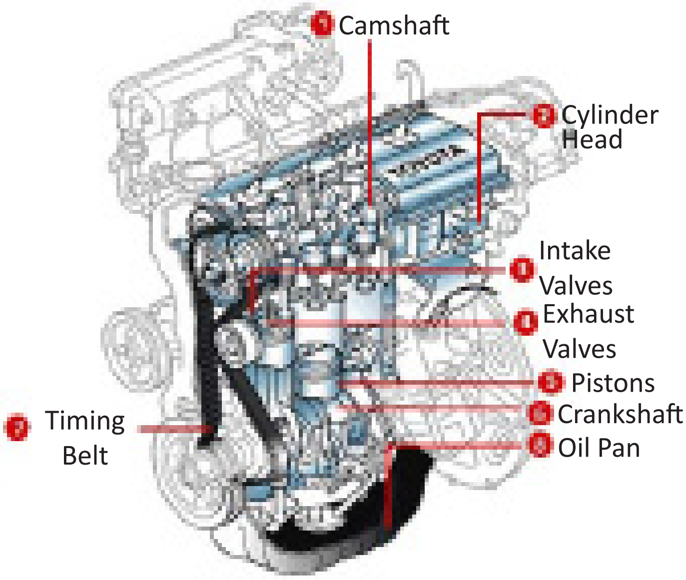
Seal gases from escaping from the engine cylinder

The lubricating oil forms a gastight seal between piston rings and cylinder walls thereby preventing the compressed gasses from escaping from the engine cylinder, ensuring maximum power output (Reduces Blow-By).

However, if the cylinder walls or piston rings are worn out, the lubricating oil will seep into the combustion chamber and burn along with the compressed gasses causing blue smoke.

It is necessary to check the lubrication system in case of the above fault, as excessive burning of lubrication oil can lead to lowering of oil level and seizing of the engine.





Clean the moving components

The lubrication oil circulates through the engine and picks up metal particles or carbon and brings them back down to the pan.

Small metal particles are caused due to the excessive friction between metal components and the carbon deposits due to the burning of oil.

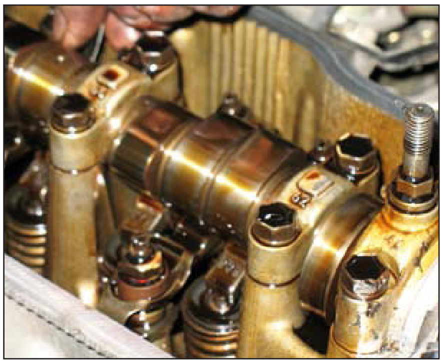
If the metal or carbon particles are not washed away, it could lead to blocking of the oil galleries that could cause engine seizing.

Cool and keep the moving components at the optimum temperature

Since the internal combustion engine operates at high speed, there is a lot of heat generated.

The heat generated needs to be controlled to the optimum temperature to prevent engine seizing.

The lubrication oil flows over the engine components and acts as a cooling agent thereby dissipating the heat and keeping the heat at the optimum temperature.

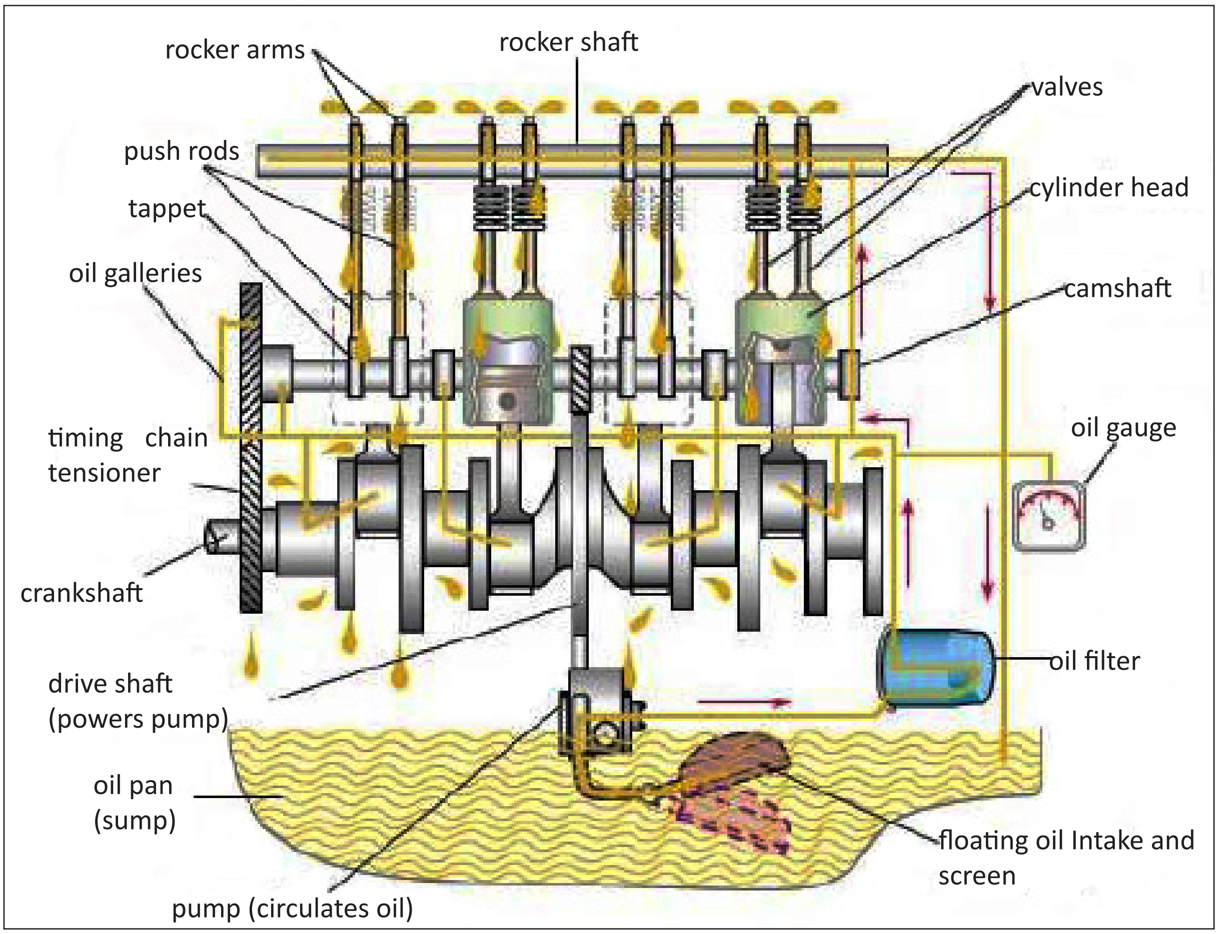


Absorb shocks

During the power stroke, high pressure is exerted on the piston which is transmitted to the engine crankshaft.

The pressure exerted on the crankshaft is absorbed by the thin layer of oil to reduce vibrations.

Lubrication system layout



Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. List down the various functions of a lubrication system.

2. Explain how sealing of gasses escaping the engine cylinder is done using lubrication system.

Worksheet

1. *Read the questions and tick the correct answer.*

   a. The lubricating oil forms a ______________________ seal between piston rings and cylinder walls.

      i. Gastight

      ii. Liquid

      iii. Rubber

      iv. None of the above

Notes

Answers: Introduction to Lubrication System

Question Number	Answer
1	a. i

Introduction to Lubricants

	At the end of this session you will be able to: ◆ state the characteristics of lubricants.

Session Plan	
1	Introduction
2	Characteristics of Lubricants
4	Key Learnings
5	Worksheet

Introduction

A lubricant is a substance introduced between moving surfaces to reduce friction. It may also transports foreign particles line small metal particles and carbon from the moving part to the oil sump. The lubrication oil has a very important property of reducing friction and is known as lubricity (Slipperiness).

Characteristics of Lubricants

A good lubricant possesses the following characteristics:

- High boiling point
- Low freezing point
- High viscosity index
- Thermal stability
- Hydraulic stability
- Corrosion prevention
- High resistance to oxidation

Engine oil

Engine oil (motor oil) is made in one of the three processes

Petroleum (natural)

- Created by refining crude oil from oil deposits in the earth
- Traditional oils

Synthetic (man-made)

- Made of small, molecular building blocks. Created from one particle and built upon lower molecular mass, higher performing, and more thermally stable.

Partial synthetic (natural/man-made)

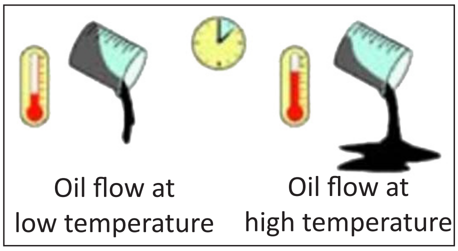
- Includes benefits of Synthetic with lower cost of petroleum.

Motor oils are categorized in SAE viscosity classes.

Viscosity is a measure of a fluid's ability to flow.

- High = thick, does not flow well.
- Low = thin, flows easily.

Oil viscosity is graded by the oil ability to flow at ambient temperature.



Engine oil temperature

Oil viscosity is greatly affected by the temperature of the oil.

- At low temperatures the oil has a higher viscosity.
- At high temperatures the oil becomes thinner and its viscosity lowers.

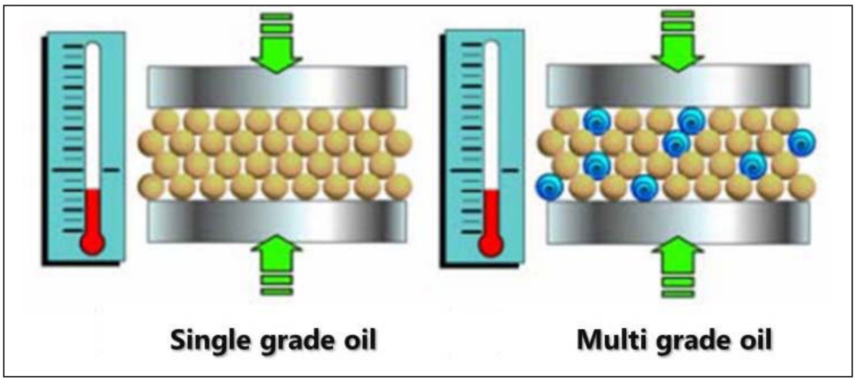
To overcome the above difficulty most engines use multi-grade oils that are adaptable to temperature variations.

Engine Oil Multi-Viscosity

SAE 40 oil performs well at higher temperatures, but becomes thick at low temperatures Multi-Viscosity oil can perform well across a larger range of oil.

- Retains a specific viscosity at 0°F.
- Increase in viscosity at high temperatures.

The molecules in multi-viscosity oils line up and increase in size the hotter they get.



An example of multi-viscosity lubrication oil is as below:

Lubrication oil should also have the following properties

Flash point

The flash point of oil is the temperature to which the oil must be heated in order to give off enough vapor to form a combustible mixture above the surface that will momentarily flash or burn when the vapor is brought into contact with a very small flame.

Fire Point

The Fire point of the oil is when the oil is able to sustain fire as its burning.

Pour Point

It is known as the lowest temperature at which the liquid remains pourable.

Volatility

Lubrication oils can get evaporated due to high operating temperatures and thus the consumption of oil is increased at normal working temperatures, thus its best if the oil has a lower Volatility.

Cloud Point

The cloud point is the temperature at which the separation of wax becomes visible in certain oils under prescribed testing conditions.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. What characteristics should a good lubricant possesses?

____

____

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____

____

2. Define flash point.

____

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____

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____

Worksheet

1. Read the questions and tick the correct answer.

a. ______________________ is known as the lowest temperature at which the liquid remains pourable.

- i. Pour point ☐
- ii. Cloud Point ☐
- iii. Flash point ☐
- iv. None of the above ☐

Notes

Answers: Introduction to Lubricants

Question Number	Answer
1	a. i

Types of Lubrication System

At the end of this session you will be able to:

- state the types lubrication systems used in automobiles.

Session Plan	
1	Introduction
2	Types of Lubrication System
3	Components of Lubrication System
4	Key Learnings
5	Worksheet

Introduction

An automobile moves on uneven surfaces and hence the oil stored in the reservoir can shift from one side to another resulting in inadequate amount of lubricant and seizure of the engine.

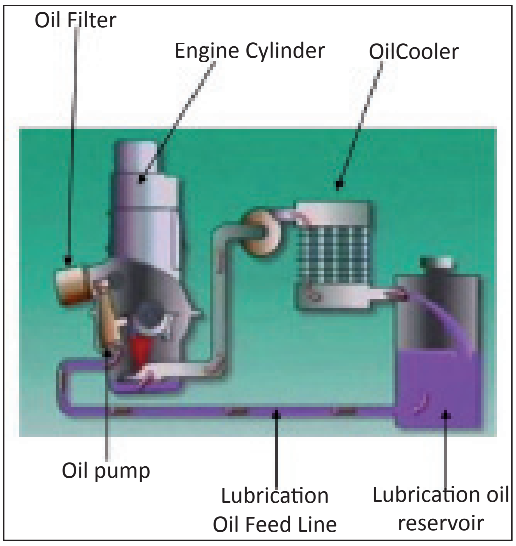
Types of Lubrication System

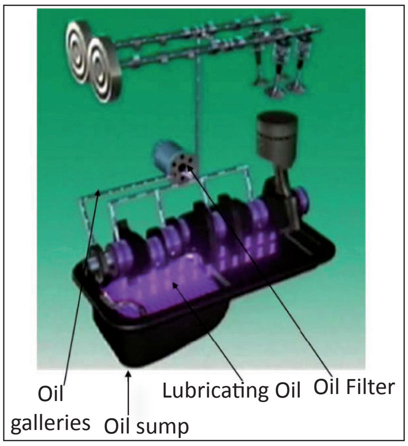
To provide adequate amount of oil to the lubrication system at all time, the following efficient systems have been in use:

- Dry sump lubrication;
- Wet sump lubrication.

Dry Sump Lubrication

In a dry sump type lubrication system, the reservoir containing lubricating oil is placed away from the engine. The oil is pumped into the lubrication system using an oil pump. This system is employed in sports car engines for situations where the vehicle has to be operated at very steep slopes. If a traditional pressure lubrication system is used in the above application, there might be instances where there may be no lubricating oil near the oil pump resulting in seizing of the engine. The use of this system also enables the designers to lower the height of the car to improve aerodynamics and performance.





Engine Oil Temperature

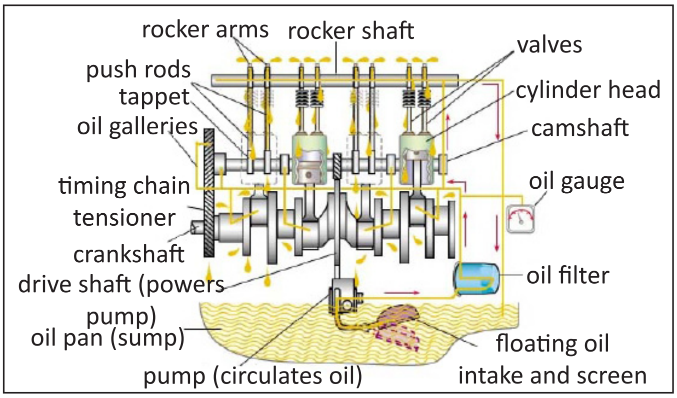
Oil viscosity is greatly affected by the temperature of the oil:

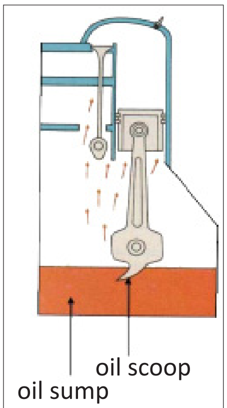
- At low temperatures the oil has a higher viscosity;
- At high temperatures the oil becomes thinner and its viscosity lowers.

To overcome the above difficulty most engines use multi-grade oils that are adaptable to temperature variations.

Pressure Lubrication

The pressure lubrication system uses a pump that pumps the engine oil from the oil sump. The oil is pressurized and is made to pass through the oil galleries in the crankshaft, camshaft etc. This system is commonly used in all modern vehicles.





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Components of Lubrication System

The lubrication system consists of various components that operate in sync to provide lubrication to the engine. Following are the components of the lubrication system:

- Oil pressure switch
- Strainer
- Pickup tube
- Oil pump

- Pressure relief valve
- Oil filter
- Spurt holes and galleries
- Sump
- Dipstick.




Engine Oil Temperature

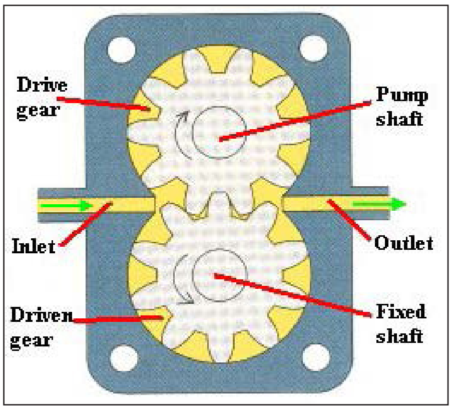
Oil viscosity is greatly affected by the temperature of the oil

- At low temperatures the oil has a higher viscosity
- At high temperatures the oil becomes thinner and its viscosity lowers

To overcome the above difficulty most engines use multi-grade oils that are adaptable to temperature variations.

Pickup Tube

The pick-up tube is connected between the strainer and the oil pump. It transfers the clean oil from the strainer to the oil pump.



Engine oil temperature

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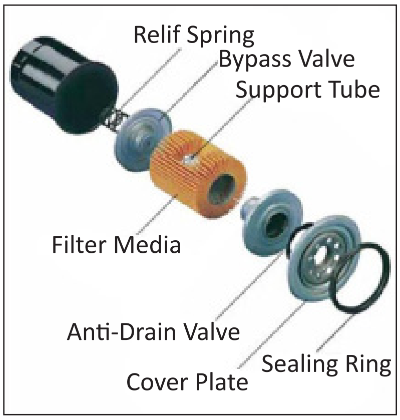
To overcome the above difficulty most engines use multi-grade oils that are adaptable to temperature variations.

Pressure Relief Valve

The maximum pressure in the lubrication system is limited by a pressure relief valve. This valve is so selected that the pump will deliver sufficient amount of lubricating oil to the engine components. In case of any excess pressure generated in the lubrication system due to blockage, the oil is returned back to the oil sump by a pressure relief valve.



Oil Filter

The pressurized oil is pumped into the oil filter before sending it to the oil galleries. The particles that cannot be trapped with the help of the strainer are trapped in the oil filter.

It has been found that impurity particles of 5-15 microns diameter are most damaging because the oil film size is bigger than this due to which smaller particles never come in contact with the mating surfaces separated by oil.

Hence it is necessary to remove it absolutely from the oil to prevent damage to the moving components.

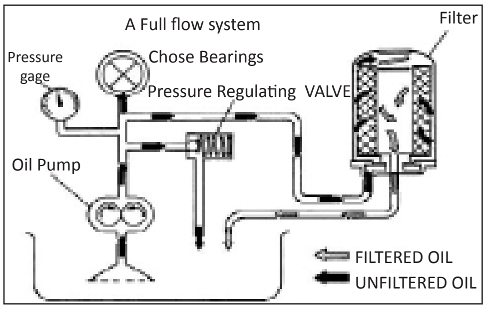
The different types of oil filters used in automobiles are:

- By-pass system;
- Full flow system.

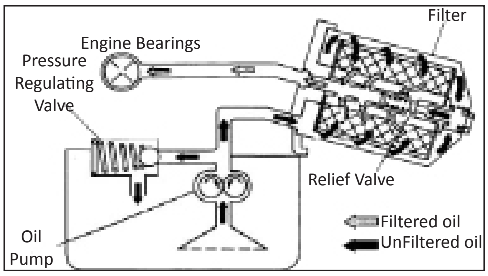
Oil Filter - By-Pass System

In a by-pass system the whole amount of oil does not pass through the oil filter at the same time. Most of the oil without being filtered goes to the engine bearings whereas the rest (approximately 10%) is passes through the filter and is cleaned and returned to the sump.

In this system the rate of flow of oil through the oil filter is slow so that very fine filtering element can be used to filter the oil completely. This system is not used in vehicles today as it has been found that it is not possible to clean the entire oil content using this system.



Oil filter - Full flow system

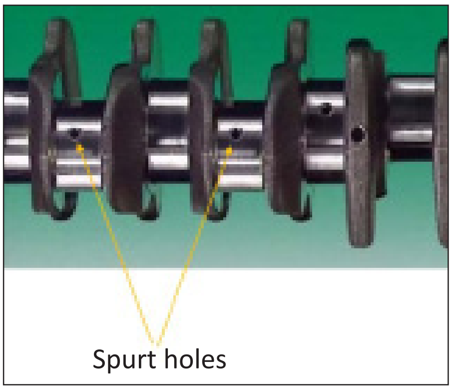


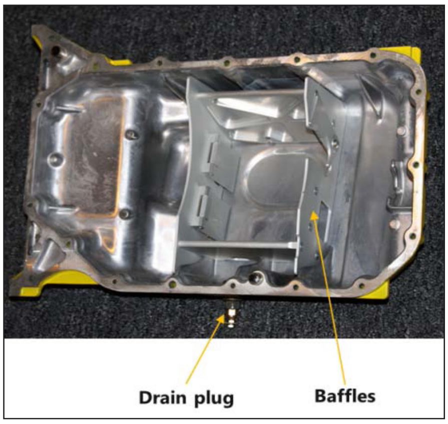
In a full flow system the oil passing through the engine bearings and galleries passes through the oil filter first. In the case of blocking of the oil filter occurs, the engine bearing will be starved from lubrication which could lead to seizing of engine.

Hence to prevent this from occurring, a spring loaded relief valve is incorporated in the filter, which by-passes an emergency supply of unfiltered oil to the bearings to provide lubrication

Spurt Holes and Galleries

Spurt holes and galleries are holes and passages drilled in the engine crankshaft and camshaft. These galleries carry oil from the oil filter to the various spurt holes. Spurt holes are openings to the galleries that allow the flow of lubricating oil on engine gearings to provide lubrication.



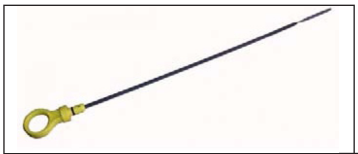


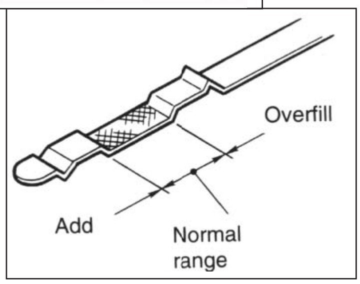
Sump

The oil sump is a metal component that is connected to the cylinder block and acts as a reservoir for lubricating oil. It consists of baffles (thin sheet of metal separators) inside to avoid the movement of lubricating oil from one side of the sump to another preventing cavitation of the oil pump. It also consists of a drain plug at the bottom to facilitate the draining of burnt oil during periodic maintenance service. It is advisable to keep the engine running for some time to reduce the viscosity of the lubricating oil before opening the drain plug so that the burnt oil flows out completely.

Dipstick

The dip stick is a long flexible metal strip that is fitted on to the cylinder block. It consists of two ends; the lower end with a gauge and is submerged in to the lubricating oil at all time, whereas the other end containing the pull handle is accessible to the technician in the engine compartment. The main function of the dip stick is to indicate the level on engine oil in the engine as it is not visible with the naked eye. It is also used to check the quality of oil in the engine. The gauge at the bottom end of the gauge indicates the level of oil and the oil need to be topped-up if necessary after reading the dip stick gauge.





Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. Describe an oil filter?

____

____

2. Explain the splash lubrication process.

Worksheet

1. Read the questions and tick the correct answer.

a. ______________________ is used to check the quality and level of lubrication oil in the engine.

i. Sump ☐

ii. Oil pump ☐

iii. Dipstick ☐

iv. Drain plug ☐

b. In a dry sump type lubrication system, the reservoir containing lubricating oil is placed away from the engine.

i. True ☐

ii. False ☐

Notes

Answers: Introduction to Lubricants

Question Number	Answer
1	a. iii b. i

Working of Lubrication System

	At the end of this session you will be able to: ◆ describe the working of lubrication system.

Session Plan	
1	Introduction
2	Working of Lubrication System
3	Key Learnings
4	Worksheet

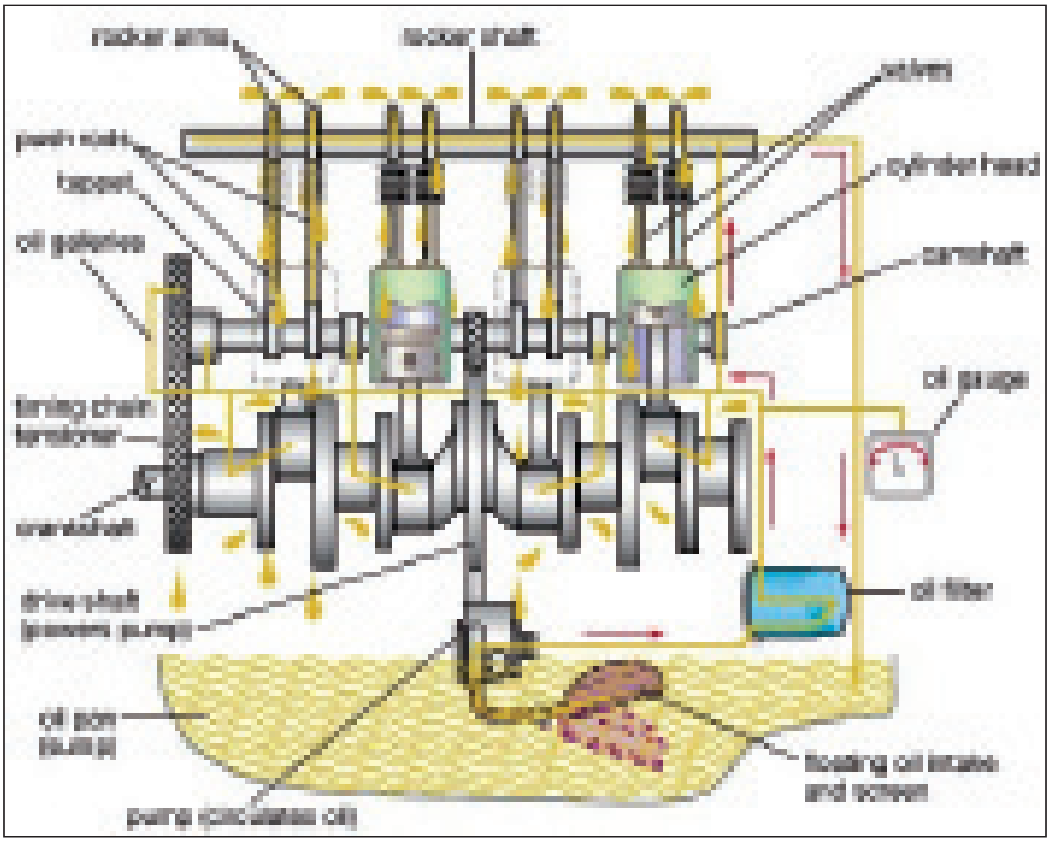
Introduction

The purpose of a lubrication system in an automobile is to form a thin protective film between two components to reduce wear and tear. Hence, resulting in increasing the life of the engine.

Working of Lubrication System

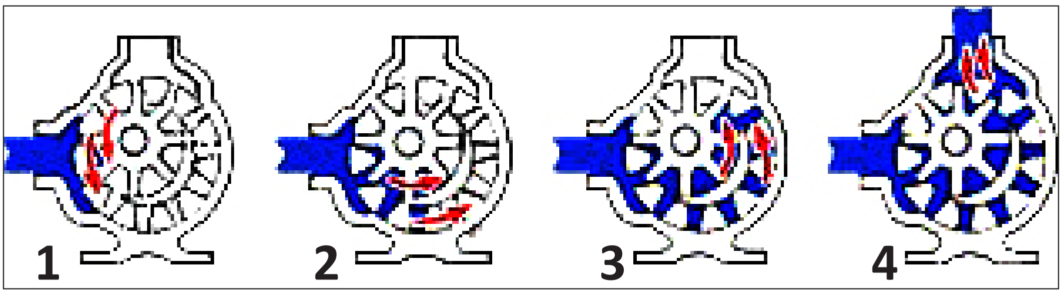
Working of pressure lubrication system

- The oil pump pumps the oil from the oil sump through the strainer when the engine is started and delivers it to the oil filter.
- The oil is then passed through the main oil gallery at a pressure of 200 to 400 kPa.
- The oil pressure is controlled by means of a pressure relief valve situated in the oil filter or pump housing in some cars.
- The oil travels to the main bearings through the drilled galleries and provides lubrication.
- The excessive oil then falls back into the sump. However, some oil still flows through the galleries to the crank pins from where the gudgeon pin is lubricated.



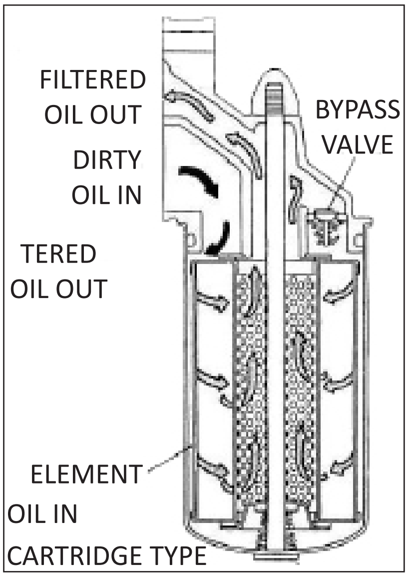
Working of Crescent Type Oil Pump

- The primary function of the oil pump is to pump the lubricating oil from the oil sump and transfer it to the oil galleries via the oil filter.
- A crescent type of oil pump contain an internal gear which is in mesh with a driving external gear which is mounted eccentrically with respect to the ring gear.
- Due to the eccentricity there is space between the two gears through which the lubricating oil flows.
- Due to the rotation of both gears suction is produced in the inlet of the pump which draws oil into the pump.
- The oil is then trapped in between the tooth spaces of the gears and is carried out towards to outlet port of the pump.
- Since the space between both the gear teeth keep decreasing towards the outlet port, more amount of oil is pushed through a small outlet which increases pressure of the lubricating oil
- The oil under high pressure is transferred to the oil filter for lubrication.



Cartridge Type oil Filter

- This oil filter construction is most widely used in automobiles and consists of a filtering material placed in the metallic casing
- The impure oil from the oil sump is pumped using an oil pump and is made to pass through the filtering element which traps all the impurities in the oil such as small metal particles and carbon
- The element is given a pleated form to maximize the surface area of the filter for a given size of filter element
- Filter element with pores also being used to trap particles of sizes within the region of 5 microns
- The oil enters the oil filter at the top and passes through the filter elements
- The pure oil then passes through the porous metallic tube from where it goes through the outlet for circulation



Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. Explain the working of a pressure lubrication system?

Worksheet

1. *Read the questions and tick the correct answer.*

   a. The oil is then passed through the main oil gallery at a pressure of ____________ .

      i. 100 to 300 kPa ☐

      ii. 250 to 400 kPa ☐

      iii. 200 to 450 kPa ☐

      iv. 200 to 400 kPa ☐

Notes

Answers: Working of Lubrication System

Question Number	Answer
1	a. iv

Introduction to Cooling Systems

At the end of this session you will be able to:

- state the need and functions of cooling system;
- describe the layout of a cooling system.

Session Plan	
1	Introduction
2	Layout of Cooling System
3	Necessity of Cooling System
4	Main Functions of Cooling System
5	Key Learnings
6	Worksheet

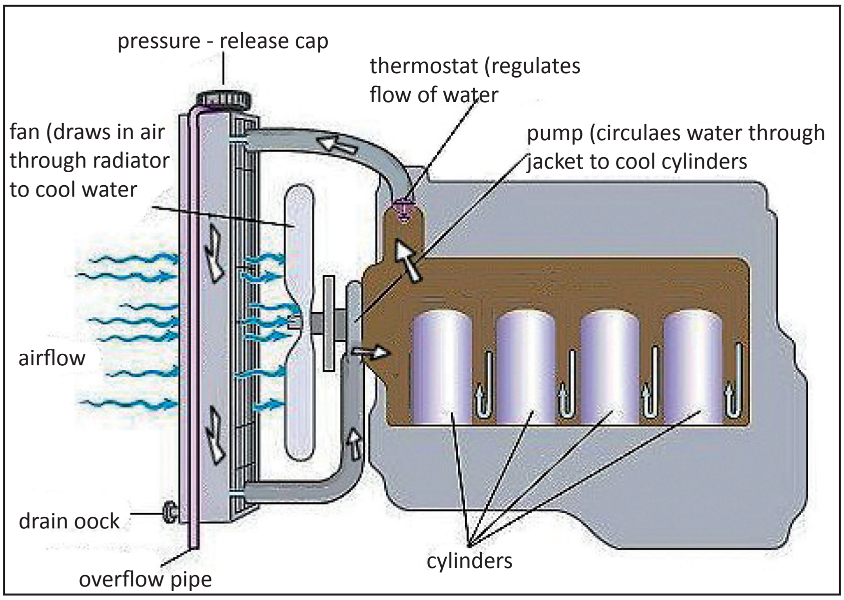
Introduction

A cooling system basically maintains the engine at optimum working temperature, without affecting its thermal efficiency.

The Radiator, Coolant Mixture, Thermostat Valve, Centrifugal Coolant Pump and the Engine Fan, together help achieving the engine heat dissipation to the atmospheric air.

It is used in the automotive system to prevent engine overheating and for improving its efficiency at various load & speed conditions.

Layout of Cooling System



Necessity of Cooling System

- The purpose of cooling system is to keep the engine at its most efficient operating temperature at all the engine speed and load conditions.
  - During the combustion process, enormous amount of heat is produced inside the engine cylinder raising the temperatures as high as 2500 degree Celsius.

This may lead to:

a. Reduction of Lubricant film viscosity between the moving parts.

b. May cause any mechanical component breakage.

c. May also end up welding the two close engine components.

Main Functions of Cooling System

- The main function of Cooling System is to cool the engine rapidly, when the temperatures crosses a certain preset level, thereby getting the engine working temperature to the optimum working level.
  - This rising temperature need to be brought down in the range of 200-250 degree Celsius without letting down the thermal efficiency of the engine.
  - Only 20-25% of the Total Energy produced is utilized at the crankshaft and the rest of it, is lost to the cylinder walls, through the exhaust gases and in friction.

- Cooling beyond permissible limits may cause:

a. Decrease in the thermal efficiency.

b. Reduced fuel vaporization decreasing the combustion efficiency.

c. Lubricant viscosity increases with the lowered engine temperatures that may lead to increase in friction between the mechanical components.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. Describe the layout of the cooling system.

____

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2. State the main function of the cooling system stressing on its necessity.

Worksheet

1. Read the questions and tick the correct answer.

a. Cooling of the engine beyond permissible limits leads to reduction in the ____________

i. volumetric efficiency ☐

ii. mechanical efficiency ☐

iii. thermal efficiency ☐

iv. all of the above ☐

b. The overheating of engine components may lead to welding of two close engine components.

i. True ☐

ii. False ☐

Notes

Answers: Introduction to Cooling System

Question Number	Answer
1	a. iii b. i

Introduction to Coolants

At the end of this session you will be able to:

- state the properties of coolant;
- state the types of coolant.

Session Plan	
1	Introduction
2	Properties of Coolants
3	Types of Coolants and their Specifications
4	How to Check the Quality of the Coolant
5	Key Learnings
6	Worksheet

Introduction

- Coolant mixture [Distilled Water + Antifreeze] is added to the radiator, which inturn circulates in the water jackets of the engine, thereby maintaining an optimum engine operating temperature.
- Addition of antifreeze raises the boiling point and lowers the freezing point of the coolant mixture, which helps the engine to operate efficiently at different load and speed conditions and also function in extreme climatic regions.
- Ethylene Glycol is the most preferred antifreeze solution.
- Specific Gravity Test is mainly used in testing and maintaining the coolant quality.

Coolant is a fluidic substance circulating in the engine water jackets, which is used to reduce the temperature of the engine below a specified value by conducting away the heat at the radiator.

Properties of Coolants

- Most of the Coolant Mixtures are prepared by mixing the Antifreeze Solutions (Red OR Green in Colour) with the Distilled water in various proportions according to the Engine Temperature Specifications.
- It's most important task is to prevent the water in the Radiator and Engine from freezing in cold temperatures and from boiling over in the summer.

1. Mix readily with the water.
2. Should prevent the freezing of the coolant mixture, even at the lowest temperature range.
3. Circulate freely in the Cooling system.

4. Should not be corrosive in nature.
5. It's Anti-Freeze property should not fade away with time.
6. Should be priced economically.
7. Should have a very High Boiling Point.
8. It should not clog the cooling system with any foreign matter getting deposited.

Types of Coolants and their Specifications:

Methanol:

1. It is also known as Methyl Alcohol.
2. It is light, volatile, colorless, flammable and poisonous liquid with a distinctive odor that is mild and sweet in nature.
3. At room temperature, it is a polar solvent and is used as an antifreeze.

Ethylene Glycol:

1. It is known as "Permanent Antifreeze" due to its higher boiling point range.
2. This property gave it an Edge and was considered suitable during summer and winter.
3. Gradually it got replaced by Propylene Glycol, due to its low toxicity.

Propylene Glycol:

1. It was known as a "Non-Toxic Antifreeze".
2. But it was observed that it gets oxidized when exposed to air and heat, forming Lactic Acid, which is very corrosive in nature.
3. So pH buffering agents are often added to it, to prevent acidic corrosion of metal components
4. It also develops bacterial slime in the system, leading to increase in corrosion.
5. If it is used an Automobile Antifreeze, then its pH level, Specific Gravity and Color, should be monitored on timely basis.
6. It should be replaced when it turns Reddish in color.

Glycerol:

1. It is considered to be Non-Toxic, has a high Boiling Point, and is Non-Corrosive.
2. But Ethylene Glycol has a Lower Freezing Point as compared to Glycerol and hence is preferred at times.
3. The minimum freezing point of a [Glycerol-Water mixture] > [Ethylene Glycol-water mixture].
4. But since Glycerol is non-toxic in nature compared to Ethylene Glycol, it is being reconsidered for use in Automotive Applications.

How to the Check the Quality of the Coolant

- The [Antifreeze and Distilled Water] mixture strength needs to be checked periodically.
- Incase there occurs a leakage or boiling of coolant then the level of antifreeze protection need a serious evaluation.

The methods that are commonly deployed to determine the Freezing Point of the Coolant Mixture are as given below:

1. **Specific Gravity Test:**
   - A Hydrometer is used to measure its specific gravity.
   - The Scale present inside and the Floating Indicator give the appropriate reading.
2. **Refractometer:**
   - It measures the Refractive Index of the antifreeze solution and converts the value obtained into Freezing Point Marking.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. State the various properties/requirements of an Antifreeze.

2. Explain the two methods of measuring the quality of a coolant mixture.

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Worksheet

1. *Read the questions and tick the correct answer.*

a. ______________________ Antifreeze is known as a "Permanent Antifreeze".

i. Methanol ☐

ii. Glycerol ☐

iii. Thermal Efficiency ☐

iv. All of the above ☐

b. "If Propylene Glycol-"The Non Toxic Antifreeze", is used an Automobile Antifreeze, then it should be replaced when it turns in ______________________ colour.

i. Blue ☐

ii. Green ☐

iii. Reddish ☐

iv. Orange ☐

Notes

Answers: Introduction to Coolants

Question Number	Answer
1	a. iii b. iii

Types of Cooling Systems

At the end of this session you will be able to:

- state the types of cooling system;
- describe the working of the cooling system.

Session Plan	
1	Introduction
2	Types of Cooling Systems
3	The Various Components of Cooling Systems
4	Warning System
5	Key Learnings
6	Worksheet

Introduction

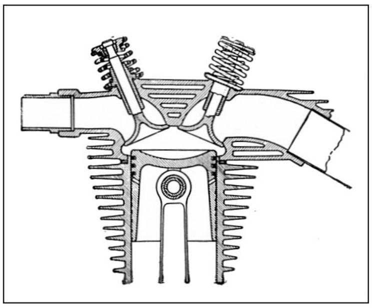
- The Air Cooling System has now become obsolete.
- The Coolant Pump & Thermostat, along with the Radiator, Pressure Cap, Expansion Reservoir and Coolant Fan together have given a Great Functional Advantage to the Modern Water Cooling System.
- All the components mentioned above are skilfully designed and are highly functional to let the engine work always at optimum operating temperature.
- The timely intimation given by Coolant temperature sensor indeed proves to be very helpful thereby preventing engine overheating.

Types of Cooling Systems

1. Air Cooling System:

- In this type of cooling method Fins & Flanges are mounted on the Cylinder Barrels.
- This type of design exposes maximum area of the heated cylinder surface to the heavy current of air.
- The heat is dissipated directly to the air after being conducted through the cylinder walls.

- **The amount of heat dissipated depends upon:**
  1. Amount of surface area of the metal in contact with air.
  2. Rate of air flow.
  3. Temperature difference between the heated surface & the air.
  4. Conductivity of the metal.

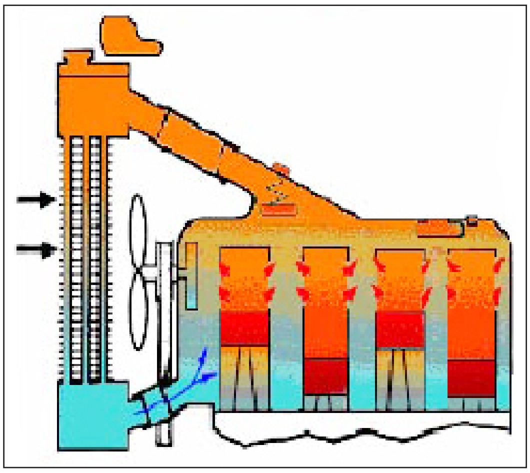


- **Advantages of Air Cooling:**
  1. Reduction in the Engine weight due to the elimination of radiator, coolant & water jackets.
  2. Works well in the cold climatic regions.
  3. No hassle of topping up of coolant or of its leakage.

- **Disadvantages of Air Cooling**
  1. Uneven cooling takes place which might lead to cylinder distortion.
  2. Cooling Efficiency is low as compared to water cooling system as the Coefficient Of air transfer is lower for air as compared to the water.
  3. They are noisy in nature whereas water acts as a sound insulator.
  4. The fan mounted adds to the weight, consumes almost 5% of the engine power to get the drive from it.

2. Water Cooling System:

- In this system the cooling medium is water to which some antifreeze is added to raise its Boiling Point & lower its freezing point.
- Water circulates in the water jackets provided around the combustion chamber.
- It absorbs the heat from the engine components, & moves to the radiator to exhaust away the heat by exchanging it with air, driven in by the fan mounted on the engine.



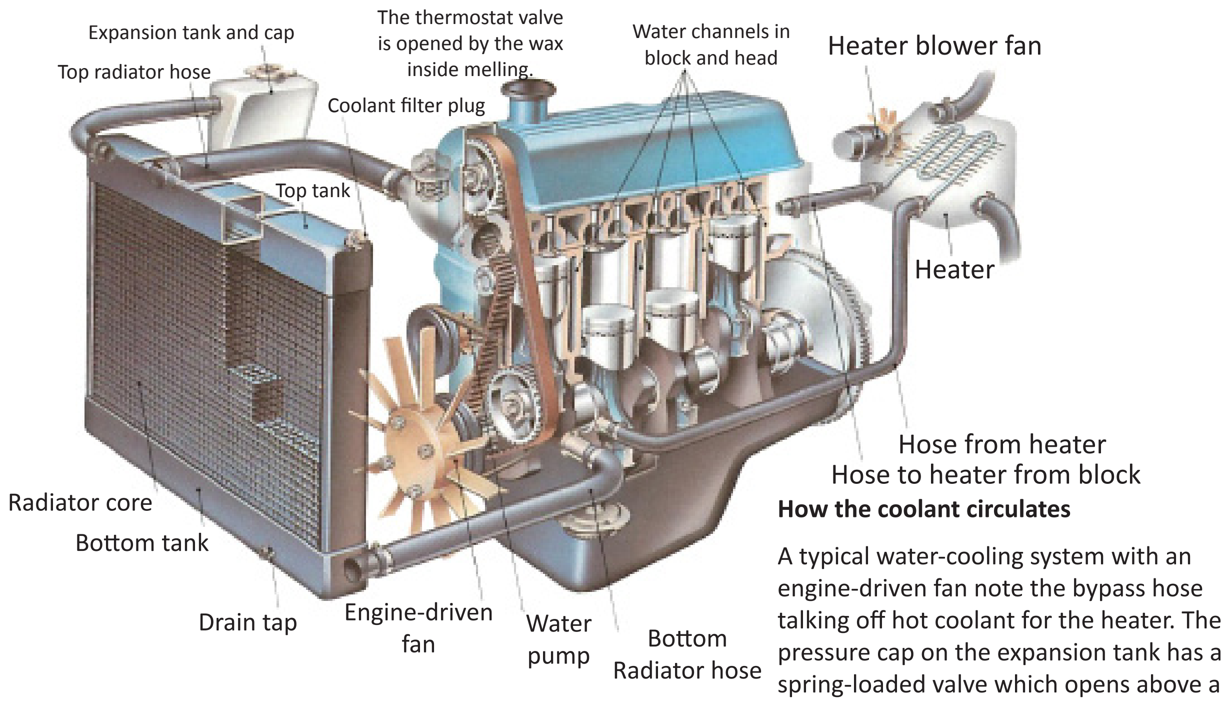
A. Thermosyphon System:

- This system works on the basic principle of differencein **densities of hot and cold regions of the cooling water.**
- The hot water being lighter in density rises up & moves to the radiator via the hose pipe.
- It is cooled here by the incoming air driven in by the moving fan as it passes through the vertical tubes.
- The high density coolant reaches at the radiator bottom half and again moves to the engine for further circulation.

- Though this sytem is simple and has low initial cost it has now become obsolete due to certain disadvantages.
- As the heat exchange occurs by natural convection, cooling process is a little slower.

- Radiator header tank needs to be located at a higher level than the cylinder coolant Jackets which is no more possible in the latest vehicle body designs.
- If the coolant level falls below a certain level then the cooling process would get ruptured.

B. Pump Circulation System:



How the coolant circulates

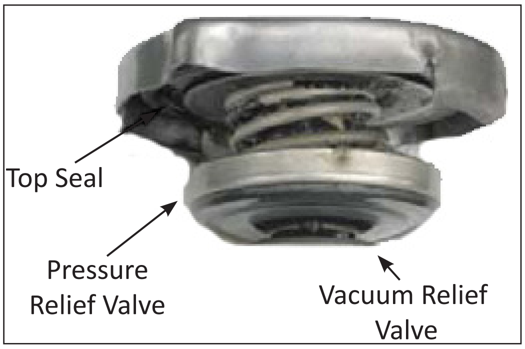
A typical water-cooling system with an engine-driven fan note the bypass hose talking off hot coolant for the heater. The pressure cap on the expansion tank has a spring-loaded valve which opens above a certain pressure.

- This system is almost similar to the Thermosyhon System of Cooling.
- The only difference being ,there is a pump mounted to circulate the coolant and a temperature sensing thermostat device is employed to control the flow of hot coolant only after it crosses a certain preset temperature level.
- The pump and the fan get the belt drive from the engine crankshaft.
- **Advantages of Pump Circulation:**
  1. Efficient coolant circulation leads to the implementation of smaller water jackets in the engine thus reducing its overall weight.
  2. Coolant circulation is proportionate to the engine load and speed variations.
  3. The Radiator has got the flexibility to be placed at the side or at the back and it need not be placed at a higher level compared to the engine.
- The only disadvantage being, this system is a little complicated and costlier than the earlier one.

Various Components of Water Cooling System

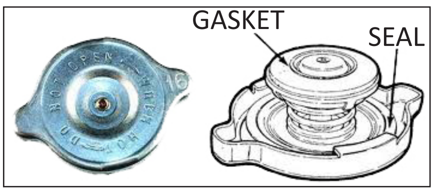
1. Radiator:

- **A radiator basically consists of :**
  1. upper header tank
  2. lower collector tank
  3. a core
- Hot coolant from the engine enters the upper tank and is cooled while passing through the core, by the cross flow of the air & finally it gets collected in the lower tank.
- It is again pumped to the engine from the lower tank, for recirculation.
- Besides, an overflow pipe in the upper tank & a drain pipe in the lower tank are also provided.
- A tubular type core is used wherein the coolant flows through the tubes and air passes around the fins.
- The materials used for radiator should be corrosion resistant and bear high thermal conductivity.
- Aluminium is a preferred choice from weight and cost consideration.



2. Pressure Cap

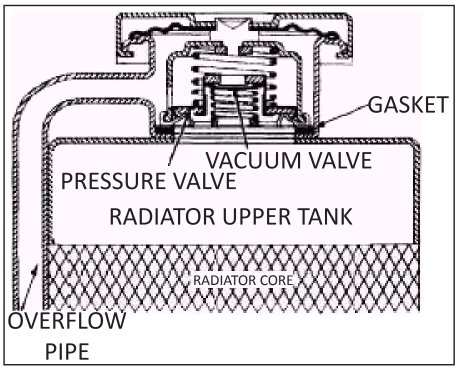
- Pressure Cap is an air tight cover at the radiator filler neck,that forms an air tight joint, which maintains the coolant at a very high pressure than the atmospheric pressure.
- High pressure developed inturn raises the boiling point of the coolant. For every 10Kpa increase in pressure, the boiling point is raised by 2.5degree Celsius.

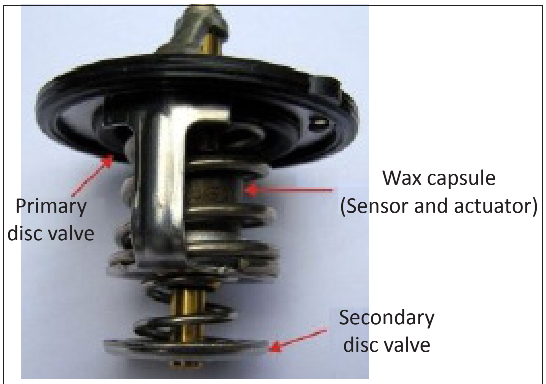


- Due to this a very high pressure is maintained irrespective of change in atmospheric pressures. It thus maintains the cooling efficiency by preventing overheating. Eg: Drive on high altitudes
- Engine can operate at higher temperatures without boiling the coolant.
- Air tight cap completely prevents evaporation and surging of the coolant.

3. Expansion Reservoir:

- Incase under severe working conditions, the coolant starts boiling and vaporizing,
- Then the boiling pressure crosses a certain value, letting the pressure blow off valve to vent out the excess pressurized coolant via the overflow pipe.
- In modern engines, an expansion reservoir is provided instead of an overflow pipe.
- With the rise in coolant temperature, the excess high pressure coolant is sent to the reservoir.
- As the coolant temperature reduces, the coolant from the reservoir is reverted back to the radiator, thus keeping it full of coolant.





Double-valve automotive engine cooling thermostat

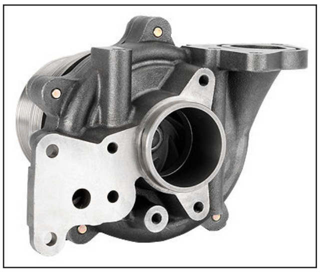
4. Thermostat:

- To control the optimum cooling of the engine, a thermostatic valve is used, which releases the coolant to radiator for cooling, only when it's temperature crosses a certain preset value.
- It is mounted in the coolant hose pipe at the engine outlet.Example: Wax Type Thermostat

- A wax type thermostat consists of a plunger, a tight seal, rubber plug and copper loaded wax.
- As the coolant crosses a certain preset temperature, it directly transmits its heat to the copper loaded wax, which inturn has high coefficient of volumetric thermal expansion (0.28% per degree Celsius).

- The expanded copper loaded wax and exerts pressure on the rubber plug.
- Contracting rubber plug inturn forces the plunger movement in upward direction, which directly opens up the thermostatic valve.
- This valve opened lets the hot coolant to flow to the radiator for optimum cooling.

5. Coolant Pump:



- A centrifugal type of coolant pump is used, to ensure the forced circulation of the coolant at various speed and load conditions.
- It is mounted on the front end of the engine and gets the belted drive from the crankshaft.
- Hence the coolant pump speed is proportional to the engine speed.
- Thus at higher speed/load conditions more coolant will be pumped to prevent the engine overheating.
- It's Components are:
    1. Outer casing
    2. Shaft mounted impeller
    3. Turning blades-Vanes
    4. Bearing-on which impeller shaft is mounted
    5. A tight Seal-to prevent the leakage of coolant around the shaft.

Working:

- When the impeller rotates, the coolant between the vanes, the coolant is thrown outwards with a centrifugal force along the periphery of the pump.
- Its speed is directly proportional to the engine speed.
- When the coolant leaves the vane casing with a very high kinetic energy and enters the volute casing having gradually increasing cross sectional area, its kinetic energy is converted to pressure energy, which inturn forces the coolant to be pumped with a very high pressure.

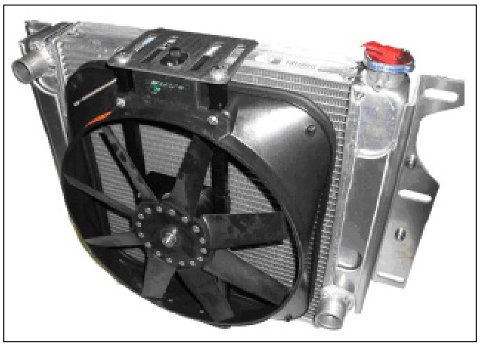
6. The Cooling Fan:

Situations, where in the cooling fan operates during different vehicle load conditions:

Scenario 1: When the vehicle is going with a high speed and light load, the natural draft of air passing through radiator cools the hot coolant.

Scenario 2: When the vehicle is moving with a heavy load and low speed, Eg: Drive uphill, the insufficient level of air drawn inwards might cause engine overheating problem.

- Hence the engine fan is mounted behind the radiator and gets the belted drive directly from the engine crankshaft pulley, thus ensuring optimum engine cooling.
- But to save the power when engine is running according to scenario 1,the Fan Blades are given a flexible plastic moulded curvy design.
- In **scenario 1**, Initially the fan operates at a high speed. =>It then leads to straightening of its bent blades and thus it's air absorbing capacity slows down, thereby using lesser engine power.
- Whereas, In **scenario 2**, fan rotates comparatively slower, letting its bent blade profile to draw in more amount of air, ensuring optimum cooling.



- Modern day fans are made up of Nylon/Propylene and has around 4-7 Blades.
- They are independent of the engine drive and are controlled by an electrical motor.

Warning System

- In certain situations, the engine overheating may occur, due to hot coolant not being able circulate at the radiator for cooling purpose.
- To detect this, a coolant temperature sensing gauge is provided on the dashboard, to sense the error with the cooling system.
- This indication helps the driver to take a timely action, by stopping the vehicle and troubleshooting the situation.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. Explain the Pump Circulation Cooling System.

2. List all the components in a cooling system and explain their functions in brief.

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Worksheet

1. *Read the questions and tick the correct answer.*

   a. The air tight cover provided by the pressure cap,raises the boiling point & lowers the freezing point of the coolant in the radiator.

      i. True ☐

      ii. False ☐

   b. The Excess pressurised coolant, during extreme speed/load conditions, is let out to the expansion reservoir via the ____________________ valve.

      i. vaccum valve ☐

      ii. inlet valve ☐

      iii. outlet valve ☐

      iv. pressure valve ☐

Notes

Answers: Types of Cooling Systems

Question Number	Answer
1	a. i b. iv

Introduction to Exhaust System

At the end of this session you will be able to:

- state the functions of the exhaust system;
- identify the components of the exhaust system;
- state the need for the exhaust system for a safe environment.

Session Plan	
1	Introduction
2	Functions of an Exhaust System
3	Layout of an Exhaust System
4	Exhaust Gasses and Emission Norms
5	Emission Standards
6	Key Learnings
7	Worksheet

Introduction

During the exhaust stroke, burnt gasses are expelled to the atmosphere. The burnt gasses contain harmful gasses that need to be controlled before entering the atmosphere to prevent damage to environment.

Functions of an Exhaust System

The compressed air fuel mixture is burned during the combustion process using a spark plug in a petrol engine, whereas the diesel fuel self-ignites in a diesel engine to produce power. During the exhaust stroke the burnt gasses are pushed out of the combustion chamber. The exhaust gasses leaving the combustion chamber contain harmful gases that need to be cleaned to prevent damage to environment, which is where the exhaust system comes into use.

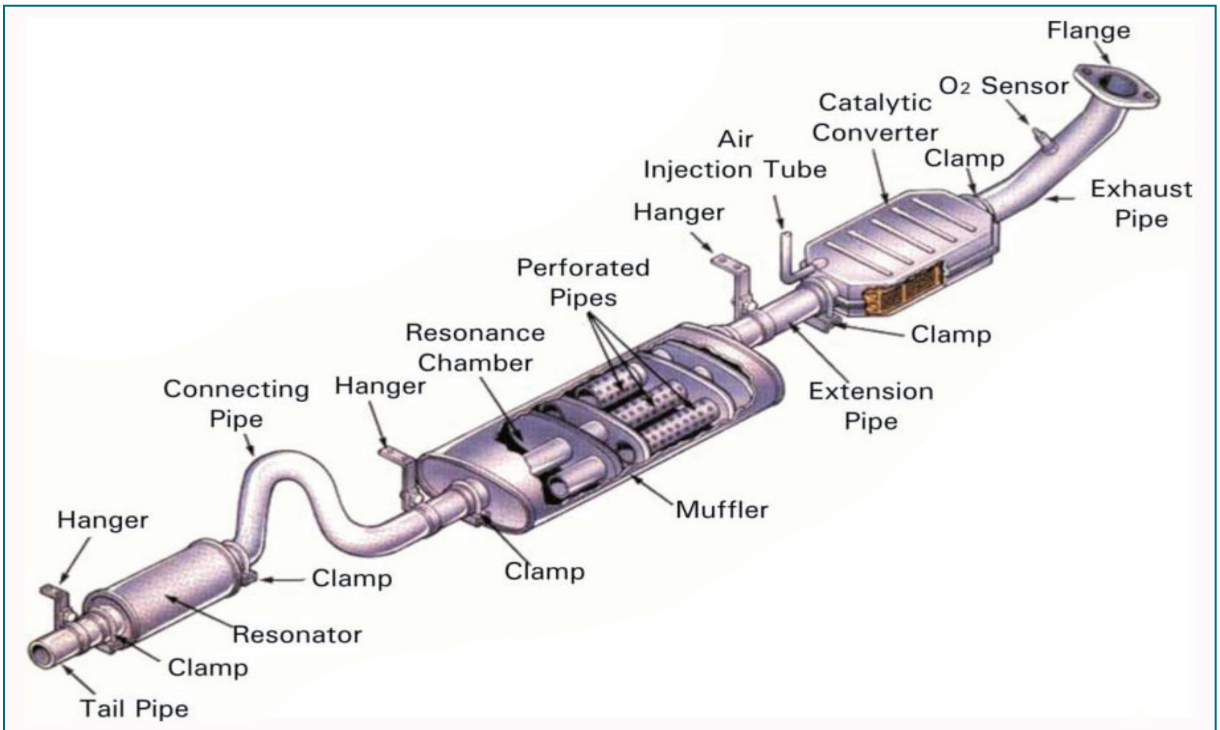
Below are the basic functions of an exhaust system employed in an automobile:

- Carry the exhaust gases from the engine's exhaust valve to the rear of the vehicle
- Reduce the level of harmful pollutants leaving the engine
- Reduce the noise produced during the combustion stroke

Layout of an Exhaust System

The exhaust system consists of a various components connected to each other. Each component functions in a unique way to reduce the level of un-burnt poisonous gasses leaving the combustion chamber to maintain the emission norms. (The main components of an exhaust system are

- Exhaust manifold
- Oxygen sensor
- Catalytic converter
- Muffler
- Exhaust pipe)



Exhaust Gasses and Emission Norms

The exhaust gasses leaving the engine cylinder are poisonous to health and environment. Following are the major constituents of the poisonous gases leaving the engine cylinder:

- Carbon Monoxide (CO)
- Hydrocarbons (HC)
- Nitrogen Oxide (NOx)

Carbon Monoxide (CO)

Carbon monoxide is a colourless, odourless and tasteless gas. This gas id injurious to humans as it reduces the human being's capacity to absorb oxygen in the blood and therefore results in poisoning. Inhaling air with a volumetric concentration of 0.3% carbon monoxide can result in death in 30 minutes.

Hydrocarbons (HC)

Hydrocarbons are chemical compounds which consist only of carbon (C) and hydrogen (H). They can be found in large quantities in crude oil, natural gas and coal, where they are the actual "fuel". Some hydrocarbon compounds cause cancer. When exposed to sunlight, hydrocarbons and nitrogen oxide react to form ozone. In the lower layers of the atmosphere this is a hazardous substance, which irritates the mucous membranes and causes headaches and nausea.

Nitrogen Oxide (NOx)

Nitrogen oxides are the gaseous oxides of nitrogen (N) and are abbreviated as NOx. If they come into contact with water (also in the form of fog), acids are formed, which irritate the mucous membranes and can even cause lung damage. Nitrogen monoxide (N2O)is also known as "laughing gas". However, this is a greenhouse gas, which damages the protective ozone layer in the upper atmosphere.

Emission Standards

The exhaust gasses leaving the combustion chamber need to be below the limit prescribed by the government of India. The standards and the timeline for implementation are set by the Central Pollution Control Board under the Ministry of Environment and Forests. In India the emission standards are known as Bharat Stage emission standards, whereas in Europe it is called EURO emission standards.

Bharat Stage emission standards

Emission norms for passenger cars (Petrol)

Norms	CO (g/km)	(HC+NOx) (g/km)
1991 Norms	14.3 - 27.1	2.0(Only HC)
1996 Norms	8.68 - 12.40	3.00 - 4.36
1998 Norms	4.34 - 6.20	1.50 - 2.18
India stage 2000 norms	2.72	0.97
Bharat stage - II	2.2	0.5
Bharat stage - III	2.3	0.35(combined)
Bharat stage - IV	1.0	0.18 (combined)

Emission norms for passenger cars (Diesel)

Norms	CO (g/km)	HC (g/kmhr)	NOx(g/kwhr)	PM (g/kwhr)
1991 Norms	14	3.5	18	-
1996 Norms	11.2	2.4	14.4	-
India stage 2000 norms	4.5	1.1	8.0	0.36
Bharat stage - II	4.0	1.1	7.0	0.15
Bharat stage - III	2.1	1.6	5.0	0.10
Bharat stage - IV	1.5	0.96	3.5	0.02

Emission norms for two wheelers

Norms	CO (g/km)	(HC+NOx) (g/km)
1991 Norms	12 - 30	8 -12 (Only HC)
1996 Norms	4.5	3.6
India stage 2000 norms	2.0	2.0
Bharat stage - II	1.6	1.5
Bharat stage - III	1.0	1.0

EURO emission standards

Emission limits for new vehicles with petrol engine

valid from		CO (g/km)	NOx (g/km)	HC (g/km)	HC + NOx (g/km)	PM
Euro I	12/92	2,72	-	-	0.97	-
Euro II	01/97	2,20	-	-	0.5	-
Euro III	01/00	2,30	0,20	0,15	-	-
Euro IV	01/05	1,00	0,10	0,08	-	-
Euro V	09/09	1,00	0,10	0,06	-	0.005*
Euro VI	08/14	1,00	0,10	0.06	-	0.005*

Emission limits for new vehicles with diesel engine

valid from		CO (g/km)	NOx (g/km)	HC (g/km)	HC + NOx (g/km)	PM
Euro I	01/92	3.16	-	-	1,13	0,14
Euro II	01/97	1,00	0,15	0,55	0,70	0,08
Euro III	01/00	0,64	0,06	0,50	0,56	0,05
Euro IV	01/05	0,50	0,05	0,25	0,30	-
Euro V	09/09	0,50	0,05	0,18	0,23	0,005
Euro VI	08/14	0,50	0,09	0,08	0,17	0,005

Current threshold values – motorcycles

valid from		CO (g/km)	NOx (g/km)	HC (g/km)
Euro I	06/99	13.00	3,00	0,30
Euro II	04/03	5,50	1,00	0,30
Euro III	01/07	2,00	0,30	0,15

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. What are the functions of an exhaust system?

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____

____

____

____

2. Note the permitted amount of CO, HC andNOx allowed to leave the engine exhaust system according to the BS4 emission norms.

Worksheet

1. ____________________ damages the protective ozone layer in the upper atmosphere?

   a. Carbon Monoxide (CO) ☐

   b. Hydrocarbons (HC) ☐

   c. Nitrogen Oxide (NOx) ☐

   d. All of the above ☐

Notes

Answers: Introduction to Exhaust System

Question Number	Answer
1	e. iii

Components of the Exhaust System

	At the end of this session you will be able to: ◆ identify the components of the exhaust system.

Session Plan	
1	Introduction
2	Components of Exhaust System
3	Key Learnings
4	Worksheet

Introduction

An exhaust system consists of various components that work together to reduce the amount of un-burnt gasses leaving the exhaust system.

Components of Exhaust System

The various components of the exhaust system are as below:

- Exhaust manifold
- Oxygen sensor
- Catalytic converter
- Muffler
- Exhaust pipe

Exhaust Manifold

The exhaust manifold is the first component of the exhaust system. It comprises of a stainless steel, aluminium or cast-iron unit that adjoins the engine's exhaust ports and collects exhaust gases from the combustion chamber. It consists of series of pipes that are individually linked to the cylinders and is funnelled into a collector that directs the exhaust to the secondary components of the exhaust system.

The manifold needs to be visually inspected for:

- Leakages
- Damages
- Distortion of gaskets
- Proper fitment of Oxygen sensor.

Leakages/Damages can lead to:

- Excessive emission
- Increased Engine noise levels
- Improper back pressure.

Oxygen (O_2) sensor

The oxygen sensor is mounted on the exhaust manifold or close to it in the exhaust pipe. It measures the amount of oxygen present in the exhaust. This information is used for fuel correction by the Engine Control Module. Malfunction of O_2 sensor can result in:

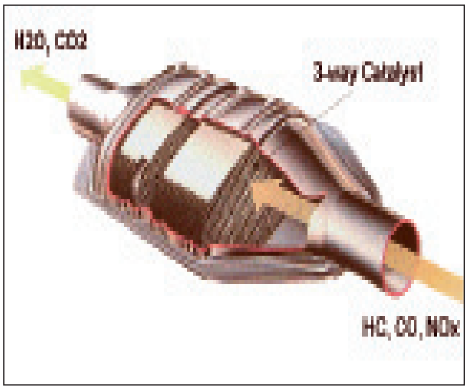
- Engine malfunction lamp glowing;
- Rough idling;
- Poor fuel average;
- Excessive exhaust emission;
- Poor response while accelerating.

Catalytic Converter

The catalytic converter is mounted in between the exhaust manifold and the muffler. It is a vehicle emissions control device which converts toxic by-products of combustion in the exhaust of an internal combustion engine to less toxic substances by way of catalysed chemical reactions and prevents pollutants such as carbon monoxide and nitrogen oxides from escaping into the atmosphere. By law, the catalytic converter must be in good working condition, and many states require annual testing of this component to assure that the vehicle is emitting minimal pollutants into the atmosphere (pollution test). The two types of catalytic converters used in automobiles are:

- Two-way catalytic converter
- Three-way catalytic converter.

Two-way catalytic converter - This type of catalytic converter is widely used on diesel engines to reduce hydrocarbon and carbon monoxide emissions



Oxygen (O_2) sensor

The oxygen sensor is mounted on the exhaust manifold or close to it in the exhaust pipe. It measures the amount of oxygen present in the exhaust. This information is used for fuel correction by the Engine Control Module. Malfunction of O_2 sensor can result in:

- Engine malfunction lamp glowing
- Rough idling
- Poor fuel average
- Excessive exhaust emission
- Poor response while accelerating

Muffler

- A system of exhaust pipes carries the exhaust gases through a muffler, which contains a series of baffles that damp the noise of the engine combustion and escaping gases. Without a muffler, the noise of combustion would escape directly from the exhaust pipe, creating a tremendous distraction for drivers and pedestrians. It is necessary to have the muffler in the best working condition to prevent noise pollution.Two-way catalytic converter.

Exhaust Pipe

It is the final part of the exhaust system. Between all of the above mention parts is the exhaust pipe which carries the gas through its journey out your tail pipe. It is hanged under chassis with the support of rubber hangers. Check for corrosion, leakages and damages.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. Describe an exhaust manifold?

2. What are the after effects of an oxygen sensor failure?

3. Describe a catalytic converter.

Worksheet

1. Read the questions and tick the correct answer.

a. A three way catalytic converter is used in ____________________ engines.

- i. petrol ☐
- ii. diesel ☐
- iii. CNG ☐
- iv. all of the above ☐

b. Leakages in an exhaust manifold can lead to ____________________ .

- i. excessive emission ☐
- ii. increased engine noise levels ☐
- iii. improper back pressure ☐
- iv. all of the above ☐

Notes

Answers: Components of the Exhaust System

Question Number	Answer
1	a. i b. iv

Introduction to EMS of Petrol Engine

At the end of this session you will be able to:

- identify the EMS system of a petrol engine;
- state the function of EMS system in a petrol engine vehicle.

Session Plan	
1	Introduction
2	EMS of petrol engine
3	Functions of EMS system
4	Key Learnings
5	Worksheet

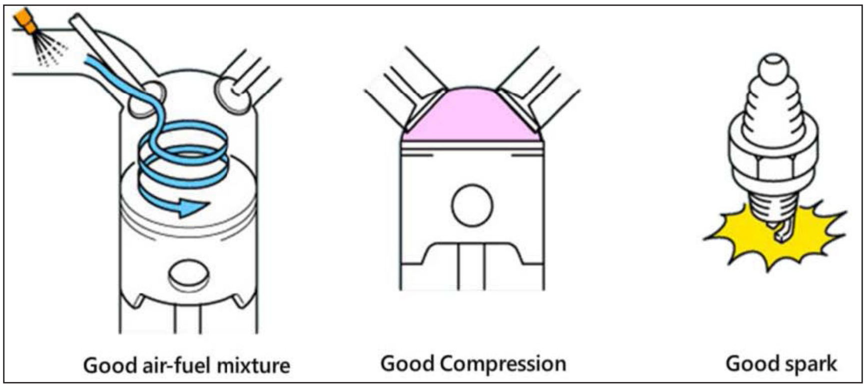
Introduction

In any petrol engine, to get the maximum power with the available engine capacity and fuel system, there should be a good fuel mixture, good compression and a good spark. To achieve this, modern Automobiles have an ECM (Engine Control Module) which collects the information from different sensors and gives output commands to actuators. The ECM has self-diagnostic capabilities which can inform the driver in case of malfunction. We will learn about the ECM, Sensors and the Actuators in this session.

EMS of Petrol Engines

A gasoline engine produces power through an explosion of a mixture of gasoline and air. Following are the three essential elements for a gasoline engine to produce power:

- Good air-fuel mixture



- Good compression
- Good spark

To achieve these three elements simultaneously, it is important to precisely control the formation of the air-fuel mixture and the timing of the sparks.

Before 1981, the only engine control system in existence was the EFI (Electronic Fuel Injection), which used a computer to control the fuel injection volume. In addition to the EFI, there are now various computer-controlled systems, including the ESA (Electronic Spark Advance), ISC (Idle Speed Control), diagnostic systems, etc.

For the computer to function properly, it requires a comprehensive system comprised of various input and output devices.

On an automobile, sensors such as a water temperature sensor or an air flow meter correspond to the input device and actuators such as injectors or igniters correspond to the output device. The computer that controls a system is called an ECU (Electronic Control Unit). The computer that controls the engine is called an engine ECU (or ECM*: Engine Control Module).

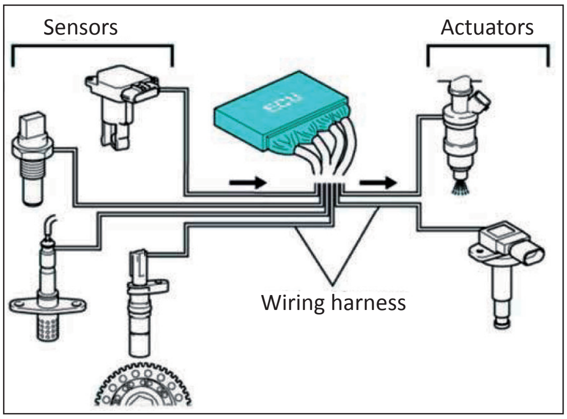
The sensors, actuators, and the engine ECU are connected with wiring harnesses. Only after the engine ECU processes the input signals from the sensors and outputs control signals to the actuators can the entire system operate as a computer-controlled system.

*The ECM is SAE (Society of Automotive Engineers) terminology.

Layout of EMS

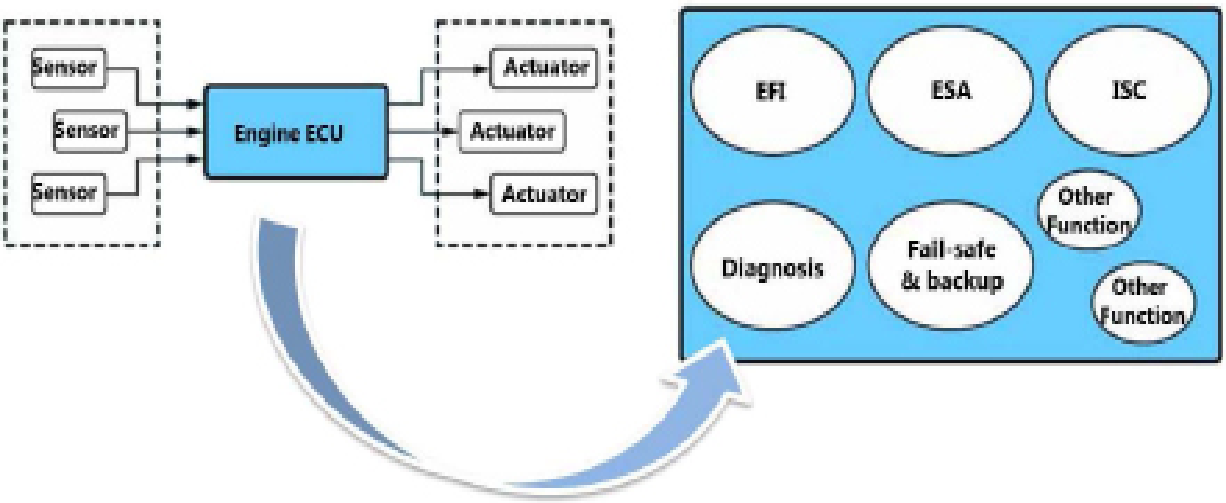
The engine control system consists of three groups:

- Sensors;
- Engine ECU;
- Actuators.



Description of EMS

The engine ECU functions are divided into EFI control, ESA control, ISC control, diagnosis function, fail-safe and backup functions, and other functions.

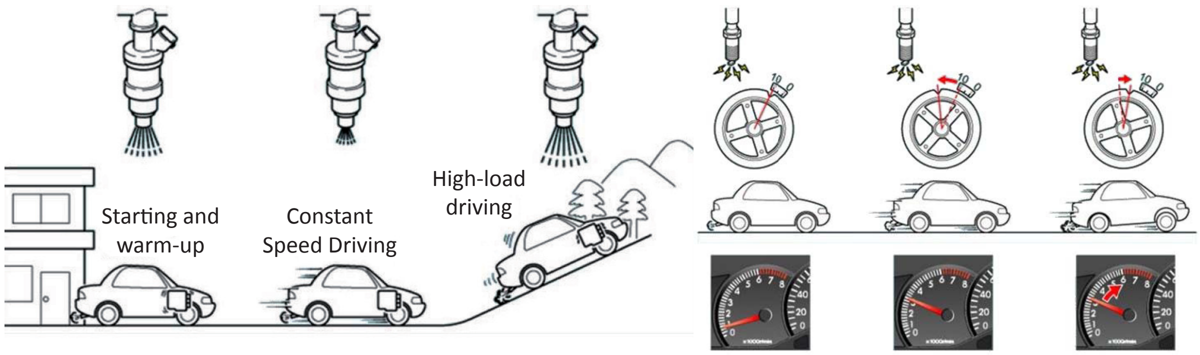


Functions of EMS

The EFI system uses various sensors to detect the operating conditions of the engine and the vehicle. In accordance with the signals from these sensors, the ECU calculates the optimal fuel injection volume and operates the injectors in order to inject the proper volume of fuel.

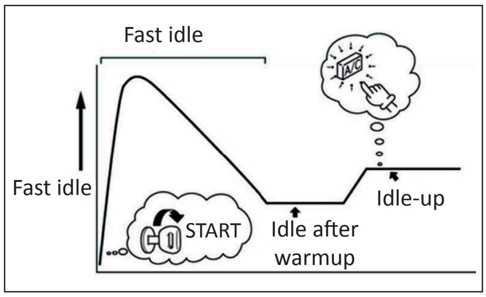
During ordinary driving, the engine ECU determines the fuel injection volume for achieving the theoretical air-fuel ratio, in order to ensure the proper power, fuel consumption and exhaust emission levels simultaneously.

At other times, such as during warm-up, acceleration, a deceleration or high-load driving condition, the engine ECU detect those conditions with the various sensors and then corrects the fuel injection volume in order to ensure an optimal air-fuel mixture at all times.



Outline of EFI (Electronic Fuel Injection) System

The ESA system detects the conditions of the engine based on the signals provided by various sensors, and controls the spark plugs to generate sparks at the appropriate timing. Based on engine speed and engine load, the ESA precisely controls the ignition timing so that the engine can generate improve power, purify exhaust gases, and prevent knocking in an effective manner.



The ISC system controls the idle speed so that it is always appropriate under varying conditions (warm-up, electrical load, etc.).

To minimize fuel consumption and noise, an engine must operate at a speed that is as low as possible while maintaining a stable idle. Moreover, the idle speed must be increased to ensure the proper warm-up and drivability when the engine is cold or the air conditioner is being used.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. What are the various functions of an Engine Management System?

2. Describe the outline of an Electronic Fuel Injection system..

Worksheet

1. *Read the questions and tick the correct answer.*

    a. Which of the following parameter/s are essentialfor a gasoline engine to produce power?

    i. Good air-fuel mixture ☐

    ii. Good compression ☐

    iii. Good spark ☐

    iv. All of the above ☐

b. Which of the following is/are group/s of the Engine Management System? .

i. Sensors ☐

ii. Wheels & tyres ☐

iii. Steering wheel ☐

iv. All of the above ☐

Notes

1

Answers: Introduction to EMS of Petrol Engine

Question Number	Answer
1	a. iv b. i

EMS Components - Petrol Engine

At the end of this session you will be able to:

- identify the vital components of EMS;
- describe the construction and working of each sensor of the EMS.

Session Plan	
1	Introduction
2	Sensors
3	Key Learnings
4	Worksheet

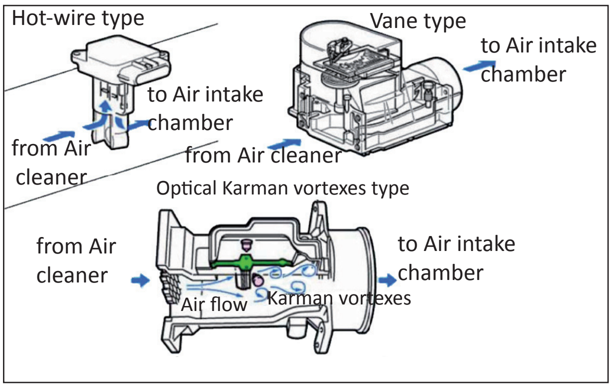
Introduction

The EMS consists of various vital components that work in sync with each other. The main components are sensors, whose input is fed to the engine ECU for efficient operation of the EMS.

Sensors

Air Flow Meter (Mass Air Flow Sensor)

The air flow meter is one of the most important sensors because it is used in L-type EFI to detect the intake air mass or volume. Signal of the intake air mass or volume is used to calculate the basic injection duration and basic ignition advance angle. The air flow meter is largely classified into two types, mass air flow meters that detect the intake air mass, and volume air flow meters, intake air mass, and volume air flow meters, respective types include the following:

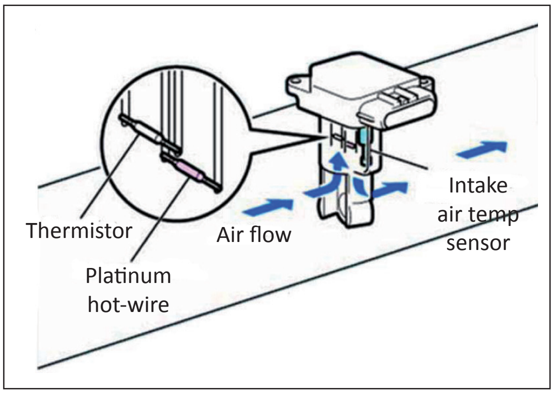


- Mass air flow meter: Hot-wire type.
- Volume air flow meter: Vane type and optical Karman vortex type.

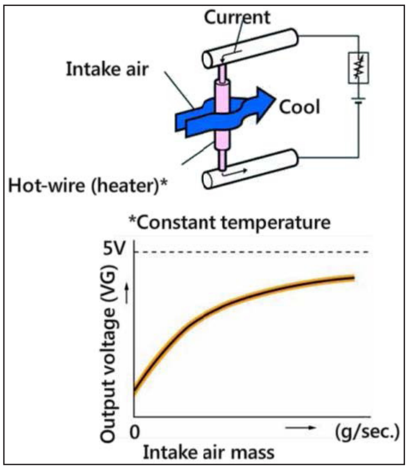
Currently, most models use the hot-wire type of air flow meter because it has superior measurement accuracy, lighter weight, and better durability.

Hot-wire type: Construction

The construction of the hot-wire type of air flow meter is very simple. The compact and lightweight mass air flow meter shown in the illustration at left is a plug-in type that is installed onto the air passage, and causes part of the intake air to flow through the detection area. As shown in the illustration, a hot-wire and thermistor, which are used as a sensor, are installed in the detection area. By directly measuring the intake air mass, detection precision is improved and there is almost no intake air resistance. In addition, since there are no special mechanisms, this meter has excellent durability. The air flow meter shown in the illustration also has a built-in intake air temperature sensor.



Hot-wire type: Operation and function

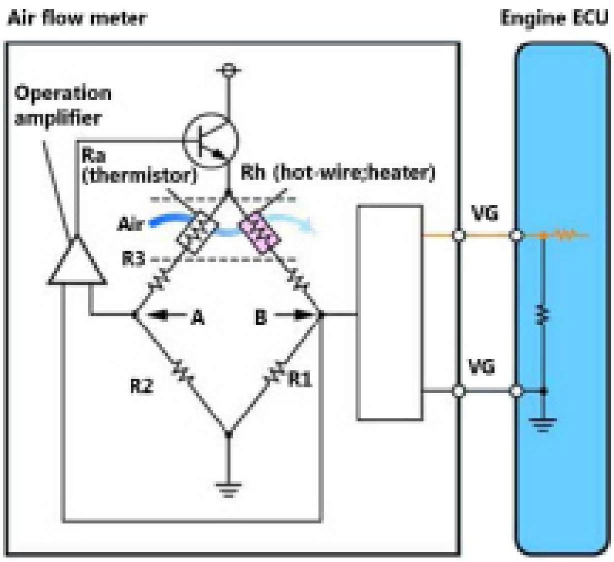


As shown in the illustration, current flows to the hot-wire (heater) causing it to be heated. When air flows around the wire, the hotwire is cooled corresponding to the intake air mass. By controlling the current flowing to the hot wire in order to keep the hot-wire temperature constant, that current becomes proportional to intake air mass. Intake air mass can then be measured by detecting that current. In case of hot-wire type air flow meter; this current is converted into a voltage that is then output to the engine ECU from the VG terminal.

Hot-wire type: Inner Circuit

In an actual air flow meter, as shown in the illustration, a hot wire is incorporated into the bridge circuit. This bridge circuit has the characteristic of the potentials at point A and B being equal when the product of resistance along the diagonal line is equal ([Ra+R3]·R1=Rh·R2).

When the hot wire (Rh) is cooled by intake air, resistance decreases resulting in the formation of a difference between the potentials of points A and B. An operational amplifier detects this difference and causes a rise in the voltage applied to the circuit (increases the current flowing to the hot-wire (Rh)). When this is done, the temperature of the hot-wire (Rh) again rises resulting in a corresponding increase in resistance until the potentials of points A and B become equal (the voltages of points A and B become higher). By utilizing the properties of this type of bridge circuit, the air flow meter is able to measure intake air mass by detecting the voltage at point B.



In this system, the temperature of the hot wire (Rh) is continuously maintained at a constant temperature higher than the temperature of the intake air by using the thermistor (Ra). Consequently, since intake air mass can be measured accurately even if intake air temperature changes, it is not necessary for the engine ECU to correct the fuel injection duration for the intake air temperature. At high altitudes, when air density decreases, the cooling capacity of the air decreases in comparison with the same intake air volume at sea level. As a result, the amount of cooling for the hot wire is reduced. Since the intake air mass detected will also decrease, the high-altitude compensation correction is not necessary.

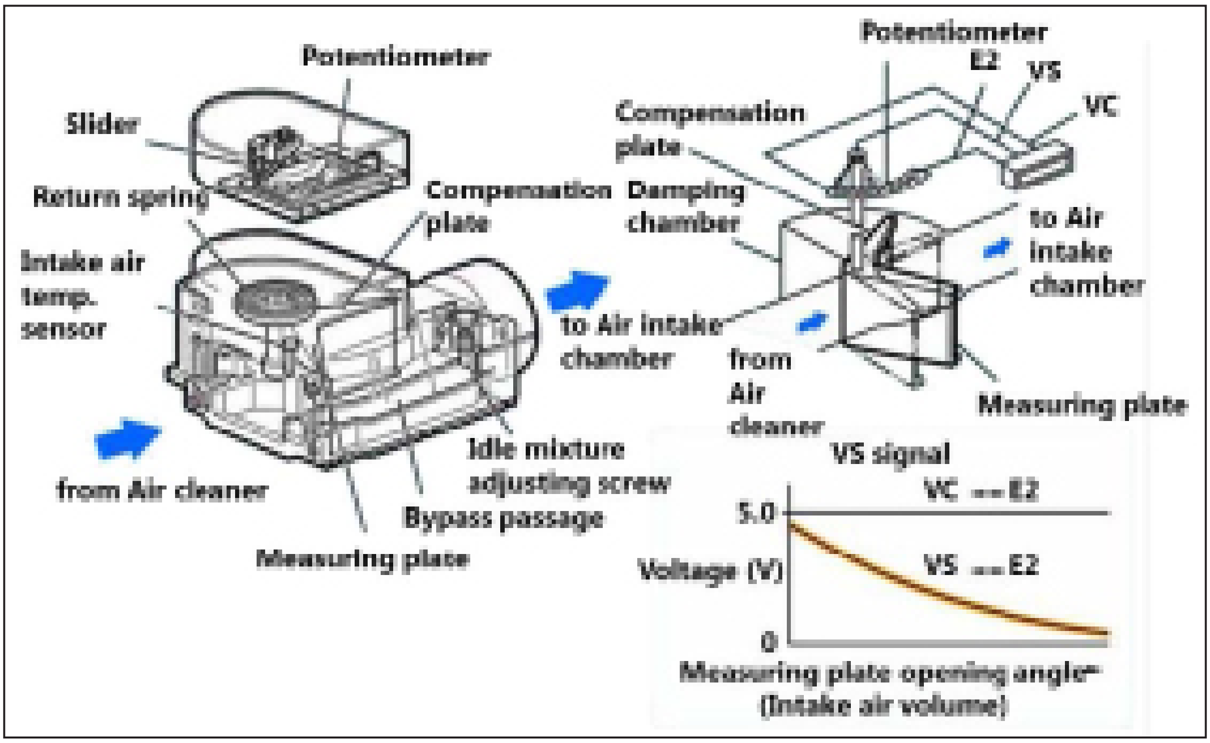
HINT:

The voltage (V) required to raise the temperature of the hot-wire (Rh) by the amount of ΔT from the intake air temperature remains constant at all times even if the intake air temperature changes. In addition, the cooling capacity of the air is always proportional to the intake air mass. Consequently, if the intake air mass remains the same, the output of the air flow meter will not change even if there is a change in intake air temperature.

Vane type

The vane type air flow meter is composed of many components, as shown in the illustration.

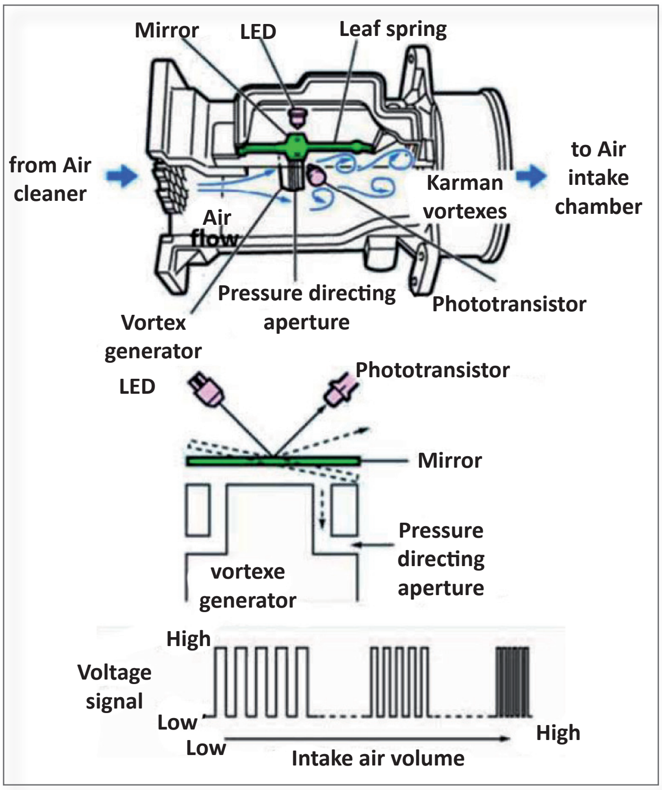
When air passes through the air flow meter from the air cleaner, it pushes open the measuring plate until the force acting on the measuring plate is in equilibrium with the return spring.The potentiometer, which is connected coaxially with the measuring plate, converts the intake air volume to a voltage signal (VS signal) which is sent to the engine ECU.



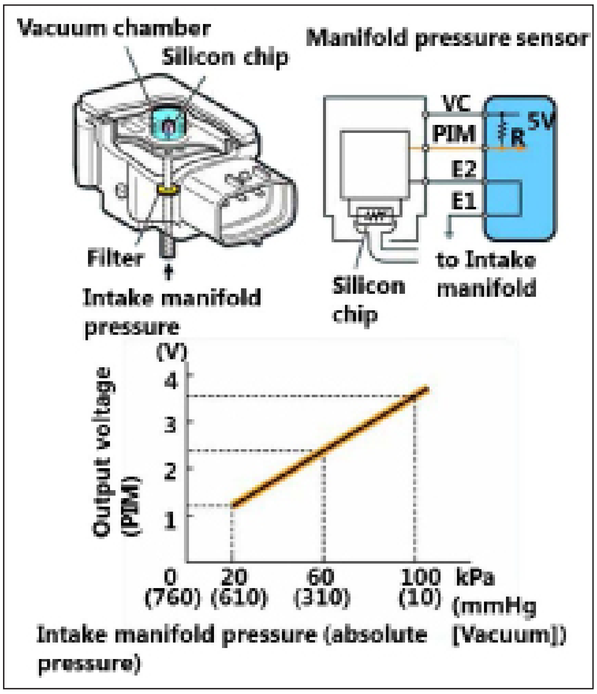
Optical Karman Vortex type

This type of air flow meter directly senses the intake air volume optically. Compared to the vane type air flow meter, it can be made smaller and lighter in weight. The simplified construction of the air passage also reduces intake air resistance.

A pillar (called the "vortex generator" placed in the middle of a uniform flow of air generates a vortex called a "Karman vortex" down-stream of the pillar. As the generated Karman vortex frequency is proportional to the air flow speed, the air flow volume can be calculated by measuring the vortex frequency.



Manifold pressure sensor (Vacuum Sensor)



The manifold pressure sensor is used with D-type EFI for sensing the intake manifold pressure. This is one of the most important sensors in D-type EFI.By means of an IC built into this sensor, the manifold pressure sensor senses the intake manifold pressure as a PIM signal. The engine ECU then determines the basic injection duration and basic ignition advance angle on the basis of this PIM signal.

A silicon chip combined with a vacuum chamber maintained at a predetermined vacuum is incorporated into the sensor unit. One side of the chip is exposed to intake manifold pressure and the other side is exposed to the internal vacuum chamber. Therefore, high-altitude compensation correction is not required because the intake manifold pressure can be measured accurately even when the altitude changes.

A change in the intake manifold pressure causes the shape of the silicon chip to change, and the resistance value of the chip fluctuates in accordance with the degree of deformation.

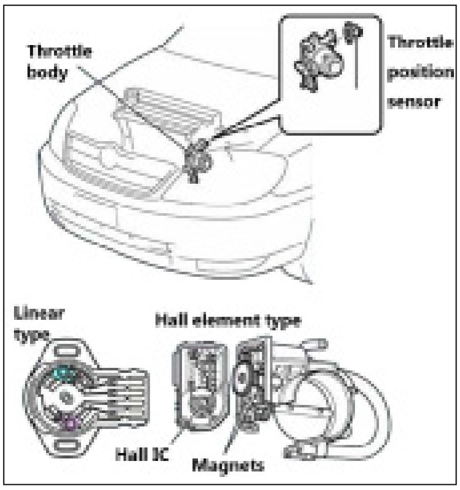
The voltage signal into which this resistance value fluctuation is converted by the IC is the PIM signal.

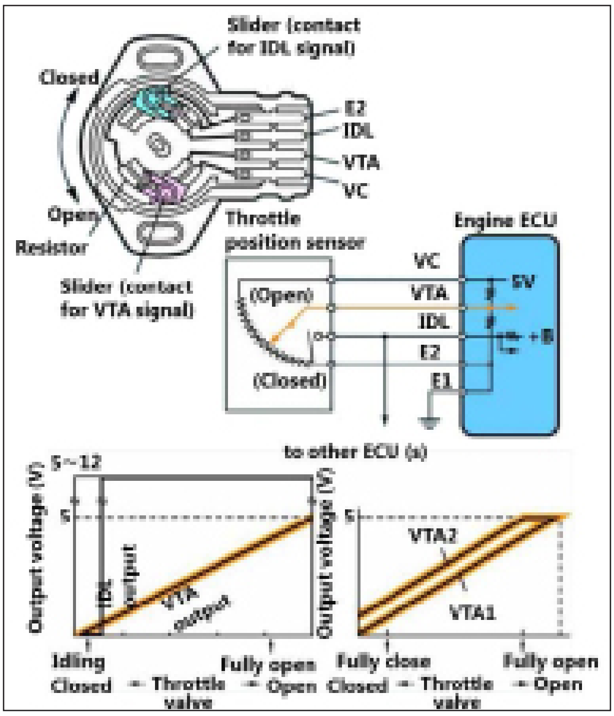
SERVICE HINT:

If the vacuum hose connected to the sensor comes off, the fuel injection volume will reach the maximum, and the engine will not run properly. In addition, if the connector comes off, the engine ECU will switch to the fail-safe mode.

Throttle Position Sensor

The throttle position sensor is installed on the throttle body. The sensor converts the throttle opening angle to voltage, which is sent to the engine ECU as the throttle opening signal (VTA). In addition, some devices output an individual IDL signal. Others determine it at idle when the VTA voltage is below the standard value. Currently, two types, the linear type and hall element type, are used. In addition, 2-system output is used to improve reliability.





Throttle Position Sensor: Linear type

As shown in the illustration, this sensor consists of two sliders and a resistor, and contacts for the IDL and VTA signals are provided on the ends of each. When the contact slides along the resistor in sync with the throttle valve opening angle, the voltage is applied to the VTA terminal proportionally to the throttle opening angle. When the throttle valve is completely closed, the IDL signal contact is connected to the IDL and E2 terminals.

HINT:

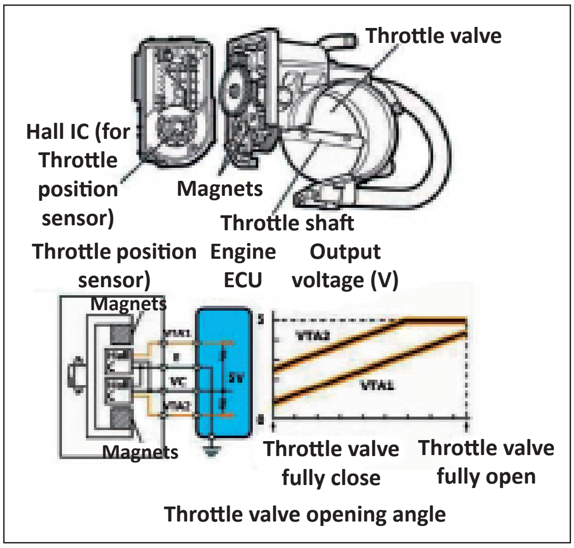
Recent linear type throttle position sensors include models without an IDL contact or models that have an IDL contact but it is not connected to the engine ECU. These models use the VTA signal to perform learned control and detect idling condition.

Some models use two-system output (VTA1, VTA2) to improve reliability.

Throttle Position Sensor: Hall element type

The hall element type throttle position sensor consists of a hall ICs made of hall elements and of magnets that rotates around them. The magnets are installed above the same axis as the throttle shaft and rotate together with the throttle valve.

When the throttle valve opens, the magnets rotate at the same time, and the magnets change their position. At this time, the hall IC detects a change in the magnetic flux caused by the change in the magnet's position, and the resulting hall effect outputs voltage from the VTA1 and VTA2 terminals in accordance with the amount of change. This signal is sent to the engine ECU as the throttle valve opening signal.



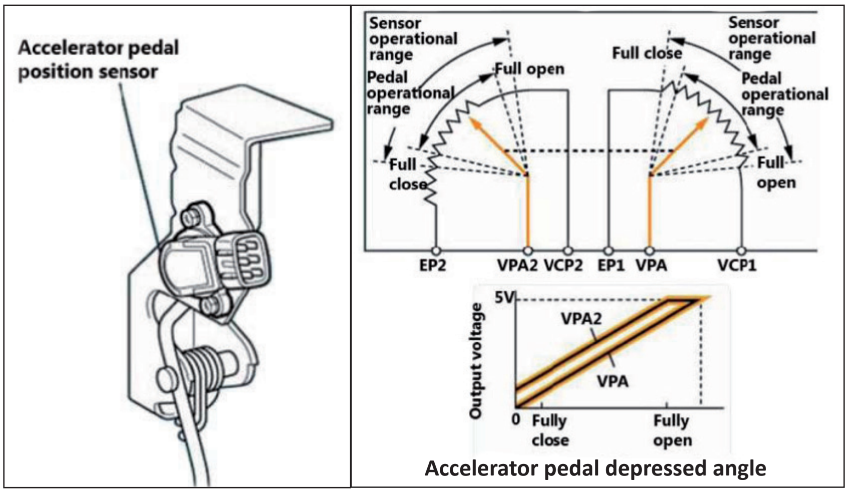
This sensor not only accurately detects the throttle valve opening, but it also uses a non-contact method and has a simple construction, so it does not break down easily. In addition, to maintain the reliability of this sensor, it outputs signals from two systems with different output characteristics.

Accelerator Pedal Position Sensor

The accelerator pedal position sensor converts the amount that the accelerator pedal is depressed (angle) to an electrical signal that is sent to the engine ECU. In addition, to ensure reliability, this sensor outputs signals from two systems with differing output characteristics. There are two types of accelerator pedal position sensors, the linear type and hall element type.

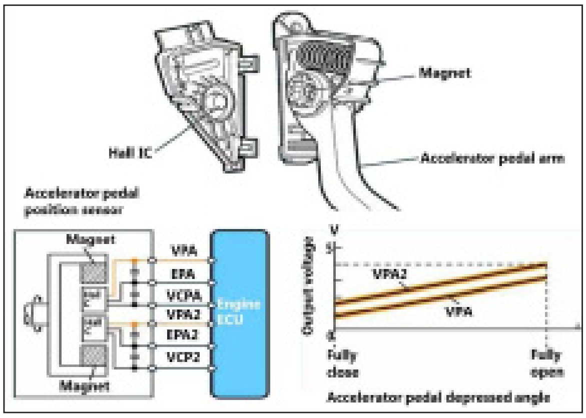
Accelerator Pedal Position Sensor: Linear type

The construction and operation of this sensor is basically the same as the linear type throttle position sensor. Of the signals from the two systems, one is a VPA signal that linearly outputs the voltage within the entire range of the accelerator pedal depression. The other is the VPA2 signal, which outputs the offset voltage from the VPA signal.



SERVICE HINT:

Do not remove the sensor. Extremely fine position adjustment is required when installing the sensor. Therefore, replace the accelerator pedal assembly when the sensor malfunctions.



Accelerator Pedal Position Sensor:

Hall element type

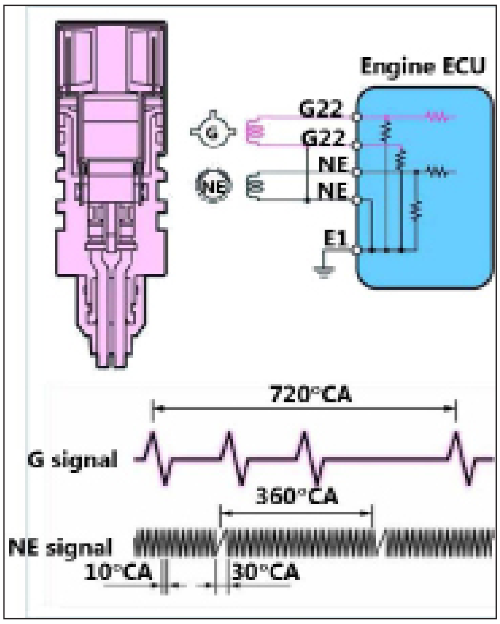
The construction and operation of this sensor is basically the same as the hall element type throttle position sensor. To ensure better reliability, an independent electrical circuit is provided for each of the two systems.

Camshaft and Crankshaft Sensors

The Camshaft signal and Crankshaft signals are generated by the pickup coil, in which the camshaft position sensor or crankshaft position sensor, and the signal plate or the timing rotor. The information from these two signals is combined by the engine ECU to comprehensively detect the crankshaft angle and engine speed. These two signals are not only very important to the EFI systems but to the ESA system as well.

Camshaft Position Sensor (G Signal Generator)

On the camshaft opposite the camshaft position sensor is a G signal plate with a protrusion(s). The numbers of protrusions are 1, 3, or another number depending on the engine model. (There are 3 protrusions in the illustration). When the camshaft rotates, the air gap between the protrusions on the camshaft and the sensor changes.This change in gap generates a voltage in the pickup coil built into the sensor, resulting in the G signal. This G signal is sent as the information of the standard crankshaft angle to the engine ECU, which combines it with the NE signal from the crankshaft position sensor to determine the compression TDC (Top Dead Center) of each cylinder for ignition and detect the crankshaft angle. The engine ECU uses this to determine the injection duration and the ignition timing

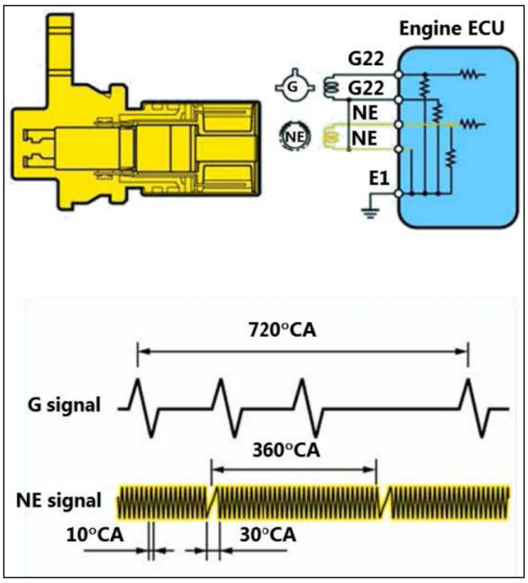


SERVICE HINT:

When a G signal from the sensor is not received by the engine ECU, there are models where the engine keeps running and a model where the engine stops

Crankshaft Position Sensor (Ne Signal Generator)

NE signal is used by the engine ECU to detect the crankshaft angle and engine speed



The engine ECU uses the NE signal and G signal to calculate the basic injection duration and basic ignition advance angle. As with the G signal, the NE signal is generated by the air gap between the crankshaft position sensor and the protrusions on the NE timing rotor periphery installed on the crankshaft. The illustration shows a type of signal generator with 34 protrusions on the NE timing rotor periphery and an area with two teeth missing.

The area with two teeth missing can be used to detect the crankshaft angle, but it cannot determine whether it is at the TDC of the compression cycle or the TDC of the exhaust cycle

The engine ECU combines the NE signal and G signal to comprehensively and accurately determine the crankshaft angle.

In addition to this, some signal generators have 12, 24, or another number of protrusions, but the crankshaft angle detection accuracy varies depending on the number of protrusions. For example, types with 12 protrusions have a crankshaft angle detection accuracy of 30°CA.

SERVICE HINT:

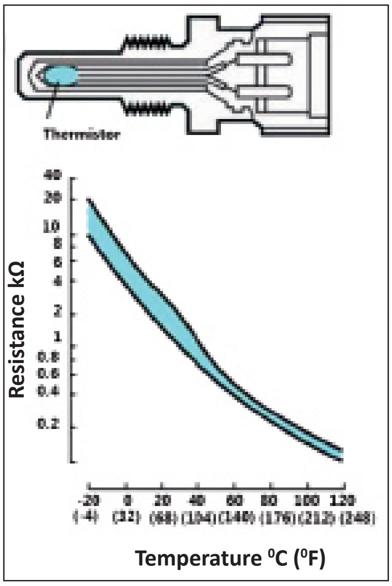
When the NE signal from the sensor is not received by the engine ECU, the engine ECU determines that the engine has stopped, causing the engine to stop.

Water Temperature Sensor/Intake Air Temperature Sensor

The water temperature sensor and intake air temperature sensor have built-in thermistors for which the lower the temperature, the larger the resistance value and, conversely, the higher the temperature, the lower the resistance value. And this change of the thermistor resistance value is used to detect the changes in the coolant and intake air temperatures.

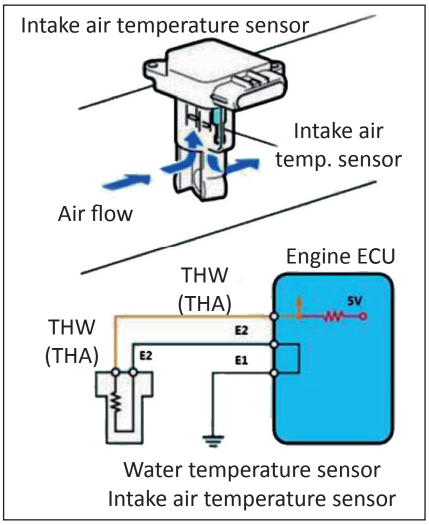
The built-in resistor in the engine ECU and the thermistor in the sensor are in connected in series in the electric circuit so that the signal voltage detected by the engine ECU changes in accordance with the changes in the thermistor resistance. When the temperature of the coolant or intake air is low, the thermistor resistance becomes large, creating a high voltage in the THW and THA signals.

Water Temperature Sensor



Water Temperature Sensor

The water temperature sensor measures the temperature of the engine coolant. When the engine coolant temperature is low, the idling must be increased, the injection duration increased, the ignition timing angle advanced, etc., to improve drivability and to warm up. For this reason, the water temperature sensor is indispensable for the engine control system



Intake Air Temperature Sensor

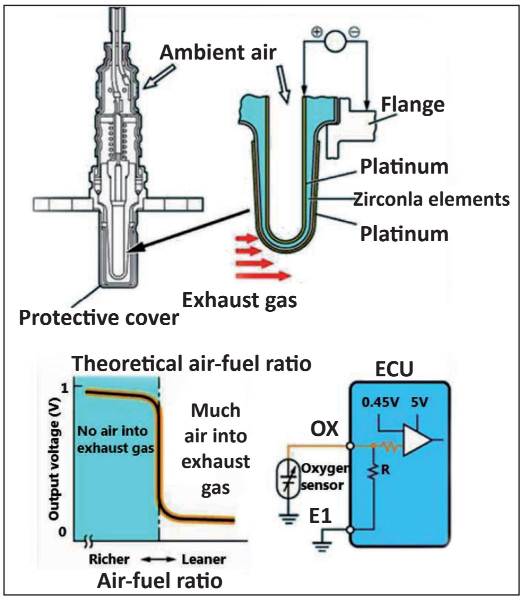
The intake air temperature sensor measures the temperature of the intake air. The air amount and density changes according to the air temperature.Therefore, even if the air amount detected by the air flow meter is the same, the amount of fuel that is injected must be corrected. However, hot-wire type air flow meter directly measures the air mass. Therefore, the correction is not required.

Oxygen Sensor (O2 Sensor)

To maximize the exhaust purification function of the engine with TWC (Three-Way Catalytic Converter), the air-fuel ratio must be kept within a narrow range around the theoretical air-fuel ratio.

The oxygen sensor detects whether the oxygen concentration in the exhaust gas is richer or leaner than the theoretical air-fuel ratio. The sensor is mainly installed in the exhaust manifold, but the location and number that are installed differ depending on the engine.

The oxygen sensor contains an element made of zirconium oxide (ZrO_2), which is a type of ceramic. The inside and outside of this element is covered with a thin coating of platinum. The ambient air is guided into the inside of the sensor and the outside of the sensor is exposed to the exhaust gas.



At high temperatures (400°C [752°F] and higher), the zirconium element generates a voltage as a result of the large difference between the oxygen concentrations on the inside and outside of the zirconium element.

In addition, the platinum acts as a catalyst to cause a chemical reaction between the oxygen and carbon monoxide (CO) in the exhaust gas. Therefore, this reduces the amount of oxygen and increases sensor sensitivity.

When the air-fuel mixture is lean, there is much oxygen in the exhaust gas so that there is only a little difference in the oxygen concentration between the inside and outside of the zirconium element. Therefore, the zirconium element will only generate a low voltage (nearly 0 V).

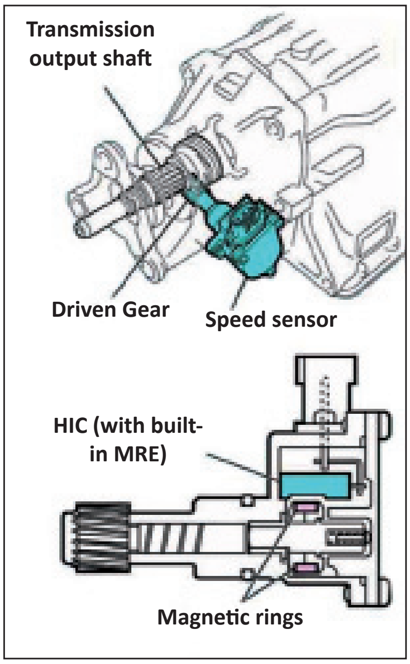
Conversely, when the air-fuel mixture is rich, there is almost no oxygen in the exhaust gas. For this reason, there is a large difference in the oxygen concentration between the inside and outside of the sensor so that the zirconium element generates a relatively large voltage (approx. 1 V).

Based on the OX signal output by the sensor, the engine ECU increases or decreases the fuel injection volume so that the average air-fuel ratio is maintained at the theoretical air-fuel ratio.

Some zirconium oxygen sensors have heaters to heat the zirconia element. This heater is also controlled by the engine ECU. When the amount of the intake air is low (in other words, when the exhaust gas temperature is low), current is sent to the heater to heat the sensor.

Vehicle Speed Sensor

The speed sensor detects the actual speed at which the vehicle is running. The sensor outputs the SPD signal, and the engine ECU uses this signal mainly to control the ISC system and the air-fuel ratio during acceleration or deceleration as well as other uses. The MRE (Magnetic Resistance Element) types are the main type of speed sensor used, but recently many models use the SPD signal from the ABS ECU.



Vehicle Speed Sensor:

MRE type – Construction

This sensor is installed on the transaxle, transmission, or transfer, and is driven by the drive gear of the output shaft. As shown in the illustration, the sensor is built-in and consists of a HIC (Hybrid Integrated Circuit) with a MRE and magnetic rings.

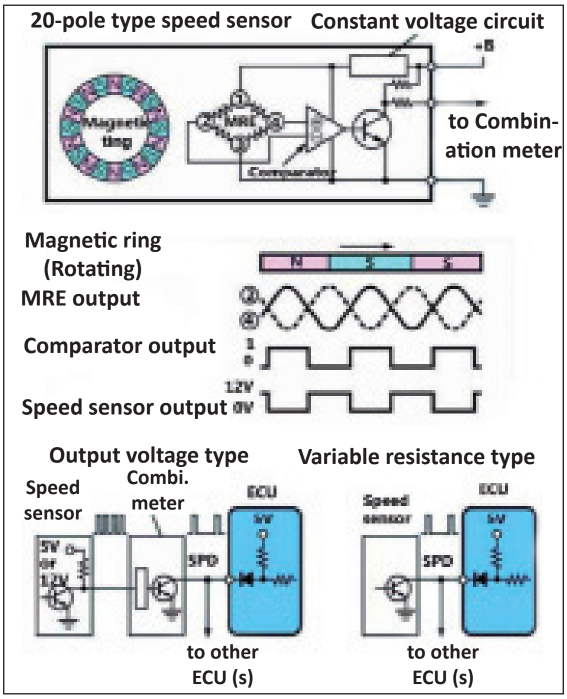
Vehicle Speed Sensor:

MRE type - Operation

The MRE resistance changes depending on the direction of the magnetic force applied to the MRE. When the direction of the magnetic force changes according to the rotation of the magnet attached to the magnetic ring, the MRE output becomes an AC waveform as shown in the illustration.

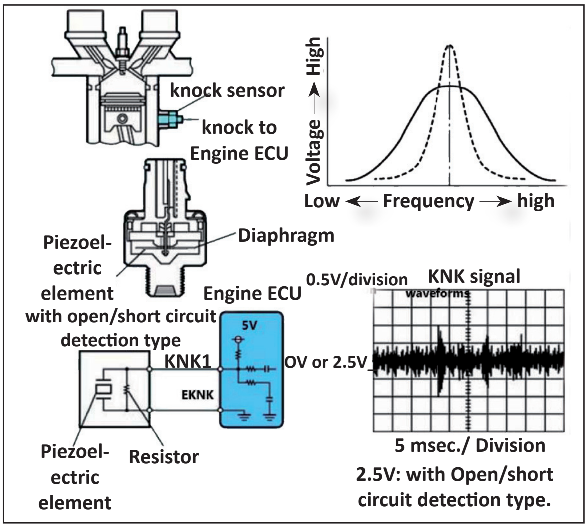
The comparator in the sensor converts this AC waveform into a digital signal and outputs it. The waveform frequency is determined by the number of poles of the magnets attached to the magnetic ring.

There are two types of magnetic rings, 20-pole type and 4-pole type, depending on the vehicle model. The 20-pole type generates a 20-cycle waveform (in other words, twenty pulses for each rotation of the magnetic ring), and the 4-pole type generates a 4-cycle waveform. In some models, the signal from the speed sensor passes through the combination meter before arriving at the engine ECU, and in the other models, the signal from the speed sensor arrives directly at the engine ECU. The output circuits of the speed sensor consist of the output voltage type and the variable resistance type.



Knock Sensor

The knock sensor is attached to the cylinder block, and sends a KNK signal to the engine ECU when engine knocking is detected. The engine ECU receives the KNK signal and retards the ignition timing to suppress the knocking. This sensor contains a piezoelectric element, which generates an AC voltage when knocking causes vibration in the cylinder block and deforms the element.



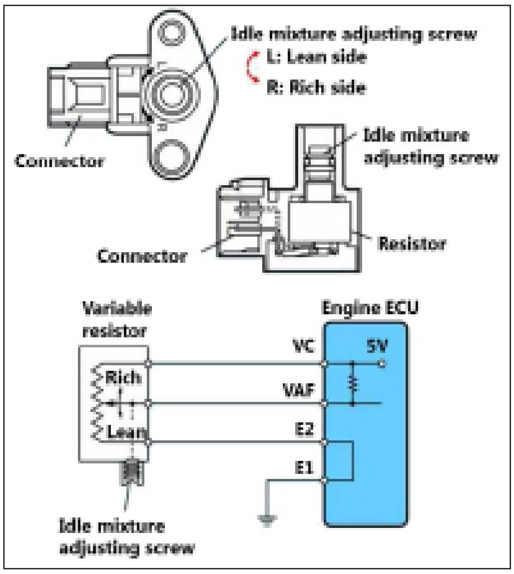
The engine knock frequency is in the range of 6 to 13 kHz depending on the engine model. The proper knock sensor is used in accordance with the knocking generated by each engine

There are two types of knock sensors. As can be seen from the graph, one type generates a high voltage in a narrow vibration frequency range, and the other generates a high voltage in a wide vibration frequency range.

Recently some sensors that detect open and short circuits, as shown in the illustration, have come into use. In this type of circuit, 2.5 V is constantly supplied so the KNK signal is also output with a 2.5 V base frequency.

Variable Resistor

When the VAF terminal voltage increases, the engine ECU slightly increases the fuel injection volume to make the air-fuel mixture a little richer.



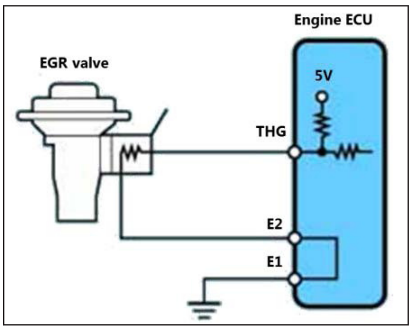
HINT:

As the vane type air flow meter has an idle mixture adjusting screw in its body, a variable resistor is not required even if there is no oxygen sensor.

The variable resistor is used to change the air-fuel ratio during idling and to adjust the idling CO.

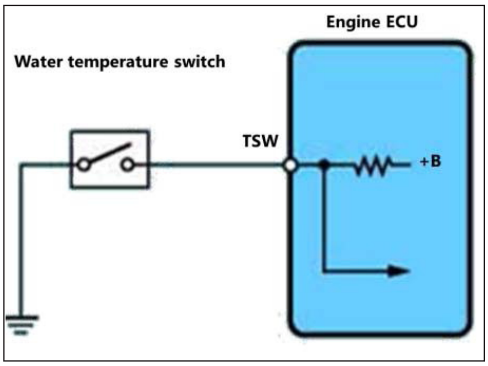
The variable resistor is installed in models without an oxygen sensor or air fuel ratio sensor

When the idle mixture adjusting screw is turned to the R direction, the contact inside the resistor moves to increase the VAF terminal voltage. Conversely, when the screw is turned to the L direction, the VAF terminal voltage is decreased.



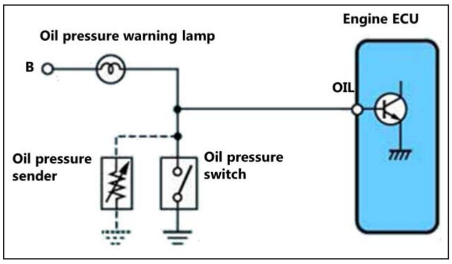
Egr Gas Temperature Sensor

The EGR gas temperature sensor is installed inside the EGR valve and uses a thermistor to measure the EGR gas temperature.



Water Temperature Switch

The water temperature switch is attached to the cylinder block, and turns ON when the coolant temperature become high.



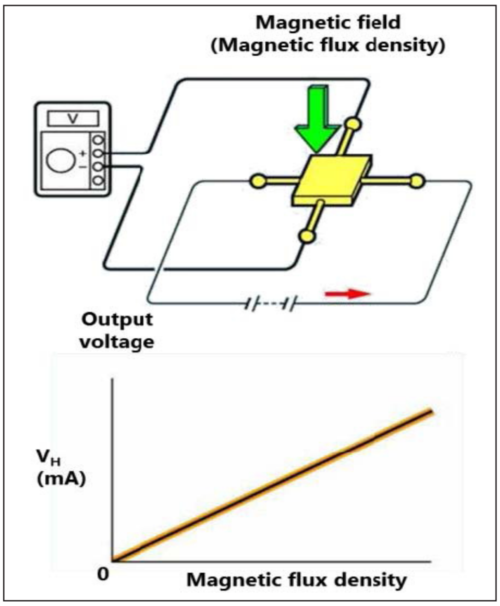
Oil Pressure Switch

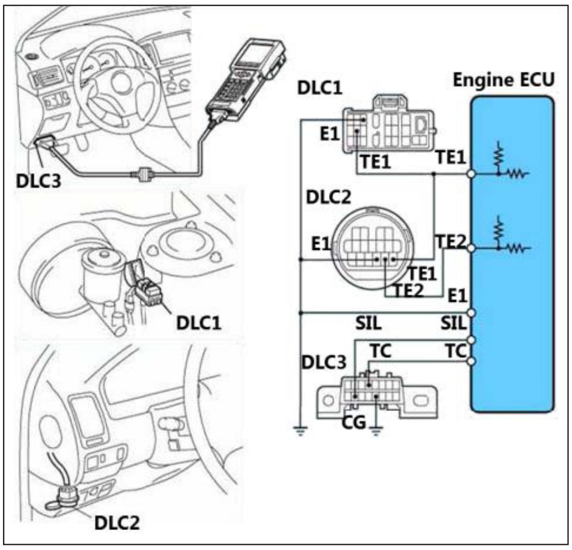
The oil pressure switch signal is used to determine the low engine oil pressure. The oil pressure signal is used to control the ISC system. When the oil pressure is low, the lubrication and cooling of the engine components will be hindered. Therefore, the engine ECU will increase idling speed, etc., to restore the oil pressure to the normal level.

Hall Effect

The hall effect is the electrical potential difference that occurs perpendicular to the current and magnetic field when a magnetic field is applied perpendicular to the current flowing in a conductor. In addition, the voltage generated by this electrical potential difference, changes proportionally to the applied magnetic flux density.

The hall element type throttle position sensor utilizes this principle to convert the change in throttle valve position (opening) to a change in flux density to accurately measure the change in throttle valve position.





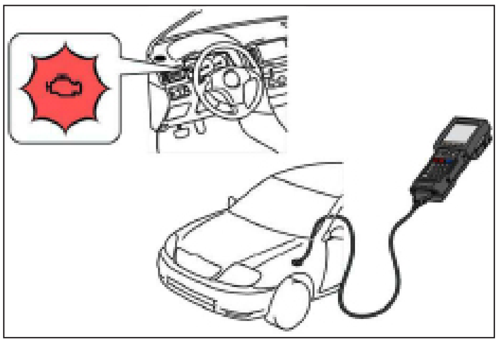
Diagnostic Terminal

When the engine ECU stores a DTC (Diagnostic Trouble Code) in memory, the DTC must be checked and repairs must be performed. The DLC contains a DLC3 SIL terminal, which is required to display the DTC to communicate directly with the engine ECU when the handheld tester is used, TE1, TE2, E1, TC and CG terminals which cause the MIL to flash.

Outline Of Diagnostic System

The ECU constantly monitors the signals that are being input by various sensors. If it detects a malfunction with an input signal, the ECU records the malfunction in the form of DTCs (Diagnostic Trouble Codes) and illuminates the MIL (Malfunction Indicator Lamp).

If necessary, the ECU can output the DTCs by blinking the MIL or displaying the DTCs or other data on the display panel of a handheld tester.



The diagnostic functions that output the DTCs and data of a malfunction on a hand-held tester are a highly advanced and complex form of electronics system. Because a diagnostic system must comply with the regulations of each country, its contents vary slightly by destination.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. Describe the construction of a hot wire type air flow sensor.

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2. What do you understand by a knock sensor?

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3. Describe the working of a vehicle speed sensor.

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4. What is the purpose of an Oxygen sensor in the EMS system?

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Worksheet

1. *Read the questions and tick the correct answer.*

   a. DTC stands for ______________________ .

      i. Diagnostic Trouble Code ☐

      ii. Double Trouble Code ☐

      iii. Distance Trouble Code ☐

      iv. All of the above ☐

   b. Currently, most models use the hot-wire type of air flow meter because it has superior measurement accuracy, lighter weight, and better durability.

      i. True ☐

      ii. False ☐

Notes

Answers: EMS Components - Petrol Engine

Question Number	Answer
1	a. i b. i

EMS Schematic and its Checking - Petrol Engine

At the end of this session you will be able to:

- describe the working of various power circuits;
- identify and trace the ground, power and sensor circuitry of ECM.

Session Plan	
1	Introduction
2	Power Circuitry
3	Ground Circuitry
4	Sensor Terminal Voltage
5	Key Learnings
6	Worksheet

Introduction

The ECM which is the heart of the EMS system in modern Automobiles has Power, Ground and Control circuits within itself to measure the sensor output, control the actuators and for OBD self-diagnostics. ECM gets the Power and Ground from Battery.

This session will explain in detail about all the circuitry of ECM.

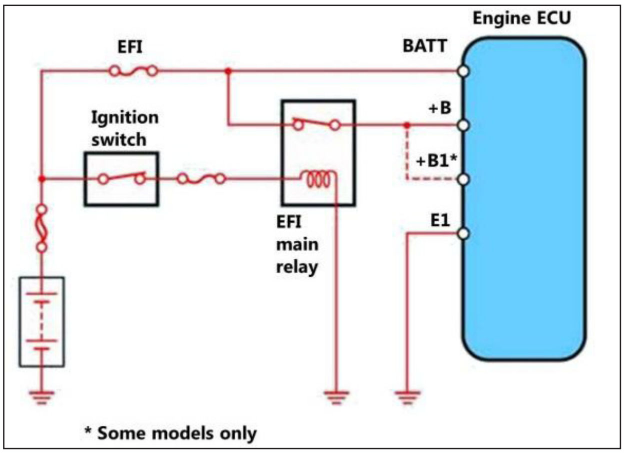
Power Circuitry

The power circuitry is the electrical circuits that supply power to the engine ECU. These electric circuits include the ignition switch, the EFI main relay, etc.The power circuitries used most commonly in automobiles are of the following two types:

- Control by ignition switch;
- Control by engine ECU.

Control by ignition switch

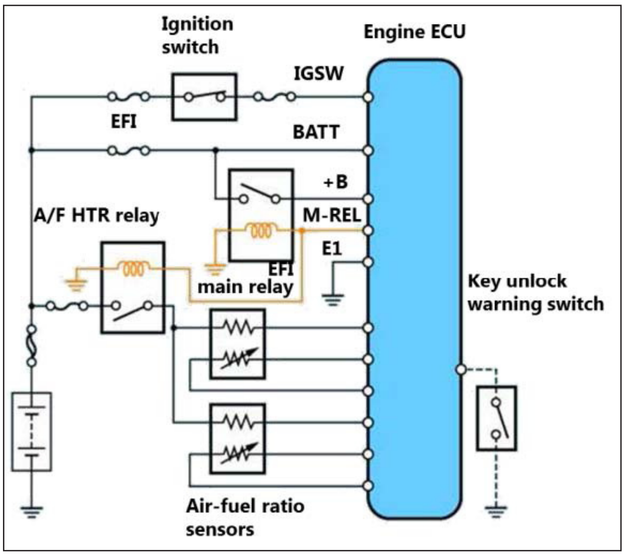
The diagrams show the type in which the EFI main relay is operated directly from the ignition switch. When the ignition switch is turned on, current flows to the coil of the EFI main relay causing the contacts to close. This supplies power to the +B and +B1 terminals of the engine ECU.



Battery voltage is supplied at all times to the BATT terminal of the engine ECU to prevent the diagnostic codes and other data in its memory from being erased when the ignition switch is turned off.

Control by Engine ECU

The power circuitry in the illustration is the type where operation of the EFI main relay is controlled by the engine ECU. This type requires that power be supplied to the engine ECU for several seconds after the ignition switch is turned OFF. Therefore, the turning ON and OFF of the EFI main relay is controlled by the engine ECU.



When the ignition switch is turned ON, battery voltage is supplied to the IGSW terminal of the engine ECU, and the EFI main relay control circuitry in the engine ECU sends a signal to the M-REL terminal of the engine ECU, turning on the EFI main relay. This signal causes current to flow to the coil, closing the contacts of the EFI main relay and supplying power to the +B terminal of the engine ECU. Battery voltage is always supplied to the BATT terminal for the same reason as Auto Service Technician

for the control by ignition switch type. In addition, some models include a special relay for the air-fuel ratio sensor heater circuitry which is required large amount of current.

Ground Circuitry

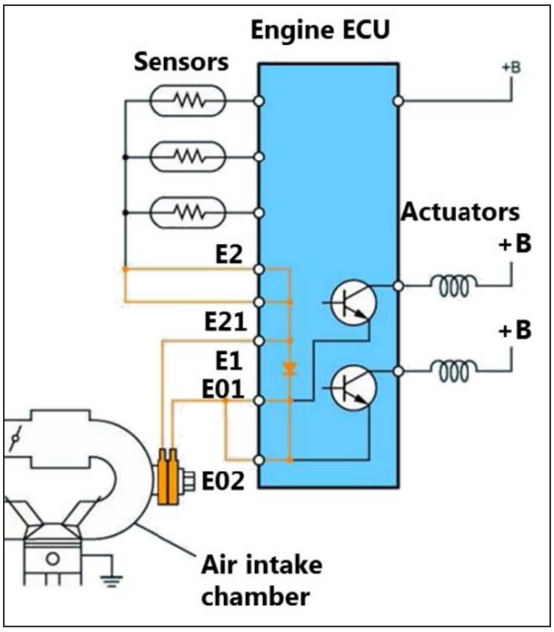
The engine ECU contains the following three basic ground circuits:

Ground for engine ECU operation (E1)

- The E1 terminal is the engine ECU unit ground terminal, and is normally connected close to the air intake chamber of the engine.

  Sensor grounds (E2, E21)

- The E2 and E21 terminals are sensor ground terminals, and these are connected to the E1 terminal in the engine ECU
- These prevent the sensors from detecting erroneous voltage values by keeping the sensor ground potential and engine ECU ground potential at the same level

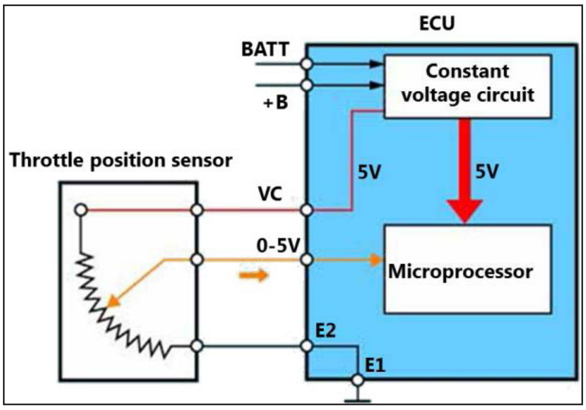


Grounds for actuator operation (E01, E02)

- The E01 and E02 terminals are actuator ground terminals, such as for the actuators, ISC valve, and air-fuel ratio sensor heater, and, as with the E1 terminal, they are connected close to the air intake chamber of the engine

Sensor Terminal Voltage

The sensor convertsvarious information into voltage change, which can be detected by the engine ECU. There are many types of sensor signals, but there are five main types of methods for converting the information into voltage. Understanding the characteristics of these types makes it possible to determine during measurement if the terminal voltage is correct or not.



Using VC voltage (VTA, PIM)

A 5V constant voltage (VC voltage) for operating the microprocessor is created inside the engine ECU by the battery voltage. This constant voltage, which is supplied as the sensor power source, is the VC terminal voltage.

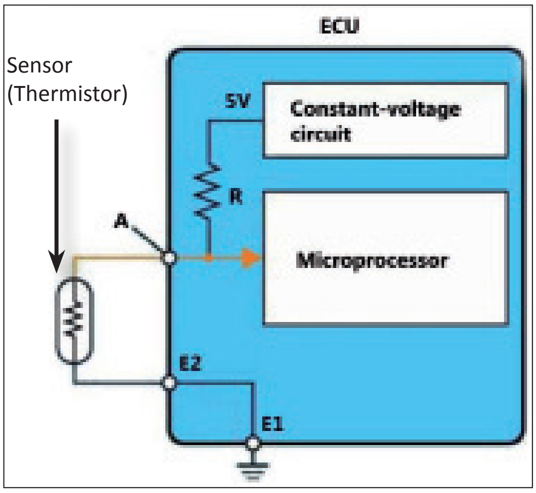
In this type of sensor, a voltage (5 V) is applied between the VC and E2 terminals from the constant-voltage circuit in the engine ECU as shown in the illustration. Then, this sensor substitutes the detected throttle valve opening or the intake manifold pressure for the voltage change between 0 and 5 V in order to output.

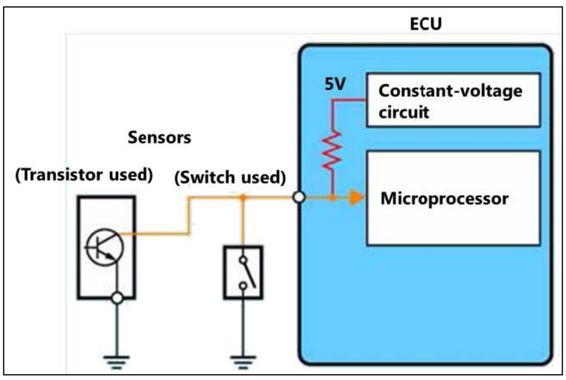
Using a thermistor (THW, THA)

A thermistor's resistance value changes in accordance with the temperature. For this reason, thermistors are used in such devices as the water temperature sensor and intake air temperature sensor, to detect changes in temperature.

As shown in the illustration, voltage is supplied to the sensor thermistor from the constant-voltage circuit (5 V) in the engine ECU via resistor R. The properties of the thermistor are used by the engine ECU to detect the temperature using the change in voltage at point A.

When the thermistor or wire harness circuit is open, the voltage at point A becomes 5 V, and when there is a short from point A to the sensor, the voltage becomes 0 V. Therefore, the engine ECU will detect a malfunction using the diagnosis function.





Using voltage ON/OFF

Devices using a switch (IDL, NSW):

When the voltage turns ON and OFF, it causes the sensor to detect the switch ON/OFF condition.A voltage of 5 V is applied to the switch by the engine ECU. The engine ECU terminal voltage is 5 V when the switch is OFF, and 0 V when the switch is ON.The engine ECU uses this change in voltage to detect the sensor condition.In addition, some devices use a battery voltage 12 V.

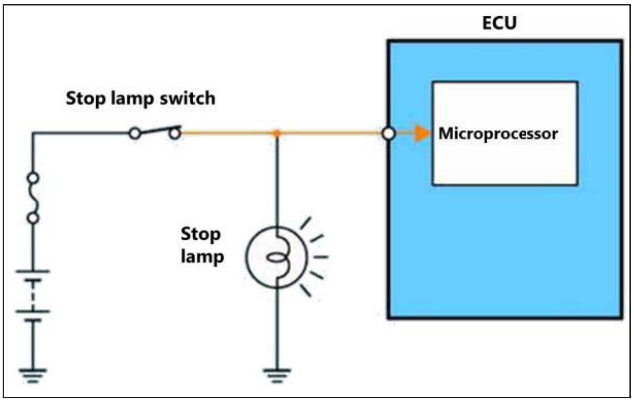
Devices using a transistor (IGF, SPD):

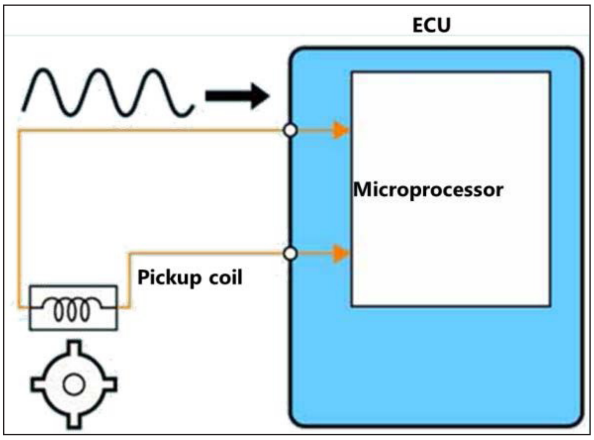
This is a device that uses transistor switching instead of a switch. As with the above device, the turning ON and OFF of the voltage is used to detect the sensor operation condition.

As with devices that use a switch, a voltage of 5 V is applied to the sensor from the engine ECU, and the engine ECU uses the change in terminal voltage when the transistor turns ON or OFF to detect the condition of the sensor. In addition, some devices use a battery voltage 12.

Using a power supply other than from the engine ECU (STA, STP)

The engine ECU determines whether another device is operating by detecting the voltage that is applied when another electrical device is operating.The illustration shows a stop lamp circuit, and when the switch is ON, a battery voltage 12 V is applied to the engine ECU terminal, and when the switch is OFF, the voltage becomes 0 V.





Using voltage generated by the sensor (G, NE, OX, KNK)

As the sensor generates and outputs power itself, a voltage does not need to be applied to the sensor.The engine ECU determines the operation condition by the voltage and frequency of the generated power.

HINT:

When inspecting the engine ECU terminal voltage, the NE signal, KNK signal and etc. are output in an AC waveform. Therefore, highly accurate measurements can be taken using an oscilloscope.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. What are the main Power Circuitries which supply the power to ECM?

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2. Explain the three main ground circuits of ECM.

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Worksheet

1. *Read the questions and tick the correct answer.*

a. NE Signals (CKP Sensor) are in ______________________.wave form

- i. DC ☐
- ii. Short ☐
- iii. AC ☐
- iv. Both A & B ☐

b. In thermistor type sensors, the resistance changes in accordance with the voltage

- i. True ☐
- ii. False ☐

Notes

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Answers: EMS Schematic & its checking - Petrol Engine

Question Number	Answer
1	a. iii b. ii

Introduction to EMS of Diesel Engines

At the end of this session you will be able to:

- describe the EMS system of a Diesel engine.

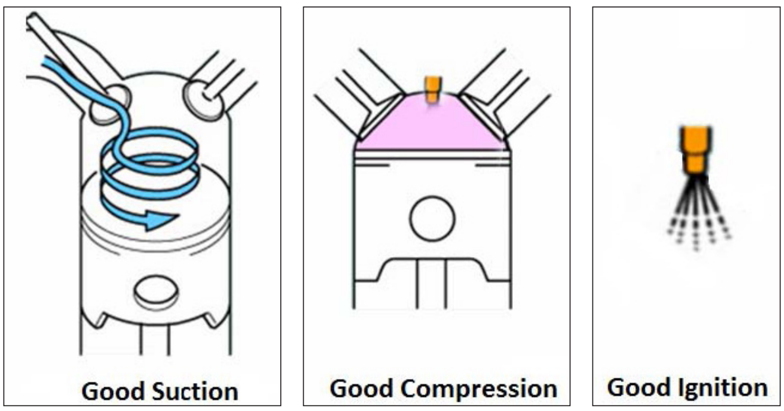
Session Plan	
1	Introduction
2	EMS of Diesel Engines
3	Functions of EMS System
4	Key Learnings
5	Worksheet

Introduction

In any diesel engine, to get the maximum power with the available engine capacity and fuel system, there should be a good suction, good compression and a good injection to achieve proper combustion. To achieve this, modern Automobiles have an ECM (Engine Control Module) which collects the information from different sensors and gives output commands to actuators. The ECM has self-diagnostic capabilities which can inform the driver in case of malfunction. We will learn about the ECM, Sensors and the Actuators in this session

EMS of Diesel Engines

- A diesel engine produces power through an explosion when fuel is sprayed on compressed air.
- The three essential elements for a Diesel engine to produce power are the following:
  - Good compression;
  - High pressure Injection of diesel.



To achieve these elements simultaneously, it is important to precisely control the injection of fuel to create proper combustion and maximum efficiency.

Layout of Engine Management System

The engine control system consists of three groups:

- Sensors
- Engine ECU
- Actuators.

Diesel Engine Management System Structure

Low Pressure

- Fuel Tank
- Advance Fuel Pump (in Tank)
- Outlet Protection Valves
- In-line Electric Fuel Pump
- Fuel Filter With Inlet Pressure Sensor
- Pressure Relief Valve (Low Pressure System)
- Fuel Cooler.

High Pressure

- High-Pressure Fuel Pump
- Fuel High-Pressure Accumulator (Rail)
- Pressure Control Valve
- Rail Pressure Sensor
- Injectors.

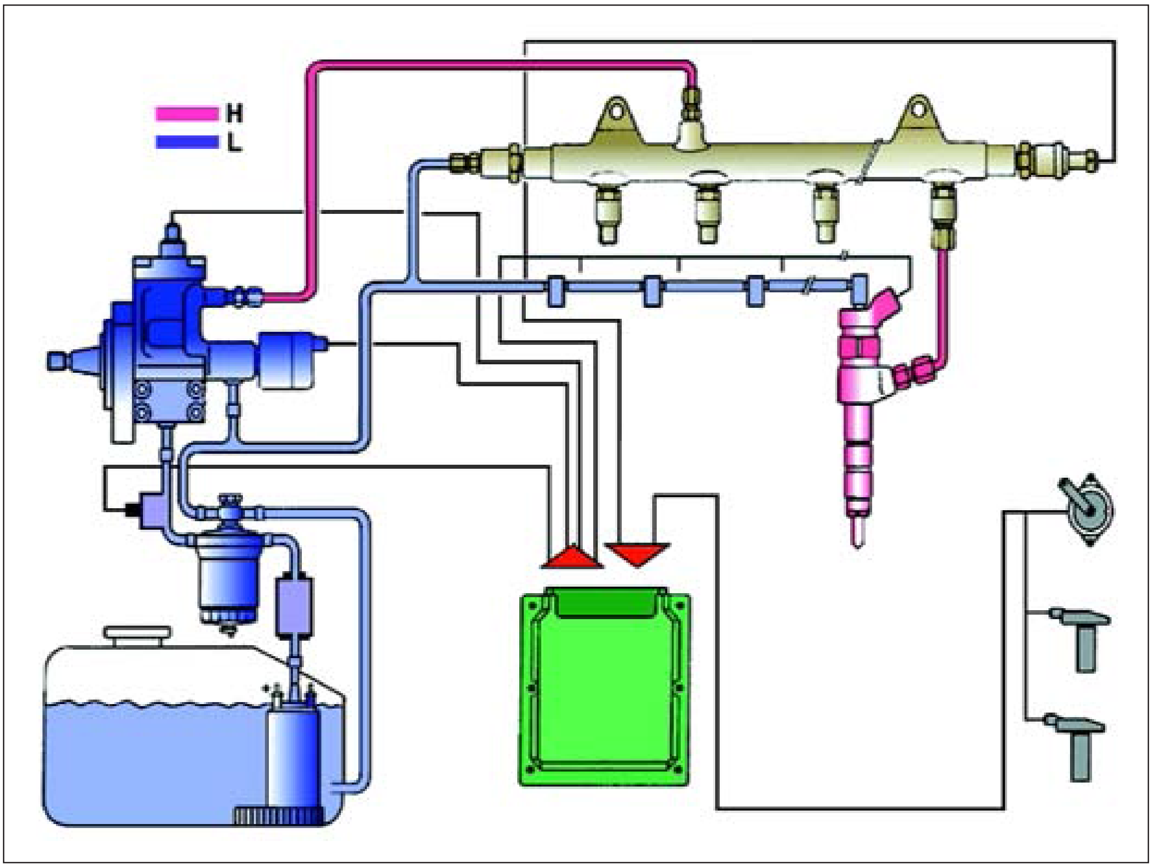
Diesel Engine Management System Inputs

- Crankshaft Sensor
- Camshaft Sensor
- Accelerator Pedal Sensor
- High Pressure Fuel Rail Sensor
- Low Pressure Fuel Sensor
- Brake Switch
- Clutch Switch
- Boost Pressure Sensor
- Mass Air Flow/Inlet Air Temperature Sensor (MAF/IAT)
- Electronic Control Unit
- Cruise Control Interface
- ABS/Traction Control ECU (Vehicle Speed)

- Coolant Temperature Sensor
- Diagnostic Line
- CAN - Bus.

Description:

- The Diesel engine management structure consists of low pressure and high pressure systems assisted by electronic sensor inputs to ECM.
- The primary feed pump, pumps the diesel to high pressure pump driven by camshaft. The pump supplies fuel to common rail (accumulator) at a pressure of 2000 Kpa.
- The common rail is fitted with pressure sensor and pressure control valve to ensure desired pressure is maintain in the common rail. If the pressure of the system exceeds above desired pressures, ECM directs pressure control valve to open.
- This high pressure fuel is supplied to solenoid injectors mounted on each cylinder.
- The glow plug is also installed in the engine cylinder for pre heating of air.
- ECM receives signals from various sensors which are part of engine management system.
- The opening of the Injector has to be done electronically rather than mechanically.
- Based on the signals ECM opens the injector for a specified duration depending upon requirement.
- If there is any malfunction in the system, ECM illuminates MIL light in the cluster fro drivers information.



Advantages of an Electronic Diesel Injection System:

- Better Combustion
- More Power
- Fuel efficient
- Less vibration
- High torque at low rpm
- Efficient combustion
- Reduce emissions
- Low noise.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. List the Diesel Engine Management System Structure.

2. What are the advantages of an Electronic Diesel Engine Management System?

Worksheet

1. *Read the questions and tick the correct answer.*

   a. The job of the Diesel EMS system is to electronically control the injection.

      i. True ☐

      ii. False ☐

Notes

Answers: Introduction to EMS of Diesel Engine

Question Number	Answer
1	a. i

EMS components - Diesel Engine

After completing this session, you will be able to:

- identify the components of EMS;
- describe the construction and working of sensors in the EMS.

Session Plan	
1	Introduction
2	Sensors
3	Key Learnings
4	Worksheet

Introduction

Diesel EMS

The Diesel EMS system will be very similar to the Petrol system, there are a few different sensors as compared to petrol. But otherwise many sensors will be found both on petrol and diesel.

Sensor

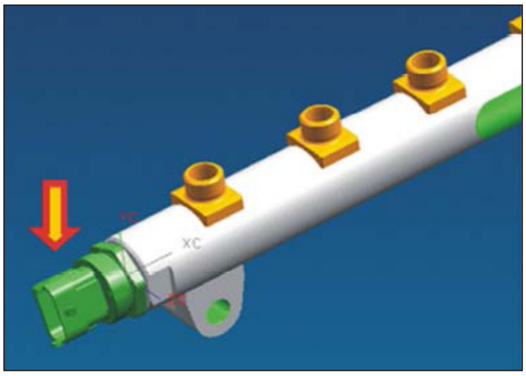
Boost Pressure Sensor

- The boost pressure sensor has its location in the air induction tubing.
- The boost pressure sensor provides a signal to the ECM, which is relative to the pressure changes in the air tubing.
- This transducer varies voltage according to changes in the air pressure inside the air tubing.
- The ECM should be able to detect a low signal voltage from the sensor when it is at a low boost pressure, such as low engine load.
- Like wise the ECM should also detect high signal voltage from the sensor at a high boost pressure, such as high engine load.
- The ECM uses this voltage signal to control turbocharger nozzle control.

Fuel Rail Pressure Sensor

- The fuel rail pressure (FRP) sensor is used to measure the fuel pressure within the fuel rail.
- The engine control module (ECM) constantly monitors the voltage on the FRP sensor circuits.
- If the fuel pressure is low, the signal voltage output is low.
- If the fuel pressure is high, the signal voltage output is high.

- The ECM supplies 5 volts to the 5-volt reference circuit and a ground to the low reference circuit.
- The FRP sensor provides a signal voltage to the ECM, relative to the pressure changes within the fuel rail on the FRP signal circuit.
- The ECM uses commanded fuel pump flow to determine the desired fuel rail pressure (FRP).



- A restricted fuel supply line or a leakage in the high pressure system, too much or too little fuel in the low pressure line may set a diagnostic trouble code.
- High Resistance in either circuit of the Fuel Pressure Regulator may set a diagnostic trouble code
- If the fuel system pressure is actually too high, knocking and smoke condition may arise and simultaneously setting a diagnostic trouble code.

Injector Control

- The engine control module (ECM) supplies voltage to each fuel injector on the injector positive voltage control circuits.
- The ECM energizes each fuel injector by grounding the control circuit of that fuel injector. The ECM monitors the status of the injector positive voltage control circuits and the fuel injector control circuits.
- The injectors are separated into groups for diagnostic codes :

  E.g. Group 1 – DTC P2146 for injectors 1 and 4
  Group 2 – DTC P2149 for injectors 2 and 3.

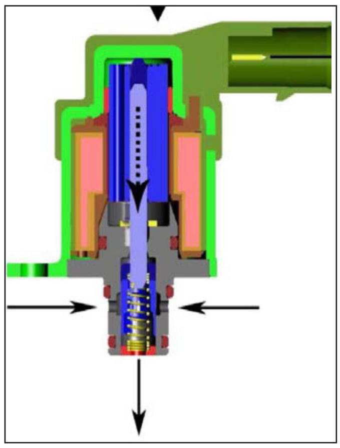
- When a fuel injector circuit condition is detected by the ECM, the affected fuel injectors will be disabled and may disable the affected group of fuel injectors.

Fuel Metering Solenoid Valve Control

- High Pressure fuel pump is fitted to the engine which utilises a metering valve to control the amount of fuel going to the plunger chambers.
- The engine control module, using a PWM signal, based on the current engine demands, actuates the metering valve.

Operation

- The metering unit is actuated by the engine control module by data of the signal. The higher the pulse ratio (and therefore the higher the current flowing in the coil), the lower the amount of fuel flow to the high-pressure pump and therefore the lower the rail pressure.



Rail Pressure Solenoid Valve Control

- The ECM uses a PWM signal to activate the valve. The Pulse ratio is varied depending on how much rail pressure is required.
- A low pulse ratio (Low Current) results in a Low rail pressure.
- A High pulse ratio (High Current) results in a High rail pressure.

- As the rail pressure control valve does not have a built-in mechanical high pressure safety valve, If a high rail pressure is detected by the rail pressure sensor the engine will shut down
- Such an event can also occur if the control control wiring has an Open circuit.
- The Fuel Pressure Regulator Solenoid is used to control the fuel pressure at the fuel rail.
- The engine control module (ECM) supplies the voltage directly to the Fuel Pressure
- Regulator Solenoid. The ECM controls the solenoid by grounding the control circuit with a solid state device called a driver.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. Explain the boost pressure sensor.

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2. Explain about the Fuel Rail Pressure Sensor.

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3. Explain about Injector Control.

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Worksheet

1. Read the questions and tick the correct answer.

a. The boost pressure sensor is located in the _______________ tubing.

i. Induction ☐

ii. Exhaust ☐

iii. Air conditioning ☐

iv. All of the above ☐

b. The fuel rail pressure (FRP) sensor is used to measure the fuel pressure within the fuel rail.

i. True ☐

ii. False ☐

Notes

Answers: EMS Components - Diesel Engine

Question Number	Answer
1	a. i b. i

Staring System and Charging System

After completing this session, you will be able to:

- identify the components of staring system and charging system;
- state the functions of staring system and charging system.

Session Plan	
1	Introduction
2	Staring Circuit and Components
3	Charging System and Components
4	Key Learnings
5	Worksheet

Introduction

The Starting system of a car is a very important system, without it getting the engine cranked would be a huge task. Similarly the Charging system of a car is of importance too, it has to keep the battery charged and supply electicity to the electrical components of a car.

Starting Circuit and Components

Starting circuit of a vehicle

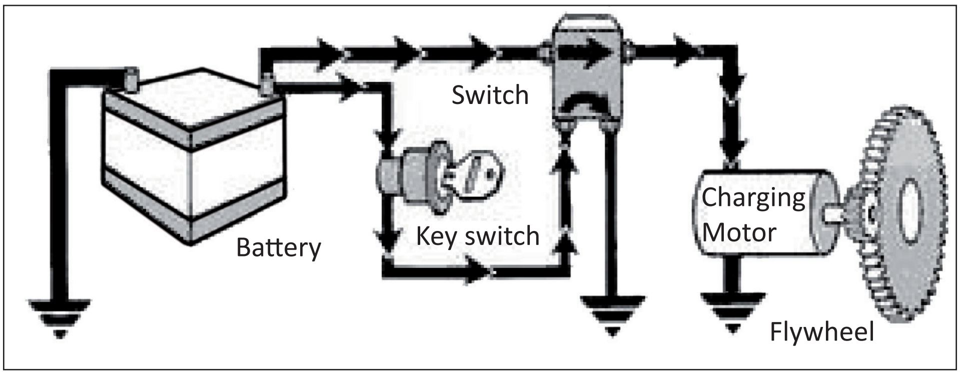
- The starting system includes the following components;
  - Battery
  - Starter motor
  - Solenoid
  - Ignition switch.

- A typical starting system converts electrical energy into mechanical energy to turn the engine.
- The starter motor is an electrical motor mounted on the engine block and draws power from the battery.
- During starting, the pinion of the starter motor engages with the flywheel ring gear and the starter motor then operates to crank the engine.

Components of a Starting Circuit

- Battery -to provide electricity to operate the starter.

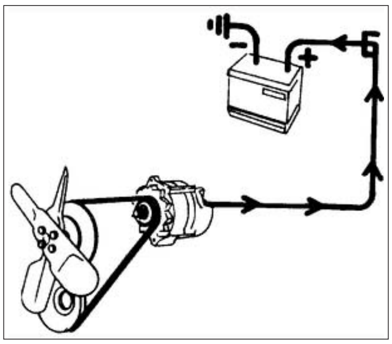
- Ignition switch - to control the energizing of the starter relay or solenoid
- Starter relay or solenoid - to make and break the circuit between the battery and starter;
- Starter motor - to convert electrical energy into mechanical energy to rotate the engine
- Pinion - to transmit the starter rotation to the engine flywheel.



Functions of an Alternator

- An Alternator produces AC (Alternate Current) instead of DC (Direct Current).
- Since Automobiles runs on Direct Current, the Alternate current developed has to be converted into DC, which is done with the help of rectifiers.
- It supplies power to the battery which is required to run the vehicle.
- Alternating voltage may be generated by rotating a coil in the magnetic field or by rotating a magnetic field within a stationary coil.
- The Alternator works on the principle of Electromagnetic Induction

- The alternator, is driven by a belt, the alternator consists of a rotating coil of laminated wire called the rotor.
- Surrounding the rotor are more coils of laminated wire that remain stationary (stator) inside the alternator case.
- When current is passed through the rotor via the slip rings and brushes, the rotor becomes a rotating magnet creating a magnetic field. When a magnetic field passes through a conductor (the stator), alternating current (A/C) is generated. This A/C current is rectified, turned into direct current (D/C), by the rectifier (diodes) located within the alternator.
- The alternator functions with the help of the engine of the car. When the engine turns on, the crankshaft of the engine turns on the fan belt or serpentine belt that is attached with the alternator and in turn connected to the battery. Thus, when the engine is running, the alternator constantly develops electricity to charge the battery.



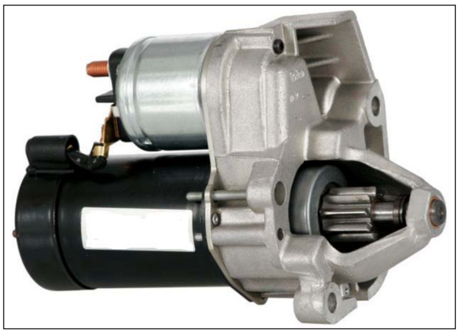
Functions of a Battery

- The function of the battery is to supply power the electrical system of the vehicle. E.g. Starter motor, ignition system, lighting and other electrical.
- It's important to remember that a battery does not store electricity, but rather it stores a series of chemicals, and through a chemical process electricity is produced.

Types of a Battery

- Lead-Acid Batteries
- Zinc-air batteries
- Alkaline batteries.

The most widely used type of battery on automobiles are Lead-Acid Batteries.



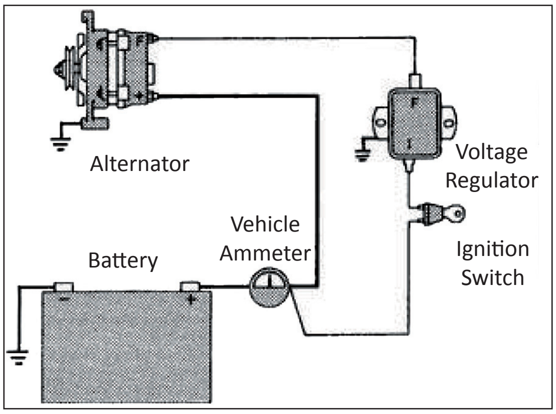
Functions of a Starter Motor

- The starter motor is used to crank the engine to start it.
- In order to crank the engine the starter motor draws huge current from the battery so that the engine cycle can start.
- The cranking of the engine is possible due to the Pinion drive, it is a small gear mounted on the armature shaft end, for the purpose of driving the ring gear on the flywheel can be rotated so that the engine will move.

Charging Circuit and Components

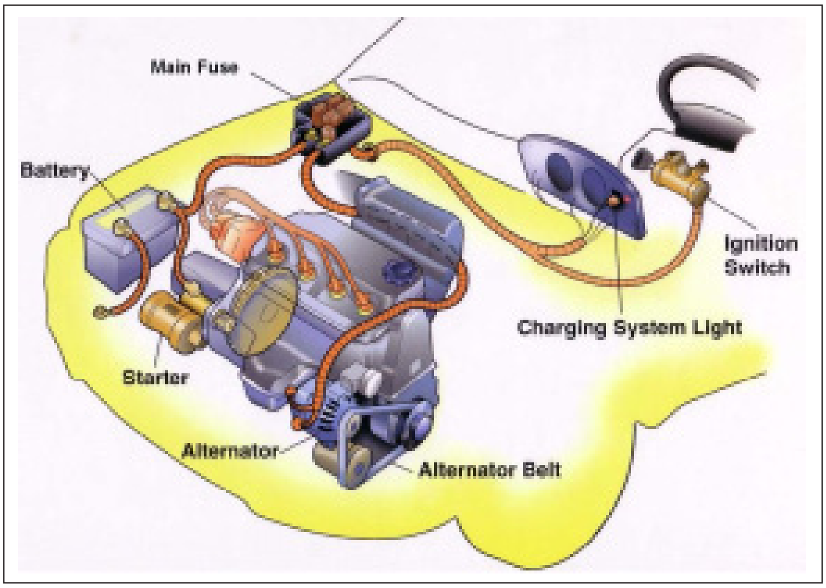
Charging System Circuit

- The job of the charging system is to ensure that the battery is charged and generate electricity to supply power to the electrical components of the vehicle.
- Most modern vehicles have an indicator light located on the dash to alert the driver of a malfunction in the charging system.



Charging System Components

- Alternator
- Battery
- Ignition Switch
- Voltage Regulator
- Fusing.



Charging System Components Alternator

- Generates electricity to supply power to the vehicle and charge the vehicle battery

Battery

- Stores electrical energy and supplies to the vehicle's electrical system when required

Ignition Switch

- When the ignition switch is in the ON position, the battery current energizes the alternator

Voltage Regulator

- Without a regulator the alternator will operate to its highest output.
- This can damage components and overcharge the battery
- The regulator prevents the alternator from undercharging or overcharging.

Fusing

- Fusible links as well as separate fuses are used in the system to protect the circuits in the charging system.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. Explain the Starting System of a vehicle

2. What are the components of a Starting system?

3. Explain the Charging System of a vehicle.

Worksheet

1. *Read the questions and tick the correct answer.*

a. The different types of batteries used on vehicles are ______________________________ .

i. Lead-Acid ☐

ii. Zinc-air ☐

iii. Alkaline ☐

iv. All of the above ☐

b. The AC current generated by the Alternator is converted in to DC by a rectifier.

i. True ☐

ii. False ☐

Notes

Answers: Staring System and Charging System

Question Number	Answer
1	a. i b. i

Introduction to Clutch

At the end of this session you will be able to:

- state the functions of the clutch;
- describe the layout of a clutch.

Session Plan	
1	Introduction
2	Function of a Clutch
3	Layout of a Clutch
4	Key Learnings
5	Worksheet

Introduction

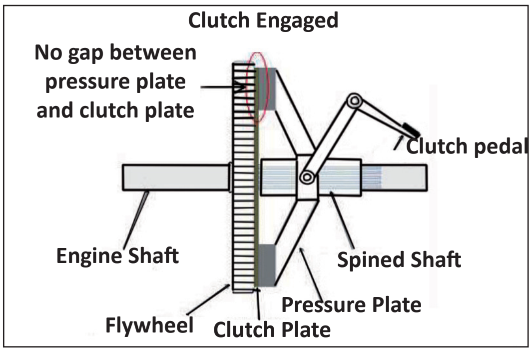
A clutch is a circular plate with friction material similar to a brake pad that connects and disconnects the shaft from its drive while the drive mechanism is running.

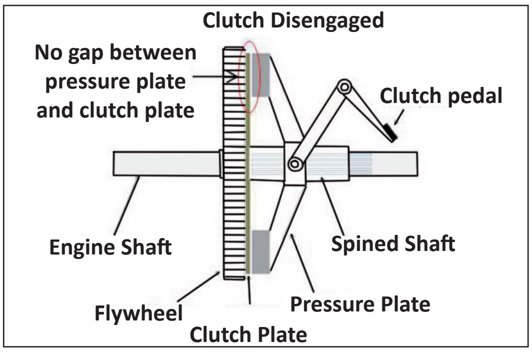
In an automotive powertrain the clutch is used to engage ad disengage the transmission from the engine when the clutch pedal is pressed.

Function of a Clutch

The functions of a clutch when in disengaged positions are:

- Allow engine cranking and permit the engine to run freely
- Permit the driver to shift the transmission into various gears





The functions of clutch when in disengaged positions are:

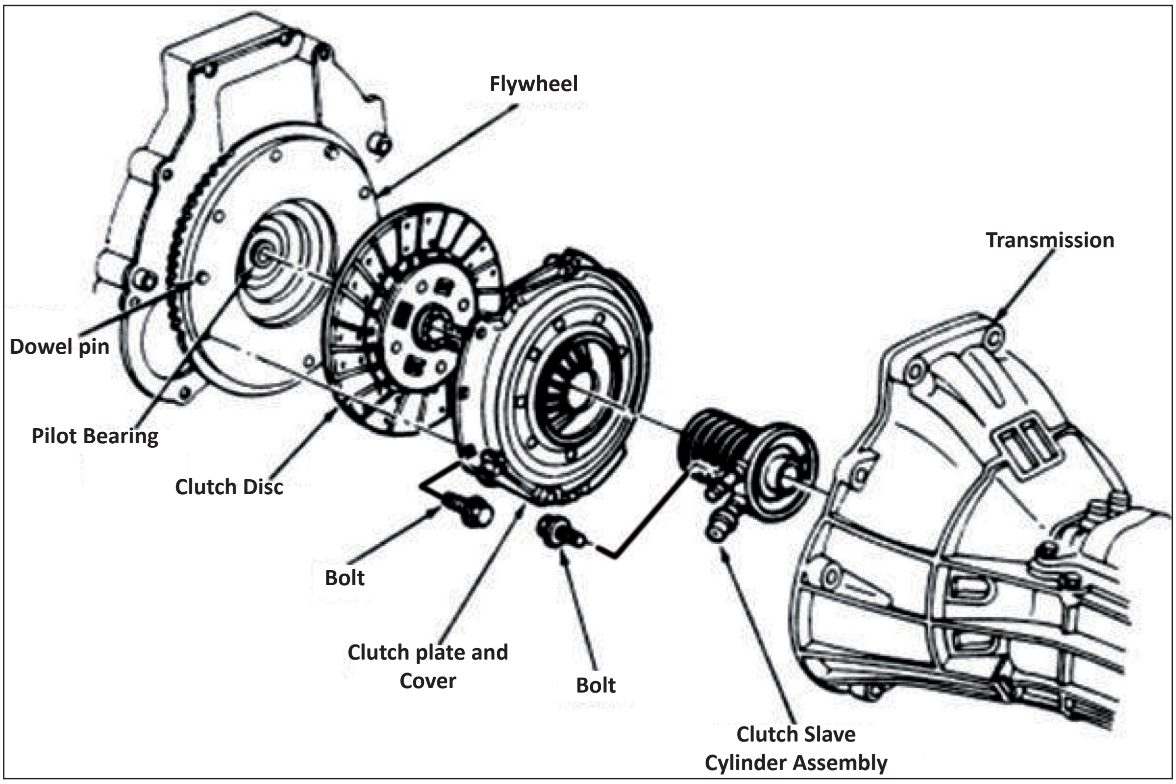
- Slip momentarily to provide smooth engagement and reduce the shock on gears, shaft and other drive train components
- Transmit power from the engine to the transmission when all slipping is stopped

Layout of a Clutch

The clutch acts as a sandwich between the engine flywheel and the transmission. It consists of a splined hole at the centre of its axis, which facilitates it to be mounted on the splined transmission input shaft. The various components that contribute in the making of the clutch

assembly are:

- Flywheel
- Clutch plate
- Pressure plate & cover
- Transmission input shaft



Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. Describe the layout of the clutch.

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2. State the various functionsof the clutch.

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Worksheet

1. Read the questions and tick the correct answer.

a. A clutch is a circular plate with friction material similar to a ______________.

   i. Brake pad ☐
   ii. Disc rotor ☐
   iii. Tyre thread ☐
   iv. All of the above ☐

b. The purpose of a clutch in an automobile is to engage and disengage the transmission to and from the engine.

   i. True ☐
   ii. False ☐

Notes

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Answers: Introduction to Clutch

Question Number	Answer
1	a. i b. i

Types of Clutch

	At the end of this session you will be able to: ◆ state the different types of clutch; ◆ describe the different methods of clutch operation.

Session Plan	
1	Introduction
2	Types of Clutch
3	Operation of a Clutch
4	Key Learnings
5	Worksheet

Introduction

Clutch systems are available in different configurations. The usage of a particular set-up is based purely on their applications.

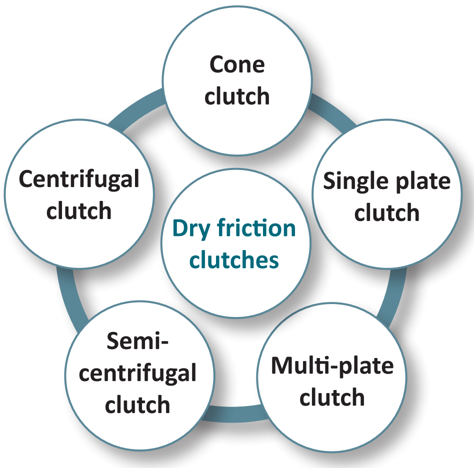
Types of Clutch

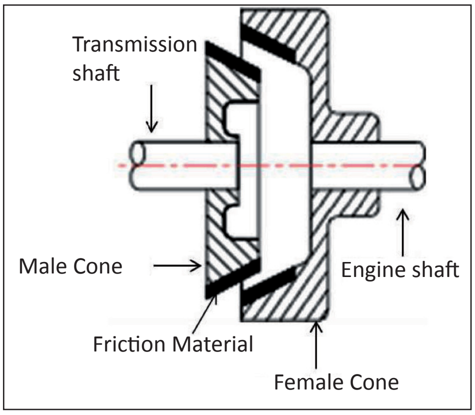
The following are the main type of clutches:

- Friction clutches
- Fluid Flywheel

The friction clutches work on the fact that friction is caused when two rotating discs come into contact with each other, on the other hand the fluid flywheel works on the transfer of energy from one rotor to the other by means of fluid. Friction clutches may be dry or the wet type. The dry clutch is preferred over the wet type mainly because of higher coefficient of friction over the latter.

The following are type of dry friction clutches:



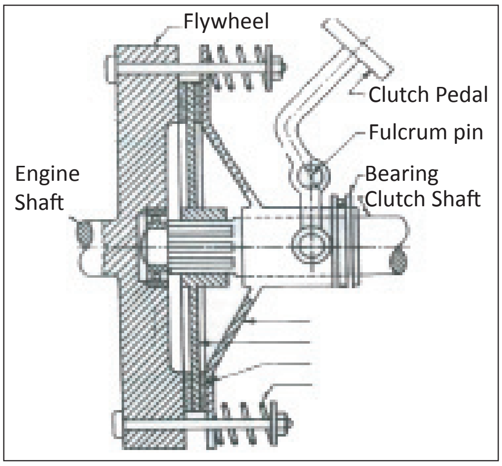


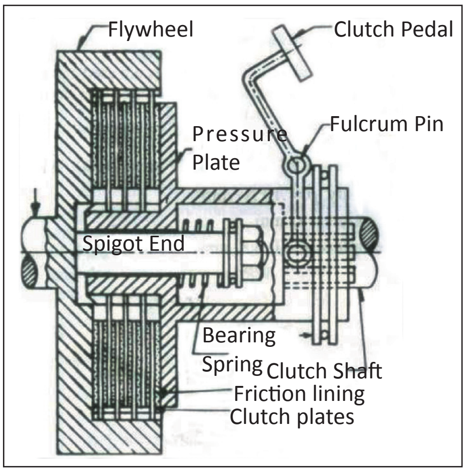
Cone clutch

In this construction the friction surfaces are in the form of cones. In the engaged position, the male cone is fully inside the female cone so that the friction surfaces are in complete contact which is done by means of springs which keep the male cone pressed all time. When the clutch is engaged, the torque is transmitted from the engine via the fly wheel and the male cone to the splined gear box shaft. For disengaging the clutch the male cone is pulled out by means of the lever system operated through the clutch pedal thereby separating the contact

Single plate clutch

In this construction the friction plate (clutch plate) is held between the flywheel and the pressure plate. Springs arranged circumferentially provide axial force to keep the clutch in an engaged position. The friction plate is mounted on a hub which is splined inside and is used to slide over the transmission shaft. Friction material on either side of the clutch plate provides two annular friction surfaces to transmit power. The clutch pedal is connected to the pressure plate through multiple linkages to slide the pressure plate when the clutch needs to be engaged and disengaged.



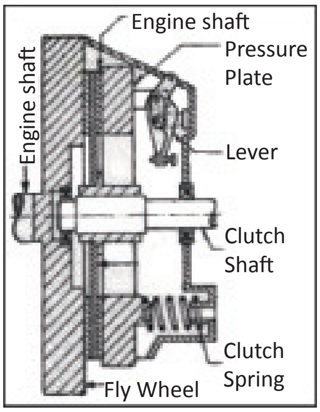


Multi-plate clutch

A multi-plate clutch is an extension of a single plate clutch. In this construction the number of friction surfaces is increased to transmit the same amount of torque that a single plate clutch would transmit. This construction is used in applications where size needs to be kept compact and high torque needs to be transmitted.

Semi-centrifugal clutch

For high powered engines, the clutch spring pressures required are high and thus the action of disengaging the clutch becomes fatiguing to the driver. The centrifugal force developed during the rotation of the clutch assembly is used to minimize the effort required to disengage the clutch. In this construction, the clutch springs are designed to transmit the torque at normal speeds, while for higher speeds, centrifugal force assists in torque transmission.

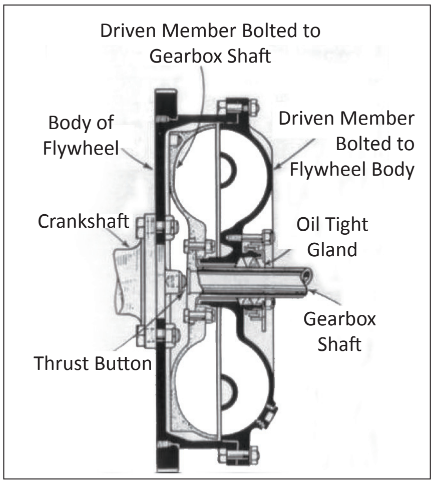


Centrifugal Clutch

In the centrifugal type of clutch, the springs are eliminated and only the centrifugal force is used to apply the required pressure for keeping the clutch in engaged position. This construction eliminates the use of a clutch pedal and hence the driver only needs to put the vehicle in gear and press the accelerator pedal, the gears shift automatically as the speed increases. This type of clutch is generally used in mopeds.

Fluid Flywheel

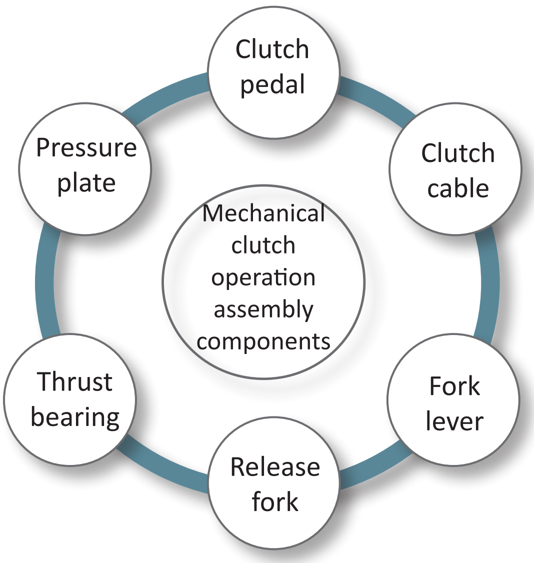
The fluid flywheel or the hydraulic coupling is used in cars employing automatic transmissions. It consists of two members, driving and driven member. The driving member is attached to the flywheel and the driven to the transmission, both the members do not have any direct contact with each other. The driven member is free to slide on splines on the transmission shaft. The two rotors are always filled with fluid of suitable viscosity and are provided with radial ribs to form a number of passages, which avoid formation of eddies and also guide the fluid to flow in the desired direction.



Operation of a Clutch

The force applied at the clutch pedal is transferred to the clutch assembly through a combination of linkages. The different methods to transfer the driver input are as follows:

- Mechanical operation
- Hydraulic operation
- Pneumatic operation
- Electromagnetic operation.



The steps to operate a mechanical clutch are:

a. Driver presses the clutch pedal.

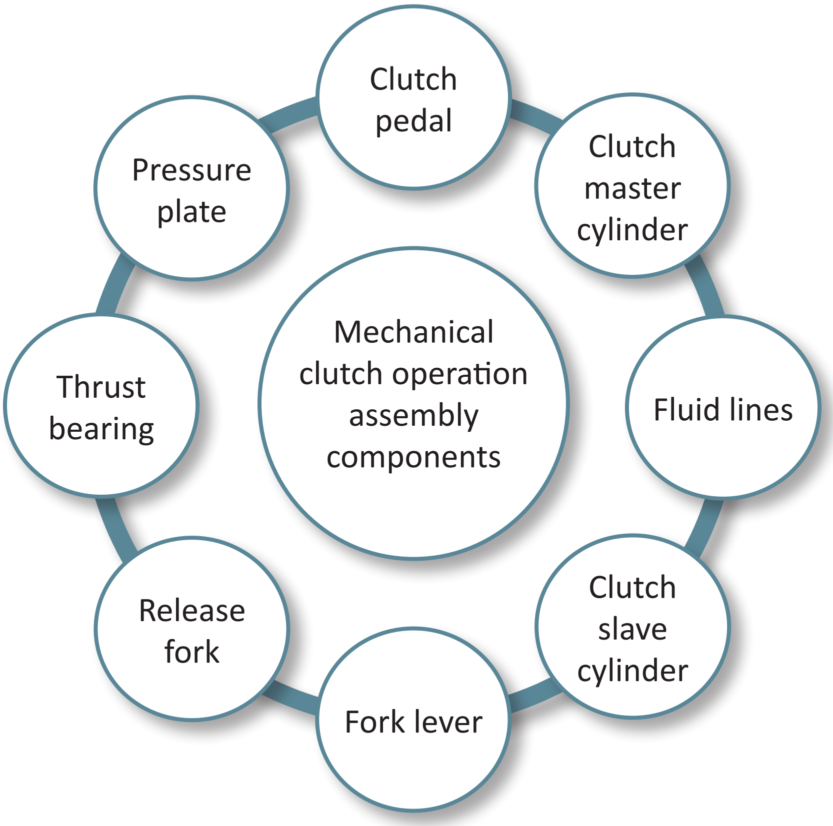
b. The force exerted by the driver is transferred to the fork lever by means of a clutch cable.

c. The spring loaded fork lever activates the release fork.

d. The release fork in turn exerts pressure on the thrust bearing and slides the same on the transmission shaft.

e. The thrust bearing presses against the diaphragm spring in the centre of the pressure plate and releases the pressure from the clutch plate, thus disengaging the clutch.

Hydraulic operation



The steps to operate a hydraulic clutch are:

a. Driver presses the clutch pedal.

b. The force exerted by the driver is transferred to the piston in the clutch master cylinder via a push rod.

c. Fluid pressure is developed in the master cylinder; this high pressure fluid is transferred to the slave cylinder via metal fluid lines.

d. The slave cylinder operates the spring loaded fork lever which in turn activates the release fork.

e. The release fork in turn exerts pressure on the thrust bearing and slides the same on the transmission shaft.

f. The thrust bearing presses against the diaphragm spring in the centre of the pressure plate and releases the pressure from the clutch plate, thus disengaging the clutch.

Pneumatic operation

a. Where mechanical clutches does everything with moving, tangible parts. Pneumatic brake clutches transfer power from one part of a machine to another using compressed air or other gases.

b. Upon clutch disengagement, an air valve is opened and an air flow is initiated through a rotary inlet of the shaft, toward the pneumatic throw-out bearing, which opens the clutch.

c. Re-engagement bleeds the air out of the system, a set of springs release, and the clutch reattaches to the flywheel.

Electromagnetic operation

a. In this type of a clutch mechanism the engaging and disengaging of gears take place electrically.

b. The engine flywheels consist of a winding that is energised with the help of battery power.

c. The pressure plate is mounted on a splined shaft and is free to slide.

d. When the winding on the flywheel is energised it attracts the pressure plate towards the flywheel which in turn applies pressure on the clutch plate and engages the clutch.

e. The clutch release switch located in the gear lever is operated when the driver moves the gear lever.

f. The switch cuts-off the electrical supply to the windings thus causing clutch disengagement.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. Describe a fluid flywheel.

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___

2. State the difference between a single plate clutch and a multi-plate clutch.

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3. Describe the working of a mechanical clutch.

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Worksheet

1. Read the questions and tick the correct answer.

a. In a clutch assembly, the clutch plate is a fixed component.

- i. True ☐
- ii. False ☐

b. The ____________________ developed during the rotation of the clutch assembly is used to minimize the effort required to disengage the clutch in a semi-centrifugal clutch.

- i. Compressing force ☐
- ii. Linear force ☐
- iii. Centrifugal force ☐
- iv. All of the above ☐

Notes

Answers: Types of Clutch

Question Number	Answer
1	a. i b. iii

Clutch Components

At the end of this session you will be able to:

- identify the various components of the clutch;
- state the functions of clutch components.

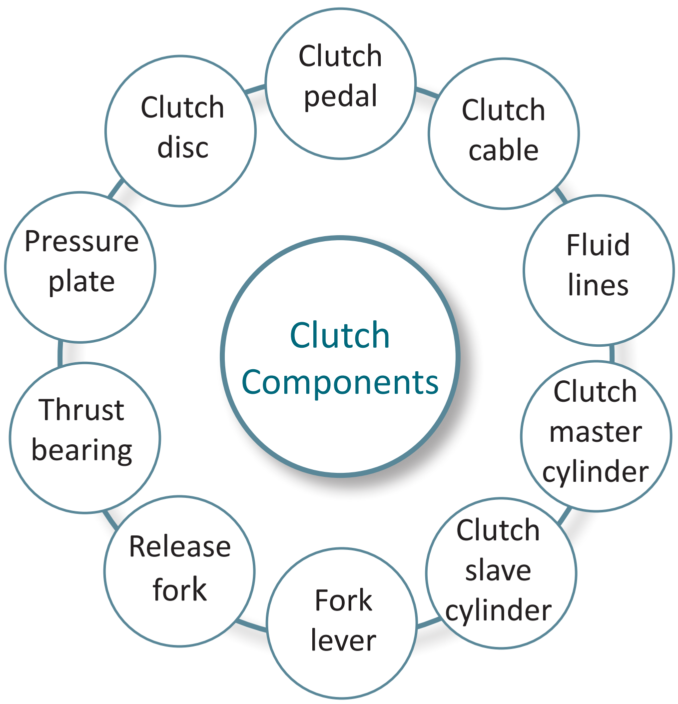
Session Plan	
1	Introduction
2	Clutch Components
3	Key Learnings
4	Worksheet

Introduction

The clutch assembly consists of various components that are used to transfer the force applied at the clutch pedal to the clutch.

Clutch Components

The vital components of a clutch system are:



Clutch Pedal

The clutch pedal is located in the vehicle cabin along with the accelerator and brake pedal. The clutch pedal takes the driver input and transfers the same to the clutch cable (in mechanical operation) or master cylinder push rod (hydraulic operation).

Clutch Cable

The clutch cable is a long metal cable that connects between the clutch pedal and the fork lever. It transfers the driver effort at the clutch pedal to the fork lever in mechanical clutch.

Fluid Lines

Fluid lines are substitute to the clutch cable. These are metal pipes that carry clutch fluid from the master cylinder to the slave cylinder and are of uniform diameter. The use of metal pipes reduces maintenance cost compared to a metal cable, as the cable is prone to wear and tear and needs to be replaced once worn out.

Clutch Master Cylinder

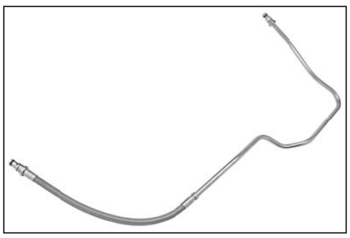
Clutch master cylinder converts mechanical energy into hydraulic energy. Depressing the clutch pedal causes the push rod to move against the piston to close the return port. Clutch fluid is forced out of the master cylinder. Releasing the clutch pedal causes the return spring to force the piston back to its original position. The return port is opened and the clutch fluid flows into the fluid reservoir.

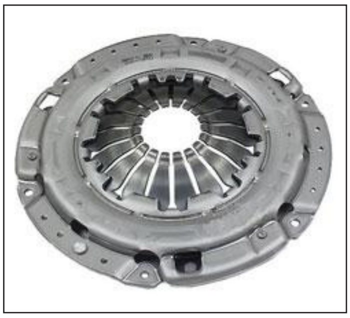
Clutch Slave Cylinder

The slave cylinder converts hydraulic energy to mechanical energy. Hydraulic fluid supplied by the master cylinder via the fluid lines moves the slave cylinder piston to actuate the shift fork. The mechanical energy produced by the slave cylinder is directly proportional to the diameters of the master cylinder and slave cylinder. A bleed screw is provided to bleed the slave cylinder.

Fork Lever

The fork lever is pivoted to the transmission casing and is spring loaded; hence it is free to move one of its end. The other end is connected to the slave cylinder piston; the fork is also connected to the release fork with the help of a shaft that protrudes through the crank case.



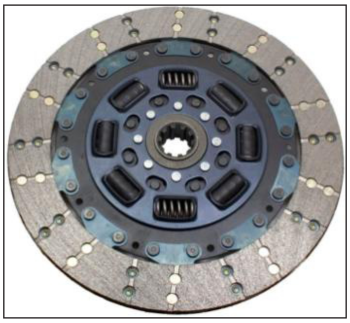


Release Fork

One end of the clutch release fork is attached to the clutch release bearing and the other to the fork lever. When clutch is applied, the movement of the lever fork makes the release fork to move and press the release bearing against the clutch pressure plate fingers resulting is clutch engagement.

Thrust Bearing

The thrust bearing is used to transfer the force at the pedal from the stationery linkage to the rotating cutch. This is either a thrust ball bearing which is packed with grease for lubrication, or else a graphite impregnated one fitted on a steel carrier and does not require any lubrication.



Pressure Plate

The pressure plate assembly consists of a clutch cover and a pressure plate with a diaphragm spring at the centre. The thrust bearing presses towards the diaphragm spring and disengages/engages the clutch.

Clutch Disc

The clutch plate consists of a plate and a friction material. It consists of a clutch centre, cushioning plate and torsion springs. The facing is reverted to both sides of the cushioning plate. The cushioning plate provides a longer service life by minimizing wear and vibration at the clutch contact surfaces.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. Describe a clutch master cylinder.

2. What is the function of a thrust bearing in the clutch assembly?

3. List the various vital components that contribute to the making of the clutch system.

Worksheet

1. Read the questions and tick the correct answer.

a. ______________________ operates the fork lever.

   i. Clutch slave cylinder ☐

   ii. Clutch master cylinder ☐

   iii. Thrust bearing

   iv. Clutch fluid lines

b. ______________________ replaces a clutch cable in the case of a hydraulic clutch system.

   i. Thrust bearing ☐

   ii. Pressure plate ☐

   iii. Fluid lines ☐

   iv. Fork lever ☐

Notes

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Answers: Clutch Components

Question Number	Answer
1	a. i b. iii

Introduction to Transmission

At the end of this session you will be able to:

- define gear ratio;
- state the types of gears used in an automobile transmission;
- state the functions of transmission.

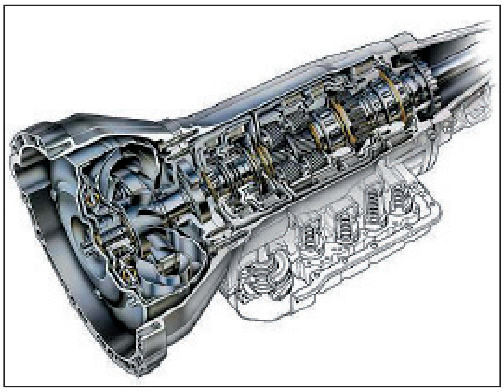
Session Plan	
1	Introduction
2	Basics of Transmission
3	Gear Ratio
4	Types of Gears
5	Function of Transmission
6	Key Learnings
7	Worksheet

Introduction

A transmission is a device that makes use of different combinations of gears. The gears could be of different shapes and sizes based on the application.

Basics of Transmission

The engine crankshaft of any automobile rotates at tremendous speed to produce the desired power/ torque output. If the same amount of rotations is given directly to the road wheels, it could result in damage to components and accidents. For example, when the first gear is engaged, the speed required at the road wheels is less as compared to the crankshaft rotation speed; hence a device that reduces the speed derived from the crankshaft is needed. Transmission is a device that fulfils this necessity perfectly.

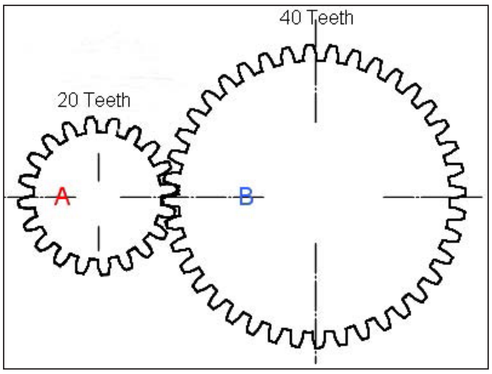


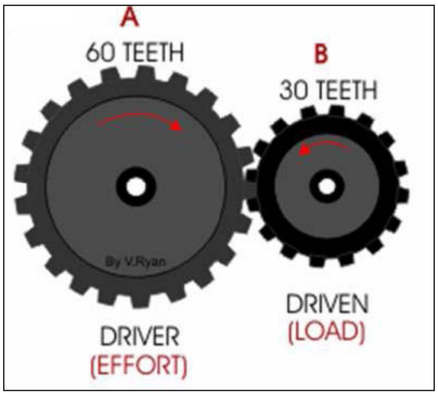
Transmission is a solid robust device that is made up of gears of different sizes mounted on parallel shafts. It is situated between the clutch and the driveshaft in the case of a front wheel drive vehicle and clutch and the propeller shaft in a rear wheel drive setup. It works on the principle of gearing, in which a set of gears mesh together to provide the desired output speed. The output speed also depends on the gear ratio of the meshing gears.

Gear Ratio

The gear ratio of a gear train is also known as its speed ratio. It is the ratio of the angular velocity of the input gear to the angular velocity of the output gear. Gear ratio can be calculated directly from the number of teeth on the gears in the gear train.

Example: if a smaller gear (driving gear) has 20 teeth and the larger one (driven gear) has 40 teeth, then the driving gear turns two times to fully turn the driven gear once, in this case the gear ratio is 2:1.



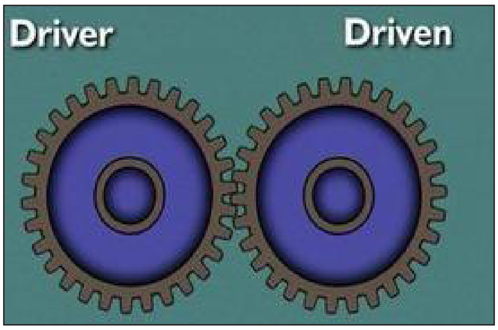


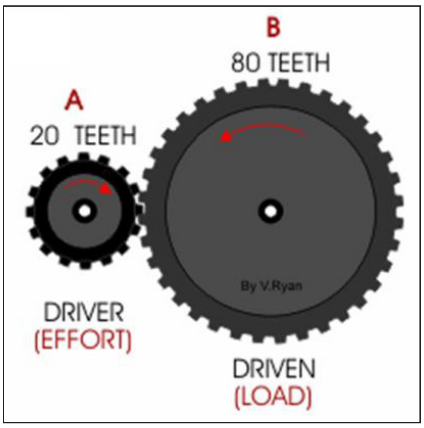
Overdrive

An overdrive is a device that is commonly used in automobiles to allow the choice of an extra-high overall gear ratio for high speed cruising, thus saving fuel at the cost of less torque. In this setup, the driving gear is larger than the driven gear. Usually the final or top gear is called an overdrive. The gear ratio for this setup is 1:2 and above.

Direct drive

In a direct drive setup, the number of teeth on the driving gear is the same as the number of gears on the driven gear. This is chosen for efficiency, as it does not require any gears to transmit power and so reduces power losses. The gear ratio for this setup is always 1:1.





Under drive

In an under drive setup, the number of teeth on the driving gear is lesser than the number of gears on the driven gear. This is chosen for lower speed operation for example, in the first gear more torque is required to move the vehicle from a halt compared to the torque required to move the vehicle in motion. The gear ratio for this setup is 2:1 and can increase depending on the requirement.

Type of Gears

Gears are available in various sizes and configurations. Following is the list of gears that are available in the automotive industry:

- Spur gears
- Helical gear
- Double helical gear
- Bevel gear
- Spiral bevel
- Hypoid
- Worm
- Rack and pinion
- Epicyclic
- Sun and planet.

However the main designs of gears used in transmissions are spur gear, helical gear and bevel gears.

Spur gears

Spur gears are the simplest form of gears and consist of straight cut gears. The teeth of the gears are parallel to the axis of rotation. These gears can be meshed together perfectly only if they are fitted to parallel shafts.

Helical gears

Helical gears offer better refinement over a spur gear. The leading edges of the teeth are not parallel to the axis of rotation but are set at an angle. Since the gear is curved, the angling causes the tooth shape to be a segment of a helix. This is also called a constant mesh gear.

Bevel gears

A bevel gear is shaped like a right circular cone with most of its tip cut off. These gears are used to transmit power at an angle of 90 degrees.

Functions of Transmission

- The torque produced by engine varies with speed only with narrow limits. But under practical considerations running of automobile demands a large variation of torque available at the road wheels. Hence the main purpose of the transmission is to provide a means to vary the torque ratio b/w the engine and the road wheels as required.
- The transmission also provides a neutral position so that the engine and the road wheels are disconnected even when the clutch is in engaged position.
- A means to back the car by reversing the direction of rotation of the drive is also provided by transmission.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. What is the purpose of transmission?

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2. What do you mean by gear ratio?

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3. State the functions of transmission?

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Worksheet

1. Read the questions and tick the correct answer.

a. The gear ratio for this setup is always ______________. FOR WHICH SET UP?

- i. 1:1 ☐
- ii. 2:1 ☐
- iii. 1:2 ☐
- iv. None of the above ☐

b. Gears that are used to transmit power at an angle of 90 degrees are called ______________

- i. Helical gears ☐
- ii. Double helical gears ☐
- iii. Spur gears ☐
- iv. Bevel gears ☐

Notes

Answers: Introduction to Transmission

Question Number	Answer
1	a. i b. iv

Types of Transmission

At the end of this session you will be able to:

- state the types of transmission;
- describe the working of manual and automatic transmission.

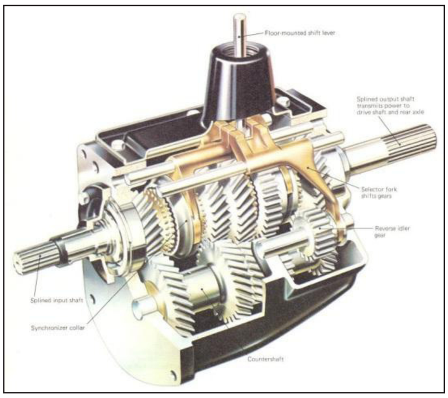
Session Plan	
1	Introduction
2	Manual Transmission
3	Automatic Transmission
4	Key Learnings
5	Worksheet

Introduction

A transmission is a device that transfers the engine power/torque to the road wheels in a varied manner to suit the load & speed requirements. The two types of transmissions used in automobiles are manual transmission and automatic transmission.

Manual Transmission

In a manual transmission, gear are changed with the help of a gear stick and pressing the clutch pedal. It causes fatigue to the driver especially when driving in bad traffic conditions due to frequent gear changing. A manual transmission is used in vehicles where manufacturing costs are to be kept low.



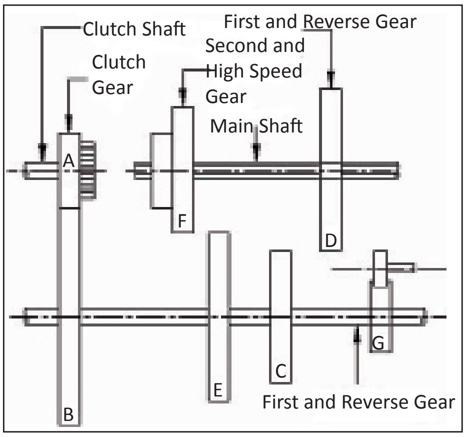
The basic elements of a manually operated transmission are:

- Single or multi-plate clutch mechanism for interrupting and engaging the power flow actuation. This actuation can be power assisted or mechanical.
- Variable ratio gear transmission unit featuring permanent mesh gears in one or several individual assemblies.
- Shift mechanism with shift lever.

The various manual transmission setups used in automobiles are:

- Sliding mesh type transmission;
- Constant mesh type transmission.

- Synchromesh type transmission.

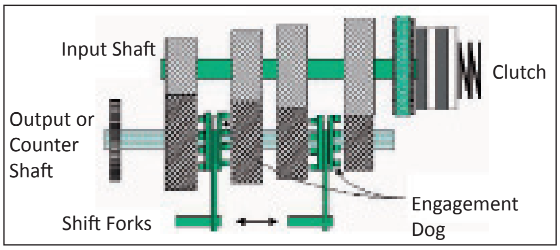


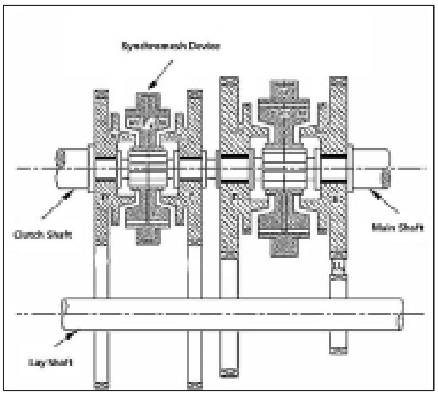
Sliding Mesh Type Transmission

This is the simplest type of transmission construction where the gears are mounted on three different shafts. The power from the engine is transferred to the clutch shaft and then to the gear of the lay shaft that is always in mesh with the clutch gear. All the gears on the lay shaft are fixed and rotate at all time with the lay shaft when the engine is running. The gears on the main shaft slide when the gear change lever is operated and mesh with the gears on the lay shaft to provide the desired output speed. This construction is not used in automobiles today as the mechanical efficiency is very low and noise level is very high.

Constant Mesh Type Transmission

In this type of construction the gears on the main shaft and the lay shaft are fixed. The gears on the main shaft always mesh with the gears on the lay shaft even if the particular gear is not engaged. Dog clutches with teeth on both sides are provided between gears and are free to slide on the splined main shaft when the gear lever is operated. Sliding of the dog clutch to the right engages one set of gears and sliding on the left engages another set of gears providing various output speeds.





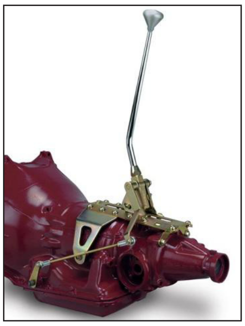
Synchromesh Type Transmission

A synchromesh type construction is similar to the constant mesh type transmission construction. The gears on the main shaft mesh with its corresponding gears on the lay shaft. The difference between the two are, in this type of setup a synchromesh device that slides on the splined section of the main shaft has been included. The synchromesh device first presses against the gear to be engaged, which gets the two parts to be finally engaged to the same speed due to friction, which results in smooth engagement of gears. This setup is most commonly used in automobiles currently as it nullifies the necessity of double declutching.

Manual Transmission Shift Mechanism

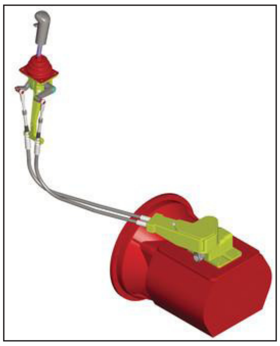
The transmission is always connected to the engine and hence is located away from the gear shift lever. In order to shift gears, it is required that the gear lever should to be connected to the transmission. This requirement is fulfilled by the following two methods:

- Mechanical linkage operated transmission
- Cable operated transmission



Mechanical Linkage Operated Transmission

In a mechanical linkage operated transmission the gear change lever need to be located in close proximity to the transmission. The gear lever is connected to the transmission with the help of mechanical linkages pivoted to each other.



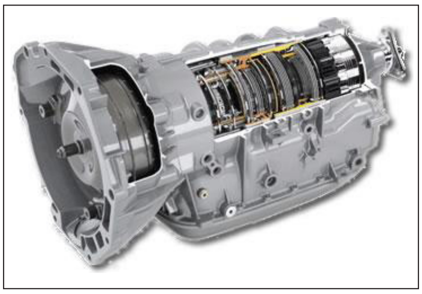
Cable Operated Transmission

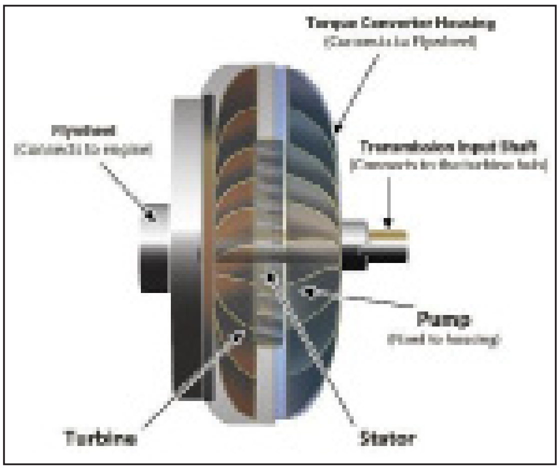
In a cable operated transmission, the transmission is connected to the gear shift mechanism with a help of a flexible metal cable. This facilitates the mounting of the transmission to a longer distance from the gear shift lever. This setup is generally used in rear wheel drive vehicles and the transmission is located at the rear of the vehicle and the shift lever at the front. It is also used in recent passenger cars as it reduces the effort in operation.

Automatic Transmission

Gear changes in this setup are carried out automatically based on vehicle speed. The use of a clutch pedal is eliminated which leads to comfortable driving. The initial buying cost of this construction is higher than the manual transmission. The various automatic transmission setups used in automobiles are:

- Torque converter transmission with sun and planetary gear sets and clutches
- Continuously variable transmission with pulleys and belts



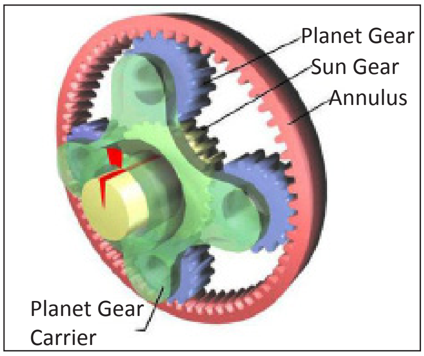


Torque Converter

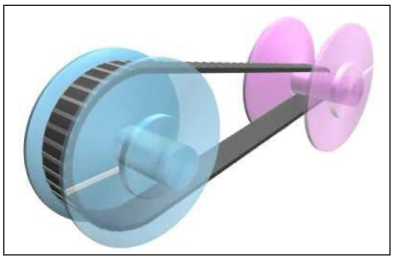
A torque converter is similar to that of a fluid flywheel and works on the principle of hydraulics. The different components of the converter are turbine, stator and the impeller. The turbine is attached to the input of the transmission main shaft and thestator in between the impeller and the turbine which acts as a torque multiplier. The fluid from the impeller is pushed to the turbine when the engine is started due to the centrifugal force.

Epicyclic Gear Box Or Planetary Gears

Present day automatic transmissions consist of an epicyclic gear box. The epicyclic gear box consists of three or even four planetary gear sets. This gear setup has a sun gear, about which the planets turn around. The planet gears are carried out by a carrier and a shaft and are also in mesh with a ring gear called annulus. Different gear ratios are achieved by making any one of the components stationary. Similarly a direct drive is achieved by locking two parts with each other. This construction has fixed number of output gear ratios.



Continuously Variable Transmission (Cvt)



CVT works on the principle of centrifugal force, where in the force exerted by a rotating object increases as the speed of rotation increases. It consists of two sets of pulleys in a form of a cone and a metal belt joining both. The pulleys are mounted on a shaft and are capable of sliding outward and inward depending on the speed variation. As the speed increases and decreases the force exerted by the driven pulley varies, which in turn exerts pressure on the driver pulley via the metal belt. This setup does not have a fixed gear ratio but the entire surface on the cone is a gear ratio, hence step less gear ratios are achieved and no shift shock is noticed.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. Describe the synchromesh type transmission?

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2. What are the basic elements of a manually operated transmission?

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3. What are the advantages of a cable operated transmission?

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Worksheet

1. Read the questions and tick the correct answer.

a. What do you mean by CVT?

- i. Constant Variable Transmission ☐
- ii. Commonly Variable Transmission ☐
- iii. Continuously Variable Transmission ☐
- iv. None of the above ☐

b. Which of the following is/are various manual transmission setups used in automobiles ______________________?

- i. Sliding mesh type transmission ☐
- ii. Constant mesh type transmission ☐
- iii. Synchromesh type transmission ☐
- iv. All of the above ☐

Notes

Answers: Types of Transmission

Question Number	Answer
1	a. iii b. iv

Transmission Components

	At the end of this session you will be able to: ◆ identify the components of manual and automatic transmission; ◆ state the functions of transmission components.

Session Plan	
1	Introduction
2	Manual Transmission Components
3	Automatic Transmission Components
4	Key Learnings

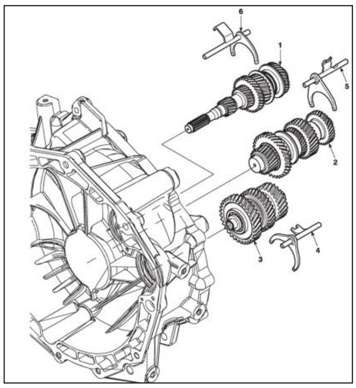
Introduction

An automobile transmission consists of various mechanical, electrical and hydraulic components that combine with each other to transfer the desired power to the road wheels. Each component has its unique way of operation to support the transfer of torque to the road wheels.

Manual Transmission Components

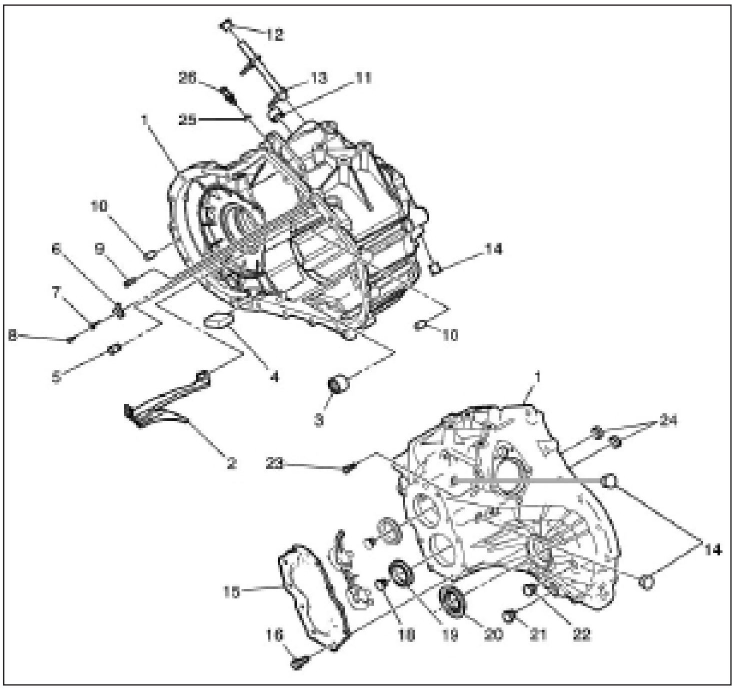
The main components of a manual transmission are:

- Input shaft assembly
- Output shaft assembly
- Interim shaft assembly
- 1st/2nd shift fork
- 5th/reverse shift fork
- 3rd/4thshift fork



Transaxle case

The transaxle is a solid aluminum casing that houses the transmission assembly. It is filled with transmission fluid that provides lubrication to the moving components. The drain plug located at the lower side of the transaxle enables draining of transmission fluid during periodic maintenance. As the transaxle case is located below the vehicle, it is advisable to take care while driving on uneven roads as the uneven road surface could hit the casing causing a fracture and draining the oil which could lead to seizing of the transmission assembly.



1. **Transaxle Housing**
2. **Drain Channel**
3. **Bearing**
4. **Magnet**
5. **Screw**
6. **Reverse Shifting Blocker**
7. **Torsion Spring**
8. **Pin**
9. **Coiled Pin**
10. **Dowel Pin**
11. **Dowel Pin**
12. **Needle Sleeve**
13. **Bushing**
14. **Idle Shift Rail**
15. **Manual Shaft Detent**
16. **Transaxle Rear Cover**
17. **Bolt**
18. **Oil Pipe**
19. **Retainer Plug**
20. **Groove Ball Bearing**
21. **Shaft Seal Ring**
22. **Fluid Drain Plug**
23. **Fluid Level Check Plug**
24. **Shift Guide Bolt**
25. **Bushing**
26. **Washer**
27. **Backup Lamp Switch**

Gear shift fork

Gear shift fork is mounted on the shift rail rods. This is used to slide the synchromesh device on the splined shaft to engage and disengage gears. The shift rail rods are locked in the engaged gear position by a spring loaded ball. The number of shift forks depend on the number of synchromesh devices in the gearbox.One shift fork is allocated to each synchromesh device.

Main shaft

The main shaft consists of two sections; splined and machined. It collects the engine power and transmits the same to the lay shaft through gears. The synchromesh device is mounted on the splined section of the shaft and the gears are mounted on the machined section.

Lay shaft

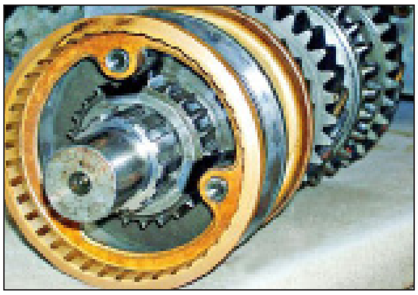
The lay shaft is the output shaft of the transmission. It consists of gears fixed on to it. The gears are always in mesh with the gears on the main shaft.

Gears

Gears play an important role in transferring power from the engine to the road wheels. In an automobile, helical gears are used to ensure easy engagement of gears. Different gear ratios depending on the teeth and size of the gear are achieved to provide the required torque at the road wheels.

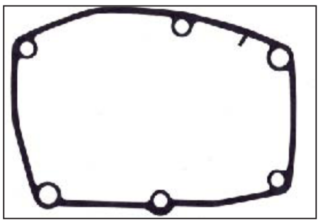
Synchromesh device

Synchromesh device acts as a dog clutch and helps in engaging and disengaging gears. The gear shift fork fits exactly over the circumference of the synchromesh device and slides the same on the splined portion of the main shaft. This device eliminates the double declutching process when shifting gears for easy gear engagement.



Reverse gear idler

Function of the reverse gear idler is to change the direction of rotation of the engine crankshaft.



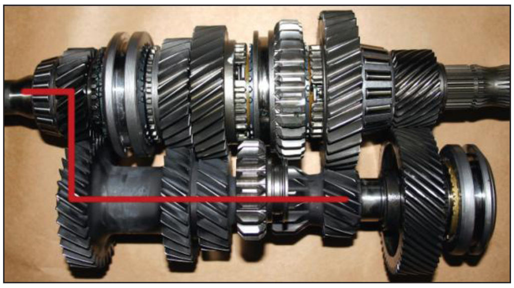
Gasket/oil seal

A gasket is a rubber membrane that is installed between two joining parts of the transaxle casing. It prevents the leakage of lubricants from the transaxle. When reinstalling a gasket/oil seal, it is necessary to refer to the manufacturer prescribed torque figures, as over tightening of bolts holding the two joining components together could damage the gasket.

Manual Transmission Power Flow

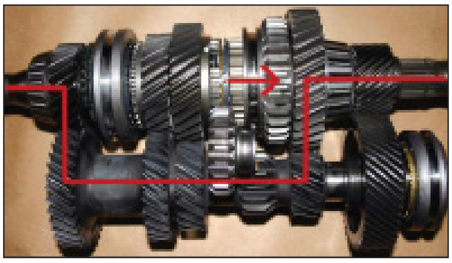
Power flow in neutral gear

In the neutral position, the power enters the transmission through the main shaft and is transmitted to the lay shaft since the main shaft gears are in constant mesh with the gears on the lay shaft.



Since speed gears one, two, three and four are not locked to the mainshaft when the transmission is in neutral, they cannot transfer power to the mainshaft. The mainshaft does not turn and there is no power output to the driveline.

Power flow in first gear

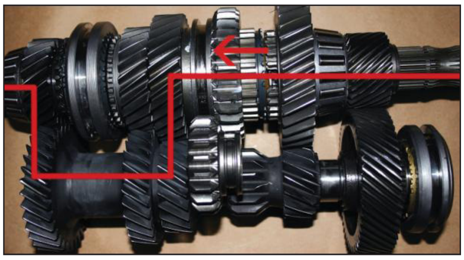


In first gear position, the power enters the transmission through the main shaft and is transmitted to the lay shaft since the main shaft gears are in constant mesh with the gears on the lay shaft.

In first gear, the first/second synchronizer moves to the rear to engage the first speed gear and lock it to the mainshaft, the first speed gear drives the main (output) shaft, which transfers power to the driveline.

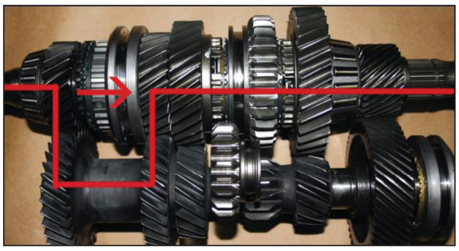
Power flow in second gear

In second gear positionthe shift fork disengages the first/second synchronizer from the first speed gear and moves it until it locks the second speed gear to the mainshaft.



Power flow is still through the input shaft and clutch gear to the counter gear. However, now the second counter gear on the cluster transfers power to the second speed gear locked on the mainshaft. Power flows from the second speed gear through the synchronizer to the mainshaft (output shaft) and driveline.

Power flow in third gear



When the shift from second to third gear is made, the shift fork returns the first/second synchronizer to its neutral position.

A second shift fork slides the third/fourth synchronizer until it locks the third speed gear to the mainshaft.

Power flow now goes through the third gear of the counter gear to the third speed gear, through the synchronizer to the mainshaft and driveline.

Power flow in fourth gear

In fourth gear, the third/fourth synchronizer is moved to lock the clutch gear on the input shaft to the mainshaft.

This means the power flow is directly from the input shaft to the mainshaft (output shaft) at a gear ratio of 1:1.

This ratio results in maximum speed output and no torque multiplication. This is also known as direct drive.

Power flow in reverse gear

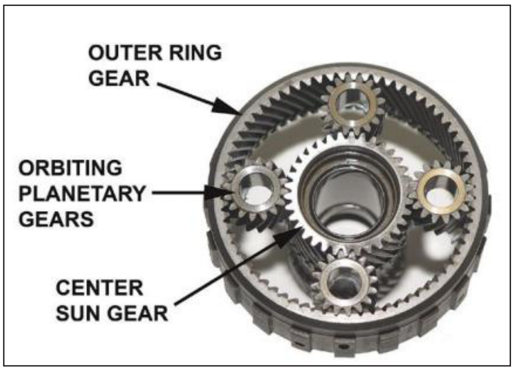
In reverse gear, it is necessary to reverse the direction of the mainshaft (output shaft). This is done by introducing a reverse idler gear into the power flow path. The idler gear is located between the countershaft reverse gear and the reverse speed gear on the mainshaft. When reverse gear is selected, both synchronizers are disengaged. In the transmission, the shifting linkage moves the reverse idler gear into mesh with the first/second synchronizer sleeve. Power flows through the input shaft and clutch gear to the countershaft. From the countershaft, it passes to the reverse idler gear, where it changes rotational direction. It then passes to the mainshaft and driveline.

Automatic Transmission Components

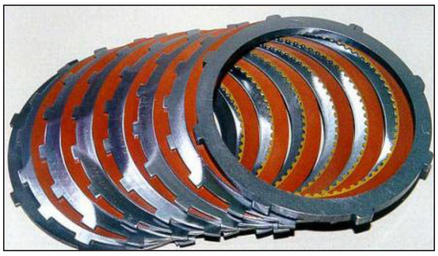
The automatic transmission mainly contains the following systems within it.

- Mechanical system
- Hydraulic systems
- Electrical systems
- Computer controls

Mechanical systems - Planetary gears



The planetary gear sets provide the 4,5 or 6 forward gear ratios and a reverse gear. Changing gear ratios is fully automatic and is accomplished through the use of a transmission control module (TCM) located inside the transmission. The TCM receives and monitors various electronic sensor inputs and uses this information to shift the transmission at the optimum time.



Mechanical Systems - Friction clutches

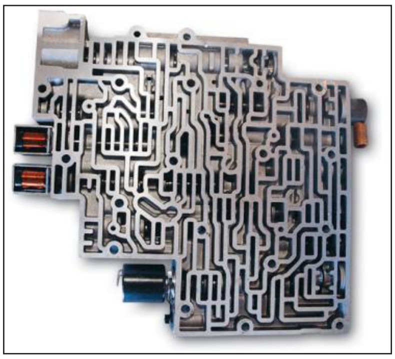
The multiple disc clutches combine with one way clutch to deliver different gear ratios, through the gear sets. The gear sets then transfer torque through the transfer drive gear, transfer driven gear and differential assembly.

Mechanical Systems - Torque converter

The 4-element torque converter contains a pump, turbine, pressure plate splined to the turbine and a stator assembly. The torque converter acts as a fluid coupling to smoothly transmit power from the engine to the transmission.It also hydraulically provides additional torque multiplication when required. The pressure plate, when applied, provides a mechanical direct drive coupling of the engine to the transmission.

Hydraulic Systems - Gear-type pump

The pump maintains the working pressures needed to stroke the clutch pistons that apply or release the friction components. These friction components, when applied or released, support the automatic shifting qualities of the transmission.



Hydraulic Systems - Control valve body assembly and case

The control valve body is made up of aluminium which has many fluid ports and passages. It houses electrical solenoids and mechanical valves which operate as per the TCM commands to apply and release the clutches.

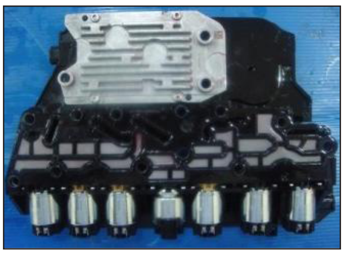
Electrical Systems

The electrical systems include the following

- Pressure control solenoids
- Speed sensors
- TCC solenoids
- Shift solenoids

The solenoids operate as per the TCM commands to operate the mechanical valves which in turn operate the mechanical clutches.

Computer Controls



The computer control system includes the TCM (Transmission Control Module). It gets the inputs from various sensors and commands the solenoid and switches inside the transmission for smooth shifting of gears.

Key Learnings

Summarise your learnings here. Write your answers in the spaces provided.

1. Describe the power flow in second gear?

2. Describe a synchromesh device?

3. State the difference between main shaft and lay shaft?

Worksheet

1. *Read the questions and tick the correct answer.*

   a. What do you mean by TCM?

      i. Transmission Control Module ☐

      ii. Torque Control Module ☐

      iii. Time Control Module ☐

      iv. None of the above ☐

   b. Function of the reverse gear idler is to change the direction of rotation of the engine crankshaft.

      i. True ☐

      ii. False ☐

Notes

Answers: Transmission Components

Question Number	Answer
1	a. iii b. iv

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