ST. ANNE'S COLLEGE OF ENGINEERING AND TECHNOLOGY

(Accredited by NAAC, Approved by AICTE, New Delhi. Affiliated to Anna University, Chennai)
ANGUCHETTYPALAYAM, PANRUTI – 607 106.

DEPARTMENT OF MECHANICAL ENGINEERING

ME3451	**THERMAL ENGINEERING**	**L T P C**
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OBJECTIVES:

1. To learn the concepts and laws of thermodynamics to predict the operation of thermodynamic cycles and performance of Internal Combustion(IC) engines and Gas Turbines.
2. To analyzing the performance of steam nozzle, calculate critical pressure ratio
3. To Evaluating the performance of steam turbines through velocity triangles, understand the need for governing and compounding of turbines
4. To analyzing the working of IC engines and various auxiliary systems present in IC engines
5. To evaluating the various performance parameters of IC engines

UNIT I THERMODYNAMIC CYCLES 12

Air Standard Cycles – Carnot, Otto, Diesel, Dual, Brayton – Cycle Analysis, Performance and Comparison, Basic Rankine Cycle, modified, reheat and regenerative cycles.

UNIT II STEAM NOZZLES AND INJECTOR 12

Types and Shapes of nozzles, Flow of steam through nozzles, Critical pressure ratio, Variation of mass flow rate with pressure ratio. Effect of friction. Metastable flow.

UNIT III STEAM AND GAS TURBINES 12

Types, Impulse and reaction principles, Velocity diagrams, Work done and efficiency – optimal operating conditions. Multi-staging, compounding and governing. Gas turbine cycle analysis – open and closed cycle. Performance and its improvement - Regenerative, Intercooled, Reheated cycles and their combination.

UNIT IV INTERNAL COMBUSTION ENGINES – FEATURES AND COMBUSTION 12

IC engine – Classification, working, components and their functions. Ideal and actual : Valve and port timing diagrams, p-v diagrams- two stroke & four stroke, and SI & CI engines – comparison. Geometric, operating, and performance comparison of SI and CI engines. Desirable properties and qualities of fuels. Air-fuel ratio calculation – lean and rich mixtures. Combustion in SI & CI Engines – Knocking – phenomena and control.

UNIT V INTERNAL COMBUSTION ENGINE PERFORMANCE AND AUXILIARY SYSTEMS 12

Performance and Emission Testing, Performance parameters and calculations. Morse and Heat Balance tests. Multipoint Fuel Injection system and Common rail direct injection systems. Ignition systems – Magneto, Battery and Electronic. Lubrication and Cooling systems. Concepts of Supercharging and Turbocharging – Emission Norms

TOTAL: 60 PERIODS

TEXT BOOKS:

1. Mahesh. M. Rathore, "Thermal Engineering", 1st Edition, Tata McGraw Hill, 2010.
2. Ganesan.V, " Internal Combustion Engines" 4th Edition, Tata McGraw Hill, 2012.

REFERENCES:

1. Ballaney. P, "Thermal Engineering", 25th Edition, Khanna Publishers, 2017.
2. Domkundwar, Kothandaraman, &Domkundwar, "A Course in Thermal Engineering", 6th Edition, DhanpatRai& Sons, 2011.
3. Gupta H.N, "Fundamentals of Internal Combustion Engines", 2nd Edition Prentice Hall of India, 2013.
4. Mathur M.L and Mehta F.S., "Thermal Science and Engineering", 3rd Edition, Jain Brothers Pvt. Ltd, 2017.
5. So man. K, "Thermal Engineering", 2nd Edition, Prentice Hall of India, 2011.

COURSE OUTCOMES (COs)

CO 1	Apply thermodynamic concepts to different air standard cycles and solve problems.
CO 2	To solve problems in steam nozzle and calculate critical pressure ratio.
CO 3	Explain the flow in steam turbines, draw velocity diagrams, flow in Gas turbines and solve problems.
CO 4	Explain the functioning and features of IC engine, components and auxiliaries.
CO 5	Calculate the various performance parameters of IC engines

MAPPING BETWEEN COs, POs AND PSOs

COs	**PROGRAMME OUTCOMES (POs)**												**PSOs**		
	PO 1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO1 0**	**PO1 1**	**PO1 2**	**PSO 1**	**PSO 2**	**PSO 3**
CO 1	3	2	1	1								1	2	1	
CO 2	3	2	2	1								1	2	1	
CO 3	3	2	2	1								1	2	1	
CO 4	3	2	1	1								1	2	1	
CO 5	3	2	1	1								1	2	1	

Low (1) ; Medium (2) ; High (3)

UNIT-I THERMODYNAMIC CYCLES

PART- A

1. What is a thermodynamic cycle?

Thermodynamic cycle is defined as the series of processes performed on the system, so that the system attains its original state.

2. What are the assumptions made for air standard cycle analysis?

(i) The working medium is a perfect gas i.e., It follows the law **pv = mRT**

(ii) The working medium does not undergo any chemical change throughout the Cycle.

(iii) The compression and expansion processes are reversible adiabatic i.e., There is no loss or gain of entropy.

(iv) The operation of the engine is frictionless.

3. Mention the various processes of dual cycle.

(i) Isentropic compression.

(ii) Constant pressure heat supplied.

(iii) Isentropic expansion, and

(iv) Constant pressure heat rejection.

4. Define air standard cycle efficiency.

Air standard efficiency is defined as the ratio of work done by the cycle to heat supplied to the cycle.

5. Define mean effective pressure as applied to gas power cycles.

Mean effective pressure is defined as the constant pressure acting on the pistonduring the working stroking. It is also defined as the ratio of work done to the stroke volume or piston displacement volume.

6. Define the following terms (i) Compression ratio (ii) Cut off ratio and (iii) Expansion ratio?

(i) Compression ratio is defined as the ratio between total cylinder volumes to clearance volume.

(ii) Cut off ratio is defined as the ratio of volume after the heat addition to volume before the heat addition.

(iii) Expansion ratio is the ratio of volume after the expansion to the volume before expansion.

7. Which cycle is more efficient with respect to the same compression ratio?

` For the same compression ratio, Otto cycle is more efficient than diesel cycle.

8. For the same compression ratio and heat supplied, state the order of decreasing air standard efficiency of Otto, diesel and dual cycle.

$\eta_{Otto} > \eta_{Dual} > \eta_{Diesel}$

9. Name the factors that affect air standard efficiency of Diesel cycle.

Compression ratio and cut-off ratio.

10. What is the effect cut-off ratio on the efficiency of diesel cycle when the compression ratio is kept constant?

When cut-off ratio of diesel cycle increases, the efficiency of cycle is decreased when compression ratio is kept constant and vice versa.

11. Write any four major differences between Otto and diesel cycle.

Sl.No.	**Otto cycle**	**Diesel cycle**
1	It consists of two isentropic and two constant volume processes.	It consists of two isentropic, one constant volume and one constant pressure processes.
2	Heat addition takes place of constant volume.	Heat addition takes place of constant Pressure.
3	Compression ratio is equal to expansion ratio.	Compression ratio is greater than Expansion ratio.

12. Name the various types of gas power cycles.

a. Carnot cycle
b. Otto cycle
c. Diesel Cycle
d. Brayton Cycle
e. Dual Combustion Cycle
f. Atkinson Cycle

13. Mention the various process of Brayton Cycle.

(a) Isentropic Compression (b).Constant Pressure Heat addition (c) Isentropic Expansion (d) Constant Pressure heat Rejection

14. What are the processes involved in Carnot cycle.

Carnot cycle consist of
i) Reversible isothermal compression ii) isentropic compression
iii) reversible isothermal expansion iv) isentropic expansion

15. What are the assumptions made for air standard cycle.

1. Air is the working substance.
2. Throughout the cycle, air behaves as a perfect gas and obeys all the gas laws.
3. No chemical reaction takes place in the cylinder
4. Both expansion and compression are strictly isentropic
5. The values of specific heats of the air remain constant throughout the cycle.

16. Define: Mean effective pressure of an I.C. engine.

Mean effective pressure is defined as the constant pressure acting on the piston during the working stroke. It is also defined as the ratio of work done to the stroke volume or piston displacement volume.

17. What will be the effect of compression ratio on efficiency of the diesel cycle?

Efficiency increases with the increase in compression ratio and vice – versa.

18. What will be the effect of cut off ratio on efficiency of the diesel cycle?

Efficiency decreases with the increase of cut off ratio and vice – versa.

19. What are the factors influencing of the Dual cycle?

1. Compression ratio 2.cut off ratio 3. Pressure ratio and 4. Heat supplied at constant Volume and constant pressure.

20. What is meant by air standard efficiency of the cycle?

It is defined as the ratio of **work** done by the cycle to the heat supplied to the cycle.

Part-B

Otto Cycle:

1. Derive an expression for air standard efficiency of an Otto cycle. Obtain an expression formean effective pressure of an Otto cycle.

2. In an engine working on constant volume cycle, the pressure, temperature and volume at the beginning of the cycle are 1.2 bar, 35oC and 0.5 m3 respectively. At the end of compression stroke, the pressure is 12 bar. 315 kJ of heat is added per kg of gas during constant volume heating process. Calculate the pressure, temperature and volume at all points. Also find the air standard efficiency of the cycle.

Diesel cycle:

3. An air standard Diesel cycle has a compression ratio of 12 and cutoff takes place at 6% ofthe stroke. Calculate the air standard efficiency of the cycle.

4. 1kg of air is taken through a diesel cycle. Initially the air is at 25oC and 1 bar. The compression ratio is 14 and the heat added is 1850KJ. Calculate the ideal cycle efficiency andthe mean effective pressure.

Dual Cycle:

5. In a dual cycle the air is compressed isentropically to 1/14th of its initial volume. At the end ofcompression heat is added at constant volume till its pressure increases to twice the pressure at the end of compression. Then heat is added at constant pressure till its volume increases to twice the volume after compression. Find the efficiency of the cycle.

6. In engine working on Dual cycle, the temperature and pressure at the beginning of cycle are 90oC and one bar. The compression ratio is 9. The maximum pressure is limited to 68bar and total heat supplied per kg of air is 1750kJ. Determine air standard efficiency and mean effective pressure.

Brayton Cycle:

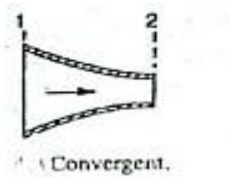
7. Derive an expression for air standard efficiency of a Brayton cycle in terms of pressure ratio and compression ratio. Also prove that the pressure ratio for maximum work is a function of limiting temperature ratio.

8. The extreme of pressure and temperature in an open circuit constant pressure gas turbine plant are 1 bar, 5.25bar and 25oC and 560oC respectively. The isentropic efficiency of the turbine is 88% and that of the compressor is 84%. Determine the efficiency of the plant.

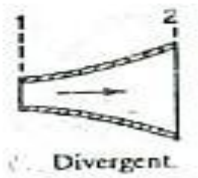
UNIT – II STEAM NOZZLES AND INJECTOR

PART – A

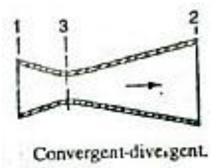
1. **What is steam nozzle?**
   A steam nozzle is defined as a passage of varying cross section, through which heat energy of steam is converted to kinetic energy. Its major function is to produce steam jet with high velocity to drive steam turbines.
2. **Write about the function of nozzle**
   The major function of nozzle is to produce jet of steam or gas of high velocity to produce thrust for the propulsion of rocket motors and jet engines and drive steam or gas turbines.
3. **List the types of nozzle.**
   1. Convergent Nozzle, 2. Divergent Nozzle, 3. Convergent-Divergent Nozzle
4. **Define Convergent nozzle.**
   In a convergent nozzle, the cross sectional area decreases continuously from its entrance to exit. It is used in a case where the back pressure is equal to or greater than the critical pressure ratio



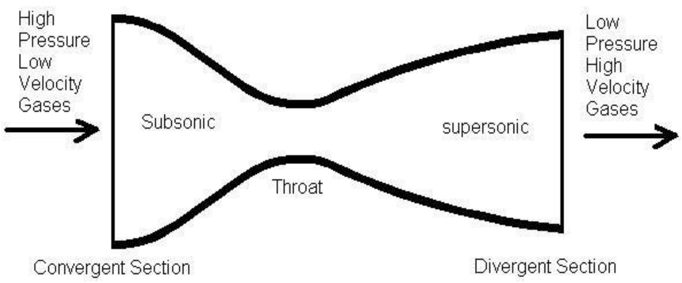
5. **Define divergent nozzle.**
   The cross sectional area of divergent nozzle increases continuously from its entrance to exit. It is used in a case, where the back pressure is less than the critical pressure ratio



6. **Define Convergent-Divergent nozzle.**
   In this case, the cross sectional area first decreases from its entrance to throat, and then increases from throat to exit.it is widely used in many type of steam turbines



7. **Draw the shape of supersonic nozzle.** **[May 2016]**



8. **Define critical pressure ratio. Give its expression. [Nov 2017,Nov 2018,Jul 2021]** The critical pressure ratio is the pressure ratio which will accelerate the flow to a velocity equal to the local velocity of sound in the fluid. The maximum gas flow through a nozzle is determined by the critical pressure. The pressure at which the area is minimum and discharge per unit area is maximum is called critical pressure ratio.

9. Define nozzle efficiency or coefficient of nozzle [Dec 2013, Nov 2018]

The nozzle efficiency is therefore defined as the ratio of the actual enthalpy dropto the isentropic enthalpy drop between the same pressures. Nozzle efficiency = (actual enthalpy drop) / (isentropic enthalpy drop)

10. List the effects of friction in nozzle. [May 2014, Dec 2015, May 2018]

In practice, there is friction produced between the steam and the sides of the nozzle; this friction causes a resistance to the flow which is converted into heat. The heat formed tends drying the steam. i) The expansion is no more isentropicand enthalpy drop is reduced ii) The final dryness fraction of steam is increased as the kinetic energy gets converted in to heat due to friction and is absorbed by steam. iii) The specific volume of steam is increased as the steam becomes more dry due to this frictional reheating.

11. List the factors which influence nozzle efficiency.

When the steam flows through a nozzle the final velocity of steam for givenpressure drop is reduced due to the following reasons

i) The friction between the nozzle surface and steam

ii) The internal friction of steam itself

iii) The shock losses.

12. Define degree of undercooling and degree of super saturation. [Jul 2021]

The difference of supersaturated temperature and saturation temperature at that pressure is known as degree of under cooling.

The ratio of super saturation pressures corresponding to the temperature between super saturated region is known as the degree of super saturation.

13. Define coefficient of velocity in nozzle. [Dec 2014]

The ratio of the actual velocity of gas emerging from a nozzle to the velocity calculated under ideal conditions; it is less than 1 because of friction losses.

14. Define coefficient of Discharge.

The ratio of the actual discharge to maximum discharge is known as coefficient of discharge.

15. What is meant by carry over loss?

The velocity of steam at exit is sufficiently high thereby resulting in a kinetic energy loss called Carry over loss or Leading velocity loss.

16. If the enthalpy drop in a stem nozzle of efficiency 92% is 100 kJ/kg determine the exit velocity of steam. [May2017]

$C_2 = \sqrt{\eta(\Delta h)} \Longrightarrow C_2 = \sqrt{0.92 \times 100} \Longrightarrow \boldsymbol{C_2 = 9.59\ m/s}$

17. Write the equation of maximum discharge through a nozzle.

$$m_{max} = A\sqrt{\frac{2n}{n+1} \times \frac{p_1}{v_1} \times \left(\frac{2n}{n+1}\right)^{\frac{2}{n-1}}}$$

18. Mention the values of maximum discharge for various steam.

Types of Steam	**Index number**	**Maximum Discharge**	**Critical Pressure ratio**
Dry saturated	n=1.135	$m_{max} = 0.637\ A\sqrt{\frac{p1}{v_1}}$	$\frac{p2}{p1} = 0.577$
Superheated	n=1.3	$m_{max} = 0.666\ A\sqrt{\frac{p1}{v_1}}$	$\frac{p2}{p1} = 0.546$
Gas	n=1.4	$m_{max} = 0.685\ A\sqrt{\frac{p1}{v_1}}$	$\frac{p2}{p1} = 0.582$
Wet steam	n=		

19. What is meant by metastable flow?

Equilibrium between the liquid and vapour phase is delayed and the steam Continues to expand in a dry state. The steam in such a set of conditions is said tobe supersaturated or in metastable state as its temperature at any pressure is less than the saturation temperature corresponding to the pressure. The flow of supersaturated steam, through the nozzle is called supersaturated flow or metastable flow.

20. What are the effects of super saturation or supersaturated flow? [Nov 2016]

- There is an increase in the entropy and specific volume of steam
- The heat drop is reduced below that for thermal equilibrium as anconsequence the exit velocity is reduced.
- The density of supersaturated steam will be more than for the equilibrium conditions which gives the increase in the mass of steam discharged.
- The dryness fraction of steam is improved.

21. Differentiate supersaturated flow and isentropic flow.

S.No	**Supersaturated flow**	**Isentropic flow**
1	Entropy is not constant	Entropy remains constant
2	Super saturation reduces the heat drop therefore exit velocity is reduced	No reduction in enthalpy drop.
3	Mollier diagram cannot be used	Mollier diagram can be used.

22. What is meant by steam injector?

A steam injector is a device employed to force water in to the boiler under pressure.

23. List the applications of steam nozzle

i) To rotate steam turbine

ii) Thermal power plant

iii) To produce a very fine jet spray

iv) It is also used for cleaning purpose.

PART – B

1. Derive the condition for maximum flow rate in steam nozzle. **[May 2018]**
2. Define critical pressure ratio of a nozzle and discuss why attainment of sonic velocity. Also determines the maximum discharge through steam nozzle.
3. Derive the equation for critical pressure ratio. **[Nov 2017]**
4. Derive the following expression for nozzle flow: $\frac{dA}{A} = \frac{1}{\gamma}\frac{dp}{p}\left[\frac{1-M^2}{M^2}\right]$ where the symbols are having usual meanings. **[Jul 2021]**
5. In a steam nozzle, the steam expands from 4 bar to 1 bar. The initial velocity is 60m/s and initial temperature is 200ºC. Determine the exit velocity if nozzle efficiency is 92%. **[Nov/Dec 2018]**
6. Steam expands isentropically in a nozzle from 1 MPa, 250º C to 10 KPa. The flow rate of the steam is 1 kg/s. Find the following when the inlet velocity is neglected, (i) Quality of steam, (ii) Velocity of steam at the exit of the nozzle, (iii) Exit area of the nozzle. **[Dec 2013]**
7. The flow rate through steam nozzle with isentropic flow from pressure of 13 bar was found 60 kg/min. steam is initially saturated. Determine the throat area. If the flow is super saturated, determine the increase in flow rate. **[May 2014]**
8. Dry saturated steam at a pressure of 11 bar enters a convergent-divergent nozzle and leaving at a pressure of 2 bar. If the flow is adiabatic and frictionless, determine i) the exit velocity of a steam, ii) Ratio of cross section of exit and that at throat. Assume the index of adiabatic expansion to be 1.135 **[May2015,Jul2021]**
9. Steam at a pressure of 10.5 bar and 0.95 dry is expanded through a CD nozzle. The pressure of steam leaving the nozzle is 0.85 bar. Find the velocity of steam at throat for maximum discharge. Take n=1.35. Also find the area at the exit and steam discharge if the throat area is 1.2square cm. Assume the flow is isentropicand there are no friction losses**.** **[Dec 2014]**
10. (a) What are the effects of friction in a nozzle? Explain
11. (b) A convergent-divergent nozzle is required to discharge 2 kg/s of steam. The nozzle is supplied with steam at 7 bar and 180ºC and discharge takes place against a back pressure of 1 bar. The expansion upto the throat is isentropic and the frictional resistance between the throat and the exit is equivalent to 63 kJ/kg of steam. Taking approach velocity of 75m/s and throat pressure of 4 bar estimate suitable areas for throat and exit and overall of the nozzle based on the enthalpy drop between the actual inlet pressure and temperature and the exit pressure. **[May 2013]**
12. In a test on a steam nozzle, the issuing steam jet impinges on a stationary flat plate which is perpendicular to the direction of flow and the force on the plate is measured. With convergent-divergent nozzle supplied with steam at 10 bar dry saturated and discharging at 1 bar; the force is experimentally measured to be 600N. The area of the nozzle at throat measures 5 cm^2 and that exit area is such that complete expansion is achieved under these conditions. Determine: (i) flow

rate of the steam, and (ii) the efficiency of the nozzle assuming that all losses occur after the throat. Assume n = 1.135 for isentropic expansion. **[May 2017]**

13. The dry and saturated steam at a pressure of 10.5 bar is expanded isentropically in a nozzle to a pressure of 0.7 bar. Determine the final velocity of the steam issuing from the nozzle, when (a) friction is neglected, and (h) 10% of the heat drop is lost in friction. The initial velocity of steam may be neglected.
14. Gases expand in a convergent divergent nozzle from 3.6 bar and 425° C to aback pressure of I bar, at the rate of 18kg/s. If the nozzle efficiency is 0.92, calculate the required throat and exit areas of the nozzle. Neglect inlet velocity and friction in the convergent part. For the gases, take C_p = 1.113 kJ/kg K and γ= 1.33
15. Dry saturated steam at 2.8bar is expanded through a convergent nozzle to 1.7 bar. The exit area is 3cm^3. Calculate the exit velocity and mass flow rate for, (i) Isentropic expansion, (ii) Super saturated flow. **[Nov/Dec 2018]**
16. Explain the supersaturated or metastable flow of steam through nozzle and the significance of Wilson's line. **[May 2016]**
17. What are the effects of super saturation on discharge and heat drop?
18. The dry saturated steam is expanded in a nozzle from pressure of 10 bar to apressure of 5 bar if she expansion is supersaturated, find: 1. the degree of undercooling and 2. the degree of supersaruration.

PART – C (C301.1)

1. Dry saturated steam at a pressure of 8bar enters a convergent divergent nozzle and leaves it at a pressure of 1.5bar. If the flow is isentropic and if the corresponding expansion index is 1.133, find the ratio of cross-sectional area atexit and throat for maximum discharge. **[AU Nov/Dec 2015]**
2. Steam turbine develops 185 kW with a consumption of 16.5 kg/kW/h. The Pressure and temperature of the steam entering the nozzle are 12 bar and 220º C. The steam leaves the nozzle at 1.2 bar. The diameter of the nozzle at throat is 7mm, Find the number of nozzles. If 8% of the total enthalpy drop is lost in friction in the diverging part of the nozzle, determine the diameter at the exit ofthe nozzle and the exit velocity of the leaving steam. Sketch the skeleton Mollier diagram and show on it the values of pressure, temperature or dryness fraction, enthalpy and specific volume at inlet, throat and exit. **[Nov/Dec 2018]**
3. Calculate the throat and exit diameters of a convergent divergent nozzle which will discharge 820kg of steam per hour from a pressure of 8bar superheated to220º C into a chamber having a pressure of 1.5bar. The friction loss in the divergent part of the nozzle maybe taken as 0.15 of the total enthalpy drop.
4. State the relation between the velocity of steam and heat during any part of a steam nozzle.
5. Find the percentage increase in discharge from a convergent-divergent nozzle expanding steam from 8.75 bar dry to 2 bar. when; 1. the expansion is taking place under thermal equilibrium, and 2. the steam is in metastable state during pan of its expansion. Take area of nozzle as 2500 mm^2

UNIT-III STEAM AND GAS TURBINES

PART-A

1. **Define Steam turbine.**
   A steam turbine is a prime mover in1iich rotary motion is obtained by thegradual change of momentum of the steam. The force exerted on the blades is due to the velocity of steam. This is due to the fact that the curved blades by changing the direction of steam receive a force or impulse.
2. **Advantage of steam turbine over reciprocating steam engines.**
   - Steam turbine may develop higher speeds and a greater steam range is possible.
   - The efficiency of a steam turbine is higher.
   - The steam consumption is less.
   - Since all the moving pails are enclosed in a casing, the steam turbine is comparatively safe.
   - A steam turbine requires less space and lighter foundations, as there arelittle vibrations.
   - There is less frictional loss due to fewer sliding parts.
   - The applied torque is more uniform to the driven shaft.
   - A steam turbine requires less attention during running. Moreover, the repair Costs are generally less.
3. **Classify steam turbine according to the classification of flow.**
   i) Impulse turbine ii) Reaction turbine iii) combination of impulse and reaction
4. **Classification of steam Turbine**
   The steam turbines may be classified into the following types:
   According to the mode of steam action: (i) Impulse turbine, and (ii) Reaction turbine.
   According to the direction of steam flow: (i) Axial flow turbine, and (ii) Radial flow turbine.
   According to the exhaust condition of steam: (i) Condensing turbine, and (ii)Non-condensing turbine.
   According to the pressure of steam: (i) High pressure turbine, (ii) Mediumpressure turbine, and (iii) Low pressure turbine.
   According to the number of stages: (i) Single stage turbine, and (ii) Multi-stageturbine.
5. **Define Impulse turbine.**
   An *impulse turbine, as the name indicates, is a turbine which runs by the impulse of steam jet In this turbine, the steam is first made to flow through a nozzle. Then the steam jet impinges on the turbine blades (which are curved like buckets) and are mounted on the circumference of the wheel. The steam jet after impinging glides over the concave surface of the blades and finally leaves the turbine. This is also known as De-Level Impulse.
6. **Define two stages Impulse turbine.**
   The steam after leaving the moving blade is made to flow through a fixed blade ring (in order to make the steam to flow at a designed angle and again impinges on second moving blade. This type of turbine is called two-stage impulse turbine.

7. Define Reaction turbine. **[Jul 2021]**

In a reaction turbine, the steam enters the wheel under pressure and flows over the blades. The steam while gliding propels the blades and makes them to move. As a matter of fact, the turbine runner is rotated by the reactive forces of steam jets. The backward motion of the blades is similar to the recoil of a gun. This is also known as Parson's Reaction Turbine

8. Differentiate impulse turbine and reaction turbine. **[MAY 2018]**

S.No	**Particulars**	**Impulse Turbine**	**Reaction Turbine**
1	Pressure drop	Only in nozzles and not in moving blades.	In fixed blades (nozzles) as well as in moving blades.
2	Area of blade channels	Constant	Varying
3	Blades	Profile type	Aerofoil type.
4	Admission of steam	Not all round	All round or complete
5	Nozzles	Diaphragm contains the nozzle	Fixed blades similar to moving blades attached to the casing serve as nozzles and guide the steam.
6	Power	Not much power can be developed.	Much power can be developed.
7	Efficiency	Low	High

9. Define blade efficiency or diagram efficiency.

It is the ratio of work done on the blade per second to the energy entering theblade per second.

10. Define stage efficiency.

The stage efficiency covers all the losses in the nozzles, blades, diaphragms and discs that associated with that stage.

$$\eta_{stage} = \frac{Networkdoneonshaftperkgofsteamflowing}{adiabaticheatdropperstage}$$

11. Define blade velocity coefficient or coefficient of velocity or Friction factor. **[Jul 2021]**

The blade velocity coefficient is defined as the ratio of relative velocity of steamas is passes over the blades without frictional resistance to relative velocity of steam with friction resistance.

$K = \frac{C_{r0}}{C_{r1}}$ where K is blade velocity coefficient

12. Define blade speed ratio

Blade speed ratio is defined as the ratio of blade speed to steam speed $\rho = \frac{Cbl}{C1}$

13. Define degree of reaction. **[May/June 2014] [Nov/Dec 2014]**

Degree of reaction or reaction ratio (R) is defined as the ratio of static pressuredrop in the rotor to the static pressure drop in the stage or as the ratio of static enthalpy drop in the rotor to the static enthalpy drop in the stage.

14. Define coefficient of velocity in nozzle? **[Nov/Dec 2014]**

The ratio of the actual velocity of gas emerging from a nozzle to the velocity calculated under ideal conditions; it is less than 1 because of friction losses.

15. What is meant by carry over loss?

The velocity of steam at exit is sufficiently high thereby resulting in a kinetic energy loss called Carry over loss or Leading velocity loss.

16. What are the methods adopted to prevent erosion in steam turbines?

i) By raising the temperature of steam at inlet, so that at exit of turbine the wetness does not exceed 10%

ii) By adopting reheat cycle; so that wetness at exit remains in limit.

iii) Drainage belts are provided on the turbine, so that the water droplets are on outer periphery, due to centrifugal force are drained. The drained amount is about 25 percent of total water particles present.

17. What do you mean by bleeding in steam turbine?

Bleeding is the process of draining steam from the turbine at certain points during its expansion and using this steam for heating the feed water supplied to the boiler.

18. What is meant by stage in turbine?

In an impulse turbine, stage means set of nozzles outside the turbine + moving blades on the rotor. In a reaction turbine, stage means one set of fixed blades + one set of moving blades.

19. What are the losses in steam turbine?

Residual velocity losses, Loss due to friction, Radiation losses, Loss due to moisture.

20. What are the possible causes of excessive vibration or noise in steam turbine?

Misalignment, worn bearings, unbalanced wheel, unbalanced coupling, bent shaft, piping strain.

21. Define compounding of turbine and classify it. [NOV 2017]

The steam is expanded from the boiler pressure to condenser pressure in one stage the speed of the rotor becomes tremendously high which crops up practicalcomplicacies. There are several methods of reducing this speed to lower value allthese methods utilize a multiple system of rotor in series keyed on a common shaft and the steam pressure or jet velocity is absorbed in stages as the steam flows over the blades. This is known as compounding. The different methods of compounding are i) Velocity compounding ii) Pressure compounding iii)Pressure velocity compounding.

22. What is the purpose of compounding?

Compounding is the method in which multiple system or rotors are keyed to common shaft in series and the steam pressure or jet velocity is absorbed in stages as it flows over the rotor blades.

Purpose of compounding: Reduction of pressure (from boiler pressure to condenser pressure) in single results in the very high velocity entering the turbine blades. Therefore, the turbine rotor will run at a high speed about 30,000rpm which is not useful for practical purpose. In order to reduce the rotor speed up to about 400 m/sec, compounding of steam turbine is necessary.

23. What is pressure compounding? [April/May 2015]

The Steam Pressure compounding is the method in which pressure in a steam turbine is made to drop in a number of stages rather than in a single nozzle. This method of compounding is used in Rateau and Zoelly turbines.

24. What are the advantages of velocity compounded impulse turbine?

i) Owing to relatively large heat drop, a velocity compounded impulse turbine requires a comparatively small number of stages.

ii) Due to number of stages being small, its cost is less

iii) The steam temperature is sufficiently low in a two or three row wheel;therefore cast iron cylinder may be used. This will cause saving in material cost.

25. What do you mean by governing of steam turbine? Classify it

Governing of steam is to control the rotational speed of turbine by controlling theflow of steam into turbine irrespective of varying load on turbine. Classification

i) Throttle governing ii) Nozzle governing iii) By-pass governing iv) combinationof Throttle Nozzle By-pass governing.

26. What is the remedy for a bent steam turbine shaft causing excessive vibration?

i) The run-out of the shaft near the centre as well as the shaft extension should be checked.

ii) If the run-out is excessive, the shaft is to be replaced

PART – B (C301.3)

1. Explain the pressure and velocity compounding diagram of multistage turbinewith neat sketch. **[Nov/Dec 2014] [Jul 2021]**

2. Elucidate the working of velocity, pressure and velocity pressure compounding methods with neat sketch. **[May 2018]**

3. Explain the pressure band velocity compounding of a multi stage turbine.

4. In a single stage impulse turbine, nozzle angle is 20º and blade angles are equal.The velocity coefficient for blade is 0.85. Find maximum blade efficiency possible. If the actual blade efficiency is 92% of the maximum blade efficiency, find the possible ratio of blade speed to steam speed. **[Jul 2021]**

5. In a De-lavel turbine, the steam enters the wheel through a nozzle with a velocity of 500 m/s and at an angle of 20º to the direction of motion of the blade. Theblade speed is 200 m/s and the exit angle of the moving blade is 25°. Find the inlet angle of the moving blade, exit velocity of steam and its direction and work done per kg of steam.

6. In a De Laval Turbine steam issues from the nozzle with a velocity of 1200 m/s. The nozzle angle is 20˚C, the mean blade velocity is 400 m/s and the inlet andoutlet angles are equal. The mass of steam flowing through the turbine per houris 1000 kg. Calculate i) Blade angles ii) Relative velocity of steam entering the blades iii) Tangential force on the blades iv) Power developed v) Blade efficiency. Take blade velocity co-efficient as 0.8 **[April/May 2015]**

7. A steam jet enters the row of blades with a velocity of 375 m/s at an angle of 20º with the direction of motion of the moving blades. If the blade speed is 165 m/s,find the suitable inlet and outlet blade angles assuming that there is no thrust onthe blades. The velocity of steam passing over the blades is reduced by 15%. Also determine power developed by the turbine per kg of steam flowing aver the blades per second.

8. In a single stage impulse turbine the isentropic enthalpy drop of 200 kJ/kg occursin the nozzle having efficiency of 96% and nozzle angle of 15°. The blade velocity coefficient is 0.96 and ratio of blade speed to steam velocity is 0.5. The steam mass flow rate is 20 kg/s and velocity of steam entering is 50 m/s. Determine (a)the blade angles at inlet and outlet if the steam enters blades smoothly and leaves axially, (b) the blade efficiency, (c) the power developed in kW and (d) the axial thrust.

9. Steam enters the blade row of an impulse turbine with the velocity of 600 m/s atan angle of 25℃ to the plane of rotation of the blades the blade mean speed is 250 m/s. The blade angle at the exit side is 30°C. The blade friction loss is 10 %.
Determine blade angle inlet, blade efficiency and work done per kg of steam

[May/ June 2014]

10. (a) The velocity of steam leaving the nozzle of an impulse turbine is 10000m/s and the nozzle angle is 20ºC . The blade velocity is 350m/s and the blade velocity of co-efficient is 0.85.Assuming no losses due to shock at inlet ,calculate for a mass flow of 1.5kg/s ,and symmetrical blading, (i) Blade inlet angle, (ii)

Driving force on the wheel, (iii) Axial thrust on the wheel and (iv) Power developed by the turbine.

(b) Differentiate between impulse and reaction turbine. **[April/May 2013]**

11. In a single stage impulse turbine the blade angles are equal and nozzle angle is 20^o.the velocity coefficient for the blade is 0.83 find the maximum blade efficiencypossible. If the actual blade efficiency is 90% of maximum blade efficiency, find the possible ratio of blade speed to steam speed. **[Nov/Dec 2017]**

12. In one stage of a reaction steam turbine, both the fixed and moving blades have inlet and outlet blade tip angles of 35º and 20º respectively. The mean blade speed is 80 m/s and the steam consumption is 22 500 kg per hour. Determine the power developed In the pair, if the isentropic heat drop for the pair is 23.5 kJ per kg.

13. A Parson's reaction turbine, while running a 1400 r.p.m. consumes 30 tonnes of steam per hour. The steam at a certain stage is at 6 bar with dryness fraction of 0.9 and the stage develops 10 kW. The axial velocity of flow is constant and equal to 0.75 of the blade velocity. Find mean diameter of the drum and the volume of steam flowing per second. Take blade tip angles at inlet and exit as 35º and 20º respectively.

14. A Parson's reaction turbine has mean diameter of blades as 1.6 m and rotor moving at 1500 rpm. The inlet and outlet angles are 80°C and 20°C respectively. Turbine receives steam at 12 bar, 200°C and has isentropic heat drop of 26 kJ/kg.5% of steam supplied is lost through leakage. Determine the following considering horse power developed in stage to be 600 hp.(a) the stage efficiency and (b) the blade height.

PART – C (C301.3)

1. A convergent-divergent nozzle for a steam turbine has to deliver steamunder a supply condition of 11 bar with 100ºC superheat and a back pressure of 0.15bar. if the outlet area of the nozzle is $9.7cm^2$, determine using steam tables, the mass of steam discharged per hour. If the turbine converts 60% of the total enthalpy drop into useful work, determine the power delivered by the turbine. Neglec the effect of friction in the nozzle. Take C_P of superheated steam as 2.3 kJ/kg.k

[Nov/Dec 2018]

2. A 50% reaction turbine (with symmetrical velocity triangles) running at 400 r.p.m. has the exit angle of the blades as 20º and the velocity of steam relative tothe blades at the exit is 1.35 times the mean blade speed. The steam flow rate is 8.33 kg/s and at a particular stage the specific volume is 1.381m3 /kg. Calculatefor this stage. A suitable blade height, assuming the rotor mean diameter to be 12 times the blade height.

3. In a reaction turbine, the blade tips are inclined at 35º and 20º in direction of motion. The guide blades are of the same shape as the moving blades, but reversed in direction. At a certain place in the turbine, the drum diameter is 1 meter and the blades are 100 mm high. At this place, steam has a pressure of 1.7

bar and dryness 0.935. If the speed of the turbine is 250 r.p.m. and the steam passes through the blades without shock, find the mass of steam flow and the power developed in the ring of the moving blades

4. A reaction turbine runs at 300 r.p.m. and its steam consumption is 15400 kg/hr. The pressure of steam at certain pair is 1.9 bar; its dryness 0.93 and power developed by the pair is 3.5 kW. The discharging blade tip angle is 20° for both fixed and moving blades and the axial velocity of flow is 0.72 of the blade velocity. Find the drum diameter and blade height. Take the tip leakage steam as 8%, but neglect blade thickness.

5. **(a)** List the advantages of steam turbines over gas turbines**.**

(b) Determine the isentropic enthalpy drop in the stage of Parson's reaction turbine which has the following particulars: speed=1500 rpm, mean diameter ofthe rotor = 1m, stage efficiency =80%, speed ratio = 0.7, blade outlet angle =20^{o}.

UNIT-IV INTERNAL COMBUSTION ENGINES – FEATURES AND COMBUSTION

PART-A

1. Write any two major differences between 'SI engine' and 'CI engine'.
2. Compare two stroke and four stroke engines.
3. Why diesel engines are more efficient than petrol engines?
4. Which is better efficient two stroke or four stroke engines? Why?
5. What is the function of camshaft and crankshaft?
6. What is the function of pushrod and rocker arm?
7. What are the functions of piston ring?
8. Why the actual cycle efficiency is much lower than the air-standard cycle efficiency? List and explain the major losses in an actual engine.
9. State the air-fuel ratio requirements of SI engine under various operating conditions.
10. Differentiate between ideal and actual valve timing diagram of a petrol engine.
11. Draw port-timing diagram of petrol engine.
12. What is scavenging in IC engines?
13. What is the function of a carburettor? What is carburetion?
14. Why a choke is used in carburettor and what is meant by automatic chocking?
15. What are the limitations of simple carburettor?
16. During peak power operation, why petrol engine requires rich mixture?

Part-B

1. (a) Explain any four types of classification of internal combustion engines.
   (b) Draw the valve timing diagram for a 4 stroke SI Engine.

2. (a) Explain any four types of classification of Internal Combustion engines.
   (b) With a neat sketch explain any one type of ignition system.

3. Explain the working of 4-stroke cycle Diesel engine. Draw theoretical and actual valve-timing diagram for the engine. Explain the reasons for the difference.

4. Explain why cooling is necessary in I.C. engine. With neat sketches describe the working

of water cooling system used for multi-cylinder engine. Why should a pump and thermostat be provided in the cooling system of an engine?

5. Explain with neat sketches the method of lubrication of the following parts of the I.C. Engines. (i) Piston and cylinder
   (ii) Crank-pin and Gudgeon pin
   (iii) Cam-shaft.

6. (i) Explain with neat sketch Air Cooling of Engines.
   (ii) Explain any one lubrication system adopted in multi cylinder SI engines.

7. Explain the principle of Magneto ignition system. Enumerate its advantages and disadvantages?

8.(a) What are the various factors influencing the flame speed in SI Engines?
   (b) Explain the normal combustion and knocking in a diesel engine with pressure-crankangle diagram

10. (i) Explain the function of a fuel injection pump with a simple sketch. (8)
   (ii) What are the advantages and disadvantages of Magneto ignition system over Batter ignition system? (8)

UNIT-V INTERNAL COMBUSTION ENGINE PERFORMANCE AND AUXILIARY SYSTEMS

PART-A

1. EXPLAIN IN DETAIL ABOUT CLASSIFICATION OF ENGINES

ANS:

Heat Engines are otherwise called "Thermal Engines". It is a machine which converts heat energy into useful mechanical work. Heat engines develop more than 80% of energy generated in the world.

They are broadly classified into two types:

1. Internal Combustion Engines
2. External Combustion Engines

TYPES OF HEAT ENGINES

Heat Engines are broadly classified as internal combustion Engines and External Combustion Engines

INTERNAL COMBUSTION ENGINES:

In the Internal Combustion Engine, the chemical energy of the fuel is released as a heat by the way of combustion inside the engine cylinder where power is produced. The heat produced is nothing but the products of combustion. By expansion of this hot medium inside the cylinder, heat energy is converted into useful work.

The name "Internal Combustion Engine" is a misnomer since the fuel is burnt internally.

EXTERNAL COMBUSTION ENGINES:

They are steam engines and steam turbines. In these, heat energy is produced during the combustion of fuel in a boiler furnace. This energy is used to produce the steam under the pressure in boiler. The steam expands in turbine and thereby does work.

The name "External combustion engine" is a misnomer since the fuel is burnt externally.

CLASSIFICATION BASED ON IGNITION:

(i) Spark Ignition Engines (S.I engines)

In this type of engine, combustible mixture is sucked into the engine cylinder. This mixture is compressed. The compression ratio is about 5:1 to 7:1. At the end of compression, the mixture exists in the cylinder as high pressure and temperature. The Electric spark ignites this mixture. The burning of mixture produces greater pressure and temperature.The product of combustion expands and produced power. Then the products are expelled out.

(ii) Combustion Ignition Engines (C.I Engines)

In this type, air alone is sucked into the engine cylinder The air is compressed. The compression ratio is about 14:1 to 17:1. The heat of compression in the air is much greater due to high compression. At the end of compression the fuel is injected in the form of fine spray into the engine cylinder. The compression heat ignites the fuel and causes in to burn. Combustionof fuel produces high pressure and temperature. The product of combustion expands and thereby produces power. The combustion products are then exhausted.

(iii) Precombustion chamber Engines

The mixture is ignited by a spark in a special small anti-chamber, while the takes in the main chamber.

CLASSIFICATION BASED ON NUMBER OF STROKES:

(i) Four stroke Engine

In this engine, four strokes of the piston is required to complete a working cycle. In this engine, two revolution of the crankshaft is used to complete the cycle of operation.

(ii) Two Stroke Engine

In this engine, two strokes of the piston is required to complete a working cycle. In this engine, one revolution of the crankshaft is used to complete the cycle of operation.

CLASSIFICATION BASED ON CYCLE OF OPERATION:

(i) Otto cycle
(ii) Diesel cycle
(iii) Dual cycle

CLASSIFICATION BASED ON THE TYPE OF FUEL USED:

(i) Engines using Light Liquid Fuels ------------Petrol Engines

(ii) Engines using Heavy Liquid Fuels ---- Diesel Engines

(iii) Engines using Gaseous Fuels-----------------Gas Engines

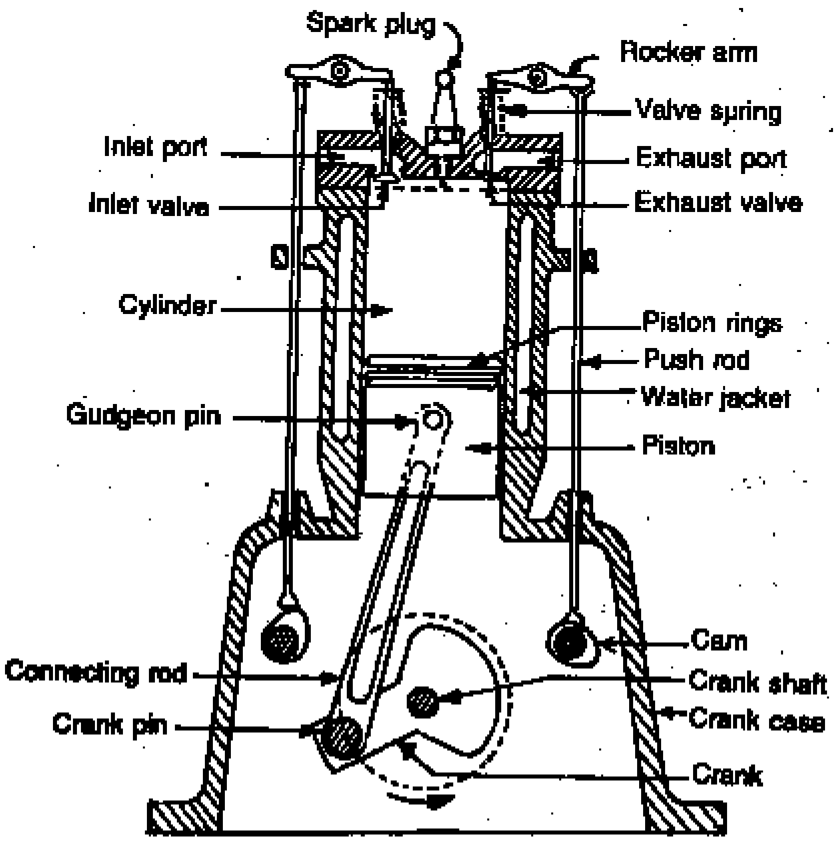
(iv) Mixed Fuel Engines

(v) Multi Fuel Engines

2. EXPALIN IN DETAIL ABOUT VARIOUS COMPONENTS OF I.C. ENGINES?

Hints:

For effective functioning of the internal combustion engine every components of the engine has to work properly. The following components of the engine are,



Components of I.C Engine

Cylinder:

It is a cylindrical space (or) container in which piston reciprocates. The working substance contained with in the cylinder is subjected to different thermodynamics processes.

Piston:

It is a reciprocating cylinder component which is fitted in to the cylinder. The power generated by the working substance during the expansion stroke is transmitted into the piston

Piston Ring:

These piston rings are fitted into the slots around the piston, provide a tight seal between piston and cylinder wall, thus preventing leakage of combustion gases

Combustion chamber:

It is the space enclosed in the upper part of the cylinder, below the cylinder head and above the top of the piston surface during the combustion process. The combustion of the fuel takes place with in this space.

Connecting Rod:

The connecting rod inter connects the piston and the crank-shaft and transmits the gas forces from the piston to the crankshaft. It has two ends called small end and big end.

3. COMPARE FOUR STROKE AND TWO STROKE CYLINDER ENGINES:

HINTS:

Four Stroke Cylinder Engine	Two Stroke Cylinder Engine
1. For every two revolution of the crank shaft, there is one power stroke.	1. For every one revolution of the crank shaft, there is one power stroke.
2. Because of the above, turning moment is not so uniform and hence heavier flywheel is needed.	2. Because of the above, turning moment is more uniform and hence a lighter flywheel is used.
3. For the same power more space is required.	3. For the same power less space is required.
4. Because of one power stroke in two revolutions, lesser cooling and lubrication requires. Lower rate of wear and tear.	4. Because of one power stroke for every revolution, greater cooling and lubrication requirements. Higher rate of wear and tear.
5. Valves are required – inlet and exhaust valves.	5. Ports are made in the cylinder walls – inlet, exhaust, and transfer port.
6. Because of heavy weight, complicated valve mechanism and water cooled, making it complicated design and difficult to maintain.	6. Simple in design, light weight and air cooled and easy to maintain.
7. The air-fuel mixture is completely utilized thus efficiency is higher.	7. As inlet and exhaust port open simultaneously, some times fresh charges may escape with exhaust gases. The exhaust gases are not always completely removed. This cause lower efficiency.
8. Volumetric efficiency is high due to more time for induction.	8. Volumetric efficiency is low due to lesser time for induction.
9. Lower fuel consumption per horse power.	9. The fuel consumption per horse power is more because of fuel dilution by the exhaust gas.
10. Used in heavy vehicles, e.g. Buses, lorries, trucks etc.	10. Used in light vehicles, e.g. Motor cycle, scooter, etc.
11. The engine cost is more.	11. The engine cost is less.
12. The exhaust is less noisy.	12. The exhaust is noisy due to short time available for exhaust.

4. COMPARE S.I. AND C.I. ENGINES.

HINTS:

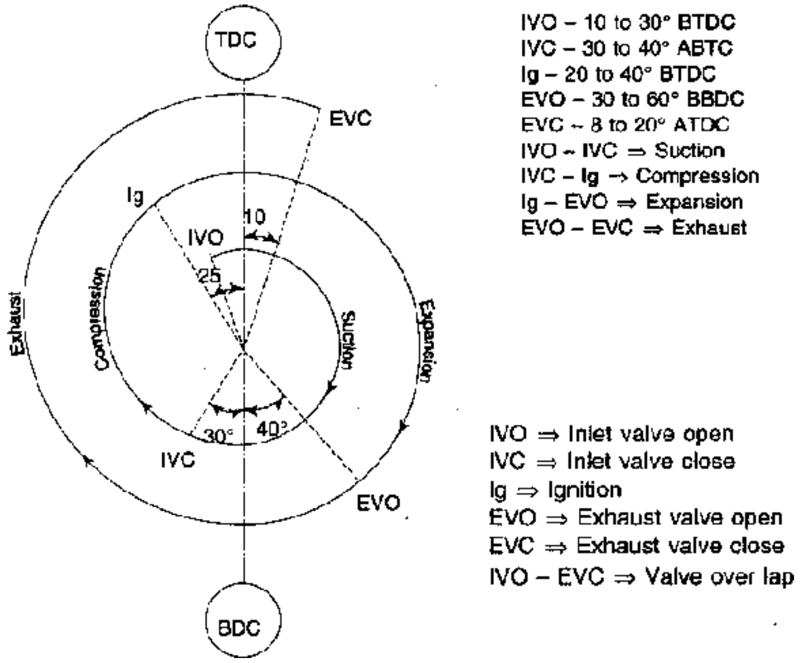
S.I. Engines	C.I. Engines
1. The fuel used is gasoline (Petrol).	1. Fuel used is Diesel.
2. Air + Fuel mixture is taken during suction.	2. Only air taken during suction.
3. For mixing air and fuel a separate device called carburettor is required.	3. No need of carburetor.
4. Since homogeneous mixture is produced in carburettor, no need of injector.	4. For atomizing and spraying the fuel inside the cylinder, fuel injector is necessary.
5. Pressure at the end of compression is about 10 bar.	5. Pressure at the end of compression is about 35 bar.
6. A spark plug is used to ignite the air fuel mixture.	6. Spark plug is not necessary.
7. Self ignition temperature of fuel is not attained. In other words, the fuel is not self ignited.	7. The fuel get ignited due to the high temperature of compressed air.
8. S.I. Engines works on otto cycle (i.e) combustion takes place at constant volume.	8. C.I. Engines works on diesel cycle (i.e) combustion takes place at constant pressure.
9. Compression ratio is around 6 to 10.	9. Compression ratio is around 15 to 25.
10. Cold starting of engine is easy.	10. Cold starting of engine is diffucult.
11. These are very lighter.	11. Heavier engine.
12. Cost is comparatively low.	12. Cost is high.
13. Running cost is high.	13. Running cost is not high.
14. Less maintenance.	14. High maintenance is needed.
15. $\square_{thernal}$ is about 25%.	15. $\square_{thernal}$ is about 35 to 45%.
16. Over heating trouble is more.	16. Over heating trouble is less.
17. Spark plug needs frequent maintenance.	17. Fuel injector needs less maintenance.
18. These are high speed engines.	18. These are low speed engines.
19. Noiseless operation due to less compression ratio.	19. Very noisy operation due to high compression ratio.
20. Engine weight / kW is less.	20. Engine weight / kW is more.
21. Vibration is less.	21. More vibration is there.
22. Generally employed for light duty vehicles e.g. two wheeler, otto etc.	22. Generally employed for heavy duty vehicles e.g. trucks, buses, etc.

5. EXPLAIN THE VALVE TIMING DIAGRAM OF S.I & C.I ENGINES

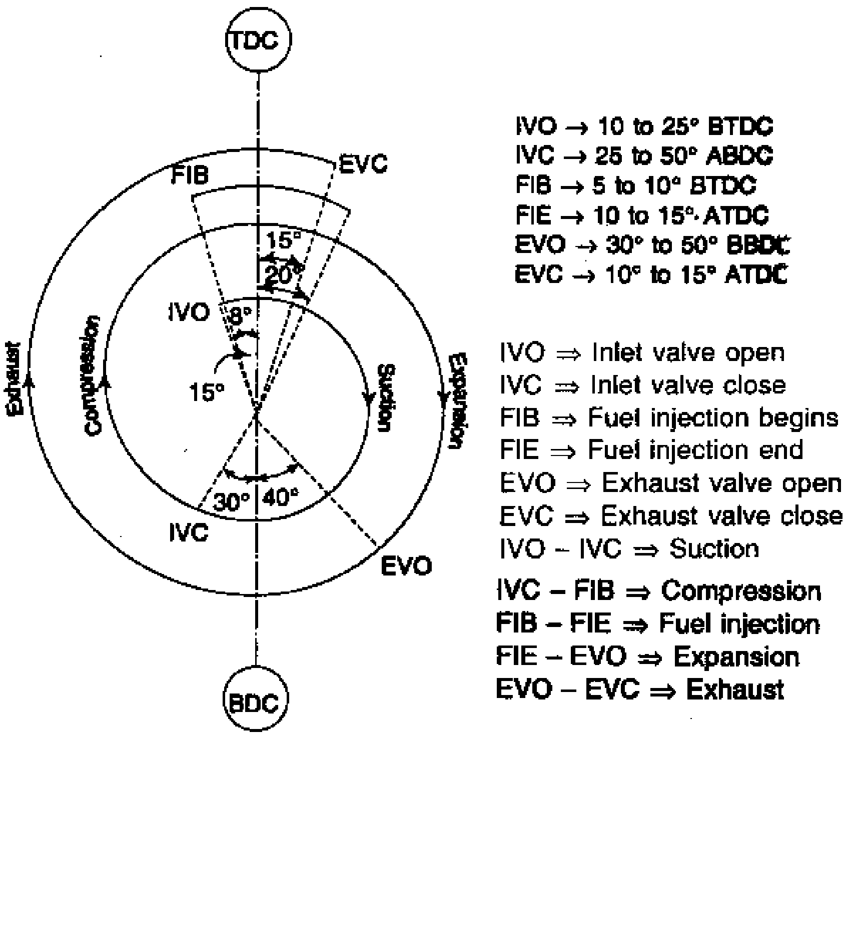
Hints

The timing of sequence of events such as inlet valve opening, inlet valve closing, ignition exhaust valve opening and exhaust valve closing can be represented graphically in terms of crank angles from dead centre position. This diagram is known as “Valve Timing Diagram

VALVE TIMING DIAGRAM FOR FOUR STROKE PETROL ENGINE:



VALVE TIMING DIAGRAM FOR FOUR STROKE DIESEL ENGINE:

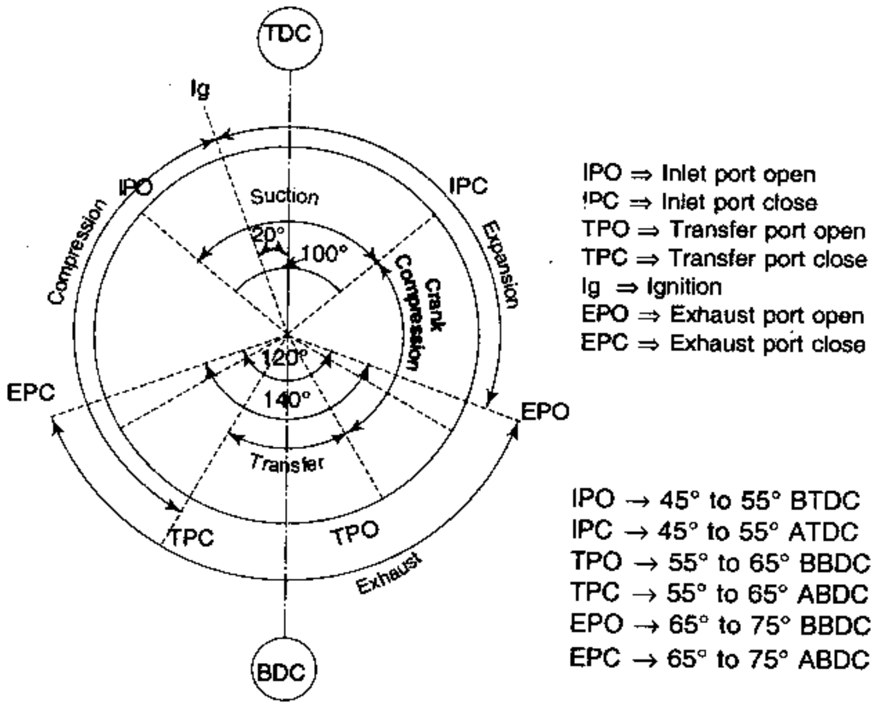


6. EXPLAIN THE PORT TIMING DIAGRAM OF S.I & C.I ENGINES

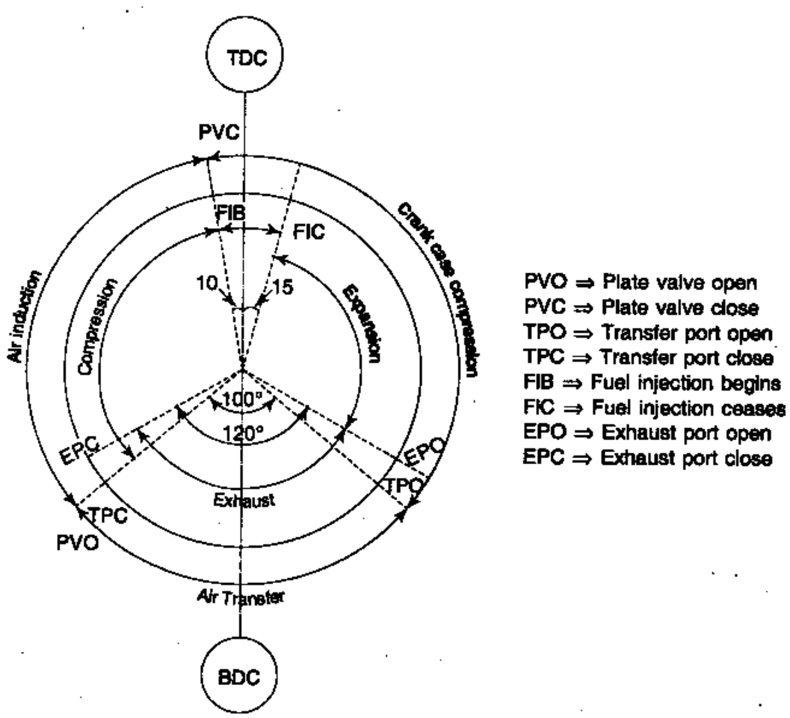
<u>Hints</u>

The timing of sequence of events such as exhaust port opening and closing, transfer port opening and closing, ignition and inlet port opening and closing can be represented graphically in terms of crank angles from dead centre position. This diagram is known as “Port Timing Diagram”.

PORT TIMING DIAGRAM FOR TWO STROKE PETROL ENGINE:



Port Timing Diagram for Two Stroke Diesel Engine:



7. EXPLAIN THE FUEL SUPPLY SYSTEM OF PETROL ENGINES

Hint

The functions of the fuel supply system are

(i) To store the fuel
(ii) To supply the fuel to the engine to the required quantity and in proper condition
(iii) To indicate the driver the fuel level in the fuel tank.

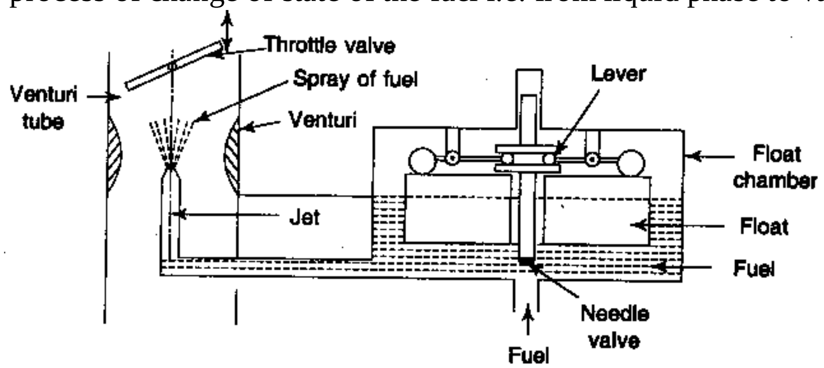
FUEL SUPPLY SYSTEM OF A PETROL ENGINE:

The fuel feed system of a petrol engine consists of the following components:

(i) Fuel Tank
(ii) Fuel Pump
(iii) Fuel Filter
(iv) Carburettor
(v) Intake manifold and
(vi) Fuel Gauge

Carburetor:

Carburetor is the device which is used for atomizing and vaporizing the fuel and mixing it with the air in varying proportions to suit the change in operating conditions of the engine. Thus the carburettor performs both the process of atomization and vaporization. Atomization is the process of breaking up the liquid petrol fuel into very small particles so that it is properly mixed with air. Vaporization is the process of change of state of the fuel i.e. from liquid phase to vapour.



Simple Carburetor

Main Parts are Float Chamber, Float, Venturi, Throttle Valve and Choke Valve

8. EXPLAIN THE FUEL SUPPLY SYSTEM OF DIESEL ENGINE

The main difference between the fuel supply system of a diesel engine and that of a petrol engine is, the system in diesel engine consists of a fuel injector instead of a carburettor and the remaining elements are the same.

So, the components of fuel supply system of a diesel engine includes

(i) Fuel Tank,
(ii) Fuel Filter,
(iii) Injection Pump (or) Fuel Pump,
(iv) Injector,

(v) Piping"s,
(vi) Fuel Gauge.

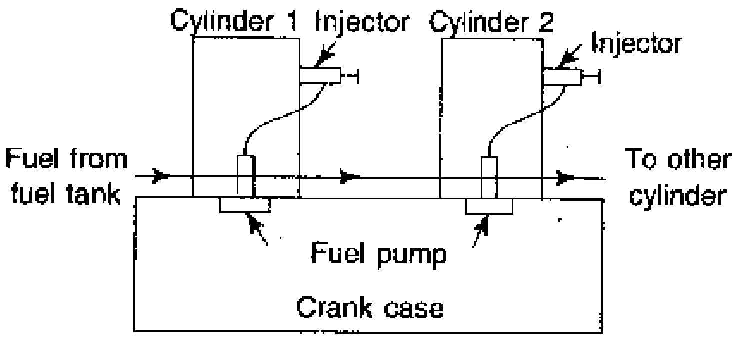
The fuel from tank directs to the main filter through a fuel pump. After filtered, the fuel proceeds to the inlet side of fuel injection pump. From the fuel injection pump the fuel under pressure flows, in the feed pipes to the fuel injector. From the fuel injector, the fuel gets injected into the cylinder in correct proportion.

FUEL INJECTION SYSTEM:

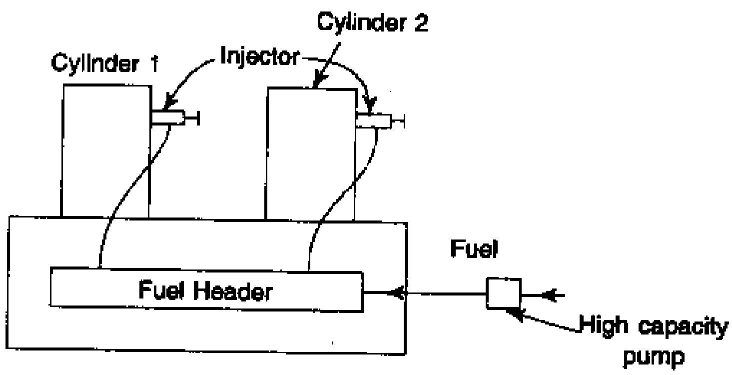
There are three different methods of fuel injection viz.

(i) Individual Pump System,
(ii) Common Rail System,
(iii) Distributor System and
(iv) Unit Injector System.

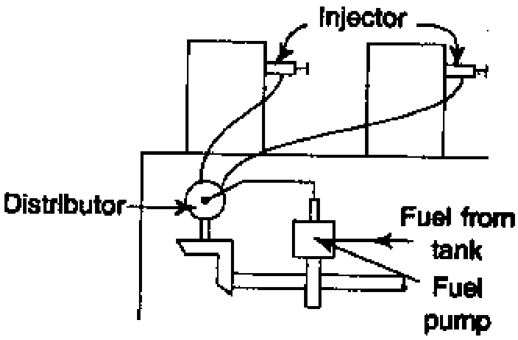
Individual Pump System



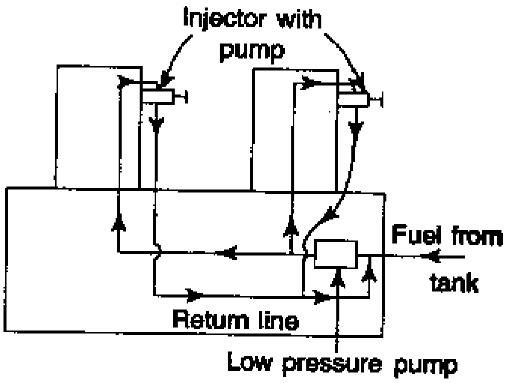
Common Rail System



Distributor System



Unit Injector System



Essential Requirements of Fuel Injection System:

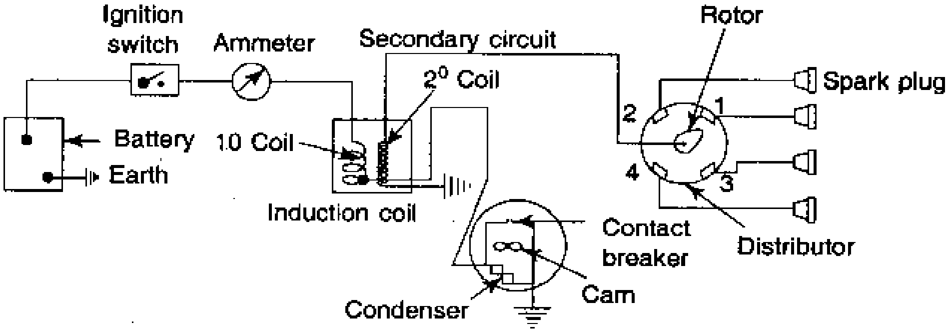
(i) The fuel should be injected in a fined automized condition.
(ii) The fuel should be properly distributed in the combustion chamber.
(iii) The fuel injection timing should occur at correct moment.
(iv) Quantity of fuel injected should meet the load condition of the engine.
(v) The beginning and end of the injection should takes place sharply.

9. EXPLAIN THE IGNITION SYSTEM FOR SPARK IGNITION ENGINE:

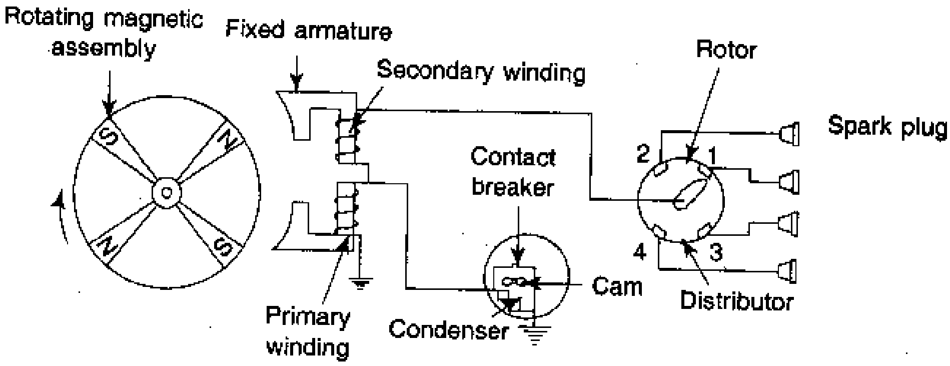
Hints:

The ignition system supplies a very high voltage up to 20,000 volts for igniting the compressed air fuel mixture by producing spark in the plug.

There are two different types of ignition systems which are commonly used in petrol engines. (i) Coil (or) Battery ignition system and (ii) Magneto ignition system.



Coil (or) Battery ignition system



Magneto ignition system

10. DISCUSS THE COOLING SYSTEM IN DETAIL

Hints:

The peak temperature that occurs during combustion in internal combustion engines varies from 1500□C to 2000□C. This large amount of heat produced due to fuel combustion is absorbed by the piston, cylinder head and cylinder walls.

The internal combustion engine at best can transform only 30% of the heat generated by burning the fuel in to “useful” work. About 30% has to be removed by the cooling system and the reminder by the exhaust and lubrication systems. What ever may be the amount of heat carried away by the coolant, it must be noted that it is a dead loss, because not only no useful work can be obtained from it, but a part of engine power is also used to remove this heat. Therefore it goes without saying that heat loss must be kept minimum by the designer.

NECESSITY OF ENGINE COOLING:

(i) The high temperature reduces the strength of the materials used for piston and piston rings.

(ii) The large temperature differences between the engines parts may cause unequal expansion, resulting in cracking of the parts and thereby the engine failure.

(iii) At high temperature, the lubricating oil may be heated up to such an extent heat decomposition of lubricating oil occurs and viscosity changes may render it unfit for effective lubrication.

(iv) At high temperatures, the lubricating may even evaporate and burn, injuring position and cylinder surfaces. Piston seizure due to overheating, resulting form the failure of the lubrication is quite common.

(v) The overheating causes excessive thermal stresses in the engine parts, which may load to their distortion.

(vi) The overheating may cause burning of valves and valve seats.

(vii) In petrol engines, the pre-ignition of the charge is possible, if the ignition parts initially are at high temperature.

(viii) The overheating reduces the efficiency of the engine.

METHODS OF COOLING:

All the heat rejected from the engine ultimately goes to air. Nevertheless, two basic systems are used to cool the engine. These are:

(i) Direct or air cooling
(ii) Indirect or Water cooling or Liquid cooling

11. COMPARISON BETWEEN AIR COOLING AND WATER COOLING SYSTEMS:

Air Cooling System	Water Cooling System
1. It is a direct cooling system.	1. It is an indirect cooling system.
2. The design of this system is simple and less costly.	2. The design of this system is complicated and more costly.
3. It does not depend on any coolant.	3. It is dependent on supply of water.
4. There is no danger of leakage of the coolant.	4. There is danger of leakage of the coolant.
5. The installation is easier as it does not require radiator and water jacket. Hence size is small, causing reduction in weight.	5. The installation is comparatively difficult; size of the engine is big with an increase in weight by about 20%.
6. It works smoothly and continuously. An air cooled engine can take up some degree of damage. A broken fin does not affect much.	6. If this system fails, it may cause serious damage to the engine within a short time.
7. Maintenance is easier.	7. It requires more maintenance.
8. used for small capacity engines.	8. Used for medium and large capacity engines.
9. Uniform cooling of cylinder, cylinder head and valve may not be possible.	9. Uniform cooling is possible with water cooling.

12. EXPLAIN THE VARIOUS TERMS TO ANALYSE THE PERFORMANCE OF INTERNAL COMBUSTION ENGINE.

Hints

Indicated mean effective pressure:

$$\text{Mean effective Pressure (mep)} = \frac{Area\,of\ Indicator\ Diagram \times Scale\,of\ the\,diagram}{Length\,of\ the\,indicator\ diagram}$$

$$= \frac{AS}{L}$$

Where, A is the area of the indicator diagram in mm^2
S is the scale of the indicator diagram in bar/mm
L is the length of the indicator diagram in mm.

Hence the mep will obtained in terms of bar.

Indicated Power:

It is the power available inside the engine cylinder

I.P. = Mean Effective Pressure X Stroke Volume

$$Stroke\,volume = \frac{LAn}{60},\ m^3/\sec$$

$$I.P. = \frac{P_m.L.A.n}{60}$$

Where L = Stroke length in „m"; A = Area of the piston in m^2

Brake Power:

It is the power available at the crank shaft

$$B.P. = \frac{2\pi N r_e (T_1 - T_2)}{60}$$

Where N = Speed of the engine in rpm

$T_1 + T_2$ = Load on the brake drum in N

r_e = Effective radius of the brake drum in m.

$$r_e = r + \left(\frac{t}{2}\right)$$

r = Radius of the brake drum in m.

t = thickness of the rope in m.

Fuel Consumption:

Fuel Consumption (or) Total Fuel Consumption $= \frac{V \times \rho_{fuel} \times 3600}{t} \quad kg/hr$

Where, V = Volume of fuel consumption in a given time in m^3

ρ = Density of fuel in kg/m^3

t = time in sec.

Specific Fuel Consumption = $\frac{Total\ Fuel\ consumption}{Brake\ Power} \quad kg/Kwhr$

Air Consumption:

Mass flow of air through the orifice is, $m_a = \rho_a V_a$

$$= C_d \frac{\pi}{4} d^2 \rho_a \sqrt{2gh} \text{ in kg/sec}$$

Where, d = diameter of the orifice in m

h_a = head of air in m

C_d = Coefficient of discharge of orifice = 0.6 to 0.62 (usually)

ρ_a = Density of air in kg/m^3

Efficiencies of Internal Combustion Engine:

Brake Thermal Efficiency:

$$\eta_{bte} = \frac{BP}{\text{Heat in fuel}}$$

$$= \frac{BP \times 3600}{m_f \times CV}$$

Where, m_f = mass flow rate of fuel in kg/hr

CV = Calorific Value of the Fuel in kJ/kg

BP = Brake Power developed in kW

Indicated Thermal Efficiency:

$$\eta_{ite} = \frac{IP}{Heat\,Supplied}$$

$$= \frac{IP \times 3600}{m_f \times CV}$$

Mechanical Efficiency:

$$\eta_m = \frac{BP}{IP}$$

Relative Efficiency:

$$\text{Relative efficiency} = \frac{\text{Indicated Thermal Efficiency}}{\text{Air Standard Efficiency}} = \frac{\eta_{ite}}{\eta_{ase}}$$

Volumetric Efficiency:

$$\eta_{vol} = \frac{\text{Actual volume of air taken}}{\text{swept volume}} = \frac{V_a}{V_s}$$

V_a = Actual Volume of air taken

$$= C_d \frac{\pi}{4} d^2 \rho_a \sqrt{2gh} \quad \frac{m^3}{s}$$

V_s = Swept Volume

$$= K \frac{\pi D^2 L n}{4} \quad \frac{m^3}{60s}$$

Where,
D = Diameter of the cylinder in m
L = Stroke length in m
K = Number of the cylinder and
n = Number of working cycles per min.