ST.ANNE'S COLLEGE OF ENGINEERING AND TECHNOLOGY
DEPARTMENT OF MECHANICAL ENGINEERING
THERMAL ENGINEERING I
UNIT I - GAS AND STEAM POWER CYCLES

Air Standard Cycles - Otto, Diesel, Dual, Brayton – Cycle Analysis, Performance and Comparison – Rankine, reheat and regenerative cycle.

Part-A (2 Marks)

1. What are the assumptions made on air standard efficiency? (Nov' 02, May'03, Apr'05, June'09, May'11, May'13, Apr'11, May'16,Nova' 16, Apr'17)

1. Air is the working fluid and it obeys the perfect gas laws.
2. The engine operates in a closed cycle. The cylinder is filled with constant amount of working substance and the same fluid is used repeatedly and hence mass remains constant.
3. The working fluid is homogeneous throughout at all times and no chemical reaction takes place, inside the cylinder.
4. The compression and expansion processes are assumed to be adiabatic.
5. The values of specific heat (Cp and Cv) of the working fluid remains constant.
6. All processes are internally reversible and no mechanical or frictional losses to occur throughout the process.
7. Combustion is replaced by heat addition process and exhaust is replaced by heat rejection process.

2. Define mean effective pressure. What is its importance in reciprocating engines? (Anna univ. Apr' 95, Apr' 96, Apr' 05, Nov' 07, Dec' 08, nov' 10, May' 11, Nov/dec' 11, May' 12 , Dec' 13)

- It is defined as the average pressure acting on the piston during the entire power stroke that would produce the same amount of net work output during the actual cycle. It is also defined as the ratio of work-done per cycle to swept volume.
- MEP is the quantity related to the operation of an IC engine and is a valuable measure of an engine's capacity to do work that is independent of engine displacement.

3. What is an air standard cycle? Why such cycles are conceived? (anna univ oct' 96, oct'97, May' 11, Dec' 12, May' 14)

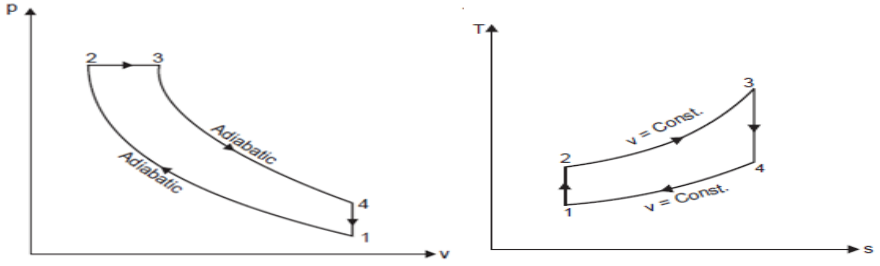
Cycle is defined as the series of operations or process performed on a system so that the system attains its original state. The thermodynamic cycles are conceived which use air as the working fluid are known as air standard cycles.

4. Define cut off ratio for a diesel cycle. (AU Apr'11, May'14)

Cut-off ratio is defined as the ratio of volume at cut off to the clearance volume.

Cut off ratio r_c $= (V_3/V_2)$

5. Sketch the dual cycle on p-v and T-s coordinates and made the various process. (AU Apr'03, Dec'10, May'13)



- 1-2=iscentropic compression
- 2-3=constant volume heat addtion
- 3-4=constant pressure heat addition
- 4-5= iscentropic expansion 5-1=constant volume heat rejection

6. Define Clearance Volume.

It is the minimum volume occupied by the fluid in the cylinder when the piston reaches the top dead centre position.

7. What are the functions of flywheel? (AU May'15)

Flywheel serves as an energy reservoir. It stores energy during power stroke and releases energy during out strokes.

8. What is meant by Atkinson cycle? (AU May'11)

The cycle with two adiabatic process for both compression, one constant volume process for heat addtion and one consatant pressure process for heat rejection is called Atkinson cycle

9. What are the conditions for maximum work of an Otto cycle?

$T_2 = T4 = (T\ 1XT3)$

$r_k = (T3/T1)^{½(\gamma-1)}$

10. Define work ratio of gas turbine.

It is the ratio of network to turbine work.

11. Write any four differences between Otto cycle and Diesel cycle. (AU nov/dec'13)

Otto cycle	Diesel cycle.
Petrol and gas engines are operated on this cycle	In it, fuel is ignited by heat generated during the compression of air in the combustion chamber, into which fuel is then injected.
Two reversible isentropic or adiabatic processes, Two constant volume processes	Isentropic compression Constant-Pressure heat addition Isentropic expansion Constant-volume heat rejection

12. What is the function of push rod and rocker arm in IC engine?

The function of push rod and rocker arm in IC engine is to transmit motion of the cam to the valve.

13. What is scavenging in IC engine? (Anna univ. Apr'03, nov'10, Apr'17)

The process of pushing out of exhaust gases from the cylinder by admitting the fresh charge into the cylinder is known as scavenging.

14. What is the function of idling jet in a carburetor?

The function of idling jet in a carburetor is to supply a mixture at an air fuel ratio of 10:1 for low speed operation.

15. What are the requirements of a fuel injection system of a diesel engine?

- To inject the fuel at correct moment, and quantity at various load conditions
- To inject the fuel in a finely atomized condition.
- To distribute the fuel uniformly in the combustion chamber.
- To control the rate of fuel injection.

16. List the advantages of electronic ignition system over the conventional system.

- Less weight.
- Compact
- Spark timing can be accurately controlled.
- Wiring is simple

17. What is the purpose of a thermostat in an engine cooling system?

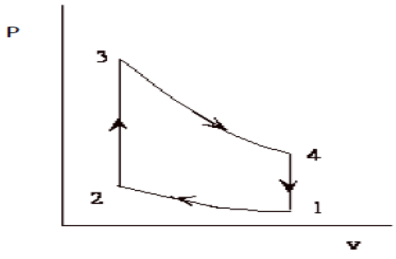
The purpose of thermostat in cooling system is to control the water flow. It allows the water circulation only, when the temperature of the radiator is about 75^oC.

18. What is meant by ignition lag?

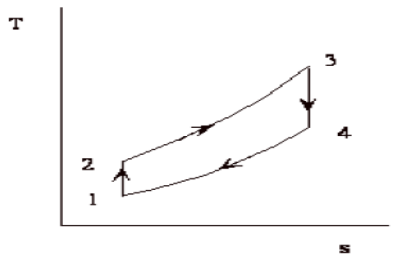
It is the time interval between the instant of spark and the instant when there is a noticeable rise in pressure due to combustion.

19. Sketch the Otto cycle on P-V and T-S planes and name all the processes.

At the start of the cycle, the cylinder contains a mass M of air at the pressure and volume indicated at point 1. The piston is at its lowest position. It moves upward and the gas is compressed isentropically to point 2. At this point, heat is added at constant volume which raises the pressure to point 3. The high pressure charge now expands isentropically, pushing the piston down on its expansion stroke to point 4 where the charge rejects heat at constant volume to the initial state, point 1.



P-V Diagram of Otto Cycle.



T-S Diagram of Otto Cycle.

20. How does the change in compression ratio affect the air standard efficiency of an ideal Otto Cycle?

It is seen that the air standard efficiency of the Otto cycle depends only on the compression ratio. However, the pressures and temperatures at the various points in the cycle and the net work done, all depend upon the initial pressure and temperature and the heat input from point 2 to point 3, besides the compression ratio.

21. Define the terms actual thermal efficiency and relative efficiency. (AU nov/dec'12)

Thermal efficiency of an engine is defined as the ratio of the output to that of the chemical energy input in the form of fuel supply.

Relative efficiency is defined as the ratio of actual thermal efficiency of the engine to the corresponding theoretical efficiency. $(\eta_{rel}) = \eta_{BT} / \eta_{air}$

22. List out the applications of compressed air.

Compressed air is mostly used in pneumatics brakes, pneumatic drills, pneumatic jacks, pneumatic lifts, spray, painting, shop, cleaning, injecting fuel in diesel engines, supercharging internal combustion engines, refrigeration and air conditioning systems.

Part-B (16Marks)

1. An engine working on Otto cycle has a volume of 0.45 m^3, pressure 1 bar and temperature 30°C at the beginning of compression stroke. At the end of compression stroke, the pressure is 11bar and 210 kJ of heat is added at constant volume. Determine the pressures and volumes at salient points in the cycle, efficiency and P_m.
2. An engine 20cm bore and 30 cm stroke works on Otto cycle. The clearance volume is 1600cu cm. The initial pressure and temperature are 1 bar and 60°C. if the maximum pressure is limited to 24 bar find the following:
   - (i) The air standard efficiency of the cycle.
   - (ii) The mean effective pressure of the cycle.
3. The minimum pressure and temperature in an Otto cycle are 100 kPa and 27°C. The amount of heat added to the air per cycle is 1500 kJ/kg.
   - (i) Determine the pressures and temperatures at all points of the air standard Otto cycle.
   - (ii) Also calculate the specific work and thermal efficiency of the cycle for a compression ratio of 8:1.

   Take for air: C_v = 0.72 kJ/kg k and γ = 1.4.
4. Sketch the Otto cycle on P-V and T-S diagrams and derive the expression for its mean effective pressure.
5. Sketch the diesel cycle on P-V and T-S diagrams and derive the expression for its mean effective pressure.

6. Sketch the dual cycle on P-V and T-S diagrams and derive the expression for its mean effective pressure.

7. Explain the working of 4 stroke cycle Diesel engine. Draw the theoretical and actual PV diagram.

8. 1kg of air is taken through a diesel cycle. Initially the air is at 25°C and 1bar .the compression ratio is 14 and the heat added is 1850kJ. Calculate the ideal cycle efficiency and mean effective pressure.

9. In an air standard diesel cycle the pressure and volume at the beginning of compression are 100 kPa and $0.03m^3$ respectively. Pressure after Isentropic compression is 4.2MPa and after isentropic expansion is 200kPa. Determine (i) Compression ratio (ii) Cut-off ratio (iii) Expansion ratio and Cycle efficiency. Assume $\gamma = 1.4$, $C_V = 0.718$kJ/kg K.

10. An ideal Diesel cycle has compression ratio of 16 with lowest temperature and pressure as 27°C and 1 bar respectively. If heat added during the cycle is 500 kJ/kg of air, determine

(i) Pressure and temperature at each salient point.
(ii) Work done in the cycle/kg.
(iii) Efficiency of the cycle.
(iv) Mean effective pressure

11. Dual combustion air standard cycle has a compression ratio of 10. The constant pressure part of combustion takes place at 40 bar. The highest and the lowest temperatures of the cycle are 1727°C and 27°C respectively. The pressure at the beginning of compression is 1bar. calculate

(i) The pressures and temperatures at the key points of the cycle.
(ii) The heat supplied at constant pressure.
(iii) The heat supplied at constant volume.
(iv) The heat rejected.
(v) The work output.
(vi) The efficiency.
(vii) Mep

12. In an engine working on dual cycle, the temperature and pressure at the beginning of the cycle are 90°C and 1 bar respectively. The compression ratio is 9. The maximum pressure is limited to 68 bar and the total heat supplied per kg of air is 1750 kJ. Determine,

(i) Pressure and temperature at all salient points.
(ii) Air standard efficiency.
(iii) Mean effective pressure.

13. Air at 1.01 bar, 20°C is admitted into an oil engine, which is working on the dual combustion cycle. The maximum cycle pressure is 69 bar. The compression ratio is 18.assuming that the heat added at constant volume is equal to the heat added at constant pressure; calculate the following:

(i) Temperature at all salient points
(ii) Total heat supplied
(iii) heat rejected
(iv) air standard efficiency.

14. (i) Derive an expression for the air-standard efficiency of a brayton cycle in terms of pressure ratio.
(ii) Prove that the pressure ratio for maximum work is a function of the limiting temperature ratio.

15. A gas turbine work on an air standard bray ton cycle. The initial condition of the air is 25°C and 1 bar. The maximum pressure and temperature are limited to 3 bar and 650°C.determine the following:

(i) Cycle efficiency.
(ii) Heat supplied and heat rejected /kg of air.
(iii) Work output /kg of air.
(iv) Exhaust temperature.

UNIT II
RECIPROCATING AIR COMPRESSOR

Classification and comparison, working principle, work of compression - with and without clearance, Volumetric efficiency, Isothermal efficiency and Isentropic efficiency. Multistage air compressor with Inter cooling. Working principle and comparison of Rotary compressors with reciprocating air compressors.

1. What are the difference between rotary air compressor and reciprocating air compressor?

Reciprocating Air compressor	Rotary Air compressor
The maximum delivery pressure may be as high as 1000 bar.	The maximum delivery pressure is 10 bar only.
They are suitable for large discharge of air at low pressure.	The speed of air compressor is high.
The speed of air compressor is low	The air supply is continuous.
The air supply is intermittent	The size of air compressor is small for the same discharge.
The size of the compressor is large for the given discharge	There is no balancing problem
The balancing is a major problem	

2. Write the difference between centrifugal and axial compressor? (Anna univ.Nov'16)

S.no	Centrifugal compressor	Axial flow compressor
1	It consists of **curved radial vanes** which are attached to shaft and rotate.	In this axial flow compressor, air is flowing parallel to the axis of compressor.
2	The **impeller** is a disc fitted with radial vanes.	It consists of stators (fixed blades) and Rotors (rotating blades) in an alternate rows.
3	The **casing** is surrounding the rotating impeller.	The rotors are fixed with rotating drum and stators are fixed to the casing.
4	The diffuser is housed in a radial portion of the housing.	One stage compressor means a row of stator blades with a row of rotor blades.

3. What is the use of catalytic converter? (AU Apr' 17)

Catalytic converter is used to convert the toxic gases and pollutants in exhaust gases to less toxic pollutants by using catalyzing a redox reaction.

4. Why Clearance volume is necessary and explains its importance?

In actual compressor, the clearance volume is provided to give cushioning effect otherwise the piston will strike the other end of the cylinder. It is generally expressed as percentage of piston displacement.

Importance of clearance volume:

- To give cushioning effect to the piston
- To provide space for valve movement.
- The maximum pressure may also be controlled by clearance volume.
- The volumetric efficiency and pressure ratio are depends upon clearance volume. If clearance volume is more, it reduces the volumetric efficiency.

5. What do you mean by perfect intercooling? (Anna univ. nov/dec'12, Apr' 17)

In two stage compressors, If the temperature of air leaving the intercooler (T_3) is equal to the original inlet temperature (T_1), then the intercooling is known as perfect the isothermal process intercooling isothermal, we can approach the isothermal efficiency will be increased by perfect intercooling

***6.* Define free air delivery. (AU Apr'11, Apr'17)**

Free air delivery is defined as the actual volume rate of air reduced to atmosphere condition and usually expressed in m^3/min.

7. What are the advantages of multi stage compressor over single stage compressor? (AU novdec'11)

- Less work is done by the compressor to deliver the same quantity of air.

- It improves the volumetric efficiency for the given pressure ratio.
- The size of the two cylinders may be adjusted to suit the volume and pressure of the air.
- It reduces the leakage losses considerably and provides effective lubrication.
- It provides more uniform torque and thus smaller size of the flywheel is required.
- It reduces the cost by selecting a cheap material for construction.

8. Define volumetric efficiency of the compressor.(May'16)

It is the ratio of actual volume of air drawn in the compressor to the stroke volume of the compressor.

9. What is the multistage compression? (Anna univ.Nov'16)

- The work done per kg of air is reduced in multistage compression with inter cooler as compared with single stage compression for the same delivery pressure.
- It improves the volumetric efficiency for the given pressure ratio.
- It reduces the leakage loss considerably.
- It reduces the cost of the compressor.

10. Define mechanical efficiency.

It is the ratio of indicated power to shaft power or brake power of motor.

11. Define isentropic efficiency.

It is the ratio of the isentropic power to the brake power required to drive the compressor.

12. What the purpose is of inter cooling and explain its process? Or List the effects of intercooling in a multi stage compression process. (AU nov/dec'13)

The purpose of inter cooling in multistage compression is to reduce the temperature without reduction in pressure. It is placed between LP cylinder and HP cylinder. When air flows through it, the temperature is reduced by maintaining the water circulation.

If $T_3=T_1$, then it is perfect intercooling

If $T_3>T_1$, then it is imperfect intercooling

13. How the compressors are classified? (AU april/may2015, nov/dec'13)

According to the number of stages:

Single stage and Multi stage

***According to the number of cylinder*:**

Single cylinder and Multi cylinder.

According to the method of cooling:

Air cooled compressor and Water cooled compressor

According to working:

Reciprocating compressor and Rotary compressor

According to the action of air:

Single acting compressor and Double acting compressor

According to the pressure limit:

Low pressure, Medium pressure and High pressure compressor.

According to the capacity:

Low capacity, Medium capacity and High capacity compressor.

14. What are the advantages of rotary compressor over reciprocating compressor?

- Maximum free air delivery is as high as 3000 m3/min.
- Air supply is continuous, more clean.
- Small size is required for the same discharge.
- No balancing problem.

15. What are the difference between centrifugal and axial flow compressors?

Centrifugal compressor

- The flow of air is perpendicular to the axis of compressor
- It has low manufacturing and running cost
- It requires low starting torque

- It is not suitable for multi staging
- It requires large frontal area for a given rate of flow

Axial flow compressor

- The flow of air is parallel to the axis of compressor
- It has high manufacturing and running cost
- It requires high starting torque
- It is suitable for multi staging.
- It requires less frontal area for a given rate of flow.

16. List out the applications of compressed air.

Compressed air is mostly used in pneumatics brakes, pneumatic drills, pneumatic jacks, pneumatic lifts, spray, painting, shop, cleaning, injecting fuel in diesel engines, supercharging internal combustion engines, refrigeration and air conditioning systems.

17. What are the advantages of multistage compression over a single stage compression for the same compression ratio?

- The work done per kg of air is reduced in
- The work done in compressing the air is reduced, thus power can be saved
- Prevents mechanical problems as the air temperature is controlled
- The suction and delivery valves remain in cleaner condition as the temperature and vaporization of lubricating oil is less

18. State the necessity of governing of steam turbines. (AU Apr'11)

Governing is to keep the turbine speed fairly constant irrespective of the load.

19. What is meant by intercooler? Or How is inter cooling used to reduce the power consumption of compressor? (AU dec'10, May'14)

An inter cooler is simple heat exchanger. It exchanges the heat of compressed air from the low-pressure compressor to the circulating water before the air enters the high pressure compressor. The purpose of interfolding is to be minimize the work of compression.

PART-B (16-marks)

1. A single stage reciprocating air compressor has clearance volume 5% of stroke volume of 0.05 m^3/sec, The intake conditions are 95kN/m^2, 300k. The delivery pressure is 720kN/m^2. Determine the volumetric efficiency referred to (i) Intake conditions (ii) Atmospheric conditions of 100 kN/m^2 and 290k (iii) FAD and Power required to derive the compressor, if the ratio of actual to indicated power is 1.5. Take index of compression and expansion as 1.3.

2. A single stage, double acting reciprocating air compressor has a free air delivery (F.A.D) of 14 m^3/min measured at 1.013 bar and 15 °C. . The pressure and temperature in the cylinder during induction are 0.95 bar and 32°C respectively. The delivery pressure is 7 bar and index of compression and expansion n=1.3. The clearance volume is 5% of the stroke volume; calculate the indicated power required and the volumetric efficiency

3. A three stage air compressor delivers 5.2 m^3 of free air per minute the suction pressure and temperature are 1 bar and 30°C. The pressure and temperature is 1.03 bar and 20°C at the free air condition the air cooled at 30°C. After each stage of compression. The delivery pressure of compressor is 150 bar. The Rpm of the compressor is 300. The clearance of L.P, I.P and H.P cylinders are 5% of the respective strokes. The index of compression and re-expansion in all stages is 1.35. Neglecting pressure losses, find the B.P of the motor required to run the compressor if the mechanical efficiency is 80%.

4. Derive the expression for minimum work required for a two stage reciprocating air compressor with perfect inter cooling and neglecting clearance.

5. A single stage single acting reciprocating air compressor delivers $14m^3$ of free air per minute from 1 bar to 7 bar. The speed of compressor is 310 rpm. Assuming that compression and expansion follow the law $pv^{1.35}$=constant and clearance is 5% of the swept volume, find the diameter and stroke of the compressor. Take stroke length is 1.5 times the bore diameter.

6. A single acting single stage compressor is belt driven from an electric motor at 400 rpm. The cylinder diameter is 15cm and the stroke 17.5 c.m. the air is compressed from 1bar to 7 bar and the law of compression $pv^{1.3}$=constant. Find the power of the motor, if transmission efficiency is 97% and the mechanical efficiency of the compressor is 90% neglect clearance effects.

7. A two stage double acting air compressor operating at 200rpm takes in air at 1.013bar and 27°C.the size of the L.P cylinder is 355x375mm, the stroke of HP cylinder is the same as the L.P cylinder and the clearance of both the cylinders is 4%.the air passes through the intercooler so that it enters the HP cylinder at 27°C and 3.850 bar ,finally it is discharged from the compressor at15.4 bar. The values of n for both cylinders are 1.25.C_p=1.0035k J/kg k and R=0.287 kJ/kg k. calculate:

i) The heat rejected in the intercooler.
ii) The diameter of HP cylinder and
iii) The power required to drive HP cylinder**.**

8. Explain with suitable sketches the working of two stage air compressor with P V Diagram and any one type of rotary compressor.
9. Explain the working principle of rotary compressor and Draw the p-v diagram.

10. A two stage singe acting air compressor compresses $2m^3$ airs from 1 bar and 20° C to 15 bar. The air from the low pressure compressor is cooled to 25° C in the intercooler. Calculate the minimum power required to run the compressor if the compression follows PV1.25=C and the compressor runs at 400rpm.

UNIT III

INTERNAL COMBUSTION ENGINES AND COMBUSTION

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.

1. What is an air-standard cycle? Why such cycles are conceived? (AU nov/dec'12)

- The thermodynamics cycle of engine using air as working medium is known as "air standard cycle".
- To compare effects of different cycles, the calorific value of fuels should be neglected. To achieve this, sir standard efficiency is used.

2. Mention any four applications of two stroke engine and four stroke engine. (AU nov/dec'11)

Two stroke engine

- Lawn movers
- Scooters
- Motors cycles

Four stroke engine.

- Cars
- Buses
- Trucks
- Tractors
- Aero plane
- Power generator

3. What are the characteristics of an efficient cooling system? (AU nov/dec'12)

- Light weight
- Simple design and low cost
- Specific fuel consumption is low
- Uniform cooling
- Minimum frontal area.

4. Define cririca l pressure ratio. Calculate the value of critical pressure ratio for super saturated steam. (AU nov/dec'12)

$(p_2/p_1) = (2/ (n+1))^{(n/(n-1))}$

5. The bore and stoke of a water-cooled, vertical, single-cylinder, four stroke diesel are 80mm and 110mm respectively and the torque is 23.5Nm. Calculate the mean effective pressure of the engine. (AU nov/dec'12)

$P=(2\Pi NT/60000) = 5.34$ bar

6. Differentiate between brake power and indicated power of an IC engine.

Brake Power: It is defined as the power developed at output crank shaft of an engine for doing external work.

Indicated Power: It is the power developed by the engine inside the cylinder due to the fuel combustion in the combustion chamber.

7. What is a unit injection system? (AU nov/dec'13)

Airless injection is further classified into two systems.

- Common rail system
- Individual pump system or unit injection system.

Each cylinder of the engine has individual injection valve, a high-pressure fuel pump and a measuring device. It is very compact.

8. What is Morse test? (AU nov/dec'13)

Morse test is a performance test conducted on multi cylinder engines to measure the indicated power without the use of indicator diagram

$I.P = I_1+I_2+I_3$

.

9. Which engine will have more cooling requirement two-stroke engine or four-stroke engine? Why?

Two stroke-engines will have more cooling requirements since power is developed for each revolution of crank. So, for each crank revolution, Combustion occurs and more heat will be generated inside the cylinder.

10. What is a carburetor? State any two function of the carburetor.

A carburetor is a device which vaporizes the fuel and mixes it with the air.

- To atomize the fuel and mix it homogeneously with the air.
- To run the engine smoothly without hunting of fuel wastage.
- To provide rich mixture during starting and idling and also for quick acceleration.
- To provide a constant air fuel ratio at various loads.
- To start the engine even in cold weather conditions.

11. List the requirements of ignition system.

- Ignition should takes place at the end of compression stroke.
- There should be no missing cycle due to the spark failure.
- Ignition must add sufficient energy for starting and sub staining the charge burning
- Ignition system should supply the minimum required energy within a small volume in a very short time.

12. What are the different types of ignition system in S.I. engines?

Battery Ignition system and Magneto ignition system.

13. What are the advantages of Battery ignition system?

- The initial cost is low (except battery).
- It provides better spark at low speed of engine during starting and idling.
- Maintenance cost is negligible. (expect for battery)
- The spark efficiency remains unaffected by advance and retard positions.
- The simplicity of the distributor drive.

14. What are the disadvantages of Battery ignition system Or limitations of battery ignition system? (AU nov/dec'11)

- The engine cannot be started if the battery is weak.
- The weight of the battery is greater than the magneto.
- The wiring involved in the coil ignition is more complicated than magneto.
- The sparking voltage drops with increasing speed of the engine.

15. What is the necessity of cooling in IC engine? (Anna univ, Apr' 02, May'11, may'12)

- To avoid un even expansion of the piston in the cylinder.
- To reduce the temperature of piston and cylinder.
- To avoid the overheating of the cylinder.
- To avoid the physical and chemical changes in the lubricating oil this may cause sticking of piston rings.

16. What are the different types of cooling in IC engines?

- Air cooling
- Water cooling system
- Thermosyphon cooling
- Forced circulation cooling
- Thermostatic regulator cooling
- Evaporative cooling

17. What are the purposes of lubrication in IC engines?

- To reduce the friction and wear between the parts having the relative motion.
- To cool the surfaces by carrying away heat generated due to friction.
- To seal between two moving parts.
- To clean the surface by carrying away the carbon particles caused by wear.
- To absorb the shock between bearings and other parts and consequently reduce noise.

18. What is flash point?

Flash point is the lowest temperature at which the given oil gives sufficient vapour to give a moment of flash, when a flame is passed across the surface.

19. What is petrol system of lubrication?

A special type of lubrication system used in two stroke engines in which lubricant (up to 60%) is thoroughly mixed with fuel and supplied to the engine. It is also known as mist lubrication.

20. What is auto ignition?

A mixture of fuel and air can react spontaneously and produce heat by chemical reaction without the uses of flame to initiate the combustion, because the temperature is high than self-ignition temperature.

21. What is meant by pre-ignition?

At very high temperature carbon deposits formed inside the combustion chamber ignites the air fuel mixture much before normal ignition occurred by spark plug. This is called pre-ignition.

22. What are the factors affecting ignition lag?

Compression ratio, speed of the engine, Chemical nature of fuel and air fuel ratio and Initial pressure and temperature.

23. What is meant by knocking? How it occurs in diesel engines?

If the delay period of C.I. engines is long, more fuel is injected and accumulated in the chamber. When ignition begins, pulsating pressure rise can be noticed and creates heavy noise. This is known as knocking.

24. What are the effects of knocking?

- The engine parts get overheated which may cause damage to the piston.
- It creates heavy vibration of engine and hence louder noise and roughness.
- Decrease in power output and efficiency.
- More heat is lost to the coolant as the dissipation rate is rapid.
- The auto-ignition may over heat the spark plug and hence pre-ignition occurs Carbon deposits.

25. What are the factors which contribute to knocking in Si engine? (Anna univ. May'11 May 12)

- Temperature factors.
- Density factors
- Time factors
- Composition factor

26. Define specific fuel consumption?

It is the ratio of fuel consumption per unit time of power developed.

27. Explain an experimental method to determine the frictional power of an IC engine.

Retardation test can be carried out to determine the frictional power of an diesel engine. In this method, the engine is started and made to run at full load conditions at rated speed. After sometimes, the fuel supply is cutoff and the necessary readings are noted. Repeat the above procedure for 50% load and calculated the frictional power of an engine using formulas.

28. What is the purpose of heat balance sheet in IC engine?

- It is the accounts of heat supplied and heat utilized in various ways in the system.
- The heat balance is generally done by minute basis or percentage basis.

29. What is the use of helical groove in a fuel injection pump used for CI engine?

- To control the delivery stroke effectively.
- To control the amount of fuel supplied to the engine.

30. Explain the location of sparkplug with respect to knocking in SI engines.

In order to reduce the knocking tendency, spark travel distance should be kept as minimum as possible. Similarly, the distance of the end charge from the spark plug also should be minimum.

25. Define the phenomenon 'knocking' in spark ignited engines. (Anna univ.May'16)

This phenomenon of combustion causing heavy pressure rise during uncontrolled combustion is known as "Knock".

26. What are the basic components of an IC engines? (AU april/may 2015)

- Cylinders, Piston ring,
- Cylinder head, Gudgeon pin,
- Connecting rod, Crank shaft,
- Bearing, Crank, Crankcase.

27. State the merits of a diesel engine over a petrol engine. (AU april/may 2015)

- Thermal efficiency is high up to 40%
- Preignition not possible
- Less running cost
- Less fuel cost

28. What are the exhaust emissions from diesel engines? (AU april/may 2015)

Hydro carbons, NO_X, SO_X, P_m are the emissions coming out from diesel engines.

29. List out major pollutants from a petrol engine. (AU Apr'11)

Oxides of nitrogen(NO_X)

Carbon monoxide(CO)

Part-B (16Marks)

1. (i)What are the causes of knock in C.I.engines?

(ii)Explain with suitable sketch the magneto-ignition system used in petrol engine and state its advantages and disadvantages over battery ignition system.

2. A four cylinder, four stroke cycle petrol engine 79mm bore, 132mm stroke develop 28.35 kw brake power while running at 1450 r.p.m and using a 20% rich mixture. If the volume of the air in to the cylinder when measured at 15.5°C and 760mm of mercury is 70% of the swept volume, the theoretical air fuel ratio is 14.8, the heating value of petrol used is 44000kj/kg and the mechanical efficiency of the engine is 90%,find the indicated thermal efficiency. Take R =0.287kj/kgk.

3. (i)Explain any four types of classification of internal combustion engines.

(ii)With a neat sketch, explain any one type of ignition system.

4. Following data related to 4cylinders, 4stroke petrol engines. Air/fuel ratio by weight 16:1Calorific value of the fuel=45200kj/kg, mechanical efficiency =82%.air standard efficiency=52%, relative efficiency=70%, volumetric efficiency=78%, stroke/bone ratio=1.25 suction conditions =1bar, 25 °C. Speed =2400 rpm power at brakes =72kw. Calculate

   i) Compression ratio
   ii) Indicated thermal efficiency
   iii) Brake specific fuel consumption and
   iv) Bore and stroke.

5. 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?(nov2006)

6. 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.

7. The following data refer to a single cylinder four stroke petrol engine:

   Compression ratio =5.6
   Mechanical efficiency =80%
   Break specific fuel consumption =0.37kg/kWh
   Calorific value of fuel =44000kJ/kg
   Adiabatic index of air =1.4

Find (i)break thermal efficiency (ii)indicated thermal efficiency (iii)air standard efficiency (iv)relative efficiency with respect to indicated thermal efficiency, and (v)relative efficiency with respect to break thermal efficiency.

8. Describe the working of a simple carburetor and derive the expression for the air-fuel ratio.

9. Following data are available for a four stroke petrol engine:

Air fuel ratio (by weight) = 15.5:1 Calorific value of the fuel = 45,000kJ/kg
Mechanical efficiency =80% Air standard efficiency = 53%
Relative efficiency based on indicated thermal efficiency = 70%
Volumetric efficiency = 80% Stroke / Bore ratio = 1.25
Speed = 2400rpm Power at brakes = 75kW

Calculate:

i) Compression ratio
ii) Indicated thermal efficiency
iii) Brake specific fuel consumption and
iv) Bore and stroke.

10. The following details were noted in a test on a four-cylinder, four stroke engine, diameter = 100mm; stroke = 120mm; speed of engine = 1600rpm; fuel consumption = 0.2kg/min; fuel calorific value = 44,000kJ/kg; difference in tension on either side of the brake pully = 40kgf; brake circumference is 300cm. If the mechanical efficiency is80%,Calculate:

i) Brake thermal efficiency,
ii) Indicated thermal efficiency,
iii) Indicated mean effective pressure and iv) Brake specific fuel consumption.

UNIT IV

INTERNAL COMBUSTION ENGINE PERFORMANCE AND SYSTEMS

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 Turbo charging – Emission Norms

1. What is the function of piston, connecting rod, crank shaft and cylinder head?

- Piston – The piston assembly transfers the force from the power stroke to the crankshaft
- Connecting rod – converts reciprocating motion of piston into rotary motion of crankshaft
- Cylinder head – it acts as a top cover to the cylinder block. The valves are placed in the cylinder head in an overhead valve engine.

2. What are the advantages of air-cooled engines?

- Less weight-power ratio
- Does not require radiator and water pump
- No antifreeze agents required
- No salt and mud deposits in the system
- Air cooled engines are cheaper

3. What is the purpose of lubricating system? State its types.

The purpose of lubrication system is to supply the lubricating oil between the moving parts of the engine in order to

1. Reduce the friction
2. Provide the cooling effect
3. carry away the deposits formed due to wear and tear

Types

- Mist lubrication
- Splash lubrication
- Pressure feed lubrication
- Combined splash & pressure feed lubrication

4. What is meant by turbo charging?

Increasing the density of inducted charge/air by using a compressor which gets its power from exhaust driven turbine is known as Turbo charging.

5. What is Gasoline Direct Injection?

The gasoline (petrol) is directly into the cylinder at the end of compression stroke as such in diesel engines. This is called Gasoline Direct Injection (GDI)

6. What is conventional ignition system?

The conventional ignition system gets its electrical voltage either from battery or dynamo, which will be boosted to a very high voltage due to which spark is produced in the cylinder to combust the mixture.

7. Define common rail injection system.

A common rail which is maintaining high fuel pressure is connected to individual fuel injectors of a multi cylinder engine.

8. What is unit injection system?

It is an integrated direct fuel injection system for diesel engines, combining the injector nozzle and the injection pump in a single component

9. What is an Electronic ignition system?

The ignition system, in which the mechanical contact points are replaced by electronic triggering and switching devices, is known as electronic ignition system.

10. What are the functions of Turbo chargers?

a. To produce more power from the same size engine
b. To provide the altitude compensation
c. To improve more complete combustion & hence less emissions

11. What is super charging?

The process of increasing the density of inducted charge/ air is known as supercharging. It is performed for the following reasons.

a. To produce more power from the same size engine
b. To provide the altitude compensation
c. To improve more complete combustion & hence less emissions

12. What is regenerative braking?

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

13. List the different methods of battery charging.

a. Constant current charging b. Constant voltage charging
c. High rate charging d. Slow rate charging

14. What are the components of lead acid battery?

a. Lead terminals
b. Electrolyte
c. Internal plates (positive and negative plates)
d. Resilient Plastic container

15. What are the different types of starter motor drives?

a. Bendix drive
b. Overrunning drive
c. Outboard drive

16. What are the chemicals used in battery?

PbO_2 – Positive plate

Pb – Negative plate

Electrolyte – Diluted Sulphuric acid

17. What is a dry charged battery?

The battery is built, charged, washed and dried, sealed, and shipped without electrolyte. It can be stored for up to 18 months. When put into use, electrolyte and charging are required

18. What is the purpose of the grid?

The more "plates" in the grid, the more surface area exposed to the electrolyte, hence the more power produced.

19. How will you distinguish a positive plate from a negative plate in a lead acid battery?

The positive plates are coated with PbO_2 and chocolate brown in color.

The negative plates are coated with spongy lead and grey in color.

20. What is the function a cut out in a charging system?

The cut out permits the current flow from dynamo/alternator to battery for charging while it does not permit the reverse flow of current.

21. What is the function of regulators in a charging system?

Current regulator – regulates the alternator/dynamo current for charging the battery (constant current charging mode)

Voltage regulator – regulates the alternator/dynamo voltage for charging the battery (constant voltage charging mode)

22. What are the advantages in MPFI System?

Separate fuel injector for individual cylinders.
High cost
Comparatively higher injection pressure
Low SFC and engine emissions

23. List the different methods of battery charging.

- Constant current charging
- Constant voltage charging
- High rate charging
- Slow rate charging

24. State the requirements of ignition system?

- It should consume minimum of power and produce high intensity spark across spark plug electrodes
- It should have a sufficient spark duration which is sufficient to establish burning of air-fuel mixture under all operating conditions
- It should provide sufficient ignition energy over the entire speed range of the engine
- Good performance at high speed
- Longer life of contact breaker points and spark plug
- Adjustment of spark advance with speed

25. What is the purpose of cooling system?

The purpose of cooling system is to cool the engine components in order to keep their temperature below certain limit and thereby avoiding excessive thermal stress in those components.

Part-B (16 Marks)

1. With neat sketch common rail direct injection systems.

2. What are the emission norms followed in operating IC engine in India?

3. With neat sketch explain the turbo charging in the CI engines

4. Explain the working principle of diesel injector with neat diagram.

5. A 4-cylinder petrol engine has a bore of 60mm and a stroke of 90mm. Its rated speed is 2800 rpm. and it is tested at this speed against brake which has a torque arm of 0.37m. The net brake load is 160N and the fuel consumption is 8.986 lit/hr. The specific gravity of petrol used is 0.74 and it has a lower calorific value of 44100 kJ/kg. A Morse test is carried out and the cylinders are cut out in the order 1,2,3,4 with corresponding brake loads of 110,107,104 and 110 N respectively. Calculate for this speed 1).The engine torque 2). B.M.E.P 3). The brake thermal efficiency 4). The specific fuel consumption 5). Mechanical efficiency 6). I.M.E.P

6. Compare battery and magneto ignition system.

7. Explain with neat sketch the working principle of battery & magneto ignition system.

8. A four stroke four cylinder gasoline engine has a bore of 60 mm and a stroke of 100 mm. On test it develops a torque of 66.5 N-m when running at 3000 rpm. If the
clearance volume in each cylinder is 60 cc the relative efficiency with respect to the BTE is 0.5 and the CV of the fuel is 42MJ/kg, determine the fuel consumption in kg/h and the BMEP

9. Following data relate to 4-cylinder four stroke petrol engine. Air fuel ratio by weight = 16: 1, calorific value of the fuel = 45200 kJ/kg, mechanical efficiency = 82%, air-standard efficiency = 52%, relative efficiency = 70%, volumetric efficiency = 78 %, stroke/bore ratio = 1.25, suction conditions = 1 bar & 25^{o}C, r.p.m. = 2400 and power at brakes =72kW. Evaluating: (1) Compression ratio, (2) Indicated thermal efficiency, (3) Brake specific fuel consumption, (4) Bore and Stroke.

10. Air consumption for a four-stroke petrol engine is measured by means of a circular orifice of diameter 3.2 cm. The co-efficient of discharge for the orifice is 0.62 and the pressure across the orifice is 150 mm of water. The barometer reads 760 mm of Hg. Temperature of air in the room is 20^{o}C. The piston displacement volume is 0.00178 m^3. The compression ratio is 6.5. The fuel consumption is 0.135 kg/min of calorific value 43900 kJ/kg. The brake power developed at 2500 rpm. is 28 kW. Determine: (1) The volumetric efficiency on the basic of air alone. (2) The air-fuel ratio. (3) The brake mean effective pressure. (4) The relative efficiency on the brake thermal efficiency on the brake thermal efficiency basis.

11. A four cylinder diesel engine of 4-stroke type has stroke to bore ratio as 1.2 and the cylinder diameter is 12 cm. Estimate indicated power of the engine using the indicator diagram arrangement. Indicator card shows the diagram having area of 30 cm^2 and length as half of stroke. Indicator spring constant is 20 × 103 kN/m^2 and engine is running at 2000 rpm. Also find out mechanical efficiency of engine if 10% of power is lost in friction and other losses.

12. During trial of four strokes single cylinder engine the load on dynamometer is found 20 kg at radius of 50 cm. The speed of rotation is 3000 rpm. The bore and stroke are 20 cm and 30 respectively. Fuel is

supplied at the rate of 0.15 kg/min. The calorific value of fuel may be taken as 43 MJ/kg. After some time the fuel supply is cut and the engine is rotated with motor which required 5 kW to maintain the same speed of rotation of engine. Determine the brake power, indicated power, mechanical efficiency, brake thermal efficiency, indicated thermal efficiency, brake mean effective pressure, indicated mean effective pressure.

13. During an experiment on four stroke single cylinder engine the indicator diagram obtained has average height of 1 cm while indicator constant is 25 kN/m^2 per mm. The engine run at 300 rpm and the swept volume is 1.5 × 104 cm3. The effective brake load upon dynamometer is 60 kg while the effective brake drum radius is 50 cm. The fuel consumption is 0.12 kg/min and the calorific value of fuel oil is42 MJ/kg. The engine is cooled by circulating water around it at the rate of 6 kg/min. The cooling water enters at 35º C and leaves at 70ºC. Exhaust gases leaving have energy of30 kJ/s with them. Take specific heat of water as 4.18 kJ/kg K. Determine indicated power output, brake power output and mechanical efficiency. Also draw the overall energy balance in kJ/s.

14. A two stroke two cylinder engine runs with speed of 3000 rpm and fuel consumption of 5 litres/hr. The fuel has specific gravity of 0.7 and air-fuel ratio is 19. The piston speed is 500 m/min and indicated mean effective pressure is 6 bar. The ambient conditions are 1.013 bar, 15ºC. The volumetric efficiency is 0.7 and mechanical efficiency is 0.8. Determine brake power output considering R for gas = 0.287 kJ/kg K(Take piston speed, m/min = 2 LN where L is stroke (m) and N is rpm)

15. A 4-stroke four cylinder petrol engine has bore and stroke as 0.15 m and 0.17 m respectively. Indicator diagram arrangement when put on a cylinder yields indicator diagram having area of 25 cm^2 and length of diagram as 6 cm. The speed of engine is 2500 rpm. Determine the indicated power and frictional power if mechanical efficiency is 88%. Take indicator spring constant as 20 × 103 kN/m^3.

16. During trial of a four cylinder four stroke petrol engine running at full load it has speed of 1500 rpm and brake load of 250 N when all cylinders are working. After some time each cylinder is cut one by one and then again brought back to same speed of engine. The brake readings are measured as 175 N,180 N, 17. N and 170 N. The brake drum radius is 50 cm. The fuel consumption rate is 0.189 kg/min with the fuel whose calorific value is 43 MJ/kg and A/F ratio of 12. Exhaust gas temperature is found to be 600ºC. The cooling water flows at 18 kg/min and enters at 27ºC and leaves at 50ºC. The atmospheric air temperature is 27ºC. Take specific heat of exhaust gas as 1.02 kJ/kg K. Determine the brake power output of engine, its indicated power and mechanical efficiency. Also draw a heat balance on per minute basis.

UNIT V
GAS TURBINES

Gas turbine cycle analysis – open and closed cycle. Performance and its improvement - Regenerative, Intercooled, Reheated cycles and their combinations. Materials for Turbines.

1. **What is reheating and regeneration of gas turbine?** [AU Nov/Dec 2016]

Reheating is applied in a gas turbine in such a way that it increases the turbine work without increasing the compressor work or melting the turbine materials. When a gas turbine plant has a high pressure and low pressure turbine a reheater can be applied successfully. Reheating can improve the efficiency up to 3 %. A reheater is generally is a combustor which reheat the flow between the high and low pressure turbines

Regeneration process involves the installation of a heat exchanger in the gas turbine cycle. The heat-exchanger is also known as the recuperator. This heat exchanger is used to extract the heat from the exhaust gas. This exhaust gas is used to heat the compressed air. This compressed and pre-heated air then enters the

combustors. Regenerated Gas turbines can improve the efficiency more than 5 %.

2. What is and air-standard cycle? Why such cycles are conceived? (AU.Oct'96, Oct'97, Nov'10, May'11,DEC'12 & May'14)

Cycle is defined as the series of operations or processes performed on a system so that the system attains its original state.The thermodynamic cycles which use air as the working fluid are known as air standard cycles. Air standard cycles are conceived to simplify the analysis of IC engines.

3. Define the terms actual thermal efficiency and relative efficiency.

Actual efficiency is defined as the ratio of work output by the cycle to the heat input to the cycle. Relative efficiency is defined as the ratio between actual efficiency and air standard efficiency

4. What is meant by Atkinson cycle? (AU.(MECH)DEC'12)

The cycle with two adiabatic processes for both compression and expansion, one constant volume process for heat addition and one constant pressure process for heat rejection is called Atkinson cycle.

5. Mention a few characteristics of Diesel power plant. (AU(MECH) DEC'12)

i. Diesel power plants are mainly used where high torque is required.

ii. Fuel and fluid characteristics mean that Diesel power plant could be operated with variety of different fuels depending on configuration.

Hybrid possibilities are to combine with other power producing devices.

6. What is the basic difference between a Diesel engine and a steam turbine? (AU(EEE)DEC'12)

The basic difference is that Diesel engine is internal combustion (IC) engine whereas the steam turbine is external combustion engine.

7. State the fuels used in the gas turbine power plants. (AU (EEE) May'11)

Residual liquid fuels, the residue left after the profitable light fractions have been extracted from the crude have been used in gas turbines to some extent

8. What are the main units in a gas turbine power plant? (AU (MECH) DEC'13 & (EEE) DEC'11)

1. Compressor
2. Combustion chamber
3. Turbine

9. What do you mean by regeneration in gas turbine power plant?(AU.(EEE)June'13)

The partial bleeding of steam from the turbine to preheat the air to reduce the fuel consumption and increase the efficiency is called regeneration.

10. How does regeneration improve the thermal efficiency of gas turbine cycle? (AU.(MECH)DEC'14)

Regeneration reduces the energy requirement from the fuel thereby increasing the efficiency of the cycle.

11. List down the various processes of the Brayton cycle. (AU.Oct'96)

1. Isentropic compression 2. Constant pressure heat supplied
3. Isentropic expansion and 4. Constant pressure heat rejection.

12. List the disadvantages of gas turbine power plant.

1.No load and Partial load efficiency is low
2.High sensitive to component efficiency
3.The efficiency depends on ambient pressure and ambient temperature
4.High air rate is required to limit the maximum inlet air temperature. Hence exhaust losses are high
5. Air and gas filter is required to prevent dust into the combustion chambers.

13. List the factors which affect the performance of gas turbine power plants.

1. Part load efficiency 2. Fuel consumption
3. Air mass flow rate 4.Thermal efficiency 5. Regeneration

PART B

1. Air enters the compressor of an open cycle constant pressure gas turbine at a pressure of 1 bar and temperature 20^0C. The pressure of the air after compression is 4 bar. The isentropic efficiencies of compressor and turbine are 80% and 85% respectively. The air-fuel ratio used is 90:1. If the flow rate of air is 3kg/s, find a)Power developed, b)Thermal efficiency of the cycle. Assume C_p=1kJ/kg K and γ=1.4 of air and gases calorific value of fuel=41800kJ/kg

2. In a constant pressure open cycle gas turbine air enters at 1 bar and 20^0C and leaves the compressor at 5bar. Using the following data: Temperature of the gas entering the turbine =680^0C, the pressure loss in the compression chamber =0.1 bar, $\eta_{compressor}$ = 85%, $\eta_{turbine}$ = 80%, $\eta_{combustion}$ = 85%, γ=1.4, C_p=1.024 kJ/kg K for air and gas, Find a)the quantity of air circulation if the plants develops 1065kW b)Heat supplied per kg of air circulation c)The thermal efficiency if the cycle, mass of the fuel may be neglected

3. Derive the expression for work done in the open cycle gas turbine with reheating and explain the importance of reheating

4. In a gas turbine the compressor is driven by the high pressure turbine. The exhaust from the high pressure turbine goes to free low pressure turbine which runs the load. The air flow rate is 20kg/s and the minimum and maximum temperature respectively 300K and 1000K. The compressor ratio is 4. Calculate the pressure ratio of low pressure turbine and temperature of exhaust gas from the unit. The compressor and turbine are isentropic. C_p of air and exhaust gases =1kJ/kg K and γ=1.4

5. Derive the expression for work done in the open cycle gas turbine with reheating and explain the importance of regeneration.

6. A gas turbine unit has a pressure ratio of 6:1 and maximum cycle temperature of 610^0C. The isentropic efficiencies of compressor and turbine are 80% and 82% respectively. Calculate the power output in KW of an electric generator geared to the turbine when the air enters the compressor at 15^0C at the rate of 16kg/s. Take C_p=1.005kJ/kg K and γ=1.4 for the compression process, and take C_p=1.11kJ/kg K and γ=1.333 for the expansion process

7. Air is drawn in a gas turbine unit at 15^0C and 0.01 bar and pressure ratio is 7:1. The compressor is driven by the HP turbine LP turbine drives a separate power shaft. The isentropic efficiencies of compressor and the HP and LP turbines are 0.82, 0.85 and 0.85 respectively. If the maximum cycle temperature is 610^0C, calculate: a) The pressure and temperature of the gases entering the power turbine b) The net power developed by the unit per kg/s mass flow c) The work ratio d) The thermal efficiency of the unit. Neglect the mass of fuel and assume the following:
For compression process: C_{pa}=1.005kJ/kg K and γ=1.4.
For combustion and expansion process: C_{pg}=1.15kJ/kg K and γ=1.333

8. A gas turbine set takes in air at 15°C, the pressure ratio is 4:1 and the maximum temperature is 560°C. Assuming efficiencies of 0.86 and 0.83 for the turbine and compressor respectively, determine the overall efficiency, (a) without heat exchanger, and (b) with heat exchanger making use of 75% of the heat available. Assume that pressure drops in the connecting pipes, etc. can be neglected and that the specific heats of air are constant.

9. A gas turbine unit receives air at 1 bar and 300K and compresses it adiabatically to 6.2 bar. The compressor efficiency is 88%.The fuel has a heating value of 44186kJ/kg and the fuel air ratio is 0.017kJ/kg of air. Take turbine internal efficiency is 90%.Calculate the work of turbine and compressor per kg of air compressed and thermal efficiency. For product of combustion, c_p =1.147kJ/kg K and γ=1.333.

10. A gas turbine plant consists of two turbines. One compressor turbine to drive compressor and other power turbine to develop power output and both are having their own combustion chamber which are served by air directly from the compressor. Air enters the compressor at 1 bar and 288K and is compressed to 8 bar with an isentropic efficiency of 76%. Due to heat added in the combustion chamber, the inlet temperature of the gas to both turbines is 86% and mass flow rate of air at the compressor is 23kg/s. The calorific value of the fuel is 4200kJ/kg. Calculate the output of the plant and the thermal efficiency if mechanical efficiency is 95%and generator efficiency is 96%. Take c_p =1.005kJ/kg K and γ=1.4 for air and C_{pg} = 1.128kJ/kg K and γ=1.34 for gases.

11. In a closed cycle gas turbine there is a two stage compressor and a two stage turbine. All the components ate mounted on the same shaft. The pressure and temperature at the inlet of the first stage compressor are 1.5 bar and 20°C. The maximum cycle temperature and pressure are limited to 750°C and 6bar. A perfect intercooler is used between the two stage compressors and a reheater is used between the two turbines. Gases are heated in the reheater to 750°C before entering in to the LP turbine. Assuming the compressor and turbine efficiencies are 0.82, calculate, (i) Efficiency of the cycle without regenerator (ii) the efficiency of the cycle with regenerator whose effectiveness is 0.70. (iii) the mass of the fluid circulated if the power developed by the plant is 350kW. The Working fluid used in the cycle is air. For air γ=1.4 and C_p=1.005 kJ/kg K.