KSR COLLEGE OF ENGINEERING, TIRUCHENGODE-637 215
DEPARTMENT OF AUTOMOBILE ENGINEERING

Year / Sem : **II / IV**
Subject Code& Name :**20AU411 - Engineering Thermodynamics and Heat Transfer**
Faculty Name :**Dr. S.NEELAMEGAN**

COURSE / LESSON PLAN SCHEDULE

A) TEXT BOOK:

T1 -. Nag.P.K. "Basic and Applied Thermodynamics" Tata McGraw – Hill, 6 th Edition, New Delhi, 2017.
T2. – Holman J.P, "Heat and Mass Transfer", Tata McGraw Hill, New Delhi, 10th Edition, 2017.

B) REFERENCE BOOK:

R1 – Yunus A. Cengel and Michael A. Boles, "Thermodynamics", Tata McGraw-Hill, New Delhi, 8th Edition, 2015.
R2 – Rajput R.K, "A Text Book of Engineering Thermodynamics", Laxmi Publications (P) Ltd, Fifth Edition, 2016.
R3 – Sachdeva R.C, "Fundamentals of Engineering Heat and Mass Transfer", 5th Edition, New Age International, 2017.
R4 – Kothandaraman.C.P, "Fundamentals of Heat and Mass Transfer" New Age International, 4rh Edition, 2012.

C) LEGEND

L	- Lecture	PPT	- Power Point
T	- Tutorial	BB	- Black Board
OHP	- Over Head Projector	PP	- Pages
T_x	- Reference	E_x	- Extra

Sl. No	Lecture Hour	Topics to be covered	Teaching Aid Required	Books No. / Page No
UNIT – I FIRST LAW OF THERMODYNAMICS				
1.	L1	Basic concepts, concept of continuum, macroscopic approach.	BB	T1 / P.873
2.	L2	Thermodynamic systems, closed, open and isolated.	BB	R3/P.5,6.
3.	L3	Property, state, path and process, quasi-static process, work, modes of work.	BB	T1 / P.12 R1/P.9

4.	L4	Zeroth law of thermodynamics.	BB	T1 / P.26 R1/P.19
5.	L5	Concept of temperature and heat. Concept of ideal and real gases.	BB	R3/365,368
6.	L6	First law of thermodynamics, application to closed and open systems.	BB	T1 / P.69 R1 / P19-20
7.	L7	Internal energy, specific heat capacities, enthalpy.	BB	R1/ P 15,37,850
8.	L8	Steady flow process with reference to various thermal equipments.	BB	T1 / P235 R1 / P 86-89
9.	L9	Steady flow energy equation engineering applications.	BB	T1 / P235 R1 / P 86-89
10.	T1	Problem solving in closed system	BB	--
11.	T2	Problem solving in closed system	BB	--
12.	T3	Problem solving in open system	BB	--
UNIT – II SECOND LAW OF THERMODYNAMICS				
13.	L10	Statements of second law of thermodynamics Kelvin-Planck and Clausius statements	BB	T1 / P. 117,121
14.	L11	Reversible and irreversibility. Carnot theorem.	BB	T1 / P.125
15.	L12	heat engine, heat pump, refrigerator, Carnot cycle, Carnot theorem	BB	T1 / P131,147,504
16.	L13	Efficiency, COP.	BB	T1/567,123,580
17.	L14	Thermodynamics temperature scale.	BB	T1 / P137
18.	L15	Inequality of Clausius,	BB	T1 / P 168,159
19.	L16	Entropy, temperature	BB	T1 / P327
20.	L17	entropy diagram and entropy changes for a closed system	BB	T1 / P166
21.	L18	Properties of pure substances	BB	T1 / P223
22.	T4	Problem solving in heat engine, heat pump	BB	--
23.	T5	Problem solving in refrigerator, heat pump and heat engine.	BB	--
24.	T6	Problem solving in entropy.	BB	--

UNIT – III GAS POWER CYCLES VAPOUR POWER CYCLE				
25.	L19	Air Standard Cycles.	BB	R2 – 508
26.	L20	Otto Cycle ,Work output, Efficiency, MEP Calculation.	BB	R2 – 508
27.	L21	Diesel Cycle ,Work output, Efficiency, MEP Calculation.	BB	R2 – 475
28.	L22	Dual Cycle - Work output, Efficiency, MEP Calculation.	BB	R2 – 489, 490
29.	L23	Comparison of the cycles for same compression ratio and heat addition , same compression ratio and heat rejection, same peak pressure, peak temperature and heat rejection, heat input, work output.	BB	R2 – 491, 492
30.	L24	BraytonCycle with inter cooling,Brayton Cycle with reheat and regeneration, Fundamentals of refrigeration, C.O.P.	BB	R2 – 515-523
31.	L25	Reversed Carnot cycle, Simple Vapour compression refrigeration system, T-S, P-H diagrams.	BB	R3–1422- 1445
32.	L26	Simple Vapour absorption refrigeration system.	BB	R3 -1448-1450
33.	L27	Desirable properties of an ideal refrigerant.	BB	R3- 1473-1475
34.	T7	Problem Solving in Otto Cycle, Diesel Cycle.	BB	--
35.	T8	Problem Solving in Brayton Cycle, Problem Solving in Dual Cycle.	BB	--
36.	T9	Problem Solving in Vapour compression and Vapour absorption refrigeration system.	BB	--
UNIT – IV CONDUCTION				
37.	L28	Basic concepts	BB	R5 – 1 – 10
38.	L29	Mechanism of Heat Transfer , Conduction,	BB	R5 – 11 – 15

39.	L30	Convection and Radiation,	BB	R5 – 16– 29
40.	L31	General differential equation of Heat conduction.	BB	R5 – 33 – 34
41.	L32	Fourier law of conduction	BB	R5 – 34
42.	L33	One Dimensional Steady State Heat Conduction, Conduction through Plane wall.	BB	R5 – 37–41
43.	L34	One Dimensional Steady State Heat Conduction, Cylinder	BB	R5– 46 – 48
44.	L35	One Dimensional Steady State Heat Conduction, Composite systems.	BB	R5 – 49 - 50
45.	L36	Extended Surfaces	BB	R5- 149 - 197
46.	T10	Problem Solving in Slabs.	BB	--
47.	T11	Problem solving in Cylinder	BB	--
48.	T12	Conduction with Internal Heat Generation.	BB	--
UNIT – V CONVECTION AND RADIATION				
49.	L37	Basic Concepts, Convective Heat Transfer Coefficients, - Types of Convection, Forced Convection,	BB	R5- 316 - 336
50.	L38	External Flow , Flow over Plates	BB	R5- 369 - 388
51.	L39	Flow over Cylinders	BB	R5- 389 - 392
52.	L40	Free Convection	BB	R5- 477 - 489
53.	L41	Flow over Vertical Plate, Horizontal Plate,.	BB	R5- 490 - 492
54.	L42	Flow over Cylinders.	BB	R5- 497 - 498
55.	L43	Basic Concepts- Laws of Radiation – Stefan Boltzman law, Kirchoff law.	BB	R5 – 633 - 636
56.	L44	Black body Radiation- Grey body radiation	BB	R5 – 639 - 642

57.	L45	Radiation Shields	BB	R5 – 644-659
58.	T13	Problem Solving in Forced Convection Plates, Cylinders, , Free Convection , Vertical Plate, Horizontal Plate, Cylinders, Spheres	BB	--
59.	T14	Problem Solving in Radiation,	BB	--
60.	T15	Problem Solving in Radiation Shields.	BB	--

Prepared By **H.O.D/AUE**

Dr.S.NEELAMEGAN **Dr. R.VENKATACHALAM**

UNIT – I

PART – A

1. **Define Zeroth law of thermodynamics. (Apr'05, Nov'03, Nov' 05)**

   Zeroth law of thermodynamics states that hen two bodies are separately in thermal equilibrium with a third body, then they themselves are in thermal equilibrium with each other.

2. **Explain Mechanical, Chemical and Thermal Equilibrium (Apr'05)**

   Mechanical Equilibrium:

   A System is said to be in mechanical equilibrium, when there is no unbalanced forces acting on it.

   Chemical Equilibrium:

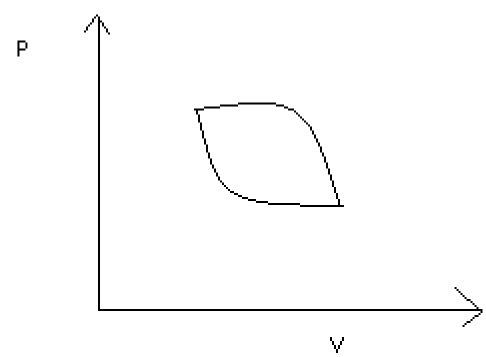
   A System is said to be in chemical equilibrium, when there is no chemical reaction throughout the system.

   Thermal Equilibrium:

   A System is said to be in thermal equilibrium, when there is no temperature difference throughout the system.

3. **Show that work is a path function and not a property. (April'05)**

   Consider two states 1 and 2 of a system represented by its properties. The state 2 could have been obtained from state 1 with the help of various quasi static process, such as along the paths A or path B as shown in figure.



Since the area under the curve represents the work done during a process, if follows that the work involved in each process defined by the paths (1-A-2) and (1-B-2) is different though the initial and final states of the system in either of the process is same. Hence the work done during a process depends upon its path followed i.e. the work is a path function and not a property.

4. **Define intensive and extensive properties with two examples for each (Nov'03)**

   Intensive Properties

   The properties, which are independent of the mass of the system, are called intensive properties.

   Eg Pressure, temperature, Viscosity etc

   Extensive properties:

The properties which are depends upon the mass of the system is called Extensive properties.

Eg length, volume and all forms of energies.

5. **What is meant by macroscopic approach.(Nov'02)**

In macroscopic approach, instead of studying parameters at molecular level, the behavior of the total system in terms of properties such as pressure, volume, temperature etc are studied. These properties at every instant can easily be measured. It is also called as macroscopic approach or classical approach. It is also called as classical thermodynamics.

6. **Define isolated system.**

Isolated system is not affected by surroundings. There is no heat, work and mass transfer takes place. In this system total energy remains constant.

Eg Entire universe.

7. **When a system is said to be in "Thermodynamic Equilibrium "? (Apr'04)**

When a system is in thermodynamic equilibrium , it should satisfy the following three conditions.

I) Mechanical Equilibrium - pressure remains constant

2) Thermal Equilibrium - temperature remains constant

3) Chemical Equilibrium – there is no chemical reaction.

8. **State the First Law of thermodynamics and any two of its corollaries.(Apr'04)**

First law of thermodynamics states that when system undergoes a cyclic process net heat transfer is equal to work transfer.

$$\sum Q = \sum W$$

Corollary I:

There exists a property of a closed system such that a change in its value is equal to the difference between the heat supplied and the work done during any change of state.

Corollary II:

The internal energy of a closed system remains unchanged if the system is isolated from its surroundings.

Corollary III:

A Perpetual motion machine of first kind (PMM –I_ is impossible.

9. **What is meant by "perpetual motion machine of First kind"? (Apr'03)**

PMM of first kind delivers work continuously without any input. It violates first law of thermodynamics. It is impossible to construct an engine working with this principle.

10. **Prove that for an isolated system, there is no change in internal energy (Apr'03)**

For an isolated system, there is no heat, work and mass transfer.

$$Q = W = 0$$

According to the first law of thermodynamics,

$Q = W + \Delta U$

Since

$$\Delta U = 0$$

11. Prove that the difference in specific heat capacities equal to $C_p - C_v = R$ (Apr'03)

Consider a gas heated at constant pressure so,

Heat supplied, $Q = m\,C_p\,(T_2 - T_1)$

Work done, $W = p\,(V_2 - V_1) = mR\,(T_2 - T_1)$

Change in internal energy, $\Delta U = m\,C_v\,(T_2 - T_1)$

According to the first law of thermodynamics,

$$Q = W + \Delta U$$

So,

$$m\,C_p\,(T_2 - T_1) = mR(T_2 - T_1) + m\,C_v\,(T_2 - T_1)$$

$$C_p = R + C_v$$

$$C_p - C_v = R$$

12. Define " Thermodynamic System". Name various types of system.(Nov'05)

A thermodynamic system is defined as a definite space or area on which the study of energy transfer and energy conversion is made.

The thermodynamic systems may be classified into three categories

i) Closed system
ii) Open system
iii) Isolated system.
iv)

13. Define the following: (Nov'05)

a. Pure Substance with examples
b. Homogeneous System

a) **Pure substance**:

A Pure substance is one which has a homogeneous and invariable chemical composition even though there is a change of phase.

Example liquid water, mixture of water and steam (vapour), mixture of ice and water etc.,

b) **Homogeneous system:**

If a system consists of homogeneous matter throughout in chemical composition and physical structure, it is called homogeneous system.

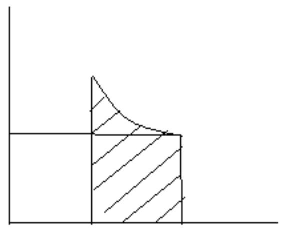
14. Define Heat.(Nov'05)

Heat is a form of energy which is transferred without transfer of mass, from one body to another body (or between system and surroundings) from higher temperature to lower temperature by virtue of temperature difference between two bodies. It is generally abbreviated as "Q".

15. Sketch Isothermal Expansion on (P-V) diagram and state the properties that remain constant. (May'04)

The following properties remain constant

1. Temperature
2. Internal energy
3. Enthalpy



PART B

1. A car of mass 2000 kg that is simultaneously accelerated from a velocity V = 0 to 55 mph (24.6 m /s) and elevated to a height of 100 m requires a work input of 3000 kJ. If the car is well insulated, what is the change in the internal energy of the car?

2. A gas in a piston–cylinder assembly undergoes an expansion process for which the relationship between pressure and volume is given by PV^{γ}The initial pressure is 3 bar, the initial volume is 0.1 m3, and the final volume is 0.2 m3. Determine the work for the process, in kJ, if (a) n= 1.5, (b) n= 1.0, and (c) n = 0.

3. A quantity of gas has a volume of $0.14m^3$ pressure 1.5 bar and temperature 100^0C. If the volume at the end of the constant pressure process is $0.112m^3$. Find final temperature, Work done, Change in internal energy and heat given out. Take Cp = 1.005 KJ/KgK, Cv = 0.712 Kj/Kg and R= 285 J/KgK.

4. A steady flow steam turbine receives steam at the rate of 1.5 Kg/sec. At inlet the steam has a specific enthalpy of 2720 KJ/Kg, velocity of 40 m/sec and an elevation of 4m from the chosen datum and their respective conditions at exit are 2243 KJ/Kg, 60 m/sec and 1.5m. Heat transfer from the system to the surrounding is 5 KJ/s. Determine the output of the turbine.

5. A mass of 0.8 kg of air at 1 bar and 25^0C in contained in a gas tight frictionless piston-cylinder device. The air is now compressed to a final pressure of 5 bar. During the process, heat is transferred from the air such that the temperature inside the cylinder remains constant. Calculate the heat transfer and work done during the process and direction of each in the process.

6. A reciprocating air compressor takes in air at 1 bar and 20^0C and delivers at 6 bar. Calculate the work done, heat transfer and change in internal energy per Kg of air compressed. If the compression process follows

a) Isothermal

b) Isentropic

c) Polytropic $PV^{1.25} = C$ Neglect Change in kinetic energy and potential energy.

7. A Fluid is confined in a cylinder by a spring loaded frictionless, piston so that the pressure in the fluid
is a linear function of the volume (P=a+bV). The internal energy of the fluid is given by the following equation U = 34+3.15PV

Where 'U' is in KJ, 'P' in Kpa and 'V' in m^3.If the fluid changes from an initial state of 170Kpa, $0.03m^3$ to a final state of 400 Kpa, 0.06 m^3 with no work other than done on the piston.

Find the direction, magnitude of the work and heat transfer.

ii) Deduce an expression for the work done by a system during polytropicproces

8. Air at a temperature of 15 ^{0}C passes through a heat exchanger at a velocity of 30 m/sec where its temperature is raised to 800 ^{0}C. It then enters a turbine with the same velocity of 30 m/sec and expands until the temperature falls to 650^{0}C. on leaving the turbine, the air is taken at a velocity of 60 m/sec to a nozzle where it expands until the temperature fallen to 500^{0}C, If the air flow rate is 2 kg/sec. Calculate

a) The rate of heat transfer to the air in the heat exchanger
b) The power output from the turbine assuming no heat loss and
c) The velocity at the exit from the nozzle assuming no heat loss. Take Enthalpy of air as h=Cpt where Cp is the specific heat equal to 1.005 Kj/kgk and "t" Temperature [april/may 2003]

9. A rigid tank contains a hot fluid that is cooled while being stirred by a paddle wheel. Initially, the internal energy of the fluid is 800 kJ. During the cooling process, the fluid loses 500 kJ of heat, and the paddle wheel does 100 kJ of work on the fluid. Determine the final internal energy of the fluid. Neglect the energy stored in the paddle wheel.

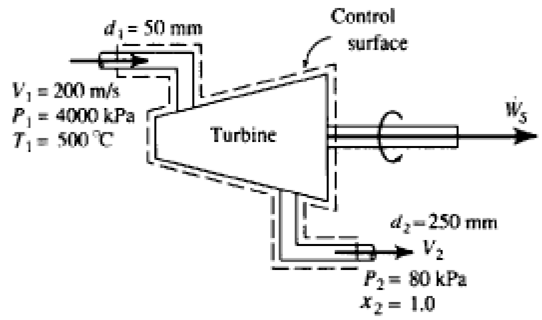
10. A piston–cylinder device initially contains 0.4 m3 of air at 100 kPa and 80°C.The air is now compressed to 0.1 m3 in such a way that the temperature inside the cylinder remains constant. Determine the work done during this process.

11. A piston–cylinder device contains 0.05 m3 of a gas initially at 200 kPa. At this state, a linear spring that has a spring constant of 150 kN/m is touching the piston but exerting no force on it. Now heat is transferred to the gas, causing the piston to rise and to compress the spring until the volume inside the cylinder doubles. If the cross-sectional area of the piston is 0.25 m2, determine (*a*) the final pressure inside the cylinder, (*b*) the total work done by the gas, and (*c*) the fraction of this work done against the spring to compress it.

10. Air at 10°C and 80 kPa enters the diffuser of a jet engine steadily with a velocity of 200 m/s. The inlet area of the diffuser is 0.4 m2. The air leaves the diffuser with a velocity that is very small compared with the inlet velocity. Determine (*a*) the mass flow rate of the air and (*b*) the temperature of the air leaving the diffuser

12. Air at 100 kPa and 280 K is compressed steadily to 600 kPa and 400 K. The mass flow rate of the air is 0.02 kg/s, and a heat loss of 16 kJ/kg occurs during the process. Assuming the changes in kinetic and potential energies are negligible, determine the necessary power input to the compressor.

13. Steam enters a turbine at 4000 kPa and 500 "C and leaves as shown in figure. For an inlet velocity of 200 m/s calculate the turbine power output. ***(a)***Neglect any heat transfer and kinetic energy change.
(b) Show that the kinetic energy change is negligible.



UNIT – II

PART – A

1. **Write the two statement of the second law of thermodynamics. [Apr 03]**

Kelvin Plank statement:

It is impossible to construct an engine working on an cyclic process, which converts all the heat energy supplied to into equivalent amount of useful work.

Clausius Statement:

It states that it is impossible to construct a device whose sole effect is to transfer of heat from a cold body to hot body.

2. **State Carnots Theorem.[.Oct02]**

No heat engine operating in a cycle process between two-fixed temperatures can be more efficient that a reversible engine operating between the temperature limits.

3. **What do you mean calusius inequality.[Nov03]**

It is a relation between the thermodynamic temperatures of any arbitrary number of heat reservoirs and heat transfer from them when some working substance is carried through a cyclic process.

$$(dQ / T) <= 0$$

4. **"Two Reversible Adiabatic lines cannot intersect". Is this statement true or false? Justify answer? (Nov'05)**

Assume that two adiabatic processes Ps and RS intersect each other as shown in fig.. consider another isothermal process Rp which intersects the two reversible adiabatic at points R and P. sothermal process RP and two reversible adiabatic PS and SR constitute a cycle PSR

Work done during the cycle = Area PSR

Heat supplied during the cycle,

$$\Sigma Q = (Q)_{RP} + (Q)_{PS} + (Q)_{SR}$$

But

$$(Q)_{PS} = (Q)_{SR} = 0 \text{ being adiabatic}$$

$$\therefore \quad \Sigma Q = (Q)_{RP}$$

follows from above that during the cycle, the system receives heat from a single heat reservoir during isothermal process RP and produces an equal amount of work. It violates the Kelvin - Planck statement of second law of thermodynamics hence, the basic assumption that two reversible adiabatic intersect at a point is wrong..

Therefore, we conclude that two reversible adiabatic paths cannot intersect each other.

5. **Write expressions for change in entropy of perfect gas during**
   i. Constant volume process in terms of pressure and in terms of temperature.
   ii. Constant pressure process in terms of volume and in terms of temperature (Nov'05)

Change in Entropy of perfect gas during constant volume process in terms of pressure and in terms of temperature:

$$S_2 - S_1 = \Delta S = mR\log_e(P_1/P_2) + mC_P\log_e(T_2/T_1)$$

Change in Entropy of perfect gas during Constant pressure process in terms of volume and in terms of temperature:

$$S_2 - S_1 = \Delta S = mR\log_e(V_2/V_1) + mC_v\log_e(T_2/T_1)$$

6. **What is meant by "perpetual motion machine of first kind" (May'03)**

   It is a machine, which will produce continuous work without receiving energy from other system. In other words, such a machine will create energy thus violating the first law of thermodynamics.

7. **What is meant by (perpetual motion machine of second kind (PMM-2)**

   A machine, which violates the second law of thermodynamics, is called the perpetual motion machine of second kind (PMM-2)

8. **What is the law of degradation of Energy?**

   Energy is said to be degraded each time it is transferred through a finite temperature difference. For this reason, the second law of thermodynamics is sometimes called the " Law of degradation of energy"

9. **What do you understand by the availability of a system?**

   When a system is subjected to a process from its initial state to a dead state (i.e., when the system is under thermodynamic equilibrium with its surroundings), the maximum amount of useful work that can be obtained under ideal conditions (i.e., without dissipative effects) is called as available energy or exergy or availability of a system.

10. **Define Entropy**

    Entropy is a property of a system which is given by

    $dS = (dQ / T)$

11. **State the principle of increase in entropy**

    The entropy change of the system and its surroundings (i.e., for universe during any process between two equilibrium states is equal to or greater than zero. This is known as Principle of increase of entropy.

$$(\Delta S)_{Universe} >= 0$$

12. **Deduce the relation between COP of heat pump and refrigerator (Nov'05)**

    The efficiency of refrigerator and heat pump is expressed in terms of co efficient of performance (C.O.P)

    From First Law $W = Q_1 - Q_2$

    $(C.O.P)_{Ref}$ = Heat rejected / Work input = $Q2/ Q_1 - Q_2$ ---------------- (A)

    $(C.O.P)_{Pump}$ = Heat Supplied / Work input = $Q1/ Q_1 - Q_2$ -----------------(B)

    From (A) and (B) we can get the relation

$$(C.O.P)_{Pump} - (C.O.P)_{Ref} = 1$$

13. **What is meant by thermodynamic temperature scale? (Nov'05)**

In thermodynamics it is very desirable to have a temperature scale that is independent of the properties of any substances. Such a temperature scale is called a thermodynamic temperature scale.

14. **What are the conditions of reversibility?(Nov'05)**

Conditions of reversibility are

Process is carried out in thermodynamic equilibrium

The dissipative effects like friction and viscosity are not present in the system.

15. **Differentiate between heat pump and refrigerator (Nov'05)**

Refrigerator:

It is a device operating on a cycle, which removes heat from a low temperature body and rejects it to a body at higher temperature body on the expense of external work supplied.

Heat pump:

If the objective of the system is to deliver heat energy at higher temperature T_1 (e.g heating in winter) then the temperature T_2 corresponds to ambient temperature. Such a device is called as heat pump.

16.**Discuss the limitations of first law of thermodynamics.**

The limitations of first law of thermodynamics are:

a. process can proceed in one direction only e.g. heat can flow from high temperature to low temperature body, however heat cannot flow from low temperature body to high temperature body though it would not violate the first law .
b. All process involving conversion of heat into work and vice- versa are not equivalent.

PART B

1) A reversible heat engine operates between two reservoirs at temperatures of 600°C and 40°C . The engine drives a reversible refrigerator which operates between reservoirs at temperatures of 40°C and -20°C .The heat transfer to the heat engine is 2000kJ and thenet work output of the combined engine refrigerator plant is 360kJ.

(a) Evaluate the heat transfer to the refrigerant and the net heat transfer to the reservoir at 40°C.
(b) Reconsider(a) given that the efficiency of the heat engine and the COP of the refrigerator are each 40% of their maximum possible values.

2).8 kg of air at 650K and 5.5 bar pressure is enclosed in a closed system. If the atmospheric temperature and pressure are 300K and 1 bar respectively. Determine: (i) The availability if the system goes through the ideal work producing process. (ii) The availability and effectiveness if the air is cooled at constant pressure to atmospheric temperature without bringing it to complete dead state .Take Cv = 0.718 kJ/kgK;Cp=1.005 kJ/kgK.

3) Heat is transferred to a heat engine from a furnace at a rate of 80 MW. If the rate of waste heat rejection to a nearby river is 50 MW, determine thenet power output and the thermal efficiency for this heat engine.

4) An inventor claims to have developed a refrigerator that maintains the refrigeratedspace at35°F while operating in a room where the temperature is75°F and that has a COP of 13.5. Is this claim reasonable?

5) A heat pump is to be used to heat a house during the winter, as shown inFig. 6–53. The house is to be maintained at 21°C at all times. The house isestimated to be losing heat at a rate of 135,000 kJ/h when the outside temperature drops to _5°C. Determine the minimum power required to drive the heat pump.

6) What is the Kelvin–Planck expression of the second law of thermodynamics?

7) What is the difference between a refrigerator and a heat pump?

8) Determine the COP of a heat pump that supplies energy to a house at a rate of 8000 kJ/h for each kW of electric power it draws. Also, determine the rate of energy absorption from the outdoor air.

9) Why are engineers interested in reversible processes even though they can never be achieved?
10) A Carnot heat engine receives 650 kJ of heat from a source of unknown temperature and rejects 250 kJ of it to as ink at 24°C. Determine (*a*) the temperature of the source and
(*b*) the thermal efficiency of the heat engine.

11) A Carnot heat engine operates between a source at1000 K and a sink at 300 K. If the heat engine is supplied with heat at a rate of 800 kJ/min, determine (*a*) the thermal efficiency and (*b*) the power output of this heat engine.

12) An inventor claims to have developed a heat engine that receives 700 kJ of heat from a source at 500 K and produces300 kJ of net work while rejecting the waste heat to a sink at 290 K. Is this a reasonable claim? Why?

13) A piston–cylinder device contains a liquid–vapor mixture of water at 300K. During a constant-pressure process, 750 kJ of heat is transferred to the water. As a result, part of the liquid in the cylinder vaporizes. Determine the entropy change of the water during this process.

14) A heat source at 800 K loses 2000 kJ of heat to a sink at (*a*) 500 K and (*b*) 750 K. Determine which heat transfer process is more irreversible.

15) A rigid tank contains 5 kg of refrigerant-134a initially at 20°C and 140kPa. The refrigerant is now cooled while being stirred until its pressure drops to100kPa. Determine the entropy change of the refrigerant during this process.

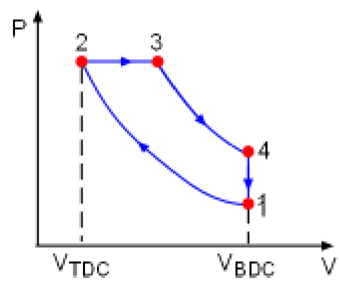
UNIT – III

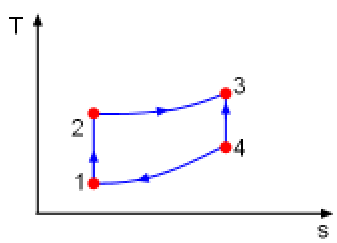
PART – A

1. **Mention the assumptions made on the air standard cycle analysis. (AU June 2009, June 2007)**
   - (i) The working medium is a perfect gas throughout 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 are no loss or gain of entropy.
   - (iv) Kinetic energy and potential energy of the working fluid are neglected.
   - (v) The operation of the engine is frictionless.
   - (vi) Heat is supplied and rejected in a reversible manner.
2. **In an Otto cycle, Pressure ratio during compression is 11. Calculate the air standard efficiency. (AU June 2009)**

3. **How does the change in compression ratio effect air standard efficiency of an ideal Otto cycle? (AU May 2008)**
   The air standard efficiency of an ideal Otto cycle increases with the increase in compression ratio.
4. **Mention the four thermodynamic processes involved in Diesel Cycle. (AU May 2008)**
   - (i) Isentropic compression
   - (ii) Constant pressure heat addition
   - (iii) Isentropic expansion
   - (iv) Constant volume heat rejection

5. **Sketch the Diesel cycle on P-V and T-S planes. (AU June 2007).**





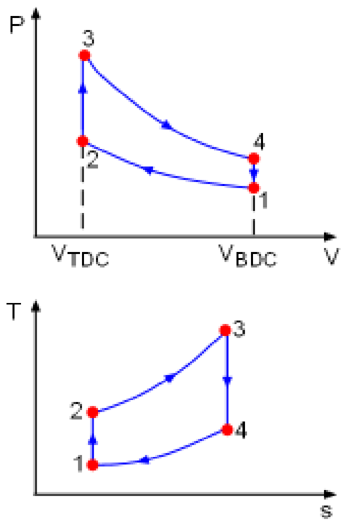
6. **Define mean effective pressure of an I.C. engine. (AU Nov 2006)**
   Mean Effective Pressure is defined as the constant pressure acting on the piston during the working stroke. It is also defined as the ratio of work done to the stroke volume or piston displacement volume.

7. **What is the significance of Mean Effective Pressure? (AU Nov 2008)**
   Mean Effective Pressure is defined as the constant pressure acting on the piston during the working stroke. It will be able to do the same amount of work, as done by the actual varying pressure, produced during the cycle.

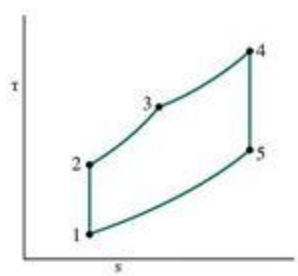
8. **Mention the various processes of dual cycle?**
   (i) Isentropic compression
   (ii) Constant volume heat addition
   (iii) Constant pressure heat addition
   (iv) Isentropic expansion
   (v) Constant volume heat rejection
9. **Mention the various processes of Brayton cycle?**
   (i) Isentropic compression
   (ii) Constant pressure heat supplied
   (iii) Isentropic expansion
   (iv) Constant pressure heat rejection
10. **Mention the various processes of Otto cycle? (AU May 2011)**
    (i) Isentropic compression
    (ii) Constant volume heat supplied
    (iii) Isentropic expansion
    (iv) Constant volume heat rejection
11. **Define air standard cycle efficiency. (AU May 2011)**
    Air standard efficiency is defined as the ratio of work done by the cycle to the heat supplied to the cycle.
12. **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.
13. **Represent the Otto, Diesel and Dual cycle on P-V co-ordinates for the same compression ratio and same heat input.**

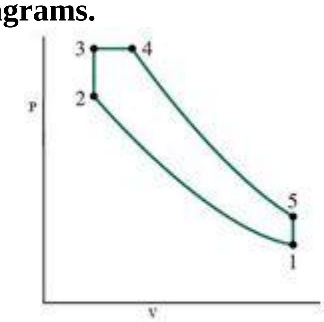
14. **What is a thermodynamics cycle?**
    Thermodynamics cycle is defined as the series of processes performed on the system, so that the system attains its original state.
15. **What is the effect of cut-off ratio on the efficiency of diesel cycle when the compression ratio is kept constant?**
    When cut-off ratio of diesel cycle increases, the efficiency of cycle is decreased when compression ratio is kept constant and vice versa.
16. **Define: Compression ratio. (AU May 2011)**
    The ratio of total cylinder volume to the clearance volume is known as compression ratio.
17. **Compare the efficiency of the Otto, Diesel and Dual combustion cycle. (AU May 2011)**

18. Sketch Otto cycle on P-V diagram.



19. Sketch the dual cycle on P-V and T-S diagrams.





20. Write an expression for mean effective pressure for an Otto cycle in terms of compression ratio and other parameters.

Mean Effective Pressure, $p_m = p_1 r\left(\frac{k-1}{\gamma-1}\right)\left(\frac{r^{\gamma-1}-1}{r-1}\right)$

Where, p_1 – Initial pressure
r - Compression ratio
k - Pressure ratio
γ - Adiabatic index

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

Compression ratio and cut-off ratio.

22. In case of regenerative cycle, what are the factors affecting thermal efficiency of the cycle?

Maximum cycle temperature and pressure ratio.

23. What are the effects of introducing regeneration in the basic gas turbine cycle?

(i) The economy is improved. The quantity of fuel required per unit mass of air is less.
(ii) The work output from turbine, work required to the compressor will not change.
(iii) Pressure drop will occur during regeneration.
(iv) It increases the thermal efficiency when the low pressure ratio reduces.

24. What are the effects of providing the intercooler in the gas turbine cycle?

(i) Heat supply is increased
(ii) It decreases the thermal efficiency.
(iii) Work ratio will be increased.
(iv) Specific volume of air is reduced.

25. What the effects are of reheat cycle?

(i) Thermal efficiency is less since the heat supplied is more.
(ii) Turbine output is increased for same expansion ratio.

26. Define relative efficiency. (AU May 2012)

27. State the merits of gas turbines over I.C. engines and steam turbines. (AU May2012)

28.Define volumetric efficiency of a reciprocating compressor. (AU May 2008, June 2007, May 2011)

Volumetric efficiency is defined as the ratio of volume of free air sucked into the compressor per cycle to the stroke volume of the cylinder.

$$\eta_{vol} = \frac{\text{Volume of free air taken per cycle}}{\text{Stroke volume of the cylinder}}$$

29.What is the main advantage of inter cooling in multi stage reciprocating compressors? (AU Apr04, May 2008) or what are the advantages of multi-stage compression? (AU Nov 2007, Nov 2006)

(i) The work done per kg of air is reduced in multi stage compression with inter cooler as compared with single stage compression for the same delivery pressure.
(ii) It improves the volumetric efficiency for the given pressure ratio.
(iii) The size of the cylinders may be adjusted to suit the volume and the pressure of the air.
(iv) It reduces the leakage loss considerably.
(v) It gives more uniform torque and hence, a smaller size flywheel is required.
(vi) It provides effective lubrication because of lower operating temperature.
(vii) It reduces the cost of the compressor.

30.What is the basic difference between vapour compression and vapour absorption refrigeration system? (AU May 2008)

Vapour Compression System	Vapour Absorption System
1. Electric power is needed to drive the system.	1. No need of electric power.
2. Wear and tear is more because of moving components.	2. Wear and Tear is less.
3. Tonne capacity is low.	3. Tonne capacity is high.
4. Charging of refrigerant is simple.	4. Charging of refrigerant is difficult.
5. More chances for leakage of refrigerant.	5. There is no leakage of refrigerant.
6. Mechanical energy is supplied.	6. Heat energy is supplied.

31.What is the effect of clearance volume on the power required and work done in a reciprocating air compressor? (AU June 2009)

The clearance volume does not effect the work done on the air and the power required for compressing the air. This is due to reason that the work required to compress the clearance volume air is theoretically regained during its expansion.

32.Give two examples for positive displacement rotary compressors.(AU June 2009)

(i) Roots blower

(ii) Vane blower

(iii) Reciprocating compressor

33.Which thermodynamic cycle is used in air conditioning of airplanes using air as a refrigerant? (AU June 2009)

Reversed Brayton cycle is used in air conditioning of airplanes using air as a refrigerant.

34.What is Isothermal efficiency of a compressor? (AU Nov 2007, Nov 2006, May 2011)

Isothermal efficiency is defined as the ratio between isothermal work to the actual work of the compressor.

$$\eta_{\text{Isothermal}} = \frac{\text{Isothermal work}}{\text{Actual work}}$$

35.Define COP of refrigeration. (AU Nov 2007)

Coefficient of performance (COP) is defined as the ratio of heat absorbed by the evaporator or refrigeration effect to the compressor work.

$$\text{COP} = \frac{\text{Refrigeration Effect}}{\text{Work done}}$$

36.What is free air delivered? (AU June 2007)

The free air delivered is the actual volume delivered at the stated pressure reduced to intake pressure and temperature and expressed in m^3/min.

37.Acarnot refrigerator requires 1.3 KW per tonne of refrigeration to maintain a region at low temperature of -38^{o}C. Determine the COP of the refrigerator and the higher temperature of the cycle. (AU June 2007)

38.What is unit of refrigeration and explain. (AU Nov 2006)

Unit of Refrigeration is expressed in terms of ‘tonne of refrigeration’.

A tonne of refrigeration is defined as the quantity of heat required to be removed from one tonne of water at 0^{o}C to convert that into ice at 0^{o}C in 24 hours.

39.Why clearance is necessary in reciprocating compressors? (AU Nov 2008)

When the piston reaches top dead center in the cylinder, there is a dead space between piston top and cylinder head. This space is known as clearance space and the volume occupied by this space is known as clearance volume.

40.Differentiate positive and non-positive displacement compressors? (AU Nov 2008)

41.Classify the various types of air compressors.

(i) According to the design and principle of operation

(a) Reciprocating compressors

(b) Rotary compressors

(ii) According to the action

(a) Single acting compressors

(b) Double acting compressors

(iii) According to the number of stages

(a) Single stage compressors

(b) Multistage compressors

(iv) According to the pressure limit

(a) Low pressure compressors

(b) Medium pressure compressors

(c) High pressure compressors

42.Draw the P-V diagram of a two stage reciprocating compressor.

43.Define the mechanical efficiency of a reciprocating compressor?

Mechanical efficiency is defined as the ratio between brake power to the indicated power.

$$\eta_{mech} = \frac{\text{Brake power}}{\text{Indicated power}}$$

44.Name the methods adopted for increasing isothermal efficiency of reciprocating compressor?

Isothermal efficiency is increased by perfect inter cooling.

45.What should be the properties of an ideal refrigerant? (AU May 2011)

(i) The refrigerant should have low freezing point.
(ii) It must have high critical pressure and temperature to avoid large power requirements.
(iii) It should have low-specific volume to reduce the size of the compressor.
(iv) It should be non flammable, non-explosive, non-toxic and non-corrosive.
(v) It must have low specific heat and high latent heat.
(vi) It should be of low cost.

46.Name four important properties of a good refrigerant.

(i) Low boiling point
(ii) High critical temperature and pressure
(iii) Low specific heat of liquid

47.How does the actual vapour compression cycle differ from that of the ideal cycle?

The main deviations between ideal (theoretical) cycle and actual cycle:

(i) The vapour refrigerant leaving the evaporator is in superheated state.
(ii) The compression of refrigerant is neither isentropic nor polytropic.
(iii) The liquid refrigerant before entering the expansion valve is sub-cooled in the condenser.
(iv) The pressure drops in the evaporator and condenser.

48.Name the various components used in simple vapour absorption refrigeration system.

(i) Absorber, (ii) Pump, (iii) Generator, (iv) Condenser, (v) Throttle valve, (vi) Evaporator.

49.Write the conditions which lower the volumetric efficiency. (AU May 2012)

50.Enumerate systems of refrigeration. (AU May 2012)

51.What is net refrigerating effect of the refrigerant?

Refrigerating effect is the total heat removed from the refrigerant in the evaporator.

$$\text{COP} = \frac{\text{Refrigeration effect}}{\text{Work done}}$$

Refrigeration effect = COP X Work done

52.What are advantages and disadvantages of air refrigeration system?

Advantages:

(i) The refrigerant used namely air is cheap and easily available.
(ii) There is no danger of fire or toxic effects due to leakages.
(iii) The weight to tonne of refrigeration ratio is less as compared to other systems.

Disadvantages:

(i) The quantity of refrigerant used per tonne of refrigeration is high as compared to other systems.
(ii) The COP of the system is very low. Therefore, running cost is high.

(iii) The danger of frosting at the expander valves is more as the air contains moisture content.

53.What are factors that affect the volumetric efficiency of a reciprocating compressor?

(i) Clearance volume

(ii) Compression ratio.

54.Give two merits of rotary compressor over reciprocating compressor.

(i) Rotary compressor gives uniform delivery of air when compared to reciprocating compressor.

(ii) Rotary compressors are small in size for the same discharge as compared with reciprocating compressors.

(iii) Lubricating system is more complicated in reciprocating compressor where as it is very simple in rotary compressor.

55.Discuss the effect of clearance upon the performance of an air compressor.

The volumetric efficiency of air compressor increases with decreases in clearance of the compressor.

The free air delivered by the compressor is increased by decreasing the clearance volume.

56.Define tons of refrigeration. (AU May 2004, May 2011)

A tonne of refrigeration is defined as the quantity of heat required to be removed from one tonne of water at 0^oC to convert that into ice at 0^oC in 24 hours.

1 tonne of refrigeration = 210KJ/min = 3.5KW

57.What are the advantages of vapour compression refrigeration system over air refrigeration system?

(i) The quantity of refrigerant used per tonne of refrigeration is high as compared to other systems.

(ii) The COP of the system is very low. Therefore running cost is high.

(iii) The danger of frosting at the expander valves is more as the air contains moisture content.

PART – B

1. Air at 1.01 bar, 20^oC 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. (AU May 2008)

2. Calculate the ideal air standard cycle efficiency based on the Otto cycle for a petrol engine with a cylinder bore of 50 mm, a stroke of 75 mm, and a clearance volume of 21.3 cm^3. (AU May 2008)

3. An engine 20 cm and 30 cm stroke works on Otto cycle. The Clearance volume is 1600 cu cm. The initial pressure and temperature are 1 bar and 60^oC. If 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. (AU Nov 2007)

4. A gas turbine works on an air standard Brayton cycle. The initial condition of the air is 1 bar and 25^oC. The maximum pressure and temperature are limited to 3 bar and 650^oC. Determine the following: (i) Cycle efficiency, (ii) Heat supplied and heat rejected/kg of air, (iii) Work output/kg of air, (iv) Exhaust temperature. (AU Nov 2007)

5. A gas engine working on the Otto cycle has a cylinder of diameter 0.2 m and stroke 0.25 m. The clearance volume is 1570cc. find the air standard efficiency. Assume C_p= 1.004 KJ/Kg-K and C_v = 0.717 KJ/Kg-K for air. (AU June 2009)

6. In an engine working on the diesel cycle the ratios of the weights of air and fuel supplied is 50:1. The temperature of air at the beginning of the compression is 333 K and the compression ratio used is 14:1. What is the ideal efficiency of the engine calorific value of fuel used is 4200 KJ/Kg. Assume = 1.004 KJ/Kg-K and C_v = 0.717 KJ/Kg-K for air. (AU June 2009)

7. An engine working on Otto cycle has a volume of 0.45 m^3, pressure 1 bar and temperature 30^oC at the beginning of compression stroke. At the end of compression stroke, the pressure is 11 bar and 210 KJ of heat is added at constant volume. Determine (i) Pressures, temperatures and volumes at all salient points in the cycle, (ii) efficiency. (AU June 2007)

8. Derive an expression for the air-standard efficiency of a Brayton cycle in terms of pressure ratio. (AU June 2007)

9. Prove that the pressure ratio for maximum work is a function of the limiting temperature ratio. (AU June 2007)

10. A 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^oC and 27^oC respectively. The pressure at the beginning of compression is 1 bar. Calculate (i) the pressures and temperatures at key points of the cycle, (ii) the heat supplied at constant volume, (iii) the heat supplied at constant pressure, (iv) the heat rejected, (v) the work output, (vi) the efficiency and (vii) mep. (AU Nov 2006, Nov 2008)

11. Air enters the compressor of a gas turbine at 100 Kpa and 25^oC. For a pressure ratio of 5 and a maximum temperature of 850^oC, determine the thermal efficiency using the Brayton cycle. (AU Nov 2006)

12. Sketch the Diesel cycle on P-V and T-S diagrams and derive the expression for its mean effective pressure. (AU Nov 2008)

13. In an air standard dual cycle, the compression ratio of 20 and compression begins at 1bar and 60^oC. The maximum pressure is 90 bar. The heat transferred to air at constant pressure is equal to that at constant volume. Estimate: (i) the temperature at the cardinal points of the cycle, (ii) the cycle efficiency and (iii) the mean effective pressure.(AU May 2011)

14. Calculate the air standard efficiency of Brayton cycle operating between a pressure of 1bar and a final pressure of 10 bar. Take γ = 1.4. Derive the expression employed. (AU May 2011)

15. In an air standard Diesel cycle, the compression ratio is 16 and the beginning of isentropic compression the temperature is 15^oC and the pressure is 0.1 MPa. Heat is added until the temperature at the end of the constant pressure process is 1480^oC. Draw the P-V and T-s diagrams. Calculate the following: (i) the cut off ratio, (ii) Heat supplied per kg of air, (iii) the cycle efficiency. (AU May 2011)

UNIT – IV

PART – A

1. **State Newton's law of cooling. (AU May 2011)**

   $Q = hA (T_S - T_\infty)$

   Where, A – Area exposed to heat transfer in m^2

   h - Heat transfer co-efficient in W / m^2K

   T_S - Temperature of the surface in K

   T_∞ - Temperature of the fluid in K

2. **What are the modes of heat transfer? (AU May 2011)**
   1. Conduction
   2. Convection
   3. Radiation.

3. **Discuss the mechanism of heat conduction in solids.**

   Heat conduction is the mode of heat transfer in which energy exchanges takes place from a region of high temperature to that of low temperature by direct molecular interactions and by the drift of electrons.

   The thermal energy in the solids may be conducted by two mechanisms, migration of free electrons and lattice vibrations.

4. **What is heat conduction?**

   Heat conduction is a mechanism of heat transfer from a region of high temperature to a region of low temperature within a medium (solid, liquid or gases) or different medium in direct physical contact.

5. **A temperature difference of 500°C is applied across a fire clay brick 10cm thick having a thermal conductivity of 1.0 W/m.k. Find the heat transfer rate per unit area.**

6. **Write the general 3-D heat conduction equation in cylindrical co-ordinates. (AU May'05, June'06)**

$$\frac{\partial^2 T}{\partial r^2} + \frac{1}{r}\frac{\partial T}{\partial r} + \frac{1}{r^2}\frac{\partial^2 T}{\partial \emptyset^2} + \frac{\partial^2 T}{\partial z^2} + \frac{\dot{q}}{k} = \frac{1}{\propto}\frac{\partial T}{\partial \emptyset}$$

7. **Write down the three dimensional heat conduction equation in Cartesian co-ordinate system. (AU May'05, June'06)**

$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} + \frac{\dot{q}}{k} = \frac{1}{\propto}\frac{\partial T}{\partial t}$$

8. Define Biot number.

It is defined as the ratio of internal conductive resistance to the surface convective resistance.

$$B_i = \frac{Internal conductive resistance}{Surface convective resistance} = \frac{hL_c}{k}$$

9. What is Lumped Capacity analysis?

In a Newtonian heating or cooling process the temperature throughout the solid is considered to be uniform at a given time. Such an analysis is called Lumped heat capacity analysis.

10. What is the main advantage of parabolic fins?

Parabolic fins contain less material and are more efficient than the rectangular fin. Thus, the parabolic fins are more suitable for applications that require minimum weight such as space applications.

11. State the applications of fins.

1. Cooling of electronic components
2. Cooling of motor cycle engines
3. Cooling of transformers
4. Cooling of small capacity compressors.

12. Define Fin efficiency. (AU Dec'04, Dec'05, Dec'07)

The efficiency of a fin is defined as the ratio of actual heat transferred to the maximum possible heat transferred by the fin.

$$\eta_{fin} = \frac{Q_{fin}}{Q_{max}}$$

13. Define Fin effectiveness. (AU Dec'04, Dec'05, Dec'07)

Fin effectiveness is the ratio of heat transfer with fin to that without fin.

$$\text{Fin effectiveness} = \frac{Q_{with fin}}{Q_{without fin}}$$

14. Write note on Conduction with Internal Heat Generation. (AU May 2011)

15. Define heat transfer. (AU May 2011)

16. Whether closely packed thin fins or loosely packed thick fins are preferred – Justify.

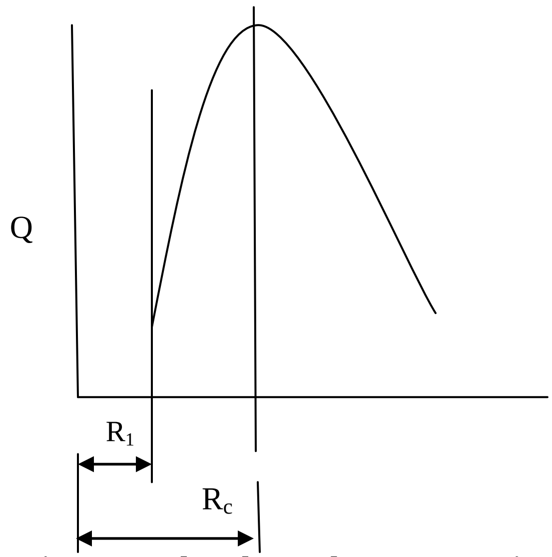
17. How does the heat transfer differ from that of thermodynamics?

18. Calculate the critical radius of insulation for asbestos (K=0.172W/mk) surroundings a pipe and exposed to room air at 300K with h = 2.8w/m^{2}c.

19. Define Coefficient of Thermal conductivity.

20. Define critical radius or critical thickness of insulation. (AU May'04, Dec'04)

Addition of insulating material on a surface does not reduce the amount of heat transfer rate always. Infact under certain circumstances it actually increases the heat loss upto certain thickness of insulation. The radius of insulation for which the heat transfer is maximum is called critical radius of insulation, and the corresponding thickness is called critical thickness.



Critical radius = R_c

Critical thickness = $R_c - R_1$

21. What is meant by thermal contact resistance? Upon what parameters does this resistance depend?(AU May 2012)

22. What are the physical assumptions necessary for a lumped-capacity unsteady state analysis to apply? (AU May 2012)

23. Mention the importance of Biot Number.

Biot number is used to find Lumped heat analysis, Semi infinite solids, and Infinite solids.

If $B_i < 0.1$ → Lumped heat analysis

$B_i = \infty$ → Semi infinite solids

$0.1 < Bi < 100$ → infinite solids

24. Write the Poisson's equation for heat conduction.

$$\nabla^2 T + \frac{q}{k} = 0$$

25. What is the physical significance of thermal diffusivity?

The physical significance of thermal diffusivity is that it tells us how fast heat is propagated or it diffuses through a material during changes of temperature with time.

26. Define convection.

Convection is a process of heat transfer that will occur between a solid surface and a fluid medium when they are at different temperatures. Convection is possible only in the presence of fluid medium.

27. State Fourier's law of conduction. (AU May'04, May'05, June'06, May'11)

The rate of heat conduction is proportional to area measured normal to the direction of heat flow and to the temperature gradient in that direction.

$$Q \ \alpha - A \frac{dT}{dx}$$

$$Q \ \alpha - KA \frac{dT}{dx}$$

Where, A – area in m^2

$\frac{dT}{dx}$ – Temperature gradient, K/m

K – Thermal conductivity, W/ mK

28. Define Radiation.

The heat transfer from one body to another without any transmitting medium is known as radiation. It is an electromagnetic wave phenomenon.

29. Define Thermal conductivity.

Thermal conductivity is defined as the ability of a substance to conduct heat.

30. What is meant by steady state heat conduction?

If the temperature of a body does not vary with time, it is said to be in a steady state and that type of conduction is known as steady state heat conduction.

31. What is meant by Transient heat conduction or unsteady state conduction?

If the temperature of a body varies with time, it is said to be in a transient state and that type of conduction is known as transient heat conduction or unsteady state conduction.

32. What is meant by Newtonian heating or cooling process?

The process in which the internal resistance is assumed as negligible in comparison with its surface resistance is known as Newtonian heating or cooling process.

33. What are Heisler charts? (AU May 2011)

In Heisler chart, the solutions for temperature distributions and heat flow in plane walls, long cylinders and spheres with finite internal and surface resistance are presented. Heisler charts are nothing but a analytical solutions in the form of graphs.

34. Explain the significance of Fourier number.

It is defined as the ratio of characteristic body dimension to temperature wave penetration depth in time.

It signifies the degree of penetration of heating or cooling effect of a solid.

PART – B

1. A steel tube of 5 cm ID, 7.6 cm OD and K = 15 W/m.k is covered with an insulation of thickness 2 cm and thermal conductivity, 0.2W/m.k. A hot gas at 330^oC and h = 400 W/m^2.k flows inside the tube. The outer surface of the insulation is exposed to cold air at

30^oC with h = 60 $W/m^2.k$. Assuming a tube length of 10 m, find the heat loss from the tube to the air. Also find, across which layer the largest temperature drop occurs.

2. Obtain an expression for the temperature profile of an infinitely long fin of uniform cross section from basic principles and hence calculate the heat transfer by fin.

3. A composite wall is formed of a 2.5 cm copper plate (k = 355 W/m.k), a 3.2 mm layer of asbestos (k = 0.110 W/m.k) and a 5 cm layer of fiber plate (k = 0.049 W/m.k). The wall is subjected to an overall temperature difference of 560^oC (560^oC on the Cu plate side and 0^oC on the fibre plate side). Estimate the heat flux through this composite wall and the interface temperature between asbestos and fiber plate.

4. When a thermocouple is moved from one medium to another medium at a different temperature, sufficient time must be given to the thermocouple to come to thermal equilibrium with the new conditions before a reading is taken. Consider a 0.1 cm diameter copper thermocouple wire originally at 150^oC. Find the temperature response (i.e. an approximate plot of temperature Vs time for intervals of 0, 40, and 120 seconds) When this wire is suddenly immersed in
   (i) Water at 40^oC (h = 80 $W/m^2.k$)
   (ii) Air at 40^oC (h = 40 $W/m^2.k$)

   Assume unit length of wire.

5. A reactor's wall 320 mm thick is made up of an inner layer of fire brick (k = 0.84 $W/m.^oC$) covered with a layer of insulation (k = 0.16 $W/m.^oC$). The reactor operates at a temperature of 1325^oC and the ambient temperature is 25^oC. Determine the thickness of the fire brick and insulation which gives minimum heat loss. Calculate the heat loss presuming that the insulating material has a maximum temperature of 1200^oC.

6. Derive an expression for the heat conduction through a hollow cylinder from the general heat conduction equation. Assume steady state unidirectional heat flow in radial direction and no internal heat generation.

7. A 25 mm diameter rod of 360 mm length connects two heat sources maintained at 127^oC and 227^oC respectively. The curved surface of the rod is losing heat to the surrounding air at 27^oC. The heat transfer coefficient is 10 $W/m^{2o}C$. Calculate the loss of heat from the rod if it is made of copper (k = 335$W/m.^oC$) and steel (k = 40 $W/m.^oC$).

8. A thermocouple junction is in the form of 8 mm diameter sphere. The properties of the material are C = 420 J/Kg ^oC, ρ = 8000 Kg/m^3, k = 40 $W/m.^oC$ and h = 40 $W/m.^oC$. The junction is initially at 40^oC and inserted in a stream of hot air at 300^oC. Find the time constant of the thermocouple. The thermocouple is taken out from the hot air after 10 seconds and kept in still air at 30^oC. Assuming the heat transfer coefficient in air of 10 $W/m.^oC$, find the temperature attained by the junction 20 seconds after removing from the hot air.

9. Derive the general one-dimensional differential equation of heat conduction in Cartesian coordinates and deduce it to Poisson and Laplace Equations.

10. The average heat produced by ripening Oranges is estimated as 300 W/m^2. Taking the average radius as 0.04 m with k = 0.15W/m.k, Calculate the temperature at the core when the surface temperature is 10^oC.

UNIT – V

PART – A

1. **What is the physical meaning of Fourier number?**
2. **Draw the velocity and temperature profiles for the free convection on a hot vertical plate.**
3. **Define Bulk temperature.**
4. **A vertical flat plate is maintained at a temperature lower than the surrounding fluid. Draw the velocity and temperature profiles assuming natural convection.**

5. **State Buckingham's π theorem.**
   It states that, "If there are n variables in a dimensionally homogenous equation and if these contain m fundamental dimensions, then the variables are arranged into (n-m) dimensionless terms. These dimensionless terms are called π terms.
6. **What is dimensional analysis?**
   It is a mathematical method which makes use of the study of the dimensions for solving several engineering problems. This method can be applied to all types of fluid resistance, heat flow problem in fluid mechanics and thermodynamics.
7. **What are the advantages of dimensional analysis?**
   (i) It expresses the functional relationship between the variables in dimensional terms.
   (ii) It enables getting up a theoretical solution in a simplified dimensionless form.
   (iii) The results of one series of tests can be applied to a large number of other similar problems with the help of dimensional analysis.
8. **Define Prandtl number and Grashoff number. (AU May 2011)**
   Prandtl Number: It is the ratio of the momentum diffusivity to the thermal diffusivity.

$$Pr = \frac{Momentumdif\ \ fusivity}{Thermaldiffusivity}$$

   Grashoff Number: It is defined as the ratio of product of inertia force and buoyancy force to the square of viscous force.

$$Gr = \frac{InertiaforceXBuoyancyforce}{(Viscousforce\ \ )^2}$$

9. **Define Reynolds number. (AU May 2011)**
   It is defined as the ratio of inertia force to viscous force.

$$Re = \frac{\text{Inertia force}}{\text{Viscous force}}$$

10. **Define Nusselt Number.**
   It is defined as the ratio of the heat flow by convection process under an unit temperature gradient to the heat flow rate by conduction under an unit temperature gradient through a stationary thickness of metre.

$$Nu = \frac{q_{convection}}{q_{conduction}}$$

11. Define Stanton number.

It is the ratio of Nusselt number to the product of Reynolds number and Prandtl number.

$$St = \frac{Nu}{Re \ X \ Pr}$$

12. Sketch the boundary layer for a vertical plate in case of free convection.

13. What is hydrodynamic boundary layer?

In hydrodynamic boundary layer, velocity of the fluid is less than 99% of free stream velocity.

14. What is thermal boundary layer?

In thermal boundary layer, temperature of the fluid is less than 99% of free stream temperature.

15. Define boundary layer thickness.

The boundary layer thickness is defined as the distance from the surface at which the local velocity or temperature reaches 99% of the external velocity or temperature.

16. What do you understand by free and forced convection? (AU May 2011)

Free Convection: If the fluid motion is produced due to change in density resulting from temperature gradients, the mode of heat transfer is said to be free or natural convection.

Forced Convection: If the fluid motion is artificially created by means of an external force like a blower or fan, that type of heat transfer is known as forced convection.

17. Mention the significance of boundary layer.

In the boundary layer concept the flow field over a body is divided into two regions:

- A thin region near the body called the boundary layer where the velocity and the temperature gradients are large.
- The region outside the boundary layer where the velocity and the temperature gradients are very nearly equal to their free steam values.

18. State the uses of dimensional analysis. (AU May 2011)

19. Distinguish between laminar and turbulent flow in a physical sense. (AU May 2012)

20. How is a modified Grashof number defined for a constant heat flux condition a vertical plate? (AU May 2012)

21.State Kirchhoff's law? (AU May 2010, Nov2007, May 2011)

This law states that the ratio of total emissive power to the absorptivity is constant for all surfaces which are in thermal equilibrium with the surroundings.

$$\frac{E_1}{\alpha_1} = \frac{E_2}{\alpha_2} = \frac{E_3}{\alpha_3}$$

It also states that the emissivity of the body is always equal to its absorptivity when the body remains in thermal equilibrium with its surroundings.

$$\alpha_1 = E_1 \ ; \quad \alpha_2 = E_2$$

22.Find the temperature of the sun assuming as a black body, if the intensity of radiation is maximum at the wave length of 0.5μ. (AU May 2010)

23.What is a radiation shield? (AU Nov 2009, May 2008)

Radiation shields constructed from low emissivity (high reflective) materials. It is used to reduce the net radiation transfer between two surfaces.

24.Define emissivity. (AU Nov 2009)

It is defined as the ability of the surface of a body to radiate heat.It is also defined as the ratio of emissive power of any body to the emissive power of a black body of equal temperature.

Emissivity, $\varepsilon = \frac{E}{E_b}$

25.What is a black body? (AU June 2009, May 2011)

Black body is an ideal surface having the following properties.

(i) A black body absorbs all incident radiation, regardless of wavelength and direction.
(ii) For a prescribed temperature and wave length, no surface can emit more energy than black body.

26.What does the view factor or shape factor represent? (AU June 2009)

It is defined as "The fraction of the radiative energy that is diffused from one surface element and strikes the other surface directly with no intervening reflections". The shape factor is used in the analysis of radiative heat exchange between two surfaces.

27.Assuming the sun to be a black body emitting radiation with maximum intensity at λ = 0.49µm, calculate the surface temperature of the sun. (AU Nov2008)

28.What is irradiation and radiosity? (AU Nov2008, AU May 2012)

Irradiation (G): It is defined as the total radiation incident upon a surface per unit time per unit area. It is expressed in W/m^2.

Radiosity (J): It is used to indicate the total radiation leaving a surface per unit time per unit area. It is expressed in W/m^2.

29.What is meant by grey body? (AU Dec 2005, June 2006, Nov2008, May 2011)

If a body absorbs a definite percentage of incident radiation irrespective of their wave length, the body is known as grey body. The emissive power of a grey body is always less than that of the black body.

30.State Planck's distribution law.

The relationship between the monochromatic emissive power of a black body and wave length of a radiation at a particular temperature is given by the following expression, by Planck.

$$E_{b\lambda} = \frac{C_1 \lambda^{-5}}{e^{\frac{C_2}{\lambda T}} - 1}$$

Where, $E_{b\lambda}$ – Monochromatic emissive power, W/m^2

λ - Wavelength – m

C_1 - 0.374 X 10^{-15} Wm^2

C_1 - 14.4 X 10^{-3}mk

31.Mention the physical significance of view factor. (AU May 2011)

32.State Wien's Displacement law. (AU May 2008, May 2011)

The Wien's law gives the relationship between temperature and wave length corresponding to the maximum spectral emissive power of the black body at that temperature.

$$\lambda_{max}T = C_3$$

where $C_3 = 2.9 \text{ X } 10^{-3}$mk

$$\lambda_{max}T = 2.9 \text{ X } 10^{-3}\text{mk}$$

33.What is Intensity of Radiation?

It is defined as the rate of energy leaving a space in a given direction per unit solid angle per unit area of the emitting surface normal to the mean direction in space.

$$I_n = \frac{E_b}{\pi}$$

34.Define Emissive power (E_b) of a black surface. (AU Dec 2005)

The emissive power is defined as the total amount of radiation emitted by a body per unit time and unit area. It is expressed in W/m^2.

35.What is Stefan's Bolts Mann law.(AU May 2012)

The emissive power of a black body is proportional to the fourth power of absolute temperature.

$$E_b \ \alpha \ T^4$$

$$E_b = \sigma T^4$$

Where E_b – Emissive power, W/m^2

σ - Stefan-Boltzmann constant = 5.67 X 10^{-8} W/m^2K^4

T – Temperature , K

36.Define monochromatic emissive power($E_{b\lambda}$)

The energy emitted by the surface at a given length per unit time per unit area in all directions is known as monochromatic emissive power.

37.What is meant by absorptivity? (AU Dec 2004)

Absorptivity is defined as the ratio between radiation absorbed and incident radiation.

Absorptivity, $\alpha = \frac{Radiation absorbed}{Incident radiation}$

38.What is meant by reflectivity? (AU Dec 2004)

Reflectivity is defined as the ratio of radiation reflected to the incident radiation.

Reflectivity, $\rho = \frac{Radiation reflected}{Incident radiation}$

39.What is meant by transmissivity?

Transmissivity is defined as the ratio of radiation transmitted to the incident radiation.

Transmissivity, $\tau = \frac{Radiation transmitted}{Incident radiation}$

PART – B

1. A sphere of diameter 25mm at 200^{o}C is immersed in air at 40^{o}C. Calculate the convective heat loss.

2. A steam pipe 20cm outside diameter runs horizontally in a room at 23^{o}C. Take the outside surface temperature of pipe as 165^{o}C. Determine the heat loss per meter length of the pipe.

3. Explain the thermal and velocity boundary layer for flow over a horizontal flat plate.

4. Engine oil (k = 0.14W/mk, v = 80 X 10^{-6}m/s) flows with a mean velocity of 0.2m/s inside a 1.25cm diameter tube which is electrically heated at the wall at a uniform rate of 2.45Kw/m^2. The heat transfer is taking place in the fully developed region. Calculate the temperature difference between the tube wall surface and the mean flow temperature.

5. Cylindrical cans of 150mm length and 65mm diameter are to be cooled from an initial temperature of 20^{o}C by exposing them to atmospheric air at a temperature of 1^{o}C and a pressure of 1 bar. Find the cooling rates when the cans are kept in (i) horizontal position, (ii) Vertical position.

6. Air at 400K and 1 atm pressure flows at a speed of 1.5m/s over a flat plate of 2m long. The plate is maintained at a uniform temperature of 300K. If the plate has a width of 0.5m, estimate the heat transfer coefficient and the rate of heat transfer from the air stream to the plate. Also estimate the drag force acting on the plate.

7. Air at 20^{o}C and at a pressure of 1 bar is flowing over a flat plate at a velocity of 3m/s. If the plate is 280mm wide and at 56^{o}C, calculate the following at x=280mm: (i) Boundary layer thickness, (ii) Local friction coefficient, (iii) Average friction coefficient, (iv) Thickness of the thermal boundary layer, (v) Local convective heat transfer coefficient, (vi) Average convective heat transfer coefficient, (vii) Rate of heat transfer by convection, (viii) Total drag force on the plate.

8. A cylindrical body of 300mm diameter and 1.6m height is maintained at a constant temperature of 36.5^{o}C. The surrounding temperature is 13.5^{o}C. Find the amount of heat generated by the body per hour if C_p= 0.96KJ/Kg^{o}C, ρ = 1.025 Kg/m^3, K = 0.0892W/m^{o}C, v = 15.06 X 10^{-6}m/s and β = 1/298 K^{-1}. Assume Nu = 0.12 (Gr.Pr)$^{1/3}$.

9. A nuclear reactor with its core constructed of parallel vertical plates 2.2m high and 1.4m wide has been designed on free convection heating of liquid bismuth. The maximum temperature of the plate surface is limited to 960^{o}C while the lowest allowable temperature of bismuth is 340^{o}C. Calculate the maximum possible heat dissipation from both sides of each plate. The properties of bismuth at film temperature are C_p= 150.7KJ/Kg^{o}C, ρ = 10000 Kg/m^3, K = 13.02W/m^{o}C, μ = 3.12 X 10^{-6} Kg/m.h. Assume Nu = 0.12 (Gr.Pr)$^{1/3}$.
10. Assuming that a man can be represented as a cylinder of 0.30m radius and height 1.7m with surface temperature of 30^{o}C, Calculate the heat he would lose while standing in a 36km/hour wind at 10^{o}C.

11. Air stream of 30^oC moves with a velocity of 0.3m/s across a 100W electric bulb at 130^oC. If the bulb is approximated by a 0.06m diameter sphere, estimate the rate and the percentage lost due to convection alone.

12. Air at 8 KN/m^2 and 242^oC flows over a flat plate of 0.3m wide and 1m long at a velocity of 8m/s. If the plate is maintained at a temperature of 78^oC, estimate the heat to be removed continuously from the plate.

13. A 0.30m long glass plate at 77^oC is hung vertically in air at 27^oC. Calculate the boundary layer thickness at the trailing edge and the average Nusselt number of the plate.

14. Derive an expression for hydrodynamic boundary layer thickness for flow over a flat plate. (AU May 2011)

15. A vertical tube of 50 mm outside diameter and 1.4 m long is exposed to steam at atmospheric pressure. The outer surface of the tube is maintained at a temperature of 40^oC by circulating cold water through the tube. Calculate: (i) the rate of heat transfer to the coolant and (ii) the rate of condensation of steam.

16. Air at 20^oC and 1 atm flows over a flat plate at 35 m/s. The plate is 75cm long and is maintained at 60^oC. Assuming unit depth in the z direction, calculate the heat transfer from the plate. (AU May 2012)

17. Air at 27^oC and 1 atm flows over a flat plate at a speed of 2 m/s. Calculate the boundary layer thickness at distances of 20 and 40 cm from the leading edge of the plate. Calculate the mass flow which enters the boundary layer between x = 20 cm and x = 40 cm. The viscosity of air at 27^oC is 1.98 X 10^{-5} kg/m.s. Assume unit depth in the z direction.

18.Derive the radiation exchange between (i) Large parallel gray surfaces and (ii) Small gray bodies. (AU May 2010)

19.Two large parallel plates of 1m X 1m spaced 0.5m apart in a very large room whose walls are at 27^oC. The plates are at 900^oC and 400^oC with emissivities 0.2 and 0.5 respectively. Find the net heat transfer to each plate and to the room. (AU May 2010)

20.Explain briefly the following: (i) Thermal radiation, (ii) Specular and diffuse reflection, (iii) Reciprocity rule and summation rule. (iv) Reflectivity and transmissivity (AU June 2009, May 2008)

21.A truncated cone has top and bottom diameters of 10 and 20cm and a height of 10cm. Estimate the shape factor between the top surface and the side and also the shape factor between the side and itself. (AU June 2009)

22.Discuss briefly the variation of black body emissive power with wavelength for different temperatures. (AU May 2008)

23.The spectral emissivity function of an opaque surface at 800K is approximated as

$$\varepsilon_\lambda = \begin{cases} \varepsilon_1 = 0.30 & 0 \le \lambda < 3\mu m \\ \varepsilon_2 = 0.80 & 3\mu m \le \lambda < 7\mu m \\ \varepsilon_3 = 0.10 & 7\mu m \le \lambda < \infty \end{cases}$$

Calculate the average emissivity of the surface and its emissive power. (AU May 2008)

24.Calculate the following for an industrial furnace in the form of a black body and emitting radiation at 2500^{o}C: (i) Monochromatic emissive power at 1.2μm length, (ii) Wavelength at which the emission is maximum, (iii) Maximum emissive power, (iv) Total emissive power, (v) Total emissive power of the furnace if it is assumed as a real surface with emissivity equal to 0.9. (AU Nov 2008)

25.Determine the radiant heat exchange in W/m^2 between two large parallel steel plates of emissivities 0.8 and 0.5 held at temperatures of 1000 K and 500K respectively, if a thin copper plate of emissivity 0.1 is introduced as a radiation shield between the two plates. (AU Nov 2008)

26.Two very large parallel plates with emissivities 0.6 exchange heat. Determine the percentage reduction in the heat transfer rate, if a polished aluminum radiation shield of ε = 0.04 is placed between the plates. (AU May 2011)