Thermodynamics

Contents

1. Basic Concepts

2. FIRST LAW OF THERMODYNAMICS

3. SECOND LAW OF THERMODYNAMICS

4. ENTROPY

5. AVAILABILITY, IRREVERSIBILITY

6. TdS RELATIONS, CLAPERYRON AND REAL GAS EQUATIONS

7. PURE SUBSTANCES

8. PROPERTIES OF GASSES AND GAS MIXTURE

VAPOUR POWER CYCLES

(With Power Plant)

GAS POWER CYCLE

(With IC Engine)

REFRIGERATION CYCLE

(With RAC)

PSYCHROMETRICS

(With RAC)

Basic Concepts

1. Which of the following are intensive properties? **[IES-2005]**

1. Kinetic Energy 2. Specific Enthalpy 3. Pressure 4. Entropy

Select the correct answer using the code given below:

(a) 1 and 3 (b) 2 and 3 (c) 1, 3 and 4 (d) 2 and 4

1. Ans. (b)

2. **[GATE-1998]**

List I	List II
(A) Heat to work	(1) Nozzle
(B) Heat to lift weight	(2) Endothermic chemical reaction
(C) Heat to strain energy	(3) Heat engine
(D) Heat to electromagnetic energy	(4) Hot air balloon/evaporation
	(5) Thermal radiation
	(6) Bimetallic strips

2. Ans. (A) -3, (B) -4, (C) -6, (D)-5

Thermodynamic System and Control Volume

3. Assertion (A): A thermodynamic system may be considered as a quantity of working substance with which interactions of heat and work are studied. **[IES-2000]**

Reason (R): Energy in the form of work and heat are mutually convertible.

3. Ans. (b)

4. Which one of the following is the extensive property of a thermodynamic system? **[IES-1999]**

(a) Volume (b) Pressure (c) Temperature (d) Density

4. Ans. (a) Extensive property is dependent on mass of system. Thus volume is extensive property.

5. The following are examples of some intensive and extensive properties:

1. Pressure 2. Temperature
3. Volume 4. Velocity
5. Electric charge 6. Magnetisation
7. Viscosity 8. Potential energy **[IAS-1995]**

Which one of the following sets gives the correct combination of intensive and extensive properties?

	Intensive	Extensive
(a)	1, 2, 3, 4	5, 6, 7, 8
(b)	1, 3, 5, 7	2, 4, 6, 8
(c)	1, 2, 4, 7	3, 5, 6, 8
(d)	2, 3, 6, 8	1, 4, 5, 7

5. Ans. (c)

Intensive properties, *i.e.* independent of mass are pressure, temperature, velocity and viscosity. Extensive properties, *i.e.* dependent on mass of system are volume, electric charge, magnetisation, and potential energy. Thus correct choice is *(c).*

Open and Closed systems

6. A closed thermodynamic system is one in which **[IES-1999]**

(a) there is no energy or mass transfer across the boundary

(b) there is no mass transfer, but energy transfer exists

(c) there is no energy transfer, but mass transfer exists
(d) both energy and mass transfer take place across the boundary, but the mass transfer is controlled by valves
6. Ans. (b) In closed thermodynamic system, there is no mass transfer but energy transfer exists.

7. Which of the following are intensive properties?
1. Kinetic energy   2. Thermal conductivity
3. Pressure   4. Entropy
Select the correct answer using the code given below:
(a) 1 and 2   (b) 2 and 3 only
(c) 2, 3 and 4   (d) 1, 3 and 4   **[IES 2007]**
7. Ans. (b)

8. Which of the following is/are reversible process (es)? **[IES-2005]**
1. Isentropic expansion   2. Slow heating of water from a hot source
3. Constant pressure heating of an ideal gas from a constant temperature source
4. Evaporation of a liquid at constant temperature
Select the correct answer using the code given below:
(a) 1 only   (b) 1 and 2   (c) 2 and 3   (d) 1 and 4
8. Ans. (b) Isentropic means reversible adiabatic.

9. Assertion (A): In thermodynamic analysis, the concept of reversibility is that, a reversible process is the most efficient process. **[IES-2001]**
Reason (R): The energy transfer as heat and work during the forward process is always identically equal to the energy transfer as heat and work during the reversal or the process.
9. Ans. (a)

10. An isolated thermodynamic system executes a process, choose the correct statement(s) form the following **[GATE-1999]**
(a) No heat is transferred   (b) No work is done
(c) No mass flows across the boundary of the system
(d) No chemical reaction takes place within the system
10. Ans. (a, b, c) For an isolated system no mass and energy transfer through the system.

$$\text{đ}Q = 0,\quad \text{đ}W = 0,\quad \therefore dE = 0 \quad \text{or} \quad E = \text{Constant}$$

Zeroth Law of Thermodynamics

11. Consider the following statements: **[IES-2003]**
1. Zeroth law of thermodynamics is related to temperature
2. Entropy is related to first law of thermodynamics
3. Internal energy of an ideal gas is a function of temperature and pressure
4. Van der Waals' equation is related to an ideal gas

Which of the above statements is/are correct?
(a) 1 only   (b) 2, 3 and 4   (c) 1 and 3   (d) 2 and 4
11. Ans. (d) Entropy - related to second law of thermodynamics.
Internal Energy (u) = f (T) only
Van der Wall's equation related to => real gas.

12. Two blocks which are at different states are brought into contact with each other and allowed to reach a final state of thermal equilibrium. The final temperature attained is specified by the

(a) Zeroth law of thermodynamics (b) First law of thermodynamics

(c) Second law of thermodynamics (d) Third law of thermodynamics **[IES-1998]**

12. Ans. (a)

13. Zeroth Law of thermodynamics states that **[IES-1996]**

(a) two thermodynamic systems are always in thermal equilibrium with each other.

(b) if two systems are in thermal equilibrium, then the third system will also be in thermal equilibrium

(c) two systems not in thermal equilibrium with a third system are also not in thermal equilibrium with

(d) When two systems are in thermal equilibrium with a third system, they are in thermal equilibrium

13. Ans. (d) Statement at (d) is correct definition of Zeroth law of thermodynamics

14. Match List-I with List-II and select the correct answer using the codes given below the lists: **[IAS-2004]**

List-I	List-II
A. Reversible cycle	1. Measurement of temperature
B. Mechanical work	2. Clapeyron equation
C. Zeroth Law	3. Clausius Theorem
D. Heat	4. High grade energy
	5. 3rd law of thermodynamics
	6. Inexact differential

Codes:	A	B	C	D		A	B	C	D
(a)	3	4	1	6	(b)	2	6	1	3
(c)	3	1	5	6	(d)	1	4	5	2

14. Ans. (a)

15. Match List I with List II and select the correct answer: **[IAS-2000]**

List I	List II
A. The entropy of a pure crystalline substance is zero at absolute zero temperature	1. First law of thermodynamics
B. Spontaneous processes occur in a certain direction	2. Second law of thermodynamics
C. If two bodies are in thermal equilibrium with a third body, then they are also in thermal equilibrium with each other	3. Third law of thermodynamics
D. The law of conservation of energy.	4. Zeroth law of thermodynamics

	A	B	C	D		A	B	C	D
(a)	2	3	4	1	(b)	3	2	1	4
(c)	3	2	4	1	(d)	2	3	1	4

15. Ans. (c)

International Temperature Scale

17. Which one of the following correctly defines 1 K, as per the internationally accepted definition of temperature scale? **[IES-2004]**
(a) 1/100th of the difference between normal boiling point and normal freezing point of water
(b) 1/273.15th of the normal freezing point of water
(c) 100 times the difference between the triple point of water and the normal freezing point of water
(d) 1/273.15th of the triple point of water
17. Ans. (d)

18. In a new temperature scale say $^o\rho$, the boiling and freezing points of water at one atmosphere are 100°ρ and 300°ρ respectively. Correlate this scale with the Centigrade scale. The reading of 0°ρ on the Centigrade scale is **[IES-2001]**
(a) 0°C (b) 50°C (c) 100°C (d) 150°C
18. Ans. (d)

20. Assertion (a): If an alcohol and a mercury thermometer read exactly 0^oC at the ice point and 100°C at the steam point and the distance between the two points is divided into 100 equal parts in both thermometers, the two thermometers will give exactly the same reading at 50°C.
Reason (R): Temperature scales are arbitrary. **[IES-1995]**
20. Ans. (a) Both A and R are correct and R is true explanation for A.

21. A new temperature scale in degrees N is to be defined. The boiling and freezing on this scale are 400^0N and 100^0N respectively. What will be the reading on new scale corresponding to 60^0C?
(a) 120^0N (b) 180^0N (c) 220^0N (d) 280^0N. **[IAS-1995]**
21. Ans. (d)

22. Match List I with II and select the correct answer using the code given below the

List I (Type of Thermometer)	List II (Thermometric Property)
A. Mercury-in-glass	1. Pressure
B. Thermocouple	2.Electrical resistant
C. Thermistor	3.Volume
D. Constant volume gas	4.Induced electric voltage

Code: **[IES 2007]**

	A	B	C	D		A	B	C	D
(a)	1	4	2	3	(b)	3	2	4	1
(c)	1	2	4	3	(d)	3	4	2	1

22. Ans. (d)

23. Pressure reaches a value of absolute zero **[IES-2002]**
(a) at a temperature of - 273 K (b) under vacuum condition
(c) at the earth's centre (d) when molecular momentum of system becomes zero
23. Ans. (d)

24. The time constant of a thermocouple is the time taken to attain:
(a) the final value to he measured (b) 50% of the value of the initial temperature difference
(c) 63.2% of the value of the initial temperature difference
(d) 98.8% of the value of the initial temperature difference **[IES-1997]**

24. Ans. (c) Time constant of a thermocouple is the time taken to attain 63.2% of the value of the initial temperature difference

Work a path function

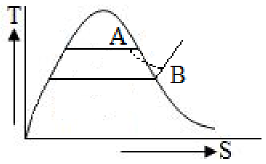
25. Assertion (A): Thermodynamic work is path-dependent except for an adiabatic process. **[IES-2005]**
Reason(R): It is always possible to take a system from a given initial state to any final state by performing adiabatic work only.
25. Ans. (c)

Free Expansion with Zero Work Transfer

26. In free expansion of a gas between two equilibrium states, the work transfer involved
(a) can be calculated by joining the two states on p-v coordinates by any path and estimating the area below **[IAS-2001]**
(b) can be calculated by joining the two states by a quasi-static path and then finding the area below
(c) is zero
(d) is equal to heat generated by friction during expansion.
26. Ans. (c)

27. Work done in a free expansion process is **[IAS-2002]**
(a) positive (b) negative (c) zero (d) maximum
27. Ans. (c) Since vacuum does not offer any resistance , there is no work transfer involved in free expansion.

28. In the temperature-entropy diagram of a vapour shown in the given figure, the thermodynamic process shown by the dotted line AB represents
(a) hyperbolic expansion(b) free expansion (c) constant volume expansion(d) polytropic expansion
[IAS-1995]



28. Ans. (b)

29. Match items in List-I (Process) with those in List-II (Characteristic) and select the correct answer using the codes given below the lists: **[IES-2001]**

List-I (Process)	List-II (Characteristic)
A. Throttling process	1. No work done
B. Isentropic process	2. No change in entropy
C. Free expansion	3. Constant internal energy
D. Isothermal process	4. Constant enthalpy

Codes:	A	B	C	D		A	B	C	D
(a)	4	2	1	3	(b)	1	2	4	3
(c)	4	3	1	2	(d)	1	3	4	2

29. Ans. (a)

30. A balloon containing an ideal gas is initially kept in an evacuated and insulated room. The balloon ruptures and the gas fills up the entire room. Which one of the following statements is TRUE at the end of above process? **[GATE-2008]**

(A) The internal energy of the gas decreases from its initial value, but the enthalpy remains constant (B) The internal energy of the gas increases from its initial value, but the enthalpy remains constant

(C) Both internal energy and enthalpy of the gas remain constant

(D) Both internal energy and enthalpy of the gas increase

30. Ans. (C) It is free expansion. Since vacuum does not offer any resistance, there is no work transfer involved in free expansion.

Here $\int_1^2 \text{đ}W=0$ and $Q_{1\text{-}2}=0$ therefore $Q_{1\text{-}2}=\Delta U+W_{1\text{-}2}$ so $\Delta U=0$

31. A free bar of length ‘l’ uniformly heated from 0°C to a temperature t° C. α is the coefficient of linear expansion and E is the modulus of elasticity. The stress in the bar is **[GATE-1995]**

(a) α tE (b) α tE/2 (c) zero (d) None of the above

31. Ans. (c) Ends are not constrained. It is a free expansion problem. Hence there is no stress in the member.

32. One kg of ice at 0^0C is completely melted into water at 0^0C at 1 bar pressure. The latent heat of fusion of water is 333 kJ/kg and the densities of water and ice at 0^0C are 999.0 kg/m^3 and 916.0 kg/ $m^{3,}$ respectively. What are the approximate values of the work done and energy transferred as heat for the process, respectively?

(a) -9.4 J and 333.0 kJ (b) 9.4 J and 333.0 kJ

(c) 333.o kJ and -9.4 J (d) None of the above **[IES 2007]**

32. Ans. (a) Work done (W) = P $\Delta V = 100\times(V_1\text{-}V_2) = 100\times\left(\frac{1}{\rho_1} - \frac{1}{\rho_2}\right)$

$$= 100\times\left(\frac{1}{999} - \frac{1}{916}\right) = \text{-}9.1\text{J}$$

33. Which one of the following is the correct sequence of the three processes A, B and C in the increasing order of the amount of work done by a gas following ideal-gas expansions by these processes?

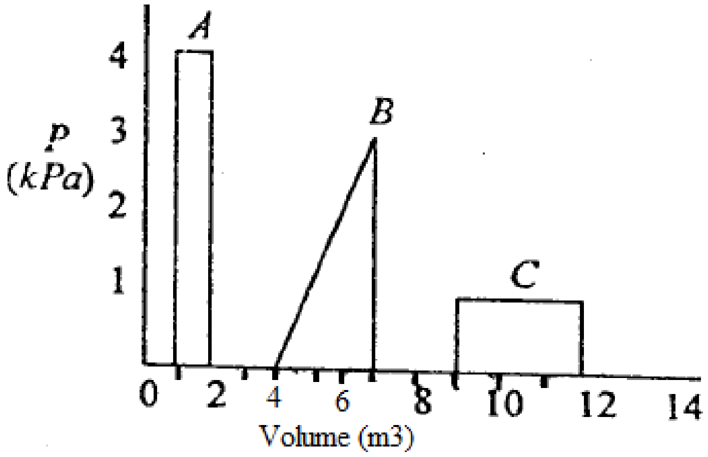
(a) A - B - C

(b) B - A – C

(c) A - C - B

(d) C - A – B

[IES-2006]



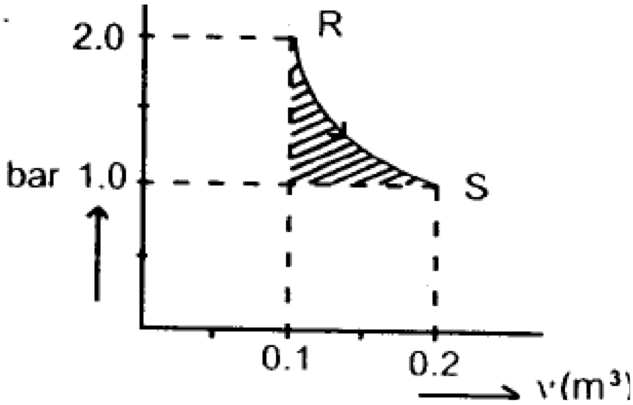
33. Ans. (d)

$$W_A = \int pdV = 4\times(2-1) = 4kJ$$

$$W_B = \int pdV = \frac{1}{2}\times 3\times(7-4) = 4.5kJ$$

$$W_C = \int pdV = 1\times(12-9) = 3kJ$$

34. An ideal gas undergoes an isothermal expansion from state R to state S in a turbine as shown in the diagram given below:
The area of shaded region is 1000 Nm. What is the amount is turbine work done during the process?
(a) 14,000 Nm (b) 12,000 Nm
(c) 11,000Nm
[IES-2004]



34. Ans. (c) Turbine work = area under curve R-S

$$= \int P dv$$
$$= 1\text{ bar} \times (0.2 - 0.1)\text{m}^3 + 1000\text{ Nm}$$
$$= 10^5 \times (0.2 - 0.1)\text{Nm} + 1000\text{Nm}$$
$$= 11000\text{Nm}$$

35. Identify the process for which the two integrals $\int pdv$ and - $\int vdp$ evaluated between any two given states give the same value **[IES-2003]**
(a) Isenthalpic (b) Isothermal (c) Isentropic (d) Polytropic
35. Ans. (b)

36. Assertion (A): The area 'under' curve on pv plane, $\int pdv$ represents the work of reversible non-flow process. **[IES-1992]**
Reason (R): The area 'under' the curve T-s plane $\int Tds$ represents heat of any reversible process.
36. Ans. (b)

37. If $\int pdv$ and $-\int vdp$ for a thermodynamic system of an ideal gas on valuation gives the same quantity (Positive/negative) during a process, then the process undergone by the system is
(a) isenthalpic (b) isentropic (c) isobaric (d) isothermal **[IAS-1997]**
37. Ans. (d)

38. For the expression $\int pdv$ to represent the work, which of the following conditions should apply?
(a) The system is closed one and process takes place in non-flow system
(b) The process is non-quasi static **[IAS-2002]**
(c) The boundary of the system should not move in order that work may be transferred
(d) If the system is open one, it should be non-reversible
38. Ans. (a)

39 Air is compressed adiabatically in a steady flow process with negligible change in potential and kinetic energy. The Work done in the process is given by
(a) -∫Pdv (b) +∫Pdv (c) -∫vdp (d) +∫vdp **[IAS-2000, GATE-1996]**

39. Ans. (c) For closed system W = $+\int pdv$, for steady flow W = $-\int vdp$

40 If ∫Pdv and -∫vdp for a thermodynamic system of an Ideal gas on valuation give same quantity (positive/negative) during a process, then the process undergone by the system is **[IES-2003, IAS-1997]**

(a) Isomeric (b) isentropic (c) isobaric (d) isothermal

40. Ans. (d) Isothermal work is minimum of any process.

41**.** Match list-I with List-II and select the correct answer using the codes given below the lists: **[IAS-2004]**

List-I	List-II
A. Bottle filling of gas	1. Absolute Zero Temperature
B. Nernst simon Statement	2. Variable flow
C. Joule Thomson Effect	3. Quasi-Static Path
D. ∫PdV	4. Isentropic Process
	5. Dissipative Effect
	6. Low grade energy
	7. Process and temperature during phase change.

Codes:	A	B	C	D
(a)	6	5	4	3
(b)	2	1	4	3
(c)	2	5	7	4
(d)	6	1	7	4

41. Ans. (b) Start with D. ∫PdV only valid for quasi-static path so choice (c) & (d) out. Automatically C-4 then eye on A and B. Bottle filling of gas is variable flow so A-2.

pdV-work or Displacement Work

42. Thermodynamic work is the product of **[IAS-1998]**
(a) two intensive properties
(b) two extensive properties
(c) an intensive property and change in an extensive property
(d) an extensive property and change in an intensive property

42. Ans. (c) W = $\int$pdv where pressure (p) is an intensive property and volume (v) is an extensive property

43. In a steady state steady flow process taking place in a device with a single inlet and a single outlet, the work done per unit mass flow rate is given by $w = -\int_{inlet}^{outlet} vdp$, where v is the specific volume and p is the pressure. The expression for w given above **[GATE-2008]**
(A) is valid only if the process is both reversible and adiabatic
(B) is valid only if the process is both reversible and isothermal
(C) is valid for any reversible process
(D) is incorrect; it must be $w = \int_{inlet}^{outlet} pdv$

43. (C)

44. A gas expands in a frictionless piston-cylinder arrangement. The expansion process is very slow,
and is resisted by an ambient pressure of 100 kPa. During the expansion process, the pressure of the system (gas) remains constant at 300 kPa. The change in volume of the gas is 0.0 l m^3. The maximum amount of work that could be utilized from the above process is **[GATE-2008]**

(A) 0kJ (B)1kJ (C) 2kJ (D) 3kJ

44. Ans. (C) $W=P.\Delta V = P_{gauge.}\Delta V = (300-200)\times 0.1$ kJ=2kJ

45. For reversible adiabatic compression in a steady flow process, the work transfer per unit mass is **[GATE-1996]**

$(a)\int pdv$ $(b)\int vdp$ $(c)\int Tds$ $(d)\int sdT$

45. Ans. (b) $W = -\int vdp$

Heat Transfer-A Path Function

46. Assertion (A): The change in heat and work cannot be expressed as difference between the end states.
Reason (R): Heat and work are both exact differentials. **[IES-1999]**

46. Ans. (c) A is true because change in heat and work are path functions and thus can't be expressed simply as difference between the end states. R is false because both work and heat are inexact differentials.

47. Match List I with List II and select the correct answer using the codes given below the lists: **[IAS-1999]**

List I (Parameter)	List II (Property)
A. Volume	1.Path function
B. Density	2. Intensive property
C. Pressure	3. Extensive property
D. Work	4. Point function

Codes:	A	B	C	D		A	B	C	D
(a)	3	2	4	1	(b)	3	2	1	4
(c)	2	3	4	1	(d)	2	3	1	4

47. Ans. (a)

2. FIRST LAW OF THERMODYNAMICS

First Law of Thermodynamics

30. Which one of the following sets of thermodynamic laws/relations is directly involved in determining the final properties during an adiabatic mixing process? **[IES-2000]**
(a) The first and second laws of thermodynamics
(b) The second law of thermodynamics and steady flow relations
(c) Perfect gas relationship and steady flow relations
(d) The first law of thermodynamics and perfect gas relationship
30. Ans. (d)

40. For a closed system, the difference between the heat added to the system and the work done by the system is equal to the change in **[IES-1992]**
(a) enthalpy (b) entropy (c) temperature (d) internal energy
40. Ans. (d)
From First law of thermodynamics, for a closed system the net wnergy transferred as heat Q and as work W is equal to the change in internal energy, U, *i.e.* Q - W = dU

15. The following four figures have been drawn to represent a fictitious thermodynamic cycle, on the p-v and T-s planes. **[GATE-2005]**

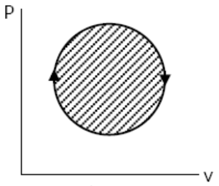


Figure 1

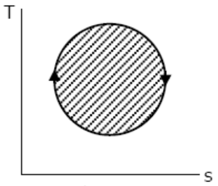


Figure 2

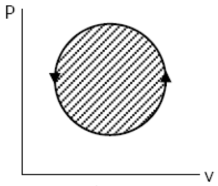
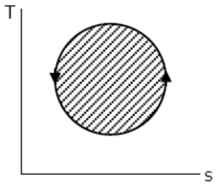


Figure 3



Figure

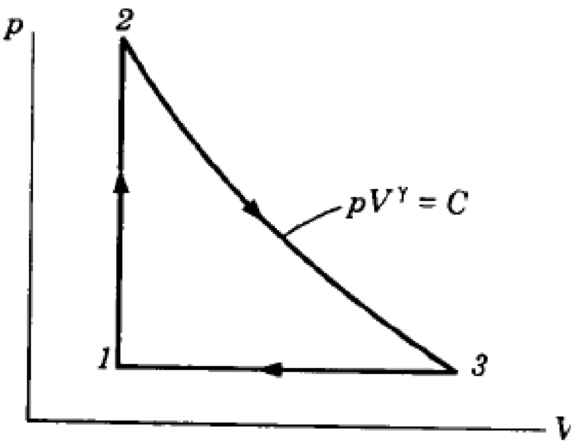
According to the first law of thermodynamics, equal areas are enclosed by
(a) figures 1and 2 b) figures 1and 3 c) figures 1and 4 d) figures 2 and 3
15. Ans. (a)
Fig-1 & 2 both are power cycle, so equal areas but fig-3 & 4 are reverse power cycle, so area is not meant something.

76. An ideal cycle is shown in the figure. Its thermal efficiency is given by

$$(a)1-\frac{\left(\frac{v_3}{v_1}-1\right)}{\left(\frac{p_2}{p_1}-1\right)} \qquad (b)\ 1-\frac{1}{\gamma}\frac{\left(\frac{v_3}{v_1}-1\right)}{\left(\frac{p_2}{p_1}-1\right)}$$

$$(c)1-\gamma\frac{(v_3-v_1)}{(p_2-p_1)}\frac{p_1}{v_1} \qquad (b)\ 1-\frac{1}{\gamma}\frac{(v_3-v_1)}{(p_2-p_1)}\frac{p_1}{v_1}$$

[IES



76. Ans. (b)

58. Which one of the following is correct?
The cyclic integral of $(\delta Q-\delta W)$ for a process is

(a) positive (b) negative
(c) Zero (d) unpredictable **[IES 2007]**

Ans. (c) It is du = đQ – đW, as u is a thermodynamic property and its cyclic integral must be zero.

71. A closed system undergoes a process 1-2 for which the values of $Q_{1\text{-}2}$ and $W_{1\text{-}2}$ are +20 kJ and +50 kJ, respectively. If the system is returned to state, 1, and $Q_{2\text{-}1}$ is -10 kJ, what is the value of the work $W_{2\text{-}1}$? **[IES-2005]**

(a) + 20 kJ (b) -40 kJ (c) - 80 kJ (d) + 40 kJ

71. Ans. (b) $\Sigma \text{đ}Q = \Sigma \text{đ}W$ or $Q_{1-2} + Q_{2-1} = W_{1-2} + W_{2-1}$

or $20 + (-10) = 50 + W_{2-1}$ or $W_{2-1} = -40\,\text{kJ}$

75. A gas is compressed in a cylinder by a movable piston to a volume one-half of its original volume. During the process, 300 kJ heat left the gas and the internal energy remained same. What is the work done on the gas? **[IES-2005]**

(a) 100kNm (b) 150 kNm (c) 200 kNm (d) 300 kNm

75. Ans. (d) $\text{đ}Q = du + \text{đ}w$ as $u = \text{const.}$

Therefore du = 0 or $\text{đ}Q = \text{đ}w = 300\,\text{kNm}$

33. In a steady-flow adiabatic turbine, the changes in the internal energy, enthalpy, kinetic energy and potential energy of the working fluid, from inlet to exit, are -100 kJ/kg, -140 kJ/kg, -10 kJ/kg and 0 kJ/kg respectively. Which one of the following gives the amount of work developed by the turbine? **[IES-2004]**

(a) 100 kJ/kg (b) 110 kJ/kg (c) 140 kJ/kg (d) 150 kJ/kg

33. Ans. (d)

$$Q - W_x = \Delta\left(h + \frac{V^2}{2} + gz\right)$$

$$O - W_x = -140 - 10 + 0$$

$$\text{or } W_x = 150\ \text{kJ/kg}$$

Change of internal energy = -100 kJ/kg is superfluous data.

67. Gas contained in a closed system consisting of piston cylinder arrangement is expanded. Work done by the gas during expansion is 50 kJ. Decrease in internal energy of the gas during expansion is 80 kJ. Heat transfer during the process is equal to **[IES-2003]**

(a) -20 kJ (b) +20 kJ (c) -80 kJ (d) +80 kJ

67. Ans. (b) Q = ΔE+ΔW

ΔE = - 30 kJ (decrease in internal energy)

ΔW = + 50 kJ (work done by the system)

Q = - 30 + 50 = + 20 kJ

16. A system while undergoing a cycle **[IES-2001]**

A - B - C - D - A has the values of heat and work transfers as given in the table:

Process	kJ/min	kJ/min
A-B	+687	+474

B-C	-269	0
C-D	-199	-180
D-A	+75	-0

The power developed in kW is, nearly,

(a) 4.9 (b) 24.5 (c) 49 (d) 98

16. Ans. (a)

57. A tank containing air is stirred by a paddle wheel. The work input to the paddle wheel is 9000 kJ and the heat transferred to the surroundings from the tank is 3000 kJ. The external work done by the system is **[IES-1999]**

(a) zero (b) 3000 kJ (c) 6000 kJ (d) 9000 kJ

57. Ans. (c)

74. The values of heat transfer and work transfer for four processes of a thermodynamic cycle are given below: **[IES-1994]**

Process	Heat Transfer (kJ)	Work Transfer (kJ)
1	300	300
2	Zero	250
3	-100	-100
4	zero	-250

The thermal efficiency and work ratio for the cycle will be respectively.

(a) 33% and 0.66 (b) 66% and 0.36. (c) 36% and 0.66 (d) 33% and 0.36.

74. Ans. (b) $\eta_{th} = \frac{\text{Work done}}{\text{heat added}} = \frac{300-100}{300} = 0.66$

$$\text{Work ratio} = \frac{\sum(+w)-\sum(-w)}{\sum(+w)} = \frac{550-350}{550} = 0.36$$

71. A system executes a cycle during which there are four heat transfers: Q_{12} = 220 kJ, Q_{23} = -25kJ, Q_{34} = -180 kJ, Q_{41} = 50 kJ. The work during three of the processes is W_{12} = 5kJ, W_{23} = -10 kJ, W_{34} = 60kJ. The work during the process 4 -1 is

(a) - 230 kJ (b) 0 kJ (c) 230 kJ (d) 130 kJ **[IAS-2003]**

71. (*b*)

Explanation : $\oint W = \oint Q$

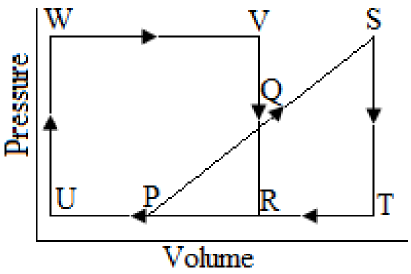
$\therefore \quad 15 - 10 + 60 + W_{4-1} = 220 - 25 - 180 + 50$

$\therefore \quad W_{4-1} = 0$

78. Two ideal heat engine cycles are represented in the given figure. Assume VQ = QR, PQ = QS and UP =PR =RT. If the work interaction for the rectangular cycle (WVUR) is 48 Nm, then the work interaction for the other cycle PST is

(a) 12Nm (b) 18 Nm

(c) 24 Nm (d) 36 Nm **[IAS-2001]**



78. Ans. (c) Area under p-v diagram is represent work.

$$\text{Areas } \Delta \text{PTS} = \frac{1}{2} \text{ Area} \,\square\, (\text{WVUR}) \quad \therefore \text{Work PTS} = \frac{1}{2} \times 48 = 24 \text{ Nm}$$

12. A system undergoes a change of state during which 80 kJ of heat is transferred to it and it does 60 kJ of work. The system is brought back to its original state through a process during which 100 kJ of heat is transferred to it. The work done by the system is **[IAS-1998]**

(a) 40 kJ (b) 60 kJ (c) 120 kJ (d) 180 kJ

12. Ans. (c)

$$Q_{1-2} = \Delta E_{1-2} + W_{1-2} \quad \text{or} \quad 80 = \Delta E_{1-2} + 60 \;\text{ or }\; \Delta E_{1-2} = 20\text{kJ}$$
$$Q_{2-1} = \Delta E_{2-1} + W_{2-1} \quad \text{or} \quad 100 = -20 + W_{2-1} \;\text{ or }\; W_{2-1} = 120\text{kJ}$$

14. A reversible heat engine operating between hot and cold reservoirs delivers a work output of 54 kJ while it rejects a heat of 66 kJ. The efficiency of this engine is

(a) 0.45 (b) 0.66 (c) 0.75 (d) 0.82 **[IAS-1998]**

14. Ans. (a) $\eta = \dfrac{\text{work output}}{\text{Heat input}} = \dfrac{\text{work out put}}{\text{work output} + \text{heat rejection}} = \dfrac{54}{54+66} = 0.45$

24. If a heat engine gives an output of 3 kW when the input is 10,000 J/s, then the thermal efficiency of the engine will be **[IAS-1995]**

(a) 20% (b) 30% (c) 70% (d) 76.7%

24. Ans. (b)

$$\text{Thermal efficiency} = \frac{W}{Q} = \frac{3 \times 10^3 \text{ watts}}{10.000 \text{ J/s}} = 0.3 = 30\%.$$

88. In an adiabatic process, 5000J of work is performed on a system. The system returns to its original state while 1000J of heat is added. The work done during the non-adiabatic process is

(a) + 4000J (b) - 4000J (c) + 6000J (d) - 6000J **[IAS-1997]**

88. Ans. (b)

$$Q_{1-2} = \Delta E_{1-2} + W_{1-2}$$
$$\text{or } 0 = \Delta E_{1-2} + (-5000) \quad \text{or } (\Delta E)_{1-2} = 5000\,\text{J}$$
$$Q_{2-1} = (\Delta E)_{2-1} + W_{2-1} \quad \text{or } \; W_{2-1} = Q_{2-1} - (\Delta E)_{2-1} = 1000 - 5000 = -4000\,\text{J}$$

26. In a thermodynamic cycle consisting of four processes, the heat and work are as follows:

Q: + 30, - 10, -20, + 5

W: + 3, 10, - 8, 0

The thermal efficiency of the cycle will be **[IAS-1996]**

(a) Zero (b) 7.15% (c) 14.33% (d) 28.6%

26. Ans. (c) Net work output = 3 + 10 – 8 = 5 unit and Heat added = 30 + 5 = 35 unit

$$\text{Therefore efficiency, } \eta = \frac{5}{35} \times 100\% = 14.33\%$$

27. Match List I (Devices) with List II (Thermodynamic equations) and select the correct answer using the codes below the lists: **[IAS-1996]**

	List I	List II
A.	Turbine	1. $W = h_2 - h_1$
B.	Nozzle	2. $h_1 = h_2$
C.	Valve	3. $h_1 = h_2 + V^2/2$
D.	Compressor	4. $W = h_1 - h_2$

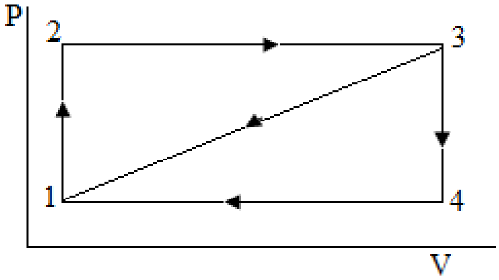
Codes:

	A	B	C	D		A	B	C	D
(a)	4	3	2	1	(b)	2	3	1	4
(c)	4	3	1	2	(d)	3	2	4	1

27. Ans. (a)

37. Given that the path 1-2-3, a system absorbs 100kJ as heat and does 60kJ work while along the path 1-4-3 it does 20kJ work (see figure given). The heat absorbed during the cycle 1-4-3 is **[IAS 1994]**

(a) - 140 kJ (b) - 80 kJ (c) - 40kJ (d) + 60 kJ

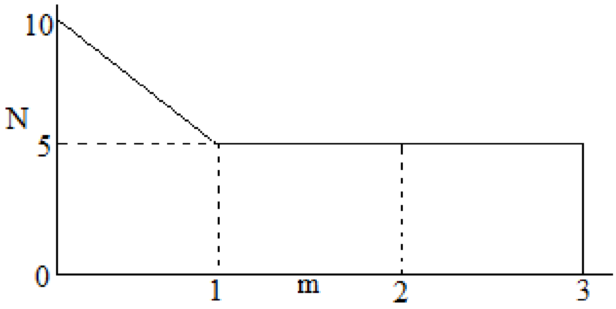


Ans. (d) $Q_{123} = U_{13} + W_{123}$ or, $100 = U_{13} + 60$ or, $U_{13} = 40$ kJ

And $Q_{143} = U_{13} + W_{143} = 40+20 = 60$ kJ

40. The given figure shows the variation of force in an elementary system which undergoes a process during which the plunger position changes from 0 to 3 m. If the internal energy of the system at the end of the process is 2.5 J higher, then the heat absorbed during the process is **[IAS 1994]**

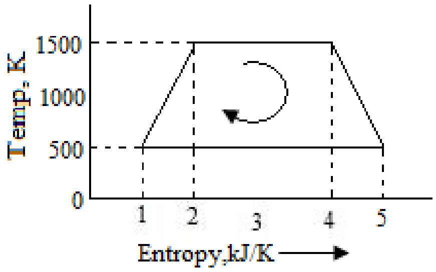
(a) 15 J (b) 20 J (c) 25 J (d) 30 J



Ans. (b) Total work = $5 \times 3 + \frac{1}{2} \times 5 \times 1 = 17.5J$ or $\delta W = du + \delta W = 2.5 + 17.5 = 20J$

45. The efficiency of a reversible cyclic process undergone by a substance as shown in the given diagram is

(a) 0.40 (b) 0.55 (c) 0.60 (d) 0.80 **[IAS 1994]**



Ans. (c)Efficiency = $\dfrac{Area \quad under \quad 500 \quad and \quad 1500}{Area \quad under \quad 0 \quad and \quad 1500} = \dfrac{\frac{1}{2} \times \{(5-1) + (4-2)\} \times (1500-500)}{\frac{1}{2} \times \{(5-1) + (4-2)\} \times (1500-500) + (5-1) \times 500} = \dfrac{3000}{5000} = 0.6$

Internal Energy--A Property of System

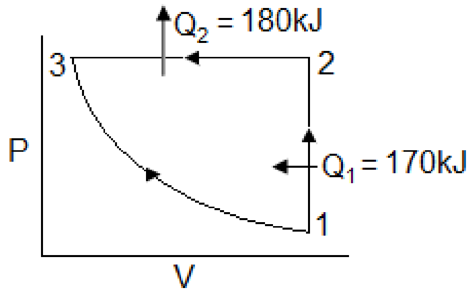
60. For a simple closed system of constant composition, the difference between the net heat and work interactions is identifiable as the change in **[IES-2003]**
(a) Enthalpy (b) Entropy (c) Flow energy (d) Internal energy
60. Ans. (d)

61. Assertion (A): The internal energy depends on the internal state of a body, as determined by its temperature, pressure and composition. **[IES-2006]**
Reason (R): Internal energy of a substance does not include any energy that it may possess as a result of its macroscopic position or movement.
61. Ans. (a)

69. Change in internal energy in a reversible process occurring in a closed system is equal to the heat transferred if the process occurs at constant: **[IES-2005]**
(a) Pressure (b) Volume (c) Temperature (d) Enthalpy
69. Ans. (b) $\text{đ}Q = dU + pdV \quad \text{if V is constant} \quad (\text{đ}Q)_v = (dU)_v$

35. 170 kJ of heat is supplied to a system at constant volume. Then the system rejects 180 kJ of heat at constant pressure and 40 kJ of work is done on it. The system is finally brought to its original state by adiabatic process. If the initial value of internal energy is 100 kJ, then which one of the following statements is correct? **[IES-2004]**
(a) The highest value of internal energy occurs at the end of the constant volume process
(b) The highest value of internal energy occurs at the end of constant pressure process.
(c) The highest value of internal energy occurs after adiabatic expansion
(d) Internal energy is equal at all points

35. Ans. (a)



$$Q_2 = 180\,kJ = \Delta u + \Delta W = \Delta u + (-40)$$
$$\therefore U_1 = 100\,kJ, \; U_2 = 100 + 170 = 270\text{ kJ},$$
$$U_3 = 270 - 180 + 40 = 130\text{ kJ}$$

40. A system undergoes a process during which the heat transfer to the system per degree increase in temperature is given by the equation: **[IES-2004]**
dQ/dT = 20 kJ/°C The work done by the system per degree increase in temperature is given by the equation
dW/dT = 2 – 0.1 T, where T is in °C. If during the process, the temperature of water varies from 100°C to 150°C, what will be the change in internal energy?

(a) 125 kJ (b) -250 kJ (c) 625 kJ (d) -1250 kJ

40. Ans. (c)

$$dQ = du + dw$$

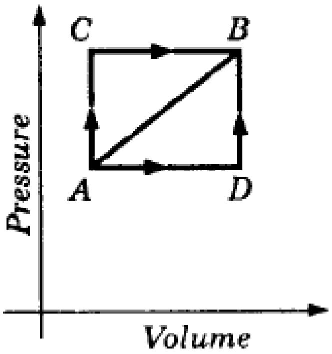
$$2.dt = du + (2 - 0.1T)dT$$

$$\text{or } \int du = \int 0.1TdT = \frac{0.1}{2} \times \left[T^2\right]_{100}^{150} = \frac{0.1}{2}\left[150^2 - 100^2\right] = 625\text{kJ}$$

29. When a system is taken from state A to state B along the path A-C-B, 180 kJ of heat flows into the system and it does 130 kJ of work (see figure given) :
How much heat will flow into the system along the path A-D-B if the work done by it along the path is 40 kJ?

(a) 40 kJ (b) 60 kJ
(c) 90 kJ (d) 135 kJ

[IES-1997]



29. Ans. (c) Change of internal energy from A to B along path ACB = 180 - 130 = 50 kJ. It will be same even along path ADB. :. Heat flow along ADB = 40 + 50 = 90 kJ

71. The heat transfer, Q, the work done W and the change in internal energy U are all zero in the case of **[IES-1996]**

(a) a rigid vessel containing steam at 150°C left in the atmosphere which is at 25^{o}C
(b) 1 kg of gas contained in an insulated cylinder expanding as the piston moves slowly outwards.
(c) a rigid vessel containing ammonia gas connected through a valve to an evacuated rigid vessel, the vessel, the valve and the connecting pipes being well insulated and the valve being opened and after a time, conditions through the two vessels becoming uniform.
(d) 1 kg of air flowing adiabatically from the atmosphere into a previously evacuated bottle

71. Ans. (c) In example of (c), heat transfer, work done, and change in internal energy are all zero.

45. The internal energy of a certain system is a function of temperature alone and is given by the formula E = 25 + 0.25t kJ. If this system executes a process for which the work done by it per degree temperature increase is 0.75 kN-m, the heat interaction per degree temperature increase, in kJ, is **[IES-1995]**

(a) -1.00 (b) -0.50 (c) 0.50 (d) 1.00.

45. Ans. (d) dQ = du +dw = 0.25 + 0.75 = 1.00 kJ

36. When a gas is heated at constant pressure, the percentage of the energy supplied, which goes as the internal energy of the gas is **[IES-1992]**

(a) more for a diatomic gas than for triatomic gas
(b) same for monatomic, diatomic and triatomic gases but less than 100%
(c) 100% for all gases (d) less for triatomic gas than for a diatomic gas

36. Ans. (a)

77. Which one of the following is the correct expression for change in the internal energy for a small temperature change ΔT for an ideal gas? **[IAS-2007]**

(a) $\Delta U = C_v \times \Delta T$ (b) $\Delta U = C_p \times \Delta T$

(c) $\Delta U = \frac{C_p}{C_v} \times \Delta T$ (d) $\Delta U = \left(C_p - C_v\right) \times \Delta T$

77. Ans. (a)

110. The heat transferred in a thermodynamic cycle of a system consisting of four processes is successively 0, 8, 6 and - 4 units. The net change in the internal energy of the system will be **[IAS-1999]**

(a) - 8 (b) zero (c) 10 (d) -10

110. Ans. (b) Internal energy is a property of a system so $\oint du = 0$

112. During a process with heat and work interactions, the internal energy of a system increases by 30 kJ. The amounts of heat and work interactions are respectively

(a) - 50 kJ and - 80 kJ (b) -50 kJ and 80 kJ **[IAS-1999]**

(c) 50 kJ and 80 kJ (d) 50 kJ and - 80 kJ

112. Ans. (a) $\cancel{d}Q = du + \cancel{d}W$ if $du = +30\,kJ$ then $\cancel{d}Q = -50\,kJ$ and $\cancel{d}W = -80\,kJ$

35. A mixture of gases expands from 0.03 m^3 to 0.06 m^3 at a constant pressure of 1 MPa and absorbs 84 kJ of heat during the process. The change in internal energy of the mixture is **[IAS 1994]**

(a) 30 kJ (c) 84 kJ (b) 54 kJ (d) 114 kJ

Ans. (b) $\delta W = du + \delta W = du + pdV$

Or $84x10^3J = du + 1x10^6x(0.06-0.03) = du + 30$ kJ or du = 83 – 30 = 54 kJ

20. A gas contained in a cylinder is compressed, the work required for compression being 5000 kJ. During the process, heat interaction of 2000 kJ causes the surroundings to the heated. The change in internal energy of the gas during the process is **[GATE-2004]**

(a) - 7000 kJ (b) - 3000 kJ (c) + 3000 kJ (d) + 7000 kJ

20. Ans. (c)

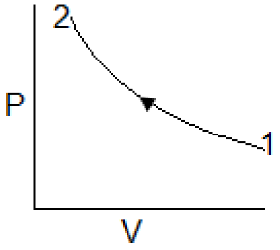
$\cancel{d}Q = du + \cancel{d}w$

$Q = u_2 - u_1 + W$ or $-2000 = u_2 - u_1 - 5000$ or $u_2 - u_1 = 3000\,kJ$

50. In an adiabatic process 6000 J of work is performed on a system. In the non-adiabatic process by which the system returns to its original state 1000J of heat is added to the system. What is the work done during non-adiabatic process? **[IAS-2004]**

(a) + 7000 J (b) - 7000 J (c) + 5000 J (d) - 5000 J

50. Ans. (a) $Q_{1-2} = U_2 - U_1 + W_{1-2}$



Perpetual Motion Machine of the First Kind-PMM1

32. Consider the following statements: **[IES-2000]**

1. The first law of thermodynamics is a law of conservation of energy.
2. Perpetual motion machine of the first kind converts energy into equivalent work.
3. A closed system does not exchange work or energy with its surroundings.
4. The second law of thermodynamics stipulates the law of conservation of energy and entropy.

Which of the statements are correct?

(a) 1 and 3 (b) 2 and 4 (c) 2, 3 and 4 (d) 1, 2 and 3

32. Ans. (d)

Enthalpy

41. The fundamental unit of enthalpy is **[IAS 1994]**

(a) MLT^{-2} (b) $ML^{-2}T^{-1}$ (c) $ML^{2}T^{-2}$ (d) $ML^{3}T^{-2}$

Ans. (c)

64. Assertion (A): If the enthalpy of a closed system decreases by 25 kJ while the system receives 30 kJ of energy by heat transfer, the work done by the system is 55 kJ. **[IES-2001]**

Reason (R): The first law energy balance for a closed system is (notations have their usual meaning) $\Delta E = Q - W$

64. Ans. (a)

Application of First Law to Steady Flow Process S.F.E.E

74. Which one of the following is the steady flow energy equation for a boiler?

(a) $h_1 + \frac{v_1^2}{2gJ} = h_2 + \frac{v_2^2}{2gJ}$ (b) $Q = (h_2 - h_1)$ **[IES-2005]**

(c) $h_1 + \frac{v_1^2}{2gJ} + Q = h_2 + \frac{v_2^2}{2gJ}$ (d) $W_s = (h_2 - h_1) + Q$

74. Ans. (b) $h_1 + \frac{v_1^2}{2} + gz_1 + \frac{\text{đ}Q}{dm} = h_2 + \frac{v_2^2}{2} + gz_2 + \frac{\text{đ}w}{dm} = 0$

For boiler v_1, v_2 is negligible and $z_1 = z_2$ and $\frac{\text{đ}w}{dm} = 0$

$$\text{or } \frac{\text{đ}Q}{dm} = (h_2 - h_1)$$

90. In a test of a water-jacketed compressor, the shaft work required is 90 kN-m/kg of air compressed. During compression, increase in enthalpy of air is 30 kJ/kg of air and increase in enthalpy of circulating cooling water is 40 kJ/ kg of air. The change is velocity is negligible. The amount of heat lost to the atmosphere from the compressor per kg of air is **[IAS-2000]**

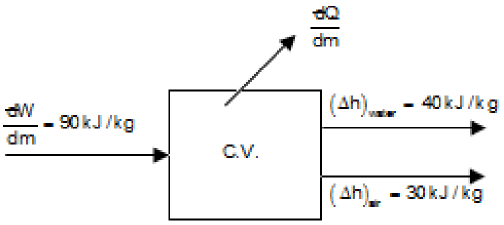
(a) 20kJ (b) 60kJ (c) 80 kJ (d) 120kJ

90. Ans. (a)

Energy balance gives as

$$\frac{\text{đ}W}{dm} = (\Delta h)_{air} + (\Delta h)_{water} + \frac{\text{đ}Q}{dm}$$

$$\text{or } \frac{\text{đ}Q}{dm} = 90 - 30 - 40 = 20\,\text{kJ/kg of air compressed.}$$



92. When air is compressed, the enthalpy is increased from 100 to 200 kJ/kg. Heat lost during this compression is 50 kJ/kg. Neglecting kinetic and potential energies, the power required for a mass flow of 2 kg/s of air through the compressor will be **[IAS-1997]**

(a) 300 kW (b) 200 kW (c) 100 kW (d) 50 kW

92. Ans. (a)

$$m(h_1)+\frac{\text{đ}Q}{dt}=m(h_2)+\frac{\text{đ}w}{dt}$$

$$\text{or } \frac{\text{đ}w}{dt}=m(h_1-h_2)+\frac{\text{đ}Q}{dt}=2\times(100-200)-50\times 2=-300\,\text{kW}$$

i.e. 300 kW work have to given to the system.

Variable Flow Processes

80. Match List-I with List-II and select the correct answer using the codes given below Lists: **[IAS-2004]**

List-I	List-II
A. Bottle filling of gas	1. Absolute zero temperature
B. Nernst Simon statement	2. Variable flow
C. Joule Thomson effect	3. Quasistatic path
D. $\int pdv$	4. Isenthalpic process
	5. Dissipative effect
	6. Low grade energy
	7. Process and temperature during phase change

Codes:	A	B	C	D		A	B	C	D
(a)	6	5	4	3	(b)	2	1	4	3
(c)	2	5	7	4	(d)	6	1	7	4

80. Ans. (b)

93. A gas chamber is divided into two parts by means of a partition wall. On one side, nitrogen gas at 2 bar pressure and 20°C is present. On the other side, nitrogen gas at 3.5 bar pressure and 35°C is present. The chamber is rigid and thermally insulated from the surroundings. Now, if the partition is removed,

(a) high pressure nitrogen will get throttled **[IAS-1997]**
(b) mechanical work, will be done at the expense of internal energy
(c) work will be done on low pressure nitrogen
(d) internal energy of nitrogen will be conserved

93. Ans. (a)

Discharging and Charging a Tank

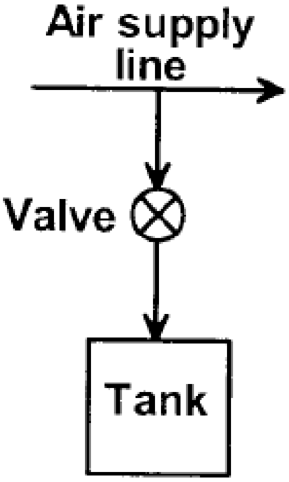
An insulated tank initially contains 0.25 kg of a gas with an internal energy of 200 kJ/kg .Additional gas with an internal energy of 300 kJ/kg and an enthalpy of 400 kJ/kg enters the tank until the total mass of gas contained is 1 kg. What is the final internal energy(in kJ/kg) of the gas in the tank?

(a) 250 (b) 275 **[IES 2007]**
(c) 350 (d) None of the above

Ans. (c) Enthalpy of additional gas will be converted to internal energy.

$U_f = m_i u_i + (m_f - m_i)h = 0.25 \times 200 + (1-0.25) \times 400 = 350$ kJ As total mass = 1kg, $u_f = 350$ kJ/kg

49. A rigid, insulated tank is initially evacuated. The tank is connected with a supply line through which air (assumed to be ideal gas with constant specific heats) passes at I MPa, 350^0 C. A valve connected with the supply line is opened and the tank is charged with air until the final pressure inside the tank reaches I MPa. The final temperature inside the tank **[GATE-2008]**



(A) is greater than 350^0C (B) is less than 350^0C
(C) is equal to 350°C (D) may be greater than, less than, or equal to 350°C, depending on the volume of the tank

49. Ans (A) The final Temp. $(T_2) = \gamma T_1$

3. SECOND LAW OF THERMODYNAMICS

59. Which one of the following is correct on basis of the second law of Thermodynamics?
(a) For any spontaneous process, the entropy of the universe increases
(b) $\Delta S = q_{rev}/T$ at constant temperature
(c) Efficiency of the Starling cycle is more than that of a Carnot cycle
(d) $\Delta E = q + w$
(The symbols have their usual meaning) **[IES 2007]**

Ans. (a)

37. Assertion (A): Second law of thermodynamics is called the law of degradation of energy. **[IES-1999]**
Reason (R): Energy does not degrade each time it flows through a finite temperature difference.
37. Ans. (b) Both A and R are true but R does not give correct reasoning for A.

1. Heat transfer takes place according to **[IES-1996]**
(a) Zeroth Law of Thermodynamics (b) First Law of Thermodynamics
(c) Second Law of Thermodynamics (d) Third Law of Thermodynamics.
1. Ans. (c) Heat transfer takes place according to second law of thermodynamics as it tells about the direction and amount of heat flow that is possible between two reservoirs.

79. Which of the following statements are associated with second law of thermodynamics?
(a) When a system executes a cyclic process, net work transfer is equal to net heat transfer.
(b) It is impossible to construct an engine, that operating in a cycle will produce no other effect than the extraction of heat from a reservoir and performance of an equivalent amount of work.
(c) It is impossible by any procedure, no matter how idealized, to reduce any system to the absolute zero of temperature in a finite number of operations.
(d) It is impossible to construct a device that operating in a cycle will produce no effect other than transfer of heat from a cooler to hotter body. **[IAS-2001]**
Select the correct answer using the codes given below:
Codes: (a) 1, 2 and 4 (b) 2 and 4 (c) 2, 3 and 4 (d) 2 and 3
79. Ans. (b)

1.10 A system undergoes a state change from 1 to 2. According the second law of thermodynamics for the process to be feasible, the entropy change, $S_2 - S_1$ of the system **[GATE-1997]**
(a) is positive or zero (b) is negative or zero (c) is zero (d) can be positive, negative or zero
1.10 Ans. (d) $(\Delta S)_{\text{isolated system}}$ can never decrease but it is only a process.

Qualitative Difference between Heat and Work

Kelvin-Planck Statement of Second Law

63. Assertion (A): No machine would continuously supply work without expenditure of some other form of energy. **[IAS-2001]**

Reason (R): Energy can be neither created nor destroyed, but it can only be transformed from one form into another.

63. Ans. (a)

42. Consider the following statements:

The definition of

1. temperature is due to Zeroth Law of Thermodynamics. **[IES-1993]**
2. entropy is due to First Law of Thermodynamics.
3. internal energy is due to Second Law of Thermodynamics.
4. reversibility is due to Kelvin-Planck's statement.

Of these statements

(a) 1,2 and 3 are correct
(b) 1, 3 and 4 are correct
(c) 1 alone is correct
(d) 2 alone is correct

42. Ans. (c) Out of 4 definitions given, only first definition is correct and balance three are wrong.

Clausius' Statement of the Second Law

36. Assertion (A): Heat cannot spontaneously pass from a colder system to a hotter system without simultaneously producing other effects in the surroundings. **[IES-1999]**

Reason (R): External work must be put into heat pump so that heat can be transferred from a cold to a hot body.

36. Ans. (a) A and R are true. A is the Clausius statement of second law of thermodynamics. Spontaneously means without change in surroundings. Statement at R provides the correct reasoning for A, i.e. the work must be done by surroundings on the system for heat to flow from lower temperature to higher temperature.

Clausius' Theorem

120. A steam power plant is shown in figure,

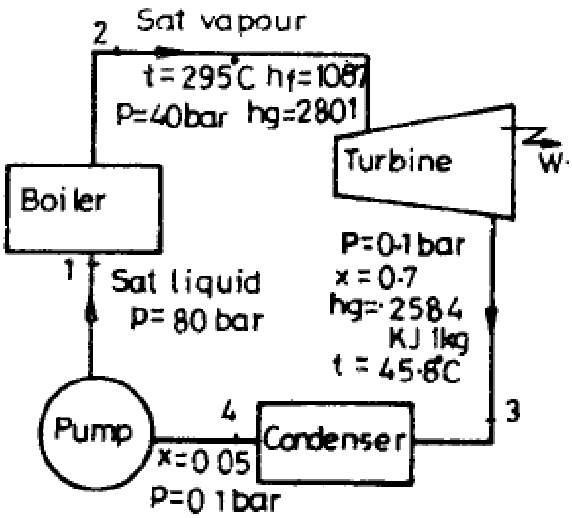
(a) the cycle violates first and second laws of thermodynamics.

(b) the cycle does not satisfy the condition of Clausius inequality.

(c) the cycle only violates the second laws of thermodynamics

(d) the cycle satisfies the Clausius inequality.

[IES



120. Ans. (d)

Refrigerator and Heat Pump **[with RAC]**

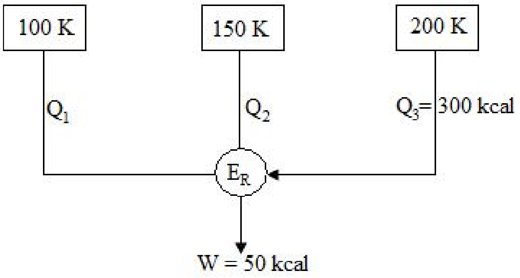
Equivalence of Kelvin-Planck and Clausius Statements

81. Assertion (A): Efficiency of a reversible engine operating between temperature limits T_1 and T_2 is maximum. **[IES-2002]**
Reason (R): Efficiency of a reversible engine is greater than that of an irreversible engine.
81. Ans. (b)

25. A heat engine is supplied with 250 KJ/s of heat at a constant fixed temperature of 227^0C. The heat is rejected at 27^0C. The cycle is reversible, if the amount of heat rejected is **[IAS-1995]**
(a) 273 KJ/s (b) 200 KJ/s (c) 180 KJ/s (d) 150 KJ/s.

25. Ans. (d) $\frac{Q_1}{T_1} = \frac{Q_2}{T_2}$

29. A reversible engine En as shown in the given figure draws 300 kcal from 200 K reservoir and does 50 kcal of work during a cycle. The sum of heat interactions
with the other two reservoir is given by
(a)$Q_1 + Q_2 = + 250$ kcal
(b) $Q_1 + Q_2 = - 250$ kcal
(c) $Q_1 + Q_2 = + 350$ kcal
(d)$Q_1 + Q_2 = - 350$ kcal **[IAS-1996]**



29. Ans. (a) $Q_1 + Q_2 = 300 – 50 = 250$ Kcal

Carnot Engine with same efficiency or same work output

30. A reversible engine operates between temperatures T_1, and T_2, The energy rejected by this engine is received by a second reversible engine at temperature T_2 and rejected to a reservoir at temperature T_3. If the efficiencies of the engines are same then the relationship between T_1, T_2 and T_3 is given by **[IES-2002]**

(a) $T_2 = \frac{(T_1 + T_3)}{2}$ (b) $T_2 = \sqrt{(T_1^2 + T_3^2)}$ (c) $T_2 = \sqrt{T_1 T_3}$ (d) $T_2 = \frac{(T_1 + 2T_3)}{2}$

30. Ans. (c)

63. A reversible engine operates between temperatures 900 K & T_2 ($T_2 < 900$ K), & another reversible engine between T_2 & 400 K ($T_2 > 400$ K) in series. What is the value of T_2 if work outputs of both the engines are equal? **[IES-2005]**
(a) 600 K (b) 625 K (c) 650 K (d) 675 K
63. Ans. (c) Figure from another question

$W_1 = W_2$

or $Q_1 - Q_2 = Q_2 - Q_3$ or $T_1 - T_2 = T_2 - T_3$ or $T_2 = \frac{T_1 + T_3}{2} = \frac{900 + 400}{2} = 650\text{K}$

38. Two reversible engine operate between thermal reservoirs at 1200 K, T_2K and 300 K such that 1st engine receives heat from 1200 K reservoir and rejects heat to thermal reservoir at T_2K, while the 2nd engine receives heat from thermal reservoir at T_2K and rejects heat to the thermal reservoir at 300 K. The efficiency of both the engines is equal

What is the value of temperature T_2? **[IES-2004]**

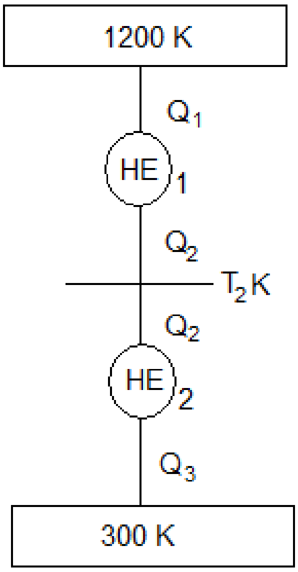
(a) 400 K (b) 500 K (c) 600 K (d) 700 K

38. Ans. (a)

$$\eta_1 = \eta_2$$

$$\text{or } 1 - \frac{T_2}{1200} = 1 - \frac{300}{T_2}$$

$$\text{or } T_2 = \sqrt{1200 \times 300} = 600\text{K}$$



29. Consider the following statements:

1. Amount of work from cascaded Carnot engines corresponding to fixed temperature difference falls as one goes to lower absolute level of temperature.
2. On the enthalpy-entropy diagram, constant pressure lines diverge as the entropy increases. **[IAS-2007]**

Which of the statements given above is/are correct?

(a) 1 only (b) 2 only (c) Both 1 and 2 (d) Neither 1 nor 2

29. Ans. (b) For reversible cycle

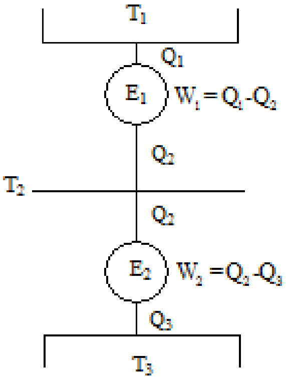
$$\frac{T_1}{Q_1} = \frac{T_2}{Q_2} = \frac{T_3}{T_3}$$

$$or \ \frac{T_1 - T_2}{T_2} = \frac{Q_1 - Q_2}{Q_2}$$

$$or \ T_1 - T_2 = (Q_1 - Q_2) \times \frac{T_2}{Q_2}$$

$$similarly \quad T_2 - T_3 = (Q_2 - Q_3) \times \frac{T_3}{Q_3}$$

$$if \ T_1 - T_2 = T_2 - T_3 \ then \ Q_1 - Q_2 = Q_2 - Q_3 \quad or \quad W_1 = W_2$$



47. One reversible heat engine operates between 1600 K and T_2 K, and another reversible heat engine operates between T_2K and 400 K. If both the engines have the same heat input and output, then the temperature T_2 must be equal to **[IES-1993]**

(a) 1000 (b) 1200 (c) 1400 (d) 800

47. Ans. (d) Two reversible heat engines operate between limits of

1600K and T_2 ; T_2 and 400K

Both have the same heat input and output,

i.e. $\frac{T_1 - T_2}{T_1}$ is same for both or $\frac{1600 - T_2}{1600} = \frac{T_2 - 400}{T_2}$ $or\, T_2 = 800\, K$

38. In a cyclic heat engine operating between a source temperature of 600°C and a sink temperature of 20°C, the least rate of heat rejection per kW net output of the engine is **[IAS 1994]**

(a) 0.460 kW (c) 0.588 kW (b) 0.505 kW (d) 0.650 kW

Ans. (b) Reversible engine has maximum efficiency where $\frac{Q_1}{T_1} = \frac{Q_2}{T_2} = \frac{Q_1 - Q_2}{T_1 - T_2} = \frac{W}{T_1 - T_2}$

Therefore least heat rejection per kW net output, $Q_2 = \frac{W}{T_1 - T_2} \times T_2 = \frac{1}{873 - 293} \times 293 = 0.505 kW$

4. ENTROPY

Two Reversible Adiabatic Paths cannot Intersect Each Other

76. Which one of the following is the correct statement? **[IAS-2007]**

Two adiabatic will

(a) intersect at absolute zero temperature (b) never intersect

(c) become orthogonal at absolute zero temperature

(d) become parallel at absolute zero temperature

76. Ans. (b)

The Property of Entropy

54. Assigning the basic dimensions to mass, length, time and temperature respectively as M, L, T and θ (Temperature), what are the dimensions of entropy?

(a) $M L T^{-2} \theta$ (b) $M L^2 T^{-1} \theta^{-1}$

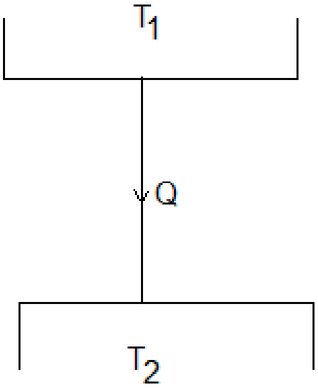
(c) $M L^2 T^{-2} \theta^{-1}$ (d) $M L^3 T^{-2} \theta^{-1}$ **[IES 2007]**

Ans. (c)

54. Heat flows between two reservoirs having temperatures 1000 K and 500 K, respectively. If the entropy change of the cold reservoir is 10 kJ/K, then what is the entropy change for the hot reservoir? **[IAS-2004]**

(a) - 10 kJ/K (b) - 5 kJ/K (c) 5 kJ/K (d) 10 kJ/K

54. Ans. (b)



$$\Delta S_2 = \frac{+Q}{500} = 10$$

$$or\ Q = 5000\,kJ$$

$$\Delta S_1 = \frac{-Q}{1000} = \frac{-5000}{1000} = -5kJ/k$$

$$\begin{bmatrix} \therefore \text{Heat added to the system is +ive} \\ \text{Heat rejected from the system is -ive} \end{bmatrix}$$

Temperature-Entropy Plot

32. A system comprising of a pure substance executes reversibly a cycle 1 -2 -3 -4 - 1 consisting of two isentropic and two isochoric processes as shown in the Fig. 1.

[IES-2002]

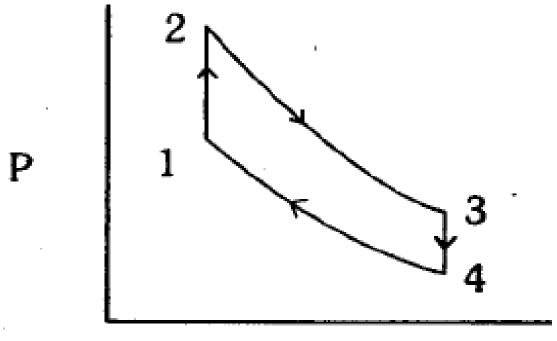
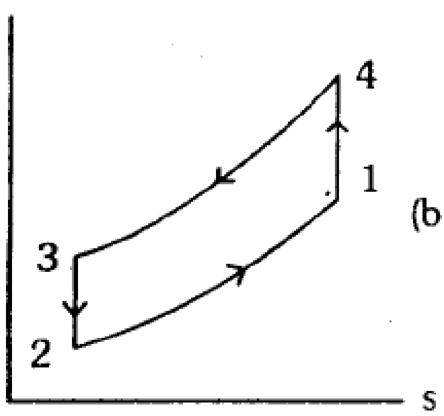


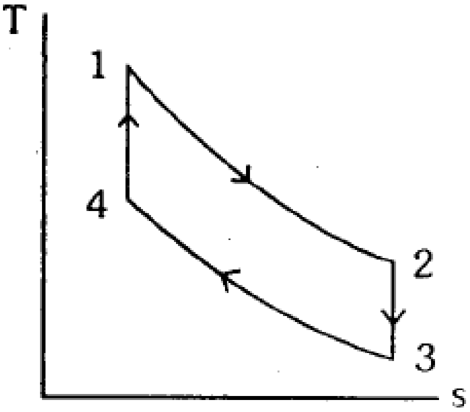
Fig. 1

Which one of the following is the correct representation of this cycle on the temperature - entropy coordinates?

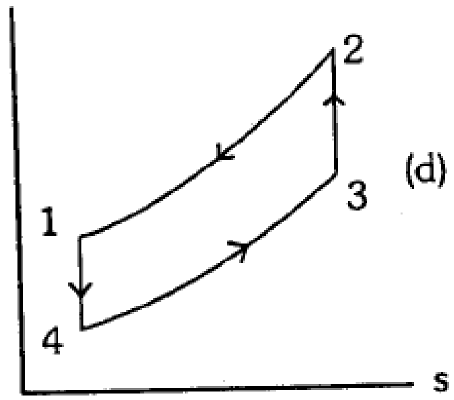
a)



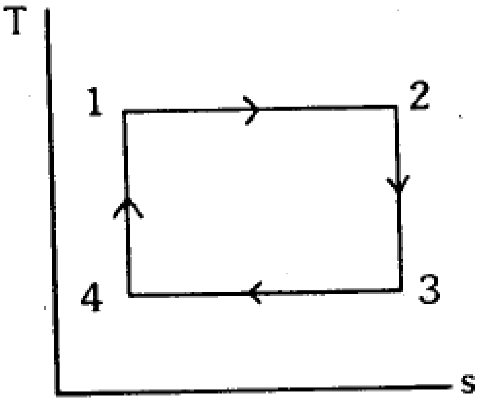
(b)



(c)



(d)



32. Ans. (c)

51. A cycle of pressure – volume diagram is shown in the given figure-I, Same cycle on temperature-entropy diagram will be represented by

[IES-1

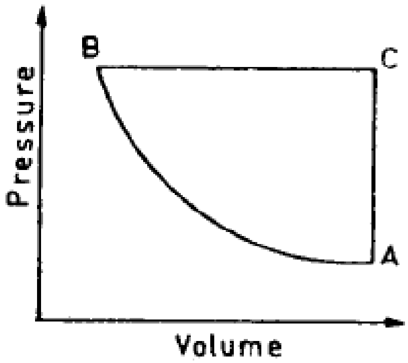
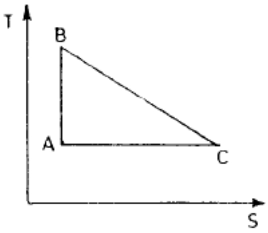
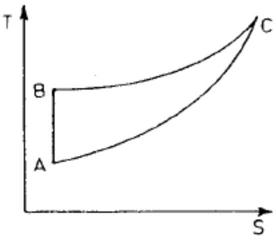


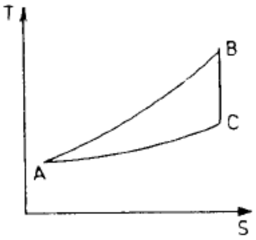
Fig. 1.



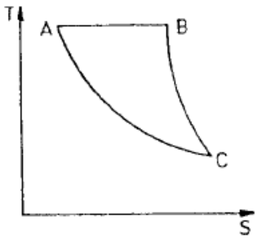
(a)



(b)



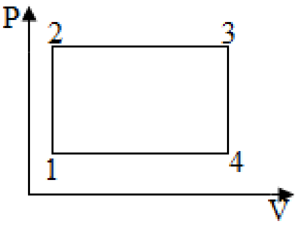
(c)



(d)

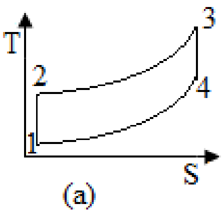
51. Ans. (d) Figure at (d) matches with given process on P-V plane.

96. An ideal cycle is shown in the given pressure-volume diagram:

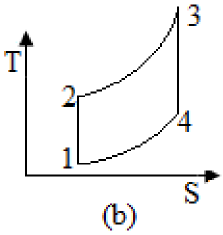


[IAS-1997]

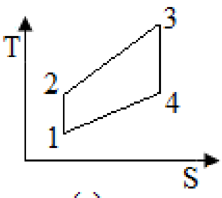
The same cycle on temperature-entropy diagram will be represented as



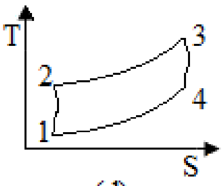
(a)



(b)



(c)

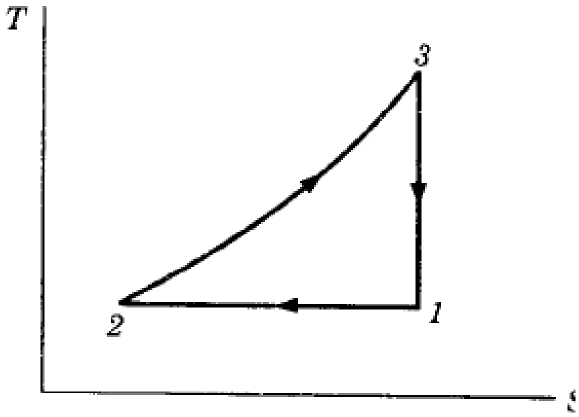


(d)

96. Ans. (d)

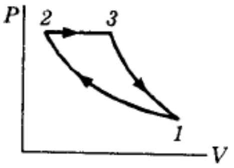
36. An ideal air standard cycle is shown in the given temperature-entropy diagram.

[IE

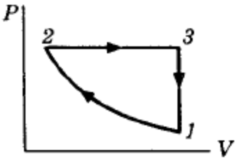


The same cycle, when represented on the pressure-volume coordinates takes the form

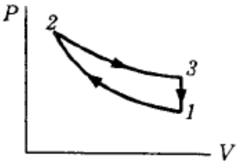
(*a*)



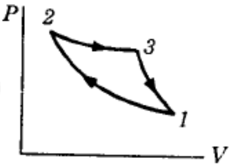
(*b*)



(*c*)



(*d*)



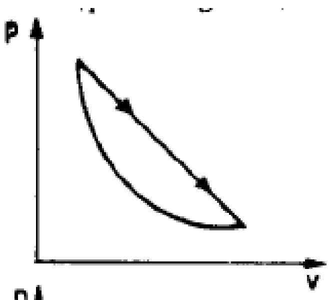
36. Ans. (a)

80. Match figures of Column I with those given in Column II and select given below the columns:

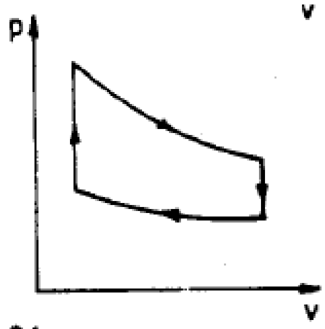
Column I (p-v diagram) Column II (T-s diagram)

[IES-1994]

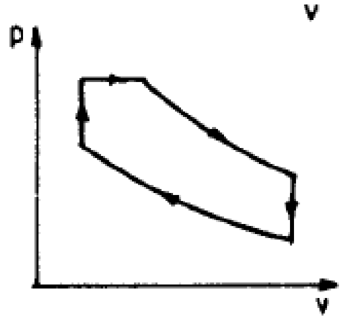
A.



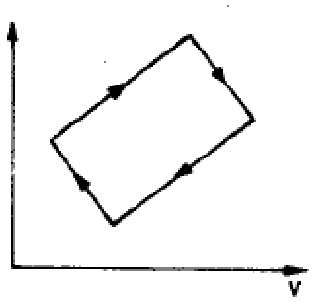
B.



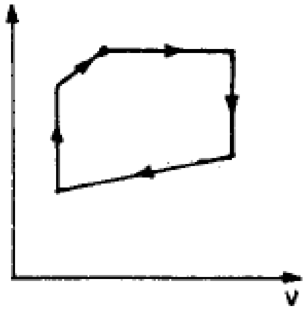
C.



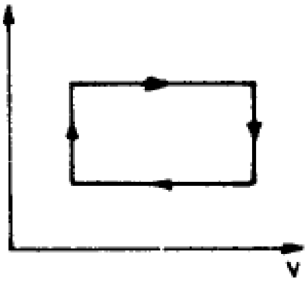
1.



2.



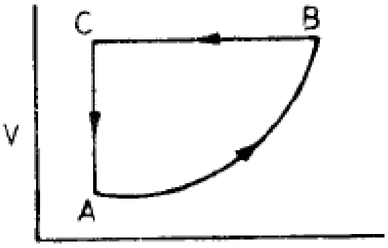
3.



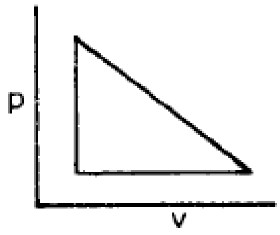
Codes:	A	B	C		A	B	C
(a)	1	2	3	(b)	2	3	1
(c)	3	1	2	(d)	3	2	1

80. Ans. (c)

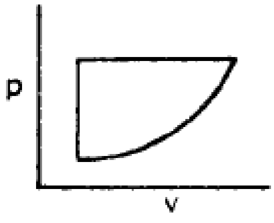
48. A cyclic process ABCD shown in the V-T diagram performed with a constant mass of an ideal gas. The process of p-V diagram will be as shown in **[IES-1992]**



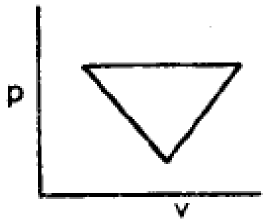
(a)



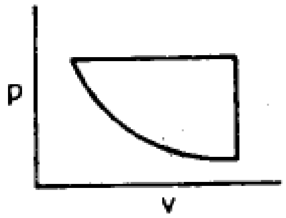
(c)



(b)

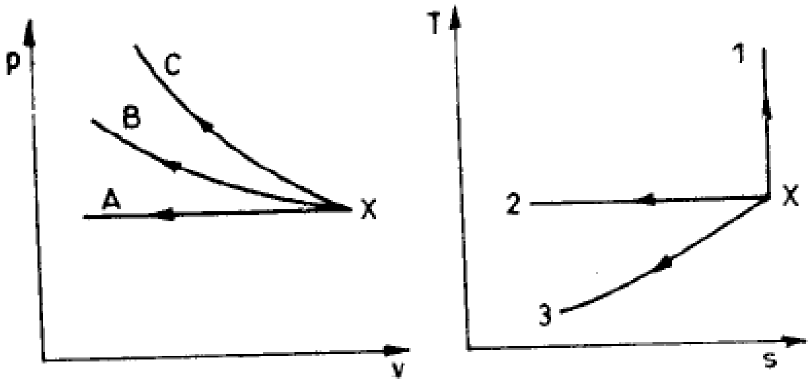


(d)



48. Ans. (d)

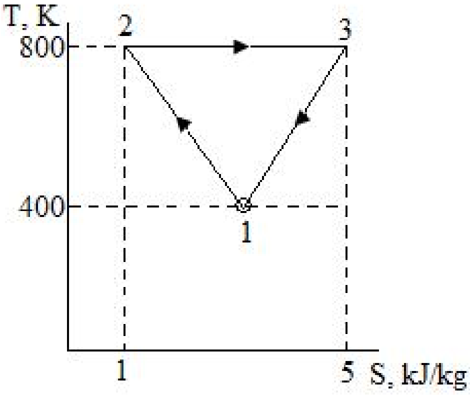
71. Three processes are represented on the p-v and T-s diagrams in the following figures. Match processes in the two diagrams and select the correct answer using the codes given below the diagrams: **[IES-1994]**



Codes:	A	B	C		A	B	C
(a)	1	2	3	(b)	2	3	1
(c)	3	2	1	(d)	1	3	2

71. Ans. (c)

93. The thermal efficiency of the hypothetical heat engine cycle shown in the given figure is



(a) 0.5
(b) 0.45
(c) 0.35
(d) 0.25
[IAS-2000]

93. Ans. (d) $\eta = \frac{\text{Work done}}{\text{Heat added}} = \frac{\text{area } 1-2-3}{\text{area under curve } 2-3} = \frac{\frac{1}{2}\times(5-1)\times(800-400)}{(5-1)\times 800} = 0.25$

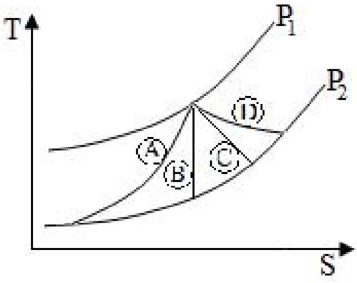
65. Which one of the following pairs best expresses a relationship similar to that expressed in the pair 'pressure-volume' for a thermodynamic system undergoing a process? **[IAS-1995]**

(a) Enthalpy-entropy (b) Pressure-enthalpy (c) Pressure-temperature (d)Temperature-entropy
65. Ans. (d)

109. An ideal gas contained in a rigid tank is cooled such that $T_2 < $ and $P_2 < P_1$ In the given temperature entropy diagram, this process path is represented by the line labeled.

(a) A
(b) B
(c) C
(d) D

[IAS-1999]

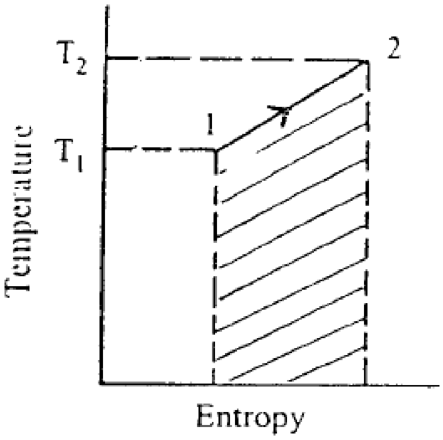


109. Ans. (a)

54. Assertion (A): If a graph is plotted for absolute temperature as a function of entropy, the area under the curve would give the amount of heat supplied. **[IES-1998]**
Reason (R): Entropy represents the maximum fraction of work obtainable from heat per degree drop in temperature.
54. Ans. (c)

87. In the T-S diagram shown in the figure, which one of the following is represented by the area under the curve? **[IAS-2004]**

(a) Total work done during the process
(b) Total heat absorbed during the process
(c) Total heat rejected during the process
(d) Degree of irreversibility



87. Ans. (b)

The Inequality of Clausius

80. Clausius inequality is stated as **[IAS-2001]**

(a) $\oint \delta Q < 0$ (b) $\oint \delta Q = 0$ (c) $\oint \delta \frac{Q}{T} > 0$ (d) $\oint \delta \frac{Q}{T} \leq 0$

80. Ans. (d)

31. For a real thermodynamic cycle, which one of the following is correct? **[IES-2005]**

(a) $\oint ds = 0$ (b) $\oint \frac{dQ}{T} < 0$ (c) $\oint \frac{dQ}{T} = 0$ (d) $\oint ds > 0$

31. Ans. (b)

72. For a thermodynamic cycle to be irreversible, it is necessary that **[IES-1998]**

$(a)\oint\frac{\delta Q}{T}=0$ $(b)\oint\frac{\delta Q}{T}<0$ $(c)\oint\frac{\delta Q}{T}>0$ $(d)\oint\frac{\delta Q}{T}\geq 0$

72. Ans. (b)

27. When a system undergoes a process such that $\int\frac{dQ}{T}=0\ and\ \Delta s>0$, the process is **[IES-1997]**

(a) irreversible adiabatic (b) reversible adiabatic (c) isothermal (d) isobaric

27. Ans. (d) Since $\int\frac{dQ}{T}=0$, process is reversible. Since $\Delta s>0$, process is constant pressure or isobaric

73. For an irreversible cycle **[IES-1994]**

(a) $\oint\frac{dQ}{T}\leq 0$ (b) $\oint\frac{dQ}{T}>0$ (c) $\oint\frac{dQ}{T}<0$ (d) $\oint\frac{dQ}{T}\geq 0$

73. Ans. (b)

79. For real thermodynamic cycle **[IAS-2003]**

(a) $\oint\frac{dQ}{T}>0\,but<\infty$ (b) $\oint\frac{dQ}{T}<0$ (c) $\oint\frac{dQ}{T}=0$ (d) $\oint\frac{dQ}{T}=\infty$

79. Ans. (b)

111. If a system undergoes an irreversible adiabatic process, then (symbols have usual meanings) **[IAS-1999]**

(a) $\int\frac{dQ}{T}=0\,and\,\Delta S>0$ (b) $\int\frac{dQ}{T}=0\,and\,\Delta S=0$

(c) $\int\frac{dQ}{T}>0\,and\,\Delta S=0$ (d) $\int\frac{dQ}{T}<0\,and\,\Delta S<0$

111. Ans. (a)

85. A cyclic heat engine receives 600 kJ of heat from a 1000 K source and rejects 450 kJ to a 300 K sink. The quantity $\oint\frac{dQ}{T}$ and efficiency of the engine are respectively **[IAS-2001]**

(a) 2.1 kJ/K and 70% (b) - 0.9 kJ/K and 25%

(c) + 0.9 kJ/K and 70% (d) - 2.1 kJ/K and 25%

85. Ans. (b) $\oint\frac{dQ}{T}=\frac{600}{1000}-\frac{(450)}{300}=-0.9kJ/K$

$$\eta=\frac{Q_1-Q_2}{Q_1}=1-\frac{Q_2}{Q_1}=1-\frac{450}{600}=0.25=25\%$$ **[IAS-2001]**

Entropy Change in an Irreversible Process

75. Consider the following statements: **[IES-1998]**
In an irreversible process

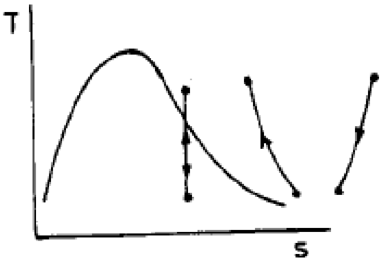
1. entropy always increases.
2. the sum of the entropy of all the bodies taking part in a process always increases.
3. once created, entropy cannot be destroyed.

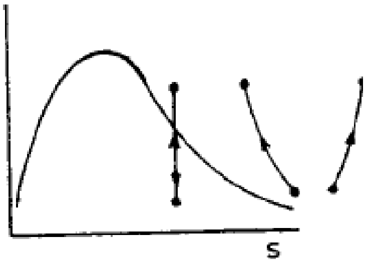
Of these statements
(a) 1 and 2 are correct (b) 1 and 3 are correct (c) 2 and 3 are correct (d) 1,2 and 3 are correct
75. Ans. (a)

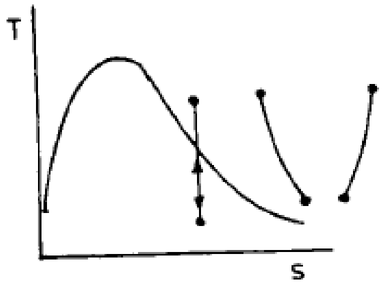
28. Consider the following statements: **[IES-1997]**
When a perfect gas enclosed in a cylinder piston device executes a reversible adiabatic expansion process,
1. its entropy will increase 2. its entropy change will be zero.
3. the entropy change of the surroundings will be zero.
Of these statements
(a) 1 and 3 are correct (b) 2 alone is correct (c) 2 and 3 are correct (d) 1 alone is correct
28. Ans. (c) In reversible adiabatic expansion, entropy change is zero and no change in entropy of surroundings

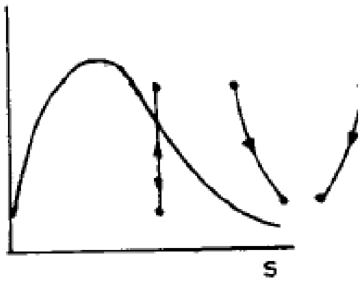
33. A system of 100 kg mass undergoes a process in which its specific entropy increases from 0.3 kJ/kg-K to 0.4 kJ/kg-K. At the same time, the entropy of the surroundings decreases from 80 kJ/K to 75 kJ/K.
The process is: **[IES-1997]**
(a) Reversible and isothermal (b) Irreversible (c) Reversible (d) Impossible
33. Ans. (b) Entropy increase in process = 100 (0.4 - 0.3) = 10 kJ/kg **[IES-1997]**
Entropy change of surroundings = 5 kJ/K
Thus net entropy increases and the process is irreversible.

75. Which one of the following temperature entropy diagrams of steam shows the reversible and irreversible processes correctly? **[IES-1996]**

a)


(b)


c)


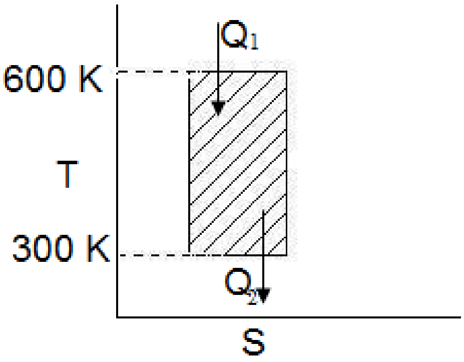
(d)


75. Ans. (c) In reversible process entropy change is zero and in four figures it is represented by straight vertical line. However, in irreversible process, entropy increases in all processes (expansion as well as compression).

Applications of Entropy Principle

73. A Carnot engine operates between 27°C and 327°C. If the engine produces 300 kJ of Work, What is the entropy change during heat addition? **[IES-2005]**
(a) 0.5 kJ/K (b) 1.0 kJ/K (c) 1.5 kJ/K (d) 2.0 kJ/K

73. Ans. (b)



$$(T_1 - T_2)\Delta S = W$$

$$\text{or}\ \Delta S = \frac{300}{600-300} = 1\,\text{kJ/k}$$

10. The entropy of a mixture of ideal gases is the sum of the entropies of constituents evaluated at: **[IES-2005]**
(a) Temperature and pressure of the mixture
(b) Temperature of the mixture and the partial pressure of the constituents
(c) Temperature and volume of the mixture
(d) Pressure and volume of the mixture
10. Ans. (c)

40. The heat added to a closed system during a reversible process is given by $Q = \alpha T + \beta T^2$, where α and β are constants. The entropy change of the system as its temperature changes from T_1 to T_2 is equal to **[IES-2000]**

$(a)\ \alpha + \beta(T_2 - T_1)$ $(b)\left[\alpha(T_2 - T_1) + \frac{\beta}{2}\left(T_2^2 - T_1^2\right)\right]/T_1$

$(c)\left[\frac{\alpha}{2}\left(T_2^2 - T_1^2\right) + \frac{\beta}{2}\left(T_2^3 - T_1^3\right)\right]/T_1^2$ $(d)\ \alpha \ln\left(\frac{T_2}{T_1}\right) + 2\beta(T_2 - T_1)$

40. Ans. (c)

72. Which one of the following statements is not correct?
(a) Change in entropy during a reversible adiabatic process is zero **[IAS-2003]**
(b) Entropy increases with the addition of heat
(c) Throttling is a constant entropy expansion process
(d) Change in entropy when a gas is heated under constant pressure given by $s_2 - s_1 = mC_p \log_e \frac{T_2}{T_1}$

72. Ans. (c)

98. Assertion (A): Entropy change for a reversible adiabatic process is zero.
Reason (R): There is no heat transfer in an adiabatic process.

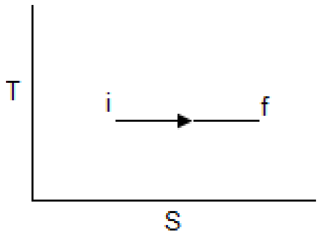
Ans. (b) **[IAS 1994]**

41. One kg of air is subjected to the following processes: **[IES-2004]**

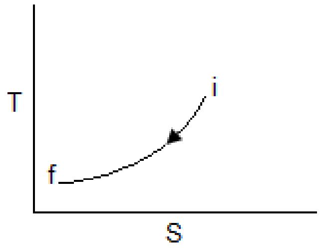
1. Air expands isothermally from 6 bar to 3 bar.
2. Air is compressed to half the volume at constant pressure
3. Heat is supplied to air at constant volume till the pressure becomes three fold

In which of the above processes, the change in entropy will be positive?

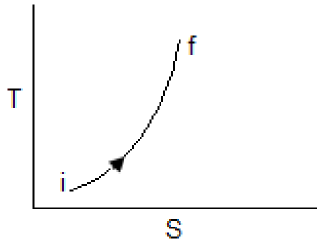
(a) 1 and 2 (b) 2 and 3 (c) 1 and 3 (d) 1, 2 and 3



(1)



(2)



(3)

37. A reversible heat engine receives 6 kJ of heat from thermal reservoir at temperature 800 K, and 8 kJ of heat from another thermal reservoir at temperature 600 K. If it rejects heat to a third thermal reservoir at temperature 100 K, then the thermal efficiency of the engine is approximately equal to: **[IES-2002]**

(a) 65% (b) 75% (c) 80% (d) 85%

37. Ans. (d)

119. A reversible engine exceeding 630 cycles per minute drawn heat from two constant temperature reservoirs at 1200 K and 800 K rejects heat to constant temperature at 400 K. The engine develops work 100kW and rejects 3200 KJ heat per minute. The ratio of heat drawn from two reservoirs $\frac{Q_{1200}}{Q_{800}}$ is nearly. **[IES-1992]**

(a) 1 (b) 1.5 (c) 3 (d) 10.5

119. Ans. (d)

119. Refer to given figure, as given,

Engine work developed = 100 kW

= 100 × 1000 × 60

= 6×10^6 J/min.

Thus, Q_s = total heat supplied

= $6 \times 10^6 + 3.2 \times 10^6$

= 9.2×10^6 J/min.

Let reservoir at 1200 K supply Q_{s1} J/min.

Therefore reservoir at 800°K will supply. $Q_{s2} = 9.2 \times 10^6 - Q_{s1}$

Also, by data the engine is a reversible heat engine completing 600 cycles/min. and therefore entropy change after every complete cycle is zero.

Thus, $$\frac{Q_{s1}}{1200} + \frac{Q_{s2}}{800} - \frac{Q_R}{400} = 0$$

or $$\frac{Q_{s1}}{1200} + \frac{9.2 \times 10^6 - Q}{800} - \frac{6 \times 3.2 \times 10^6}{400} = 0$$

$$\frac{2\,Q_{s1} + 3(9.2 \times 10^6 - Q_{s1}) - 6 \times 3.2 \times 10^6}{2400} = 0$$

or $$\begin{aligned} Q_{s1} &= 3 \times 9.3 \times 10^6 - 6 \times 3.2 \times 10^6 \\ &= 8.4 \times 10^6 \text{ J/min} \end{aligned}$$

Therefore, $$\begin{aligned} Q_{s2} &= 9.2 \times 10^6 - 8.4 \times 10^6 \\ &= 0.8 \times 10^6 \text{ J/min} \\ &= 8000 \text{ kJ/min.} \end{aligned}$$

$$\text{Hence ratio} = \frac{8.4}{0.8} = \mathbf{10.5}$$

38. In which one of the following situations the entropy change will be negative
(a) Air expands isothermally from 6 bars to 3 bars **[IES-2000]**
(b) Air is compressed to half the volume at constant pressure
(c) Heat is supplied to air at constant volume till the pressure becomes three folds
(d) Air expands isentropic ally from 6 bars to 3 bars
38. Ans. (a)

2.13. A 1500 W electrical heater is used to heat 20 kg of water (C_p = 4186 J/kg K) in an insulated bucket, from a temperature of 30°C to 80°C. If the heater temperature is only infinitesimally larger than the water temperature during the process, the change in entropy for heater is….. J/k and for water .... J/K. **[GATE-1994]**
3.13 Ans. - 11858 J/K, 12787 J/K.

Entropy Generation in a Closed System

92. 1600 kJ of energy is transferred from a heat reservoir at 800 K to another heat reservoir at 400 K. The amount of entropy generated during the process would be **[IAS-2000]**
(a) 6 kJ/k (b) 4 kJ/k (c) 2kJ/k (d) zero

92. Ans. (c) $\text{Entropy generated} = ds_{\text{at }400\text{K}} - ds_{\text{at }800\text{K}} = \frac{\cancel{d}Q}{400} - \frac{\cancel{d}Q}{800} = \frac{1600}{400} - \frac{1600}{800} = 2\,\text{kJ/K}$

21. An electric motor of 5 kW is subjected to a braking test for 1 hour. The heat generated by the frictional forces in the process is transferred to the surroundings at 20°C. The resulting entropy change will be **[IAS-1998]**
(a) 22.1 kJ/K (b) 30.2 kJ/K (c) 61.4 kJ/K (d) 82.1 kJ/K

21. Ans. (c) $\Delta S = \frac{\Delta Q}{T} = \frac{5 \times 3600}{293}\,\text{kJ/K} = 61.4\,\text{kJ/K}$

Data for Q. 85 - 86 are given below. Solve the problems and choose correct answers.
Nitrogen gas (molecular weight 28) is enclosed in a cylinder by a piston, at the initial condition of 2 bar, 298 K and 1 m^3. In a particular process, the gas slowly expands under isothermal

condition, until the volume becomes 2m^3. Heat exchange 42 occurs with the atmosphere at 298 K during this process.

85. The work interaction for the Nitrogen gas is **[GATE-2003]**

(a) 200 kJ (b) 138.6 kJ (c) 2 kJ (d) - 200 kJ

85. Ans. (b) $w_{1-2} = \text{mRT}\ \ln\left(\frac{\upsilon_2}{\upsilon_1}\right) = p\upsilon\ \ln\left(\frac{\upsilon_2}{\upsilon_1}\right) = 200 \times 1 \times \ln\left(\frac{2}{1}\right)\text{kJ} = 138.6\ \text{kJ}$

86. The entropy change for the Universe during the process in kJ/K is **[GATE-2003]**

(a) 0.4652 (b) 0.0067 (c) 0 (d) - 0.6711

86. Ans. (c) It is reversible process so $(\Delta S)_{\text{universe}} = 0$

Entropy Generation in an Open System

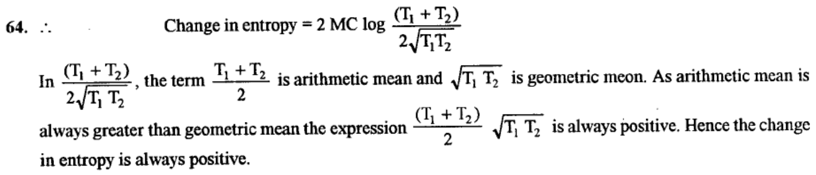
Reversible Adiabatic Work in a Steady Flow System

Entropy and Direction: The Second Law a Directional law of Nature

64. A mass M of a fluid at temperature T_1 is mixed with an equal mass of the same fluid at temperature T_2. The resultant change in entropy of the universe is **[IES-1992]**

(a) zero (b) negligible (c) always negative (d) always positive

64. Ans. (d)



64. $\therefore$ Change in entropy $= 2\ \text{MC}\ \log \frac{(T_1 + T_2)}{2\sqrt{T_1 T_2}}$

In $\frac{(T_1 + T_2)}{2\sqrt{T_1\ T_2}}$, the term $\frac{T_1 + T_2}{2}$ is arithmetic mean and $\sqrt{T_1\ T_2}$ is geometric meon. As arithmetic mean is always greater than geometric mean the expression $\frac{(T_1 + T_2)}{2}\ \sqrt{T_1\ T_2}$ is always positive. Hence the change in entropy is always positive.

81. M_1 kg of water at T_1 is isobarically and adiabatically mixed with M_2 kg of water at T_2 $(T_1 > T_2)$. The entropy change of the universe is **[IAS-2004]**

(a) Necessarily positive (b) Necessarily negative.

(c) Always zero (d) Negative or positive but not zero

81. Ans. (a)

30. In which one of the following processes is there an increase in entropy with no degradation of energy?

(a) Polytropic expansion (b) Isothermal expansion

(c) Isochoric heat addition (d) Isobaric heat addition **[IAS-1996]**

30. Ans. (b)

5. AVAILABILITY, IRREVERSIBILITY

Available Energy

42. What will be the loss of available energy associated with the transfer of 1000 kJ of heat from constant temperature system at 600 K to another at 400 K when the environment temperature is 300 K? **[IAS-1995; IES-2004]**

(a) 150 kJ (b) 250 kJ (c) 500 kJ (d) 700 kJ

42. Ans. (b) Loss of available energy $= T_o \times (\Delta S)_{\text{univ.}} = 300\left\{\frac{1000}{400} - \frac{1000}{600}\right\}\text{kJ} = 250\,\text{kJ}$

60. An inventor claims that heat engine has the following specifications:
Power developed = 50 kW; **[IAS-2002]**
Fuel burned per hour = 3 kg,
Heating value of fuel =75,000 kJ per kg
Temperature limits = 627°C and 27°C
Cost of fuel =Rs. 30/kg,
Value of power = Rs. 5/kWh,

(a) possible (b) not possible (c) economical (d) uneconomical

60. Ans. (b) Maximum possible efficiency ($\eta_{\max}$) $= 1 - \frac{T_2}{T_1} = 1 - \frac{300}{900} = \frac{2}{3}$

Maximum possible Power output with this machine

($W_{\max}$) $= Q \times \eta_{\max} = \frac{3 \times 75000}{3600} \times \frac{2}{3} kW$ 41. 67 KW

So above demand is impossible.

94. For a reversible power cycle, the operating temperature limits are 800 K and 300 K. It takes 400kJ of heat. The unavailable work will be **[IAS-1997]**

(a) 250 kJ (b) 150 kJ (c) 120 kJ (d) 100 kJ

94. Ans. (b) Available part of the heat (W_E) $= Q\left(1 - \frac{T_2}{T_1}\right) = 400\left(1 - \frac{300}{800}\right)$ =250 kJ

Unavailable work (W_u) = 400 – 250 = 150 kJ

Available Energy Referred to a Cycle

54. A steel billet of 2000 kg mass is to be cooled from 1250 K to 450 K. The heat released during this process is to be used as a source of energy. The ambient temperature is 303 K and specific heat of steel is 0.5 kJ/kg K. The available energy of this billet is **[GATE-2004]**

(a) 490.44 MJ (b) 30.95 MJ (c) 10.35 MJ (d) 0.10 MJ

54. Ans. (a) $\text{A.E} = \int_{T_1}^{T_2} mc_p\left(1 - \frac{T_o}{T}\right)dT = \int_{T_1}^{T_2} mc_p\left[(T_2 - T_1) - T_o \ln\left(\frac{T_2}{T_1}\right)\right]$

$$= 2000 \times 0.5\left[(1250 - 450) - 303\ln\left(\frac{1250}{450}\right)\right] = 490\,\text{MJ}$$

83. A heat source H_1 can supply 6000kJ/min. at 300°C and another heat source H_2 can supply 60000 kJ/min. at 100°C. Which one of the following statements is correct if the surroundings are at 27°C? **[IES-2006]**
(a) Both the heat sources have the same efficiency
(b) The first heat source has lower efficiency
(c) The second heat source has lower efficiency
(d) The first heat source produces higher power

83. Ans. (c) $\eta = 1 - \frac{T_{ource}}{T_{surroundings}} \quad \therefore \eta_1 > \eta_2$

Quality of Energy

42. Increase in entropy of a system represents **[IAS 1994]**
(a) increase in availability of energy
(b) increase in temperature
(c) decrease in pressure
(d) degradation of energy

Ans. (d)

Maximum Work in a Reversible Process

Reversible Work by an Open System Exchanging Heat only with the Surroundings

Useful Work

Dead State

Availability

1.5 Availability of a system at any given state is **[GATE-2000]**
(a) a property of the system
(b) the maximum work obtainable as the system goes to dead state
(c) the total energy of the system
(d) the maximum useful work obtainable as the system goes to dead state
1.5 Ans. (d) maximum useful work, i.e. total work minus pdv work. Not maximum work.

62. Assertion (A): The change in availability of a system is equal to the change in the Gibbs function of the system at constant temperature and pressure. **[IES-2006]**
Reason (R): The Gibbs function is useful when evaluating the availability of systems in which chemical reactions occur.
62. Ans. (a)

72. For a steady flow process from state 1 to 2, enthalpy changes from $h_1 = 400$ kJ/kg to $h_2 = 100$ kJ/kg and entropy changes from $s_1 = 1.1$ kJ/kg-K to $s_2 = 0.7$ kJ/kg-K. Surrounding environmental temperature is 800 K. Neglect changes in kinetic and potential energy. The change in availability of the system is **[IES-2003]**
(a) 420 kJ/kg (b) 300 kJ/kg (c) 180 kJ/kg (d) 90 kJ/kg
72. Ans. (c)

$$\text{U.E.} = T_o\ (s_1 - s_2)$$
$$= 300 \times (1.1 - 0.7) = 120 \text{ kJ/kg}$$
$$\text{Change in availability} = (h_1 - h_2) - (\text{U.E.})$$
$$= (400 - 100) - 120 = 180 \text{ kJ/kg}$$

35. Availability function for a closed system is expressed as: **[IES-2002]**

(a) $\phi = u + p_o v - T_o S$ (b) $\phi = du + p_o dv - T_o ds$

(c) $\phi = du + p_o dv + T_o ds$ (d) $\phi = u + p_o v + T_o S$

35. Ans. (a)

22. Consider the following statements: **[IES-2001]**

1. Availability is the maximum theoretical work obtainable.

2. Clapeyron's equation for dry saturated steam is given by $\left(V_g - V_f\right) = \frac{dT_s}{dQ}\left[\frac{h_g - h_f}{T_s}\right]$

3. A gas can have any temperature at a given pressure unlike a vapour which has a fixed temperature at a given pressure.

4. Joule Thomson coefficient is expressed as $\mu = \left[\frac{\partial s}{\partial p}\right]_h$

Of these statements

(a) 1, 2 and 3 are correct (b) 1, 3 and 4 are correct

(c) 2 and 3 are correct (d) 1, 2 and 4 are correct

22. Ans. (a)

37. 10kg of water is heated from 300 K to 350 K in an insulated tank due to churning action by a stirrer. The ambient temperature is 300 K. In this context, match List I and List II and select the correct answer using the codes given below the Lists: **[IES-2000]**

List I	List II
A. Enthalpy change	1. 12.2 kJ/kg
B. Entropy change/kg	2. 1968 kJ
C. Availability/kg	3. 2090 kJ
D. Loss of availability	4. 656 J/kg-k

Codes:	A	B	C	D		A	B	C	D
(a)	3	1	4	2	(b)	2	4	1	3
(c)	3	4	1	2	(d)	2	1	4	3

37. Ans. (c)

73. Neglecting changes in kinetic energy and potential energy, for unit mass the availability in a non-flow process becomes a = $\phi - \phi_o$, where ϕ is the availability function of the **[IES-1998]**

(a) open system (b) closed system (c) isolated system (d) steady flow process

73. Ans. (a)

76. Consider the following statements: **[IES-1996]**

1. Availability is generally conserved 2. Availability can either be negative or positive.

3. Availability is the maximum theoretical work obtainable.

4. Availability can be destroyed in irreversibility.

Of these correct statements are:

(a) 3 and 4 (b) 1 and 2 (c) 1 and 3 (d) 2 and 4

76. Ans. (a) Availability is the maximum theoretical work obtainable and it can be destroyed in irreversibility.

73. If u, T, v, s, hand p refer to internal energy, temperature, volume, entropy, enthalpy and pressure respectively; and subscript 0 refers to environmental conditions, availability function for a closed system is given by **[IAS-2003]**
(a) u+P_o v-T_o s (b) u- P_o v+ T_o s (c) h + P_o v – T_os (d) h - P_o v + T_o s
73. Ans. (a)

22. Match List - I with List - II and select the correct answer using the codes given below the lists:

List - I	List - II
A. Irreversibility	1. Mechanical equivalent
B. Joule Thomson experiment	2. Thermodynamic temperature scale
C. Joule's experiment	3. Throttling process
D. Reversible engines	4. Loss of availability

Codes:	A	B	C	D		A	B	C	D
(a)	1	2	3	4	(b)	1	2	4	3
(c)	4	3	2	1	(d)	4	3	1	2

22. Ans. (d)

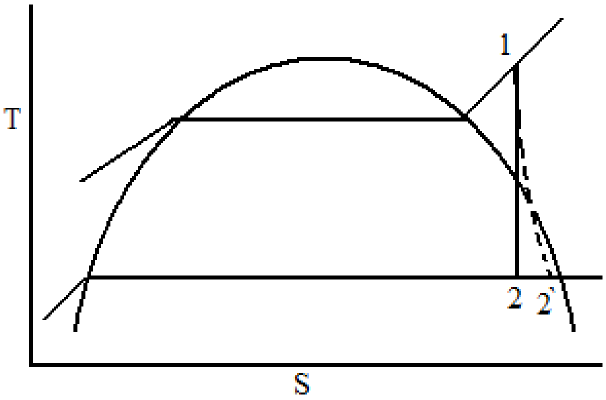
5.10 A heat reservoir at 900 K is brought into contact with the ambient at 300 K for a short time. During this period 9000 kJ of heat is lost by the heat reservoir. The total loss in availability due to this process is **[GATE-1995]**
(a) 18000 kJ (b) 9000 kJ (c) 6000 kJ (d) None of the above
5.10 Ans. (d) The availability of a thermal reservoir is equivalent to the work output of a Carnot heat engine operating between the reservoir and the environment. Here as there is no change in the temperatures of source (reservoir) or the sink (atmosphere), the initial and final availabilities are same, Hence there is no loss in availability.

Irreversibility

77. The irreversibility is defined as the difference of the maximum useful work and actual work: I = $W_{max,useful}$- $W_{actual.}$ How can this be alternatively expressed? **[IES-2005]**
(a) $I = T_o(\Delta S_{system} + \Delta S_{surrounding})$ (b) $I = T_o(\Delta S_{system} - \Delta S_{surrounding})$
(c) $I = T_o(\sqrt{\Delta S_{system}} + \sqrt{\Delta S_{surrounding}})$ (d) $I = T_o(\sqrt{\Delta S_{system}} - \sqrt{\Delta S_{surrounding}})$
77. Ans. (a) $I = T_o \times (\Delta S)_{universe} = T_o \times \left[\Delta S_{system} + \Delta S_{surrounding}\right]$

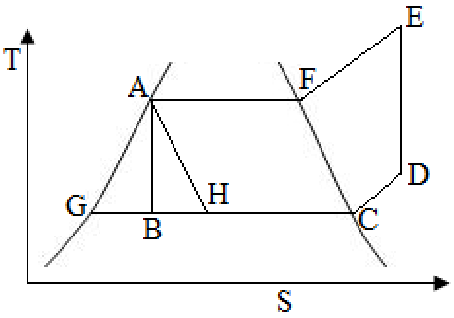
63. Assertion (A): All constant entropy processes are adiabatic, but all adiabatic processes are not isentropic. **[IES-2006]**
Reason (R): An adiabatic process which resists the exchange of energy to the surroundings may have irreversibility due to friction and heat conduction.

63. Ans. (d) A is false, For a process due to irreversibility entropy will increase and actual process may be 1-2` but due to heat loss to the surroundings, may 2` coincide with 2 but the process not adiabatic. So all isentropic process is not adiabatic.



4. Which of the following statement is incorrect? **[IES-1992]**
(a) The greater the pressure difference in throttling the lesser the irreversibility
(b) The primary source of internal irreversibility in power is fluid friction in rotary machines.
(c) The greater the irreversibility, the greater the increase in adiabatic process
(d) The entropy of the universe is continually on the increase.
4. Ans. (a)

1. The loss due to irreversibility in the expansion valve of a refrigeration cycle shown in the given figure is represented by the area under the line·
(a) GB
(b) AG
(c) AH
(d) BH
[IAS-1999]



1. Ans. (d) Entropy will increase in the process AH is BH.
Therefore Irreversibility (I) = $T_o \times \Delta S$ i.e. area under the line BH.

29. Assertion (A): When a gas is forced steadily through an insulated pipe containing a porous plug, the enthalpy of gas is the same on both sides of the plug. **[IAS-1997]**
Reason (R): The gas undergoes an isentropic expansion through the porous plug.
29. Ans. (c) Expansion through the porous plug is adiabatic as no heat added or rejected to the system. It is not reversible, due to large irreversibility entropy increases so it is not an isentropic process.

Second Law efficiency

69. Assertion (A): The first-law efficiency evaluates the energy quantity utilization, whereas the second-law efficiency evaluates the energy quality utilization. **[IAS-1998]**
Reason (R): The second-law efficiency for a process is defined as the ratio of change of available energy of the source to the change of available energy of the system.

69. Ans. (c) $\eta_{II} = \dfrac{\text{mimimum energy intake to perform the given task}}{\text{actual energy intake to perform the same task}}$

6. TdS RELATIONS, CLAPERYRON AND REAL GAS EQUATIONS

Highlight

5. Adiabatic index (γ) $=1+\frac{2}{N}$ where N is degrees of freedom of molecules

N=3 for monatomic gas
N=5 for diatomic gas
N=6 for try atomic gas

Some Mathematical Theorems

43. Given:

p = pressure, **[IES-1993]**
T = Temperature,
v = specific volume,

Which one of the following can be considered as property of a system?

$(a)\int pdv$ $(b)\int vdp$ $(c)\int\left(\frac{dT}{T}+\frac{p.dv}{v}\right)$ $(d)\int\left(\frac{dT}{T}-\frac{v.dp}{T}\right)$

43. Ans. (d) P is a function of v and both are connected by a line path on p and v coordinates. Thus $\int pdv$ and $\int vdp$ are not exact differentials and thus not properties.

If X and Y are two properties of a system, then dx and dy are exact differentials. If the differential is of the form Mdx + Ndy, then the test for exactness is $\left[\frac{\partial M}{\partial y}\right]_x=\left[\frac{\partial N}{\partial x}\right]_y$

Now applying above test for

$$\int\left(\frac{dT}{T}+\frac{p.dv}{v}\right),\left[\frac{\partial(1/T)}{\partial v}\right]_T=\left[\frac{\partial(p/v)}{\partial T}\right]_v=\left[\frac{\partial(RT/v^2)}{\partial T}\right]_v\ or\ 0=\frac{R}{v^2}$$

This differential is not exact and hence is not a point function and hence $\int\left(\frac{dT}{T}+\frac{p.dv}{v}\right)$ is not a point function and hence not a property.

And for $\int\left(\frac{dT}{T}-\frac{v.dp}{T}\right)\left[\frac{\partial(1/T)}{\partial p}\right]_T=\left[\frac{\partial(-v/T)}{\partial T}\right]_P=\left[\frac{\partial(-R/P)}{\partial T}\right]_P\ or\ 0=0$

Thus $\int\left(\frac{dT}{T}-\frac{v.dp}{T}\right)$ is exact and may be written as ds, where s is a point function and hence a property

Maxwell's Equations

55. Which thermodynamic property is evaluated with the help of Maxwell equations from the data of other measurable properties of a system?

(a) Enthalpy (b) Entropy (c) Latent heat (d) Specific heat **[IES 2007]**

55. Ans. (a) From Maxwell relation Clapeyron equation comes.

87. Consider the following statements pertaining to the Clapeyron equation:

1. It is useful to estimate properties like enthalpy from other measurable properties.
2. At a change of phase, it can be used to find the latent heat at a given pressure.
3. It is derived from the relationship $\left(\frac{\partial p}{\partial v}\right)_T = \left(\frac{\partial s}{\partial T}\right)_V$ **[IES-2006]**

Which of the statements given above are correct?

(a) 1,2 and 3 (b) Only 1 and 2 (c) Only 1 and 3 (d) Only 2 and 3

87. Ans. (b) 3 is false. It is derived from the Maxwell's 3rd relationship

$$\left(\frac{\partial p}{\partial T}\right)_v = \left(\frac{\partial s}{\partial v}\right)_T$$

89. According to the Maxwell relation, which of the following is/are correct?

(a) $\left(\frac{\partial v}{\partial T}\right)_p = -\left(\frac{\partial s}{\partial P}\right)_T$ (b) $\left(\frac{\partial s}{\partial v}\right)_T = \left(\frac{\partial P}{\partial T}\right)_v$ **[IAS-2007]**

(c) $\left(\frac{\partial P}{\partial T}\right)_v = \left(\frac{\partial s}{\partial v}\right)_T$ (d) All of the above

89. Ans. (c) $\left(\frac{\partial P}{\partial T}\right)_V = \left(\frac{\partial S}{\partial V}\right)_T$ To memorize Maxwell's relation remember T V P S, -ive and S S V P see highlights.

TdS Equations

36. T ds equation can be expressed as **[IES-2002]**

(a) $Tds = C_v dt + \frac{T\beta dv}{k}$ (b) $Tds = C_v dt + \frac{Tdv}{k}$

(c) $Tds = C_v dt + \frac{Tk}{\beta} dv$ (d) $Tds = C_v dt + \frac{T\beta}{k} dp$

36. Ans. (a)

56. Which of the following relationships is valid only for reversible processes undergone by a closed system of simple compressible substance (neglect changes in kinetic and potential energy? **[GATE-2007]**

(a) δQ = dU + δW (b) TdS = dU + pdV (c) TdS = dU + δW (d) δQ = dU + pdV

56. Ans. (d)

49. Considering the relationship TdS = dU + pdV between the entropy (S), internal energy (U), pressure (p), temperature (T) and volume (V), which of the following statements is correct? **[GATE-2003]**

(a) It is applicable only for a reversible process (b) For an irreversible process, TdS > dU + pdV

(c) It is valid only for an ideal gas (d) It is equivalent to 1 law, for a reversible process

49. Ans. (d)

73. Which one of the following statements applicable to a perfect gas will also be true for an irreversible process? (Symbols have the usual meanings). **[IES-1996]**

(a) dQ = du + pdV (b) dQ = Tds (c) Tds = du + pdV (d) None of the above

73. Ans. (c) The relations in (a) and (b) are applicable for a reversible processes and (c) Tds = du + pdV is a relation among properties which are independent of the path.

15. Which one of the following expressions for T ds is true for a simple compressible substance? (Notations have the usual meaning) **[IAS-1998]**
(a) dh – vdp (b) dh + vdp (c) dh - pdv (d) dh +pdv
15. Ans. (a) dQ = dh - Vdp or Tds = dh - Vdp

39. Consider the following thermodynamic relations: **[IES-2000]**

$1. Tds = du + pdv \qquad 2. Tds = du - pdv$

$3. Tds = dh + vdp \qquad 4. Tds = dh - vdp$

Which of these thermodynamic relations are correct?
(a) 1 and 3 (b) 1 and 4 (c) 2 and 3 (d) 2 and 4
39. Ans. (b)

Difference in Heat Capacities and Ratio of Heat Capacities

1.12 The specific heats of an ideal gas depend on its **[GATE-1996]**
(a) temperature (b) pressure (c) volume (d) molecular weight and structure
1.12 Ans. (a)

70. Match List-l (Terms) with List-II (Relations) and select the correct answer using the codes given below the Lists: **[IES-2003]**

List I (Terms)	List II (Relations)
A. Specific heat at constant volume C_v	1. $\frac{1}{v}\left(\frac{\partial v}{\partial T}\right)_p$
B. Isothermal compressibility k_T	2. $T\left(\frac{\partial p}{\partial T}\right)_v\left(\frac{\partial v}{\partial T}\right)_p$
C. Volume expansivity β	3. $T\left(\frac{\partial s}{\partial T}\right)_v$
D. Difference between specific heats at constant pressure and at constant C_p-C_v	4. $-\frac{1}{v}\left(\frac{\partial v}{\partial p}\right)_T$

Codes:

	A	B	C	D		A	B	C	D
(a)	3	4	2	1	(b)	4	1	3	2
(c)	3	4	1	2	(d)	4	1	2	3

70. Ans. (c)

82. Assertion (A): Specific heat at constant pressure for an ideal gas is always greater than the specific heat at constant volume. **[IES-2002]**
Reason (R): Heat added at constant volume is not utilized for doing any external work.
82. Ans. (a)

36. An insulated box containing 0.5 kg of a gas having C_v = 0.98 kJ/kgK falls from a balloon 4 km above the earth's surface. What will be the temperature rise of the gas when the box hits the ground? **[IES-2004]**

(a) 0 K (b) 20 K (c) 40 K (d) 60 K

36. Ans. (c) Potential energy will converted to heat energy.

$$mgh = mc_v\Delta T \quad \text{or} \quad \Delta T = \frac{gh}{c_v} = \frac{980 \times 4000}{980} = 40\text{K}$$

83. As compared to air standard cycle, in actual working, the effect of variations in specific heats is to **[IES-1994]**

(a) increase maximum pressure and maximum temperature.

(b) reduce maximum pressure and maximum temperature.

(c) increase maximum pressure and decrease maximum temperature.

(d) decrease maximum pressure and increase maximum temperature.

83. Ans. (b)

95. The specific heat C_p is given by **[IAS-2000]**

(a) $T\left(\frac{\partial v}{\partial T}\right)_p$ (b) $T\left(\frac{\partial T}{\partial s}\right)_p$ (c) $T\left(\frac{\partial s}{\partial T}\right)_p$ (d) $T\left(\frac{\partial T}{\partial v}\right)_p$

95. Ans. (c) $C_p = \frac{\text{đ}Q_p}{\partial T} = T\left(\frac{\partial s}{\partial T}\right)_p$ $\qquad [\because \text{đ}Q = TdS]$

29. The number of degrees of freedom for a diatomic molecule **[IES-1992]**

(a) 2 (b) 3 (c) 4 (d) 5

29. Ans. (d)

A diatomic gas (such as that of oxygen) has six degrees of freedom in all-three corresponding to translator motion, two corresponding to rotatory motion and one corresponding to vibratory motion. Experiments have shown that at ordinary temperatures, the vibratory motion does not occur. Hence, at 27°C, an oxygen molecule has just five degrees of freedom.

32. The ratio $\frac{C_p}{C_v}$ for a gas with n degrees of freedom is equal to: **[IES-1992]**

(a) n + l (b) n – l (c) $\frac{2}{n} - 1$ (d) $1 + \frac{2}{n}$

32. Ans. (d)

32. $C_v = \frac{n}{2}R,$ $\qquad C_p = \left(\frac{n}{2}+1\right)R$

$\therefore \qquad \frac{C_p}{C_v} = \frac{n+2}{n}$

12. The specific heats of an ideal gas depends on its **[GATE-1996]**

(a) Temperature (b) pressure (c) volume (d) molecular weight and structure.

Ans. (d)

1.9 For an ideal gas the expression $\left[T\left(\frac{\partial s}{\partial T}\right)_p - T\left(\frac{\partial s}{\partial T}\right)_v\right]$ is always equal to

[IAS-2003, GATE-1997]

$(a)\, zero$ $(b)\frac{c_p}{c_v}$ $(c)\, R$ $(d)\, RT$

1.9 Ans. (c)

$$\mathrm{T}\left(\frac{\partial \mathrm{S}}{\partial \mathrm{T}}\right)_\mathrm{P} = \left(\frac{\mathrm{T}\partial \mathrm{S}}{\partial \mathrm{T}}\right)_\mathrm{P} = \left(\frac{\text{đ}\mathrm{Q}}{\partial \mathrm{T}}\right)_\mathrm{P} = \mathrm{C_P}$$

$$\mathrm{T}\left(\frac{\partial \mathrm{S}}{\partial \mathrm{T}}\right)_\mathrm{V} = \left(\frac{\mathrm{T}\partial \mathrm{S}}{\partial \mathrm{T}}\right)_\mathrm{V} = \left(\frac{\text{đ}\mathrm{Q}}{\partial \mathrm{T}}\right)_\mathrm{V} = \mathrm{C_V}$$

$$\therefore \mathrm{T}\left(\frac{\partial \mathrm{S}}{\partial \mathrm{T}}\right)_\mathrm{P} - \mathrm{T}\left(\frac{\partial \mathrm{S}}{\partial \mathrm{T}}\right)_\mathrm{V} = \mathrm{C_P} - \mathrm{C_V} = \mathrm{R}$$

14. Assertion (A): Specific heat at constant pressure for an ideal gas is always greater than the specific heat at constant volume.

Reason (R): Heat added at constant volume is not utilized for doing any external work. **[IAS-2000, IES-2002]**

Ans. (a) Both A and R correct and R is the correct explanation of A

16. Assertion (A): Ratio of specific heats $\frac{C_p}{C_v}$ decreases with increase in temperature.

Reason (R): With increase in temperature, C_p decreases at a higher rate than C_v.

[IES-1996]

Ans. (C): A is correct but R is false.

We know that $C_p = a + KT + K_1T^2 + K_2T^3$

$C_v = b + KT + K_1T^2 + K_2T^3$

See C_p and C_v both increase with temperature and by same amount. As $C_p > C_v$ then percentage increase of C_p is less than C_v. So $\frac{C_p}{C_v}$ decreases with temperature.

17. It can be shown that for a simple compressible substance, the relationship

$C_p - C_v = -T\left(\frac{\partial V}{\partial T}\right)_p^2\left(\frac{\partial P}{\partial T}\right)_T$ exists. Where C_p and C_v are specific heats at constant pressure and constant volume respectively. T is the temperature V is volume and P is pressure. **[IES-1998]**

Which one of the following statements is NOT true?

(a) C_p is always greater than C_v.

(b) The right side of the equation reduces to R for ideal gas.

(c) Since $\left(\frac{\partial P}{\partial T}\right)_T$ can be either positive or negative, and $\left(\frac{\partial V}{\partial T}\right)_p^2$ must be positive, T must have a sign that is opposite to that of $\left(\frac{\partial P}{\partial T}\right)_T$

(d) Is very nearly equal to   for liquid water.

Ans. (c) Sign of T must be positive. $\left(\frac{\partial P}{\partial T}\right)_T$ is always negative.

18 Match List-I with List-II and select the correct answers using the codes given below the lists. **[IAS-2002]**

List-I	List-II
A. Joule Thomson co-efficient	1. $\frac{5}{2}$ R
B. C_p for monatomic gas	2. C_v
C. C_p - C_v for diatomic gas	3. R
D. $\left(\frac{\partial U}{\partial T}\right)_v$	4. $\left(\frac{\partial T}{\partial P}\right)_h$

Codes:	A	B	C	D		A	B	C	D
(a)	3	2	4	1	(b)	4	1	3	2
(c)	3	1	4	2	(d)	4	2	3	1

Ans. (b) Cp-C_v for all ideal gas is R, So C-3, (a) & (c) out. A automatically match 4,and

$C_p = \frac{\gamma}{\gamma - 1}R$ for monatomic gas $\gamma = \frac{5}{3}$ so $= \frac{5}{2}R$

108. Ratio of specific heats for an ideal gas is given by (symbols have the usual meanings) **[IAS-1999]**

(a) $\frac{1}{1-\frac{R}{C_p}}$ (b) $\frac{1}{1-\frac{C_p}{R}}$ (c) $\frac{1}{1+\frac{C_p}{R}}$ (d) $\frac{1}{1+\frac{R}{C_p}}$

108. Ans. (a) $C_p - C_v = R$ and $\gamma = \frac{C_p}{C_v} = \frac{C_p}{C_p - R} = \frac{1}{1-\frac{R}{C_p}}$

14. A 2 kW, 40 litre water heater is switched on for 20 minutes. The heat capacity C_p for water is 4.2 kJ/kg K. Assuming all the electrical energy has gone into heating the water, increase of the water temperature in degree centigrade is **[GATE-2003]**

(a) 2.7 (b) 4.0 (c) 14.3 (d) 25.25

14. Ans. (c)

Heat absorbed by water = Heat supplied by heater

$m_w c_{pw} (\Delta T)_w = P \times t$ or $40 \times 4.2 \times (\Delta T)_w = 2 \times 20 \times 60$ or $(\Delta T)_w = 14.3^\circ C$

Energy Equation

Joule-Kelvin Effect or Joule-Thomson coefficient

44. Joule-Thomson coefficient is defined as **[IES-1995]**

(a) $\left(\frac{\partial T}{\partial p}\right)_h$ (b) $\left(\frac{\partial h}{\partial p}\right)_T$ (c) $\left(\frac{\partial h}{\partial T}\right)_p$ (d) $\left(\frac{\partial p}{\partial T}\right)_h$

44. Ans. (a)

58. Which combination of the following statements is correct? **[GATE-2007]**

P: A gas cools upon expansion only when its Joule-Thomson coefficient is positive in the temperature range of expansion.

Q: For a system undergoing a process, its entropy remains constant only when the process is reversible.

R: The work done by a closed system in an adiabatic process is a point function.

S: A liquid expands upon freezing when the slop of its fusion curve on Pressure Temperature diagram is negative.

(a) R and S (b) P and Q (c) Q, R and S (d) P, Q and R

58. Ans. (b)

1.19 A positive value to Joule-Thomson coefficient of a fluid means **[GATE-2002]**

(a) temperature drops during throttling (b) temperature remains constant during throttling

(c) temperature rises during throttling (d) none of these

1.19 Ans. (a) $\mu = \left(\frac{\partial T}{\partial P}\right)_h$ i,e. $\mu > o$, ∂P is $(-\text{ive})$ so ∂T must be $-\text{ive}$.

1.14 A gas having a negative Joule-Thompson coefficient (μ< 0), when throttled, will

(a) become cooler (b) become warmer **[GATE-2001]**

(c) remain at the same temperature (d) either be cooler or warmer depending on the type of gas

1.14 Ans. (b) Joule-Thomson co-efficient $\left(\frac{\partial T}{\partial P}\right)_h$ Here ∂p, $-\text{ive}$ and $\left(\frac{\partial T}{\partial P}\right)_h$, -ive so ∂T must be +ive so gas will be warmer

4.3 Match 4 correct pairs between list I and List II for the questions

For a perfect gas: **[GATE-1994]**

List I	List II
(a) Isobaric thermal expansion coefficient	1. 0
(b) Isothermal compressibility	2. ∞
(c) Isentropic compressibility	3. 1/v
(d) Joule - Thomson coefficient	4. 1/T
	5. 1/p
	6. $1/\gamma$ p

4.3 Ans. (a) – 4, (b) - 5, (c) - 6, (d) – 1

26. The throttling of certain gasses may be used for getting the refrigeration effect. What is the value of Joule – Thomson coefficient (μ) for such a throttling process?

(a) $\mu = 0$ (b) $\mu = 1$

(c) $\mu < 1$ (d) $\mu > 1$ **[IES 2007]**

Ans. (d) Actually Joule-Thomson coefficient will be positive.

81. Which one of the following is correct?
When a real gas undergoes Joule-Thomson expansion, the temperature

(a) may remain constant. (b) always increases.
(c) may increase or decrease. (d) always decreases. **[IES 2007]**

Ans. (c) For ideal gas μ = 0 and for real gas μ may be positive (N_2, O_2, CO_2 etc.) or negative (H_2)

36. Assertion (A): Throttling process for real gases at initial temperature higher than maximum inversion temperature is accompanied by decrease in temperature of the gas.
Reason (R): Joule-Kelvin coefficient μ_j is given $\left(\partial T/\partial p\right)_h$ and should have a positive value for decrease in temperature during throttling process. **[IES-2003]**

36. Ans. (a)

18. Match List-I (Name of entity) with List-II (Definition) and select the correct answer using the codes given below the lists:

List-I (Name of entity)	List-II (Definition) **[IES-2001]**
A. Compressibility factor	1. $-\frac{1}{v}\left(\frac{\partial v}{\partial T}\right)_p$
B. Joule- Thomson coefficient	2. $\left(\frac{\partial h}{\partial T}\right)_p$
C. Constant pressure specific heat	3. $\left(\frac{\partial T}{\partial p}\right)_h$
D. Isothermal compressibility	4. $\left(\frac{pv}{RT}\right)$

Codes:	A	B	C	D		A	B	C	D
(a)	2	1	4	3	(b)	4	3	2	1
(c)	2	3	4	1	(d)	4	1	2	3

18. Ans. (b)

54. Joule-Thomson coefficient is the ratio of **[IES-1999]**

(a) pressure change to temperature change occurring when a gas undergoes the process of adiabatic throttling
(b) temperature change to pressure change occurring when a gas undergoes the process of adiabatic throttling
(c) temperature change to pressure change occurring when a gas undergoes the process of adiabatic compression
(d) pressure change to temperature change occurring when a gas undergoes the process of adiabatic compression

54. Ans. (b) Joule Thomson coefficient is the ratio of temperature change to pressure change when a gas undergoes adiabatic throttling.

78. The Joule-Thomson coefficient is the **[IES-1996]**

(a) $\left(\frac{\partial T}{\partial p}\right)_h$ of pressure-temp curve of real gases (b) $\left(\frac{\partial T}{\partial s}\right)_v$ of temp.-entropy curve of real gases

(c) $\left(\frac{\partial h}{\partial s}\right)_T$ of enthalpy-entropy curve of real gases

(d) $\left(\frac{\partial V}{\partial T}\right)_p$ of pressure-volume curve of real gases.

78. Ans. (a) The slope of the isenthalpic curve at any point is know!) as Joule-Thomson coefficient and is expressed as $\mu = \left(\frac{\partial T}{\partial p}\right)_h$

69. Match the following

List I	List II
A. Work	1. Point function
B. Heat	2. $\int Tds$
C. Internal energy	3. $\left(\frac{\partial u}{\partial T}\right)_h$
D. Joule Thomson Coefficient	4. $\int pdv$

[IES-1992]

Code:	A	B	C	D		A	B	C	D
(a)	4	2	1	3	(b)	1	2	4	3
(c)	4	1	2	3	(d)	2	1	4	3

69. Ans. (a)

85. Which one of the following properties remains unchanged for a real gas during Joule-Thomson process? **[IAS-2000]**

(a) Temperature (b) Enthalpy (c) Entropy (d) Pressure

85. Ans. (b)

Clausius-Clapeyron Equation

53. Consider the following statements in respect of the Clausius – Clapeyron equation:

1. It points to one possible way of measuring thermodynamic temperature.
2. It permits latent heat of vaporization to be estimated from measurements of specific volumes of saturated liquid, saturated vapour and the saturation temperatures at two nearby pressures.
3. It does not apply to changes from solid to the liquid phase and from solid to the Vapour phase.

Which of the statements given above are correct?

(a) 1,2 and 3 (b) 1 and 2 only
(c) 2 and 3 only (d) 1 and 3 only **[IES 2007]**

Ans. (b)

32. The equation relating the following measurable properties: **[IES-2005]**

(i) the slope of saturation pressure temperature line
(ii) the latent heat, and
(iii) the change in volume during phase transformation; is known as :

(a) Maxwell relation (b) Joules equation
(c) Clapeyron equation (d) None of the above

32. Ans. (c)

43. The variation of saturation pressure with saturation temperature for a liquid is 0.1 bar/K at 400 K. The specific volume of saturated liquid and dry saturated vapour at 400

K are 0.251 and 0.001 m^3/kg What will be the value of latent heat of vaporization using Clausius Clapeyron equation ? **[IES-2004]**

(a) 16000 kJ/kg (b) 1600 kJ/kg (c) 1000 kJ/kg (d) 160 kJ/kg

43. Ans. (c) $\left(\frac{dP}{dT}\right)_{sat} = \frac{h_{fg}}{T\left(V_g - V_f\right)}$

$$\text{or } h_{fg} = T\left(V_g - V_f\right)\times\left(\frac{dP}{dT}\right)_{sat} = 400\times\left(0251-0.001\right)\times 0.1\times 10^5 J/kg = 1000kJ/kg$$

74. If h, p, T and v refer to enthalpy, pressure, temperature and specific volume respectively and subscripts g and f refer to saturation conditions of vapour and liquid respectively then Clausius-Clapeyron equation applied to change of phase from liquid to vapour states is

(a) $\frac{dp}{dt} = \frac{(h_g - h_f)}{(v_g - v_f)}$ (b) $\frac{dp}{dt} = \frac{(h_g - h_f)}{T(v_g - v_f)}$ **[IAS-2003, IES-1996, 2006]**

(c) $\frac{dp}{dt} = \frac{(h_g - h_f)}{T}$ (d) $\frac{dp}{dt} = \frac{(v_g - v_f)T}{(h_g - h_f)}$

74. Ans. (b)

39. Which one of the following functions represents the Clapeyron equation pertaining to the change of phase of a pure substance? **[IES-2002]**

(a) f (T, p, h_{fg}) (b) f (T, p, h_{fg}, v_{fg}) (c) f (T, p, h_{fg}, s_{fg}) (d) f (T, p, h_{fg}, s_{fg}, v_{fg})

39. Ans. (b)

43. The Clapeyron equation with usual notations is given by **[IES-2000]**

(a) $\left(\frac{dT}{dP}\right)_{sat} = \frac{h_{fg}}{Tv_{fg}}$ (b) $\left(\frac{dP}{dT}\right)_{sat} = \frac{h_{fg}}{Tv_{fg}}$ (c) $\left(\frac{dT}{dP}\right)_{sat} = \frac{Th_{fg}}{v_{fg}}$ (d) $\left(\frac{dP}{dT}\right)_{sat} = \frac{Th_{fg}}{v_{fg}}$

43. Ans. (b)

59. Clausius-Clapeyron equation gives the 'slope' of a curve in **[IES-1999]**

(a) p-v diagram (b) p-h diagram (c) p – T diagram (d) T-S diagram

59. Ans. (c)

34. The thermodynamic parameters are: **[IES-1997]**

I. Temperature II. Specific Volume III. Pressure IV. Enthalpy V. Entropy

The Clapeyron Equation of state provides relationship between:

(a) I and II (b) II, III and V (c) III, IV and V (d) I, II, III and TV

34. Ans. (d) Clapeyron equation state provides relationship between temperature, specific volume, pressure and enthalpy.

52. Which one of the following is the correct statement? **[IAS-2007]**

Clapeyron equation is used for

(a) finding specific volume of vapour (b) finding specific volume of liquid

(c) finding latent heat of vaporization (c) finding sensible heat

52. Ans. (c)

118. Assertion (A): Water will freeze at a higher temperature if the pressure is increased.

Reason (R): Water expands on freezing which by Clapeyron's equation gives negative slope for the melting curve. **[IAS-2003]**

118. Ans. (a)

36. Match List I with List II and select the correct answer using the codes given below the lists

[IAS 1994]

List I	List II
A. Mechanical work	1. Clausius-Clapeyron equation
B. $\int \frac{dQ}{T} \le 0$	2. Gibb's equation
C. Zeroth Law	3. High grade energy
D. H-TS	4. Concept of temperature

Codes:	A	B	C	D		A	B	C	D
(a)	1	3	2	4	(b)	3	-	2	4
(c)	-	2	3	1	(d)	3	-	4	2

Ans. (d)

Mixtures of Variable Composition

Conditions of Equilibrium of a Heterogeneous System

Gibbs Phase Rule

21. Number of components (C), phase (P) and degrees of freedom (F) are related by Gibbs-phase rule as **[IES-2001]**

(a) C – P – F = 2 (b) F – C – P = 2 (c) C + F – P = 2 (d) P + F – C = 2

21. Ans. (d)

3. As per Gibb's phase rule, if number of components is equal to 2 then the number of phases will be **[IES-2002]**

(a) ≤ 2 (b) ≤ 3 (c) ≤ 4 (d) ≤ 5

3. Ans. (c)

4. Gibb's phase rule is given by **[IES-1999]**

(F = number of degrees of freedom; C = number of components; P = number of phases)

(a) F= C+ P (b) F=C+P-2 (c) F= C-P-2 (d) F= C-P+ 2

4. Ans. (d) F = C - P + 2

55. Gibb's free energy 'c' is defined as **[IES-1999]**

(a) G = H - TS (b) G = U - TS (c) G = U + pV (d) G = H + TS

55. Ans. (a) Gibb's free energy 'G' is defined as G = H - TS.

88. Which one of the following relationships defines Gibb's free energy G? **[IAS-2007]**

(a) G=H + TS (b) G=H-TS (c) G= U+ TS (d) G= U-TS

88. Ans. (b)

52. Which one of the following relationships defines the Helmholtz function F?

(a) F = H + TS (b) F = H – TS

(c) F = U – TS (d) F = U +TS **[IES 2007]**

Ans. (c)

20. The Gibbs free-energy function is a property comprising **[IAS-1998]**
(a) pressure, volume and temperature (b) ethalpy, temperature and entropy
(c) temperature, pressure and ethalpy (d) volume, ethalpy and entropy
20. Ans. (b)

53. Assertion (A): For a mixture of solid, liquid and vapour phases of a pure substance in equilibrium, the number of independent intrinsic properties needed is equal to one.
Reason(R): Three phases can coexist only at one particular pressure. **[IES-2005]**
53. Ans. (d) F = C – P + 2
C = 1, P = 3 or F = 1 – 3 + 2 = 0

112. Consider the following statements: **[IES-2000]**

1. Azeotropes are the mixtures of refrigerants and behave like pure substances.
2. Isomers refrigerants are compounds with the same chemical formula but have different molecular structures.
3. The formula n + p + q = 2m is used for unsaturated chlorofluorocarbon compounds

(m, n, p and q are the numbers atoms of carbon, hydrogen, fluorine and chlorine respectively)
Which of these statements are correct?
(a) 1 and 3 (b) 2 and 3 (c) 1 and 2 (d) 1, 2 and 3
112. Ans. (a)

Types of Equilibrium

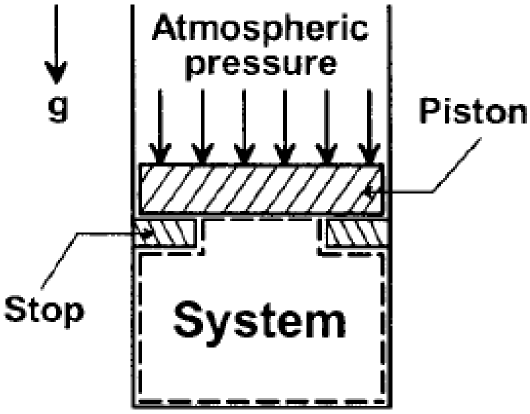
Local Equilibrium Conditions

Conditions of Stability

7. PURE SUBSTANCES

Common data for Question 71, 72 and 73

In the figure shown, the system is a pure substance kept in a piston-cylinder arrangement. The system is initially a two-phase mixture containing 1 kg of liquid and 0.03 kg of vapour at a pressure of 100 kPa. Initially, the piston rests on a set of stops, as shown in the figure. A pressure of 200 kPa is required to exactly balance the weight of the piston and the outside atmospheric pressure. Heat transfer takes place into the system until its volume increases by 50%. Heat transfer to the system occurs in such a manner that the piston, when allowed to move, does so in a very slow (quasi-static I quasi-equilibrium) process. The thermal reservoir from which heat is transferred to the system has a temperature of 400°C. Average temperature of the system boundary can be taken as 17^0C. The heat transfer to the system is I kJ, during which its entropy increases by 10 J/K.
Atmospheric pressure



Specific volumes of liquid (v_f) and vapour (v_g) phases, as well as values of saturation temperatures, are given in the table below.

Pressure (kPa)	Saturation temperature, T_{sat} (^oC)	$v_f(m^3/kg)$	$v_g(m^3/kg)$
100	100	0.001	0.1
200	200	0.0015	0.002

71. At the end of the process, which one of the following situations will be true? **[GATE-2008]**
(A) superheated vapour will be left in the system
(B) no vapour will be left in the system
(C) a liquid + vapour mixture will be left in the system
(D) the mixture will exist at a dry saturated vapour state

71. Ans. (A) Initial Volume (V_1) = $0.001 + 0.03 \times 0.1\ m^3 = 0.004\ m^3$
let dryness fraction = x
Therefore $0.004 \times 1.5 = (1-x) \times 0.0015 \times 1.03 + x \times 0.002 \times 1.03$
That gives an absurd value of x =8.65 (It must be less than equal to unity)
So vapour is superheated.

72. The work done by the system during the process is **[GATE-2008]**

(A) 0.1 kJ (B) 0.2 kJ (C) 0.3 kJ (D) 0.4kJ

72. Ans. (D) Work done = first constant volume heating + $\int pdv$

= 0 + P (V_2-V_1) = 200 $\times$(0.006-0.004) = 0.4 kJ

73. The net entropy generation (considering the system and the thermal reservoir together) during the process is closest to **[GATE-2008]**

(A) 7.5 J/K (B) 7.7 J/K (C) 8.5 J/K (D) 10 J/K

73. Ans. (C)

($\Delta S = (\Delta S)_{syatem} + (\Delta S)_{surroundings}$ = 10 – $\frac{1000}{(273+400)}$ =8.51 J/K

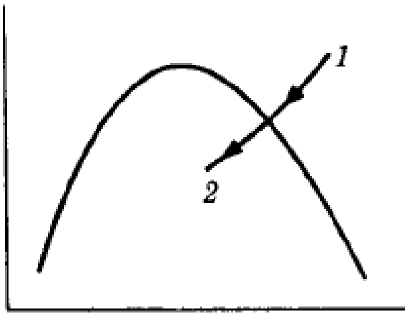
38. Assertion (A): Water is not a pure substance. **[IES-1999]**
Reason (R): The term pure substance designates a substance which is homogeneous and has the same chemical composition in all phases.

38. Ans. (d) Water for all practical purpose can be considered as pure substance because it is homogeneous and has same chemical composition under all phases.

71. The given diagram shows an isometric cooling process 1-2 of a pure substance. The ordinate and abscissa are respectively

(a) pressure and volume
(b) enthalpy and entropy
(c) temperature and entropy
(d) pressure and enthalpy

[IES-1998]

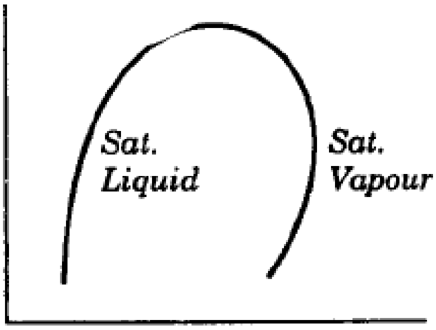


71. Ans. (c)

31. The ordinate and abscissa in the given figure showing the saturated liquid and vapour regions of a pure substance represent:

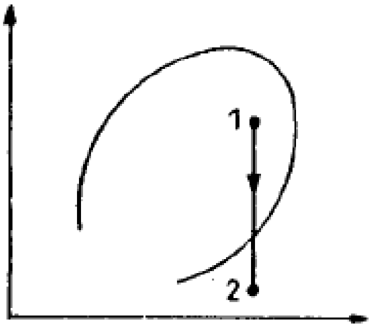
(a) temperature and pressure
(b) enthalpy and entropy
(c) pressure and volume
(d) pressure and enthalpy

[IES-1997]



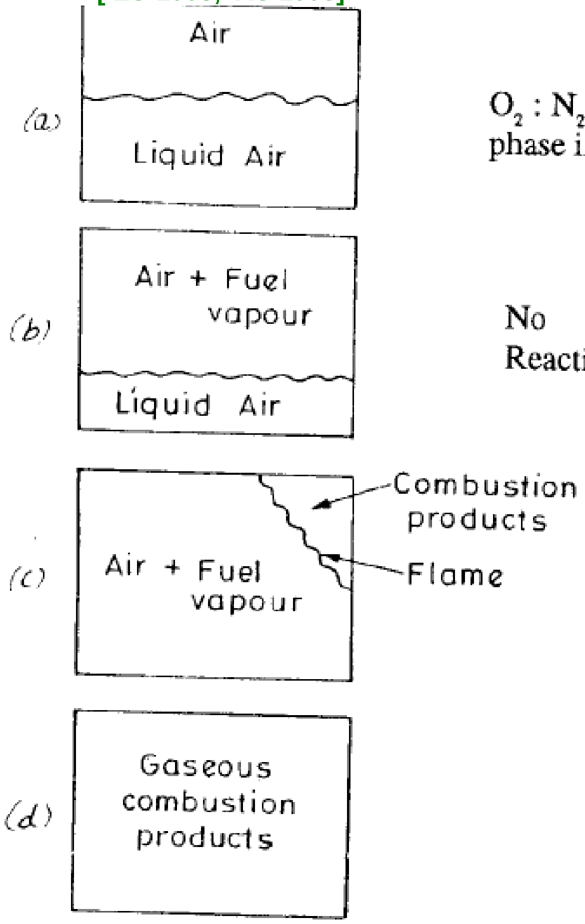
31. Ans. (d) The ordinate and abscissa in given figure are pressure and enthalpy. Such diagram is common in vapour compression refrigeration systems.

49. The given diagram shows the throttling process of a pure substance. **[IES-1995]**
The ordinate and abscissa are respectively
(a) pressure and volume (b) enthalpy and entropy
(c) temperature and entropy (d) pressure and enthalpy.



49. Ans. (d) The throttling process given in figure is on pressure-enthalpy diagram.

44. Which one of the following systems can be considered to be containing a pure substance? **[IES-1993, IAS 1998]**



$O_2 : N_2$ proportions differ in the gas and liquid phase in equilibrium

No Reaction

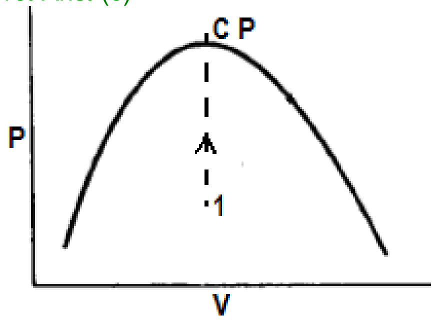
Fig. 8

44. Ans. (a) Air and liquid air can be considered to be containing a pure substance, because air is also considered to be a perfect gas. All other mixtures are not pure substances.

64. Assertion (A): On the enthalpy-entropy diagram of a pure substance the constant dryness fraction lines start from the critical point. **[IAS-2001]**
Reason (R): All the three phases co-exist at the critical point.
64. Ans. (c) Only two phase liquid-vapour is co-exists at the critical point, but at triple point-all three phase are co-exists.

26. Assertion (A): Air, a mixture of O_2 and N_2, is a pure substance. **[IAS-2000]**
Reason(R): Air is homogeneous in composition and uniform in chemical aggregation.
26. Ans. (a) A pure substance is a substance of constant chemical composition throughout its mass.

16. If a pure substance contained in a rigid vessel passes through the critical state on heating, its initial state should be **[IAS-1998]**
(a) subcooled water (b) saturated water (c) wet steam (d) saturated steam
16. Ans. (c)



80. Assertion (A): Air is a pure substance but a mixture of air and liquid air in a cylinder is not a pure substance.
Reason (R): Air is homogeneous in composition but a mixture of air and liquid air is heterogeneous. **[IAS-1996]**
80. Ans. (a)

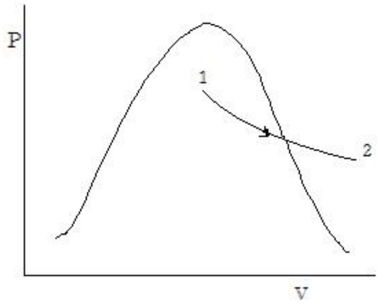
114. Assertion (A):Temperature and pressure are sufficient to fix the state of a two phase system.
Reason(R): Two independent and intensive properties are required to be known to define the state of a pure substance. **[IAS-1995]**
114. Ans. (d) A is false but R is true

53. Assertion (A): At a given temperature, the enthalpy of super-heated steam is the same as that of saturated steam. **[IES-1998]**
Reason (R): The enthalpy of vapour at lower pressures is dependent on temperature alone.
53. Ans. (d)

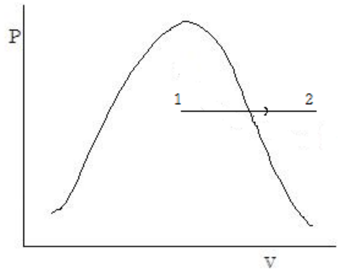
p-v Diagram for a Pure Substance

50. Which p-v diagram for steam illustrates correctly the isothermal process undergone by wet steam till it becomes superheated?

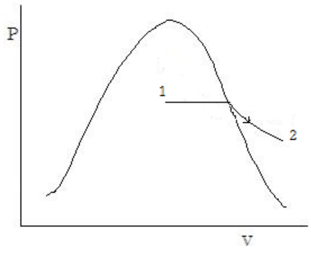
(a)



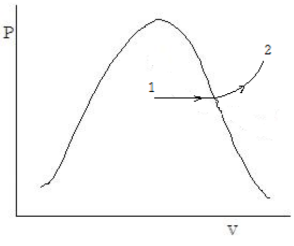
(b)



(c)



(d)



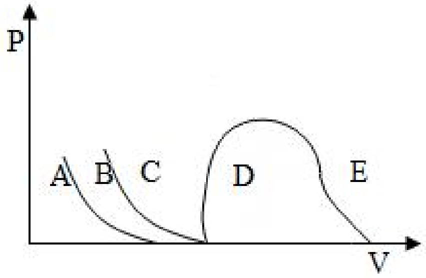
[IES 1995, 2007]

Ans. (c) Up to saturation point pressure must be constant. After saturation its slope will be –ive, as pv=RT or pv=const. or vdp+pdv=0 or $\frac{dp}{dv} = -\frac{p}{v}$

114. Two-phase regions in the given pressure-volume diagram of a pure substance are represented by

(a) A, E and F
(b) B, C and D
(c) B, D and F
(d) A, C and E

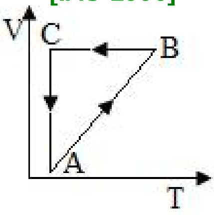
[IAS-1999]



114. Ans. (c)

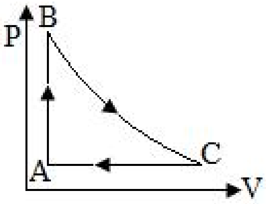
23. A cyclic process ABC is shown on a V- T diagram in fig.

[IAS-1996]

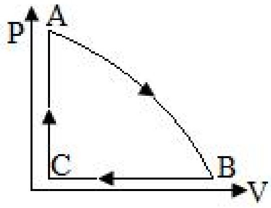


The same process on a P-V diagram will be represent as

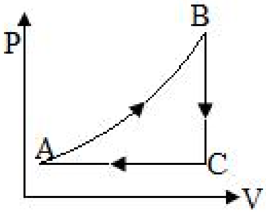
(a)



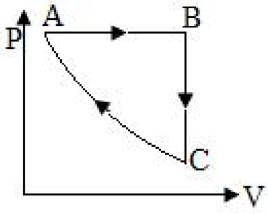
(b)



(c)



(d)

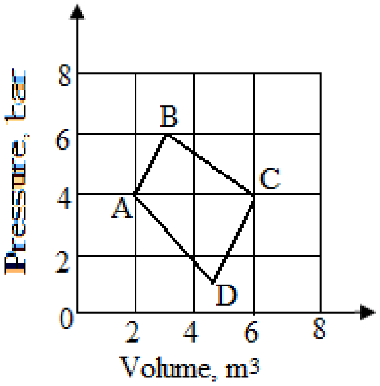


23. Ans. (d)

57. The network done for the closed shown in the given pressure-volume diagram, is

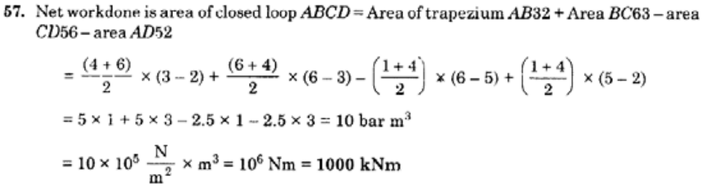
(a) 600kN-m (b) 700kN-m

(c) 900kN-m (d) 1000kN-m



[IAS-1995]

57. Ans. (d)



57. Net workdone is area of closed loop $ABCD$ = Area of trapezium $AB32$ + Area $BC63$ – area $CD56$ – area $AD52$

$$= \frac{(4+6)}{2} \times (3-2) + \frac{(6+4)}{2} \times (6-3) - \left(\frac{1+4}{2}\right) \times (6-5) + \left(\frac{1+4}{2}\right) \times (5-2)$$

$$= 5 \times 1 + 5 \times 3 - 2.5 \times 1 - 2.5 \times 3 = 10 \text{ bar m}^3$$

$$= 10 \times 10^5 \frac{\text{N}}{\text{m}^2} \times \text{m}^3 = 10^6 \text{ Nm} = 1000 \text{ kNm}$$

Triple point

89. Triple point temperature of water is **[IAS-2000]**

(a) 273 K (b) 273.14 K (c) 273.15K (d) 273.16 K

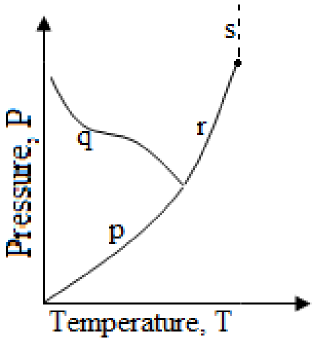
89. Ans. (d) Remember: Triple point temperature of water = 273.16 K = 0.01°C

p-T Diagram for a Pure Substance

17. In the following P-T diagram of water showing phase equilibrium lines, the sublimation line is

(a) p

[IAS-1998]



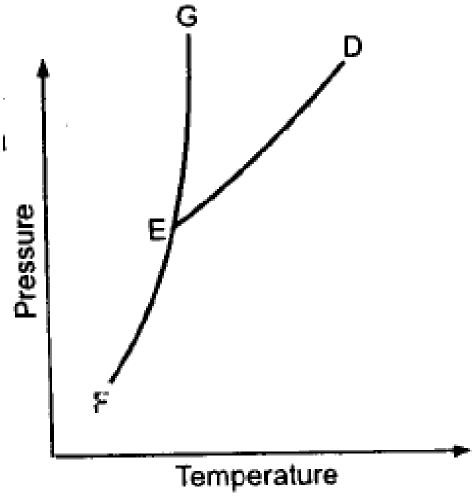
17. Ans. (a)

20. Consider the phase diagram of a certain substance as shown in the given figure. Match List-I (Process) with List-II (Curves/lines) and select the correct answer using the codes given below the lists:

List-I (Process	List-II (Curves/lines)
A. Vaporization	1. EF
B. Fusion	2. EG
C. Sublimation	3. ED

	A	B
(a)	1	3
(c)	3	2

[IES-2001]



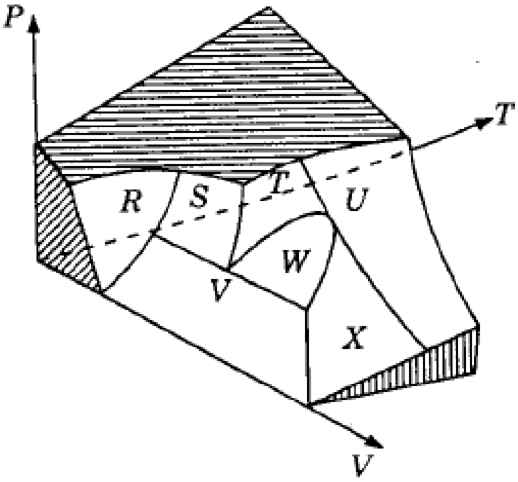
20. Ans. (a)

p-v-T Surface

58. The p-v-T surface of a pure substance is shown in the given p figure. The two-phase regions are labelled as

(a) R, T and X
(b) S, U and W
(c) S, W and V
(d) R, T and V

[IES-1999]

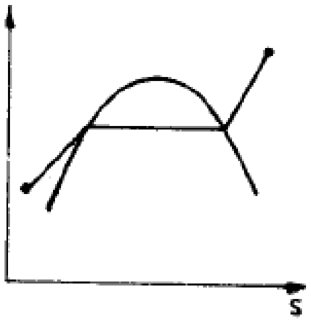


58. Ans. (c)

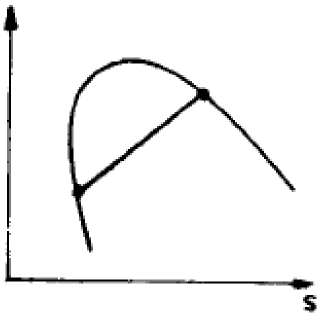
T-s Diagram for a Pure Substance

76. The conversion of water from 40°C to steam at 200°C pressure of 1 bar is best represented as **[IES-1994]**

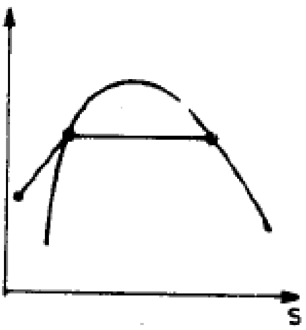
(a)



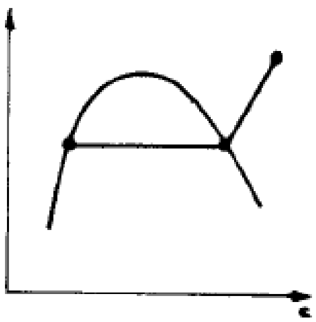
(b)



c)



(d)

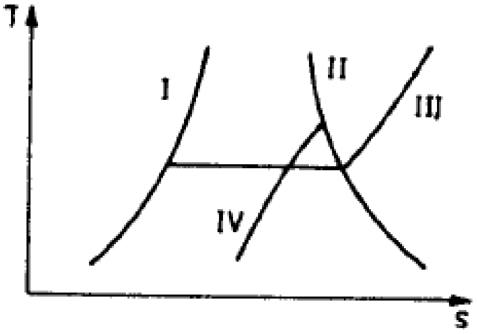


76. Ans. (a)

77. The following figure shows the T-s diagram for steam. With respect to this figure, match List I with List II and select the correct answer using the codes given below the Lists:

List I	
A. Curve I	1. Saturated liquid line
B. Curve II	2. Saturated vapour line
C. Curve III	3. Constant pressure line
D. Curve IV	4. Constant volume line

[IES-1994]



Codes:	A	B	C	D		A	B	C	D
(a)	2	1	4	3	(b)	2	1	3	4
(c)	1	2	3	4	(d)	1	2	4	3

77. Ans. (c)

86. Entropy of a saturated liquid at 227^0 C is 2.6 kJ/kgK. Its latent heat of vaporization is 1800 kJ/kg; then the entropy of saturated vapour at 227^{0}C would be **[IAS-2001]**
(a) 2.88 kJ/kg K (b) 6.2 kJ/kg K (c) 7.93 kJ/kg K (d) 10.53 kJ/kg K

86. $S_g = S_f + \frac{h_{fg}}{T_{sat}} = 2.6 + \frac{1800}{500} = 6.2\, kJ / kgK$

115. Two heat engine cycles (l - 2 - 3- 1 and l' - 2' - 3' - l') are shown on T-s co-ordinates in

[IAS-1999]

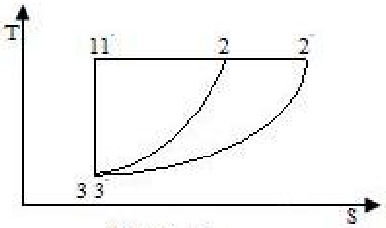
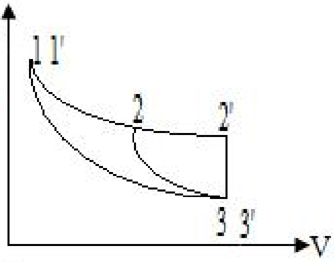
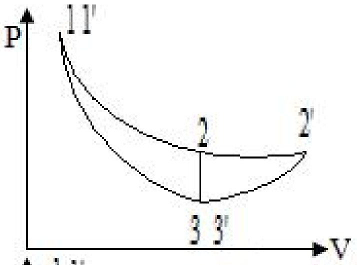


Figure - I

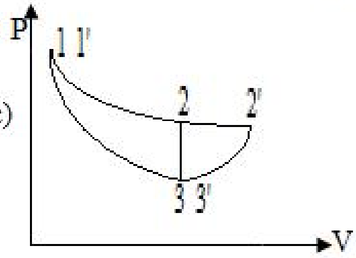
(a)



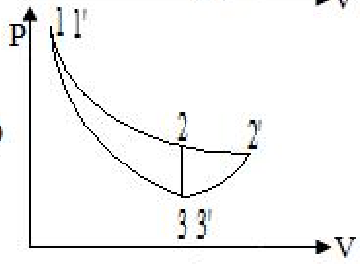
(b)



(c)

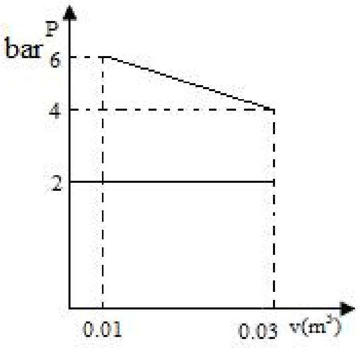


(d)



115. Ans. (d)

117. The mean effective pressure of the thermodynamic cycle shown in the given pressure-volume diagram is



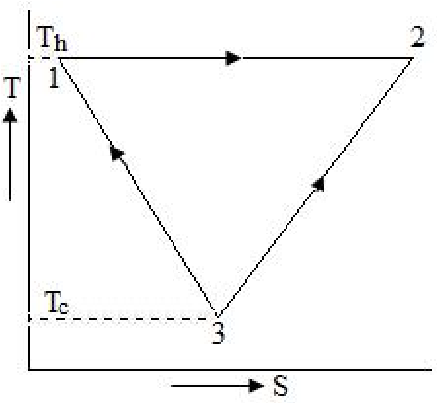
(a) 3.0 bar
(c) 4.0 bar

[IAS-1999]

117. Ans. (a) Work (W) = $(0.03-0.01)\times(400-200)+\frac{1}{2}\times(600-400)\times(0.03-0.01)=6\text{kJ}$

$$W=p_m\times\Delta V \text{ or } p_m=\frac{W}{\Delta V}=\frac{6}{(0.03-0.01)}\text{kPa}=3\text{bar}$$

25. The given figure shows a thermodynamic cycle on T-s diagram. All the processes are straight times. The efficiency of the cycle is given by



(a) $(0.5\ T_h - T_e)/\ T_h$
(b) $0.5\ (T_h - T_e)/\ T_h$
(c) $(T_h - T_e)/\ 0.5\ T_h$
(d) $(T_h - 0.5\ T_e)/\ T_h$
[IAS-1996]

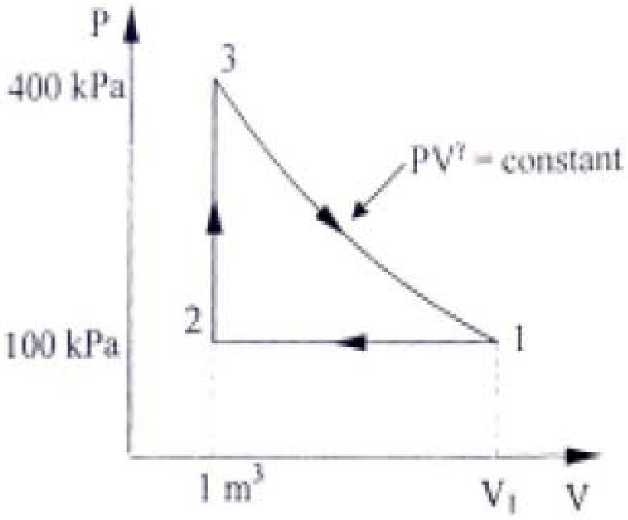
25. Ans. (b) Work output = Area 123 = $\frac{1}{2}\times\left(T_h - T_c\right)\times\left(S_2 - S_1\right)$

Heat added = Area under $1-2 = T_h\left(S_2 - S_1\right)$

$$\therefore \eta = \frac{\frac{1}{2}\left(T_h - T_c\right)\left(S_2 - S_1\right)}{T_h\left(S_2 - S_1\right)} = 0.5\left(T_h - T_c\right)/\,T_h$$

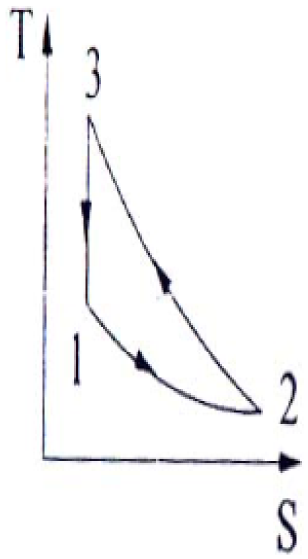
Common Data for Questions 59-60

A thermodynamic cycle with an ideal gas as working fluid is shown below.

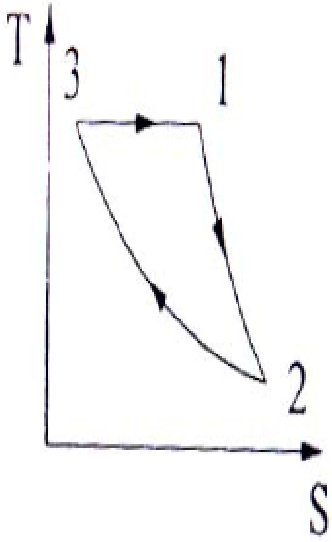


59. The above cycle is represented on T-S plane by **[GATE-2007]**

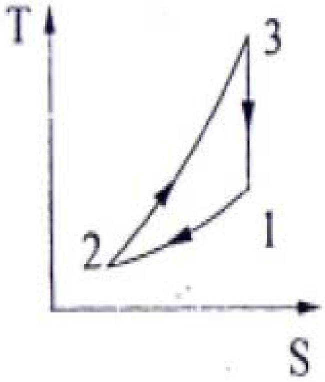
(A)



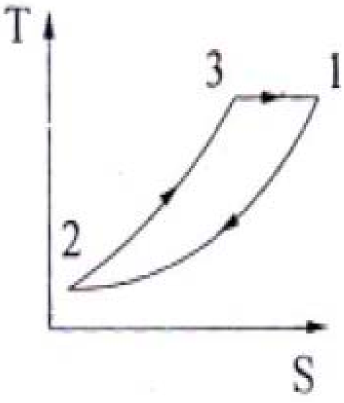
(B)



(C)



(D)



59. Ans. (c)

60. If the specific heats of the working fluid are constant and the value of specific heat ratio γ is 1.4, the thermal efficiency (%) of the cycle is **[GATE-2007]**
(a) 21 (b) 40.9 (c) 42.6 (d) 59.7
60. Ans. (b)

2.12. The slopes of constant volume and constant pressure lines in the T- s diagram are….. and….. respectively. **[GATE-1994]**
2.12 Ans. Higher, Lower

Critical Point

100. Which one of the following statements is correct when saturation pressure of a vapour increases?
(a) Saturation temperature decreases (b) Enthalpy of evaporation decreases
(c) Enthalpy of evaporation increases

(d) Specific volume change of phase increases **[IES 2007]**
Ans. (b)

64. Match List I with List II and select the correct answer using the code given below the Lists:

List I	List II **[IES-2005]**
A Critical point	1. All the three phases - solid, liquid and vapour co-exists in equilibrium
B. Sublimation	2. Phase change form solid to liquid
C. Triple point	3. Properties of saturated liquid and saturated vapour are identical
D. Melting	4. Heating process where solid gets directly transformed to gaseous phase

	A	B	C	D		A	B	C	D
(a)	2	1	4	3	(b)	3	4	1	2
(c)	2	4	1	3	(d)	3	1	4	2

64. Ans. (b)

33. With increase of pressure, the latent heat of steam **[IES-2002]**
(a) remains same (b) increases (c) decreases (d) behaves unpredictably
33. Ans. (c)

45. Consider the following statements about critical point of water: **[IES-1993]**
1. The latent heat is zero.
2. The liquid is denser than its vapour.
3. Steam generators can operate above this point.

Of these statements
(a) 1,2 and 3 are correct (b) 1 and 2 are correct
(c) 2 and 3 are correct (d) 1 and 3 are correct
45. Ans. (d) At critical point, the latent heat in zero and steam generators can operate above this point as in the case of once through boilers.
The density of liquid and its vapour is however same and thus statement 2 is wrong.

48. List I gives some processes of steam whereas List II gives the effects due to the processes. Match List I with List II, and select the correct answer using the codes given below the lists:

List I	List II **[IES-1995]**
A. As saturation pressure increases	1. Entropy increases.
B. As saturation temperature increases	2. Specific volume increases.
C. As saturation pressure decreases	3. Enthalpy of evaporation decreases.
D. As dryness fraction increases	4. Saturation temperature increases.

Code:	A	B	C	D		A	B	C	D
(a)	1	3	2	4	(b)	4	3	2	1
(c)	4	3	1	2	(d)	2	4	3	1

48. Ans. (c)

h-s Diagram or Mollier Diagram for a Pure Substance

1.12. Constant pressure lines in the superheated region of the Mollier diagram will have **[GATE-1995]**

(a) a positive slope (b) a negative slope (c) zero slope (d) both positive and negative slope
1.12 Ans. (a)

86. Constant pressure lines in the superheated region of the Mollier diagram have what type of slope? **[IAS-2007]**
(a) A positive slope (b) A negative slope
(c) Zero slope (d) May have either positive or negative slopes
86. Ans. (a) Mollier diagram is a h-s plot.

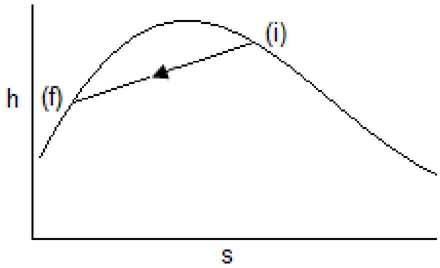
$$Tds = dh - \upsilon dp \qquad \text{or} \qquad \left(\frac{\partial h}{\partial s}\right)_P = T = slope$$

T is always + ive so slope always +ive. Not only this if T↑ then slope ↑

113. Assertion (A): In Mollier chart for steam, the constant pressure lines are straight lines in wet region.
Reason (R): The slope of constant pressure lines in wet region is equal to T. **[IAS-1995]**
113. Ans. (a) Both A and R are true and R is the correct explanation of A

44. Which one of the following represents the condensation of a mixture of saturated liquid and saturated vapour on the enthalpy-entropy diagram? **[IES-2004]**
(a) A horizontal line (b) An inclined line of constant slope
(c) A vertical line (d) A curved line

44. Ans. (b)



$$Tds = dh - Vdp \qquad \text{Or} \qquad \left(\frac{\partial h}{\partial s}\right)_P = T$$

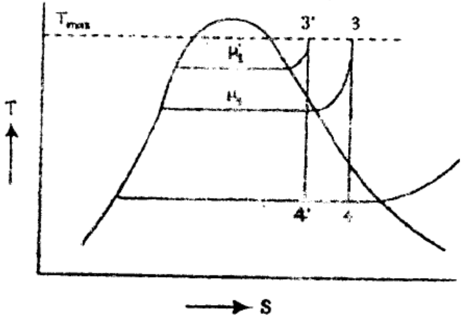
The slope of the isobar on the h-s diagram is equal to the absolute temp, for condensation T is cost so slope is const, but not zero so it is inclined line.

Quality or Dryness Fraction

84. Dryness fraction of steam means the mass ratio of **[IAS-2001]**
(a) wet steam, to dry steam (b) dry steam to water particles in steam
(c) water particles to total steam (d) dry steam to total steam
84. Ans. (d)

3.6 Consider a Rankine cycle with superheat. If the maximum pressure in tile cycle is increased without changing the maximum temperature and the minimum pressure, the dryness fraction of steam after the isentropic expansion will increase. **[GATE-1995]**
3.6 Ans. False

Explanation. $P'_1 > P_1$. Dryness fraction after isentropic expansion decreases.



Steam Tables

Charts of Thermodynamic Properties

Measurement of Steam Quality

69. Saturated liquid at a high pressure P_1 having enthalpy of saturated liquid 1000 kJ/kg is throttled to a lower pressure P_2. At pressure p_2 enthalpy of saturated liquid and that of the saturated vapour are 800 and 2800 kJ/kg respectively. The dryness fraction of vapour after throttling process is **[IES-2003]**

(a) 0.1 (b) 0.5 (c) 18/28 (d) 0.8

69. Ans. (a)

$$\text{For throttling process } (1-2),\ h_1 = h_2$$
$$h_1 = h_f = 1000 \text{ kJ/kg at pressure } P_1$$
$$h_2 = h_f + x\,(h_g - h_f) \text{ at pressure } P_2$$
$$\therefore 1000 = 800 + x\,(2800 - 800)$$
$$\text{or}\quad x = 0.1$$

34. Consider the following statements regarding the throttling process of wet steam: **[IES-2002]**
1. The steam pressure and temperature decrease but enthalpy remains constant.
2. The steam pressure decreases, the temperature increases but enthalpy remains constant.
3. The entropy, specific volume, and dryness fraction increase.
4. The entropy increases but the volume and dryness fraction decrease.

Which of the above statements are correct?

(a) 1 and 4 (b) 2 and 3 (c) 1 and 3 (d) 2 and 4

34. Ans. (c)

79. Match List - I with List - II and select the correct answer using the code given below the Lists: **[IES-2006]**

List - I (Apparatus)	List - II (Thermodynamic process)
A. Separating calorimeter	1. Adiabatic process
B. Throttling calorimeter	2. Isobaric process
C. Sling psychrometer	3. Isochoric process
D. Gas thermometer	4. Isenthalpic process

	A	B	C	D		A	B	C	D
(a)	1	3	2	4	(b)	2	4	1	3
(c)	1	4	2	3	(d)	2	3	1	4

79. Ans. (c)

79. Select the correct answer using the codes given below the Lists:

List-I	List-II **[IES-1998]**
A. Bomb calorimeter	1. Pressure
B. Exhaust gas calorimeter	2. Enthalpy
C. Junker gas calorimeter	3. Volume
D. Throttling calorimeter	4. Specific heats

Code:	A	B	C	D		A	B	C	D
(a)	3	4	1	2	(b)	2	4	1	3
(c)	3	1	4	2	(d)	4	3	2	1

79. Ans. (a)

Throttling

36. Consider the following statements: **[IES-2000]**

When dry saturated steam is throttled from a higher pressure to a lower pressure, the

1. pressure decreases and the volume increases
2. temperature decreases and the steam becomes superheated
3. temperature and the dryness fraction increase
4. entropy increases without any change in enthalpy

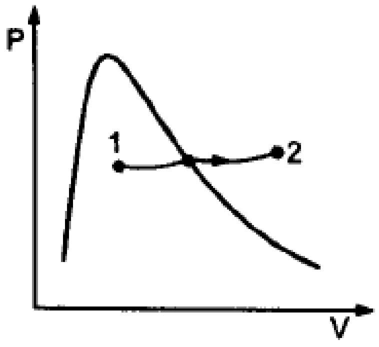
Which of these statements are correct?

(a) 1and 4 (b) 1, 2 and 4 (c) 1 and 3 (d) 2 and 4

36. Ans. (b)

34. The process 1-2 for steam shown in the given figure is

(a) isobaric
(b) isentropic
(c) isenthalpic
(d) isothermal
[IES-2000]



34. Ans. (c)

A fluid flowing along a pipe line undergoes a throttling process from 10 bar to 1 Bar in passing through a partially open valve. Before throttling, the specific volume of the fluid is 0.5 m^3 /kg and after throttling is 2.0 m^3 /kg. What is the Change in specific internal energy during the throttling process?

(a) Zero (b) 100 kJ/kg
(c) 200 kJ/kg (d) 300 kJ/kg **[IES 2007]**

Ans. (d) Throttling is a isenthalpic process

$h_1=h_2$ or $u_1+p_1v_1=u_2+p_2v_2$ or $u_2-u_1=p_1v_1-p_2v_2 = 1000\text{x}0.5 - 100\text{x}2 = 300$ kJ/kg

84b. When saturated liquid at 40°C is throttled to -20°C, the quality at exit will be **[GATE-2005]**
(a) 0.189 (b) 0.212 (c) 0.231 (d) 0.788

84b. Ans. (b)

$$h_{40} = h_{-20} = (1-x)h_{f-20} + xh_g$$

$$\text{or } 371.43 = (1-x)89.05 + x \times 1418.0 \quad \text{or } x = 0.212$$

1.17 When wet steam flows through a throttle valve and remains wet at exit **[GATE-1996]**
(a) its temperature and quality increases
(b) its temperature decreases but quality increases
(c) its temperature increases but quality decreases
(d) its temperature and quality decreases

1.17 Ans. (b)

2.7 When an ideal gas with constant specific heats is throttled adiabatically, with negligible changes in kinetic and potential energies **[GATE-2000]**

$(a)\, \Delta h = 0, \Delta T = 0$ $(b)\, \Delta h > 0, \Delta T = 0$ $(c)\, \Delta h > 0, \Delta S > 0$ $(d)\, \Delta h = 0, \Delta S > 0$

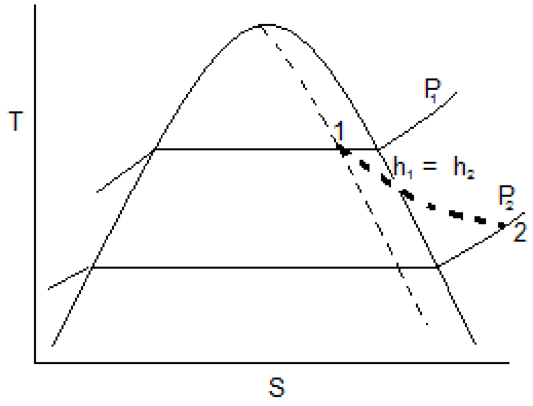
Where h, T and S represent respectively, enthalpy, temperature and entropy, temperature and entropy

2.7 Ans. (d)

$\Delta h = o$

$\Delta s > 0$

$\Delta T < 0$



5.9 One kilomole of an ideal gas is throttled from an initial pressure of 0.5 MPa to 0.1 MPa. The initial temperature is 300 K. The entropy change of the universe is **[GATE-1995]**
(a) 13.38 kJ/K (b)401.3 kJ/K (c) 0.0446 kJ/K (d) -0.0446 kJ/K

5.9 Ans. (a)

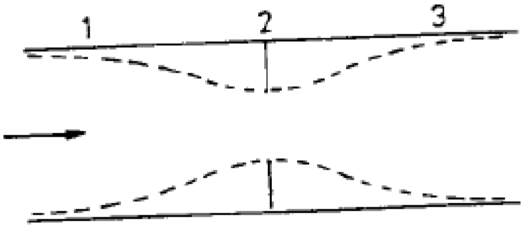
Explanation. $S_2 - S_1 = C_{p\,av}\, ln\frac{T_2}{T_1} - R_u\, ln\frac{P_2}{P_1}$

Change in entropy of the universe $= -R_u\, ln\frac{P_2}{P_1}$

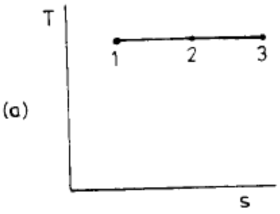
$$= -8.314\, ln\frac{0.1}{0.5} = 13.38\frac{kJ}{K}.$$

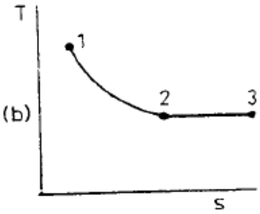
For an ideal gas change in enthalpy is a function of temperature alone and change in enthalpy of a throttling rocess is zero.

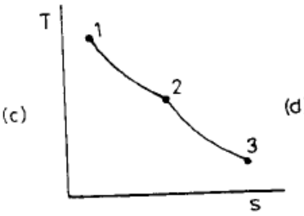
74. The throttling process undergone by a gas across an orifice is shown by its states in the following figure:

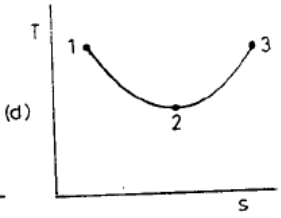


[IES-1996]





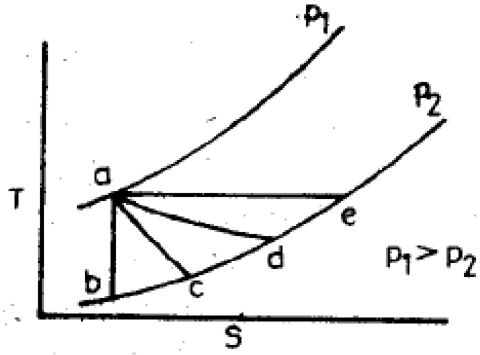




74. Ans. (c) The throttling process takes places with enthalpy remaining constant. This process on T-S diagram is represented by a line starting diagonally from top to bottom.

26. In the figure shown, throttling process is represented by
(a) a e
(b) a d
(c) a c
(d) a b

[IES-1



26. Ans. (b)

20. Assertion (A): Throttle governing is thermodynamically more efficient than nozzle control governing for steam turbines. **[IAS-2000]**
Reason (R): Throttling process conserves the total enthalpy.
20. Ans. (d) If throttle governing is done at low loads, the turbine efficiency is considerably reduced. The nozzle control may then be a better method of governing.

8. PROPERTIES OF GASSES AND GAS MIXTURE

HIGHLIGHTS

1. The functional relationship among the independent properties, pressure P, molar or specific volume v, and temperature T, is known as '*Equation of state*' i.e. PV=RT for gases.

2. A hypothetical gas which obeys the law PV = RT at all temperatures and pressures is called an '*ideal gas*'
   - An '*ideal gas*' has no forces of intermolecular attraction.
   - The specific heat capacities are constant.

3. *'Real gas'* does not conform to equation of state with complete accuracy. As $P \rightarrow 0$ or $T \rightarrow \infty$, the real gas approaches the ideal gas behavior.

4. Joule's law states that the specific internal energy of a gas depends only on the temperature of the gas and is independent of both pressure and volume.

5. Reversible adiabatic process for a gas
   (i) $PV^{\gamma} = c$ (ii) $\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{(\gamma-1)/\gamma} = \left(\frac{V_1}{V_2}\right)^{(\gamma-1)}$

6. For Isentropic processes

   (i) For closed system $\int_1^2 pdv = \frac{P_1V_1 - P_2V_2}{\gamma - 1}$ (note p_1v_1 terms comes first)

   (ii) For flow work or steady flow $-\int_1^2 vdp = \frac{\gamma}{\gamma - 1}(P_1V_1 - P_2V_2)$

7. Polytropic process
   It is not adiabatic, but it can be reversible.
   For reversible polytropic process [all n]

   For closed system, $W = \int_1^2 pdv = \frac{P_1V_1 - P_2V_2}{n - 1}$

   For Open system, $W = -\int_1^2 vdp = \frac{n}{n - 1}[P_1V_1 - P_2V_2]$

   If the process is polytropic but we don't know it is reversible or not then use [mix. of n & γ]

   For closed system, First Law $W - Q = \frac{P_1V_1 - P_2V_2}{\gamma - 1} = \frac{P_1V_1}{\gamma - 1}\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$

   For steady flow, SFEE $W - Q + \Delta\left(\frac{v^2}{2} + gz\right) = \frac{\gamma}{\gamma - 1}(P_1V_1 - P_2V_2)$

$$=\frac{\gamma}{\gamma-1}P_1V_1\left[\left(\frac{P_2}{P_1}\right)^{\frac{(n-1)}{n}}-1\right]$$

8. a. Isobaric process (P=C), i.e. n=0 ($PV^0=C$)
   b. Isothermal process (T=C), i.e. n=1 (PV=RT)
   c. Isentropic process (S=C), i.e. n=γ ($PV^\gamma=C$)
   d. Isomeric or Isochoric process (V=C) i.e. n=∞ ($P^{\frac{1}{\gamma}}V=C^{\frac{1}{\gamma}}$ if $\gamma\rightarrow\infty$, V = C)

9. For minimum work in multistage compression $P_2=\sqrt{P_1P_3}$

   a. Equal pressure ratio i.e. $\frac{P_2}{P_1}=\frac{P_3}{P_2}$
   b. Equal discharge temperature i.e. $T_2=T_3$
   c. Equal work required for both the stages.

10. Equation of states for real gas

    a. Van der waals equation $(P+\frac{a}{v^2})(v-b)=RT$

    The coefficient a is introduced to account for the existence of mutual attraction between the molecules. The term a/v^2 is called the *force of cohesion.* The coefficient b is introduced to account for the volumes of the molecules, and is known as *co-volume*.

    b. Beattie Bridgeman equation

    $$P=\frac{RT(1-e)(v+B)}{v^2}-\frac{A}{v^2}$$

    Where $A=A_0\left(1-\frac{a}{v^2}\right)$

    $B=B_0\left(1-\frac{b}{v}\right)$

    $e=\frac{c}{vT^3}$

    This equation does not give satisfactory results in the critical point region.

11. The ratio $\frac{PV}{RT}$ is called the *compressibility factor.*

    Value of compressibility factor (Z) at critical point is 0.375 for Van der waals gas.
For ideal gas z = 1

12. Critical Properties

$$a = 3P_cV_c^2, \qquad b = \frac{V_c}{3}, \text{ and } \quad R = \frac{8}{3}\frac{P_cV_c}{T_c}$$

Where P_c, V_c and T_c are critical point pressure, volume and temperature respectively.

At Critical Point

(i) Three real roots of Vander Waal equation coincide.

(ii) $\left(\frac{\partial p}{\partial v}\right)_{T_c} = 0$ i.e. Slope of p-v diagram is zero.

(iii) $\left(\frac{\partial^2 p}{\partial v^2}\right)_{T_c} = 0$ i.e. Change of slope also zero.

(iv) $\left(\frac{\partial^3 p}{\partial v^3}\right)_{T_c} < 0$ i.e. negative, and equal to $-9p_c$

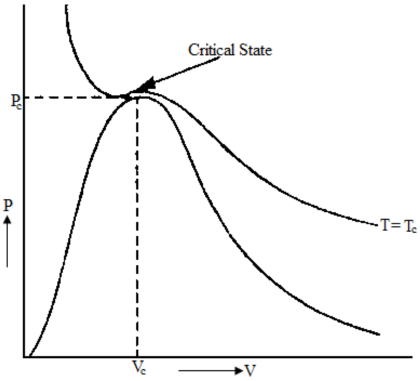


Fig. Critical properties on p-v diagram

13. Boyle's Temperature (T_B) = $\frac{a}{bR}$

Boyle's Law is obeyed fairly accurately up to a moderate pressure and the corresponding temperature is called the Boyle's Temperature.

14. Dalton's Law

a. The pressure of a mixture of gases is equal to the sum of the partial pressures of the constituents.

b. The partial pressure of each constituent is that pressure which the gas would exert if it occupied alone that volume occupied by the mixture at the same temperature.

15. Gibbs-Dalton Law

a. The internal energy, enthalpy and entropy of a gaseous mixture are respectively equal to the sum of the internal energies, enthalpies, entropies of the constituents.

b. Each Constituent has that internal energy, enthalpy and entropy, which it would have if it occupied alone that volume occupied by the mixture at the same temperature.

16. Equivalent molecular weight (M_e) = $x_1M_1+x_2M_2+$------------$+ x_nM_n$
Equivalent gas constant (R_e) = $x_1R_1+x_2R_2+$-------------$+x_nR_n$
Equivalent constant volume specific heat (Cv_e) = $x_1Cv_1+x_2Cv_2+$------------$+x_nC_nv$
Equivalent constant pressure specific heat (Cp_e) = $x_1Cp_1+x_2Cp_2+$------------$+x_nCp_n$

$$x_i = \frac{m_i}{m} = \text{mass fraction of a constituent}$$

17. The value of Universal Gas constant R = 8.3143 KJ/Kg mole K

Avogadro's Law

6. Assertion (A): The mass flow rate through a compressor for various refrigerants at same temperature and pressure, is proportional to their molecular weights.

Reason (R): According to Avogardo's Law all gases have same number of moles in a given volume of same pressure and temperature. **[IES-2002]**

Ans. (a) Both A and R correct and R is the correct explanation of A

Ideal Gas

1. Variation of pressure and volume at constant temperature are correlated through
(a) Charles law (b) Boyle's law (c) Joule's Law (d) Gay Lussac's Law **[IAS-2002]**

Ans. (b) Boyle's law: It states that volume of a given mass of a perfect gas varies inversely as the absolute pressure when temperature is constant.

30. Assertion (A): A perfect gas is one that satisfies the equation of state and whose specific heats are constant. **[IES-1993]**

Reason (R): The enthalpy and internal energy of a perfect gas are functions of temperature only.

30. Ans. (b) For perfect gas, both the assertion A and reason R are true. However R is not the explanation for A. A provides definition of perfect gas. R provides further relationship for enthalpy and internal energy but can't be reason for definition of perfect gas.

30. Consider an ideal gas contained in vessel. If intermolecular interaction suddenly begins to act, which of the following happens? **[IES-1992]**

(a) The pressure increase (b) The pressure remains unchanged
(c) The pressure increase (d) The gas collapses

30. Ans. (a)

52. Which of the following statement is correct? **[IES-1992]**

(a) Boilers are occasionally scrubbed by rapidly and artificially circulating water inside them to remove any thin water film may have formed on their inside

(b) A sphere, a cube and a thin circular plate of the same mass are made of the same material. If all of them are heated to the same high temperature, the rate of cooling is maximum for the plate and minimum for the sphere.

(c) One mole of a monoatomic ideal gas is mixed with one mole of diatomic ideal gas. The molar specific heat of the mixture a constant volume is 2R, where R is the molar gas constant.

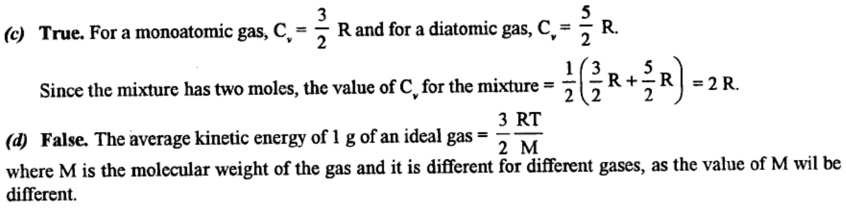
(d) The average kinetic energy of 1 kg of all ideal gases, at the same temperature, is the same.

52. Ans. (d)

(a) True. A water film, if formed, will act as a very poor conductor of heat and will not easily let the heat of the furnace pass into the boiler. An oil film if present, is even worse than water film and the formation of such films inside the boiler must be avoided.

(b) Since the mass and material are the same, the volumes must also be the same. For the same volume, the surface area of the plate is the greatest and that of the sphere is the least. The rate of loss of heat by

radiation being proportional to the surface area, the plate cools the fastest and the sphere the slowest.



(c) **True.** For a monoatomic gas, $C_v = \frac{3}{2}$ R and for a diatomic gas, $C_v = \frac{5}{2}$ R.

Since the mixture has two moles, the value of C_v for the mixture $= \frac{1}{2}\left(\frac{3}{2}R + \frac{5}{2}R\right) = 2R$.

(d) **False.** The average kinetic energy of 1 g of an ideal gas $= \frac{3}{2}\frac{RT}{M}$
where M is the molecular weight of the gas and it is different for different gases, as the value of M wil be different.

84. Assertion (A): For a perfect gas, hyperbolic expansion is an isothermal expansion.

Reason (R): For a perfect gas, $\frac{Pv}{T}$ = constant. **[IAS-2007]**

84. Ans. (a)

57. Variation of pressure and volume at constant temperature are correlated through
(a) Charle's law (b) Boyle's law(c) Joule's law (d) Gay Lussac's law
57. Ans. (b) **[IAS-2002]**

83. An ideal gas with initial volume, pressure and temperature of 0.1 m^3, 1bar and 27^0C respectively is compressed in a cylinder by a piston such that its final volume and pressure are 0.04m3 and 5bars respectively, then its final temperature will be **[IAS-2001]**
(a) - 123^0 C (b) 54^0 C (c) 327^0 C (d) 600^0 C

83. Ans. (c) $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \quad or\, T_2 = \frac{P_2V_2}{P_1V_1} \times T_1 = \frac{5\times 0.04}{1\times 0.1} \times (300) = 600\,K = 327^0 C$

5. Consider the following statements:
A real gas obeys perfect gas law at a very
1. High temperature 2. High-pressure 3. Low pressure
Which of the following statements is/are correct?
(a) 1 alone (b) 1 and 3 (c) 2 alone (d) 3 alone **[IES-2000]**
Ans (b) In Perfect gas intermolecular attraction is zero. It will be only possible when intermolecular distance will be too high. High temperature or low pressure or both cause high intermolecular distance so choice 1 and 3.

Equation of State of a Gas

46. The correct sequence of the decreasing order of the value of characteristic gas constants of the given gases is **[IES-1995]**
(a) hydrogen, nitrogen, air, carbon dioxide (b) carbon dioxide, hydrogen, nitrogen, air.
(c) air, nitrogen, carbon dioxide, hydrogen (d) nitrogen, air, hydrogen, carbon dioxide.
46. Ans. (a) The correct sequence for decreasing order of the value of characteristic gas constants is hydrogen, nitrogen, air and carbon dioxide.

63. If a real gas obeys the Clausius equation of state p(v - b) = RT then, **[IES-1992]**

(a) $\left(\frac{\partial u}{\partial v}\right)_T \neq 0$ (b) $\left(\frac{\partial u}{\partial v}\right)_T = 0$ (c) $\left(\frac{\partial u}{\partial v}\right)_T = 1$ (d) $\left(\frac{\partial u}{\partial v}\right)_T = \frac{1}{p}$

63. Ans. (b)

87. The volumetric air content of a tyre at 27°C and at 2 bars is 30 litres. If one morning, the temperature dips to -3°C then the air pressure in the tyre would be **[IAS-2000]**
(a) 1.8 bars (b) 1.1 bars (c) 0.8 bars (d) the same as at 27°C
87. Ans. (a) Apply equation of states

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \; [\because V_1 = V_2] \quad \text{or } P_2 = P_1 \times \frac{T_2}{T_1} = 2 \times \frac{(273-3)}{(273+27)} = 1.8\,\text{bar}$$

8.An Ideal gas with initial volume, pressure and temperature of 0.1m^3, 1 bar and 27^0C respectively is compressed in a cylinder by piston such that its final volume and pressure $0.04\ \text{m}^3$ and 5bar respectively, then its final temperature will be
(a) -123^0C (b) 54^0C (c) 327^0C (d) 600^0C **[IAS-2001]**

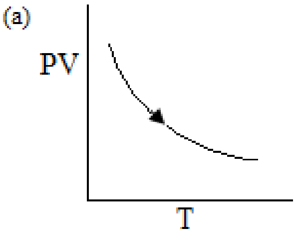
Ans. (c) : Apply equation of states $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ or $T_2 = \frac{P_2V_2}{P_1V_1} \text{x} T_1$

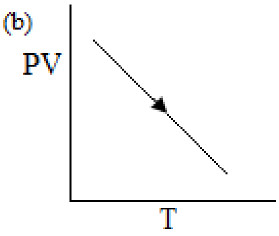
$$\therefore T_2 = \left(\frac{5}{1}\right) \text{x} \left(\frac{0.04}{0.1}\right) \text{x} (273+27) = 600\text{K} = 327^0\text{C}$$

10. Pressure reaches a value of absolute zero
(a) at a temperature of -273K
(b) under vacuum condition
(c) at the earth's centre
(d) when molecular momentum of system becomes zero. **[IES-2002]**

Ans. (d) we know that $P = \frac{1}{3}\rho C^2$ If momentum is zero then C must be zero. Hence P would be zero. That will occur at absolute zero temperature. But note here choice (a) has in defined temp. –273K which is imaginary temp.

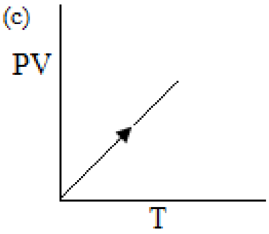
62. Which one of the following PV-T diagrams correctly represents the properties of an ideal gas?



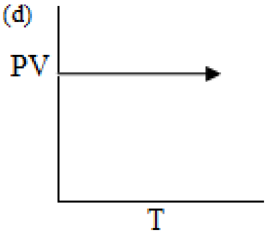


[IAS-1995]

(c)



(d)



62. Ans. (c)
For an ideal gas *PV* = *MRT i.e. P* and *T* follow direct straight line relationship, which is depicted in figure *(c).*

Van der Waals equation

85. Which one of the following is the characteristic equation of a real gas? **[IES-2006]**

(a) $\left(p+\frac{a}{v^2}\right)(v-b)=RT$ (b) $\left(p-\frac{a}{v^2}\right)(v+b)=RT$

(c) $pv=RT$ (d) $pv=nRT$

85. Ans. (a)

41. Which of the following statement about Van der waal's equation i valid?
(a) It is valid for all pressure and temperatures **[IES-1992]**
(b) It represents a straight line on pv versus v plot
(c) It has three roots of identical value at the critical point
(d) The equation is valid for diatomic gases only.
41. Ans. (c)

75. If a gas obeys van der Waals' equation at the critical point, then $\frac{RT_c}{p_c v_c}$ is equal to which one of the following? **[IAS-2004; 2007]**
(a) 0 (b) 1 (c) 1·5 (d) 2·67

75. Ans. (d) a=3 $p_c V_c^2$, b=$\frac{V_c}{3}$, $R=\frac{8}{3}\frac{P_c V_c}{T_c}$

28 In Van der Waal's gas equation

$$\left(P + \frac{a}{v^2}\right)(v - b) = RT$$ (R = Universal gas constant)

the unit of 'b' is **[IAS-1997]**

(a) liter/mole^{0}C (b) m^3/mole (c) Kg-liter/mole (d) dimensionless

Ans. (b): According to dimensional homogeneity law unit of molar-volume and 'b' must be same. i.e. m^3/mole

29 Nitrogen at an initial stage of 10 bar, 1 m^3 and 300K is expanded isothermally to a final volume of 2 m^3. The P-V-T relation is $\left(P + \frac{a}{V^2}\right)v = RT$, where a>0. The final pressure will be **[GATE-2005]**

(a) slightly less than 5 bar (b) slightly more than 5 bar

(c) exactly 5 bar (d) cannot be ascertained.

Ans. (b): Let no of mole = n

Initial	$P_1 = 10$ bar	Final	$P_2 = ?$
	$V_1 = (\frac{1}{n})$ m^3/mole		$V_2 = (\frac{2}{n})$ m^3/mole
	$T_1 = 300K$		$T_2 = 300K = T_1 = T$ (say)

$\therefore (P_1 + a/v_1^2)\, v_1 = (P_2 + a/v_2^2)\, v_2$

$\Rightarrow (10 + an^2) \times (1/n) = (P_2 + an^2/4) \times (2/n)$

$\Rightarrow 2P_2 = 10 + an^2 - an^2/2 = 10 + an^2/2$ $\Rightarrow P_2 = 5 + an^2/4$

as a>0 $\therefore P_2$ is slightly more than 5 bar.

30 A higher value of Van der waal's constant for a gas indicates that the

(a) Molecules of the gas have smaller diameter. **[IAS-2003]**

(b) Gas can be easily liquefied.

(c) Gas has higher molecular weight.

(d) Gas has lower molecular weight.

Ans. (b)

31. The internal energy of a gas obeying Van der Waal's equation

$\left(P + \frac{a}{V^2}\right)(v - b) = RT$, depends on **[IES-2000]**

(a) temperature (b) temperature and pressure

(c) temperature and specific volume (d) pressure and specific volume

Ans. (b): Joule's law states that for an Ideal gas internal energy is a function of temperature only. u = f(T). But this is not Ideal gas it is real gas.

32 Van der Waal's equation of state is given by $\left(P + \frac{a}{v^2}\right)(v - b) = RT$

The constant 'b' in the equation in terms of specific volume at critical point V_c is equal to **[IES-2003]**

(a) $V_c/3$ (b) $2\ V_c$ (c) $3\ V_c$(d) $\frac{8a}{27VcR}$

Ans. (a): We know that at critical point

$a = 3P_cV_c^2$; $b = V_c/3$ and $R = \frac{8PcVc}{3Tc}$

Beattie-Bridgeman equation

Virial Expansions

Compressibility

51. Consider the following statements:
1. A gas with a compressibility factor more than 1 is more compressible than a perfect gas.
2. The x and y axes of the compressibility chart are compressibility factor on y-axis and reduced pressure on x-axis.
3. The first and second derivatives of the pressure with respect to volume at critical points are zero.

Which of the statements given above is/are correct? **[IES 2007]**

(a) 2 and 3 only (b) 1 and 3 only
(c) 1 and 2 only (d) 1, 2 and 3

Ans. (a) 1 is false. At very low pressure, all the gases shown have $z \approx 1$ and behave nearly perfectly. At high pressure all the gases have $z>1$, signifying that they are more difficult to compress than a perfect gas (for a given molar volume, the product pv is greater than RT). Repulsive forces are now dominant. At intermediate pressure, must gasses have $Z < 1$, including that the attractive forces are dominant and favour compression.

60. Which one of the following statements is correct?
(a) Compressibility factor is unity for ideal gases
(b) Compressibility factor is zero for ideal gases **[IES 2007]**
(c) Compressibility factor is lesser than unity for ideal gases
(d) Compressibility factor is more than unity for ideal gases

Ans. (a)

64. Assertion (A): At very high densities, compressibility of a real gas is less than one. **[IES-2006]**
Reason (R): As the temperature is considerably reduced, the molecules are brought closer together and thermonuclear attractive forces become greater at pressures around 4 MPa.
64. Ans. (d)

38. The value of compressibility factor for an ideal gas may be: **[IES-2002]**
1. less or more than one 2. equal to one 3. zero 4. less than zero
The correct value(s) is/are given by
(a) 1 and 2 (b) 1 and 4 (c) 2 only (d) 1 only
38. Ans. (c)

88. Assertion (A): The value of compressibility factor, Z approaches zero of all isotherms as pressure p approaches zero. **[IES-1992]**
Reason (R): The value of Z at the critical points is about 0.29.
88. Ans. (d)

Critical Properties

113. The mathematical conditions at the critical point for a pure substance are represented by **[IAS-1999]**

(a) $\frac{\delta p}{\delta v}<0, \frac{\delta^2 p}{\delta v^2}=0 \, and \, \frac{\delta^3 p}{\delta v^3}=0$ (b) $\frac{\delta p}{\delta v}=0, \frac{\delta^2 p}{\delta v^2}<0 \, and \, \frac{\delta^3 p}{\delta v^3}=0$

(c) $\frac{\delta p}{\delta v}=0, \frac{\delta^2 p}{\delta v^2}=0 \, and \, \frac{\delta^3 p}{\delta v^3}<0$ (d) $\frac{\delta p}{\delta v}=0, \frac{\delta^2 p}{\delta v^2}=0 \, and \, \frac{\delta^3 p}{\delta v^3}=0$

113. Ans. (c)

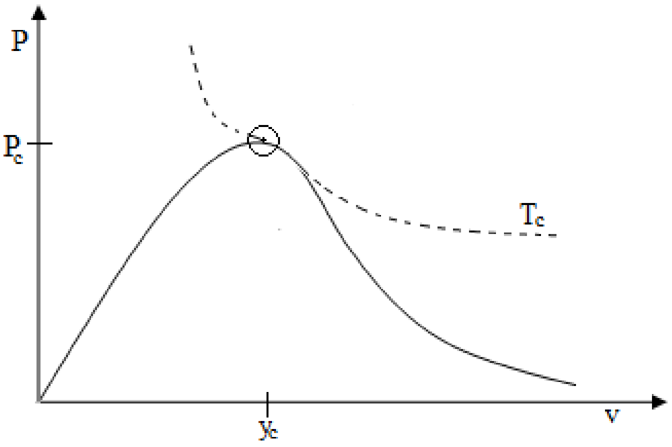
90. In the above figure, y_c corresponds to the critical point of a pure substance under study. Which of the following mathematical conditions applies/apply at the critical point?

(a) $\left(\frac{\partial P}{\partial v}\right)_{T_c}=0$

(b) $\left(\frac{\partial^2 P}{\partial v^2}\right)_{T_c}=0$

(c) $\left(\frac{\partial^3 P}{\partial v^3}\right)_{T_c}<0$ **[IAS-2007]**

(d) All of the above



90. Ans. (d) Van der Waals equation

$$\left(P+\frac{a}{\upsilon^2}\right)(\upsilon-b)=RT \qquad or\ P=\frac{RT}{\upsilon-b}-\frac{a}{\upsilon^2}$$

At critical point a= $3p_cV_c^2$, b=$\frac{V_c}{3}$, $R=\frac{8}{3}\frac{P_cV_c}{T_c}$

$$\left(\frac{\partial P}{\partial V}\right)_{T=T_c}=\frac{-RT_c}{(V_c-b)^2}+\frac{2a}{V_c^3}=0$$

$$\left(\frac{\partial^2 P}{\partial V^2}\right)_{T=T_c}=\frac{2.RT_c}{(V_c-b)^3}-\frac{6a}{V_c^4}=0$$

$$\& \quad \left(\frac{\partial^3 P}{\partial V^3}\right)_{T=T_c}=-\frac{6RT_c}{(v_c-b)}-\frac{24a}{v_c^5}=-9p_c \text{ i.e.-ive}$$

Boyle temperature

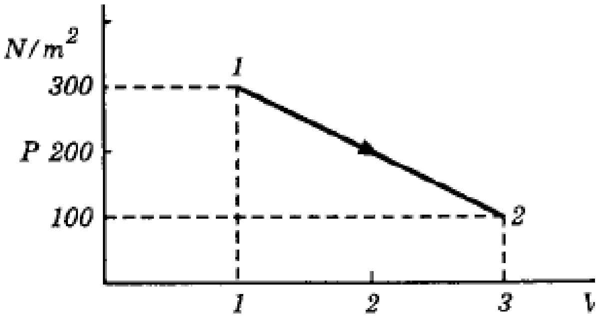
Law of Corresponding States

Adiabatic process

55. Assertion (A): An adiabatic process is always a constant entropy process.
Reason(R): In an adiabatic process there is no heat transfer. **[IES-2005]**
55. Ans. (d)

69. A control mass undergoes a process from state 1 to state 2 as shown in the given figure. During this process, the heat transfer to state 2 to state 1 by another process, then the work interaction during the return process (in kNm) would be
(a) -400 (b) -200
(c) 200 (d) 400

[II



69. Ans. (b) During adiabatic process, work done = change in internal energy.

30. A gas expands from pressure P_1 to pressure P_2 ($P_2 = p_1/10$). If the process of expansion is isothermal, the volume at the end of expansion is 0.55 m^3. If the process of expansion is adiabatic, the volume at the end of expansion will be closer to **[IES-1997]**
(a) 0.45 m^3 (b) 0.55 m^3 (c) 0.65 m^3 (d) 0.75 m^3

30. Ans. (a) For isothermal process, $p_1v_1=p_2v_2,\ \ or\ p_1v_1=\frac{p_1}{10}\times 0.55,\ v_1=0.055\,m^3$

For adiabatic process

$$p_1 v_1^{1.4} = p_2 v_2^{1.4}, \ \ or\ p_1\left(0.055\right)^{1.4} = \frac{p_1}{10}\times v_2^{1.4} \ \ or\ \ v_2 = 0.055\sqrt[1.4]{10} = 0.45\,m^3$$

28. Consider the following statements: **[IAS-2007]**

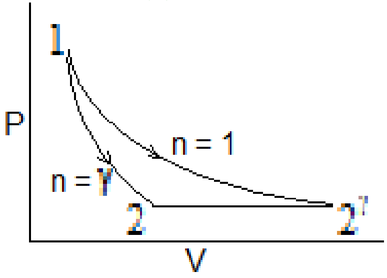
1. During a reversible non-flow process, for the same expansion ratio, work done by a gas diminishes as the value of n in $pv^n = C$ increases.
2. Adiabatic mixing process is a reversible process.

Which of the statements given above is/are correct?

(a) 1 only (b) 2 only (c) Both 1 and 2 (d) Neither 1 nor 2

28. Ans. (a)

In adiabatic mixing there is always increase in entropy so large amount of irreversibility is these.



Statement for Linked Answer Questions 80 & 81:

A football was inflated to a gauge pressure of 1 bar when the ambient temperature was 15°C. When the game started next day, the air temperature at the stadium was 5°C. Assume that the volume of the football remains constant at 2500 cm^3.

80. The amount of heat lost by the air in the football and the gauge pressure of air in the football at the stadium respectively equal **[GATE-2006]**

(a) 30.6 J, 1.94 bar (b) 21.8 J, 0.93 bar (c) 61.1 J, 1.94 bar (d) 43.7 J, 0.93 bar

80. Ans. (d)

$$\text{Heat lost} = n\, C_V\, d_T$$

81. Gauge pressure of air to which the ball must have been originally inflated so that it would equal 1 bar gauge at the stadium is **[GATE-2006]**

(a) 2.23 bar (b) 1.94 bar (c) 1.07 bar (d) 1.00 bar

81. Ans. (c)

48. A 100 W electric bulb was switched on in a 2.5 m x 3 m x 3 m size thermally insulated room having a temperature of 20°C. The room temperature at the end of 24 hours will be **[GATE-2006]**

(a) 321°C (b) 341°C (c) 450°C (d) 470°C

48. Ans. (c) Heat produced by electric bulb in 24 hr. = $100\times24\times60\times60\,\text{J} = 8640\,\text{kJ}$

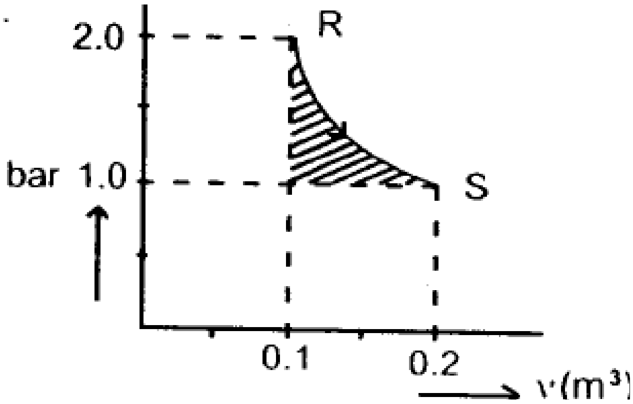
Volume of air = $2.5\times3\times3 = 22.5\,\text{m}^3$

Density (ρ) = 1.24 kg/m^3

$$\Delta Q = mC_v\Delta t \quad \text{or}\ \Delta t = \frac{\Delta Q}{mC_v} = \frac{8640}{22.5\times1.24\times0.716} = 430\,°\text{C}\ \ \therefore t = 430 + 20 = 450\,°\text{C}$$

Isothermal Process

34. An ideal gas undergoes an isothermal expansion from state R to state S in a turbine as shown in the diagram given below:
The area of shaded region is 1000 Nm. What is the amount is turbine work done during the process?
(a) 14,000 Nm (b) 12,000 Nm
(c) 11,000Nm
[IES-2004]



34. Ans. (c) Turbine work = area under curve R-S

$$\begin{aligned}&= \int P\,dv\\&= 1\text{ bar} \times (0.2 - 0.1)\text{m}^3 + 1000\text{ Nm}\\&= 10^5 \times (0.2 - 0.1)\text{Nm} + 1000\text{Nm}\\&= 11000\text{Nm}\end{aligned}$$

35. The work done in compressing a gas isothermally is given by: **[IES-1997]**

$(a)\dfrac{\gamma}{\gamma-1}p_1v_1\left[\left(\dfrac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}}-1\right]$ $(b)\,mRT_1\log_e\left(\dfrac{p_2}{p_1}\right)$

$(c)\,mc_p(T_2-T_1)$ $(d)\,mRT_1\left(1-\dfrac{T_2}{T_1}\right)$

35. Ans. (b)

31. The slope of log P-log V graph for a gas for isothermal change is m_1 and for adiabatic changes is m_2. If the gas is diatomic gas, then **[IES-1992]**
(a)$m_1 < m_2$ (b)$m_1 > m_2$ (c) $m_1 + m_2 = 1.0$ (d) $m_1 = m_2$
31. Ans. (a)

31.

$$\begin{aligned}& PV = \text{constant, C}\\ \Rightarrow\ & \log P + \log V = \log C\\ & m_1 = -1\\ & Pv^q = C\\ \Rightarrow\ & \log P + q\log V = \log C\\ & m_2 = -q = -1.4\\ \therefore\ & m_2 > m_1\end{aligned}$$

35. The work done during expansion of a gas is independent of pressure if the expansion takes place. **[IES-1992]**
(a) isothermally (b) adiabatically (c) in both the above cases (d) in none of the above cases
35. Ans. (d)

70. Identify the process of change of a close system in which the work transfer is maximum.
(a) Isothermal (b) Isochoric (c) Isentropic (d) Polytropic **[IAS-2003]**
70. Ans. (c) Aamar mone hoy (a) hobe

38. Three moles of an ideal gas are compressed to half the initial volume at a constant temperature of 300k. The work done in the process is **[IES-1992]**

(a) 5188 J (b) 2500 J (c) -2500 J (d) -5188 J

38. Ans. (d)

38. Since the temperature remains constant, the process is isothermal.

$\therefore$ work-done in the process, $W = 2.303\, n\text{RT} \log\left(\frac{V_2}{V_1}\right)$

$= 2.303 \times 3 \times 8.315 \times 8.315 \times 300 \log\left(\frac{1}{2}\right)$

$= -5188$ J.

The negative sign indicates that work is done on the gas.

91. In a reversible isothermal expansion process, the fluid expands from 10 bar and 2 m^3 to 2 bar and 10 m^3. During the process the heat supplied is at the rate of 100 kW. What is the rate of work done during the process? **[IAS-2007]**

(a) 20 kW (b) 35 kW (c) 80 kW (d) 100 kW

91. Ans. (d) For reversible isothermal expansion heat supplied is equal to work done during the process and equal to $Q = W = mRT_1 \ln\left(\frac{v_2}{v_1}\right)$

$\because$ Temperature constant so no change in internal energy dQ = dU + dW; dU=0

Therefore dQ = dW

86. In respect of a closed system, when an ideal gas undergoes a reversible isothermal process, the **[IAS-2000]**

(a) heat transfer is zero (b) change in internal energy is equal to work transfer

(c) work transfer is zero (d) heat transfer is equal to work transfer

86. Ans. (d) In reversible isothermal process temperature constant. No change in internal energy. So internal energy constant $\cancel{d}Q = \delta u + \delta W$ as $\delta u = 0, \cancel{d}Q = \cancel{d}W$

Polytropic process

31. Assertion (A): Though head is added during a polytropic expansion process for which $\gamma > n > 1$, the temperature of the gas decreases during the process. **[IES 2007]**

Reason (R): The work done by the system exceeds the heat added to the system.

Ans. (a)

70. In a polytropic process, the term $\left(\frac{\gamma - n}{\gamma - 1}\right)\left\{\frac{p_1v_1 - p_2v_2}{(n-1)}\right\}$ is equal to: **[IES-2005]**

(a) Heat absorbed or rejected (b) Change in internal energy

(c) Ratio of T_1/T_2 (d) Work done during polytropic expansion

70. Ans. (a)

31. The heat absorbed or rejected during a polytropic process is equal to **[IES-2002]**

(a) $\left(\frac{\gamma - n}{\gamma - 1}\right)^{1/2}$ x work done (b) $\left(\frac{\gamma - n}{n - 1}\right)$x work done

(c) $\left(\frac{\gamma-n}{\gamma-1}\right)$x work done (d) $\left(\frac{\gamma-n}{\gamma-1}\right)^2$ x work done

31. Ans. (c)

Constant Pressure or Isobaric Process

72. Change in enthalpy in a closed system is equal to the heat transferred, if the reversible process takes place at **[IES-2005]**

(a) Temperature (b) Internal energy (c) Pressure (d) Entropy

72. Ans. (c) $\text{đ}Q = du + pd\upsilon + \upsilon pd - \upsilon dp = d(u + p\upsilon) - \upsilon dp = dh - \upsilon dp$

if $dp = 0$ or $p = \text{const.}$ these for $(\text{đ}Q)_p = (dh)_p$

64. Which one of the following phenomena occurs when gas in a piston-in-cylinder assembly expands reversibly at constant pressure? **[IES-2003]**

(a) Heat is added to the gas (b) Heat is removed from the gas

(c) Gas does work from its own stored energy (d) Gas undergoes adiabatic expansion

64. Ans. (b)

32. A standard vapour is compressed to half its volume without changing its temperature. The result is that: **[IES-1997]**

(a) All the vapour condenses to liquid

(b) Some of the liquid evaporates and the pressure does not change

(c) The pressure is double its initial value

(d) Some of the vapour condenses and the pressure does not change

32. Ans. (d) By compressing a vapour, its vapours condense and pressure remains unchanged.

78. For a non-flow constant pressure process the heat exchange is equal to

(a) zero (b) the work done **[IAS-2003]**

(c) the change in internal energy (d) the change in enthalpy

78. Ans. (d)

Constant volume or isochoric Process

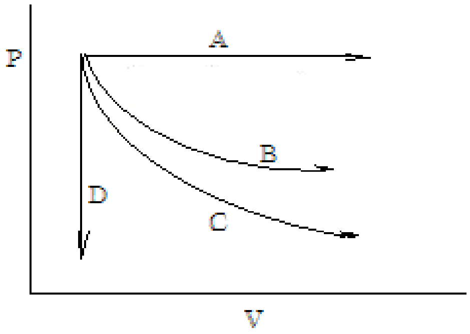
35. Which one of the following thermodynamic processes approximates the steaming of food in a pressure cooker?

(a) Isenthalpic (b) Isobaric

(c) Isochoric (d) Isothermal **[IES 2007]**

Ans. (c) In a pressure cooker, the volume of the cooker is fixed so constant volume process but for safety some of steam goes out to maintain a maximum pressure. But it occurs after proper steaming.

57.



Consider the four processes A, B, C and D shown in the graph given above:
Match List 1 with List 2 and select the correct answer using the code given below the lists:

List 1 (Processes shown in the graph)	List 2 (Index 'n' in the equation pv^n = Const)
A. A	1. 0
B. B	2. 1
C. C	3. 1.4
D. D	4. ∞

Code: **[IES 2007]**

	A	B	C	D		A	B	C	D
(a)	4	2	3	1	(b)	1	2	3	4
(c)	1	3	2	4	(d)	4	3	2	1

Ans. (b)

21 Match List-I (process) with List-II (index n in PV^n = constant) and select the correct answers using the codes given below the lists. **[IES-1999]**

List-I	List-II
A. Adiabatic	1. n = infinity
B. Isothermal	2. n = $\frac{C_p}{C_v}$
C. Constant pressure	3. n = 1
D. Constant volume	4. n = $\frac{C_p}{C_v}-1$
	5. n = zero

Codes:	A	B	C	D		A	B	C	D
(a)	2	3	5	4	(b)	3	2	1	5
(c)	2	3	5	1	(d)	2	5	3	1

Ans. (c)

72. A system at a given state undergoes change through the following expansion processes to reach the same final volume **[IES-1994]**

1. Isothermal 2. Isobaric 3. Adiabatic (γ=1.4) 4. Polytropic (n =1.3).

The correct ascending order of the work output in these four processes is

(a) 3,4,1,2 (b) 1,4,3,2 (c) 4,1,3,2 (d) 4,1,2,3

72. Ans. (a)

70. Match the curves in Diagram I with the curves in Diagram II and select the correct answer.

Diagram I (Process on p- V plane)

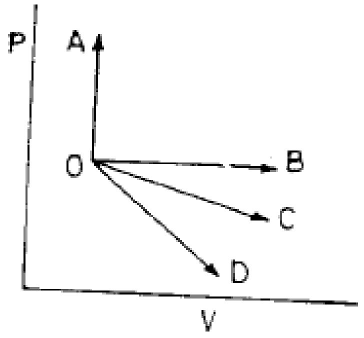
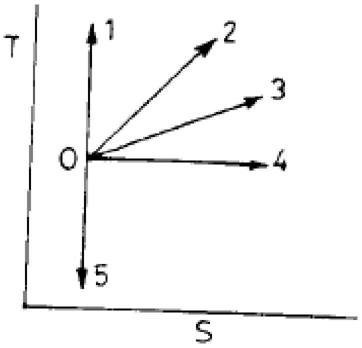


Diagram II (Process on T-s plane)



Code:	A	B	C	D		A	B	C	D	
(a)	3	2	4	5	(b)	2	3	4	5	
(c)	2	3	4	1	(d)	1	4	2	3	**[IES-1996]**

70. Ans. (b)

70.

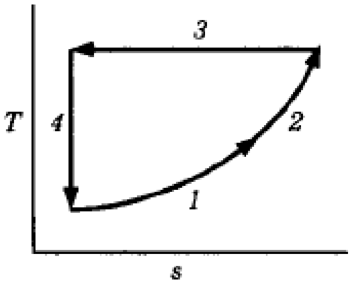


Fig. I

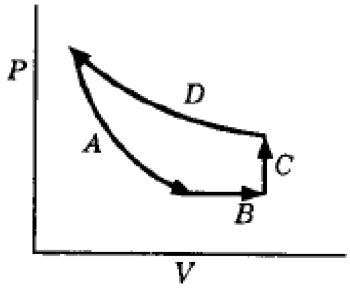


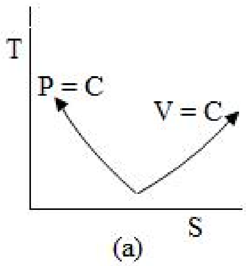
Fig. II

Four processes of a thermodynamic cycle are shown above in Fig. I on the T-s plane in the sequence 1-2-3-4. The corresponding correct sequence of these processes in the p- V plane as shown above in Fig. II will be **[IES-1998]**

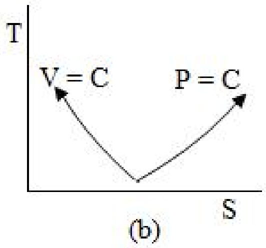
(a) (C-D-A-B) (b)(D-A-B-C) (c)(A-B-C-D) (d)(B-C-D-A)

70. Ans. (d)

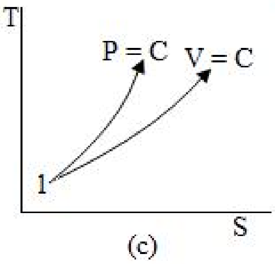
24. An ideal gas is heated (i) at constant volume and (ii) at constant pressure from the initial state 1. Which one of the following diagrams shows the two processes correctly? **[IAS-1996]**



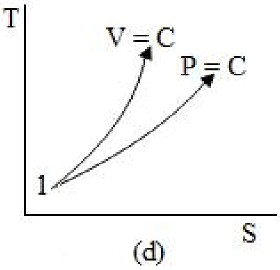
(a)



(b)



(c)



(d)

24. Ans. (d)

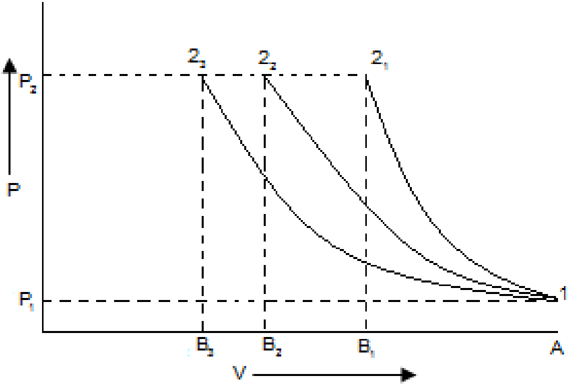
69. Match List I with List II and select the correct answer **[IES-1996]**

List I	List II
A. Work done in a polytropic process	1. $-\int v\,dp$
B. Work done in a steady flow process	2. zero
C. Heat transfer in a reversible adiabatic process	3. $\dfrac{p_1V_1 - p_2V_2}{\gamma - 1}$
D. Work done in an isentropic process	4. $\dfrac{p_1V_1 - p_2V_2}{n - 1}$

69. Ans. (c)

88. One kg of a perfect gas is compressed from pressure P_1 to pressure P_2 by
1. isothermal process 2. adiabatic process 3. the law $pv^{1.4}$= constant **[IAS-2000]**
The correct sequence of these processes in increasing order of their work requirement is
(a)1, 2, 3 (b) 1, 3, 2 (c) 2, 3, 1 (d) 3, 1, 2

88. Ans. (b)
Work requirement
1. isothermal – area under 12_1B_1A
2. adiabatic – area under 12_2B_2A
3. $pv^{1.1}$= c – area under 12_3B_3A



39. A perfect gas at 27°C was heated until its volume was doubled using the following three different processes separately: **[IES-2004]**
1. Constant pressure process 2 Isothermal process 3. Isentropic process
Which one of the following is the correct sequence in the order of increasing value of the final temperature of the gas reached by using the above three different processes?
(a) 1 - 2 - 3 (b) 2 - 3 – 1 (c) 3 - 2 - 1 (d) 3 - 1 – 2

39. Ans. (b) Heat addition:
Min^{m} heat required for isothermal process.
Medium heat required for isentropic process.
Max^{m} heat required for constant pressure process.

90. Match List-I with List-II and select the correct answer using the codes given below the Lists:

List-I	List- II
A. Constant volume process	I. $\dfrac{dP}{dV} = -\dfrac{P}{V}$ **[IAS-1997]**
B. Constant pressure process	2. $\dfrac{dP}{dV} = -\dfrac{\gamma P}{V}$

C. Constant temperature process 3. $\frac{dT}{ds} = -\frac{T}{C_V}$

D. Constant entropy process 4. $\frac{dT}{ds} = -\frac{T}{C_P}$

Codes:	A	B	C	D		A	B	C	D
(a)	3	2	1	4	(b)	2	4	3	1
(c)	3	4	1	2	(d)	1	3	4	2

90. Ans. (c)

54. A reversible thermodynamic cycle containing only three processes and producing work is to be constructed. The constraints are

(i) there must be one isothermal process, **[GATE-2005]**

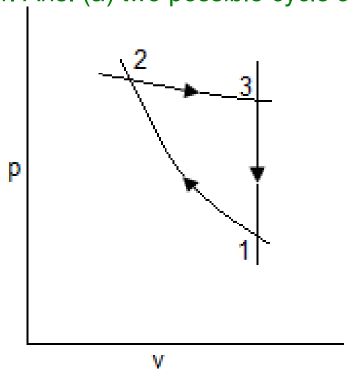
(ii) there must be one isentropic process,

(iii) the maximum and minimum cycle pressures and the clearance volume are fixed, and

(iv) polytropic processes are not allowed. Then the number of possible cycles are

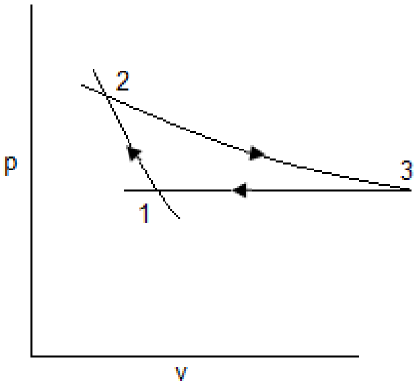
(a) 1 (b) 2 (c) 3 (d) 4

54. Ans. (a) two possible cycle are given below.



(a)

1-2: Isentropic
2-3: Isothermal
3-1: Constant volume



(b)

1-2: Isentropic
2-3: Isothermal
3-1: Constant pressure

Properties of Mixtures of Gases

74. If M_1, M_2, M_3, be molecular weight of constituent gases and m_1, m_2, $m_{3...}$ their **[IAS-2007]**corresponding mass fractions, then what is the molecular weight M of the mixture equal to?

(a) $m_1M_1 + m_2M_2 + m_3M_3 + ...$

(b) $\frac{1}{m_1M_1 + m_2M_2 + m_3M_3 + ...}$

(c) $\frac{1}{m_1M_1} + \frac{1}{m_2M_2} + \frac{1}{m_3M_3} + ...$

(d) $\frac{1}{\left(\frac{m_1}{M_1}\right) + \left(\frac{m_2}{M_2}\right) + \left(\frac{m_3}{M_3}\right) + ...}$

74. Ans. (a)

19. The entropy of a mixture of pure gases is the sum of the entropies of constituents evaluated at **[IAS-1998]**
(a) temperature and pressure for the mixture
(b) temperature of the mixture and the partical pressure of the constituents
(c) temperature and volume of the mixture
(d) pressure and volume of the mixture
19. Ans. (b)

13. 2 moles of oxygen are mixed adiabatically with another 2 moles of oxygen in a mixing chamber, so that the final total pressure and temperature of the mixture become same as those of the individual constituents at their initial states. The universal gas constant is given as *R.* The change in entropy due to mixing, per mole of oxygen, is given by **[GATE-2008]**
(A) –Rln2 (B) 0 (C) Rln2 (D) Rln4
13. Ans. (B) Remember if we mix 2 mole of oxygen with another 2 mole of *other gas* the volume will be doubled for first and second constituents $\Delta S = nR\ln\frac{V_{total}}{V_{initial}} = 2R\ln 2 \quad \therefore$ Total Entropy change = 4Rln2 So, Entropy change per mole=Rln2. And it is due to diffusion of one gas into another.