6. Power Plant Engineering

1. Introduction

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Basics of Power Plant

Objective Questions (IES, IAS, GATE)

1. The correct sequence off actors in order of deceasing importance for location of a thermal power plant is **[IAS-2001]**
(a) load, coal, water (b) coal, water, load (c) water, load, coal (d) water, coal, load

2. A thermoelectric engine which consists of two dissimilar electric conductors connected at two junctions maintained at different temperatures, converts **[IES-2006]**
(a) Electric energy into heat energy (b) Heat energy into electric energy
(c) Mechanical work into electric energy (d) Electric energy into mechanical work

3. In thermal power plants, coal is transferred from bunker to the other places by
(a) hoists (b) conveyors (c) cranes (d) lifts **[IES-1992]**

Answers with Explanation (Objective)

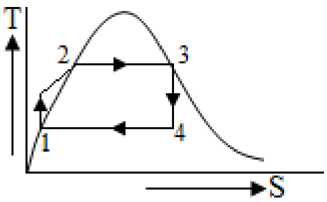
1. Ans. (b)
2. Ans. (b)
3. Ans. (b)

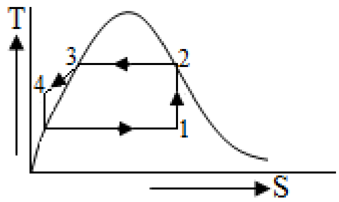
Steam Cycles

Objective Questions (IES, IAS, GATE)

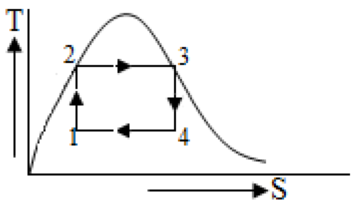
Rankine Cycle

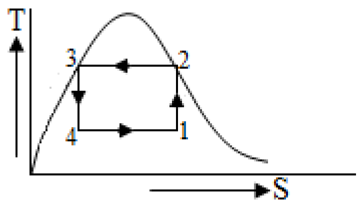
1. The correct representation of a simple Rankine cycle on a T-S diagram is

(a)


(b)


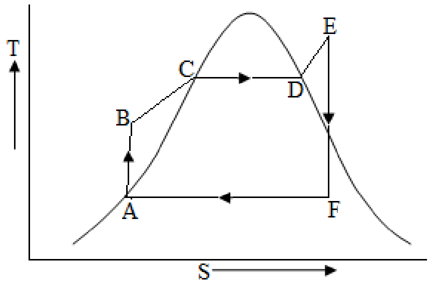
[IAS 1994]

(c)


(d)


1. Ans. (a)

2. A superheat Rankine Cycle is shown in the given T-S diagram. Starting from the feed pump, the fluid flow upto the boiler exit is represented by state-line
(a) ABCD (b) BCDE
(c) ABDEFA (d) ABCDE



[IAS-1995]

2. Ans. (a)

3. Consider the following processes: **[IES-1999]**
1. Constant pressure heat addition. 2. Adiabatic compression.
3. Adiabatic expansion. 4. Constant pressure heat rejection.
The correct sequence of these processes in Rankine cycle is:
(a) 1, 2, 3, 4 (b) 2, 1, 4, 3 (c) 2, 1, 3, 4 (d) 1, 2, 4, 3
3. Ans. (c)

4. In a Rankine cycle, with the maximum steam temperature being fixed from metallurgical considerations, as the boiler pressure increases **[IES-1997]**
(a) the condenser load will increase
(b) the quality of turbine exhaust will decrease
(c) the quality of turbine exhaust will increase
(d) the quality of turbine exhaust will remain unchanged
4. Ans. (b) With increase in pressure, state of steam shifts towards left and thus on expansion, quality of steam will decrease.

5. In the Rankine cycle lower limit on the condenser pressure is due to the
(a) expansion limit in turbine (b) condenser size **[IAS-1996]**

(c) air leakage into the condenser (d) temperature of cooling water
5. Ans. (d)

6. Consider the following statements regarding Rankine Cycles:
1. It reduces the specific steam consumption. **[IAS-1995]**
2. It increases the dryness fraction of steam at the exhaust for the same value of condenser pressure.
3. It reduces the cycle efficiency.
Of the these statements
(a) 1 and 2 are correct (b) 2 and 3 are correct
(c) 1and 3 are correct (d) 1,2 and 3 are correct
6. Ans. (a) Superheating in Rankine cycle increases efficiency and statement 3 is incorrect. Statement at 1 and 2 are correct. Thus choice *(a)* is Correct.

7. Which one of the following statements is correct? **[IES 2007]**
(a) Efficiency of the Carnot cycle for thermal power plant is high and work ratio is also high in comparison to the Rankin cycle.
(b) Efficiency of the Carnot cycle is high and work ratio is low in comparison to the Rankin cycle.
(c) Efficiency of the Carnot cycle is low and work ratio is also low in comparison to the Rankin cycle.
(d) Both the cycle have same efficiencies and work ratio.
7. Ans. (b) Carnot cycle has highest efficiency but very high back. So work ratio is low.

8. During which of following process does heat refection take place in Carnot vapour cycle? **[IES-1992]**
(a) constant volume (b) constant pressure
(c) constant temperature (d) constant entropy
8. Ans. (c)

Mean Temperature of Heat Addition

9. Assertion (A): The Rankine cycle with regenerative feed heating always has higher cycle efficiency than the Rankine cycle without regenerative feed heating. **[IAS-2000]**
Reason(R): The higher efficiency of regenerative cycle is due to decrease in the temperature of heat rejection.
9. Ans. (c) Higher efficiency of regenerative cycle is due to increase in the mean temperature of heat addition.

10. The efficiency of superheat Rankine cycle is higher than that of simple Rankine cycle because **[GATE-2002]**
(a) the enthalpy of main steam is higher for superheat cycle
(b) the mean temperature of heat addition is higher for superheat cycle
(c) the temperature of steam in the condenser is high
(d) the quality of stem in the condenser is low
10. Ans. (b)

11. Employing superheated steam in turbines leads to **[IES-2003]**
(a) Increase in erosion of blading (b) Decrease in erosion of blading
(c) No erosion in blading (d) No change in erosion of blading
11. Ans. (a)

12. In which one of the following working substances, does the relation $\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{0.286}$ hold good if the process takes place with zero heat transfer?
(a) Wet steam (b) Superheated steam **[IES-2000]**
(c) Petrol vapour and air mixture (d) Air
12. Ans. (b)

Reheating of Steam

13. Consider the following for a steam turbine power plant: **[IES-2006]**
1. Reduction in blade erosion. 2. Increase in turbine speed.
3. Increase in specific output. 4. Increase in cycle efficiency.
Which of the above occur/occurs due to reheating of steam?
(a) Only 1 (b) 1 and 2 (c) 1, 3 and 4 (d) 2 and 3
13. Ans. (c) 1. Quality of steam improves so blade erosion reduced.
2. Reheating has no effect on speed. So 2 is false.

14. Blade erosion in steam turbines takes place **[IES 2007]**
(a) Due to high temperature steam (b) Due to droplets in steam
(c) Due to high rotational speed (c) Due to high flow rate
14. Ans. (b)

15. Consider the following statements: **[IES-2005]**
Which of the following increase the work ratio in a simple gas turbine plant?
1. Heat exchanger 2. Inter cooling 3. Reheating
Select the correct answer using the code given below:
(a) 1 and 2 (b) 2 and 3 (c) I and 3 (d) 1, 2 and 3
15. Ans. (b)

16. The main advantage of a reheat Rankine cycle is **[IES-2002]**
(a) reduced moisture content in L.P. side of turbine (b) increase efficiency
(c) reduced load on condenser (d) reduced load on pump
16. Ans. (a)

17. Assertion (A): The performance of a simple Rankine cycle is not sensitive to the efficiency of the feed pump. **[IES-2002]**
Reason (R): The net work ratio is practically unity for a Rankine cycle.
17. Ans. (a)

18. Consider the following statements: **[IAS-2001]**
The purpose of reheating, the steam in a steam turbine power plant is to
1. increase specific output
2. increase turbine efficiency
3. reduce the turbine speed
4. reduce specific steam consumption
Which of these statements are correct?
(a) 2 and 4 (b) 1 and 3 (c) 1, 2 and 4 (d) 1, 3 and 4
18. Ans. (c)

19. In an ideal steam power cycle with the same inlet pressure, the low dryness fraction of steam in the last stage of expansion process can be avoided by **[IAS-1999]**
(a) providing regeneration (b) providing reheating
(c) reducing the superheat (d) lowering the condenser pressure

19. Ans. (b)

20. Consider the following statements **[IES-2000]**
The reheat cycle helps to reduce
1. fuel consumption 2. steam flow 3. the condenser size
Which of these statements are correct?
(a) 1 and 2 (b) 1 and 3 (c) 2 and 3 (d) 1, 2 and 3
20. Ans. (a)

21. Consider the following statements regarding effects of heating of steam in a steam turbine: **[IES-1999]**
1. It increases the specific output of the turbine
2. It decreases the cycle efficiency
3. It increases blade erosion.
4. It improves the quality of exit steam?
Which of these statements are correct?
(a) 1 and 2 (b) 2 and 3 (c) 3 and 4 (d) 1 and 4
21. Ans. (d) Heating of steam increases specific output of turbine and improves the quality of exit steam.

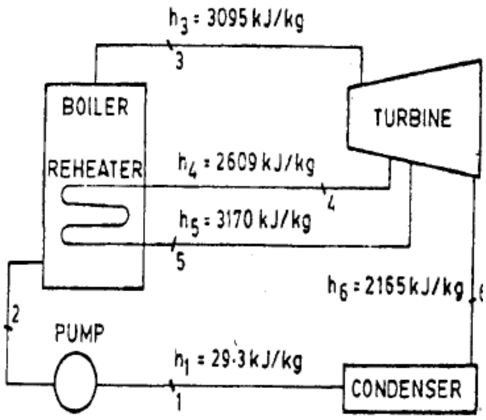
22. The reheat cycle in steam power plant is mainly adopted to **[IES-1999]**
(a) improve thermal efficiency
(b) decrease the moisture content in low pressure stages to a safe value
(c) decrease the capacity of condenser (d) recover the waste heat of boiler
22. Ans. (a) Though answers at (a) and (b) are correct, still the reheat cycle in steam power plant is mainly adopted to improve thermal efficiency.

23. Assertion (A): The purpose of employing reheat in a steam power plant is mainly to improve its thermal efficiency. **[IES-1998]**
Reason (R): The use of regeneration in a steam power plant improves the efficiency.
23. Ans. (b)

24. Consider the following statements: **[IES-1997]**
If steam is reheated during the expansion through turbine stages
1. erosion of blade will decrease 2. the overall pressure ratio will increase.
3. the total heat drop will increase.
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
24. Ans. (d) Overall pressure ratio depends on inlet pressure and condenser pressure

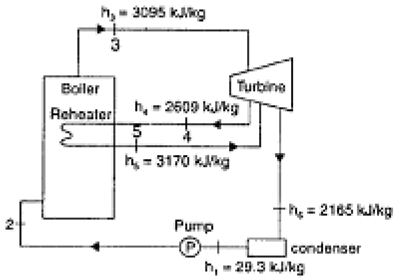
Data for Q 25 and 26 are given below. Solve the problem and choose correct answers.

Consider a steam power plant using a reheat cycle as shown. Steam leaves the boiler and enters the turbine at 4 MPa, 350°C (h_3 = 3095 kJ/kg). After expansion in the turbine to 400 kPa (h_4 = 2609 kJ/kg), the steam is reheated to 350°C (h_5 = 3170 kJ / kg), and then expanded in a low pressure turbine to 10 kPa (h_6= 2165 kJ/kg). The specific volume of liquid handled by the pump can be assumed to be



25. The thermal efficiency of the plant neglecting pump work is **[GATE-2004]**
(a) 15.8% (b) 41.1% (c) 48.5% (d) 58.6%
25. Ans. (b)

Given : h_1 = 29.3 kJ/kg, h_2 = ?
h_3 = 3095 kJ/kg, h_4 = 2609 kJ/kg
h_5 = 3170 kJ/kg, h_6 = 2165 kJ/kg
Turbine work $W_T = (h_3 - h_4) + (h_5 - h_6)$
$= (3095 - 2609) + (3170 - 2165)$
$= 1491$ kJ/kg
Q = Heat input $= (h_3 - h_1) + (h_5 - h_4)$
$= (3095 - 29.3) + 3(3170 - 2609)$
$= 3626.7$ kJ/kg
∴ Thermal efficiency of the plant
$= \frac{1491}{3626.7} = 41.11\%.$



26. The enthalpy at the pump discharge (h_2) is **[GATE-2004]**
(a) 0.33 kJ /kg (b) 3.33 kJ /kg (c) 4.0 kJ/k (d) 33.3 kJ /kg
26. Ans. (d)

Enthalpy at the pump discharge will be greater than 29.3 kJ/kg
Hence from given choice clearly we can say
h_2 = 33.3 kJ/kg.

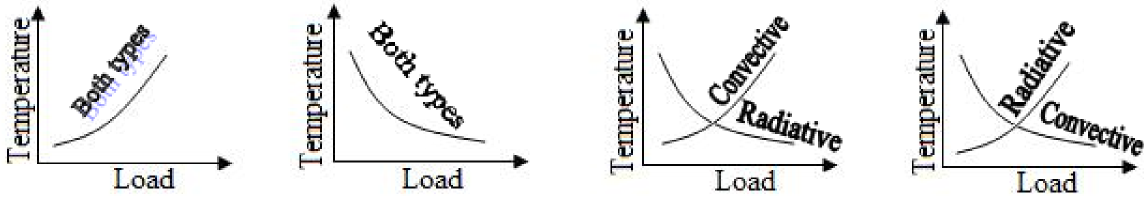
27. A steam turbine operating with less moisture is............ (more/less) efficient and........................... (less/more) prone to blade damage **[GATE-1992]**
27. Ans. more; less

Superheating of steam

28. Which one of the following is the correct statement? **[IAS-2007]**
Steam is said to be superheated when the
(a) actual volume is greater than volume of saturated steam
(b) actual volume is less than volume of saturated steam
(c) actual volume is equal to volume of saturated steam
(d) None of the above
28. Ans. (a)

29. Assertion (A): In convection superheaters, the exit steam temperature increases with load. **[IAS-2000]**
Reason(R): The combustion temperature does not significantly change with load.
29. Ans. (b) As load increases demand for steam increases, fuel and air flow increases hence, combustion gas flow increased which increases convective heat transfer co-efficient.

30. The variation of superheater outlet temperature with variation of load in the case of convective type and radiative type superheaters is best represented as **[IAS-1999]**



(a) (b) (c) (d)

30. Ans. (c)

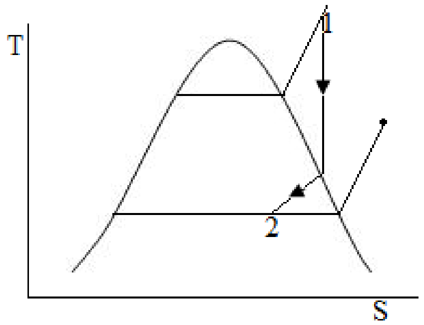
Regenerative Feed water Heating

31. What is the efficiency of an ideal regenerative Rankine cycle power plant using saturated steam at 327°C and pressure 135 bar at the inlet to the turbine, and condensing temperature of 27°C (corresponding saturation pressure of 3.6 kPa)?
(a) 92% (b) 33% (c) 50% (d) 42% **[IAS-2004]**
31. Ans. (c) Ideal regenerative Rankine cycle efficiency is same as Carnot cycle

$$(\eta) = 1 - \frac{T_2}{T_1} = 1 - \frac{300}{600} = 50\%$$

32. The most efficient ideal regenerative steam power cycle is **[IAS-2001]**
(a) Rankine cycle (b) Carnot cycle (c) Brayton cycle (d) Joule cycle
32 Ans. (b) Ideal regeneration Rankine Rankin cycle efficiency is same as Carnot cycle, but most efficient cycle is Carnot cycle.

33. The curve labeled 1-2 in the given figure refers to the expansion process of a
(a) Rankine cycle
(c) regenerative cycle
(d) reheat cycle



[IAS-1997]

33. Ans. (b)

34. Assertion (A): An ideal regenerative Rankine cycle power plant with saturated steam at the inlet to the turbine has same thermal efficiency as Carnot cycle working between the same temperature limits. **[IES-2003]**
Reason (R): The change in entropy of steam during expansion in the turbine is equal to the change in entropy of the feed water during sensible heating at steam generator pressure.
34. Ans. (a)

35. Which one of the following additions/sets of additions to simple gas turbine cycle will have NO effect on the power output of the cycle?
(a) Regeneration (b) Intercooling and regeneration **[IAS-1997]**

(c) Reheating and Intercooling (d) Reheating, Intercooling and regeneration

35. Ans. (a)

36. Assertion (A): The thermal efficiency of a regenerative Rankine cycle is always higher than that of a cycle without regeneration.

Reason (R): In regeneration cycle the work output is more **[IES-1994]**

36. Ans. (c) Thermal efficiency of Regenerating Rankine cycle is higher than without regeneration. However, work output is less due to partial extraction of steam. Thus A is true but R is false.

37. Consider an actual regenerative Rankine cycle with one open feed water heater. For each kg steam entering the turbine, m kg steam with a specific enthalpy of h_1 is bled from the turbine. Specific enthalpy of water entering the heater is h_2. The specific enthalpy of saturated liquid leaving the heater is equal to **[IAS-2003]**

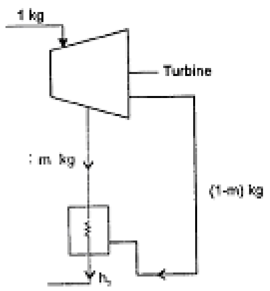
(a) $mh_1 - (h_2 - h_1)$ (b) $h_1 - m(h_2 - h_1)$ (c) $h_2 - m(h_2 - h_1)$ (d) $mh_2 - (h_2 - h_1)$

37. Ans. (c)

(c)

Explanation : Applying Cherry balance equation, we get

$$mh_1 + (1-m)h_2 = h_3 \text{ (sp. enthalpy of saturated liquid leaving the heater)}$$



$$\therefore \quad h_3 = mh_1 + h_2 - mh_2$$

$$\therefore \quad h_2 - m(h_2 - h_1)$$

38. Which one of the following modifications to a Rankine cycle would upgrade/enhance its efficiency so as to approach that of Carnot cycle? **[IAS-1996]**

(a) Incomplete expansion of steam (b) Reheating of steam

(c) Regenerative feed heating by steam (d) Partial condensation of steam

38. Ans. (c)

39. Assertion (A): In a power plant working on a Rankine cycle, the regenerative feed water heating improves the efficiency of the steam turbine. **[GATE-2006]**

Reason (R): The regenerative feed water heating raises the average temperature of heat addition in the Rankine cycle.

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

40. In a Rankine cycle, regeneration results in higher efficiency because

(a) pressure inside the boiler increases **[GATE-2003]**

(b) heat is added before steam enters the low pressure turbine

(c) average temperature of heat addition in the boiler increases

(d) total work delivered by the turbine increases

40. Ans. (c)

50. Consider an actual regenerative Rankine cycle with one open feed water heater. For each kg steam entering the turbine, If m kg steam with a specific enthalpy of h_1 is

bled from the turbine, and the specific enthalpy of liquid water entering the heater is h_2, then h_3 specific enthalpy of saturated liquid leaving the heater Is equal to

$(a)\, mh_1 - (h_2 - h_1)$ $(b)\, h_1 - m(h_2 - h_1)$ **[GATE-1997]**

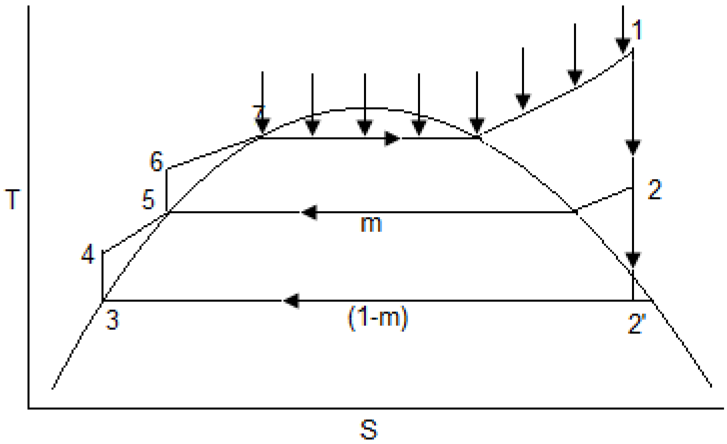
$(c)\, h_2 - m(h_2 - h_1)$ $(d)\, mh_2 - (h_2 - h_1)$

50 Ans. (c)

Heat balance of heat give

$$mh_1 + (1-m)h_2 = 1 \times h_3$$

$$\text{or } h_3 = h_2 - m(h_2 - h_1)$$



51. For a given set of operating pressure limits of a Rankine cycle, the highest, efficiency occurs for **[GATE-1994]**
(a) Saturated cycle (b) Superheated cycle
(c) Reheat cycle (d) Regenerative cycle.
51. Ans. (d) Efficiency of ideal regenerative cycle is exactly equal to that of the corresponding Carnot cycle. Hence it is maximum.

52. Consider the following statements pertaining to the features of a regenerative steam cycle plant as compared to a non-regenerative plant: **[IES-2003]**
1. It increases the cycle efficiency 2. It requires a bigger boiler.
3. It requires a smaller condenser.
Which of the above statements are correct?
(a) 1, 2 and 3 (b) 1 and 2 (c) 2 and 3 (d) 1 and 3
52. Ans. (d)

53. In a steam power plant, the ratio of the isentropic heat drop in the prime mover to the amount of heat supplied per unit mass of steam is known as **[IES-2000]**
(a) stage efficiency (b) degree of reaction
(c) Rankine efficiency (d) relative efficiency
53. Ans. (c)

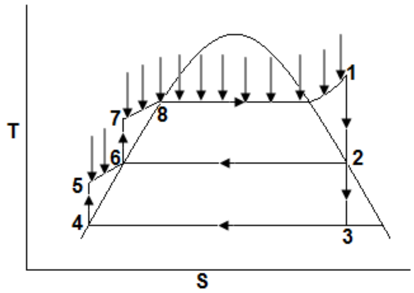
54. Assertion (A): Rankine efficiency would approach Carnot cycle efficiency by providing a series of regenerative feed heating. **[IES-2002]**
Reason (R): With regenerative feed heating, expansion through the turbine approaches an isentropic process.
54. Ans. (a)

55. A regenerative steam cycle renders **[IES-1993]**
(a) increased work output per unit mass of steam
(b) decreased work output per unit mass of steam
(c) increased thermal efficiency
(d) decreased work output per unit mass of steam as well as increased thermal efficiency.
55. Ans. (d) In regenerative steam cycle. a part of steam is extracted from turbine and utilized to heat up condensate. In this way some work is lost per unit mass of

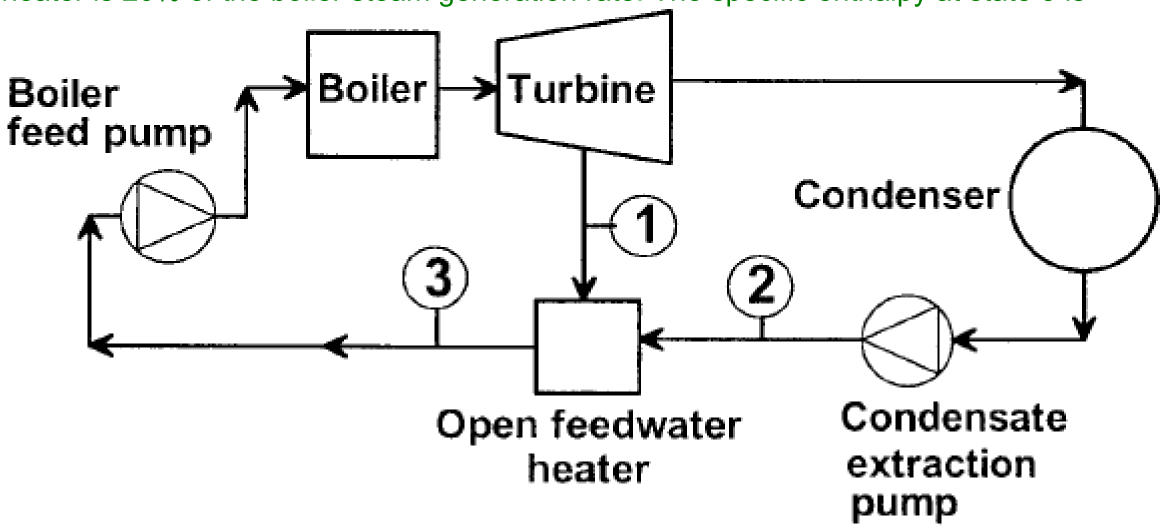
steam corresponding to steam extracted out, but its heat is not wasted to cooling water but conserved within the cycle thus increasing thermal efficiency.

56. In a regenerative cycle, steam with enthalpy of 3514 kJ/kg is expanded in h.p. turbine to a state corresponding to saturated enthalpy of water equal to 613 kJ/kg. If the pump work requirements in high pressure and low pressure zones are respectively 3 and 1 kJ/kg, amount of heat transferred in boiler is **[IAS-2002]**
(a) 2897 kJ/kg (b) 2898 kJ/kg (c) 2904 kJ/kg (d) 2905 kJ/kg
56. Ans. (a)

$$\text{Heat added} = h_1 - h_4 - \text{pump works}$$
$$= h_1 - h_4 - (h_7 - h_6) - (h_5 - h_4)$$
$$= 3514 - 613 - 3 - 1 = 2897 \text{ kJ/kg}$$



57 . A thermal power plant operates on a regenerative cycle with a single open feed water heater, as shown in the figure. For the state points shown, the specific enthalpies are: h_1 = 2800 kJ/kg and h_2 = 200 kJ/kg. The bleed to the feed water heater is 20% of the boiler steam generation rate. The specific enthalpy at state 3 is



(A) 720kJ/kg (B) 2280kJ/kg (C) 1500kJ/kg (D) 3000kJ/kg **[GATE-2008]**
57. Ans. (A) : let 100 kg steam is in (m_3) then m_1=20kg and m_2=80kg
Therefore $m_1h_1+m_2h_2 = m_3h_3$

or $h_3 = \dfrac{20 \times 2800 + 80 \times 200}{100} = 720 kJ/kg$

58. Assertion (A): In gas turbines, regenerative heating always improves the efficiency unlike that in the case of reheating.
Reason (R): Regenerative heating is isentropic. **[IES-1998]**
58. Ans. (c)

59. When is the greatest economy obtained in a regenerative feed heating cycle?
(a) Steam is extracted from only one suitable point of a steam turbine **[IES-2006]**
(b) Steam is extracted only from the last stage of a steam turbine
(c) Steam is extracted only from the first stage of a steam turbine

(d) Steam is extracted from several places in different stages of steam turbines
59. Ans. (d)

60. In a regenerative feed heating cycle, the economic number of the stages of regeneration **[IES-2003]**
(a) increases as the initial pressure and temperature increase
(b) decreases as the initial pressure and temperature increase
(c) is independent of the initial pressure and temperature
(d) depends only on the condenser pressure
60. Ans. (a) Since efficiency is proportional to gain in feed water temperature. As initial temperature and pressure increases the gain in feed water temperature decreases i.e. efficiency gain follows the law of diminishing return with increase in the number of heaters.

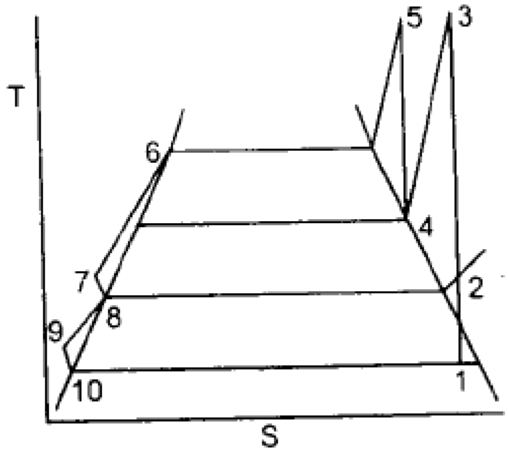
61. Which one of the following statements is not correct for a regenerative steam cycle?
(a) It increases the thermodynamic efficiency **[IES-2005]**
(b) It reduces boiler capacity for a given output
(c) It reduces temperature stresses in the boiler due to hotter feed
(d) The efficiency increases with increased number of feed heaters
61. Ans. (c) (i) $\eta\uparrow$ with increased number of feed heaters but Efficiency gain $(\Delta\eta)$ successively diminishes with the increase in the number of heaters
(ii) It increases the stream flow rate (requiring bigger boiler)
(iii) It reduces the steam flow to the condenser (needing smaller condenser)

62. In which one of the following steam turbines, steam is taken from various points along the turbine, solely for feed water heating? **[IES-2004]**
(a) Extraction turbine (b) Bleeder turbine (c) Regenerative turbine (d) Reheat turbine
62. Ans. (b) Note: Regenerative cycle **not** regenerative turbine so choice is 'b'

63. Consider the following statements: **[IAS-1997]**
The overall efficiency of a steam power plant can be increased by
1. increasing the steam temperature. 2. increasing the condenser pressure
3. improving turbine blade cooling. 4. Providing air preheaters.
Of these correct statements are:
(a) 1, 2 and 3 (b) 2 and 3 (c) 1 and 4 (d) 2 and 4
63. Ans. (c)

Feedwater Heaters

64. The temperature-entropy diagram for a steam turbine power plant, operating on the Rankine cycle with reheat and regenerative feed heating is shown in the given figure. If m denotes the fraction of steam bled for feed heating, the work developed in the turbine per kg steam entering the turbine at state



(a) $(h_5 - h_4) + (1-m)(h_3 - h_1)$

(b) $(h_5 - h_4) + (h_3 - h_2) + (1-m)(h_2 - h_1)$

(c) $2h_5 - h_4 - h_2 + (1-m)(h_2 - h_1)$

(d) $(h_5 - h_4) + (1-m)(h_3 - h_2)$

[IES-2001]

64. Ans. (a)

Optimum Degree of Regeneration

Deaerator

65. In thermal power plants, the deaerator is used mainly to **[IES-1996]**
(a) remove air from condenser. (b) increase feed water temperature.
(c) reduce steam pressure (d) remove dissolved gases from feed water.
65. Ans. (d) In thermal power plants, the deaerator is used mainly to remove dissolved gases from feed water

66. Match List I with List II and select the correct answer: **[IES-2002]**

List I (Equipment)	List II (Application area)
A. Anticipatory gear	1. Sealing system
B. Labyrinth	2. Steam power plant
C. Inverted T-attachment	3. Turbine governing system
D. De aerator	4. Blades

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

66. Ans. (b)

67. In steam and other vapour cycles, the process of removing non-condensable is called
(a) Scavenging process (b) De aeration process
(c) Exhaust process (d) Condensation process **[IAS-2003]**
67. Ans. (b)

68. In steam and other vapour cycles, the process of removing non-condensable is called **[GATE-1992]**
(a) scavenging process (b) de-aeration process
(c) exhaust process (d) condensation process
68. Ans. (b)

Typical Layout of Steam Power Plant

Efficiencies in a Steam Power Plant

69. A steam plant has the boiler efficiency of 92%, turbine efficiency (mechanical) of 94%, generator efficiency of 95% and cycle efficiency of 44%. If 6% of the generated power is used to run the auxiliaries, the overall plant efficiency is **[GATE-1996]**

(a) 34% (b) 39% (c) 45% (d) 30%

69. Ans. (a) $\eta_{\text{overall}} = \eta_{\text{boiler}} \times \eta_{\text{turbine(mech)}} \times \eta_{\text{generator}} \times \eta_{\text{aux}}$

$$\text{Note}: \eta_{\text{aux}} = \frac{\text{net power transmitted by the generator}}{\text{Gross power produced by the plant}} = 0.94 \text{ (here)}$$

$$\eta_{\text{overall}} = 0.92 \times 0.44 \times 0.94 \times 0.95 \times 0.94 = 0.34 = 34\%$$

70. Consider the following statements: **[IES-1999]**

The efficiency of the vapour power Rankine cycle can be increased by

1. increasing the temperature of the working fluid at which heat is added.
2. increasing the pressure of the working fluid at which heat is added.
3. decreasing the temperature of the working fluid at which heat is rejected.

Which of these statements is/are correct?

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

70. Ans. (d)

71. Assertion (A): Rankine cycle is preferred for waste heat recovery. **[IES-1992]**
Reason (R): Rankine cycle gives high thermal efficiency even at low temperatures compared to other dynamic energy conversion systems

71. Ans. (a)

72. The efficiency of Rankine cycle is lower than that corresponding Carnot cycle because

(a) the average temperature at which heat is supplied in Rankine cycle is lower than corresponding Carnot cycle **[IES-1992]**

(b) the Carnot cycle has gas as working substance and Rankine cycle has steam has working substance

(c) the Rankine cycle efficiency depends upon properties of working substance where as Carnot cycle efficiency is independent of the properties of working substances.

(d) the temperature range of Carnot cycle is greater tan that for Rankine cycle.

72. Ans. (a)

73. The thermal efficiency of the plant neglecting pump work is **[GATE-2004]**

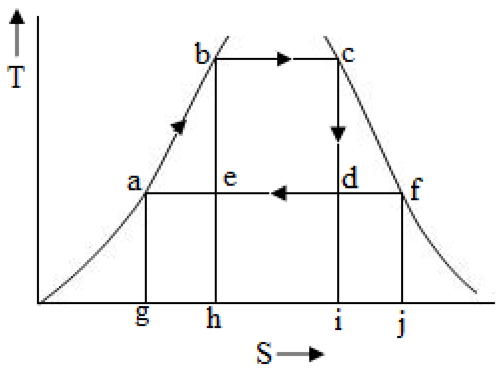
(a) 15.8% (b) 41.1% (c) 48.5% (d) 58.6%

73. Ans. (b) $\eta = \dfrac{\text{work done}}{\text{Heat supplied}} = \dfrac{(h_3 - h_4) + (h_5 - h_6)}{(h_3 - h_2) + (h_5 - h_4)} = 41.1\%$

74. Assertion (A): For the same limits of boiler pressure and temperature, the specific steam consumption of ideal Carnot cycle is less than that of ideal Rankine cycle.
Reason (R): For the same limits of boiler pressure and temperature, Carnot cycle is more efficient than Rankine cycle.

74. Ans. (d)

75. In the given figure Rankine efficiency is equal to the ratio of the areas
(a) abeda/ gabedig
(b) abeda/ abcfa
(c) ebcde / gabcfjg
(d) ebcde / hebcdih



[IAS-2001]

75. Ans. (a) Heat input = area of T-S diagram = gabcdig
Work done = Heat addition – heat rejection
= gabcdig - gadig = abcda

Cogeneration of Power and Process Heat

76. In the bottoming cycle of cogeneration, low grade waste heat is used for
(a) processing (b) power generation **[IES-1992]**
(c) feed water heating (d) none of the above
76. Ans. (b)

Combined Cycle Power Generation

Binary Vapour Cycles

Combined Cycle Plants

77. A power plant, which uses a gas turbine followed by steam turbine for power generation, is called: **[IES-2005]**
(a) Topping cycle (b) Bottoming cycle (c) Brayton cycle (d) Combined cycle
77. Ans. (d)

78. Which of the following power plants use heat recovery boilers (unfired) for steam generation? **[IES-1998]**
1. Combined cycle power plants 2. All thermal power plants using coal
3. Nuclear power plants 4. Power plants using fluidised bed combustion.
Select the correct answer using the codes given below:
(a) 1 and 2 (b) 3 and 4 (c) 1 and 3 (d) 2 and 4
78. Ans. (c)

79. Which of the following thermal power plants will have the highest overall thermal efficiency? **[IAS-2003]**
(a) Steam power plant (b) Gas turbine power plant
(c) Combined gas and steam power plant (d) Diesel power plant
79. Ans. (c)

80. For two cycles coupled in series, the topping cycle has an efficiency of 30% and the bottoming cycle has an efficiency of 20%. The overall combined cycle efficiency is **[GATE-1996]**
(a) 50% (b) 44% (c) 38% (d) 55%

80. Ans. (b) $(1-\eta)=(1-\eta_1)(1-\eta_2)(1-\eta_3)..........(1-\eta_m)$

or $\eta=\eta_1+\eta_2-\eta_1\eta_2=(0.30+0.2-0.3\times0.2)\times100\%=44\%$

Steam Generators

1. Heat is mainly transferred by conduction, convection and radiation in **[IES-1998]**
(a) insulated pipes carrying hot water (b) refrigerator freezer coil
(c) boiler furnaces (d) condensation of steam in a condenser
1. Ans. (c) All modes of heat transfer occur in boiler furnace

2. An attemparator is used in some utility boilers
(a) ahead of super heater for initial superheating **[IAS-2004]**
(b) for optimizing steam output from the generator
(c) to regulate steam pressure
(d) to control degree of superheat
2. Ans. (d)

3. When inspection doors on the walls of boilers are opened, flame does not leap out because **[IAS-1998]**
(a) these holes are small (b) pressure inside is negative
(c) flame travels always in the direction of flow
(d) these holes are located beyond the furnace
3. Ans. (b)

4. Assertion (A): An 'air-to-close' valve should be used to control the fuel supply to the furnace. **[IAS-1997]**
Reason (R): In the event of air failure, the valve would be closed and the fuels cut off to prevent overheating.
4. Ans. (a)

Fire-tube Boilers

5. Assertion (A): Fire tube boilers do not operate at high pressures while water tube boilers operate at high pressures. **[IES-2006]**
Reason (R): Due to high temperature of flue gases, fire tubes may fail due to creep.
5. Ans. (a)

6. Assertion (A): Fire tube boilers have quick response to load changes.
Reason (R): Fire tube boilers have large water storage capacity and hence small pressure changes can meet sudden demands. **[IAS-1999]**
6. Ans. (a)

Cochran boiler

7. Match List-I (Name of boiler) with List-II (Special features) and select the correct answer using the codes given below the lists:

List-I	List-II	**[IES-1999]**
A. Lancashire	1. High pressure water tube	
B. Cornish	2. Horizontal double fire tube	
C. La Mont	3. Vertical multiple fire tube	
D. Cochran	4. Low pressure inclined water tube	

5. Horizontal single fire tube

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

7. Ans. (a) Lancashire boiler is horizontal double fire tube type, Cornish boiler is horizontal single fire tube type. La Mont boiler is high pressure water type, and Cochran boiler is vertical multiple fire tube type.

8. Match List I with List II and select the correct answer using the codes given below the lists: **[IES-1995]**

List I (Type of boiler)	List II (Classification of boiler)
A. Babcock and Wilcox	1. Forced circulation
B. Lancashire	2. Fire tube
C. La-mont	3. Water tube
D. Cochran	4. Vertical

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

8. Ans. (c)

Cornish boiler

9. Match List I (Equipments) with List II (Types) and select the correct answer using the codes given below the Lists: **[IAS-2001]**

List I	List II
A. Steam trap	1. Fire tube type
B. Water-level indicator	2. Boiler mounting
C. Cornish boiler	3. Drum less type
D. Benson boiler	4. Boiler accessory
	5. Indirectly heated

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

9. Ans. (d)

Lancashire boiler

10. Match List I (Boilers) with List II (Type/Description) and select the correct answer using the codes given below the Lists: **[IES-2003]**

List I (Boilers)	List II (Type/Description)
A. Lancashire	1. Horizontal straight tube, fire-tube boiler
B. Benson	2. Inclined straight tube, water-tube boiler
C. Babcock and Wilcox	3. Bent tube, water-tube boiler
D. Stirling	4. High pressure boiler

Codes:

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

10. Ans. (d)

Locomotive boiler

12. The draught in locomotive boilers is produced by **[IES-2003]**
(a) Chimney (b) Centrifugal fan (c) Steam jet (d) Locomotion
12. Ans. (c)

13. Which one of the following is the fire-tube boiler? **[IES-2005]**
(a) Babcock and Wilcox boiler (b) Locomotive boiler
(c) Stirling boiler (d) Benson boiler
13. Ans. (b)

Scotch boiler

Water-Tube Boilers

Babcock and Wilcox boiler

Stirling boiler

High pressure boiler

Lamont boiler

Loeffler boiler

Benson boiler

14. There is no steam drum in **[IAS-2001]**
(a) La Mont boiler (b) Loffler boiler (c) Benson boiler (d) Velox boiler
14. Ans. (c)

15. Benson boiler is one of the high pressure boilers having **[IES-1999]**
(a) one drum (b) one water drum and one steam drum
(c) three drums (d) no drum
15. Ans. (d) Benson boiler is drum less, once-through boiler.

16. Consider the following components: **[IES-1997]**
1. Radiation evaporator 2. Economiser
3. Radiation superheater 4. Convection superheater
In the case of Benson boiler, the correct sequence of the entry of water through these components is:
(a) 1, 2, 3, 4 (b) 1, 2, 4, 3 (c) 2, 1, 3, 4 (d) 2, 1, 4, 3
16. Ans. (c) The correct sequence of water entry in Benson boiler is -economiser, radiation evaporator, radiation superheater and finally convection superheater

17. **Assertion (A):** Benson boiler is much lighter than other boilers.
Reason (R): Boiler pressure raised to the critical pressure in Benson boiler permits doing away with steam (separating) drums. **[IAS-1995]**
17. Ans. (a) Both A and R are true and R is the correct explanation of A
Benson boiler is lighter and one of the reasons is absence of boiler drum. However lightness is due to elimination of water walls also. Thus both *A* and *R* ill' true and *R* is also explanation for *A.*

18. Which one of the following statements is ***not*** true for a supercritical steam generator?
(a) It has a very small drum compared to a conventional boiler **[IES-2005]**
(b) A supercritical pressure plant has higher efficiency than a subcritical pressure plant
(c) The feed pressure required is very high, almost 1.2 to 1.4 times the boiler pressure
(d) As it requires absolutely pure feed water, preparation of feed water is more important than in a subcritical pressure boiler
18. Ans. (a) It has no drum.

Velox boiler

19. The distinguishing feature of Velox boiler is that it **[IAS-1996]**
(a) is drumlins (b) uses supersonic
(c) operates under supercritical pressure (d) uses indirect heating
19. Ans. (b) Due to supersonic flue gas velocity in the Velox Boiler larger heat transfer from a smaller surface area is possible.

Supercritical boiler

20. Once-through boilers operate at **[IES-2000]**
(a) subcritical pressure (b) supercritical pressure
(c) subcritical as well as supercritical pressures (d) critical pressure only
20. Ans. (c)

21. Once-through boilers will NOT have **[IES-1998]**
(a) drums, headers and pumps (b) drums, steam separators and pumps
(c) drums, headers and steam separators (d) drums, headers, steam separators and pumps
21. Ans. (c)

22. Once through boiler is named as such because **[IES-1993]**
(a) flue gas passes only in one direction (b) there is no recirculation of water
(c) air is sent through the same direction (d) steam is sent out only in one direction
22. Ans. (b) Once through boiler is named as such because there is no recirculation of water as in case of natural or forced circulation boiler.

23. Consider the following statements
1. Boilers rated above 500 MW are not necessarily supercritical boilers.
2. Power plant boilers are generally once-through boilers.
3. Blow down at regular intervals is done to remove solids. **[IAS 1994]**
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
23. Ans. (d)

24. In large power boilers, soot blowers are used at regular intervals for cleaning the tubes. What is the fluid used for the same? **[IAS-1998]**
(a) Low pressure steam (b) Hot gases (c) Hot air (d) Boiling water
24. Ans. (a)

25. In high pressure water tube boilers, the tube bundles are **[IAS-1998]**

(a) hung from top girders (b) supported on brick walls
(c) bolted on steel sturctures (d) firmly fixed on any structure
25. Ans. (a)

26. Blowers deliver gaseous fluids at pressure ratios………….. (below/above) 1.15 and.......................... (have/have no) artificial cooling arrangement **[GATE-1992]**
26. Ans. Below; have no

Boiler Mountings

Water level indicator

Pressure gauge

27. Consider the following:
1. Safety valve. 2. Fusible plug. 3. Feed water pump 4. Pressure gauge.
The essential boiler mountings would include **[IAS-1999]**
(a) 1, 3 and 4 (b) 3 and 4 (c) 1, 2 and 3 (d) 1, 2 and 4
27. Ans. (d)

28. Which one of the following accessories is connected to the steam supply pipe line to maintain constant pressure?
(a) Pressure reducing valve (b) Steam separator
(c) Steam trap (d) Injector **[IES 2007]**
28. Ans. (a)

Safety Valve

29. Consider the following: **[IES-1994]**
1. Safety valve 2. Steam trap 3. Steam separator 4. Economizer
Among these, the boiler accessories would include.
(a) 1, 2 and 3 (b) 2, 3 and 4 (c) 1 and 4 (d) 1, 2, 3 and 4
29. Ans. (a) Safety valve, steam trap, and steam separator are boiler accessories.

30. Consider the following statements: **[IAS-1998]**
1. Safety value in boilers will operate as soon as the pressure reaches the rated value.
2. Two safety valves are provided for quick release of pressure.
3. Blow down valve is operated regularly to remove sediments if any.
4. Water level is monitored electrically in all large boilers.
Of these statements:
(a) 1 and 2 are correct (b) 2 and 3 are correct(c) 3 and 4 are correct (d) 1 and 4 are correct
30. Ans. (c)

31. Which of the following statements are false? **[IAS 1994]**
1. Soot blowers are used generally in oil fired boilers.
2. There will be at least three safety valves on the boiler drum
3. Recuperative heating is better than regenerative heating in the case of pre-heaters.
Select the correct answer using the codes given below:
Codes:

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

31. Ans. (a)

High steam and low water safety valve

Fusible plug

32. Which one of the following fittings is mounted on the boiler to put off the fire in the furnace, when water level falls to an unsafe limit?

(a) Feed check valve (b) Safety valve

(c) Fusible plug (d) Blow off cock **[IES 2007]**

32. Ans. (c)

33. Which of the following are boiler mountings? **[IES-2005]**

1. Fusible plug 2. Blow-off cock 3. Steam trap 4. Feed check valve

Select the correct answer using the code given below:

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

33. Ans. (d)

34. Match List I (Components) with List II (Functions) codes given below the Lists **[IES-2000]**

List I	List II
A. Steam trap	1. Controls steam flow rate
B. Fusible plug	2. Controls rate of water flow to boiler
C. Blow-off cock	3. Puts off furnace fire when water level reaches unsafe limit
D. Feed check valve	4. Removes mud and dirt collected at the bottom of boiler
	5. Drains off water collected by partial condensation of steam in pipes

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

34. Ans. (c)

35. Which one of the following safety devices is used to protect the boiler when the water level falls below a minimum level? **[IES-1999]**

(a) Water level indicator (b) Fusible plug (c) Blow off cock (d) Safety valve

35. Ans. (b) When water level falls below a minimum level, fusible plug melts and extinguishes fire to protect the boiler from overheating.

36. When the water level in the boiler falls to an unsafe limit, safety is ensured by the

(a) stop valve (b) safety valve (c) fusible valve (d) blow-off cock **[IAS-2000]**

36. Ans. (c)

Blow off cock

37. The blow-off valve of a boiler helps to **[IAS-1996]**

(a) provide safety (b) maintain solids in suspension below a certain value

(c) regulate the flow of steam (d) shut down the boiler

37. Ans. (b)

Feed check valve

38. Which of the following form part (s) of boiler mountings? **[IES-1998]**
1. Economiser 2. Feed check valve 3. Steam trap 4. Superheater
Select the correct answer using the codes given below:
Codes: (a) 2 alone (b) 1 and 3 (c) 2, 3 and 4 (d) 1, 2, 3 and 4
38. Ans. (a)

Stop valve

39. Consider the following statements: **[IES-1995]**
1. Boiler mountings are mainly protective devices
2. Steam stop valve is an accessory
3. Feed water pump is an accessory
Of these correct statements are:
(a) 1, 2 and 3 (b) 1 and 2 (c) 2 and 3 (d) 3 and 1
39. Ans. (c)

40. Assertion (A): In modem boilers, a combination of convection superheater and radiant superheater maintains a constant steam temperature at the stop valve at all loads. **[IES-1994]**
Reason (R): The radiant superheater absorbs more heat as the load increases and convection superheater absorbs less heat as the load increases.
40. Ans. (c) Statement at A is correct. Radiant superheater absorbs less heat as load increases and convection superheater absorbs more heat as the load increases. Thus R is false.

Boiler Accessories

Feed pumps

Injection

41. Which one of the following boiler accessories does not need 'flue-gas' for its operation?
(a) Economiser (b) Preheater (c) Injector (d) Superheater **[IES 2007]**
41. Ans. (c)

Economizer

42. Consider the following: **[IES-2006]**
1. Superheater 2. Economizer 3. Air pre-heater 4. Condenser
Which of the above improve overall steam power plant efficiency?
(a) Only 1, 2 and 3 (b) Only 2 and 3 (c) Only 1 and 4 (d) 1, 2, 3 and 4
42. Ans. (d)

43. Consider the following: **[IES-2006]**
1. Injector 2. Economizer 3. Blow-off cock 4. Steam stop valve
Which of the above is/are not boiler mountings?
(a) Only 1 (b) Only 1 and 2 (c) 1, 2 and 3 (d) 2 and 4
43. Ans. (b)

44. The device used to heat feed-water by utilizing the heat of the exhaust flue gases before leaving through the chimney, is called **[IES-1999]**
(a) superheater (b) economizer (c) air preheater (d) ID fan
44. Ans. (b) Economiser is used to heat feed water by utilising the heat of the exhaust flue gases before leaving through the chimney.

45. Economizer is generally placed between **[IES-1992]**
(a) last superheater/ reheater and air preheater (b) air preheater and chimney
(c) electrostatic precipitators (d) induced draft fan and forced draft fan
45. Ans. (a)

46. The function of an economizer in a steam power plant is to **[IAS-2001]**
(a) increase the temperature of air supplied to a boiler
(b) increase the enthalpy of feed water
(c) condense the exhaust steam from the turbine
(d) heat the fuel before combustion
46. Ans. (b)

47. In modern steam plants using pulverized fuel firing, the flue gases **[IAS-2001]**
(a) first pass through air preheater and then through economizer
(b) first pass through economizer and then through air preheater
(c) pass simultaneously through air preheater and economizer which are connected in parallel
(d) pass through economizer only
47. Ans. (b)

48. Consider the following accessories: **[IAS-2000]**
1. Superheater 2. Air-pre-heater 3. Economizer
The correct sequence of the position of these accessories along the flow of flue gas in a steam power plant is
(a) 3, 1, 2 (b) 1, 2, 3 (c) 1, 3, 2 (d) 2, 1, 3
48. Ans. (c)

49. Larger temperature rise of boiler feed water in the economizer should be avoided because **[IAS-2000]**
(a) the economizer efficiency will reduce
(b) the overall steam generator efficiency will reduce
(c) effectiveness of regenerator will be lower
(d) flue gas will cool to its dew point
49. Ans. (c) Cycle efficiency is maximum when the total enthalpy rise of feed water from the condenser temperature to the boiler saturation temperature is divided equally among the feed water heaters and the economizer. If n number of feed water heaters is used then

$$(\Delta h)_{\text{preheater}} = (\Delta h)_{\text{economizer}} = \frac{h_{\text{boiler saturation}} - h_{\text{condenser}}}{n+1}$$

50. Assertion (A): An economizer is placed between the boiler and the chimney to recover heat carried away in the flue gases. **[IAS-1996]**
Reason (R): Combustion air can easily abstract some heat from the flue gases that would otherwise pass up the chimney.
50. Ans. (b) R is explanation of air preheater.

51. Which among the following is the boiler mounting? **[GATE-1997]**
(a) Blow off cock (b) Feed pump (c) Economiser (d) Superheater

51. Ans. (c)

Air Preheater

52. In a steam power plant, feed water heater is a heat exchanger to preheat feed water by **[IES-1992]**
(a) live steam from steam generator
(b) hot flue gases coming out of the boiler furnace
(c) hot air from air preheater (d) extracting steam from turbine
52. Ans. (d)

53. Assertion (A): The use of air preheater is much economical when used with pulverised fuel boilers. **[IES-1992]**
Reason (R): The temperature of flue gases going out is sufficiently large.
53. Ans. (a)

54. Consider the following stages: **[IAS-1997]**
1. Superheater 2. Economiser 3. Electrostatic precipitator 4. Air preheater
The correct sequence of the stages through which gases flow from the boiler to the chimney is:
(a) 2, 1, 3, 4 (b) 1, 2, 3, 4 (c) 2, 1, 4, 3 (d) 1, 2, 4, 3
54. Ans. (d)

Superheater

Steam Separator

Steam trap

55. A device which is used to drain off water from steam pipes without escape of steam is called **[IES-2002]**
(a) Steam separator (b) Steam trap (c) Pressure reducing valve (d) Injector
55. Ans. (b)

Draught

Natural draught

56. Assertion (A): Excess air in the case of natural draught system is more when compared to artificial draught system in a boiler. **[IES-1993]**
Reason (R): To ensure complete combustion of a fuel, a quantity of air in excess of the theoretical minimum is supplied.
56. Ans. (d) Assertion A is not true because excess air is controlled by forced draft fan. However reason R is true.

Efficiency of a Chimney

57. Given that, h is draught in mm of water, H is chimney height in meters,

T_1 is atmospheric temperature in K, the maximum discharge of gases through a chimney is given by **[IES-1996]**

$(a) h = 176.5T_1 / H$ $(b) h = H / 176.5T_1$ $(c) h = 1.765H / T_1$ $(d) h = 176.5H / T_1$

57. Ans. (c)

Forced draught

58. Assertion (A): The efficiency of a boiler is more if it is provided with mechanical draught rather than with natural draught. **[IES-1996]**

Reason (R) The exhaust gases can be cooled to the lowest possible temperature if mechanical draught is provided.

58. Ans. (a) Both A and R are true and R is correct explanation for A

Induced draught

Balanced draught

Power required for Fan

Boiler Performance

Equivalent Evaporation

59. Which one of the following factors has the maximum effect of the equivalent evaporation of a boiler? **[IES-1992]**

(a) Steam generator pressure (b) Feed water inlet temperature
(c) Heating surface of the boiler (d) Quality of steam produced

59. Ans. (a)

60. The equivalent evaporation (kg/hr) of a boiler producing 2000 kg/hr of steam with enthalpy content of 2426 kJ/kg from feed water at temperature 40°C (liquid enthalpy = 168 kJ/kg, enthalpy of vaporisation of water at 100°C = 2258 kJ/kg) is

(a) 2000 (b) 2149 (c) 1682 (d) 1649 **[GATE-1993]**

60. Ans. (a)

Equivalent evaporation of boiler

$$= \frac{m_s (h - h_f)}{\text{Enthalpy of vaporisation of water at } 100^\circ C}$$

$$= \frac{2000 \text{ kg/hr} (2426 - 168) \text{ kJ/kg}}{2258 \text{ kJ/kg}} = \mathbf{2000 \ kg/hr}$$

61. Boiler rating is usually defined in terms of **[GATE-1992]**

(a) maximum temperature of steam in Kelvin (b) heat transfer rate in KJ/hr
(c) heat transfer area in metre^2 (d) steam output in kg/hr

61. Ans. (D)

Factor of Evaporation

Boiler Efficiency

62. In a boiler, feed water supplied per hour is 205 kg while coal fired per hour is 23 kg. Net enthalpy rise per kg of water is 145 kJ for conversion to steam. If the calorific value of coal is 2050 kJ/kg, then the boiler efficiency will be **[IAS 1994]**
(a) 78% (b) 74% (c) 62% (d) 59%

62. Ans. (c) $Boiler\ efficiency = \frac{Heat\ utilized}{Heat\ \text{sup}\ plied\ by\ coal} = \frac{205 \times 145}{23 \times 2050} = 0.62$

63. The output of a boiler is normal1y stated as **[IES-1994]**
(a) evaporative capacity in tonne of steam that can be produced from and at 100°C.
(b) weight of steam actual1y produced at rated pressure in tonne per hour.
(c) boiler horse power (d) weight of steam produced per kg of fuel.
63. Ans. (b) Output of boiler is stated as weight of steam at rated pressure.

Heat losses in a boiler

Circulation ratio

64. In forced circulation boilers, about 90% of water is recirculated without evaporation. The circulation ratio is **[IES-1996]**
(a) 0.1 (b) 0.9 (c) 9 (d) 10
64. Ans. (b) Circulation ratio is 0.9

65. The circulation ratio for once through steam generators is **[IAS-2000]**
(a) 1 (b) 2 (c) 2.5 (d) 5
65. Ans. (a)

66. Consider the following: **[IES-1996]**
1. Increasing evaporation rate using convection heat transfer from hot gases.
2. Increasing evaporation rate using radiation.
3. Protecting the refractory walls of the furnace. 4. Increasing water circulation rate. The main reasons for providing water wall enclosures in high pressure boiler furnaces would include
(a) 2 and 3 (b) 1 and 3 (c) 1 and 2 (d) 1, 2, 3 and 4
66. Ans. (c)

67. Assertion (A): All boilers used in power plants necessarily use forced circulation.
Reason (R): Forced circulation increases heat transfer. **[IES-1995]**
67. Ans. (d) Boilers of 200-250 MW used in power plants are based on natural circulation. Forced circulation increases heat transfer.

Electrostatic Precipitator

68. Consider the following statements **[IES-2000]**
    1. Forced circulation is always used in high pressure power boilers.
    2. Soot blowers are used for cleaning tube surfaces at regular intervals.
    3. Electrostatic precipitator is used to remove fly ash from flue gases.

Which of these statements are correct?
(a) 1, 2 and 3 (b) 2 and 3 (c) 1 and 3 (d) 1 and 2
68. Ans. (b)

69. Match List I with List II and select the correct answer using the codes given below the lists: **[IES-1995]**

List I	List II
A. Soot Blower	1. Removal of solids from boiler drums
B. Electrostatic precipitator	2. To clean the tube surfaces of fly ash
C. Blow down	3. Cleaning of flue gas
D. Zeolite	4. Air cleaning.
	5. Water purification

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

69. Ans. (d)

Feedwater Treatment

Boiler Blowdown

70. Consider the following statements: **[IES-1993]**
Blowdown is necessary on boilers, because
1. the boiler water level is lowered rapidly in case it accidentally rises too high.
2. the precipitated sediment or sludge is removed while the boiler is in service.
3. the concentration of suspended solids in the boiler is controlled.
Of these statements
(a) 1, 2 and 3 are correct (b) 1 and 2 are correct
(c) 3 alone is correct (d) 1 and 3 are correct
70. Ans. (b)

71. Blowing down of boiler water is the process to **[IES-2002]**
(a) reduce the boiler pressure (b) increase the steam temperature
(c) control the solids concentration in the boiler water (d) control the drum level
71. Ans. (c)

72. Which one of the following is the purpose of blow-down in a boiler?
(a) To control drum level **[IAS-2004]**
(b) To control solid concentration in the boiler water
(c) To increase the steam temperature
(d) To lower the steam temperature
72. Ans. (b)

Steam Purity

Path of flue gas

73. Which one of the following is the correct path of water flow through various components of boiler of a modern thermal power plant? **[IES-2005]**
(a) Economizer - boiler drum - water walls - boiler drum - superheater - turbine
(b) Economizer - boiler drum - water wall – superheater - turbine
(c) Economizer - water walls - boiler drum – superheater - turbine
(d) Economizer - water walls - superheater – turbine

73. Ans. (a)

74. The correct gas flow path in a typical large modern natural circulation boiler is (a) Combustion chamber - Reheater - Superheater - Economiser - Air Preheater – I.D. fan - Electrostatic precipitator - Stack **[IES-2003]**
(b) Combustion chamber - Superheater - Reheater - Economiser - Air Preheater - Electrostatic precipitator - I.D. fan - Stack
(c) Combustion chamber - Reheater - Superheater - Air Preheater - Economiser - Electrostatic precipitator – I.D. fan - Stack
(d) Combustion chamber - Superheater - Reheater - Economiser - Air Preheater – I.D. fan - Electrostatic precipitator – Stack
74. Ans. (b)

75. Which one of the following sequences indicates the correct order for flue gas flow in the steam power plant layout? **[IES-2001]**
(a) Superheater, economiser, air preheater
(b) Economiser, air preheater, superheater
(c) air preheater, economiser, superheater
(d) economiser, superheater, air pre heater
75. Ans. (a)

76. Which one of the following indicates the correct order in the path of flue gas?
(a) Super-heater, economiser, air pre-heater, precipitator
(b) Super-heater, economiser, precipitator, air pre-heater
(c). Super-heater, precipitator, economizer, air pre-heater
(d) Super-heater, air pre-heater, economizer, precipitator **[IAS-1995]**
76. Ans. (a)

77. In High pressure natural circulation boilers the flue gases flow through the following boiler accessories : **[IES-1997]**
1. Superheater 2. Air heater 3. Economiser 4. I.D. fan.
The correct sequence of the flow of flue gases through these boiler accessories is:
(a) 1, 3, 4, 2 (b) 3, 1, 4, 2 (c) 3, 1, 2, 4 (d) 1, 3, 2, 4
77. Ans. (d) The correct sequence for flow of flue gases in boiler is superheater, economiser, air heater and I. D. fan.

78. Pertaining to a steam boiler, pick the correct statement among the following
(a) Primary boiler heat surfaces include evaporator section, economizer and air preheater
(b) Primary boiler heat transfer surfaces include evaporator section, super heater section and economizer.
(c) Secondary boiler heat transfer surfaces include super heater, economizer and air preheater.
(d) Primary boiler heat transfer surfaces include evaporator section, super heater section and reheat section **[GATE-1998]**
78. Ans. (c) Economizer, preheater, Super heater are all accessories of the boiler and hence forms secondary boiler heat transfer surface.

79. Which one of the following group of devices are used for part recovery of heat from the flue gases leaving the tube banks in a water tube boiler? **[IAS-1998]**
(a) Drum internals, super heaters and economiser
(b) Economiser, air preheater and electrostatic precipitator
(c) Water wall, drum internals and super heaters
(d) Super heaters, economiser and air preheater
79. Ans. (d)

80. Consider the following statements regarding waste heat boilers: **[IES-2004]**

1. Waste-heat boilers placed in the path of exhaust gases
2. These are fire tube boilers
3. The greater portion of the heat transfer in such boilers is due to convection

Which of the statements given above are correct?

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

80. Ans. (d)

Answers with Explanation (Objective)

Steam Turbine

Objective Questions (IES, IAS, GATE)

1. What is the ratio of the isentropic work to Euler's work known as? **[IES-2006]**

(a) Pressure coefficient (b) Slip factor

(c) Work factor (d) Degree of reaction

1. Ans. (a)

2. In steam turbine terminology, diaphragm refers to **[IES-1993]**

(a) separating wall between rotors carrying nozzles

(b) the ring of guide blades between rotors

(c) a partition between low and high pressure dies

(d) the flange connecting the turbine exit to the condenser

2. Ans. (a) Diaphragm in steam turbines is a separating wall between rotors carrying nozzles,

Impulse Turbines

3. In an ideal impulse turbine, the **[IES-1993]**

(a) absolute velocity at the inlet of moving blade is equal to that at the outlet

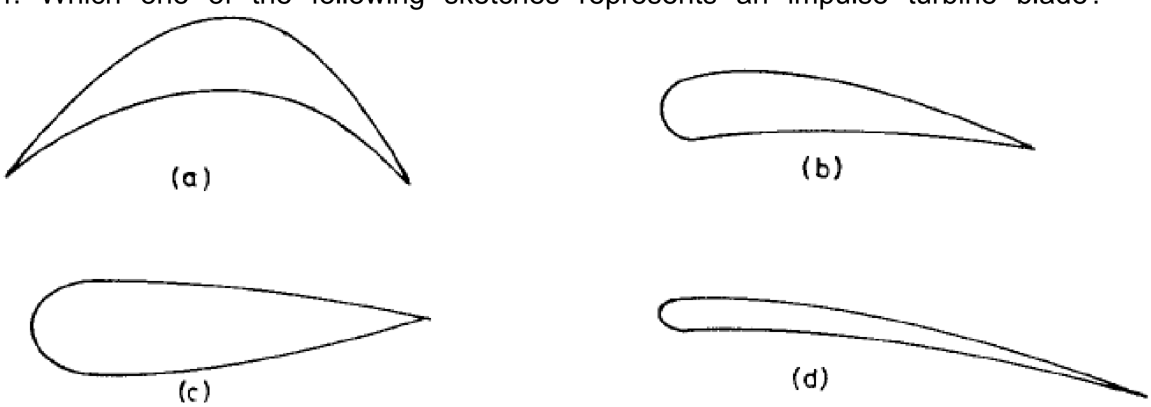
(b) relative velocity at the inlet of the moving blade is equal to that at the outlet

(c) axial, velocity at the inlet is equal to that at the outlet

(d) whirl velocity at the inlet is equal to that at the outlet

3. Ans. (b) For an ideal impulse turbine, relative velocity at inlet of the moving blade is equal to that at the outlet.

4. Which one of the following sketches represents an impulse turbine blade?

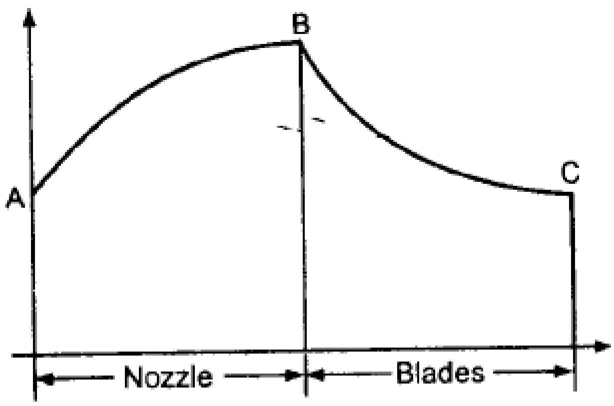


[IES-1995]

4. Ans. (a) Figure at (a) is for impulse turbine blade. As no pressure change from inlet to outlet no area change is allowed.

5. Steam enters a De Laval steam turbine with an inlet velocity of 30 m/s and leaves with an outlet velocity of 10 m/s. The work done by 1kg of steam is **[IES-2003]**
(a) 400 Nm (b) 600 Nm (c) 800 Nm (d) 1200Nm
5. Ans. (a)
The work done by 1kg of steam is = $\frac{1}{2}m\left(V_1^2 - V_2^2\right) = \frac{1}{2}\times 1\times\left(30^2 - 10^2\right) = 400\ Nm$

6. The given figure shows the variation of certain steam parameter in case of a simple impulse turbine. The curve A-B-C represents the variation of
(a) pressure in nozzle and blades
(b) velocity in nozzle and blades
(c) temperature in nozzle and blades
(d) enthalpy in nozzle and blades



[IES-2001]

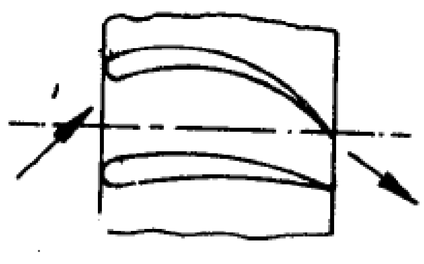
6. Ans. (b)

7. Consider the following characteristics: **[IAS-2002]**
1. High steam and blade velocities
2. Low steam and blade velocities
3. Low speeds of rotation
4. High carry-over loss

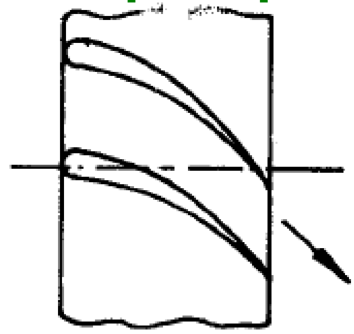
Which of these characteristics are possessed by a simple impulse turbine?
(a) 1 and 2 (b) 2 and 3 (c) 1 and 4 (d) 3 and 4
7. Ans. (c)

8. The blade passage for the nozzle blade row of the first stage of an impulse turbine is best represent as **[IAS-1999]**

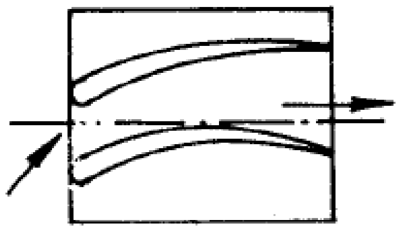
(a)



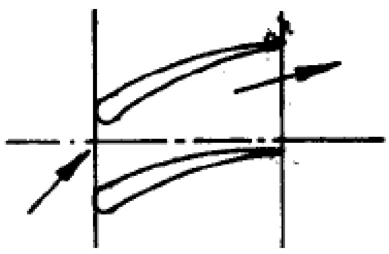
(b)



(c)



(d)



8. Ans. (a)

9. If in an impulse turbine designed for free vortex flow, tangential velocity of steam at the root radius of 250 mm is 430 m/s and the blade height is 100 mm, then the tangential velocity of steam at the tip will be **[IAS-1998]**

(a) 602 m/s (b) 504 m/s (c) 409 m/s (d) 307 ms

9. Ans. (d) For free vortex V.r = const.

$$\therefore V_1 r_1 = V_2 r_2 \text{ or } V_2 = \frac{V_1 r_1}{r_2} = 430 \times \frac{250}{(250+100)} = 307 \text{m/s}$$

10. Consider the following statements:

In an impulse turbine, **[IAS-1997]**

1. the relative velocity of steam at inlet and outlet of moving blades are equal.
2. the moving blades are symmetrical.
3. the outlet area of the moving blades is smaller than the inlet area.

Of these statements:

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

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

10. Ans. (c)

11. In an axial flow steam turbine, the path traced by a fluid particle at the design point is a

(a) helix of constant radius (b) helix of varying radius

(c) Cycloidal path (d) toroidal path **[IAS-1997]**

11. Ans. (b)

12. Considering the variation of static pressure and absolute velocity in an impulse stream turbine, across one row of moving blades **[GATE-2003]**

(a) both pressure and velocity decrease

(b) pressure decreases but velocity increases

(c) pressure remains constant, while velocity increases

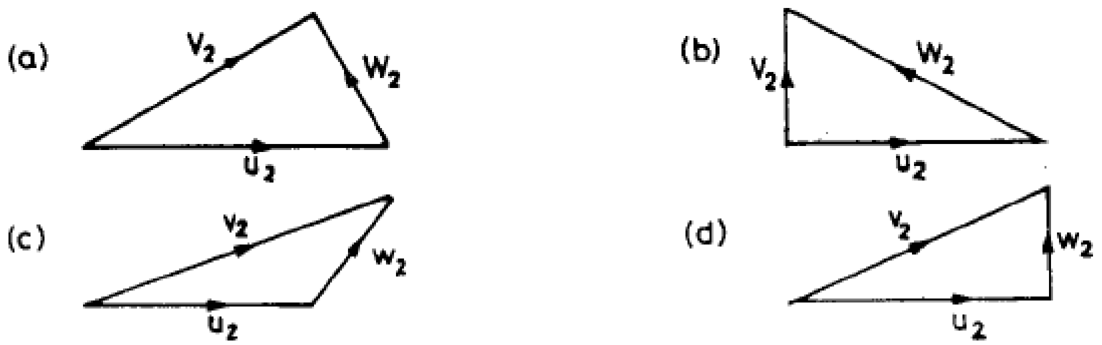
(d) pressure remains constant, while velocity decreases

12. Ans. (d)

Velocity diagram

13. Which one of the following velocity triangles represents the one at the exit of a radial impeller with forward curved blades? **[IES-1994]**

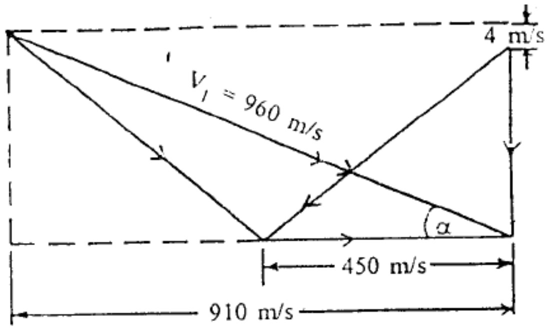
(u_2 = peripheral velocity, v_2 = absolute velocity, w_2 = relative velocity).



13. Ans. (b) Velocity triangle at (b) is correct. Actual velocity v_2 is at right angle and angle between u_2 and w_2 is acute.

14. Velocity diagram shown above is for an impulse turbine stage. What is the, tangential force and axial thrust per kg/s of steam, respectively?

(a) 450 N, 8 N
(b) 560 N, 8 N
(c) 680 N, 4 N
(d) 910 N, 4 N



[IAS-2004]

14. Ans. (d) Tangential force= $\dot{m} \times \Delta V_w = 1 \times 910N = 910N$

$\text{Axial force} = \dot{m} \times \Delta V_a = 1 \times 4N = 4N$

15. The following data pertain to a single stage impulse steam turbine: **[GATE-1997]**
Nozzle angle = 20°, Blade velocity = 200 m/s
Relative steam velocity at entry = 350 m/s Blade inlet = 30° Blade exit angle = 25°.
If blade friction is neglected, tire work done per kg steam is

(a) 124 kJ (b) 164 kJ (c) 169 kJ (d) 174 kJ

15. Ans. (a)

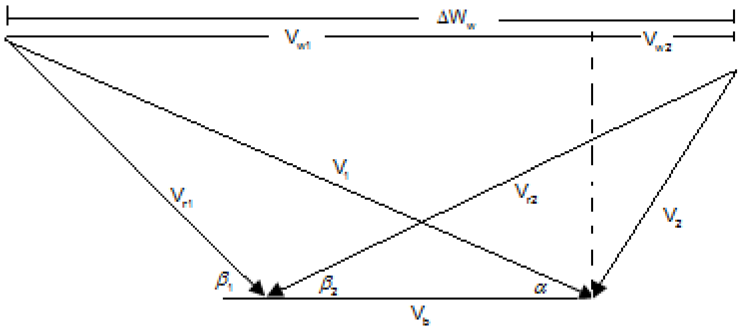
$\alpha = 20^\circ$

$V_b = 200 \text{ m/s}$

$V_{r1} = 350 \text{ m/s} = V_{r2}$

$\beta_1 = 30^\circ$

$\beta_2 = 25^\circ$



$\therefore \Delta V_w = V_{r1}\cos\beta_1 + V_{r2}\cos\beta_2 = 350 \times [\cos 30 + \cos 25] = 620.32$

$W_D = \Delta V_w \times V_b = 620.32 \times 200 \text{ J/kg} = 124 \text{kJ/kg}$

16. Consider the following statements regarding an impulse turbine:
1. Relatives velocity at the inlet and exit of the rotor blades are the same
2. Absolute velocity at the inlet and exit of the rotor blades are the same
3. Static pressure within the rotor blade channel is constant
4. Total pressure within the rotor blade channel is constant **[IAS-1999]**

Of these statements:

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

16. Ans. (c)

17. The isentropic heat drop in the nozzle of an impulse steam turbine with a nozzle efficiency 0.9, blade velocity ratio 0.5, and mean blade velocity 150 m/s in kJ/kg are

(a) 50 (b) 40 (c) 60 (d) 75 **[GATE-1998]**

17. Ans. (a) $V_b = 150 \text{ m/s}$ $\therefore 0.5 = \dfrac{V_b}{V_1}$ or $V_1 = 300 \text{ m/s}$

or $V_1^2 = 2000 \times (\Delta h_s) \times \eta$ or $(\Delta h_s) = \dfrac{300^2}{2000 \times 0.9} = 50 \text{ kJ/kg}$

Tangential force and thrust

Axial Thrust

18. Consider the following statements in respect of impulse steam turbines:
1. Blade passages are of constant cross-sectional area. **[IES-2006]**
1. Partial admission of steam is permissible.
3. Axial thrust is only due to change in flow velocity of steam at inlet and outlet of moving blade.

Which of the statements given above are correct?

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

18. Ans. (a)

Diagram work (Blading Work)

19. In an axial flow impulse turbine, energy transfer takes place due to **[IES-2006]**

(a) Change in relative kinetic energy (b) Change in absolute kinetic energy
(c) Change in pressure energy
(d) Change in energy because of centrifugal force

19. Ans. (b)

20. An impulse turbine produces 50 kW of power when the blade mean speed is 400 m/s. What is the rate of change of momentum tangential to the rotor? **[IES-1997]**

(a) 200 N (b) 175 N (c) 150 N (d) 125 N

20. Ans. (d) Power = $\dfrac{m(V_{w1}-V_{w2})V_b}{1000}\,kW,\ \ or\ 50=\dfrac{m(V_{w1}-V_{w2})400}{1000}$

$$m(V_{w1}-V_{w2}) = \text{rate of change of momentum tangential to rotor} = \frac{50\times1000}{400} = 125\,N$$

21. A single-stage impulse turbine with a diameter of 120 cm runs at 3000 rpm. If the blade speed ratio is 0.42 then, the inlet velocity of steam will be **[IES-1993]**

(a) 79 m/s (b) 188m/s (c) 450 m/s (d) 900 m/s

21. Ans. (c) Blade speed ratio = $\dfrac{\text{blade speed}}{\text{velocity of steam at entry}}$

$$V_b = \frac{\pi DN}{60} = \frac{\pi\times1.2\times3000}{60}\text{m/s} \quad \therefore\ \text{Inlet velocity steam} = \frac{\pi\times1.2\times50}{0.42} = 450\,\text{m/s}$$

22. Steam enters the rotor of a reaction turbine with an absolute velocity of 236 m/s and the relative velocity of 132 m/s. It leaves the rotor with a relative velocity of 232 m/s absolute velocity of 126 m/s. The specific work output is **[IAS-2000]**

(a) 38.1 kW (b) 40.1 kW (c) 43.8 kW (d) 47.4 kW

22. Ans. (a) $W=\left(\dfrac{V_1^2}{2}-\dfrac{V_2^2}{2}\right)+\left(\dfrac{V_{r_2}^2}{2}-\dfrac{V_{r_1}^2}{2}\right)$ [Note V_{r_2} comes first]

$$=\frac{1}{2}\left(236^2-126^2\right)+\frac{1}{2}\left(232^2-132^2\right)=38.1\text{ KW}$$

Optimum velocity ratio

24. Given, V_b = Blade speed **[IES-1997; 2001; GATE-1998]**
V = Absolute velocity of steam entering the blade, α = Nozzle angle.
The efficiency of an impulse turbine is maximum when

(a) $V_b = 0.5V\cos\alpha$ (b) $V_b = V\cos\alpha$ (c) $V_b = 0.5V^2\cos\alpha$ (d) $V_b = V^2\cos\alpha$

24. Ans. (a)

26. In a simple impulse turbine, the nozzle angle at the entrance is 30°. What will be the blade-speed ratio for maximum diagram efficiency? **[IAS-2002]**
(a) 0·433 (b) 0·25 (c) 0·5 (d) 0·75

26. Ans. (a) $u = \frac{V\cos\alpha}{2}$ or $\frac{u}{V} = \frac{\cos 30^o}{2} = \frac{\sqrt{3}}{4}$

27. For an impulse turbine with exit angle ‘’, the maximum efficiency is **[IAS-1999]**

(a) $\left(1-\frac{\cos\phi}{2}\right)$ (b) $\left(\frac{1}{2}+\cos\phi\right)$ (c) $\left(\frac{1+\cos\phi}{2}\right)$ (d) $\left(\frac{1-\cos\phi}{2}\right)$

27. Ans. (c)

28. For a single stage impulse turbine with a rotor diameter of 2 m and a speed of 3000 rpm when the nozzle angle is 20°, the optimum velocity of steam in m/s is
(a) 334 (b) 356 (c) 668 (d) 711 **[GATE-1994]**
28. Ans. (c)

For optimum condition, $u = \frac{v}{2}$

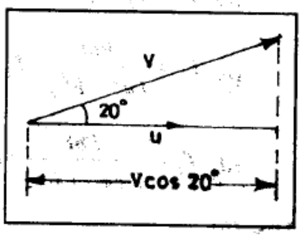
where u = blade speed, and

v = jet velocity in the direction of blade.

Also $u = \frac{\pi DN}{60}$

$= \frac{\pi \times 2 \times 3000}{60} = 314.2 \text{ m/s}$

$V\cos 20° = 2u = 314.2 \times 2 = 628.4$



∴ Jet velocity $= \frac{628.4}{\cos 20} = 668$ **m/sec.**

Compounding of turbine

29. Which one of the following is used to bring down the speed of an impulse steam turbine to practical limits? **[IES-2006]**
(a) A centrifugal governor (b) Compounding of the turbine
(c) A large flywheel (d) A gear box
29. Ans. (b)

30. Why is compounding of steam turbines done? **[IES-2005]**
(a) To improve efficiency (b) To reduce the speed of rotor
(c) To reduce exit losses (d) To increase the turbine output
30. Ans. (b)

31. List I gives the various velocities in the velocity diagrams of a two-stage impulse turbine. List II gives the blade angles. Match the velocity from List I with the angle in List II and select the correct answer using the codes given below the lists:

List I List II **[IES-1995]**

A. Relative velocity of steam at inlet tip of blade 1. Nozzle angle

B. Absolute velocity of steam at inlet tip of blade 2. Moving blade leading edge angle
C. Relative velocity of steam at outlet tip of blade 3. Moving blade trailing edge angle
D. Absolute velocity of steam at outlet tip of blade 4. Fixed blade leading edge angle

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

31. Ans. (c)

32. Assertion (A): Impulse staging is commonly employed in high pressure part and reaction staging in intermediate low pressure parts of the steam turbine. **[IES-2003]**
Reason (R): The tip leakage across moving blades is less in impulse staging as the pressure drop is small and there can be large pressure drop across fixed blades and nozzles.
32. Ans. (a)

33. The compounding of steam turbines is done to **[IES-1999]**
(a) improve efficiency (b) reduce turbine speed
(c) increase blade speed ratio (d) reduce axial thrust
33. Ans. (b) The compounding of steam turbine is done to reduce turbine speed.

34. The main aim of compounding steam turbine is to **[IES-1992]**
(a) improve efficiency (b) reduce steam consumption
(c) reduce motor speed (d) reduce turbine size
34. Ans. (c)

35. Running speeds of steam turbine can be brought down to practical limits by which of the following methods)? **[IES-1996]**
1. By using heavy flywheel. 2. By using a quick response governor.
3. By compounding 4. By reducing fuel feed to the furnace.
(a) 3 alone (b) 1, 2, 3 and 4 (c) 1, 2 and 4 (d) 2 and 3
35. Ans. (d)

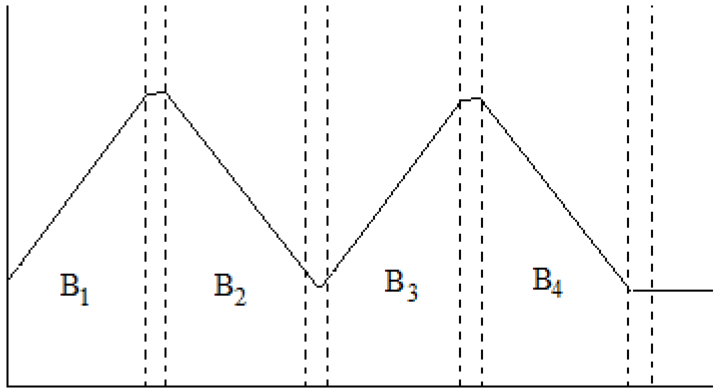
Pressure compounding (Rateau Turbine)

36. Which one of the following is the feature of pressure compounding (Rateau staging)? **[IES-2004]**
(a) Low efficiency at low rotational speeds
(b) High efficiency with low fluid velocities
(c) High efficiency with high fluid velocities
(d) Low efficiency at high rotational speeds
36. Ans. (b)

37. The Rateau turbine belongs to the category of **[GATE-2001]**
(a) pressure compounded turbine (b) reaction turbine
(c) velocity compounded turbine (d) redial flow turbine
37. Ans. (a)

38. In the given figure, B_1, B_2, B_3, and B_4 represent blade passages in an impulse turbine. Consider the following statements in this regard **[IAS 1994]**
1. The solid line represents velocity variation.
2. The solid line represents pressure variation.
3. B_2 and B_4 are rotor passages. 4. B_1 and B_3 are rotor passages.
Of these statements:

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



38. Ans. (b)

Velocity compounding (Curtis Turbine)

39. Which of the following statements are correct? **[IES-1994]**
1. Impulse turbine rotor blades are thick at the centre.
2. Rateau turbine is more efficient than Curtis turbine.
3. Blade velocity coefficient for an impulse turbine is of the order of 60%.

Codes: (a) 1, 2 and 3 (b) 1 and 2 (c) 1 and 3 (d) 2 and 3.

40. Ans. (b)

41. Assertion (A): Modern turbines have velocity compounding at the initial stages and pressure compounding in subsequent stages. **[IES-2000]**
Reason (R): Excessive tip leakage occurs in the high pressure region of reaction blading.

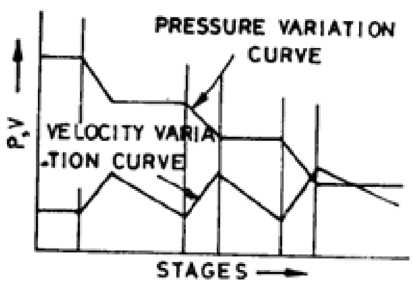
41. Ans. (d)

42. The net result of pressure-velocity compounding of steam turbine is: **[IES-1997]**
(a) Less number of stages (b) Large turbine for a given pressure drop
(c) Shorter turbine for a given pressure drop (d) Lower friction loss

42. Ans. (a) Pressure-velocity compounding of steam turbines results is less number of stages

43 *The given figure represents pressure and velocity variation for a*

(a) reaction type turbine
(b) velocity compounded impulse turbine
(c) pressure-velocity compounded impulse turbine
(d) pressure compounded impulse turbine



[IAS-1995]

43. Ans. (d) The pressure and velocity variations in given figure correspond to pressure gets dropped in three stages and in each stage the velocity increases in

passing through nozzle and then decreases in passing through blades (Impulse stage).

Work done in different stages

44. A 4-row velocity compounded steam turbine develops total 6400 kW. What is the power developed by the last row? **[IES-2005]**
(a) 200 kW (b) 400 kW (c) 800 kW (d) 1600 kW
44. Ans. (b) work done in different stages in velocity compounding is

$$W_1 : W_2 : W_3 : W_4 = 7:5:3:1$$
$$\text{or } W_4 = \frac{6400}{7+5+3+1} = 400\text{kW}$$

45. In a two-row Curtis stage with symmetrical blading,
(a) work done by both rows of moving blades are equal **[IAS-2002]**
(b) work done by the first row of moving blades is double of the work done by second row of moving blades
(c) work done by the first row of moving blades is three times the work done by second row of moving blades
(d) work done by the first row of moving blades is four times the work done by the second row of moving blades
45. Ans. (c) For two-row Curtis W_1:W_2=3:1
For 3-stage Curtis W_1:W_2:W_3=5:3:1

Reaction Turbine (Parson's Turbine)

46. In Parson's reaction turbines, the velocity diagram triangles at the inlet and outlet are which of the following? **[IES-2004]**
(a) Asymmetrical (b) Isosceles (c) Right-angled (d) Congruent
46. Ans. (d)

47. Match List-I (Different turbine stages) with List-II (Turbines) and select the correct answer using the codes given below the lists: **[IES-1999]**

List-I	List-II
A. 50% reaction stage	1. Rateau
B. Two-stage velocity compounded turbine	2. Parson
C. Single-stage impulse	3. Curtis
D. Two-stage pressure compounded turbine	4. De-Laval
	5. Hero

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

47. Ans. (a) 50% reaction turbine is Parson, 2-stage velocity compounded turbine is Curtis, single stage impulse turbine is De-Laval, and 2-stage pressure compounded turbine is Rateau.

48. Match the following **[GATE-2003]**

P. Curtis	1. Reaction steam turbine
Q. Rateau	2. Gas turbine
R. Kaplan	3. Velocity compounding
S. Francis	4. Pressure compounding
	5. Impulse water turbine
	6. Axial turbine
	7. Mixed flow turbine

8. Centrifugal pump

Code:	P	Q	R	S		P	Q	R	S
(a)	2	1	7	6	(b)	3	1	5	7
(c)	1	3	1	5	(d)	3	4	7	6

48. Ans. (d)

49. A Curtis stage, Rateau stage and a 50% reaction stage in a steam turbine are examples of **[GATE-1998]**
(a) different types of impulse stages (b) different types of reaction stages
(c) a simple impulse stage, a velocity compounded impulse stage and reaction stage
(d) a velocity compounded impulse stage, a simple impulse stage and a reaction stage
49. Ans. (d)

50. Assertion (A): The work done in Parson's reaction turbine is twice the work done during expansion in the moving blades. **[IES-1997]**
Reason (R): The steam expands both in the moving as well as in the fixed blades in a reaction turbine and in the Parson's turbine, the fixed and moving blades are identical.
50. Ans. (a)

51. The correct sequence of the given steam turbines in the ascending order of efficiency at their design points is **[IES-1995]**
(a) Rateau, De Laval, Parson's, Curtis (b) Curtis, De Laval, Rateau, Parson's.
(c) De Laval, Curtis, Rateau, Parson's (d) Parson's, Curtis, Rateau, De Laval.
51. Ans. (c) Ascending order for efficiency is De Laval, Curtis, Rateau, Parson's.

52. Match List-I (Machines) with List-II (Features) and select the correct answer using the codes given below the lists:

List-I (Machines)	List-II (Features) **[IES-2001]**
A. Steam engine	1. Velocity compounding
B. Impulse turbine	2. Diagram factor
C. Reaction turbine	3. Continuous pressure drop
D. Centrifugal compressor	4. Isentropic efficiency

Codes

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

52. Ans. (b)

53. Among other things, the poor part-load performance of De laval turbines is due to the **[IES-1995]**
(a) formation of shock waves in the nozzle
(b) formation of expansion waves at the nozzle exit
(c) turbulent mixing at the nozzle exit
(d) increased profile losses in the rotor.
53. Ans. (b) In De Laval turbine, at part load, pressure is reduced but velocity increases which is not fully dropped in single stage. Thus expansion waves occur at nozzle exit.

54. Assertion (A): Reaction blading is commonly used in intermediate and low pressure parts of steam turbines. **[IES-2001]**
Reason (R): Reaction blading gives higher efficiency than impulse blading.
54. Ans. (a)

55. Partial admission steam turbine refers to the situation where the **[IES-2000]**
(a) steam is admitted partially into the blades through nozzles
(b) nozzles occupy the complete circumference leading into the blade annulus
(c) nozzles do not occupy the complete circumference leading into the annulus
(d) steam is admitted partially into the blades directly
55. Ans. (a)

56. In reaction turbines, with reduction of inlet pressure **[IAS-2002]**
(a) the blade heights increase as the specific volume of steam decreases
(b) the blade heights increase as the specific volume of steam increases
(c) the blade heights decrease as the specific volume of steam increases
(d) the blade heights decrease as the specific volume of steam decreases
56. Ans. (b) $P\alpha\frac{1}{\upsilon}$ if P reduced then υ increases to handle more volume we need more area i,e. increase heights of blade.

Degree of reaction

57. In a reaction turbine the enthalpy drop in a stage is 60 units. The enthalpy drop in the moving blades is 32 units. What is the degree of reaction? **[IES-2006]**
(a) 0·533 (b) 0·284 (c) 0·466 (d) 1·875
57. Ans. (a) Degree of reaction = $\frac{(\Delta h)_{mb}}{(\Delta h)_{fb}+(\Delta h)_{mb}}=\frac{(\Delta h)_{mb}}{(\Delta h)_{total}}=\frac{32}{60}=0.533$

48. Which one of the following is the correct statement? **[IES-2005]**
The degree of reaction of an impulse turbine:
(a) is less than zero (b) is greater than zero
(c) is equal to zero (d) increases with steam velocity at the inlet
58. Ans. (c)

59. In a reaction turbine stage enthalpy drop in the stator blades is 4.62 kJ/kg and that in the rotor blades is 2.38 kJ/kg. The degree of reaction of the stage is
(a) 0.52 (b) 0.43 (c) 0.34 (d) 0.26 **[IES-2003]**
59. Ans. (c) degree of reaction = $\frac{(\Delta h)_{mb}}{(\Delta h)_{mb}+(\Delta h)_{fb}}=\frac{2.38}{2.38+4.62}=0.34$

60. Assertion (A): Parsons turbine has a degree of reaction equal to 50%. **[IES-1999]**
Reason (R): It is a reaction turbine with symmetrical fixed and moving blades.
60. Ans. (a) Because fixed and moving blades are symmetrical, the enthalpy drop in both becomes equal and this results in degree of reaction as 50%.

61. In an impulse-reaction turbine stage, the heat drops in fixed and moving blades are 15 kJ/kg and 30 kJ/kg respectively. The degree of reaction for this stage will be
(a) 1/3 (b) 1/2 (c) 2/3 (d) ¾ **[IES-1998]**
61. Ans. (c) Degree of reaction = $\frac{\text{heat drop in moving blade}}{\text{heat drop in both blades}}=\frac{30}{45}=\frac{2}{3}$

62. The degree of reaction of a turbine is defined as the ratio of **[IES-1995]**
(a) static pressure drop to total energy transfer
(b) total energy transfer to static pressure drop
(c) change of velocity energy across the turbine to the total energy transfer

(d) velocity energy to pressure energy

62. Ans. (a) Degree of reaction of turbine is ratio of static pressure drop to total energy transfer

63. The following data refer to an axial flow turbine stage: **[IES-1995]**
Relative velocity of steam at inlet to the rotor = 79.0 m/s., Relative velocity at the rotor exit = 152 m/s rotor mean peripheral velocity = 68.4 m/s, work output per kg. of steam = 14100 J. What is the approximate degree of reaction?
(a) 0.9 (b) 0.8 (c) 0.7 (d) 0.6

63. Ans. (d) Enthalpy drop in moving blades = $\frac{V_{r_2}^2 - V_{r_1}^2}{2\times 1000} = \frac{152^2 - 79^2}{2000}$ = 8.43 kJ/kg

Degree of Reaction = $\frac{8.43}{14.1} = 0.597 \cong 0.6$

64. In a reaction turbine, the enthalpy drop in the fixed blade ring is 50 hJ per Kg and the enthaply drop in the moving blade ring Is 25 hJ per Kg. The degree of reaction of the turbine is **[IAS-1995]**
(a) 66.7% (b) 50.0% (c) 33.3% (d) 6.0%

64. Ans. (c)

65. The degree of reaction of a turbo machine is defined as the ratio of the
(a) static pressure change in the rotor to that in the stator **[IES-1993]**
(b) static pressure change in the rotor to that in the stage
(c) static pressure change in the stator to that in the rotor
(d) total pressure change in the rotor to that in the stage.

65. Ans. (b) The degree of reaction of a turbomachine is defined as the ratio of the static pressure change in the rotor to that in the stage.

66. The isentropic enthalpy drop in moving blade is two-thirds of the isentropic enthalpy drop in fixed blades of a turbine. The degree of reaction will be **[IES-1993]**
(a) 0.4 (b) 0.6 (c) 0.66 (d) 1.66

66. Ans. (a) $\text{Degree of reaction} = \frac{\Delta\text{h}\ (\text{moving blade})}{\Delta\text{h}\ (\text{moving blade}) + \Delta\text{h}(\text{fixed blade})} = 0.4$

67. If the enthalpy drops of moving blade and fixed blade of a stage in a reaction turbine are 9 and 11 kJ/kg respectively, then degree of reaction of the stage is
(a) 0.1 (b) 0.45 (c) 0·55 (d) 1·0 **[IAS-2002]**

67. Ans. (b) degree of reaction= $\frac{(\Delta h)_{nb}}{(\Delta h)_{mb} + (\Delta h)_{fb}} = \frac{9}{9+11} = 0.45$

68. Ratio of enthalpy drop in moving blades to the total enthalpy drop in the fixed and moving blades is called **[IAS-2001]**
(a) Reheat factor (b) Blade efficiency (c) Degree of reaction (d) Internal efficiency

68. Ans. (c)

69. In a steam turbine, the enthalpy drops in the fixed blade and moving blade are 48 kJ and 32 kJ respectively. The degree of reaction is **[IAS-2000]**
(a) 40% (b) 55% (c) 60% (d) 66.6%

69. Ans. (a) $\text{Degree of reaction} = \frac{(\Delta\text{h})_{\text{moving blade}}}{(\Delta\text{h})_{\text{fixed blade}} + (\Delta\text{h})_{\text{moving blade}}} = \frac{32}{48+32} = 0.4$

70. If in a steam turbine stage, heat drop in moving blade ring is 40 kJ/kg and hat in the fixed blade ring is 60 kJ/kg, then the degree of reaction is **[IAS-1998]**
(a) 20% (b) 40% (c) 60% (d) 70%

70. Ans. (b) Degree of reaction = $\frac{(\Delta h)_{mb}}{(\Delta h)_{fb} + (\Delta h)_{mb}} = \frac{40}{40+60} = 0.4$

71. Degree of reaction is defined as the ratio of **[IAS-1996]**
(a) enthalpy drop in moving blades to enthalpy drop in fixed blades
(b) enthalpy drop in fixed blades to total enthalpy drop in moving and fixed blades
(c) enthalpy drop in fixed blades to enthalpy drop in moving blades
(d) enthalpy drop in moving blades to total enthalpy drop in fixed and moving blades
71. Ans. (d)

72. Symmetrical blading is used in a turbine when its degree of reaction is
(a) 25% (b) 50% (c) 75% (d) 100% **[IAS-1995]**
72. Ans. (b)

73. The degree of reaction of a turbine is the ratio of enthalpy drop in
(a) moving blades to enthalpy drop in the stage
(b) fixed blades to enthalpy drop in the stage
(c) moving blades to enthalpy drop in fixed blades
(d) fixed blades to enthalpy drop in moving blades
73. Ans. (a)

74. In a reaction turbine the heat drop in fixed blade is 8 kJ/kg and the total head drop per stage is 20 kJ/kg. The degree of reaction is **[IES-2002]**
(a) 40% (b) 66.7% (c) 60% (d) 25%
74. Ans. (c)

100% Reaction Turbine (Hero's Turbine)

75. Consider the following statements regarding a 100% reaction turbine: **[IES-2000]**
1. Change in absolute velocity of steam across the moving blades is zero.
2. Change in absolute velocity of steam across the moving blades is negative.
3. Enthalpy drop in fixed blades is zero

Which of these statements is/are correct?
(a) 1 alone (b) 2 alone (c) 2 and 3 (d) 1 and 3
75. Ans. (c)

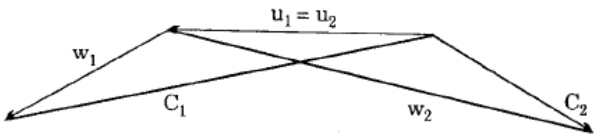
76. Assertion (A): Reaction turbines are not built on pure reaction principle.
Reason (R): Pure reaction is difficult to realise in practice. **[IES-1998]**
76. Ans. (a)

77. The outward radial flow turbine in which there are two rotors rotating in opposite directions is known **[IES-1994]**
(a) 50% reaction radial turbine (b) cantilever turbine.
(c) Ljungstrom turbine (d) pass-out turbine.
77. Ans. (c) Description of turbine given is for Ljungstrom turbine.

50% Reaction Turbine (Parsons Turbine)

Velocity diagram for reaction turbine blade

78. In the velocity diagram shown below, u = blade velocity, C = absolute fluid velocity and ω = relative velocity of fluid and the subscripts 1 and 2 refer to inlet and outlet.



[GATE-2005]

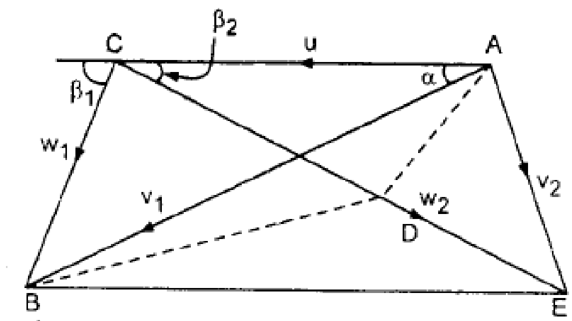
(a) an impulse turbine
(b) a reaction turbine
(c) a centrifugal compressor
(d) an axial flow compressor

78. Ans. (b)

As $u_1 = u_2$ and $w_2 >> w_1$

79. Velocity triangle for a reaction turbine stage is shown it: the given figure. (AB = v_1 = absolute velocity at rotor blade inlet; CB = w_1 = relative velocity at rotor blade inlet; CE= w_2 = relative velocity at rotor blade exit and CD = CB) The ratio of reaction force to impulse force is

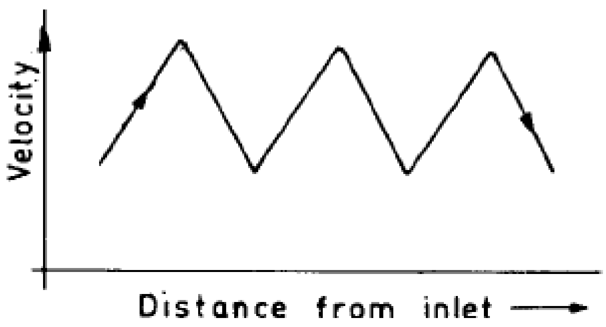
(a) CE/CB (b) CD/CE
(c)DE/BD (d)AE/AB



[IES-2000]

79. Ans. (c)

80. The graph given in the figure represents the variation absolute velocity of steam along the length of a steam turbine.
The turbine in question is
(a) Curtis turbine
(b) De Leval turbine
(c) Radial turbine
(d) Parson's turbine



80. Ans. (d) Velocity diagram shown in figure is for Parson's turbine.

81. Which one of the following relationship between angles of fixed blades and moving blades corresponds to that of Parson's turbine? **[IES-1995]**

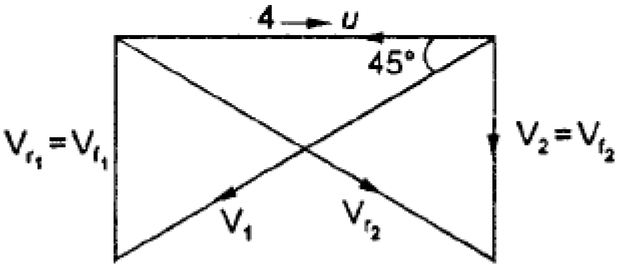
$(a)\, \alpha_1 = \alpha_2$ $(b)\, \alpha_1 = \beta_2$ $(c)\, \alpha_1 = \beta_2$ $(d)\, \beta_1 = \beta_2$

81. Ans. (b)

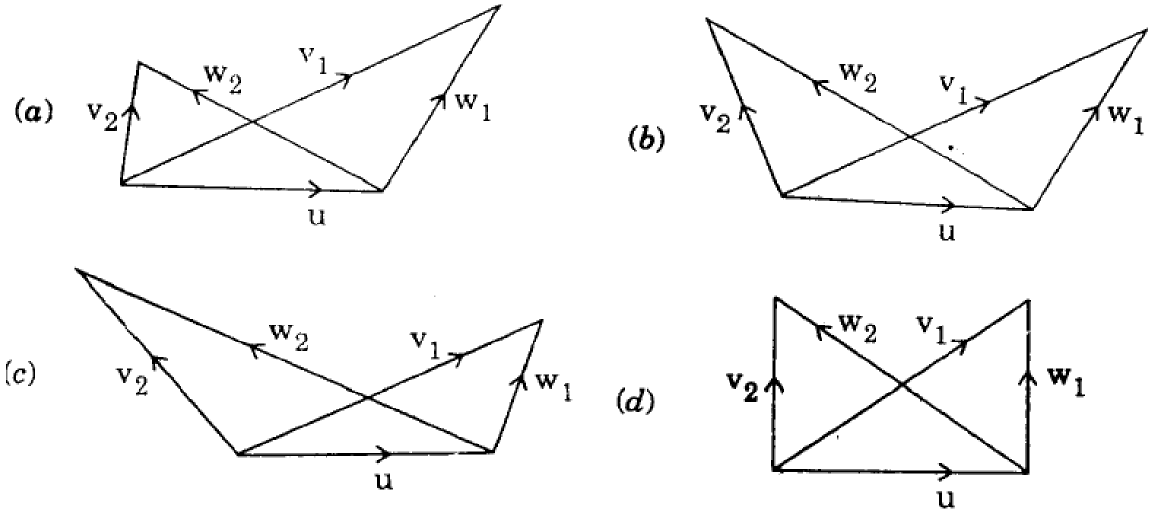
82. In a 50% reaction stage, absolute velocity angle at inlet is 45° mean peripheral speed is 75 m/s and the absolute velocity at the exit is axial. The stage specific work is **[IES-2003]**

(a) 2500 m^2/s^2 (b) 3270 m^2/s^2 (c) 4375 m^2/s^2 (d) 5625 m^2/s^2

82. Ans. (d)
For 50% reaction stage, inlet and outlet velocity stages are equal
So, $u = V_w = V_{w1} + V_{w2} = 75\,m/s$
specific work =
$u \times (V_{w1} + V_{w2}) = 75 \times 75 = m^2/s^2$

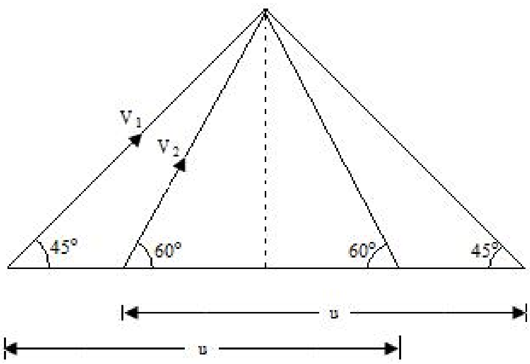


83. If u, v, w represent the peripheral, absolute and relative velocities, respectively, and suffix 1 and 2 refer to inlet and outlet, then which one of the following velocity triangles could be a reaction turbine stage with reaction more than 50% ? **[IAS-2003]**



83. Ans. (c)

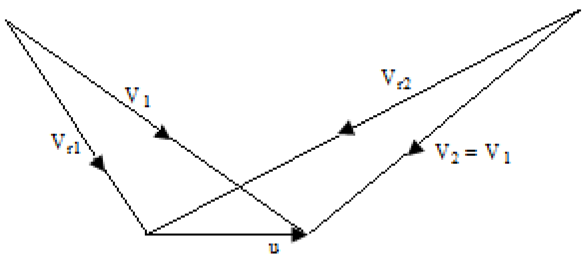
84. The given figure represents velocity diagram for a tubomachine stage. The stage in question is
(a) power absorbing and 50%reaction
(b) power absorbing and impulse
(c) power generating and 50% reaction
(d) power generating and impulse



[IAS-1999]

84. Ans. (c)

85. Given that 'u' is the blade velocity, V is the absolute velocity of steam and V_r is the relative velocity, subscripts 1and 2 refer to the inlet and exit of the rotor, the velocity triangle for and axial flow steam turbine shown in the given figure, refers to which one of the following types of turbine stages?
(a) Pure impulse
(b) Pure reaction



[IAS-1997]

(c) 50% reaction
(d) 25% reaction
85. Ans. (b)

Optimum velocity ratio

86. For a reaction turbine with degree of reaction equal to 50%, (V is the absolute steam velocity at inlet and a. is the angle made by it to the tangent on the wheel) the efficiency is maximum when the blade speed is equal to **[IES-2002]**

(a) $V\cos\alpha/2$ (b) $2V\cos\alpha$ (c) $V\cos^2\alpha$ (d) $V\cos\alpha$

86. Ans. (d)

87. The impulse turbine rotor efficiency will have a maximum value 0.5 $\cos^2\alpha_1$ where α_1 is the nozzle exit flow angle, if the **[IAS 1994]**

(a) blades are equiangular (b) blade velocity coefficient is unity
(c) blades are equiangular and frictionless (d) blade solidity is 0.65

87. Ans. (c) The impulse turbine rotor efficiency, $\eta = (1+kc)\frac{\cos^2\alpha_1}{2}$

If friction factor k = 0 and c = $\frac{\cos\gamma}{\cos\beta} = 1$ i.e. blades are equiangular then $\eta_{\max} = 0.5\cos^2\alpha_1$

Diagram work (Blading Work)

88. For maximum blade efficiency (utilization factor), what is the work (J/kg) done in a single stage 50% reaction turbine?

(a) $2u^2$ (b) $1/u^2$ (c) u^3 (d) u^2 **[IES 2007]**

88. Ans. (d)

89. Assertion (A): Work output per stage of an impulse turbine is double that of a 50% reaction stage at the same speed. **[IES-1998]**
Reason (R): Maximum speed ratio is limited for any class of turbine.
89. Ans. (d)

90. In a 50%, reaction turbine stage, the tangential component of absolute velocity at rotor inlet is 537 m/s and blade velocity is 454 m/s. The power output in kW of steam will be **[IAS 1994]**

(a) 302 (b) 282 (c) 260 (d) 284

90. Ans. (b) If reaction is 50% then work done = $\frac{V_b}{1000}(2V_i\cos\alpha - V_b)\,kJ/kg$

$V_i\cos\alpha$ = 537 m/s and V_b= 454 m/s $\therefore$ Work done = $\frac{454}{1000}(2\times 537 - 454) = 282\,kW/kg$

Condition for maximum efficiency and Turbine Efficiencies

91. Assertion (A): Large reaction turbines have higher overall efficiency than the small reaction turbines. **[IES-2003]**

Reason (R): The mechanical efficiency of small reaction turbines is higher than that of larger ones.
91. Ans. (b)

92. The work output from a reaction turbine stage is 280 kW per kg/s of steam. If the nozzle efficiency is 0.92 and rotor efficiency is 0.90, the isentropic static enthalpy drop will be **[IAS-2000]**
(a) 352 kW (b) 347 kW (c) 338 kW (d) 332 kW

92. Ans. (c) $W = (\Delta h)_{total} \times \eta_{nozzle} \times \eta_{rotor}$ or $(\Delta h)_{total} = \dfrac{280}{0.92 \times 0.9} = 338KW$

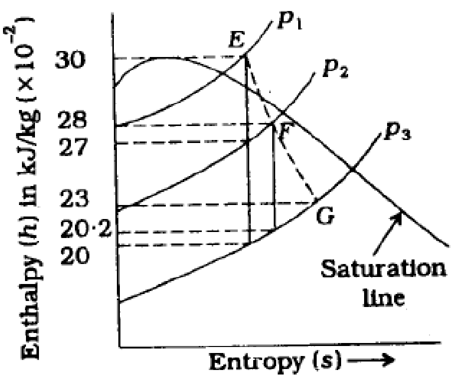
93. Which one of the following expresses the maximum blade efficiency of a Parson's turbine? **[IES-1994; 1996; 1999; 2004; 2006]**
(a) $\dfrac{2\cos^2\alpha}{1+\cos^2\alpha}$ (b) $\dfrac{\cos^2\alpha}{1+2\cos^2\alpha}$ (c) $\dfrac{\cos\alpha}{1+\cos^2\alpha}$ (d) $\dfrac{\cos\alpha}{2}$
Where α is the jet angle at the entrance.
93. Ans. (a)

94. Which one of the following pairs is correctly matched? **[IES-1993]**
(a) $\text{Stage efficiency} = \dfrac{\text{actual enthalpy drop}}{\text{isentropic enthalpy drop}}$
(b) $\text{Nozzle efficiency} = \dfrac{\text{work delivered}}{\text{isentropic enthalpy drop}}$
(c) $\text{Diagram efficiency} = \dfrac{\text{work deliveredby blades}}{\text{isentropic enthalpy drop}}$
(d) $\text{Blade efficiency} = \dfrac{\text{workdone on moving blades}}{\text{actual enthalpy drop}}$
94. Ans. (a)

'State Point Locus' and 'Reheat Factor'

95. What is the value of the reheat factor in multi-stage turbine? **[IES-2004]**
(a) 1.03 to 1.04 (b) 1.10 to 1.20 (c) 0.90 to 1.00 (d) 1.20 to 1.25
95. Ans. (a)

96. Expansion line EFG of a 2-stage steam turbine is shown in the given h-s diagram.
The reheat factor for this turbine is
(a) 1.08
(c) 0.648
(b) 0.7
(d) 1.43



[IAS-2001]

96. Ans. (a) R.F = $\dfrac{(30-27)+(28-20.2)}{(30-20)}=1.08$

97. Which one of the following statements is correct? **[IES-2000]**
(a) Reheat factor is zero if efficiency of the turbine is gose to unity.
(b) Lower the efficiency, higher will be the reheat factor.
(c) Reheat factor is independent of steam conditions at turbine inlet.
(d) Availability of reheat is higher at low pressure end.
97. Ans. (*)

98. Which one of the following pairs is NOT correctly matched? **[IES-2000]**
(a) Internal efficiency of steam turbine : Product of stage efficiency and reheat factor
(b) Stage efficiency of a turbine : Ratio of adiabatic heat drop to the isentropic heat drop per stage
(c) Dryness fraction of steam within a stage : Decreases due to reheating
(d) Steam condensation during expansion through the turbine : Enhances blade erosion
98. Ans. (c)

99. Match List I with List II and select the correct answer using the code given below the Lists: **[IAS-2007]**

List I (Turbine Performance Factor)	List II (Definition)
A. Reheat factor	1. $\dfrac{\text{Adiabatic heat drop}}{\text{Heat supplied}}$
B. Internal efficiency	2. $\dfrac{\text{Total work done on the rotor}}{\text{Total adiabatic heat drop}}$
C. Degree of reaction	3. $\dfrac{\text{Cumulative heat drop of all stages}}{\text{Total adiabatic heat drop}}$
D. Rankine efficiency	4. $\dfrac{\text{Enthalpy drop in moving blades}}{\text{Enthalpy drop in the stage}}$

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

99. Ans. (a)

Reheating Steam

Energy Losses in Steam Turbines

100. A steam turbine receives steam steadily at 10 bar with an enthalpy of 3000 kJ/kg and discharges at 1 bar with an enthalpy of 2700 kJ/kg. The work output is 250 kJ/kg. The changes in kinetic and potential energies are negligible. The heat transfer from the turbine casing to the surroundings is equal to **[GATE-2000]**
(a) 0 kJ (b) 50 kJ (c) 150 kJ (d) 250 kJ
100. Ans. (b) Enthalpy drop = Power output + losses
Or 3000 – 2700 = 250 + losses
Or losses = 50 kJ to the surrounding

101. If 'D' is the diameter of the turbine wheel and 'U' is its peripheral velocity, then the disc friction loss will be proportional to **[IES-1998]**

(a) $(DU)^3$ (b) D^2U^3 (c) D^3U^2 (d) DU^4

101. Ans. (c)

Steam Turbine Governing and Control

102. Assertion (A): In the case of reaction turbines for power plant applications, a large number of stages is common in practice. **[IES-1996]**
Reason (R): A pressure drop takes place in the moving blade in a reaction turbine unlike an impulse turbine, where pressure remains constant across the moving blade.
102. Ans. (b) Both A and R are true, but R is not a correct explanation of A

Throttle governing

103. Assertion (A): Throttle governing is used only in small steam turbines.
Reason(R): At part loads, the efficiency of steam turbine reduces considerably with throttle governing. **[IES-2005]**
103. Ans. (a)

104. Consider the following statements **[IES-2000]**

1. Throttle governing improves quality of steam in the last few stages.
2. Internal efficiency of steam is not seriously affected by throttle governing.
3. Throttle governing is better than nozzle governing.

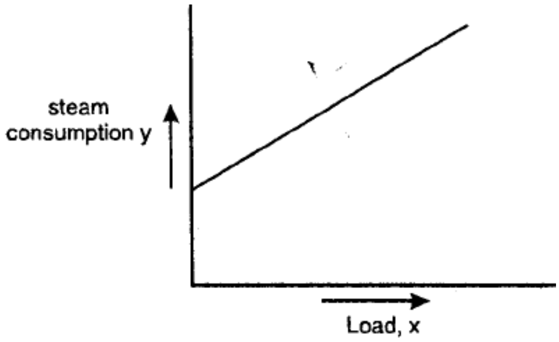
Which of these statements arc correct?
(a) 1, 2 and 3 (b) 1 and 3 (c) 2 and 3 (d) 1 and 2
104. Ans. (d)

105. Assertion (A): A throttle-governed steam engine has a high thermal efficiency.
Reason (R): In a throttle-governed steam engine, the speed of the engine is maintained constant with the help of a governor irrespective of the load on the engine. **[IES-1994]**
105. Ans. (d) A cut off governing engine has better efficiency than throttle governed engine. Statement at R is correct.

106. Assertion (A): Throttle governing is generally adopted to maintain constant speed of a small turbine, irrespective of load. **[IES-1994]**
Reason (R): In throttle governing, with the help of a valve, the number of steam passages is reduced by leaving just the required number of passages uncovered depending upon the load.
106. Ans. (c) A is correct. R is true for nozzle governing.

107. A throttle governed steam develops 20 I.H.P. with 281 kg/hr of steam and 50 IHP with 521 kg/hr of steam. The steam consumption in kg/hr when developing 15 IHP will be nearly
(a) 150 kg/hr (b) 156 kg/hr (c) 241 kg/hr (d) 290 kg/hr **[IES-1992]**

107. Ans. (c)
y = A + Bx
281 = A + B x 20
581 = A + B x 50
Solving above equations, we get
B = 8 and A= 121
y = 8 + 15 x 21
= 241 kg/hr.



108. Governing of steam turbines can be done by the following **[IES-1992]**
1. Nozzle control 2. Throttle control 3. Providing additional value and passage
The correct answer will be
(a) 1,2 and 3 (b) 1 and 2 only (c) 2 and 3 only (d) 1 and 3 only
108. Ans. (a)

Nozzle governing

109. Assertion (A): Nozzle control governing cannot be used in reaction steam turbines. **[IES-2006]**
Reason (R): In reaction steam turbines, full admission of steam must take place.
109. Ans. (a)

110. Consider the following statements regarding the nozzle governing of steam turbines:
1. Working nozzles receive steam at full pressure **[IES-1995]**
2. High efficiency is maintained at all loads
3. Stage efficiency suffers due to partial admission
4. In practice each nozzle of the first stage is governed individually.
Of these correct statements are:
(a) 1, 2 and 3 (b) 2, 3 and 4 (c) 1, 3 and 4 (d) 1, 2 and 4
110. Ans. (d)

111. Efficiency of nozzle governed turbine is affected mainly by losses due to
(a) partial admission (b) throttling **[IES-1993]**
(c) inter-stage pressure drop (d) condensation in last stages
111. Ans. (a) Efficiency of nozzle governed turbine is affected mainly by losses due to partial admission because nozzle governing is accomplished by covering some of the nozzles and permitting entry through partial of the nozzles.

112. In the case of nozzle governed steam turbines, stage efficiencies vary very little when compared with those with full steam flow because
(a) mass flow rate does not affect the stage efficiency **[IAS-1997]**
(b) inlet steam pressure in the first stage is not affected
(c) mass rate of flow of steam in all the stages is the same
(d) stage pressures are not much different from the design value
112. Ans. (*)

By-pass governing

Emergency governing

113. Throttle governing in steam turbines **[IES 2007]**

(a) Leads to significant pressure loss (b) Increases the efficiency

(c) Increases heat losses (d) Decreases steam temperature

113. Ans. (a)

114. An emergency governor of a steam turbine trips the turbine when **[IES-2003]**

1. Shaft exceeds 100% of its rated speed
2. Condenser becomes hot due to inadequate cooling water circulation
3. Lubrication system fails
4. Balancing of turbine is not proper

Select the correct answer from the codes given below:

Codes:

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

114. Ans. (a)

115. Assertion (A): Never connect a solenoid valve directly to the motor leads.
Reason (R): The high current drawn to start the motor may drop the voltage enough to prevent the valve from opening. **[IES-1995]**

115. Ans. (a) A and R are correct. R is also right reason for A.

Blading and Fastening

116. Match List I (Blades) with List II (Features) and select the correct answer using the codes given below the Lists: **[IES-2003]**

List I (Blades)	List II (Features)
A. Ceramic blades	1. High creep strength
B. Steam turbine blades	2. Forged and machined
C. Alloy steel blades	3. Precision cast
D. Compressor blades	4. Thick at mid chord
	5. Thin trailing edge

Codes:

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

116. Ans. (a)

117. A three-stage Rateau turbine is designed in such a manner that the first two stages develop equal power with identical velocity diagram while the third one develops more power with higher blade speed. In such a multistage turbine, the blade ring diameter **[IES-1993]**

(a) is the same for all the three stages

(b) gradually increases from the first to the third stage

(c) of the third stage is greater than that of the first two stages

(d) of the third stage is less than that of the first two stages

117. Ans. (b) In multistage steam turbines, the pressure drops in each stage and specific volume increases. To handle higher specific volume of steam, the blade size and accordingly the blade ring diameter has to gradually increase from the first to the third stage.

118. At a particular section of a reaction turbine, the diameter of the blade is 1.8 m, the velocity of flow of steam is 49 m/s and the quantity of steam flow is 5.4 m^3/s. The blade height at this section will be approximately: **[IES-1997]**
(a) 4 cm (b) 2 cm (c) 1 cm (d) 0.5 cm
118. Ans. (b) Steam flow = $\pi D \times \text{height of blade} \times V \text{ or height of blade} = \dfrac{5.4 \times 100}{3.14 \times 1.8 \times 49} \simeq 2\,cm$

119. Assertion (A): During the operation of a steam turbine, it is necessary to maintain the moisture content of steam below 10%. Hence, the steam quality at turbine exit must be greater than 0.9. **[IES-1994]**
Reason (R): The precaution has to be taken in order to prevent corrosion and the consequent damage to the turbine.
119. Ans. (c) A is correct. R is true for erosion more than corrosion.

120. For a free vortex design of blade in the rotor of a reaction axial turbine, the specific work along the blade height is **[IES-1994]**
(a) higher at the blade hub and lower at the blade tip (b) constant from hub to tip.
(c) lower at the hub and higher at the tip.
(d) same at the hub and tip but different from the mean section.
120. Ans. (a)

121. Consider the following statements: The erosion of steam turbine blades increases with the increase of **[IAS-2000]**
1. moisture in the steam 2. blade speed
Which of these statements(s) is/are correct?
(a) 1 alone (b) 2 alone (c) 1 and 2 (d) Neither 1 nor 2
121. Ans. (c) both increases impact between blade and droplet of water.

Condensers

122. In a surface condenser used in a steam power station, under cooling of condensate is undesirable as this would **[IES-1996]**
(a) not absorb the gases in steam.
(c) increase the cooling water requirements.
(b) reduce efficiency of the plant.
(d) increase thermal stresses in the condenser.
122. Ans. (c) In a surface condenser used in a steam power station, under cooling of a condensate is undesirable as this would increase the cooling water requirements

123. An Important parameter to be monitored continuously for safeguarding turbine rotor in a steam power plant is
(a) steam inlet pressure (b) steam inlet temperature
(c) shaft vibration level (d) beaming temperatures **[IAS-1997]**
123. Ans. (d)

124. Ambient air dry- bulb temperature is 45°C and wet bulb temperature is 27°C. Select the lowest possible condensing temperature from the following for an evaporative cooled condenser.
(a) 25°C (b) 30°C (c) 42°C (d) 48° C **[GATE-1999]**
124 Ans. (d)

125. The practice to use steam on the shell side and cooling water on the tube side in condensers of steam power plant is because **[GATE-1994]**
(a) to increase overall heat transfer coefficient water side velocity can be increased if water is on the tube side.
(b) condenser can act as a storage unit for condensed steam.
(c) rate of condensation of steam is invariably smaller than the mass flow rate of cooling water.
(d) it is easier to maintain vacuum on the shell side than on the tube side.
125. Ans. (a) Specific volume of steam is large. More volume is required for steam. Hence shell side is used for steam and water is circulated through the tube in condenser.

Vacuum Efficiency

Condenser Efficiency

126. Assertion (A): Air leaking into condenser of steam power plant reduces the output of the plant.
Reason (R): Air inside condenser increases back pressure of steam turbine in steam power plants. **[IAS-2001]**
126. Ans. (a)

127. The pressure of air in a condenser **[IAS-1995]**
(a) increases the pressure in the condenser and decrease the condensing coefficient
(b) decreases the pressure in the condenser but increase the condensing coefficient
(c) increases the pressure in the condenser as well as the condensing coefficient
(d) decreases the pressure in the condenser as well as the condensing coefficient
127. Ans. (a)

128**.** In a steam condenser, the partial pressure of steam and air are 0.06 bar and 0.007 bar respectively. The condenser pressure is **[IAS 1994]**
(a) 0.067 bar (b) 0.06 bar (c) 0.053bar (d) 0.007 bar
128. Ans. (a) Condenser pressure = partial pressure of steam + partial pressure of air = 0.06 + 0.07 = 0.067 bar

Air Pumps

129. Assertion (A): The rate of heat transfer drops heavily in condensation of vapours containing air and this necessitates the use of a deaerating pump in surface condensers. **[IES-1994]**
Reason (R): The air accumulating at the heat transfer surface serves as a serious obstacle to vapour reaching the wall.
129. Ans. (a) Both A and R are true and R is right explanation for A.

Cooling Towers

130. Which one of the following is the correct statement?
Performance of mechanical draft cooling tower is superior to natural draft with
(a) Increase in air wet bulb temperature
(b) Decrease in air wet bulb temperature
(c) Increase in dry bulb temperature
(d) Increase in recirculation of air. **[IES 2007]**

130. Ans. (d)

131. Hot coffee in a cup is allowed to cool. Its cooling rate is measured and found to be greater than the value calculated by conduction, convection and radiation measurements. The difference is due to
(a) properties of coffee changing with temperature
(b) currents of air flow in the room
(c) underestimation of the emissivity of coffee (d) evaporation **[IES-1997]**
131. Ans. (d) The difference is due to evaporation

132. In a cooling tower, "approach" is the temperature difference between the
(a) hot inlet water and cold outlet water (b) hot inlet water and WBT
(c) cold outlet water and WBT (d) DBT and WBT **[IES-1996]**
132. Ans. (b) Approach in cooling towers refers to temperature difference between the hot inlet water and wet bulb temperature

133. Cooling tower in a steam power station is a device for **[IAS-1995]**
(a) condensing the steam into water
(b) cooling the exhaust gases coming out of the boiler
(c) reducing the temperature of superheated steam
(d) reducing the temperature of cooling water used in condenser.
133. Ans. (d)

Answers with Explanation (Objective)

Gas Turbine

Objective Questions (IES, IAS, GATE)

Advantages and disadvantages of Gas turbine

1. Which one of the following is correct? **[IES 2007]**
For the same net power output
(a) The turbine used in gas turbine power plant is larger than that used in steam power plants.
(b) The turbine used in gas turbine power plants is smaller than that used in steam power plants.
(c) The same turbine can be used for both plants. (d) None of the above
1. Ans. (b)

2. Consider the following statements: **[IES-2004]**
1. The speed of rotation of the moving elements of gas turbines is much higher than those of steam turbines
1. 2 Gas turbine plants are heavier and larger in size than steam turbine plants
2. 3 Gas turbines require 'cooling water for its operations
3. Almost any kind of fuel can be used with gas turbines

Which of the statements given above are correct?
(a) 1 and 2 (b) 1 and 3 (c) 1 and 4 (d) 3 and 4
2. Ans. (c)

3. Assertion (A): The thermal efficiency of a gas turbine plant is low as compared to that of reciprocating IC engines. **[IES-1997]**
Reason (R): In a gas turbine plant, the maximum pressure and temperature are low when compared to those of reciprocating IC engines.
3. Ans. (a)

4. Assertion (A): The thermal efficiency of gas turbine plants is higher compared to diesel plants. **[IES-1995]**
Reason (R): The mechanical efficiency of gas turbines is higher compared to diesel engines.
4. Ans. (d) A is false and R is true.

5. Assertion (A): The air-fuel ratio employed in a gas turbine is around 60: 1
Reason (R): A lean mixture of 60: 1 in a gas turbine is mainly used for complete combustion. **[IES-2000]**
5. Ans. (c)

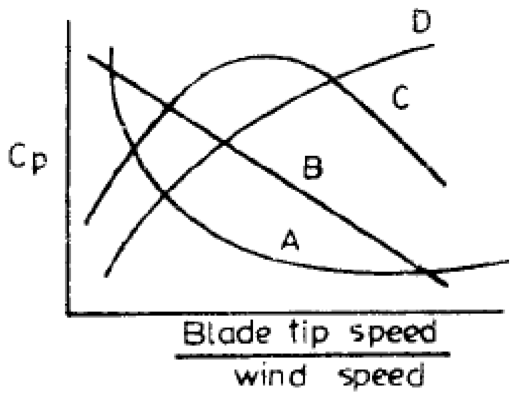
6. Assertion (A): Gas turbines use very high air fuel ratio. **[IES-1995]**
Reason (R): The allowable maximum temperature at the turbine inlet is limited by available material considerations.
6. Ans. (b) Though A and R are true, but R is not correct reason for A.

7. Consider the following statements comparing I.C. engines and gas turbines:
1. Gas turbines are simple, compact and light in weight. **[IES-1993]**
2. Complete expansion of working substance is possible in I.C. engines and not in gas turbines.
3. There is flexibility in the design of different components of gas turbines as different processes take place in different components.
4. Even low grade fuels can be burnt in gas turbines.
Of these statements
(a) 1, 2 and 3 are correct (b) 1, 3 and 4 are correct
(c) 2, 3 and 4 are correct (d) 1, 2 and 4 are correct
7. Ans. (a) Low grade fuel can't be burnt in gas turbine since it leads to poor life of turbine blades, etc.

8. Consider the toll owing statements: **[IAS-2000]**
Steam turbines are suitable for use as prime movers for large steam power plants because
1. a single steam turbine can be designed for a capacity of 1000 MW or more
2. much higher speed may be possible as compared to a reciprocating engine
3. they are more compact when compared to a gas turbine power plant
4. the maintenance cost and running cost may not increase with years of service
Which of these statements are correct?
(a) 1, 2 and 3 (b) 2, 3 and 4 (c) 1, 2 and 4 (d) 1, 3 and 4
8. Ans. (c) Gas turbine is more compact than I.C. engine & steam turbine for same power output.

9. Assertion (A): A gas turbine power plant is very sensitive to turbine and compressor inefficiencies. **[IAS 1994]**
Reason(R): In a gas turbine power plant, a large portion of the turbine work is consumed by the compressor.
9. Ans. (a)

10. The power coefficient (c_p) variation of a wind mill with the speed ratio is correctly shown by
(a) Curve A
(b) Curve B
(c) Curve C
(d) Curve D



[IES-1992]

10. Ans. (d)

Joule cycle or Brayton cycle

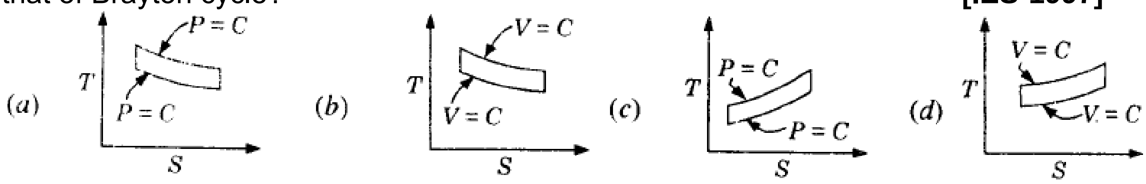
11. A Bell-Coleman air refrigeration cycle works as a reversed: **[IES-2005]**
(a) Stirling cycle (b) Otto cycle (c) Diesel cycle (d) Brayton cycle
11. Ans. (d)

12. Assertion (A): The thermal efficiency of Brayton cycle would not necessarily increase with reheat. **[IES-2000]**
Reason (R): Constant pressure lines on the T-s diagram slightly diverge with increase in entropy.
12. Ans. (b)

13. Assertion (A): The thermal efficiency of Brayton cycle with regeneration decreases as the compressor ratio increases. **[IES-1999]**
Reason (R): As the compression ratio of compressor increases, the range of temperature in the regenerator decreases and the amount of heat recovered reduces.
13. Ans. (a) Both A and R are true and R is correct explanation for A.

14. A gas turbine works on which one of the following cycles? **[IES-1998]**
(a) Brayton (b) Rankine (c) Stirling (d)Otto
14. Ans. (a)

15. Which one of the thermodynamic cycles shown in the following figures represents that of Brayton cycle? **[IES-1997]**



15. Ans. (c)

16. For a Brayton cycle, match the following using codes given below:
List I List II
A. Compression 1. Isothermal **[IES-1992]**

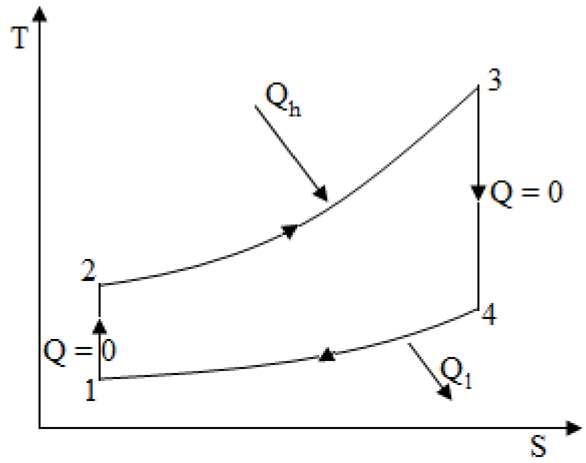
B. Rejection 2. Isobaric
C. Expansion 3. Isentropic
D. Heat addition 4. Constant enthalpy

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

16. Ans. (d)

17. Use of maximum pressure ratio, corresponding to maximum to minimum cycle temperature ratio in case of Joule cycle gives which one of the following?
(a) Maximum efficiency but very less specific work output
(b) Maximum efficiency and very high specific work output
(c) Minimum efficiency and very less specific work output
(d) Minimum efficiency but very high specific work output **[IES 2007]**
17. Ans. (a)

18. Which cycle is represented in the diagram given above?
(a) Miller cycle
(b) Ericsson cycle
(c) Atkinson cycle
(d) Brayton cycle



[IAS-2007]
18. Ans. (d) it is clear from the diagram
1-2: isentropic compression
2-3: isobaric or isochoric heat addition
3-4: isentropic expansion
4-1: isobaric or isochoric heat rejection
So it must be Otto or Brayton cycle. 'Otto' option is not there so answer is Brayton cycle.

19. Assertion (A): Brayton cycle is not suitable for reciprocating engines.
Reason (R): A reciprocating engine cannot have complete expansion. **[IAS-1999]**
19. Ans. (a)

20. For air standard Brayton cycle, increase in the maximum temperature of the cycle, while keeping the pressure ratio the same would result in
(a) increase in air standard efficiency
(b) decrease in air standard efficiency
(c) no change in air standard efficiency
(d) increase in the efficiency but reduction in net work **[IAS-1998]**
20. Ans. (c) air standard efficiency of Brayton cycle (η) = $1-\frac{1}{r_p^{\frac{\gamma-1}{\gamma}}}$

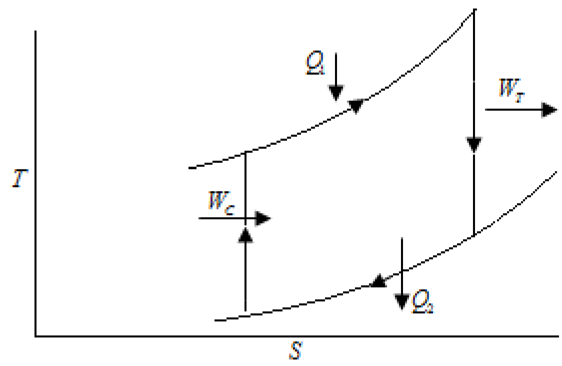
21. In a simple gas turbine power plant operating on standard Brayton cycle power needed to drive the compressor is 175 kW, rate of heat supplied during constant pressure heat addition process is 675 kW. Turbine output obtained during expansion is 425 kW. What is the rate of heat rejection during constant pressure heat rejection?
(a) 75 kW (b) 425 kW (c) 500 kW (d) 925 kW **[IAS-2004]**

21. Ans. (b) $\Sigma dQ = \Sigma dW$

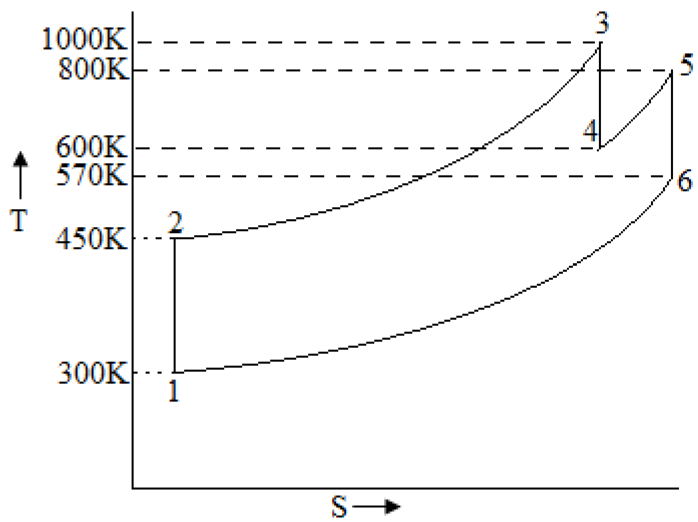
$or\ Q_1 - Q_2 = W_T - W_C$

$or\ 675 - Q_2 = 675 - 425$

$or\ Q_2 = 425 kW$



22. The given figure shows an open-cycle gas turbine employing reheating, on T-s plane. Assuming that the specific heats are same for both air and gas, and neglecting the increase in mass flow due to addition of fuel, the efficiency is
(a) 33.3%
(b) 64%
(c) 72.7%
(d) 84%



[IAS-2001]

22. Ans. (b)

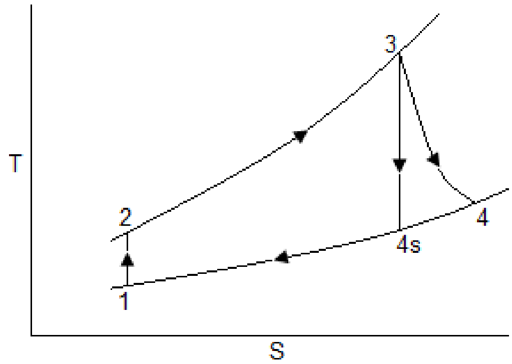
Heat addition (Q_1) $= C_p(T_3 - T_2) + C_p(T_5 - T_4) = C_p[1000 - 450 + 800 - 600] = 750 C_p$

Heat rejection (Q_2) = $C_p(T_6 - T_1) = C_p[570 - 300] = 270 C_p$

Therefore Work done (W) = Q_1 - Q_2 = $480C_p$ $\therefore \eta = \frac{480}{750} = 64\%$

23. In a gas turbine, hot combustion products with the specific heats C_p = 0.98 kJ/kgK, and C_v = 0.7538 kJ/kg K enter the turbine at 20 bar, 1500 K and exit at 1 bar. The isentropic efficiency of the turbine is 0.94. The work developed by the turbine per kg of gas flow is **[GATE-2003]**
(a) 689.64 kJ/kg (b) 794.66 kJ/kg (c) 1009.72 kJ/kg (d) 1312.00 kJ/kg

23. Ans. (a)



$$\frac{T_{4S}}{T_3} = \left(\frac{P_4}{P_3}\right)^{\frac{r-1}{r}} = \left(\frac{1}{20}\right)^{\frac{1.3-1}{1.3}}$$

$$\text{or } T_{4S} = T_3 \times (20)^{-\frac{0.3}{1.3}} = 751\,\text{K}$$

$$\eta_{isen} = \frac{T_4 - T_3}{T_{4S} - T_3} \Rightarrow T_4 = T_3 + \eta\left(T_{4S} - T_3\right) = 796\ \text{K}$$

$$\left[\gamma = \frac{c_p}{c_v} = 1.3\right]$$

$$W_T = h_3 - h_4 = C_p\left(T_3 - T_4\right) = 0.98(1500 - 796)$$
$$= 689.92\ \text{kJ/kg}$$

24. A gas turbine power plant has a specific output of 350 kJ/kg and an efficiency of 34%. A regenerator is installed and the efficiency increases to 51%. The specific output will be closest to **[GATE-1999]**

(a) 350 kJ/kg (b) 468 kJ/kg (c) 525 kJ/kg (d) 700 kJ/kg

24. Ans. (a) $\eta = \frac{W_{net}}{Q}$ or $0.34 = \frac{350}{Q}$ ---(i) and $0.51 = \frac{W_{net}}{Q}$ ----(ii)

or $\frac{W_{net}}{350} = \frac{51}{34}$ or $W_{net} = \frac{3}{2} \times 350\,\text{kJ/kg} = 525\,\text{kJ/kg}$

25. Consider the following statements relating to a closed gas turbine cycle:

1. The cycle can employ monatomic gas like helium instead of air to increase the cycle efficiency if other conditions are the same.
2. The efficiency of heat exchanger increases with the use of helium.
3. The turbine blades suffer higher corrosion damages.
4. Higher output can be obtained for the same size.

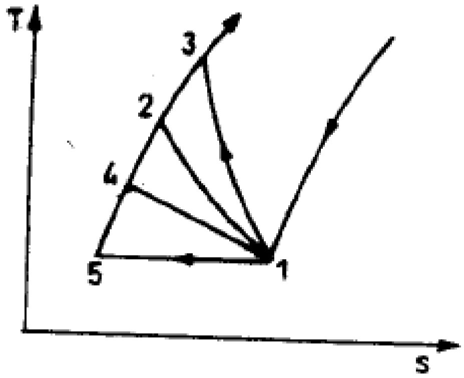
Which of these statements are correct? **[IES-1999]**

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

25. Ans. (b) Item 3 is not correct and other items are correct.

26. Consider the T-s diagram shown in the following figure:
Actual compression process in gas turbines is indicated by the process.

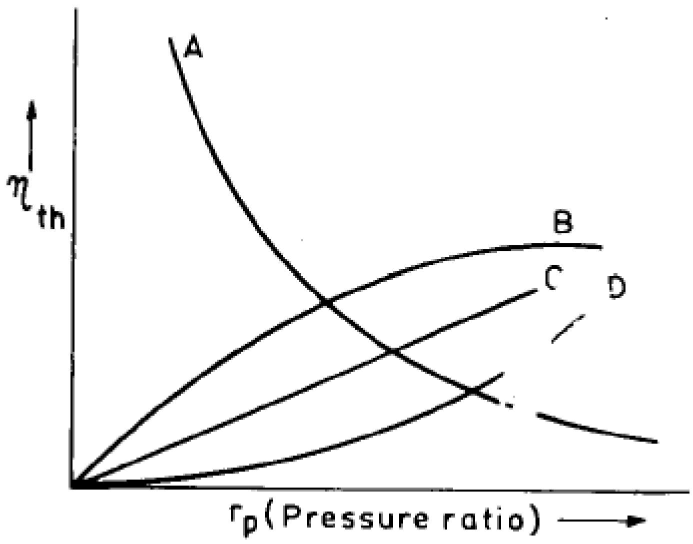
(a) 1-2
(b) 1-3
(c) 1-4
(d) 1-5.



[IES-1994]

26. Ans. (b) Curve 1-3 is actual compression process in gas turbine.

27. The given figure shows four plots A, B, C and D of thermal efficiency against pressure ratio:



[IES-1995]

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

The curve which represents that of a gas turbine plant using Brayton cycle (without regeneration) is the one labeled

27. Ans. (b)

Efficiency

28. Consider the following statements in respect of gas turbines:

  1. Supersonic flow leads to decrease in efficiency.
  2. Supersonic flow leads to decrease in flow rate.

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 **[IES 2007]**

28. Ans. (d)

29. An open cycle constant pressure gas turbine uses a fuel of calorific value 40,000 kJ/kg, with air fuel ratio of 80:1 and develops a net output of 80 kJ/kg of air. What is the thermal efficiency of the cycle?

(a) 61% (b) 16% (c) 18% (d) None of the above **[IES 2007]**

29. Ans. (b) take air = 80 kg so fuel = 1 kg

$$\therefore \ \eta = \frac{Power \quad Plant}{Heat \quad Added} = \frac{80 \times 80}{40000} = 0.16$$

30. In a gas turbine cycle, the turbine output is 600kJ/kg, the compressor work is 400kJ/kg and the heat supplied is 1000 kJ/kg. The thermal efficiency of this cycle is:

(a) 80% (b) 60% (c) 40% (d) 20% **[IES-1997]**

30. Ans. (d) $\frac{W_T - W_C}{Heat} = \frac{600 - 400}{1000} = 20\%$

Optimum pressure ratio

31. The power required to drive a turbo-compressor for a given pressure ratio decreases when **[IES-2006]**

(a) Air is heated at entry (b) Air is cooled at entry

(c) Air is cooled at exit (d) Air is heated at exit

31. Ans. (b)

33. Optimum pressure ratio for maximum specific output for ideal gas turbine plant operating at initial temperature of 300 k and maximum temperature of 100 k is closer to **[IES-1992]**

(a) 4 (b) 8 (c) 12 (d) 16

33. Ans. (b)

$$\text{Maximum possible pressure ratio, } (R_p)_{max} = \left(\frac{T_3}{T_1}\right)^{\gamma/\gamma-1} = \left(\frac{1000}{300}\right)^{1.4/(1.4-1)} = \left(\frac{10}{3}\right)^{3.5}$$

$$\therefore \quad \text{pressure ratio for maximum output, } R_p = \sqrt{(R_p)_{max}} = \left(\frac{10}{3}\right)^{3.5/2} \approx 8$$

36. The compression ratio of a gas power plant cycle corresponding to maximum work output for the given temperature limits of T_{min} and T_{max} will be

(a) $\left(\frac{T_{max}}{T_{min}}\right)^{\frac{\gamma}{2(\gamma-1)}}$ (b) $\left(\frac{T_{min}}{T_{max}}\right)^{\frac{\gamma}{2(\gamma-1)}}$ (c) $\left(\frac{T_{max}}{T_{min}}\right)^{\frac{\gamma-1}{\gamma}}$ (d) $\left(\frac{T_{min}}{T_{max}}\right)^{\frac{\gamma-1}{\gamma}}$

[IES-2001; 2005; IAS-1995; GATE-2004]

36. Ans. (a)

Open and closed cycle

37. **Assertion (A) :** The cycle gas turbines are preferred over closed cycle when the gas is air.

Reason (R): The expansion of combustion products can take place up to atmospheric pressure. **[IAS-1995]**

37. Ans. (b) Both A and R are true but R is NOT the correct explanation of A

Number of stages etc

38. In a single-stage open-cycle gas turbine, the mass flow through the turbine is higher than the mass flow through compressor, because **[IES-1997]**

(a) the specific volume of air increases by use of intercooler

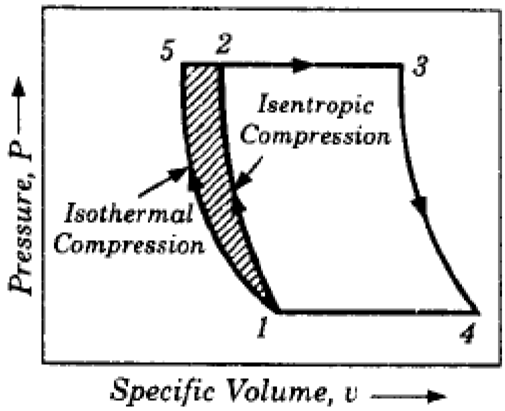
(b) the temperature of air increases in the reheater

(c) the combustion of fuel takes place in the combustion chamber

(d) the specific heats at constant pressure for incoming air and exhaust gases are different

38. Ans. (C) Due to combustion of fuel in combustion chamber, mass flow through turbine is higher than compressor

39. The given figure shows the effect of the substitution of an isothermal compression process for the isentropic compression process on the gas turbine cycle. The shaded area (1-5-2-1) in the p-v diagram represents
(a) reduction In the compression work
(b) reduction in the specific volume
(c) increment in the compression work
(d) increment in the specific volume

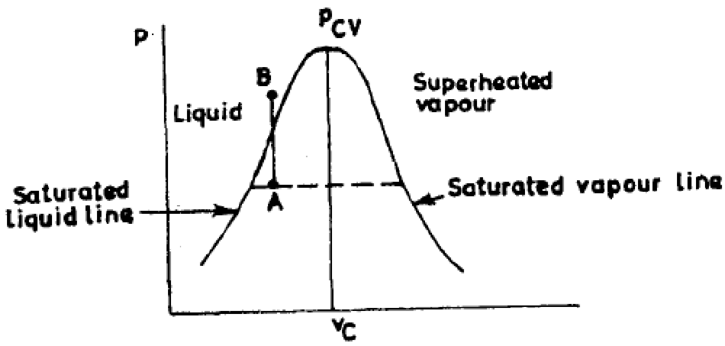


[IES-1997]

39. Ans. (c) Shaded area corresponds to increment in the compression work

40. Isentropic compression of saturated vapour of all fluids leads to superheated vapour. **[GATE-1994]**

40. Ans. False



Compression from A to B, where the specific volume is below the critical level, will give liquid phase.

Regeneration

41. The efficiency of a simple gas turbine can be improved by using a regenerator, because the **[IES-2000]**
(a) work of compression is reduced (b) heat required to be supplied is reduced
(c) work output of the turbine is increased (d) heat rejected is increased
41. Ans. (b)

42. A gas turbine develops 120 kJ of work while the compressor absorbed 60 kJ of work and the heat supplied is 100 kJ. If a regenerator which would recover 40% of the heat in the exhaust was used, then the increase in the overall thermal efficiency would be: **[IES-1997]**
(a) 10.2% (b) 8.6% (c) 6.9% (d) 5.7%

42. Ans. (d) $\eta = \frac{120-60}{200} = \frac{60}{200} = 30\%$; Heat in exhaust gas = 200 - 120 = 80 kJ

Heat recovery in regenerator = 0.4 x 80 = 32 kJ; Thus heat supply will reduce by 32 kJ, i.e. heat supply = 200 - 32 = 168 kJ ;

$\eta = \frac{120-60}{168} = \frac{60}{168} = 35.7\% \quad \therefore \eta \text{ increased by } 5.7\%$

43. The use of regenerator in a gas turbine cycle **[IES-1993]**

(a) increases efficiency but has no effect on output
(b) increases output but has no effect on efficiency
(c) increases both efficiency and output
(d) increases efficiency but decreases output

43. Ans. (a) The addition of regenerator in gas turbine reduces the heat required from external source but work output remains same and efficiency increases.

Reheating

44. Consider the following statements in respect of gas turbines:
A gas turbine plant with reheater leads to a

1. Considerable improvement in the work output
2. Considerable improvement in the thermal efficiency.

(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Nether 1 and 2 **[IES 2007]**

44. Ans. (a) In gas power plant reheat always decrease thermal efficiency.

45. Assertion (A): In a gas turbine, reheating is preferred over regeneration to yield a higher thermal efficiency. **[IES-1996]**
Reason (R): The thermal efficiency given by the ratio of the difference of work done by turbine (W_t) and work required by compressor (W_c) to heat added (Q_A) is improved by increasing the W_t keeping W_c and Q_A constant in reheating, whereas in regeneration Q_A is reduced keeping W_t and W_c constant.
45. Ans. (d) A is false but R is true

46. A gas turbine cycle with heat exchanger and reheating improves **[GATE-1993]**
(a) only the thermal efficiency
(b) only the specific power output
(c) both thermal efficiency and specific power output
(d) neither thermal efficiency nor specific power output
46. Ans. (*)

47. Reheating in a gas turbine **[IES-1998]**
(a) increases the compressor work (b) decreases the compressor work
(c) increases the turbine work (d) decreases the turbine work
47. Ans. (c)

Inter cooling

48. Inter-cooling in gas turbines **[IES-1993]**
(a) decreases net output but increases thermal efficiency
(b) increases net output but decreases thermal efficiency
(c) decreases both net output and thermal efficiency
(d) increases both net output and thermal efficiency
48. Ans. (b) Inter-cooling in gas turbine is used to compress air in two stages with inter-cooling. With inter-cooling the work to be done on compressor decreases and thus net output of turbine increases. However more heat has to be added in combustion chamber which results in decrease in thermal efficiency.

49. Consider the fo1lowing statements: **[IES-1994]**
1. Inter-cooling is effective only at lower pressure ratios and high turbine inlet temperatures.

2. There is very little gain in thermal efficiency when inter-cooling is used without the benefit of regeneration
With high values of 'γ' and c_p of the working fluid, the net power output of Brayton cycle will increase.
(a) 1, 2 and 3 are correct (b) 1 and 2 are correct (c) 1 and 3 are correct (d) 2 and 3.are correct.
49. Ans. (d)

50. Consider the following statements: **[IES-1995]**
When air is to be compressed to reasonably high pressure, it is usually carried out by a multistage compressor with an intercooler between the stages because
1. work supplied is saved. 2. weight of compressor is reduced.
3. more uniform torque is obtained leading to the reduction in the size of flywheel.
4. volumetric efficiency is increased.
Of the four statements listed above correct is/are?
(a) 1 alone (b) 2 and 4 (c) 1, 2 and 3 (d) 1 2, 3 and 4
50. Ans. (a)

6. Air Compressors
(With RAC)

Fuels and Flue gas Analysis

Objective Questions (IES, IAS, GATE)

Coal Analysis

1. Match List I with List II and select the correct answer: **[IES-2002]**

List I (Type of Coal)	List II (Coal properties)
A. Lignite	1. Artificial fuel derived from coal
B. Anthracite	2. Contains inflammable gas (volatile matter) and bums with flame
C. Bituminous	3. Very hard and high heating value
D. Cock	4. High ash content and less volatile matter

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

1. Ans. (a)

2. Match List-I (Fuels) with List-II (Characteristics/usages) and select the correct answer using the codes given below the lists: **[IES-2001]**

List I (Fuels)	List-II (Characteristics/usages)
A. Semi – bituminous coal	1. Methane and carbon dioxide
B. High – speed diesel oil	2. Propane and butane
C. Biogas	3. Calorific value of 10, 600 kcal/kg
D. LPG	4. Power plants

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

2. Ans. (b)

3. Match List I with List II and select the correct answer using the code given below the Lists: **[IAS-2007]**

List I (Purpose of Transportation)	List II (Device)
A. Coal from the pit to surface	1. Bucket elevator
B. Lump and powder material in bulk transportation to storage	2. Belt conveyor
C. Stacking components in store	3. Fork lift truck
D. Heavy material transportation in machine shop	4. Crane

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

3. Ans. (b)

Proximate Analysis

4. Weight percentage of which one of the following is determined by Proximate analysis of coal? **[IES-2005]**

(a) Fixed carbon, volatile matter, moisture and ash
(b) All solid and gaseous components
(c) All solid & gaseous components except volatile matter
(d) Fixed carbon and volatile matter

4. Ans. (a)

Ultimate Analysis

5. Volumetric analysis of sample of dry products -of combustion gave the following results:

CO_2 = 10% CO = 1% O_2 = 8% N_2 = 81%

Their proportions by weight will be **[IES-1993]**

(a) 440: 28 : 256 : 2268 (b) 22 : 14 : 256 : 1134
(c) 440: 14: 28: 2268 (d) 22: 28: 14: 1134

5. Ans. (a) Conversion from volumetric to gravimetric is done as below:

Gas	% volume (1)	Mol. weight (2)	Proportional weight (1) x (2)
CO_2	10	44	440
CO	1	28	28
O_2	8	32	256
N_2	81	28	2268

Their proportion by weight are as per (a).

Heating Value

Determination of Heating Value, Solid and liquid fuel (Bomb Calorimeter)

6. Bomb calorimeter is used to determine the calorific value of **[IES-2003]**

(a) Solid fuel only (b) Gaseous fuels only
(c) Solid as well as gaseous fuels (d) Solid as well as liquid fuels

6. Ans. (d)

7. Match List I (Measuring Appliances) with List II (Properties/Composition of Fuel) and select the correct answer using the codes given below the Lists: **[IES-2003]**

List-I (Measuring Appliances)	List-II (Properties/Composition of Fuel)
A. Hydrometer	1. Vapour pressure
B. Bomb calorimeter	2. Composition of products of combustion
C. Reid bomb	3. Specific gravity
D. Orsat apparatus	4. Heating value

Codes:

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

7. Ans. (b)

8. Assertion (A): With the help of a Bomb calorimeter, the lower calorific value of a solid or liquid fuel can be determined, as the water vapour formed is carried away by the exhaust gases.
Reason (R): The lower calorific value of a fuel is the net value of heat available found by subtracting the latent head of the water formed and carried away by exhaust gas from the higher calorific value. **[IES-2000]**
8. Ans. (a)

9. The calorific value determined by the bomb calorimeter is **[IES-1992]**
(a) lower calorific value at constant pressure (b) higher calorific value at constant pressure
(c) lower calorific value at constant volume (d) higher calorific value at constant volume
9. Ans. (d)

10. Which one of the following fuels is used to determine the water equivalent of a bomb calorimeter?
(a) Benzoic acid (b) Octane (c) Coke (d) Cetane **[IAS-1997]**
10. Ans. (a)

Determination of Heating Value, Gaseous fuel (Junker's Gas Calorimeter)

HHV and LHV

11. Which one of the following gaseous fuels does not have different higher and lower calorific values? **[IES-1999]**
(a) Methane (b) Ethane (c) Carbon monoxide (d) Hydrogen
11. Ans. (c) Since CO does not have hydrogen content; the HCV and LCV are same

12. Consider the following statements: **[IES-1998]**
The difference between higher and lower heating values of the fuels is due to
1. heat carried by steam from the moisture content of fuel.
2. sensible heat carried away by the flue gases.
3. heat carried away be steam from the combustion of hydrogen in the fuel.
4. heat lost by radiation

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

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

12. Ans. (c)

13. Consider the following statements: **[IES-1998]**

The maximum temperature produced by the combustion of a unit mass of fuel depends upon

1. LCV 2. ash content 3. mass of air supplied 4. pressure in the furnace

Of these statements

(a) (a) 1 alone is correct (b) 1 and 3 are correct

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

13. Ans. (b)

Combustion (Stoichiometric Air)

14. In Combustion process, the effect of dissociation is to **[IES-1992]**

(a) reduce the flame temperature (b) separate the products of combustion

(c) reduce the proportion of carbon monoxide in gases (d) reduce the use of excess air

14. Ans. (a)

15. The amount of CO_2 produced by 1 kg of carbon on complete combustion is

(a) $\frac{3}{11}$ kg (b) $\frac{3}{8}$ kg (c) $\frac{8}{3}$ kg (d) $\frac{11}{3}$ kg **[IES-1999]**

15. Ans.(d) $12\,\text{kg of C} + 32\,\text{kg of } O_2 \rightarrow 44\,\text{kg of } CO_2$

$$\text{Or } 1\,\text{kg of C} + \frac{8}{3}\text{kg of } O_2 \rightarrow \frac{11}{3}\text{kg of } CO_2$$

16. Methane burns with stoichiometric quantity of air. The air/fuel ratio by weight is

(a) 4 (b) 14.7 (c) 15 (d) 17.16 **[IES-1999]**

16. Ans.(d) 16 kg of methane (CH_4) + 64 kg of O_2 $\rightarrow$ 44 kg of CO_2 + 36 kg of water

$$1\text{ kg of methane }(CH_4) + 4\text{ kg of } O_2 \rightarrow \frac{11}{4}\text{ kg of } CO_2 + \frac{9}{4}\text{ kg of water}$$

Thus O_2 requirement for burning 1 kg of methane is 4 kg.

Since air contains 23% ofoxygen by weight,

$$\text{air / fuel ratio} = \frac{4/0.23}{1} = 17.16\%.$$

17. The minimum weight of air required per kg of fuel for complete combustion of a fuel is given by **[IES-1993]**

(a) $11.6C+34.8\left(H-\frac{O}{8}\right)+4.35S$ (b) $11.6C+34.8\left(H+\frac{O}{8}\right)+4.35S$

(c) $11.6C-34.8\left(H-\frac{O}{8}\right)+4.35S$ (d) $11.6C-34.8\left(H-\frac{O}{8}\right)+4.35S$

17. Ans. (a) Oxygen required for C. H_2 S and O_2 in fuel respectively is

$$\frac{8}{3}C + 8H_2 + S - O_2$$

$$or\ \frac{8}{3}C + 8\left(H_2 - \frac{O_2}{8}\right) + S$$

Since atmospheric air contains 23% by weight of oxygen,

Therefore minimum air required per kg of fuel = $\frac{100}{23}\left[\frac{8}{3}C + 8\left(H_2 - \frac{O_2}{8}\right) + S\right]$

$$= 11.6C + 34.8\left(H - \frac{O}{8}\right) + 4.35S$$

18. The mass of air required for complete combustion of unit mass of fuel can always be calculated from the formula, where C, H, O and S are in percentage. **[IES-1995]**
(a) 0.1152C + 0.3456H (b) 0.1152C + 0.3456 (H - 0.125 O)
(c) O.I 152C + 0.3456 (H - 0.125 O) + 0.0432S
(d) 0.1152C + 0.3456 (H + 0.125) + 0.0432S.
18. Ans. (c) Mass of air for complete combustion is 0.1152C + 0.3456 (H - 0.125 O) + 0.0432 S.

19. One mole of hydrogen is burnt with chemically correct quantity of air and cooled to N.T.P The change in volume in mole is **[IES-1992]**
(a) zero (b) ½ (c) 2/3 (d) 3/2
19. Ans. (d)

20. Amount of oxygen needed to completely burn I1lg of methane (CH_4) is
(a) 2 kg (b) 4 kg (c) 16 kg (d) 22 kg **[IAS-2001]**
20. Ans. (b)

$$CH_4 + 2O_2 = CO_2 + 2H_2O$$

$$16\,\text{kg} \; + 2\times 32\,\text{kg}$$

$$\text{Therefore for 1 kg of methane } \frac{2\times 32}{16} = 4\,\text{kg of } O_2 \text{ is needed.}$$

21. In order to burn 1 kilogram of CH_4 completely, the minimum number of kilograms of oxygen needed is (take atomic weight of H, C and O as 1, 12 and 16 respectively).
(a) 3 (b) 4 (c) 5 (d) 6 **[GATE-1995]**
21. Ans. (b)

Explanation. $CH_4 + 2C_2 \rightarrow CO_2 + 2H_2O$

16 kg 64 kg

16 kg of CH_4 requires 64 kg of oxygen.

$\therefore$ 1 kg of CH_4 requires 4kg of oxygen

Fuel bed furnace for coarse particle

Pulverized coal furnace for fine particle

22. Match List I with List II and select the correct answer. **[IES-1994]**

List I	List II
A. Bin system	1. Dust col1ection.
B. Cyclone furnace	2. High turbulence
C. Tangential burners	3. High slag recovery
D. Scrubber	4. Pulverized fuel

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

22. Ans. (b)

23. In a pulverised-fuel-fired large power boiler, then heat transfer from the burning fuel to the walls of the furnace is **[GATE-1999]**
(a) by conduction only (b) By convection only
(c) by conduction and convection (d) predominantly by radiation
23. Ans. (c)

24. Consider the following statements: **[IES-1999]**
1. Pulverised fuel gives high and controlled burning rate.
2. Insufficient air causes excessive smoking of exhaust.
3. Excess air is provided to control the flue gas temperature.
4. Effect of sulphur in fuel is to give high heat transfer rate.

Which of these statements are correct?
(a) 3 and 4 (b) 2 and 3 (c) 1 and 2 (d) 1 and 4
24. Ans. (c)

25. Coal fired power plant boilers manufactured in India generally use: **[IES-1997]**
(a) Pulverised fuel combustion (b) fluidised bed combustion
(c) circulating fluidised bed combustion (d) moving stoker firing system
25. Ans. (a) Coal fired power plant boilers manufactured in India generally use pulverised fuel combustion which can only offer high capacity of boilers compared to other choices

Cyclone furnace for crushed particle bed furnace for coarse particle

Fluidized bed furnace for crushed small particle

26. Consider the following statements regarding the f1uidized bed combustion boilers:
1. The combustion temperatures are low, around 900°C. **[IES-2003]**
2. The formation of oxides of nitrogen is low.
3. It removes sulphur from coal during combustion process.
4. It requires high quality of coal as fuel.

Which of these statements are correct?
(a) 1, 2, 3 and 4 (b) 1, 2 and 3 (c) 2, 3 and 4 (d) 1 and 4
26. Ans. (b)

27. Which one of the following statements is ***not*** correct? In a fluidized-bed boiler?
(a) the combustion temperatures are higher than those in the conventional boilers
(b) inferior grade of coal can be used without slagging problems **[IES-2001]**
(c) the formation of NO, is less than that in the conventional boilers
(d) the volumetric heat release rates are higher than those in the conventional boilers
28. Ans. (d)

29. In fluidized bed combustion velocity of fluid is proportion of (r =radius of the particle) as
$(a)\dfrac{1}{r}$ $(b)\dfrac{1}{\sqrt{r}}$ $(c)\sqrt{r}$ $(d)\,r$ **[IES-1992]**

29. Ans. (c) A fluidized bed contains solid particles which are in intimate contact with a fluid passing through at a velocity sufficiently high to cause the particles to separate and become freely supported by the fluid.

$$v_s = \sqrt{\frac{8}{3C_D}\frac{\rho_s}{\rho_f} r.g.}$$

$$v_s \propto \sqrt{r}$$

Actual Air-fuel Ratio (Orsat Analyzer)

30. The Orsat apparatus, which gives volumetric percentage of four constituents of dry flue gas, is arranged for absorption of three gases and the fourth content being obtained by difference

Match List I with List II and select the correct answer using the given code given below the lists:

List I (Gases)	List I (Solution for Absorption/ By difference)
A. Carbon dioxide	1. By difference
B. Carbon monoxide	2. Caustic soda
C. Oxygen	3. Pyrogallic acid
D. Nitrogen	4. Cuprous chloride

Codes: **[IES 2007]**

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

30. Ans. (c)

31. The combustion analysis carried out by the Orsat Apparatus renders which one of the following?
(a) The percentage composition by weight on the dry basis
(b) The percentage composition by volume on the dry basis
(c) The percentage composition by weight on the wet basis
(d) The percentage composition by volume on the wet basis **[IES 2007]**

31. Ans. (b) Since the sample is collected over water, any water vapour in the flue gas would have connected during the collection process. So the flue gas analysis thus measured is on the dry basis.

32. Consider the following statements: **[IES-2006]**
1. The gases measured directly by Orsat apparatus from a flue gas sample are CO_2, O_2 and N_2·
2. Bomb calorimeter measures higher calorific value of fuel at constant pressure.
3. For burning I kg of fuel (carbon) to carbon monoxide, the stoichiometric quantity of air required is 8/3 kg.

Which of the statements given above is/are correct?
(a) Only 1 (b) Only 2 (c) Only 3 (d) 1, 2 and 3

32. Ans. (a) 1. Orsat apparatus measures the volume of CO_2, CO and O_2 in the dry flue gas and N_2 by balance.
2. Bomb calorimeter measures higher calorific value of fuel at *constant volume*.
3.For burning one Kg of fuel to CO the stoichiometric quantity of air required is 5.797 Kg of air/Kg of carbon.

2C	+	O_2	=	2CO
2x12 kg		32 kg		2x28 kg

1 kg (carbon) + 4/3 kg (oxygen) = 7/3 kg (carbon monoxide)

air requirement = (100/23)X 4/3 kg per kg of carbon

33. Which one of the following orders is the correct order of passing the flue gases through the different absorbents (in the flasks) during analysis in Orsat apparatus?
(a) Potassium hydroxide solution - alkaline solution of Pyrogallic acid - cuprous chloride solution **[IES-2004]**
(b) Potassium hydroxide solution - cuprous chloride solution - alkaline solution of pyrogallic acid
(c) Alkaline solution of pyrogallic acid – cuprous chloride solution - potassium hydroxide solution
(d) Cuprous chloride solution - potassium hydroxide solution - alkaline solution of pyrogallic acid
33. Ans. (a)

34. Orsat apparatus is used to determine products of **[IES-2003]**
(a) All constitt1ents of fuel combustion by mass
(b) All constituents of fuel combustion by volume
(c) Only dry constituents of combustion by mass
(d) Only dry constituents of combustion by volume
34. Ans. (d)

35. A hydrocarbon fuel was burnt with air and the Orsat analysis of the dry products of combustion yielded the following data:
Initial volume of dry gas sample……………………………… 100 cc **[IES-2001]**
Volume after absorption in pipette 1 containing
potassium hydroxide solution………………………………… 89 cc
Volume after absorption in pipette 2 containing
solution of pyrogallic acid and potassium hydroxide…………84 cc
Volume after absorption in pipette 3 containing
cuprous chloride solution…………………………………… 82 cc
The percentage (by volume) of CO_2 in the dry products was
(a) 2% (b) 5% (c) 11% (d) 18%
35. Ans. (c)

36. Items given in List I and List II pertain to gas analysis. Match List I with List II and select the correct answer. **[IES-1996]**

List I	List II
A. CO_2	1. Alkaline pyrogallol
B. Orsat apparatus	2. KOH solution
C. CO	3. Wet analysis
D. O_2	4. Ammonaical cuprous chloride
	5. Dry analysis

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

36. Ans. (d)

37. In the Orsat flue gas analyser, ammoniacal cuprous chloride is used to absorb.
(a) CO_2 (b) CO (c) O_2 (d) N_2 **[IES-1995]**
37. Ans. (b)

38. In Orsat apparatus **[IES-1992]**
(a) Carbon dioxide is absorbed in cuprous chloride
(b) Carbon monoxide is absorbed in caustic potash solution
(c) Oxygen is absorbed in pyrogalic acid

(d) Nitrogen is absorbed is hot nickel chrome compound
38. Ans. (c)

39. Orsat's apparatus is employed to determine **[IES-1992]**
(a) ultimate analysis of fuel (b) gravimetric analysis of fuel
(c) volumetric analysis of dry products of combustion
(d) gravimetric analysis of dry products of combustion
39. Ans. (c)

40. Orsat gas analyser determines volumetric composition of the flue gases in respect of **[IAS-2002]**
(a) O_2 and N_2 (b) O_2 and CO_2 (c) O_2, CO and N_2 (d) N_2, O_2, CO_2 and CO
40. Ans. (d) Directly measures CO_2, O_2 and CO
But N_2 is calculated by difference.

41. Consider the following statements: **[IES-2001]**
1. For the combustion of pulverized coal, 5 to 10% excess air is required.
2. Air contains 21 % oxygen by weight.
3. The flue gases from a coal-fired furnace contain around 70% nitrogen by volume.
4. In the combustion of liquid fuels the number of moles of the products are invariably greater than the number of moles of the reactants.
Of these statements
(a) 1, 2 and 4 are correct (b) 1, 3 and 4 are correct
(c) 2, 3 and 4 are correct (d) 1 and 3 are correct
41. Ans. (a)

42. When solid fuels are burned, the nitrogen content of the flue gas by volume is about **[IES-1996]**
(a) 60% (b) 70% (c) 80% (d) 90%.
42. Ans. (b) When solid fuels are burnt, the nitrogen content of flue gas by volume is about 70%.

Excess Air

43. Assertion (A): In constant pressure type gas turbines, large quantity of air is used, in excess of its combustion requirements. **[IES-2003]**
Reason (R): Excess air is used to compensate for inevitable air-loss due to leakages in the system.
43. Ans. (c)

44. The excess air required for combustion of pulverised coal is of the order of
(a) 100 to 150 % (b) 30 to 60% (c) 15 to 40% (d) 5 to 10%. **[IES-1996]**
44. Ans. (d) The excess air required for combustion of pulverised coal is of the order of 5 to 10%

45. Dry flue gases with a composition of CO_2 = 10.4%, O_2 = 9.6 and N_2 = 80%, indicate that **[IES-1995]**
(a) excess air is used (b) air is insufficient
(c) hydrogen is not present in the coal (d) air is just sufficient.
45. Ans. (a) O_2 = 9.6 means excess air is used

46. Assertion (A): Excess air supplied to a combustor increases the efficiency of combustion. **[IES-1994]**

Reason (R): Excess air tends to lower the temperature of the products of combustion.
46. Ans. (d) Excess air up to a limit increases efficiency, but beyond that the efficiency decreases for the reason given in R

47. Which of the following combustion systems requires maximum excess air?
(a) Pulverized coal combustion (b) Oil burners **[IAS-2002]**
(c) Bas burners (d) Chain grate stoker
47. Ans. (d) pulverized coal combustion required less amount of excess air as it burns fine particles.

48. Assertion (A): The calorific value of a fuel depends on the excess air used for combustion. **[IAS-2002]**
Reason (R): The purpose of supplying excess air is to ensure complete combustion.
48. Ans. (d) A is false. Calorific value is the heat transferred when the product of complete combustion of a sample of fuel are cooled to the initial temperature of air and fuel. There is no relation with excess air.

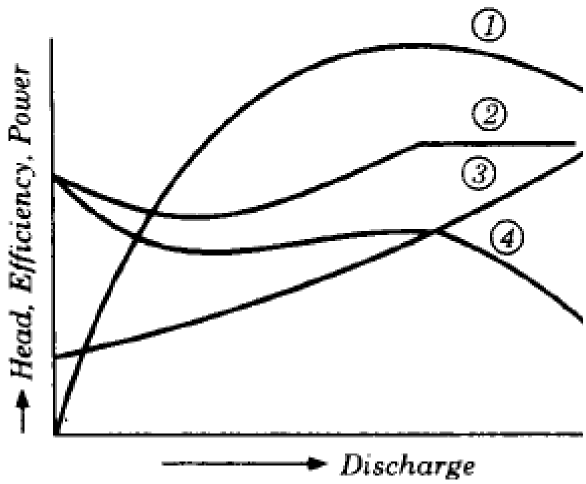
Fan

49. Consider the following statements: **[IES-2006]**
1. Forward swept blade impeller is used in draft fans.
2. Forward swept blade impeller is used in room air-conditioners.
3. Radial tipped blade impeller is used in draft fans.
4. Forward swept blade impeller is used in exhaust fans.

Which of the statements given above is/are correct?
(a) Only 1 (b) Only 2 and 3 (c) Only 4 (d) 1, 2, 3 and 4
49. Ans. (b)

50. Forced draught fans of a large steam generator have **[IES-1999]**
(a) backward curved blades (b) forward curved blades
(c) straight or radial blades (d) double curved blades
50. Ans. (a) Forced draught fans of a large steam generator have backward curved blades because these have steep head characteristics, good efficiency, high speed and ability to operate in parallel.

51. The characteristics of a centrifugal fan are shown in the given figure. The curves (in the figure) representing total head and static head characteristics are respectively
(a) 1 and 2
(b) 3 and 4
(c) 1 and 3
(d) 2 and 4



[IES-1998]

51. Ans. (b)

52. At constant efficiency, the horse power of a fan is **[IES-1998]**
(a) proportional to rpm (b) proportional to $(rpm)^2$

(c) proportional to $(rpm)^3$ (d) a polynomial function of rpm
52. Ans. (b)

53.Induced draught fans of a large steam generator have **[IES-1996]**
(a) backward curved blades. (b) forward curved blades
(c) straight or radial blades. (d) double curved blades.
53. Ans. (a) Induced draught fans of a large steam generator have backward curved blades

54. or 15 m^3/s air flow at 10 mm WG head, which one of the following would be the best choice ?
(a) Centrifugal fan with forward curved blades. **[IES-1994]**
(b) Axial fan with a large number of blades in rotor.
(c) Axial propeller fan with a few blades in rotor.
(d) Cross-flow fan.
54. Ans. (a)

55. Assertion (A): The driving motor of a fan with backward curved blades cannot be overloaded whatever the flow rate be. **[IES-1993]**
Reason (R): The power curve of fan with backward curved blades increases to a maximum at about 70% of the maximum flow rate and then falls.
55. Ans. (a)

56. Fans used for mechanical draft (induced) cooling towers are **[IES-1992]**
(a) axial flow type (b) radial flow type (c) centrifugal type (d) propeller type
56. Ans. (d)

57. According to fan laws, which of the following relation is valid? **[IES-1992]**
(Q – discharge, N - speed, D - diameter) Subscripts 1 and 2 for two sets of conditions)
(a) $\left(\frac{Q_1}{Q_2}\right)=\left(\frac{N_1}{N_2}\right)^2$ (b) $\left(\frac{Q_1}{Q_2}\right)=\left(\frac{N_1}{N_2}\right)^3$ (c) $\left(\frac{Q_1}{Q_2}\right)=\left(\frac{D_1}{D_2}\right)^2$ (d) $\left(\frac{Q_1}{Q_2}\right)=\left(\frac{D_1}{D_2}\right)^3$
57. Ans. (d)

58. Inside a large power boiler, the flue gas pressure will be above the atmospheric pressure
(a) at the furnace (b) near superheater region
(c) at the base of the chimney (d) after the forced draught fan **[IAS-2000]**
58. Ans. (d)

59. An induced draft fan is normally located at the **[IAS-1998]**
(a) outlet of the steam generator before the dust collector
(b) outlet of the steam generator after the dust collector
(c) inlet of the steam generator before the air heater
(d) inlet of he steam generator after the air heater
59. Ans. (b)

60. A power plant consumes coal at the rate of 80 kg/s while the combustion air required is 11kg/kg of coal. What will be the power of the F.D. fan supplying the air, if its efficiency is 80% and it develops a pressure of 1.2 m of water? (Assume density of air to be 1.2 kg/m^3) **[IAS-1997]**
(a) 10.97MW (b) 9.87MW (c) 9.21 MW (d) 8.78MW
60. Ans. (a)

$P_1 = 101.325\,kPa = 10.33\,m\, of\ H_2O$

$m_1 = 80 \times 11\,kg/s \therefore V_1 = \frac{80 \times 11}{1.2} m^3/s = 733.33\,m^3/s$

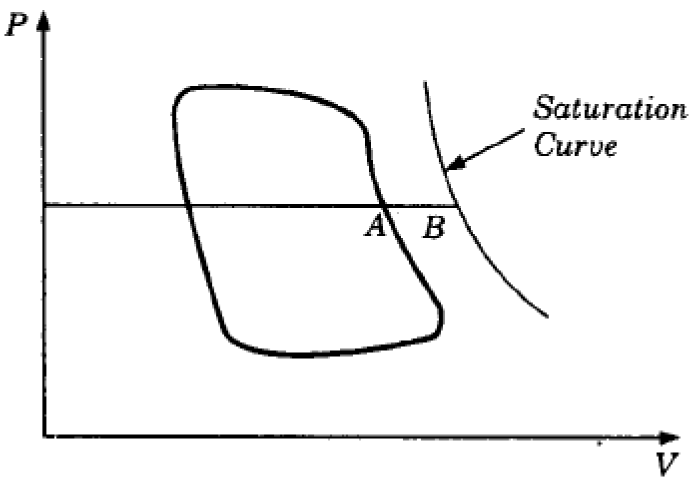
$$\therefore W_{ideal} = \frac{\gamma p_1 V_1}{\gamma - 1}\left[\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right] = 8.295\,MW$$

$$W_{ideal} = \frac{1.4 \times 101.325 \times \left(\frac{80 \times 11}{1.2}\right)}{(1.4-1)}\left[\left(\frac{11.53}{10.33}\right)^{\left(\frac{1.4-1}{1.4}\right)} - 1\right] = 8.299\,MW$$

$$\text{Therefore}, W_{actul} = \frac{W_{ideal}}{\eta} = \frac{8.295}{0.8} = 10.369\,MW$$

Steam Engine

61. The p-V diagram for the reciprocating steam engine is shown in the figure. The length A-B represents the
(a) condensation loss
(b) friction loss
(c) missing quantity
(d) dryness fraction



[IES-1999]

61. Ans. (c) The length AB in the figure represents the missing quantity.

62. Ratio of actual indicated work to hypothetical indicated work in a steam engine is the **[IES-1996]**
(a) indicated thermal efficiency (b) friction factor
(c) mechanical efficiency (d) diagram factor.
62. Ans. (d) Ratio of actual indicated work to hypothetical indicated work in a steam engine is the diagram factor.

63. Consider the following statements: **[IES-1996]**
Expansion joints in steam pipelines are installed to
1. allow for future expansion of plant 2. take stresses away from flanges and fittings.
3. permit expansion of pipes due to temperature rise.
Of these correct statements are
(a) 1, 2 and 3 (b) 1 and 2 (c) 2 and 3 (d) 1 and 3
63. Ans. (c) Expansion joints in steel pipe lines are installed to take stresses away from flanges and fittings and also to permit expansion of pipes due to temperature rise.

64. A double acting steam engine with a cylinder diameter of 19 cm and a stroke of 30 cm has a cut-off of 0.35. The expansion ratio for this engine is nearly **[IES-1993]**

(a) 1.05 (b) 2.85 (c) 6.65 (d) 10.05

64. Ans. (b) The expansion ratio = $\dfrac{1}{\text{cut off ratio}} = \dfrac{1}{0.35} = 2.85$

Miscellaneous

1. In an axial flow gas turbine, the hot gases approach the rotor inlet with an absolute velocity of 600 m/s in a direction 30°from the wheel tangent. The gases leave the rotor axially. If the blade speed is 300 m/s, then the theoretical power output per kg/s of gas flow will be approximately

(a) 132 kW (b) 156kW (c) 172 kW (d) 205 kW **[IAS-1998]**

1. Ans. (b)

$$\Delta V_w = V_1 \cos\alpha = 600 \times \cos 30 = 520\,\text{m/s}$$

$$\text{blade velocity}\left(V_b\right) = 300\,\text{m/s}$$

$$\therefore P = \Delta V_{w.} V_b = 156\ \text{kW}$$

2. Consider the following statements about modification in a gas turbine power plant working on a simple Brayton cycle: **[IES-2003]**

1. Incorporation of regeneration process increases specific work output as well as thermal efficiency.
2. Incorporation of regeneration process increases thermal efficiency but specific work output remains unchanged.
3. Incorporation of inter cooling process in a multi-stage compression increases specific work output but the heat input also increases.
4. Incorporation of intercooling process in a multi-stage compression system increases specific work output, the heat addition remains unchanged.

Which of the above statements are correct?

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

2. Ans. (d)

3. Consider the following features for a gas turbine plant: **[IES-2006]**

1. Intercooling 2. Regeneration 3. Reheat

Which of the above features in a simple gas turbine cycle increase the work ratio?

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

3. Ans. (a)

4. Consider the following statements with reference to Gas turbine cycle:

1. Regeneration increases thermal efficiency.
2. Reheating decreases thermal efficiency. **[IES-1995]**
3. Cycle efficiency increases when maximum temperature of the cycle is increased.

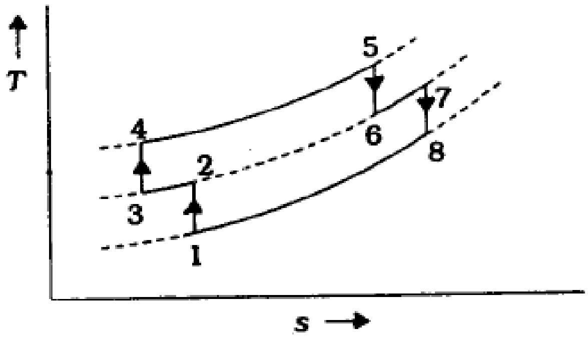
Of these correct statements are

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

(c) 1 and 2 (d) 1 and 3

4. Ans. (a)

5. The cycle shown in the given figure represents a Gas Turbine Cycle with intercooling and reheating Match List X (Units) with List Y (Processes) and select the correct answer using the codes given below the Lists:



[IAS-2001]

List X	List Y
A. Intercooler	I. 1-2
B. Combustor	II. 2-3
C. Reheater	III. 3-4
D. High pressure compressor	IV. 4-5
	V. 6-7

Codes:	A	B	C	D		A	B	C	D
(a)	I	II	IV	III	(b)	II	IV	V	III
(c)	III	IV	V	II	(d)	II	V	IV	I

5. Ans. (b)

GAS TURBINE

1. A **closed cycle** gas turbine works on **Joule cycle** or **Brayton cycle.**
2. The ideal air standard efficiency (with isentropic expansion and compression) of a **Joule cycle** is equal to $1-\left(\frac{1}{r_p}\right)^{\frac{r-1}{r}}$
3. The plant which is smaller in size and lower in weight for the same power, is **Gas turbine plant.**
4. **Bleeding** in turbines means **extracted steam for pre-heating feed water.**
5. The **thermal efficiency** of gas turbines as compared to I.C engine is **less.**
6. Mechanical efficiency of gas turbines as compared to I.C engine is higher.
7. Pressure ratio for maximum work output

$$r_p = \left(\frac{T_{\max}}{T_{\min}}\right)^{\frac{\gamma}{2(\gamma-1)}} \qquad r_p^{\frac{\gamma-1}{\gamma}} = \sqrt{\frac{T_{\max}}{T_{\min}}}$$

8. Pressure ratio for No work output

$$r_p = \left(\frac{T_{\max}}{T_{\max}}\right)^{\frac{\gamma}{2(\gamma-1)}} \quad \text{i.e. maximum efficiency}$$

9. Pressure ratio for maximum specific output

$$r_p = \left(\eta_e \eta_t \frac{T_{\max}}{T_{\min}}\right)^{\frac{\gamma}{2(\gamma-1)}}$$

where: η_c = compressure efficiency

η_t =Turbine efficiency

10. Pressure ratio for maximum cycle efficiency

$$r_p = \left[\frac{T_{\max}/T_{\min}}{1+\left(\sqrt{T_{\max}/T_{\min}}-1\right)}\right]^{\frac{\gamma}{\gamma-1}}$$

11. Work ratio= $\frac{\text{Net work output}}{\text{Turbine work}} = 1-\left(\frac{T_{\min}}{T_{\max}}\right)^{r_p^{\frac{\gamma-1}{\gamma}}} = \eta_{th}$ *of* regenartive cycle
12. With ideal regenerative heat exchanger, the thermal efficiency of gas turbine cycle is **equal to work ratio. If r_p increases in Regenerative cycle efficiency decreases.**
13. **High air-fuel ratio** in gas turbine **reduces exhaust temp.**
14. Thermal efficiency of closed cycle gas turbine plant increased by Regenerating
15. **In two stage** gas turbine plant reheating after first stage decrease thermal efficiency.

16. **In two stage** gas turbine plant reheating after first stage increase work ratio
17. In a gas turbine cycle **two stage of reheating**, working between maximum pressure $p_1$and minimum pressure P_4 the optimum reheat pressure would be $(P_1P_4)^{1/3}$ and $(P_1P_4)^{2/3}$
18. The work ratio of closed cycle gas turbine depends upon
    a) Pressure ratio b) temperature ratio c) specific heat ratio(γ)
19. The work of closed cycle gas turbine plant with fixed top temperature of the cycle and fixed pressure ratio increase with decrease in air inlet temperature to compressor.
20. With intercooling and reheating in a two stage gas turbine plant **work ratio improves and thermal efficiency decreases.**
21. **Pressure ratio** for a Gas Turbine may be in the range 3 to 5.The compression ratio in gas turbine is of the order of 8:1.
22. The function of a heat exchanger in a gas turbine plant is to heat the compressed air before it enters the combustion chamber.
23. **The maximum temp of a gas turbine is** 700°C
24. **The number of stage in gas turbine**= $\dfrac{\text{Total heat drop}}{\text{Heat drop in a stage}}$
25. **In a gas turbine cycle, the turbine output is 600 kJ/kg. The compressor work is 400 kJ/kg and the heat supplied is 1000 kJ/kg. The thermal efficiency is**
    $$\eta=\frac{W_T-W_c}{Q}=\frac{600-400}{1000}\times 100\%=20\%$$
26. **A gas turbine developed 120 kJ of work while compressor absorb 60 kJ of work and the heat supplied is 200 kJ. If a regenerator which would recover 40% of the heat in the exhaust were used, there the increase the overall thermal efficiency.**
    1st case: W_T=120kJ, W_c=60kJ $\therefore$ W= 60kJ $\therefore \eta=\frac{60}{200}$ heat rejected =200-60=140 kJ
    $$140\times\frac{40}{100}=56\,\text{kJ}$$
    2nd case: heat gain $\therefore$Hence heat added= 200-56=144 kJ
    $$\therefore \eta=\frac{60}{144}\times 100\%=41.67\% \therefore \text{increase} = 11.67\%$$
27. **The** weight of gas turbine per KN developed is about one-sixth as that of an I.C. engine.
28. **Regenenation**: ↑ efficiency(has no effect on sp. work output)
29. **Reheating**: ↑ sp.workoutput ; ↓ efficiency
30. **Intercooling**: ↑ sp.workoutput;↓ efficiency but not as marked as reheating.

NUCLEAR POWER PLANTS

1. The mass of electron as compared to that of neutron is $\frac{1}{1839}$

2. Isotopes of same elements have same chemical properties, same atomic number, same position in periodic table and different mass number.

3. The number of isotopes of hydrogen are three. ${}_1H^1, {}_1H^2, {}_1H^3$

4. Atomic number of an elements in the periodic table represents the numbers of protons in the nucleus.

5. The mass number of a substance represents the sum of total number of protons and neutrons in a nucleus.

6. One atomic mass unit (a.m.u) $= \frac{1}{12} \times \textit{mass}$ of one $\overset{12}{\mathrm{C}}\,\textit{atom}$

$$= 1.6603 \times 10^{-24}\ g$$

It is used to measure of mass of particles.

7. Energies involved in nuclear reactions are expressed in terms of electron volts. in form MeV

1. electon-Volt=1.6×10^{-19}J i.e. watt-sec

$=1.6\times10^{-12}$erg.

1.MeV=10^6ev

9. Radioactivity is the process of disintegration of an unstable nucleus. α=particle, β-particles, γ-radiation, and neutrons are emitted during the process of radioactive decay. These four radiations (known as ionising radiation) are capable of ionising the atoms of matter through which they pass. The quantity of radioactive material in any sample is measured in

i) Curie=3.7×10^{10} nuclear disintegrations per second (dps)

ii) Rutherfod=10^6 nuclear disintegrations per second (dps)

iii)Becaral =1(dps)

10. Einstein's Theory of Relativity shows that mass is convertible into energy and this energy is given by the formula

$\Delta E = \Delta \mathrm{m.c}^2$

Where ΔE = Energy in Joules

Δ m = mass in kg

C=Velocity of light in m/s(2.997925×10^8)

say 3×10^8m/sec

$\Delta E = 931 \times \Delta \mathrm{m}$ Mev

where Δm = mass in a.m.u.

as 1 a.m.u $\approx$ 931 Mev

11. Nuclear Fission: (ESE-96)

When an unstable heavy nucleus is bombarded with high energy neutrons, splits into two fragments of approximately equal mass. This process is known as 'Nuclear Fission'

To sustain the fission process, the following requirements must be fulfilled

(i) The bombarded neutrons must have sufficient energy to cause fission of another nucleus to overcome the binding energy.

(ii) The number of neutrons produced must be able to increase the rate of fission as certain loss of neutrons by absorption and leakage is unavoidable.

(iv) The fission process must be controlled.

(v) A nuclear fission is initiated when the critical energy as compared to neutron binding energy of the atom is more.

(vi) A nuclear fission produced energy of 200 Mev.

12. In triggering fission type of neutrons are more effective slow neutron.

13. In nuclear fission the original elements change into completely different elements.

14. In a fission process, maximum % age of energy is released as kinetic energy of fission products.

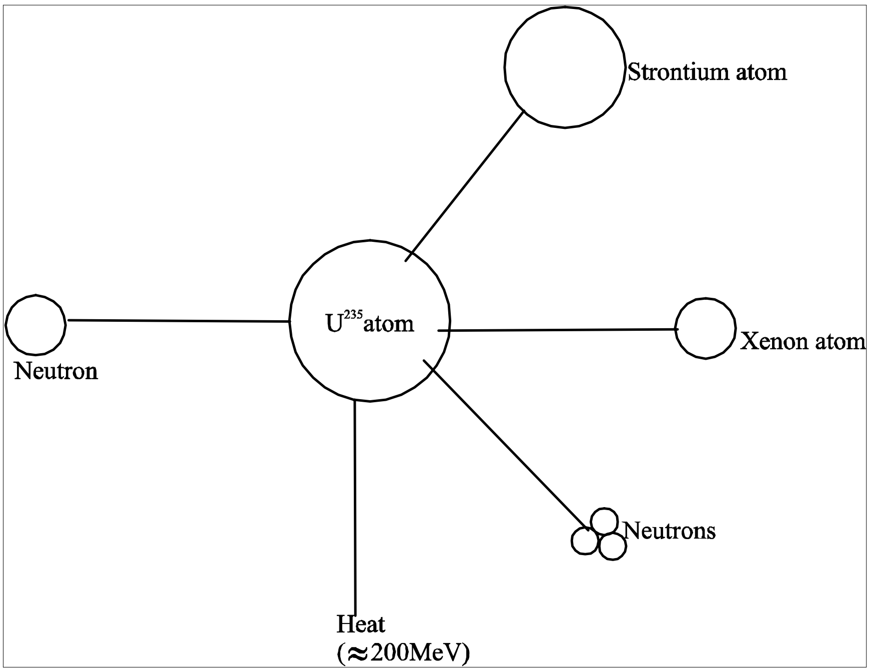
15. Each fission of U^{235} Produces $2\frac{1}{2}$ neutrons of fast neutrons per fission.

The energy is distributed in the fission process as follows

	Mev	
Kinetic energy of fission fragments	165	(84%)
Kinetic energy of fission neutrons	5	(2.5%)
Beta particles from fission products	7	(3.5%)
Instantaneous gamma rays	7	(3.5%)
Neutron capture γ's	7	(3.5%)
Gamma rays from fission product	6	(3%)

The energy of a chemical reaction, approximately 3 to 4 eV; is many times lower than that of a nuclear reaction. The fission of U^{235} yields 2.5 million times as much energy as the combustion of the same weight of carbon.

U^{235} nucleus hit by a neutron, fissions or splits into two smaller nuclei.



These smaller nuclei are generally termed fission products since they are the direct result of fission of the nucleus. In addition, energy, two or three neutrons and gamma radiations are released when the nucleus is plit.

The most significant fact arising from the fission of the U^{235} apart from the release of energy, is that one neutron hitting the nucleus not only release energy but also provided a source of two or three neutrons which in favorable circumstances, could cause fission reactions with other U^{235} nuclei.

In such a continuous reaction could be controlled, it would result in a continuous release of energy at a steady rate, the rate depending on the number of fissions occurring in particular time. A reaction of this kind is known as a 'chain Reaction'

The assembly of fuel and other materials in which the self-sustaining chain reaction is maintained is called a reactor. This may be captured by another nucleus causing further fission as described above or it may be captured without causing fission in the various other materials contained in the assembly or it may escape out of the matrix. In a self-sustaining chain reaction, a proper balance between the neutron produced in the fission and the neutrons lost, is maintained in such a way that the reaction does not die out. The various ways by which the balance is adjusted are given below.

1. The number of neutrons produced in a reactor is proportional to the number of fuel nuclei and the reactor volume, but the number of neutrons escaping from the reactor is proportional the surface area. The ratio of surface volume of a given solid shape decreases as the solid grows larger is size. Hence the number of neutrons escaping in relation to those produced can be diminished by increasing the size of the reactor. In fact for any given material and shape of a reactor, there is a minimum of critical size below which the proportion of escaping neutrons is excessive and the reactor will not be able sustain the chain reaction.

2. If the energy level of the neutrons produced by fission is reduced, they are likely to be captured by the fissionable material. The energy level of the neutrons can be reduced by slowing down or moderating from their velocity at fission to the velocity of atoms at the reactor temperature (called the thermal velocity.) This slowing down of the neutrons in a reactor is done by the use of 'moderators'.

3. The required balance can be achieved by decreasing the number of neutrons parasitically in structural and other non-fuel materials. This is accomplished by using materials which have a small tendency to absorb neutrons.

When the self-sustaining chain reaction is established the reactor becomes a source of energy. Since the fission process is to all intents and purposes independent of reactor temperature. It is possible to achieve any desired temp. level in reactor.

One of the major uses of nuclear energy for useful purposes is in the generation of power. Enormous amount of power can be released from very small amount of fuel as compared to other conventional types of power stations.

Obviously, 'fuel' is one of the major problems encountered in nuclear power stations. Besides this, the rate of energy released must be under control so that the flow of energy released can be regulated as desired. For this purpose, nuclear reactors are used, the main purpose of which is to 'burn' the 'fuel' at a controlled rate. Energy so released in a reactor is utilized in heating a primary working fluid which may be liquid or a gas. The heat of primary working fluid is transferred to a 'secondary' working fluid which undergoes usual thermodynamic cycle as used in conventional type of thermal stations. Thus, primary working fluid acts as a source of heat for secondary working fluid. The secondary working fluid may be water or any other fluid suitable from the thermodynamic point of view.

The energy changes in a nuclear reactor are extremely large as compared with those of chemical reactions. The release of nuclear energy at a controlled rate depends at present on the large energy release involved in one type of nuclear reaction, the fission or splitting of heavy nuclei such as Uranium. The fissioning of one kilogram of Uranium produces the heat of equivalent of the combustion of 4500 tons of coal.

ADVANTAGES OF NUCLEAR POWER PLANTS:

Some of the major advantages of the nuclear power plant are:

1. As the amount of fuel consumed is very small as compared to the conventional types of power plants, so there is saving in the cost of the fuel transportation.
2. Nuclear power plants require less space compared to any other plant of the equivalent size.
3. Bigger capacity of a nuclear plant is an additional advantage
4. Besides producing large amounts of power, the nuclear power plants produce valuable fissile material, which is produced when the fuel is renewed.

DIS-ADVANTAGES AND LIMITATIONS OF THE NUCLEAR POWER PALNATS ARE

1. In spite of utmost precautions and care, the danger of radioactivity always persists in the nuclear stations.
2. Working conditions in a nuclear power station are detrimental to the health of the workers.
3. Present practice is to give compulsory leave, at least for six months in a year to the employees of the station in order to relieve them of radioactivity effects. This causes the wage bill to go high as extra labour is always to be employed.

4. The disposal of the products of fission is a big problem as the same has to be either disposed of in a deep trench or in sea away the seashore.

5. Capital cost of nuclear station is always high.

6. Nuclear power plants cannot be operated at varying loads efficiency. The reactor does not respond to the load fluctuations immediately.

7. This field of engineering is still in the stage of development and most of the details are kept as secret by the bonafide manufacturers. For spare parts and particularly, during the days of war or sometimes the due to political reasons, this dependence may prove to be very costly affair.
8. The cost of maintenance of the plant is always high to lack of standardisation and high salaries of the trained personnel in this fields of specialisation.

Classification of nuclear reactors:

1. On the basis of neutron energy:

A. Fast rector

Fast reactors are those in which fission occurs with high energy neutrons, in the absence of moderation high energy neutrons are those travel with high velocity in this case.

B. Intermediate reactor

C. Thermal reactor

If the energy of neutrons is reduced to low electron voltage range-that is the thermal range-the reactor are known as thermal reactor.

Most of the modern reactors are of thermal type

2. On the basis of fuel reproduction Characteristics:

A Non-regenerative

A reactor may be non-regenerative type, if it does not create an appreciable amount of replacement fuel as the fuel is burned. Reactors using highly enriched fuel containing 90% or more of U^{235} in the fuel are of non-regenerator type.

B. Regenerative

Regenerative reactors are those in which the fuel is highly enriched. This type of reactor does not replace the used fuel fully.

C. Breeder

In this type of reactor, the fissionable type of fuel produced to more than the fuel consumed.

3. On the basis of fuel moderator arrangements:

A. Homogenous

In this case, the finely divided fuel is mixed with moderator so as to form a homogeneous mixture.

B. Heterogeneous

In this case, the fuel is in the form of rods or plates (or any other shape) in the matrix of moderator.

4. **On the basis of type of moderator used:**
   A. Graphite
   B. Light water
   C. Heavy water
   D. Beryllium
   E. Organic liquid
5. **On the basis of type of coolant used:**
   A. Light water
   B. Heavy water
   C. Liquid metal
   D. Organic metal
   E. Gas

6. **On the basis of type of fuel used**
   A. ${}_{94}Pu^{239}$ and ${}_{92}U^{233}$
   B ${}_{92}U^{238}$ and ${}_{90}Th^{232}$
   C. ${}_{92}U^{235}$ and ${}_{92}U^{238}$
7. **On the basis of type of fuel enrichment.**
   A. Natural fuel.
   B. Enriched fuel
8. **On the basis of their function, the reactors may be classified.**
   1. Research Reactors:
      A. Isotope production
      B. Material production
      C. As neutron Sources
   2. Plutonium production
   3. Power Reactors
      A. <u>Stationary power plants</u>
         Central station
         Package reactors
      B. <u>Mobile reactors</u>
         Naval reactors
         Aircraft reactors
         Merchant Ship reactors

1. The efficiency of a nuclear power plant in comparsion to a conventional thermal power plant is less. The average thermal efficiency of a modern nuclear power plant is about 30%
2. India's first nuclear power plant was started at tarapur (Mumbai) and has boiling water reactor.

Evolution of Nuclear Power Systems

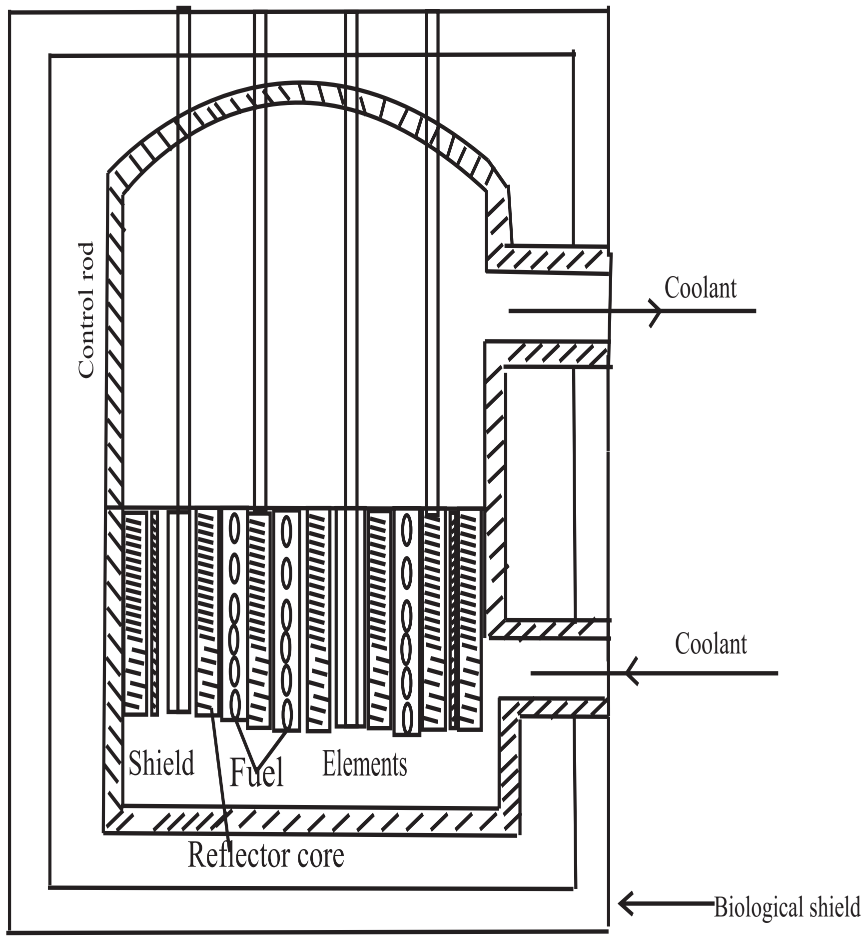
Generation I	Generation II	Generation III	Generation IV

Early Prototype Reactors •Shippingport •Dresden, Fermi-I •Magnox	Commercial Power Reactors •LWR: PWR/BWR •CANDU •VVER/RBMK	**(1995-now)** Advanced LWRs •System 80+ •EPR •AP600 •ABWR	**(2020-2050)** □ Highly economical □ Enhanced Safety □ Minimized Wastes □ Proliferation Resistance

Nuclear power Reactor:(CSE-96) markes-20 (ESE-96)

The nuclear reactor may be assumed as an equivalent of the boiler fire box in a steam plant or a combustion chamber of a gas turbine plant. The steam or gas may be utilized as working fluid in a nuclear power plant.

The general arrangement of a nuclear power plant with essential components using steams as working plant is shown in fig below.



ESE-.02

1. **Fuel** –The nuclear fuels which are generally used are ${}_{92}U^{235}$, ${}_{92}U^{233}$. The first one is available in nature with 0.7% in the Uranium and the remaining is ${}_{92}U^{238}$. The other two fuels are formed in the nuclear reactors during fission processes.

2. The fuel is shaped and located in the reactor in such a manner that the heat produced within the reactor is uniform.

   In homogeneous reactors; the fuel (say, uranium) and moderating material (say, carbon) are mixed and used in the form of rods and plates in the reactor core. In homogenous reactors, the fuel is used in the form of rods or plates and moderator surrounds the fuel elements. This arrangement is commonly used in most of the reactors.

2. **Moderator:** The moderator is a material which reduces the kinetic energy of a fast neutron (1Mev) or 13200 km/s) to a slow neutron (0.25 eV or 2200 m/s). The slowing down of neutrons is done by light elements as H_2, D_2, N_2, C and Be.

3. **Reflector;** It is necessary to conserve the neutrons as much as possible in order to reduce the consumption of fissile material and to keep the reactor size small. The neutrons which are released in fission process may be absorbed by the fuel itself. Moderator, Coolant or Structural materials. To reduce the loss of escape, the inner surface of the reactor is surrounded by a material which reflects the escaping neutrons back into the core. This material is known as the reflector.

   The material used as a moderator is also used as reflector because the moderating materials have good reflecting properties. D_2O and C are typical reflectors.

   It is necessary to provide some method of cooling the reflector as it becomes hot due to collision of neutrons with its atoms.

4. **Coolant:** The coolant transfers the heat produced inside the reactor to the heat exchanger for further utilization in power generation.

   Water, heavy water (D_2O), He, Co_2, Na etc. are used as coolants.

   A good coolant must not absorb the neutrons. It must have high chemical and radiation stability. It must be non-corrosive and non-toxic.
5. **Control rods:** Control is necessary to ensure the following functions:

   A) To start the nuclear chain reaction when the reactor is started from cold.

   B) To maintain the chain reaction at a steady state.

   C) To shut down the reactor automatically….an emergency (e.g.) coolant circulating pump fails.

   To control of chain reaction is possible either by removing the fuel rods or the neutrons continuing the chain reaction from the reactor core. It is easier to get rid of the neutrons. It is generally done by insisting the control rods into the fuel tubes.

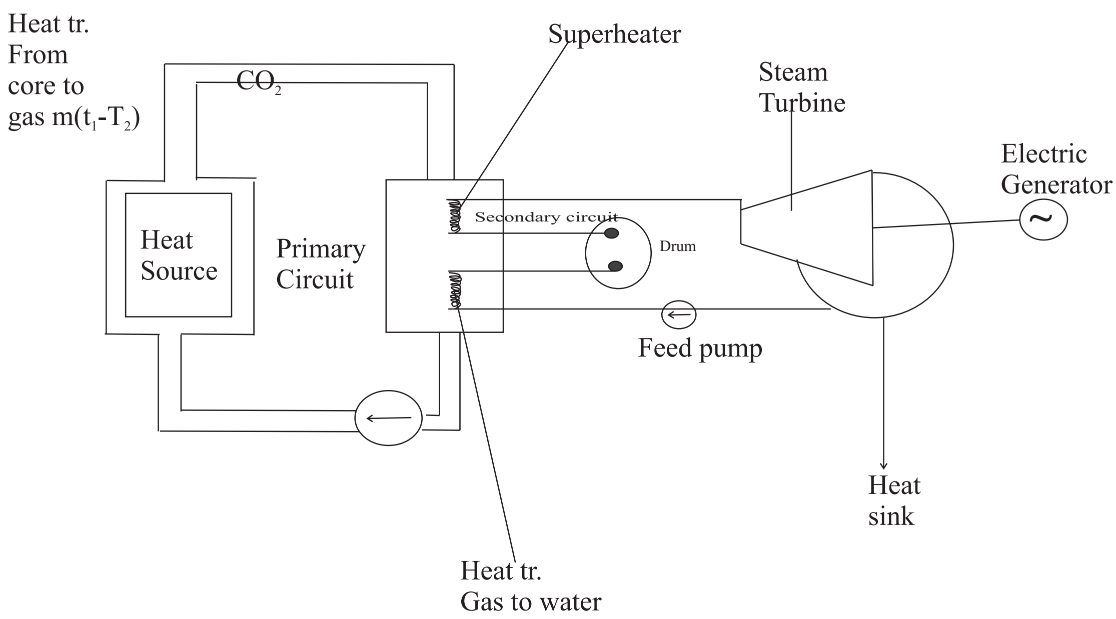
The materials used for control rods must have high absorption capacity of neutrons. The common materials used for control rods are cadmium, Boron or hafnium.

6. **Shielding:** The reactor is a source of intense radioactivity which is quite harmful to human life. The common radiations from the reactor are α-rays, β-rays, γ-rays and fast neutrons. Shielding (concrete and steel) absorbs them before the harmful radiations are emitted to the atmosphere.

   The inner lining of the core is made of 50cm thich steel plate and further thickened by a few metres of concrete. The steel plate lining absorbs the radiations and becomes heated but prevents the adjacent wall of the reactor vessel from becoming hot. The steel plate (thermal shield) is cooled by circulation of water.
7. **Reactor vessel:** The reactor vessel encloses the reactor core, reflector and shield. It provides entry and exit passages for the coolant. The reactor vessel has to withstand high pressures of the order of 200 kgf/cm^2. Holes at the top of the vessel are provided to insert the control rods. The reactor core-fuel and moderator assembly is placed at the bottom of the reactor vessel.

1. The commonly used material for shielding is lead or concrete.
2. The main interest of shielding in nuclear reactor is protection against neutrons and gamma rays.
3. Thermal shielding is provided to absorb the fast neutrons and protect the operating personnel from exposure to radiation.
4. In a nuclear reactor the function of a reflector is to reflects the escaping neutrons back into the core.
   Reflector of a nuclear reactor are made up of beryllium.
5. The function of control rods in nuclear plants is to control absorption of neutron. It is made of boron or cadmium. The presence of reflector in nuclear power plants results in decreased leakage of neutrons.
6. Moderator in nuclear power plants is used to cause collision with the fast moving neutrons to reduce their speed. The most commonly used moderator is graphite. Effective materials of moderator is that material which contain light weight atoms. In boiling water reactor. Moderator is collant itself.

7. **Critical**
   A nuclear unit becoming critical means chain reaction that causes automatic splitting of the fuel nuclei has been established. The size of the reactor is said to be critical when chain reaction can be initiated. When a reactor becomes critical, then the production of neutrons is exactly balanced by the loss of neutrons through leakage. If k is ratio of the rate of production of neutrons to the rate of loss of neutrons the reactor is called a critical reactor, when k=1. (ESE-03) Critical mass of fuel is the amount required to make the multiplication factor equal to unity. When a nuclear reactor is operating at constant power the multiplication factor is equal to unity.



A typical gas cooled reactor (magnox or AGR)
For a natural uranium metal fuel, the power output=5.9×10^{-12} W/Cm^3 unit flux
In order to get reasonable power rating, or power per unit mass of fuel, the flux must be of the order of 10^{13} neutron/cm^2/sec. In actual practice flux distribution radially and axially is of sine wave form, being minimum at boundaries and maximum at the centre due to leakage of neutrons at the core boundaries. The flux distribution in the reactor can be flattened by several methods.

Much of the engineering of nuclear reactors is concerned with the process of extracting heat from the reactor core and striking a balance between many conflicting factors in order to reach the most economical selection.

Thermal reactors owe their name to the fact that they make use of slow neutrons having energies of the order of 0.1 eV (corresponding to the temp. of the moderator) as the main source of fission.

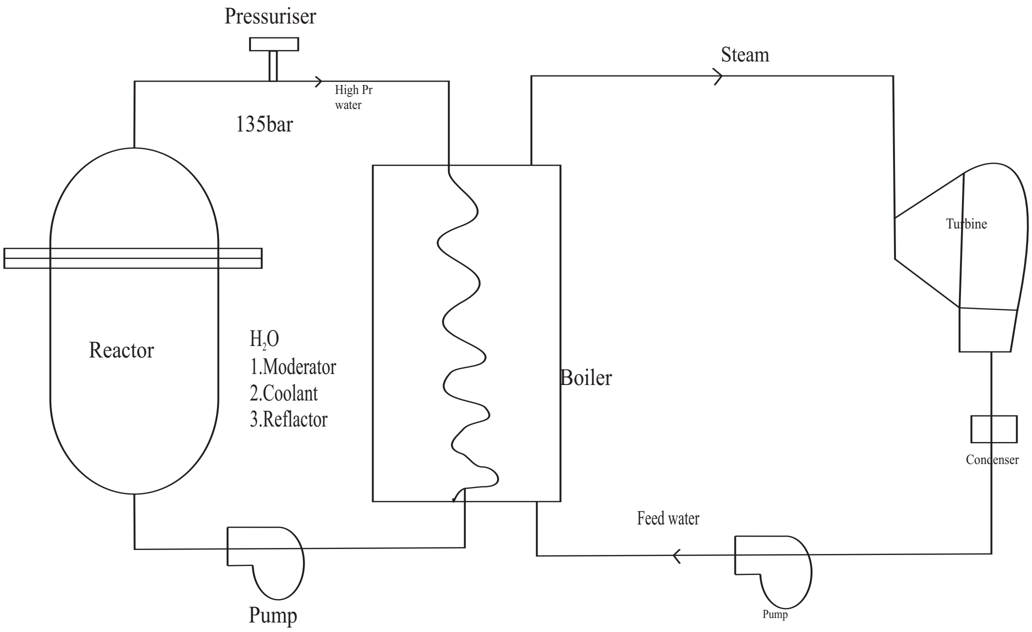
Such reactors can be classified according to the type of fuel, the moderator and the coolant. The most practical fuel the moderator and the coolant. The most practical fuel for a thermo-nuclear reactor, both from economical and nuclear consideration is deuterium.

Reactors Types:

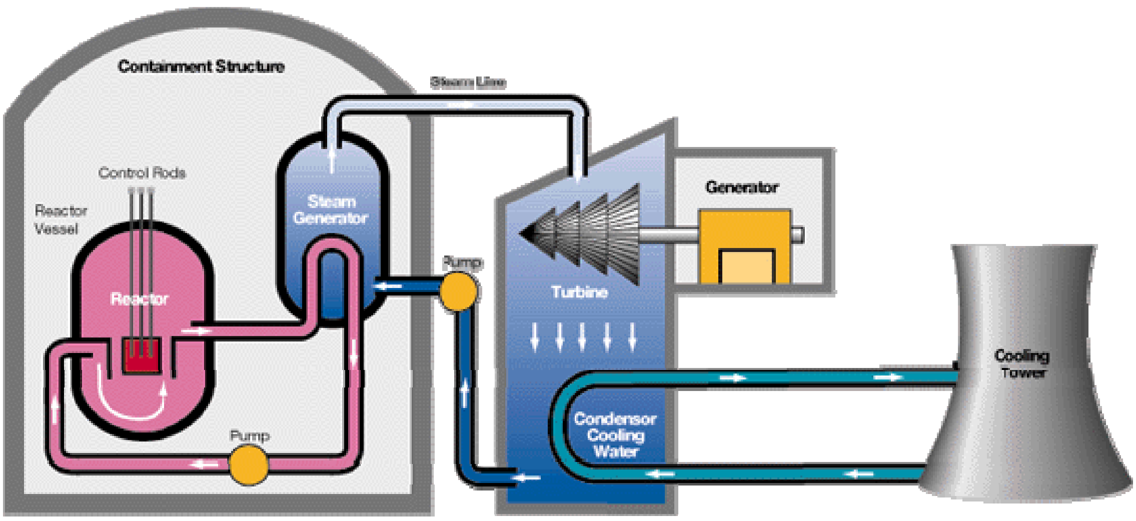
1. Pressurized water Rector:(PWR) (ESE-98)

In a pressurized water reactor system, heat generated, in the nuclear core is removed by water (reactor coolant) circulating at high pressure through the primary circuit. The water in the primary circuit cools and moderates the reactor. The heat is transferred from the primary to the secondary system in a heat exchanger, or boiler, thereby generating steam. Generally, a tube and shell type heat exchanger is at lower pressure and temperature than the primary coolant. Therefore the secondary portion of the cycle is similar to that of the moderate pressure thermal plant. Principal parts of the reactor are:

A. Pressure Vessel: The pressure vessel is cylindrical in shape provided with hemispherical domes on the two sides.



Pressurised water reactor



The hemispherical dome is secured to the vessel by means of studs; These studs are typical in construction as they incorporate a heater so that they can be heated and expanded before installations which results in their being highly stressed when cooled. This is necessary for safe operation of the vessel at elevated working temperatures. Pressure vessel is usually operated at high pressure of the order of 135 bar.

B. **Reactor Thermal shield:** when the reactor is in operation, a large neutron and gamma flux leaks from the core. In order to minimise the absorption of gamma rays and neutrons in the pressure vessel's wall, a thermal shield is interposed between the reactor core the pressure vessel wall.

C. **Fuel Elements:** Fuel elements are incorporated in speed assemblies and blanket assemblies. Speed assemblies consists of a number of plates welded together to form a square cross-sectional arrangement with passages left between them for water to pass through.

D. **Control rods:** The control rods in this type of reactor are made of hafnium in a cruciform shape. The control rods are driven by canned rotor type electric motor through the seed elements where power density is highest.

E. **Reactor containment**: Usually there are a number of reactor coolant loops. Some loops are meant for regular service with the choice of the number of loops in operation depending on the load on the plant. Some standby loops are also provided for emergency.

F. **Reactor Pressuriser**: The function of pressuiser is to maintain high pressure of the order of 135 bar in the loop. A pressuriser usually remains half-filled with water and partly with steam. It acts as a surge tank of accumulated for the system. If a reactor transient occurs and the pressure in the reactor system goes up, coolant is forced through the line to the pressuiser and condenses there. If the pressure in the primary system drops some of the steam in the pressuriser flashes forcing the coolant from the pressuriser into the primary coolant loop.

The component of the secondary system of the pressurised water plant are similar to those in a normal steam station.

Advantages of pressurized water reactor:

1. The reactor makes use of single fluid coolant moderator and reflector.
2. Water used in reactor is cheap and available in plenty.
3. The reactor is compact and the size is also minimum.
4. Power density is high in such reactors.
5. Fission products remain contained in the reactor and are not circulated.
6. Being compact, it is suitable for propulsion unit.

Disadvantage of pressurized water reactor:

1. High primary loop pressure require strong pressure vessel.
2. Low pressure and temperature in secondary loop result in poor thermodynamic efficiency.
3. Use of water under pressure at high temperature creates the problem of corrosion which calls for use of the stainless steel.

4 Fuel element fabrication is expensive

5 Fuel suffers radiation damage and its reprocessing is difficult.

6. Reactor must be shut down for recharging

7. Low volume ratio of moderator to fuel makes fuel elements design and insertion of control rods difficult.

1) A pressurised water reactor employs pressurize to maintain constant pressure in primary circuit under varying load.

2) Pressurized water reactor is designed to prevent the water coolant from boiling in the core.

2. **Boiling Water Reactor :(BWR)**

Apart from its heat source, the boiling water reactor generation cycle is substantially similar to that found in thermal power plants. The boiling water reactor is a water cooled reactor which uses light water as the cooling fluid. **A boiling water reactor system using light water both as a coolant and as a moderator.**

The Fuel used is enriched uranium oxide (oxide of uranium with additional U^{235} content to that contained in natural Uranium) canned in zirconium alloy. A reactor Operating at 80 bar can produce steam at 60 to 65 bar pressure so that a conventional thermal plant cycle could be used on secondary side.
The steam from such reactors is of course radioactive. This radioactivity of the steam system is short-lived and exists only during power generation. Extensive generating experience has fully demonstrated that shut down maintenance on BWR turbine. Condensate and feed water components can be performed essentially as a thermal plant.
The reactor core, the source of nuclear heat, consists of fuel assemblies and control rods contained within the reactor vessel and cooled by the circulating water system. The power level is maintained or adjusted by positioning control rods up and down within the core. The BWR core power level is further adjustable by changing the circulating flow rate without changing control rod position, a feature that contributes to the superior load following capability of the BWR.
The BWR operates at constant pressure and maintains constant steam pressure as in thermal plants. The integration of the turbine pressure regulator and control system with reactor water circulation flow control system permits automated changes in steam flow to accommodate varying load demands on the turbine. Power changes of up to 25 percent can be accomplished automatically by circulation flow control alone at rates 15 percent per minute increasing and 60 percent per minute decreasing. This provides a load following capability that can track rapid changes in power demand. Following auxiliary system are used for normal plant operation.

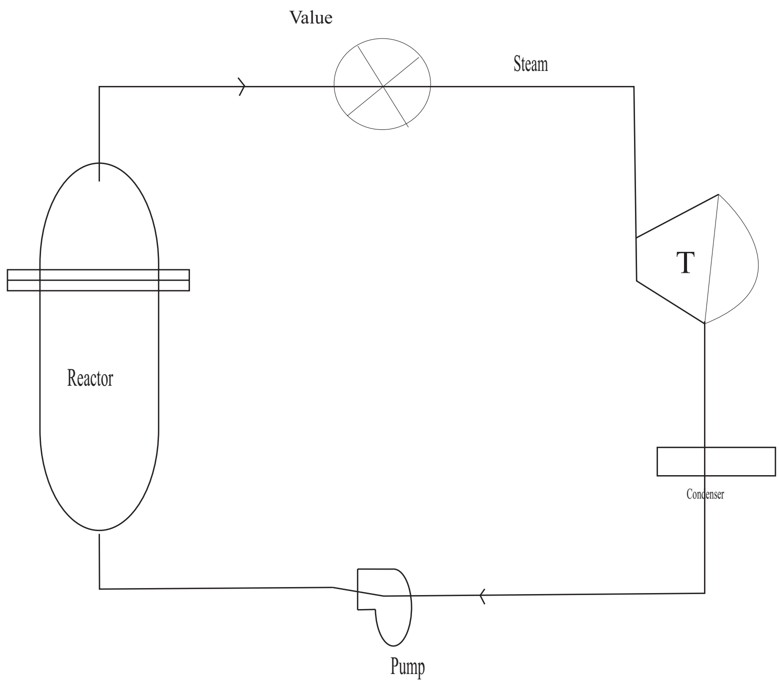


Fig: Boiling water reactor:

1. Reactor water clean up system.
2. Shut down cooling function of residual heat removal system.
3. Fuel and containment pools cooling and filtering system.
4. Closed cooling water system for reactor service.
5. Radioactive waste treatment system.

The following auxiliary systems are used as back up (stand by) or emergency system.

1. Stand by liquid control system.
2. Reactor core isolation cooling system.
3. Residual heat removal system with
   a) Containment cooling function and
   b) Low pressure cooling injection function
4. High pressure core spray system.
5. Automatic depressurization function.

Advantages of BWR:

1. There is only single working loop as light water is used both as a coolant and as a moderator.
2. As the pressure inside the press are vessel is not high, the pressure vessel size (thickness, etc.) is less.
3. The metal temperature remains low for given out put conditions.
4. The reactor is capable of promptly meeting the fluctuating load requirements.
5. Enrichment of fuel allows materials with moderate absorption cross- section. Such as stainless steel to be used for structural purposes.

Disadvantages of BWR:

1. Activation of water (used as coolant and moderator) and hence steam, involves the risk of radioactive contamination of the steam turbine used.
2. More biological protection is required.
3. Boiling limits power density only 3to 5 percent by mass can be converted to steam per pass through boiler.
4. Part of steam is wasted at low loads.
5. Enrichment of fuel for the reactor is an extremely costly process.

1. BWR employs direct cycle of coolant system.
2. BWR does not need a heat exchanger for generation of steam.
3. BWR uses the ordinary water as moderator, coolant and working fluid.
4. The risk of radioactive hazard is greatest in the turbine with BWR

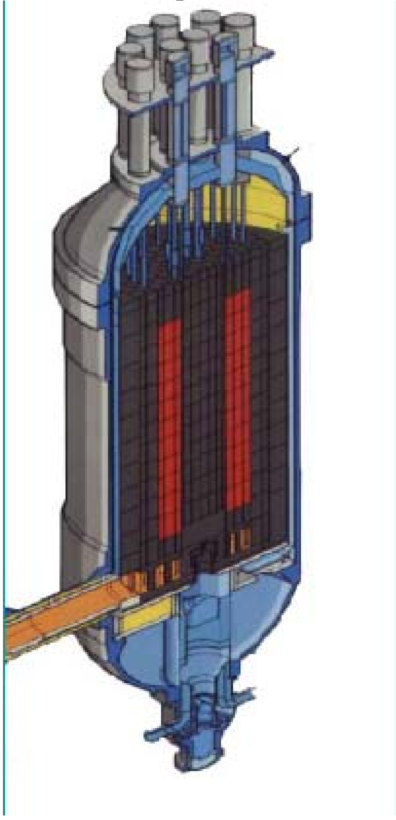
5. A B.W.R uses enriched uranium as fuel.
6. Most serious drawback in using water as coolant in nuclear plants is its high vapour pressure.

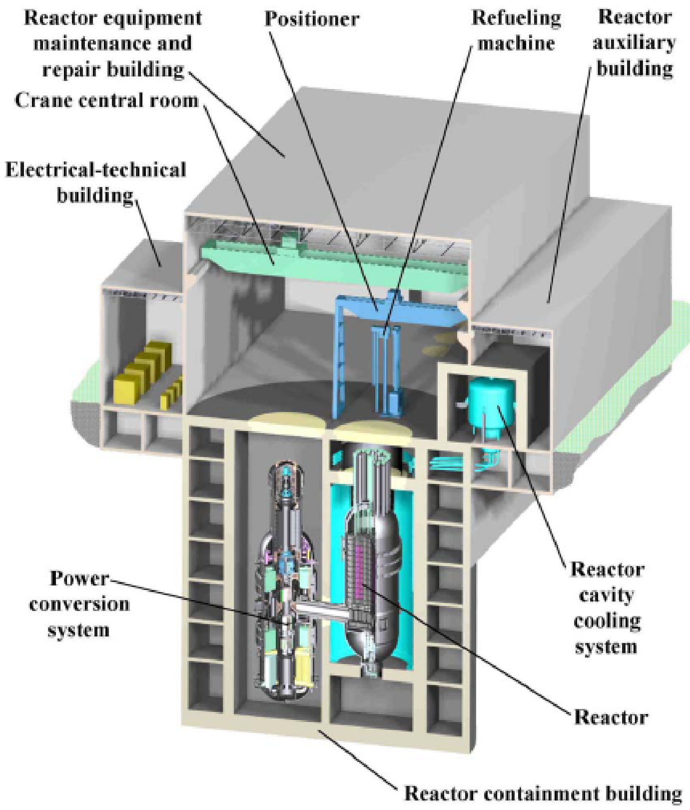
3. Fast Breeder Reactor: It uses high-energy neutrons. In it the average neutron yield of a fission is greater than in thermal reactors and accordingly all absorption cross-sections are much reduced. Plutonium is the fissile material for fast reactors. Liquid metal coolants are used.

1. Breeder reactor has a conversion ratio of more than unity.
2. Fast breeder reactor uses double circuit system of coolant cycle.
3. In fast breeder reactors moderator is dispensed with.
4. The breeding gain in case of thermal breeder reactor as compared fast breeder reactor is lower.
5. The fast breeder reactor uses the following moderator $\rightarrow$ no moderator is used. (IAS-2002)
6. Fast breeder reactors operate at extremely high power densities. It are liquid-metal coolded. It produces more fuel than they consume. They are unmoderated.
7. Breeder reactors employ liquid-metal coolant because it transfers heat from core at a fast rate.
8. In the breeder reactors the generation of new fissionable atom is at a higher rate than the consumption.
9. The energy produced by a thermal reactor of same size as a breeder reactor is much less.
10. A fast breeder reactor uses following as fuel U^{235}
11. A fast breeder reactor has no moderator.
12. A fast breeder reactor uses 90% U^{235}
13. Fast breeder reactors are best suited for India because of large thorium deposits.

4. <u>Advanced a Gas Cooled Reactors (AGR):</u> It uses uranium oxide fuel clad in stainless steel, thus permitting higher coolant temperature and pressure. The core temperatures are much higher and thus CO_2 is also passed through the core and in the spaces between graphite bricks (moderator)

1. Gas cooled reactor uses graphite, CO_2 as moderator and coolant materials.
2. Hydrogen is preferred as better coolant in comparison to CO_2 because former has high specific heat.
3. Superheated steam is generated in gas cooled reactor.



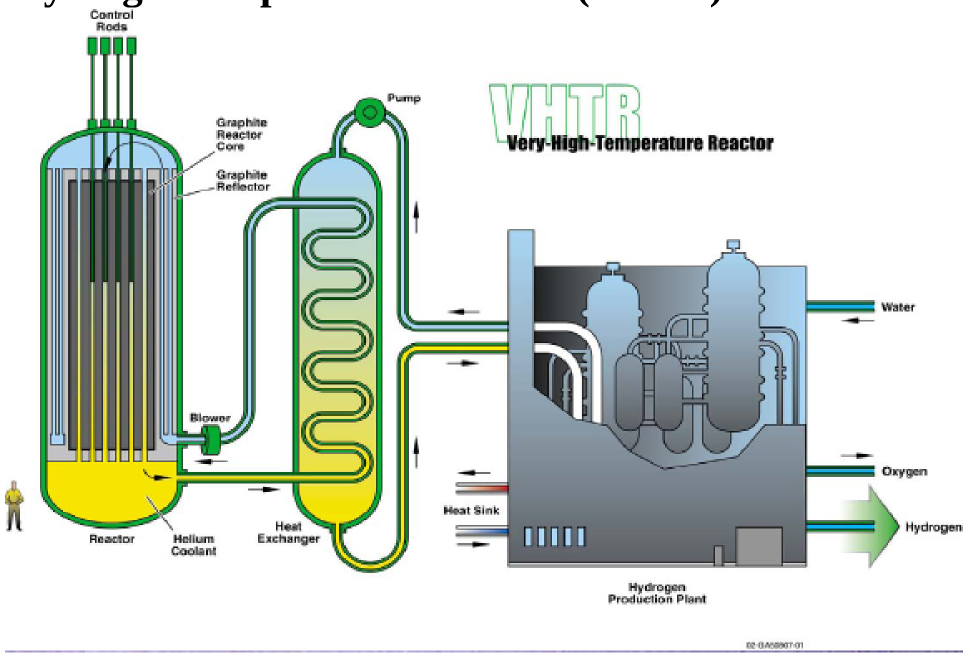


5. **<u>CANDU (CANadian Deuterium Uranium)</u>** : It uses heavy water as moderator and coolant, and UO_2 as fuel.

6 (SGHW) Steam Generating Heavy water Reactor: It is an attempt to combine as many as possible of the virtues of CANDU and BWR. It is a heavy water moderated pressure tube reactor using ordinary water as coolant in the boiling regime. The steam is used in a direct cycle.

7. Magnox: It uses graphite as moderator, metallic uranium, fuel clad in magnesium alloy cans and Co_2 as coolant. Reactor pressure vessel is surrounded by a thick concrete biological shield, which attenuates the gamma and neutron radiation from the core.

8. Very-High-Temperature Reactor (VHTR)



Characteristics

- **Helium coolant**
- **1000°C outlet temp.**
- **600 MWth**
- **Water-cracking cycle**

Key Benefit

- **High thermal efficiency**
- **Hydrogen production by water-cracking**

NUCLEAR FUEL:

Fuel for a nuclear reactor should be a fissionable material and can be an element or isotope whose nuclei can be caused to undergo nuclear fission by nuclear bombardment and to produce fission chain reaction.

If can be $_{92}U^{235}$, $_{94}Pu^{239}$ and $_{92}U^{233}$ Among these there $_{92}U^{235}$ is naturally available upto 0.7% in the uranium ore. The other two fuels $_{94}Pu^{239}$ and $_{92}U^{233}$ are formed in the nuclear reactors during fission process from $_{92}U^{238}$ and $_{90}Th^{232}$ due to the absorption of neutron without fission. $_{92}U^{235}$ is called the primary fuel. Following qualities are essential for nuclear fuel.

i. It should be able to operate at high temp.
ii. It should be resistant to radiation damage and
iii. It should not be expensive to fabricate.

Fuel will be protected from corrosion and erosion of coolant by using metal cladding. This is generally made up of aluminum or stainless steel.

The fuel is shaped and located in the reactor in such a manner that the heat production within the reactor is uniform.

In homogenous reactors fuel and moderators are mixed to form a uniform mixture and will be used in the form of rods or plates.
The spent up fuel elements are intensively radioactive and emits neutrons and gamma rays and should be handled carefully and special attention should be paid to reprocess the spent up fuel element.

Uranium Oxide UO_2 is another important fuel element.

It has many advantages over the natural uranium. It is listed below.

i. More stable
ii. Less corroding effects
iii. More compatible with most of the coolants.
iv. Not attacked by N_2 and H_2
v. Greater ………
vi. Can be used for higher temperature as there is no problem of phase change.

The disadvantages are:

i. Low thermal conductivity
ii. More brittle
iii. Enrichment is essential

Uranium carbide UC is also used in nuclear reactors as fuel.
Properties of U^{235} *and* U^{238}

i. U^{235} Will undergo fission on capturing a neutron of any energy. Since its capture cross-section is larger at lower energies it is more likely to capture slow (low- energy) neutrons than fast (high-energy) neutrons.
ii. U^{238} Will undergo fission with neutrons of energy greater than 1.1 MeV
iii. U^{238} Will capture neutrons of intermediate energy to from plutonium
iv. On fissioning any uranium atom, on an average about 2.5 neutrons having high kinetic energy of the order of 2 MeV are produced.
v. Energy obtained by fission is of the order of 200 MeV per atom fissioned.

1. Fissionable materials are U^{233} *and* Pu^{239}
2. The most usable isotope of uranium is ${}_{92}U^{235}$
3. Enriched uranium is one in which % age of U^{235} has been artificially increased.
4. The most abundant isotope of uranium on earth is U^{238}.
5. Enriched uranium may contain fissionable uranium of the order of 1 to 99%
6. U^{235} will undergo fission by either fast or slow neutrons.
7. U^{235} will undergo fission by higher energy (fast) neutrons alone.
8. Natural Uranium is made up of $\underline{99.282\% U^{238}, 0.712\% U^{235}, 0.006\% U^{234}}$
9. plutonium is produced by neutron irradiation of U^{238}
10. U^{233} is produced by neutron irradiation of thorium.
11. Plutonium -239 is produced by neutron irradiation of U^{238}
12. U^{235} is the primary fuel.

13. U^{233} and P_u^{239} is secondary fuel.
14. Solid fuel for nuclear reactions may be fabricated into various small shapes such as plates, pallets, pins, etc.
15. A fission chain reaction in uranium can be developed by slowing down fast neutrons so that U^{235} fission continues by slow motion neutrons.

Miscellaneous:

1. **Ferrite material** is the material which absorbs neutrons and undergoes spontaneous changes leading to the formation of fissionable material $_{92}U^{238}$ *and* $_{90}Th^{232}$ are ferrite materials. A reactor capable of converting a ferrite material into fissile isotopes is called regenerative reactor.
2. The energy required to be applied to a radioactive nucleus for the emission of a neutron is 7.8 MeV
3. In a heterogeneous or solid -fuel reactor, the fuel is mixed in a regular pattern within moderator.
4. Slow or thermal neutrons have energy of the order of 0.025 ev.
5. Fast neutrons have energies above 1000ev.
6. Electromagnetic pump is used in liquid metal cooled reactor for circulation of liquid metal.
7. Molten lead reactors are used for propulsion application.
8. For economic operation of a nuclear plant used fuel should be reprocessed.
9. Reactors designed for propulsion applications are desired for enriched uranium.
10. Moderator does not absorb neutrons.
11. Artificial radioactive isotopes find application in medical Field.
12. Half life of a radioactive isotope corresponds to the time required for half of the atom to decay.
13. Fission chain reaction is possible when fission produces more ϕ neutrino than are absorbed.
14. In nuclear chain reaction, each neutron which causes fission produces more than one new neutron.

Objective Question (IES, IAS, GATE)

Basic concept

1. The half life of radioactive radon is 3.8 days. The time at the end of which 1/20th of the Radon sample will remain undecayed will be **[IES-1992]**
(a) 3.8 days (b) 16.5 day (c) 33 days (d) 76 days

2. A nucleus ${}_{92}A^{235}$ emits alpha and beta particles and is converted, to the nucleus ${}_{82}B^{y}$. The total number of alpha and beta particles emitted in the reaction is 11. Their respective numbers are: **[IES-1992]**
(a) 5 and 6 (b) 7 and 4 (c) 4 and 7 (d) 6 and 5

Units of radioactivity

3. S.I. unit for radioactivity is **[IES-1992]**
(a) joule (b) amu (c) Curie (d) bec querel

Nuclear Fission

4. Which one of the following is the correct statement? **[IES-2006]**
A nuclear fission is initiated when the critical energy as compared to neutron binding energy atoms is
(a) less (b) same (c) more (d) exactly two times

5. The energy released during the fission of one atom of Uranium-235 in million electron volts is about **[IES-1995]**
(a) 100 (b) 200 (c) 300 (d) 400

6. Energy released by the fission of one U-235 atom is nearly **[IAS-1999]**
(a) 2000 MeV (b) 1000 MeV (c) 200MeV (d) 20MeV

7. The energy released in the fission of one U-235 nucleus is approximately
(a) 100 MeV (b) 200 MeV (c) 300 MeV (d) 400 MeV **[IES-1993]**

8. The average number of fast neutrons produced in the fission of an U-235 atom is nearly **[IAS-1999]**
(a) 1.23 (b) 2.46 (c) 3.69 (d) 4.92

Advantages and limitation of Nuclear power plant

9. Consider the following ways of disposal of nuclear wastes: **[IAS-1997]**
1. Throwing them in the deep sea.
2. Leaving them in remote, isolated open spaces in barren mountainous regions.
3. Sealing- them in concrete and depositing them in crevices and caverns in the deep sea.
4. Storing them in sealed concrete containers in disused deep mine shafts.
Safe ways of disposal of nuclear wastes would include.
(a) 1, 2, 3 and 4 (b) 1, 3 and 4 (c) 1 and 2 (d) 3 and 4

10. Assertion (A): The liquid waste from a nuclear power plant is concentrated to a small volume and stored in underground tanks. **[IAS-1996]**
Reason (R): Dilution of radioactive liquid waste is not desirable due to the nature of the isotopes.

Type of Nuclear Reactor

11. A sodium graphite reactor uses sodium **[IAS-2001]**
(a) as coolant and graphite as moderator
(b) as moderator and graphite as coolant
(c) with graphite as moderator and water as coolant
(d) as moderator and sodium, graphite and water together as coolant

Basic Nuclear power reactor

12. What is the function of heavy water in a nuclear reactor? **[IES-2006]**
(a) It serves as a coolant (b) It serves as a moderator
(c) It serves as a coolant as well as a moderator
(d) It serves as a neutron absorber

13. The most commonly used moderator in nuclear power plants is **[IES-2000]**
(a) heavy water (b) concrete and bricks (c) steel (d) graphite

14. Shielding in a nuclear reactor is generally done to protect against **[IES-2000]**
(a) excess electrons (b) X-rays (c) α-and β-rays (d) neutron and gamma rays

15. Which one of the following pairs of materials is used as moderators in nuclear reactors?
(a) Heavy water and zirconium (b) Zirconium and beryllium **[IES-1995]**
(c) Cadmium and beryllium (d) Beryllium and heavy water.

16. Match List I with List II and select the correct answer (these pertain to nuclear reactors).

List I	List II
A. Coolant	1. Carbon dioxide
B. Control rod	2. Zirconium
C. Poison	3. Cadmium
D. Cladding	4. Graphite
	5. Hafnium

[IES-1994]

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

17. What is the purpose of a moderator in a nuclear reactor? **[IAS-2004]**
(a) Moderate the fission temperature (b) Reduce the speed of fast moving neutrons
(c) Reduce β and γ rays (d) Absorb excess neutrons in the reactor

18. The function of the moderator in a nuclear reactor is to
(a) stop chain reaction (b) reduce the speed of the neutrons
(c) absorb neutrons (d) reduce temperature **[IAS-2003]**

19. Purpose of moderator in nuclear reactor is to **[IAS-2001]**
(a) slow down the neutrons produced in fission
(b) reduce nuclear pollution
(c) control the reactor temperature so that protons produced are less
(d) moderate the steam pressure to slow down the chain reaction

20. Match List I with List II regarding nuclear reactor and select the correct answer: **[IAS-2000]**

List I	List II
A. Moderator	1. U-233
B. Biological shield	2. Hafnium
C. Poison	3. Beryllium
D. Nuclear fuel	4. Sodium
	5. Lead

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

21. Match List I (Component) with List II (Properties) in the context of nuclear reactors and select the correct answer using the codes given below the lists: **[IAS-1999]**

List I	List II
A. Coolant	1. Low neutron absorption
B. Moderator	2. Low radiation damage
C. Fuel	3. High heat transfer coefficient
D. Shield	4. High absorption of radiation

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

22. Match List I with List II in respect of nuclear reactor and select the correct answer using the codes given below the lists: **[IAS-1999]**

List I	List II
A. Poison	1. Hafnium
B. Moderator	2. Graphite
C. Cladding	3. Zironium
D. Fission Product	4. Strontium-90

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

23. Consider the following statements: **[IAS-1998]**
1. Breeder reactor produces more plutonium than what it consumes.
2. Zirconium is used as a shield material
3. Lead is the commonly used moderator
Of these, the ones which are not correct, will include:
(a) 1, 2 and 3 (b) 1 and 2 (c) 2 and 3 (d) 1 and 3

24. Which one of the following pairs is NOT correctly matched? **[IAS-1997]**

Material		Function in a nuclear reactor
(a) Graphite	:	Moderator
(b) Lead	:	Reflector

(c) Uranium-235 : Fuel
(d) Concrete : Biological shield

25. Match List I (Materials) with List II (Application in a nuclear reactor) and select the correct answer using the codes given below the lists: **[IAS-1996]**

List I	List II
A. Zirconium	1. Cladding
B. Graphite	2. Coolant
C. Liquid sodium	3. Control rod
D. Cadmium	4. Shield

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

26. Match the following: **[IES-1992]**

List-I	List-II
A. Moderator	1. Graphite
B. Control rod	2. Boron
C. Poison	3. Concrete
D. Shield Material	4. Hafnium

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

Critical

27. A nuclear unit becoming critical means: **[IES-2005]**
(a) It is generating power to rated capacity
(b) It is capable of generating power much more than the rated capacity
(c) There is danger of nuclear spread
(d) Chain reaction that causes automatic splitting of the fuel nuclei has been established

28. A nuclear reactor is said to be "critical" when the neutron population in the reactor core is
(a) rapidly increasing leading to the point of explosion (c) constant **[IAS-1995]**
(b) decreasing from the specified value (d) reduced to zero

29. If k is the ratio of the rate of production of neutrons to the rate of loss of neutrons, the reactor is called a critical reactor, when
(a) k= 0 (b) 0<k<l (c) k = 1 (d) k> 1 **[IAS-2003]**

Pressurised water reactor (PWR)

30. Assertion (A): Pressurized water reactor (PWR) nuclear power plants use superheated steam.
Reason (R): An increase in the superheat at constant pressure increases the cycle efficiency. **[IES-2001]**

31. Assertion (A): The thermal efficiency of a nuclear power plant using a boiling water reactor is higher than of a plant using a pressurized water reactor. **[IES-1999]**

Reason (R): In a boiling water reactor, steam is directly allowed to be generated in the reactor itself, whereas in a pressurized water reactor, steam is generated in a separate boiler by heat exchanger device using water of the primary circuit which absorbs the fission energy.

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

List I	List II
A. Fast Reactor	1. Breeding
B. Sodium Cooled Reactor	2. Graphite
C. Pressurized Water Reactor	3. Magnetic Pump
D. Gas-cooled Reactor	4. Natural uranium

[IES-1993]

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

Boiling Water reactor (BWR)

33. Which one of the following types of nuclear reactor DOES NOT require a heat exchanger? **[IAS-2000]**
(a) Boiling water (b) Pressurized water (c) Sodium-cooled (d) Gas-cooled

34. The boiler used in the Nuclear Power Station at Tarapore, is of the
(a) pressurized water type (b) boiling water type **[IAS-1998]**
(c) gas cooled type (d) liquid metal cooled type

Fast breeder reactor

35. The moderator used in a fast breeder nuclear reactor is
(a) graphite or liquid sodium (b) graphite or beryllium oxide.
(c) graphite, liquid sodium or beryllium oxide (d) none of the above **[IAS 1994]**

36. Assertion (A): A breeder reactor does not require moderator. **[IES-1992]**
Reason (R): The parasite absorption of neutrons is low.

37. A fast breeder reactor uses which one of the following as fuel? **[IAS-2007]**
(a) Thorium (b) U^{235} (c) Plutonium (d) Enriched uranium

38. In Fast Breeder Reactor **[IAS-2002]**
(a) the moderator used is water (b) the moderator used is graphite
(c) the moderator used is carbon dioxide (d) No moderator is used

39. Consider the following statements regarding the features of a Breeder reactor:
1. It produces more fuel than it consumes 2. It converts fertile fuel into fissile fuel
3. It requires liquid sodium metal as moderator. 4. It requires highly enriched fuel
Of these statements: **[IAS-1995]**
(a) 1, 2 and 3 are correct (b) 1, 2 and 4 are correct
(c) 1, 3 and 4 are correct (d) 2, 3 and 4 are correct

Advanced Gas cooled reactor (AGR)

40. Consider the following statements regarding nuclear reactors: **[IES-1998]**

1. In a gas-cooled thermal reactor, if CO_2 is used as the coolant, a separate moderator is not necessary as the gas contains carbon.
2. Fast reactors using enriched uranium fuel do not require a moderator.
3. In liquid metal-cooled fast breeder reactors, molten sodium is used as the coolant because of its high thermal conductivity.
4. Fast reactors rely primarily on slow neutrons for fission.

Of these statements
(a) 1 and 2 are correct (b) 2 and 4 are correct (c) 2 and 3 are correct (d) 1 and 3 are correct

CANDU (CANadian Deuterium Uranium) reactor

41. Which one of the following statements is correct? **[IES-2004]**
In CANDU type nuclear reactor
(a) natural uranium is used as fuel and water as moderator
(b) natural uranium is used as fuel and heavy water as moderator
(c) enriched uranium is used as fuel and water as moderator
(d) enriched uranium is used as fuel and heavy water as moderator

42. Consider the following statements: **[IES-1997]**
CANDU-type nuclear reactor using natural uranium finds extensive use because
1. heavy water is used both as coolant and moderator.
2. cost of fuel used is much lower than that used in pressurized water or boiling water reactor.
3. small leakage of heavy water does not affect the performance of the reactor substantially.
4. fuel consumption is low because of use of heavy water.
Of these statements
(a) 1, 2, 3 and 4 are correct (b) 1, 2 and 4 are correct
(c) I and 2 are correct (d) 3 and 4 are correct

43. Consider the following statements:
1. Gas cooled thermal reactors use CO_2 or helium as coolant and require no separate moderator.
2. Fast reactors use heavy water as moderator and coolant.
3. Liquid metal fast breeder reactors use molten sodium as coolant. **[IES-1996]**
4. In CANDU type reactors heavy water is used as moderator.
Of these correct statements are
(a) 1 and 3 (b) 2 and 4 (c) 3 and 4 (d) 1 and 2

44. Which of the following statements are true about CANDU reactors? **[IES-1992]**
1. Fuel elements contain natural-uranium dioxide
2. Pressurized heavy-water coolant is used
3. Horizontal pressure tube is used
(a) 1 and 2 only (b) 1 and 3 only (c) 2 and 3 only (d) 1, 2 and 3

Magnox

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

List I	List II	[IAS-2002]
A. Fuel	1. Graphite	
B. Cladding	2. Natural Uranium	
C. Coolant	3. Magnox	
D. Moderator	4. CO_2	

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

Nuclear Fuel

46. Match List I (Material) With List II (Application) and select the correct answer. **[IES-2004]**

List I	List II
A. Plutonlum-239	1. Fertile material
B. Thorium-232	2. Control rods
C. Cadmium	3. Moderator
D. Graphite	4. Fissile material

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

47. Enriched uranium is required as fuel in a nuclear reactor, if light water is used as moderator and coolant, because light water has **[IES-1994]**
(a) high neutron absorption cross- section. (b) low moderating efficiency.
(c) high neutron scatter cross-section. (d) low neutron absorption cross - section.

48. Which of the following are fertile materials? **[IAS-2004]**
(a) U^{233} and Pu^{239} (b) U^{238} and Th^{239} (c) U^{238} and Th^{232} (d) U^{235} and Th^{236}

49. Match List-I with List-II and select the correct answer using the codes given below the Lists: **[IES-1997]**

List I	List II
A. Prepared fuel	1. Uranium-235
B. Primary fuel	2. Graphite
C. Moderator	3. Uranium-233
D. Control rod	4. Cadmium

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

50. Which one of the following pairs is not correctly matched? **[IES-1995]**
(a) Fertile material ………..U-233
(b) Atomic number………. Number of protons
(c) Mass defect.... …………Binding energy
(d) Cross-section ....Scattering.

51. Consider the following statements: **[IAS-2007]**
1. Heat is generated in a nuclear reactor by fission of U-235 by neutron.
2. Percentage of U-238 in natural Uranium is around 0·71.
3. Plutonium is not a naturally occurring nuclear fuel.

Which of the statements given above is/are correct?

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

52. Consider the following statements regarding nuclear reactors:
1. A mixture of radioactive materials is used as fuel
2. Spent fuel is reprocessed to recover thorium /plutonium **[IAS-2000]**
3. Control rods are made of zirconium
4. Spent fuel is fully disposed of safely, as waste

Which of these statements are correct?
(a) 1 and 2 (b) 3 and 4 (c) 1 and 3 (d) 1, 3 and 4

53. Consider the following statements: **[IAS-1999]**
Uranium oxide is chosen as fuel element in the nuclear reactors, because Uranium oxide
1. is more stable than Uranium 2. does not corrode easily
3. is more brittle. 4. has dimensional stability

Among these statements:
(a) 1, 2 and 4 are correct (b) 1, 2 and 3 are correct
(c) 1, 2 and 4 are correct (d) 3 and 4 are correct

54. Match List-I (Material) with List-II (Use) and select the correct answer using the codes given below the lists:

List-I (Material) List-II (Use) **[IES-2001]**
A. Graphite 1. Coolant
B. Thorium-233 2. Moderator
C. Molten Sodium 3. Fissionable material
D. Plutonium-239 4. Fissile material

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

55. Match List I with List II and select the correct answer. **[IES-1996]**

List I List II
A. Plutonium-239 1. Fissile material
B. Thorium-233 2. Fissionable material
C. Cadmium 3. Moderator
D. Graphite 4. Poison

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

56. Uranium 238 is represented as ${}_{92}U^{238}$. What does it imply? **[IES 2007]**
(a) It has 92 protons and 146 neutrons (b) It has 146 protons and 92 neutrons
(c) It has 92 protons and 238 neutrons (d) It has 92 protons and 238 neutrons

Answer with Explanation

1. Ans. (b)
2. Ans. (b)
3. Ans. (d)
4. Ans. (c)
5. Ans. (b) Energy released during fission of U-235 is 200 million electron volt

6. Ans. (c)
7. Ans. (b) The energy released in the fission of one U-235 nucleus is approximately 200 MeV.
8. Ans. (b)
9. Ans. (d)
10. Ans. (a)
11. Ans. (a)
12. Ans. (c)
13. Ans. (d)
14. Ans. (d)
15. Ans. (d) Moderator in nuclear reactor is Beryllium and heavy water.
16. Ans. (c)
17. Ans. (b)
18. Ans. (b)
19. Ans. (a)
20. Ans. (b)
21. Ans. (b)
22. Ans. (c)
23. Ans. (c)
24. Ans. (b)
25. Ans. (a)
26. Ans. (d)
27. Ans. (a)
28. Ans. (c)
29. Ans. (c)
30. Ans. (d)
31. Ans. (a) Both A and R are true and R provides reason for thermal efficiency of boiling water reactor to be high compared to pressurized water reactor.
32. Ans. (a) Since fast reactor is related with breeding, magnetic pump is needed for sodium cooled reactor, mainly natural uranium (with some enriched uranium) is used in pressurized water reactor, and graphite is moderator for gas cooled reactor.
33. Ans. (a) BWR is similar to the thermal power plant. So condenser is used no heat exchanger.
34. Ans. (b)
35. Ans. (d)
36. Ans. (b)
37. Ans. (b)
38. Ans. (d)
39. Ans. (b)
40. Ans. (c)
41. Ans. (b)
42. Ans. (c)
43. Ans. (c)
44. Ans. (a)
45. Ans. (b)
46. Ans. (d)
47. Ans. (c)
48. Ans. (c)
49. Ans. (c)
50. Ans. (a) U-233 is not fertile material.
51. Ans. (c) composition of Uranium ore

U-238 is abundant Uranium up to 99.282%
U-235=0.712%
U-233=0.006%

52. Ans. (a) i) The materials used for control rods are cadmium, boron or hafnium.

ii) In fast breeder reactor ${}_{92}U^{238}$ and ${}_{90}Th^{232}$ produces two other fuel ${}_{94}Pu^{239}$ and ${}_{92}U^{233}$ so spent fuel is reprocessed to recover thorium/plutonium.

53. Ans. (a)
54. Ans. (b)
55. Ans. (c)
56. Ans. (a) Atomic weight (238) = number of protons + number of neutrons.