S K Mondal's

Power Plant

GATE, IES & IAS 20 Years Question Answers

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Note

If you think there should be a change in option, don’t change it by yourself send me a mail at swapan_mondal_01@yahoo.co.in I will send you complete explanation.

Every effort has been made to see that there are no errors (typographical or otherwise) in the material presented. However, it is still possible that there are a few errors (serious or otherwise). I would be thankful to the readers if they are brought to my attention at the following e-mail address: swapan_mondal_01@yahoo.co.in

S K Mondal

1. Introduction

Previous Years IES Questions

IES-1. 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

IES-1. Ans. (b)

IES-2. In thermal power plants, coal is transferred from bunker to the other places by **[IES-1992]**
(a) Hoists (b) conveyors (c) cranes (d) lifts

IES-2. Ans. (b)

IES-3. A thermal electric power plant produces 1000 MW of power. If the coal releases 900 x 10^7 kJ/h of energy, then what is the rate at which heat is rejected from the power plant? **[IES-2009]**
(a) 500 MW (b) 1000 MW (c) 1500 MW (d) 2000 MW

IES-3. Ans. (c) Energy Released by the coal = 900×10^7 kJ/hr = 2500 MW
Heat rejected from the power plant 2500-1000 = 1500 MW

Previous Years IAS Questions

IAS-1. The correct sequence of factors 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

IAS-1. Ans. (b)

2. Steam Cycle

Previous Years GATE Questions

Rankine Cycle

Common Data Questions GATE-1 and GATE-2: **[GATE-2010]**

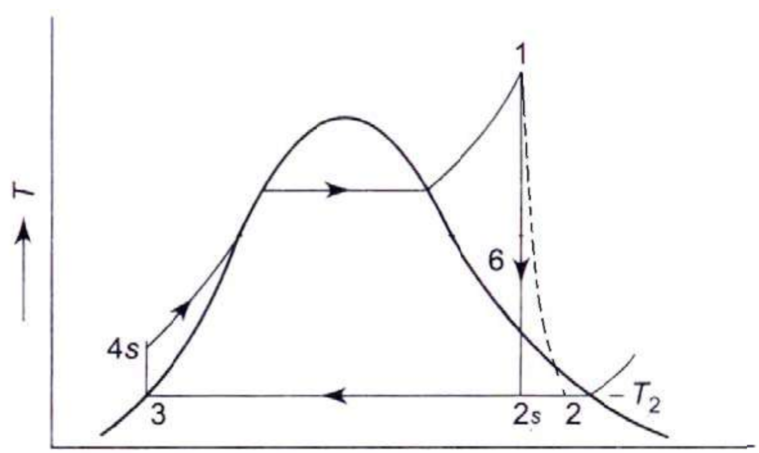
In a steam power plant operating on the Rankine cycle, steam enters the turbine at 4 MPa, 350°C and exits at a pressure of 15 kPa. Then it enters the condenser and exits as saturated water. Next, a pump feeds back the water to the boiler. The adiabatic efficiency of the turbine is 90%. The thermodynamic states of water and steam are given in the table.

State	$h (kJ\,kg^{-1})$		$s (kJ\,kg^{-1}K^{-1})$		$v (m^3kg^{-1})$	
Steam : 4 MPa, 350°C	3092.5		6.5821		0.06645	
Water : 15 kPa	h_f	H_g	s_f	s_g	v_f	v_g
	225.94	2599.1	0.7549	8.0085	0.001014	10.02

h is specific enthalpy, s is specific entropy and v the specific volume; subscripts f and g denote saturated liquid state and saturated vapour state.

GATE-1. The net work output ($kJ\,kg^{-1}$) of the cycle is **[GATE-2010]**
(a) 498 (b) 775 (c) 860 (d) 957

GATE-1. Ans. (c)



$$h_1 = 3092.5\, kJ/kg$$
$$s_1 = 6.5821\, kJ/kg\,K$$
$$s_{2f} = 0.7549\, kJ/kg\,K$$
$$s_{2g} = 8.0085\, kJ/kg\,K$$
$$s_1 = s_{2s}$$
$$6.5821 = (1-x)\,0.7549 + x \times 8.0085$$
$$or \quad x = 0.8034$$
$$Therefore\ h_{2s} = (1-x)\,225.94 + x \times 2509.1$$
$$= 2132\, kJ/kg$$
$$\eta_{\text{adiabatic}} = \frac{h_1 - h_2}{h_1 - h_{2s}}$$
$$or \quad h_1 - h_2 = W_T = \eta_{\text{adiabatic}} \times \left(h_1 - h_{2s}\right)$$
$$= 0.9 \times (3092.5 - 2132)$$
$$= 865\, kJ/kg$$
$$Pump\,Work(W_P) = v_f \times \Delta P$$
$$= 0.001014 \times (4000 - 15)\, kJ/kg$$
$$= 4.04\, kJ/kg$$
$$Net\,Work\,done = 865 - 4.04$$
$$= 860.9\, kJ/kg$$

GATE-2. Heat supplied ($kJ\ kg^{-1}$) to the cycle is **[GATE-2010]**

(a) 2372 (b) 2576 (c) 2863 (d) 3092

GATE-2. Ans. (C)

$$\text{Heat supplied to the cycle} = h_4 - h_2$$
$$= 3092.5 - 229.98$$
$$= 2863\, kJ/kg$$

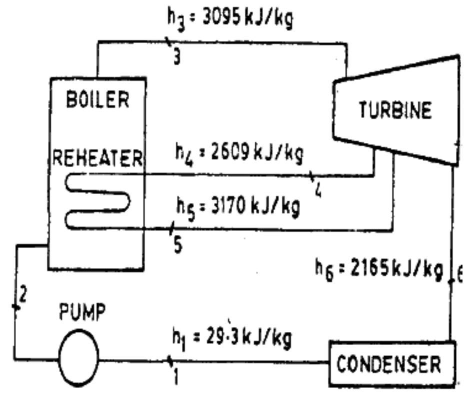
GATE-3. The efficiency of superheat Rankine cycle is higher than that of simple Rankine cycle because **[GATE-2002]**

(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

GATE-3. Ans. (b)

Data for GATE-4 and GATE-5 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



GATE-4. The thermal efficiency of the plant neglecting pump work is [GATE-2004]
(a) 15.8% (b) 41.1% (c) 48.5% (d) 58.6%

GATE-4. Ans. (b)

Given :

$h_1 = 29.3\,kJ/kg, h_2 = ?$

$h_3 = 3095\,kJ/kg, h_4 = 2609\,kJ/kg$

$h_5 = 3170\,kJ/kg, h_6 = 2165\,kJ/kg$

$\text{Turbine work } W_T = (h_3 - h_4) + (h_5 - h_6)$

$= (3095 - 2609) + (3170 - 2165)$

$= 1491\,kJ/kg$

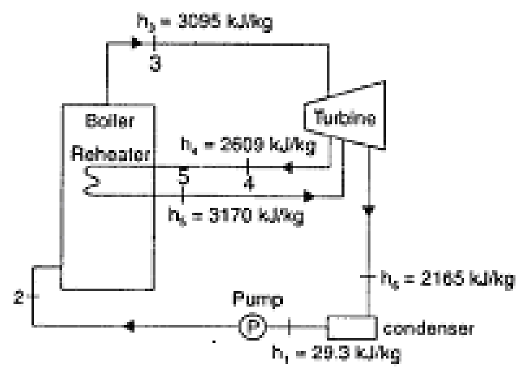
$Q = \text{Heat input} = (h_3 - h_2) + (h_5 - h_4)$

$= (3095 - 29.3) + (3170 - 2609)$

$= 3626.7\,kJ/kg$

$\therefore$ Thermalefficiencyoftheplant

$$= \frac{1491}{3626.7} = 41.11\%$$



GATE-5. 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

GATE-5. Ans. (d) Enthalpy at the pump discharge will be greater than 29.3 kJ/kg
Hence from given choice clearly we can say

$$h_2 = 33.3\,kJ/kg$$

GATE-6. A steam turbine operating with less moisture is............ (more/less) efficient and........................... (less/more) prone to blade damage[GATE-1992]

GATE-6. Ans. more; less

GATE-7. 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.
(a) Both A and R are individually true and R is the correct explanation of A

(d) A is false but R is true

GATE-7. Ans. (a) Both A and R are true and R is the correct explanation of A

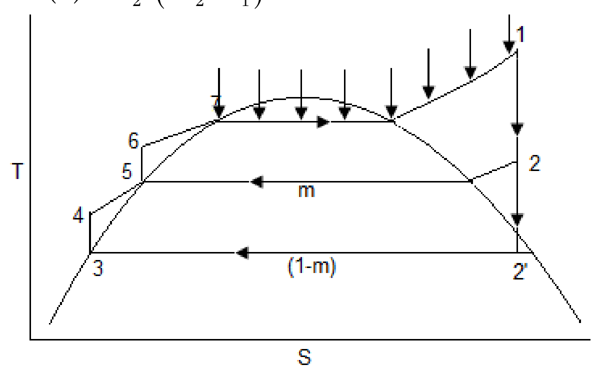
GATE-8. In a Rankine cycle, regeneration results in higher efficiency because
(a) Pressure inside the boiler increases **[GATE-2003]**
(b) Heat is added before steam enters the low pressure turbine
(c) Average temperature of heat addition in the boiler increases
(d) Total work delivered by the turbine increases

GATE-8. Ans. (c)

GATE-9. 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 **[GATE-1997]**

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

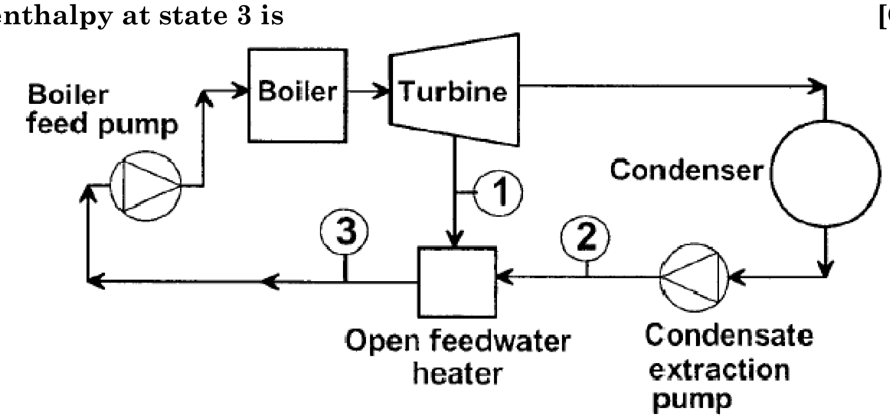
GATE-9. Ans. (c)
Heat balance of heat give
$mh_1 + (1-m)h_2 = 1\times h_3$
or $h_3 = h_2 - m(h_2 - h_1)$



GATE-10. 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.

GATE-10. Ans. (d) Efficiency of ideal regenerative cycle is exactly equal to that of the corresponding Carnot cycle. Hence it is maximum.

GATE-11. 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 **[GATE-2008]**



(a) 720 kJ/kg (b) 2280 kJ/kg (c) 1500 kJ/kg (d) 3000kJ/kg

GATE-11. Ans. (a): let 100 kg steam is in (m_3) then m_1= 20 kg and m_2 = 80 kg

Therefore $m_1h_1+m_2h_2 = m_3h_3$

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

Efficiencies in a Steam Power Plant

GATE-12. 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%

GATE-12. Ans. (a) $\eta_{overall} = \eta_{boiler}\times\eta_{turbine(mech)}\times\eta_{generator}\times\eta_{aux}$

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

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

GATE-13. In steam and other vapour cycles, the process of removing non-condensable is called [GATE-1992]

(a) Scavenging process (b) Deaeration process

(c) Exhaust process (d) Condensation process

GATE-13. Ans. (b)

GATE-14. 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%

GATE-14. Ans. (b) $(1-\eta) = (1-\eta_1)(1-\eta_2)(1-\eta_3)\ldots\ldots\ldots(1-\eta_m)$

or $\eta = \eta_1+\eta_2-\eta_1\eta_2 = (0.30+0.2-0.3\times 0.2)\times 100\% = 44\%$

Previous Years IES Questions

IES-1. 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

IES-1. Ans. (c)

IES-2. In a Rankine cycle, with the maximum steam temperature being fixed from metallurgical considerations, as the boiler pressure increases

(a) The condenser load will increase **[IES-1997]**

(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

IES-2. Ans. (b) with increase in pressure, state of steam shifts towards left and thus on expansion, quality of steam will decrease.

IES-3. 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.

IES-3. Ans. (b) Carnot cycle has highest efficiency but very high back. So work ratio is low.

IES-4. During which of following process does heat rejection take place in Carnot vapour cycle? [IES-1992]
(a) Constant volume (b) constant pressure
(c) Constant temperature (d) constant entropy

IES-4. Ans. (c)

IES-5. 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

IES-5. Ans. (d) zero heat transfer means adiabatic process.

$$\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}}$$ Where γ =1.4 air.

Reheating of Steam

IES-6. 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

IES-6. Ans. (c) 1. Quality of steam improves so blade erosion reduced.
2. Reheating has no effect on speed. So 2 is false.

IES-7. 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

IES-7. Ans. (b)

IES-8. 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

IES-8. Ans. (a)

IES-9. 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.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false
(d) A is false but R is true

IES-9. Ans. (a)

IES-10. **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

IES-10. Ans. (d)

IES-11. **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

IES-11. Ans. (d) Heating of steam increases specific output of turbine and improves the quality of exit steam.

IES-12. **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) Recovers the waste heat of boiler

IES-12. Ans. (b)

IES-13. **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.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-13. Ans. (d)

IES-14. **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

IES-14. Ans. (d) Overall pressure ratio depends on inlet pressure and condenser pressure

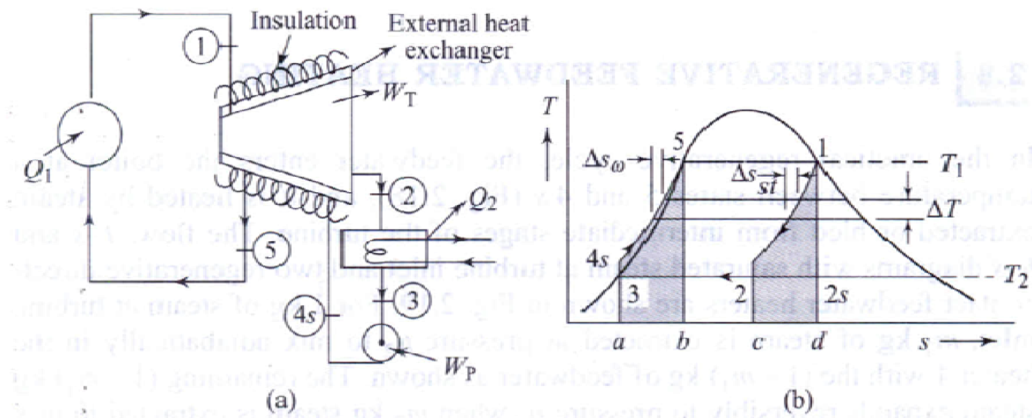
IES-15. **Employing superheated steam in turbines leads to** **[IES-2003]**
(a) Increase in erosion of blading (b) Decrease in erosion of blading
(c) No erosion in blading (d) No change in erosion of blading

IES-15. Ans. (b)

Regenerative Feed water Heating

IES-16. Which one of the following is correct? **[IES-2008]**
In ideal regenerative cycle the temperature of steam entering the turbine is same as that of
(a) Water entering the turbine
(b) Water leaving the turbine
(c) Steam leaving the turbine
(d) Water at any section of the turbine

IES-16. Ans. (b)



Ideal regenerative cycle

Here temperature of steam entering the turbine is T_1
And temperature of water leaving the turbine is T_5 [refer fig. (a)]
Therefore, temperature of steam entering the turbine is T_1 = temperature of water leaving the turbine is T_5 [refer fig. (b)]

IES-17. **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.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-17. Ans. (a)

IES-18. 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]**
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-18. 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.

1. It increases the cycle efficiency **2. It requires a bigger boiler.**
3. It requires a smaller condenser. **[IES-2003]**
Which of the above statements are correct?
(a) 1, 2 and 3 (b) 1 and 2 (c) 2 and 3 (d) 1 and 3

IES-19. Ans. (a) Same amount of heat transfer is required but temperature difference is less in regenerative plant.

IES-20. **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**
(a) Stage efficiency (b) degree of reaction **[IES-2000]**
(c) Rankine efficiency (d) relative efficiency

IES-20. Ans. (c)

IES-21. **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.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-21. Ans. (b)

IES-22. 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.

IES-22. 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.

IES-23. When is the greatest economy obtained in a regenerative feed heating cycle? **[IES-2006]**
(a) Steam is extracted from only one suitable point of a steam turbine
(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

IES-23. Ans. (d)

IES-24. **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

IES-24. 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.

IES-25. **Which one of the following statements is not correct for a regenerative steam cycle?** **[IES-2005]**

(a) It increases the thermodynamic efficiency
(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

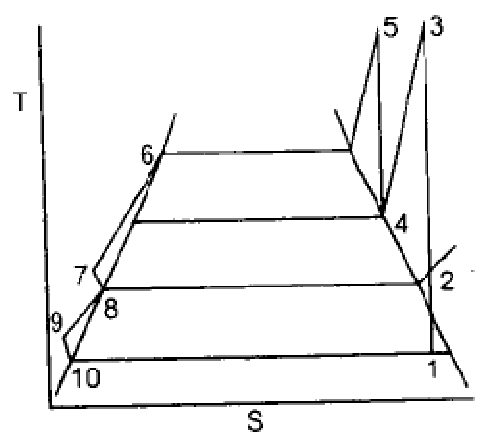
IES-25. Ans. (c) (i) $\eta \uparrow$ with increased number of feed heaters but Efficiency ain$(\Delta\eta)$ successively diminishes with the increase in the number of heaters
(ii) It increases the stream flow rate (requiring bigger boiler)
(iii) It reduces the steam flow to the condenser (needing smaller condenser)

IES-26. **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

IES-26. Ans. (b) Note: Regenerative cycle **not** regenerative turbine so choice is 'b'

Feed water Heaters

IES-27. 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 5 is



(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]

IES-27. Ans. (b)

Optimum Degree of Regeneration

Deaerator

IES-28. **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.

IES-28. Ans. (d) In thermal power plants, the deaerator is used mainly to remove dissolved gases from feed water

IES-29. **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. Deaerator	**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

IES-29. Ans. (b)

IES-30. **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

IES-30. Ans. (d)

IES-31. **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
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-31. Ans. (a)

IES-32. **The efficiency of Rankine cycle is lower than that corresponding Carnot cycle because** **[IES-1992]**
(a) The average temperature at which heat is supplied in Rankine cycle is lower than corresponding Carnot cycle
(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 than that for Rankine cycle.

IES-32. Ans. (a)

Cogeneration of Power and Process Heat

IES-33. **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

IES-33. Ans. (b)

Combined Cycle Plants

IES-34. **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

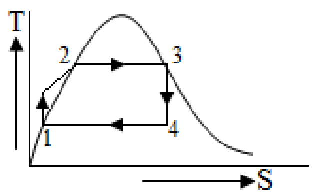
IES-34. Ans. (d)

IES-35. **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

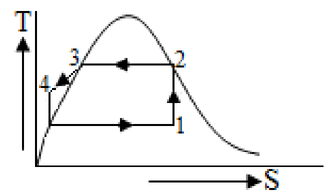
IES-35. Ans. (c)

Previous Years IAS Questions

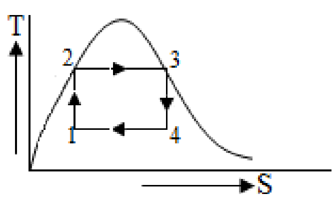
IAS-1. **The correct representation of a simple Rankine cycle on a T-S diagram**



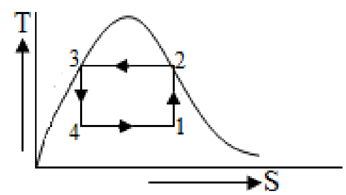
(a)



(b)



(c)

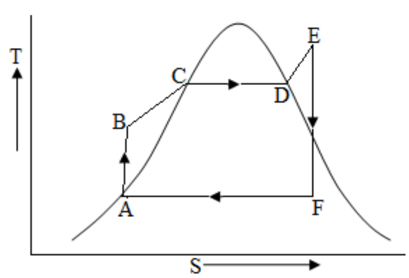


(d)

[IAS 1994]

IAS-1. Ans. (a)

IAS-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]

IAS-2. Ans. (a)

IAS-3. **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

IAS-3. Ans. (d)

Mean Temperature of Heat Addition

IAS-4. **Assertion (A):** The Rankine cycle with regenerative feed heating always has higher cycle efficiency than the Rankine cycle without regenerative feed heating.
Reason(R): The higher efficiency of regenerative cycle is due to decrease in the temperature of heat rejection. **[IAS-2000]**
(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IAS-4. Ans. (c) Higher efficiency of regenerative cycle is due to increase in the mean temperature of heat addition.

IAS-5. **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

IAS-5. Ans. (c)

IAS-6. **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**
(a) Providing regeneration (b) providing reheating **[IAS-1999]**
(c)- Reducing the superheat (d) lowering the condenser pressure

IAS-6. Ans. (b)

Superheating of steam

IAS-7. **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

IAS-7. Ans. (a)

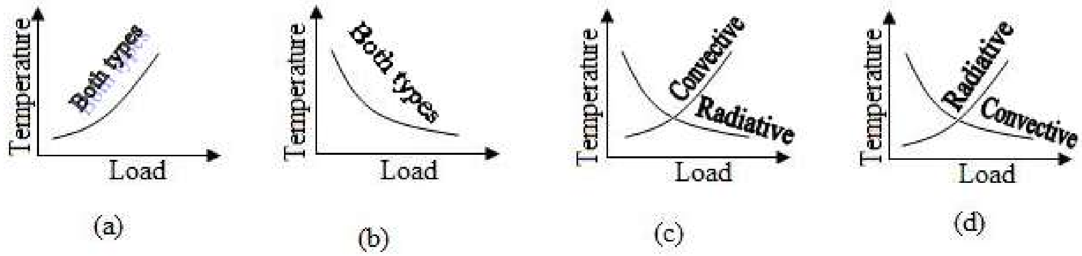
IAS-8. **Assertion (A):** In convection super heaters, the exit steam temperature increases with load. **[IAS-2000]**
Reason(R): The combustion temperature does not significantly change with load.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IAS-8. 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.

IAS-9. **Consider the following statements regarding superheating 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

IAS-9. Ans. (a) Superheating in Rankine cycle increases efficiency marginally.

IAS-10. **The variation of super heater outlet temperature with variation of load in the case of convective type and radiative type super heaters is best represented as** **[IAS-1999]**



IAS-10. Ans. (c)

IAS-11. **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)?** **[IAS-2004]**
(a) 92% (b) 33% (c) 50% (d) 42%

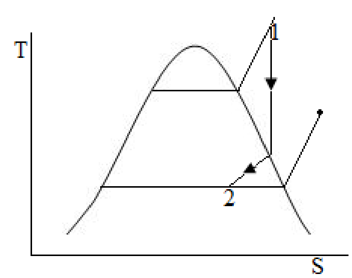
IAS-11. Ans. (c) Ideal regenerative Rankine cycle efficiency is same as Carnot cycle

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

IAS-12. **The most efficient ideal regenerative steam power cycle is** **[IAS-2001]**
(a) Rankine cycle (b) Carnot cycle
(c) Brayton cycle (d) Joule cycle

IAS-12. Ans. (b) Ideal regeneration Rankine Rankin cycle efficiency is same as Carnot cycle, but most efficient cycle is Carnot cycle.

IAS-13. **The curve labeled 1-2 in the given figure refers to the expansion process of a**
(a) Rankine cycle
(b) Modified Rankine cycle
(c) regenerative cycle
(d) reheat cycle



[IAS-1997]

IAS-13. Ans. (b)

IAS-14. **Which one of the following modifications to a Rankine cycle would upgrade/enhance its efficiency so as to approach that of Carnot cycle?**
(a) Incomplete expansion of steam **[IAS-1996]**

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

IAS-14. Ans. (c)

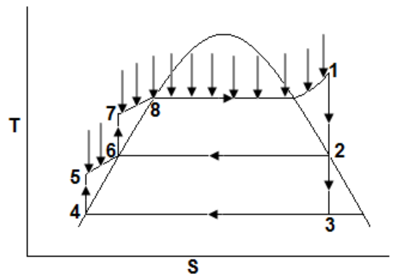
IAS-15. **In a regenerative cycle, steam with enthalpy of 3514 kJ/kg is expanded in h.p. turbine to a state corresponding to saturated enthalpy of water equal to 613 kJ/kg. If the pump work requirements in high pressure and low**

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

IAS-15. Ans. (a)

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



IAS-16. **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

IAS-16. Ans. (c)

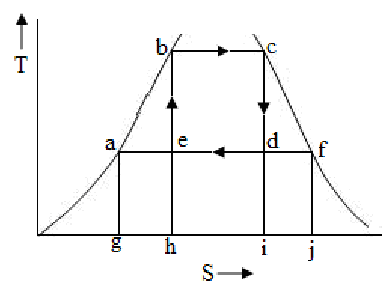
IAS-17. **In steam and other vapour cycles, the process of removing non-condensable is called** **[IAS-2003]**

(a) Scavenging process (b) Deaeration process
(c) Exhaust process (d) Condensation process

IAS-17. Ans. (b)

IAS-18. 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]

IAS-18. Ans. (a) Heat input = area of T-S diagram = gabcdig
Work done = Heat addition – heat rejection
= gabcdig - gadig = abcda

IAS-19. **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

IAS-19. Ans. (c)

3. Boilers

Previous Years GATE Questions

Economizer

GATE-1. Which among the following is the boiler mounting? [GATE-1997]
(a) Blow off cock (b) Feed pump (c) Economiser (d) Superheater

GATE-1. Ans. (a)

Equivalent Evaporation

GATE-2. 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 [GATE-1993]
(a) 2000 (b) 2149 (c) 1682 (d) 1649

GATE-2. Ans. (a)
Equivalent evaporation of boiler

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

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

GATE-3. 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

GATE-3. Ans. (d)

Previous Years IES Questions

IES-1. Heat is mainly transferred by conduction, convection and radiation in
(a) Insulated pipes carrying hot water **[IES-1998]**
(b) Refrigerator freezer coil
(c) Boiler furnaces
(d)condensation of steam in a condenser

IES-1. Ans. (c) All modes of heat transfer occur in boiler furnace

Fire-tube Boilers

IES-2. 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.
(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-2. Ans. (a)

Cochran boiler

IES-3. Match List-I (Name of boiler) with List-II (Special features) and select the correct answer using the codes given below the lists [IES-1999]

List-I	List-II
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

IES-3. 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.

IES-4. 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

IES-4. Ans. (c)

Lancashire boiler

IES-5. 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

IES-5. Ans. (b)

Locomotive boiler

IES-6. The draught in locomotive boilers is produced by [IES-2003]

(a) Chimney (b) Centrifugal fan (c) Steam jet (d) Locomotion

IES-6. Ans. (c)

IES-7. 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
IES-7. Ans. (b)

Benson boiler

IES-8. There is no steam drum in [IES-1999]
(a) La Mont boiler (b) Loffler boiler (c) Benson boiler (d) Velox boiler
IES-8. Ans. (c)

IES-9. Consider the following components: [IES-1997]
1. Radiation evaporator 2.Economiser
3. Radiation super heater 4.Convection super heater
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
IES-9. Ans. (c) The correct sequence of water entry in Benson boiler is economiser, radiation evaporator, radiation super heater and finally convection super heater.

IES-10. Which one of the following statements is *not* true for a supercritical steam generator? [IES-2005]
(a) It has a very small drum compared to a conventional boiler
(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
IES-10. Ans. (a) It has no drum.

Previous Years IAS Questions

IAS-1. An attemparator is used in some utility boilers [IAS-2004]
(a) Ahead of super heater for initial superheating
(b) For optimizing steam output from the generator
(c) To regulate steam pressure
(d) To control degree of superheat
IAS-1. Ans. (d)

IAS-2. 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
IAS-2. Ans. (b)

IAS-3. 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.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IAS-3. Ans. (a)

IAS-4. **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]**
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IAS-4. Ans. (a)

IAS-5. **There is no steam drum in** **[IAS-2001]**
(a) La Mont boiler (b) Loffler boiler (c) Benson boiler (d) Velox boiler

IAS-5. Ans. (c)

IAS-6. **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]**
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IAS-6. **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 is true and R is also explanation for A.

Velox boiler

IAS-7. **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

IAS-7. **Ans. (b)** Due to supersonic flue gas velocity in the Velox Boiler larger heat transfer from a smaller surface area is possible.

4. Steam Turbine

Previous Years GATE Questions

Optimum velocity ratio

GATE-1. Given, V_b = Blade speed **[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) $V_b = V^2\cos\alpha$

GATE-1. Ans. (a)

GATE-2. 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 **[GATE-1994]**
(a) 334 (b) 356 (c) 668 (d) 711

GATE-2.Ans. (c) Just use $u = \frac{V\cos\alpha}{2}$ and $u = \frac{\pi DN}{60}$

Pressure compounding (Rateau Turbine)

GATE-3. 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

GATE-3. Ans. (a)

Reheating Steam

GATE-4. 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

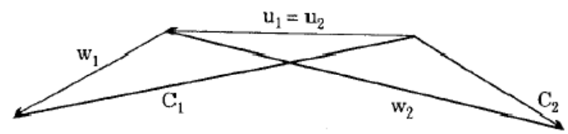
GATE-4. Ans. (d)

GATE-5. 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

GATE-5. Ans. (d)

Velocity diagram for reaction turbine blade

GATE-6. 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.



(a) an impulse turbine **[GATE-2005]**
(b) a reaction turbine
(c) a centrifugal compressor
(d) an axial flow compressor

GATE-6.Ans. (d)

Energy Losses in Steam Turbines

GATE-7. 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

GATE-7. Ans. (b) Enthalpy drop = Power output + losses
Or 3000 – 2700 = 250 + losses
Or losses = 50 kJ to the surrounding

Condensers

GATE-8. 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. [GATE-1999]
(a) 25°C (b) 30°C (c) 42°C (d) 48° C

GATE-8. Ans. (b) It should be greater than 27°C

GATE-9. 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.

GATE-9. 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.

Previous Years IES Questions

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

(a) Pressure coefficient (b) Slip factor **[IES-2006]**
(c) Work factor (d) Degree of reaction

IES-1. Ans. (a)

IES-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 sides
(d) The flange connecting the turbine exit to the condenser

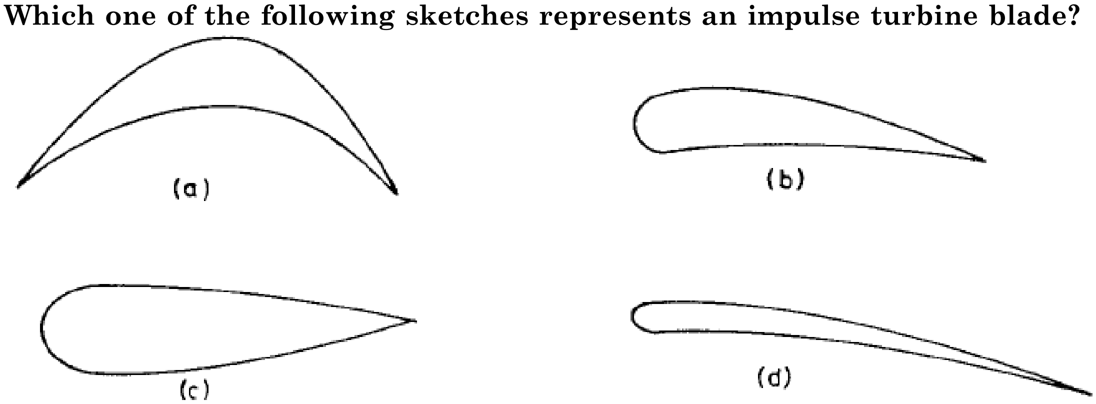
IES-2. Ans. (a) Diaphragm in steam turbines is a separating wall between rotors carrying nozzles.

Impulse Turbines

IES-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

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

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



[IES-1995]

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

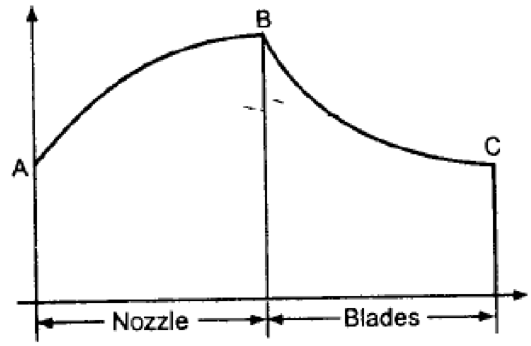
IES-5. Steam enters a De Laval steam turbine with an inlet velocity of 30 m/s and leaves with an outlet velocity of 10 m/s. The work done by 1kg of steam is
(a) 400 Nm (b) 600 Nm (c) 800 Nm (d) 1200Nm **[IES-2003]**

IES-5. Ans. (a)

The work done by 1kg of steam is $= \frac{1}{2}m\left(V_1^2 - V_2^2\right) = \frac{1}{2}\times 1\times\left(30^2 - 10^2\right) = 400\,Nm$

IES-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

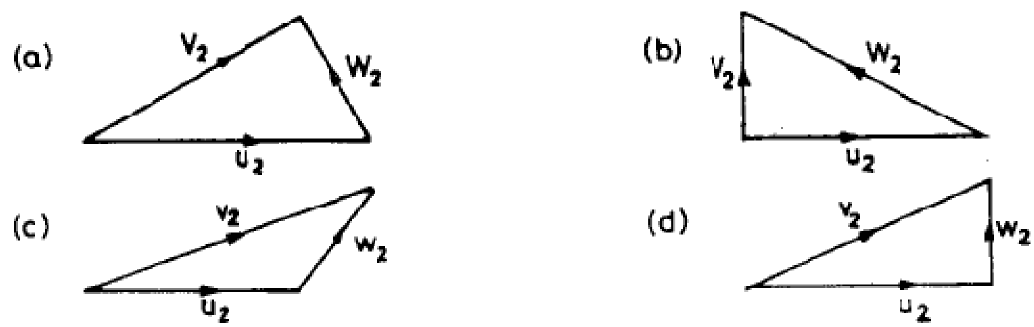


[IES-2001]

IES-6. Ans. (b)

Velocity diagram

IES-7. **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).



IES-7. 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.

Axial Thrust

IES-8. **Consider the following statements in respect of impulse steam turbines:**
1. Blade passages are of constant cross-sectional area. [IES-2006]
2. 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

IES-8. Ans. (a)

Diagram work (Blading Work)

IES-9. **In an axial flow impulse turbine, energy transfer takes place due to**
(a) Change in relative kinetic energy **[IES-2006]**
(b) Change in absolute kinetic energy
(c) Change in pressure energy
(d) Change in energy because of centrifugal force

IES-9. Ans. (b)

IES-10. **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?**

(a) 200 N (b) 175 N (c) 150 N (d) 125 N **[IES-1997]**

IES-10. Ans. (d) Power = $\dfrac{m(V_{w1}-V_{w2})V_b}{1000}kW,\ or\ 50=\dfrac{m(V_{w1}-V_{w2})400}{1000}$

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

IES-11. 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
(a) 79 m/s (b) 188m/s (c) 450 m/s (d) 900 m/s **[IES-1993]**

IES-11. Ans. (c) Blade speed ratio = $\dfrac{\text{blade speed}}{\text{velocity of steam at entry}}$

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

Optimum velocity ratio

IES-12. Given, V_b = Blade speed **[IES-1997; 2001]**
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) $V_b = V^2\cos\alpha$

IES-12. Ans. (a)

Compounding of turbine

IES-13. 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

IES-13. Ans. (b)

IES-14. 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

IES-14. Ans. (b)

IES-15. 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: **[IES-1995]**

List I	List II
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

IES-15 Ans. (c)

IES-16. **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.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-16. Ans. (a)

IES-17. **The compounding of steam turbines is done to** **[IES-1992; 1999]**
(a) Improve efficiency (b) reduce turbine speed
(c) Increase blade speed ratio (d) reduce axial thrust

IES-17. Ans. (b) The compounding of steam turbine is done to reduce turbine speed.

IES-18. **Running speeds of steam turbine can be brought down to practical limits by which of the following method(s)?** **[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

IES-18. Ans. (d)

Pressure compounding (Rateau Turbine)

IES-19. **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

IES-19. Ans. (b)

Velocity compounding (Curtis Turbine)

IES-20. **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%.
(a) 1, 2 and 3 (b) 1 and 2 (c) 1 and 3 (d) 2 and 3.

IES-20. Ans. (b) 3 is wrong because blade velocity coefficient for an impulse turbine is of the order less than 50%. $u = \dfrac{V\cos\alpha}{2}$

IES-21. **In a simple impulse turbine the nozzle angle at the entrance is 30°. For maximum diagram efficiency what is the blade-speed ratio?** **[IES-2009]**
(Note: sin 30° = 0·5, cos 30° = 0·866, sin 15° = 0·259, cos 15° = 0.966)

(a) 0·259 (b) 0·75 (c) 0·5 (d) 0.433

IES-21.Ans. (d) For maximum efficiency of Impulse turbine.

$$\text{Blade speed ratio} = \frac{\cos\alpha}{2}$$

$$= \frac{\cos 30}{2} = \frac{0.866}{2} = 0.433$$

IES-22. **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.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-22. Ans. (a)

IES-23. **The net result of pressure-velocity compounding of steam turbine is:**
(a) Less number of stages **[IES-1997]**
(b) Large turbine for a given pressure drop
(c) Shorter turbine for a given pressure drop
(d) Lower friction loss

IES-23. Ans. (a) Pressure-velocity compounding of steam turbines results is less number of stages

Work done in different stages

IES-24. **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

IES-24. Ans. (b) work done in different stages in velocity compounding is

$$W_1 : W_2 : W_3 : W_4 = 7 : 5 : 3 : 1$$

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

Reaction Turbine (Parson's Turbine)

IES-25. **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

IES-25. Ans. (d)

IES-26. **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

IES-26. Ans. (c) 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.

IES-27. **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.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-27. Ans. (a)

IES-28. **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.

IES-28. Ans.(c) Ascending order for efficiency is De Laval, Curtis, Rateau, Parson's.

IES-29. **Match List-I (Machines) with List-II (Features) and select the correct answer using the codes given below the lists:** **[IES-2001]**

List-I (Machines)	List-II (Features)
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

IES-29. Ans. (b)

IES-30. **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.

IES-30. 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.

IES-31. **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.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-31. Ans. (b)

IES-32. Partial admission steam turbine refers to the situation where the
(a) Steam is admitted partially into the blades through nozzles **[IES-2000]**
(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

IES-32. Ans. (c)

Degree of reaction

IES-33. If the enthalpy drop in the moving blades and fixed blades of a steam turbine is 10 kJ/kg and 15 kJ/kg respectively then what is the degree of reaction? [IES-2009]
(a) 67% (b) 60% (c) 40% (d) 33%

IES-33. Ans. (c) Degree of reaction $= \dfrac{10}{10+15} = \dfrac{10}{25} = 0.4$

IES-34. 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?
(a) 0·533 (b) 0·284 (c) 0·466 (d) 1·875 **[IES-2006]**

IES-34. Ans. (a) Degree of reaction $= \dfrac{(\Delta h)_{mb}}{(\Delta h)_{fb} + (\Delta h)_{mb}} = \dfrac{(\Delta h)_{mb}}{(\Delta h)_{total}} = \dfrac{32}{60} = 0.533$

IES-35. 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

IES-35. Ans. (c)

IES-36. 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 [IES-2003]
(a) 0.52 (b) 0.43 (c) 0.34 (d) 0.26

IES-36. Ans. (c) degree of reaction $= \dfrac{(\Delta h)_{mb}}{(\Delta h)_{mb} + (\Delta h)_{fb}} = \dfrac{2.38}{2.38+4.62} = 0.34$

IES-37. 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.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-37. 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%.

IES-38. 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 [IES-1998]
(a) 1/3 (b) 1/2 (c) 2/3 (d) 3/4

IES-38. Ans. (c) Degree of reaction $= \dfrac{\text{heat drop in moving blade}}{\text{heat drop in both blades}} = \dfrac{30}{45} = \dfrac{2}{3}$

IES-39. **The degree of reaction of a turbine is defined as the ratio of**
(a) Static pressure drop to total energy transfer **[IES-1993; 1995]**
(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

IES-39. Ans. (a) Degree of reaction of turbine is ratio of static pressure drop to total energy transfer

IES-40. **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

IES-41. Ans. (d) Enthalpy drop in moving blades = $\dfrac{V_{r_2}^2 - V_{r_1}^2}{2\times1000} = \dfrac{152^2 - 79^2}{2000}$ = 8.43 kJ/kg

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

IES-42. **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

IES-42. Ans. (a) Degree of reaction $= \dfrac{\Delta h\ (\text{moving blade})}{\Delta h\ (\text{moving blade}) + \Delta h\ (\text{fixed blade})} = 0.4$

IES-43. **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%

IES-43. Ans. (c)

100% Reaction Turbine (Hero's Turbine)

IES-44. **Consider the following statements regarding a 100% reaction turbine:**
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 **[IES-2000]**
Which of these statements is/are correct?
(a) 1 alone (b) 2 alone (c) 2 and 3 (d) 1 and 3

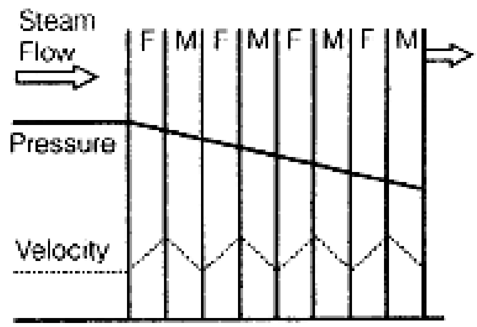
IES-44. Ans. (d)

IES-45. **Assertion (A):** Reaction turbines are not built on pure reaction principle.
Reason (R): Pure reaction is difficult to realise in practice. **[IES-1998]**
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-45. Ans. (a)

Velocity diagram for reaction turbine blade

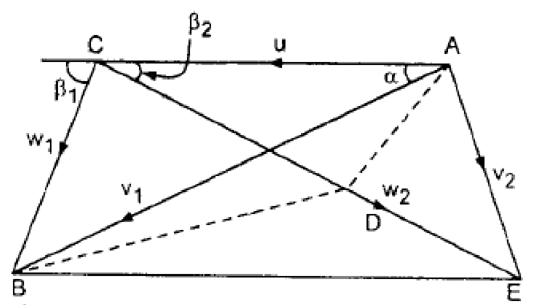
IES-46.



The pressure and velocity diagram as shown in the figure above for a steam turbine refers to which one of the following:
(Where: M-moving blade, F-fixed-blade) **[IES-2009]**
(a) Impulse turbine-Velocity compounded
(b) Impulse turbine-Pressure compounded
(c) Impulse turbine-Pressure and Velocity compounded
(d) Reaction turbine stages

IES-46. Ans. (d)

IES-47. 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

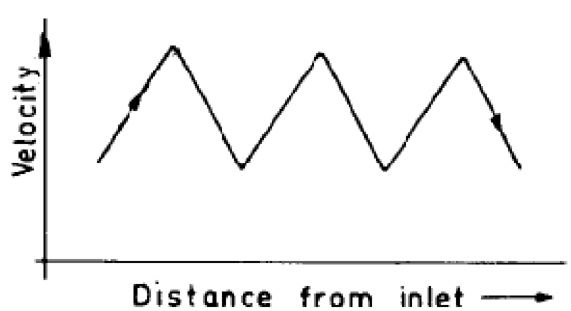


[IES-2000]

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

IES-47. Ans. (c)

IES-48. 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



[IES-1995]

IES-48. Ans. (d) Velocity diagram shown in figure is for Parson's turbine.

IES-49. **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) $\beta_1 = \beta_2$

IES-49. Ans. (b)

IES-50. **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]**

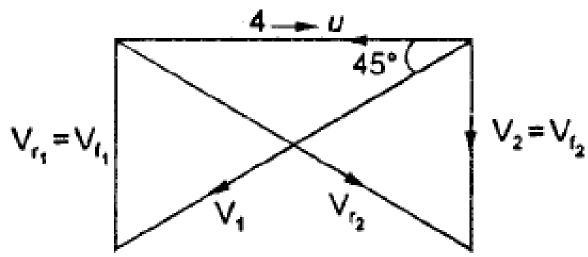
(a) 2500 m^2/s^2 (b) 3270 m^2/s^2 (c) 4375 m^2/s^2 (d) 5625 m^2/s^2

IES-50. 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 = $u \times \left(V_{w1} + V_{w2}\right) = 75 \times 75 = m^2/s^2$



Optimum velocity ratio

IES-51. **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) $V \cos\alpha$

IES-51. Ans. (d)

Diagram work (Blading Work)

IES-52. **For maximum blade efficiency (utilization factor), what is the work (J/kg) done in a single stage 50% reaction turbine? [IES 2007]**

(a) $2u^2$ (b) $1/u^2$ (c) u^3 (d) u^2

IES-52. Ans. (d)

IES-53. **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.

(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-53. Ans. (d)

Condition for maximum efficiency and Turbine Efficiencies

IES-54. **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.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-54. Ans. (b)

IES-55. **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.

IES-55. Ans. (a)

'State Point Locus' and 'Reheat Factor'

IES-56. **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

IES-56. Ans. (a)

IES-57. **Which one of the following statements is correct? [IES-2000]**

(a) Reheat factor is zero if efficiency of the turbine is goes 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.

IES-57. Ans. (b)

IES-58. **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: Enhances blade erosion through the turbine

IES-58. Ans. (c)

IES-59. **Which one of the following pairs is correctly matched? [IES-1993]**

(a) Stage efficiency $=\dfrac{\text{actual enthalpy drop}}{\text{isentropic enthalpy drop}}$

(b) Nozzle efficiency $=\dfrac{\text{work delivered}}{\text{isentropic enthalpy drop}}$

(c) Diagram efficiency $=\dfrac{\text{work deliveredby blades}}{\text{isentropic enthalpy drop}}$

(d) Blade efficiency $=\dfrac{\text{workdone on moving blades}}{\text{actual enthalpy drop}}$

IES-59. Ans. (a)

IES-60. **Given, [IES-2008]**
η_s = stage efficiency
η_n = nozzle efficiency
η_b = blade efficiency
Which one of the following is correct?

(a) $\eta_n = \eta_b \eta_s$ (b) $\eta_b = \eta_s \eta_n$ (c) $\eta_b \times \eta_n \times \eta_s = 1$ (d) $\eta_s = \eta_b \eta_n$

IES-60. Ans. (d)

Energy Losses in Steam Turbines

IES-61. **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

IES-61. Ans. (c)

Steam Turbine Governing and Control

IES-62. **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.

(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-62. Ans. (b) Both A and R are true, but R is not a correct explanation of A

Throttle governing

IES-63. **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]**

(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-63. Ans. (d)

IES-64. **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 are correct?

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

IES-64. Ans. (d)

IES-65. **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]**

(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

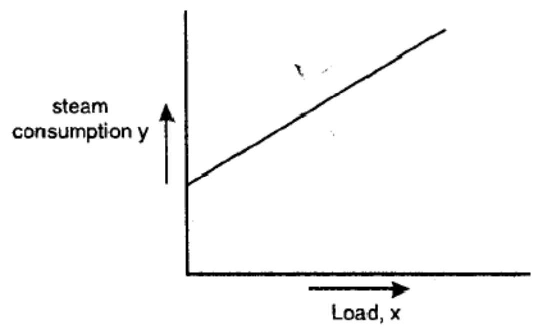
IES-65. Ans. (d) A cut off governing engine has better efficiency than throttle governed engine. Statement at R is correct.

IES-66. **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.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-66. Ans. (c) A is correct. R is true for nozzle governing.

IES-67. **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 lHP will be nearly** **[IES-1992]**
(a) 150 kg/hr (b) 156 kg/hr (c) 241 kg/hr (d) 290 kg/hr

IES-67. 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.



IES-68. **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

IES-68. Ans. (a)

Nozzle governing

IES-69. **Assertion (A):** Nozzle control governing cannot be used in reaction steam turbines.
Reason (R): In reaction steam turbines, full admission of steam must take place.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false **[IES-2006]**
(d) A is false but R is true

IES-69. Ans. (a)

IES-70. **Consider the following statements regarding the nozzle governing of steam turbines:** **[IES-1995]**
1. Working nozzles receive steam at full pressure
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

IES-70. Ans. (a)

IES-71. 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

IES-71. Ans. (c)

Emergency governing

IES-72. 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

IES-72. Ans. (a)

IES-73. An emergency governor of a steam turbine trips the turbine when
1. Shaft exceeds 100% of its rated speed [IES-2003]
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:
(a) 1, 2 and 3 (b) 2, 3 and 4 (c) 3, 4 and 1 (d) 4, 1 and 2

IES-73. Ans. (b)

IES-74. 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]**
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-74. Ans. (a) Both A and R are individually true and R is the correct explanation of A

Blading and Fastening

IES-75. 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

IES-75. Ans. (a)

IES-76. 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

IES-76. 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.

IES-77. **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 m³/s. The blade height at this section will be approximately:**

(a) 4 cm (b) 2 cm (c) 1 cm (d) 0.5 cm **[IES-1997]**

IES-77. **Ans. (b)** Steam flow = $\pi D \times \text{height of blade} \times V$

$$or\ \text{height of blade} = \frac{5.4 \times 100}{3.14 \times 1.8 \times 49} \approx 2\,cm$$

IES-78. **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.

(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-78. Ans. (c) A is correct. R is true for erosion more than corrosion.

IES-79. **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.

IES-79. Ans. (a)

Condensers

IES-80. **In a surface condenser used in a steam power station, under cooling of condensate is undesirable at this would** **[IES-1996]**

(a) Not absorb the gases in steam.
(b) Reduce efficiency of the plant.
(c) Increase the cooling water requirements.
(d) Increase thermal stresses in the condenser.

IES-80. 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

Air Pumps

IES-81. **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.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-81. Ans. (a) Both A and R are true and R is right explanation for A.

Cooling Towers

IES-82. Which one of the following is the correct statement? [IES 2007]
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-82. Ans. (d)

IES-83. 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 [IES-1997]
(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-83. Ans. (d) The difference is due to evaporation

IES-84. In a cooling tower, "approach" is the temperature difference between the
(a) hot inlet water and cold outlet water **[IES-1996]**
(b) hot inlet water and WBT
(c) cold outlet water and WBT
(d) DBT and WBT

IES-84. Ans. (c) Cooling towers are rated in terms of **approach** and **range,** where
- The **approach** is the difference in temperature between the cold water temperature leaving the tower and the entering-air *wet bulb* - t_{wb} - temperature
- The **range** is the temperature difference between the water inlet and exit states

Since a cooling tower is based on evaporative cooling the maximum cooling tower **efficiency** is limited by the *wet bulb temperature* - t_{wb} - of the cooling air.

Previous Years IAS Questions

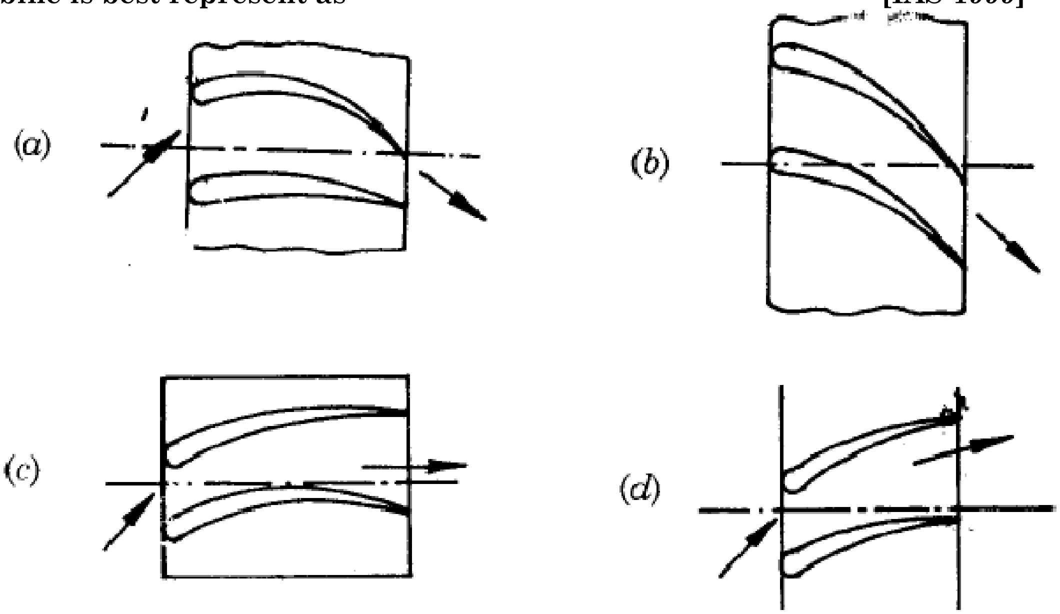
Impulse Turbines

IAS-1. 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

IAS-1. Ans. (c)

IAS-2. **The blade passage for the nozzle blade row of the first stage of an impulse turbine is best represent as [IAS-1999]**



IAS-2. Ans. (a)

IAS-3. **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

IAS-3. Ans. (d) For free vortex V.r = const.

$$\therefore V_1r_1 = V_2r_2 \text{ or } V_2 = \frac{V_1r_1}{r_2} = 430\times\frac{250}{(250+100)} = 307 m/s$$

IAS-4. **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

IAS-4. Ans. (c)

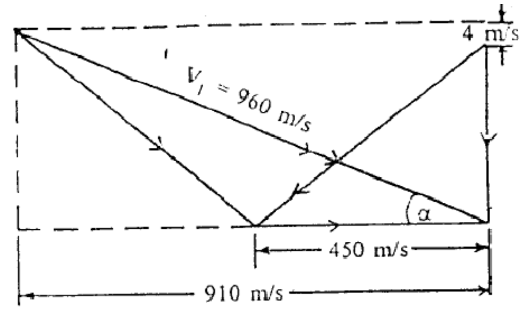
IAS-5. **In an axial flow steam turbine, the path traced by a fluid particle at the design point is a [IAS-1997]**
(a) Helix of constant radius (b) helix of varying radius
(c) Cycloidal path (d) toroidal path

IAS-5. Ans. (b)

Velocity diagram

IAS-6. 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]

IAS-6. Ans. (d) Tangential force $= \dot{m} \times \Delta V_w = 1 \times 910N = 910N$

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

IAS-7. 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

IAS-7. Ans. (c)

Diagram work (Blading Work)

IAS-8. 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

IAS-8. Ans. (a) $W = \left(\frac{V_1^2}{2} - \frac{V_2^2}{2}\right) + \left(\frac{V_{r_2}^2}{2} - \frac{V_{r_1}^2}{2}\right)$ [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

IAS-9. 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

IAS-9. Ans. (a) $u = \frac{V\cos\alpha}{2} \quad or \frac{u}{V} = \frac{\cos 30^o}{2} = \frac{\sqrt{3}}{4}$

IAS-10. For an impulse turbine with exit angle ‘’, the maximum efficiency is

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

[IAS-1999]

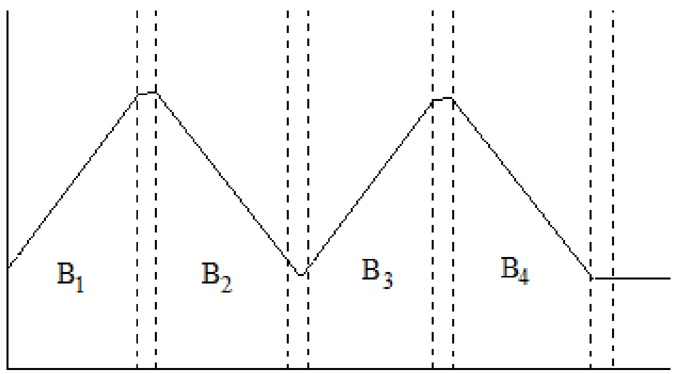
IAS-10. Ans. (c)

Pressure compounding (Rateau Turbine)

IAS-11. 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

1. The solid line represents velocity variation. [IAS-1994]
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 (d) 2 and 4 are correct



IAS-11. Ans. (b)

Velocity compounding (Curtis Turbine)

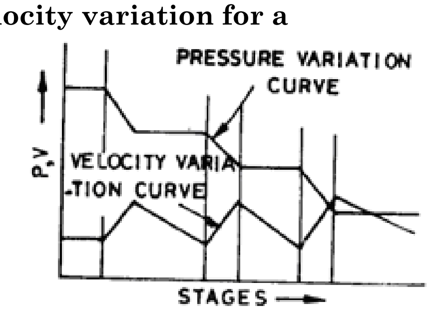
IAS-12. The given figure represents pressure and velocity variation for a

(a) Reaction type turbine

(b) Velocity compounded impulse turbine

(c) Pressure- velocity compounded impulse turbine

(d) Pressure compounded impulse turbine



[IAS-1995]

IAS-12. 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

IAS-13. In a two-row Curtis stage with symmetrical blading, [IAS-2002]
(a) Work done by both rows of moving blades are equal
(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

IAS-13. 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)

IAS-14. 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

IAS-14. 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

IAS-15. In a reaction turbine, the enthalpy drop in the fixed blade ring is 50 kJ per Kg and the enthaply drop in the moving blade ring is 25 kJ per Kg. The degree of reaction of the turbine is [IAS-1995]
(a) 66.7% (b) 50.0% (c) 33.3% (d) 6.0%

IAS-15. Ans. (c) 25/75

IAS-16. 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 [IAS-2002]
(a) 0.1 (b) 0.45 (c) 0·55 (d) 1·0

IAS-16. Ans. (b) degree of reaction= $\frac{(\Delta h)_{nb}}{(\Delta h)_{mb}+(\Delta h)_{fb}}=\frac{9}{9+11}=0.45$

IAS-17. 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

IAS-17. Ans. (c)

IAS-18. 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%

IAS-18. Ans. (a) $\text{Degree of reaction} = \dfrac{(\Delta h)_{\text{moving blade}}}{(\Delta h)_{\text{fixed blade}} + (\Delta h)_{\text{moving blade}}} = \dfrac{32}{48+32} = 0.4$

IAS-19. **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**
(a) 20% (b) 40% (c) 60% (d) 70% **[IAS-1998]**

IAS-19. Ans. (b) Degree of reaction = $\dfrac{(\Delta h)_{mb}}{(\Delta h)_{fb} + (\Delta h)_{mb}} = \dfrac{40}{40+60} = 0.4$

IAS-20. **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

IAS-20. Ans. (d)

IAS-21. **Symmetrical blading is used in a turbine when its degree of reaction is %**
(a) 25% (b) 50% (c) 75% (d) 100 **[IAS-1995]**

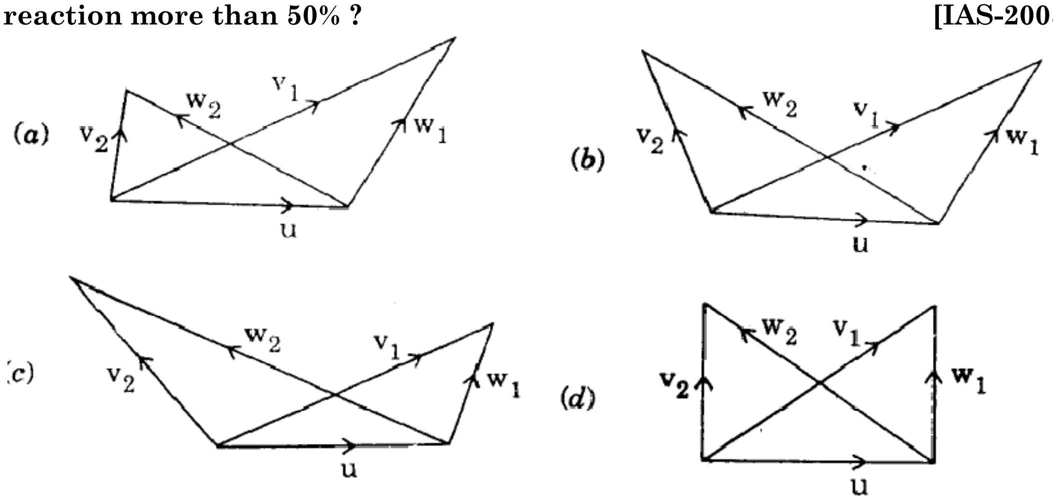
IAS-21. Ans. (b)

IAS-22. **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

IAS-22.Ans. (a)

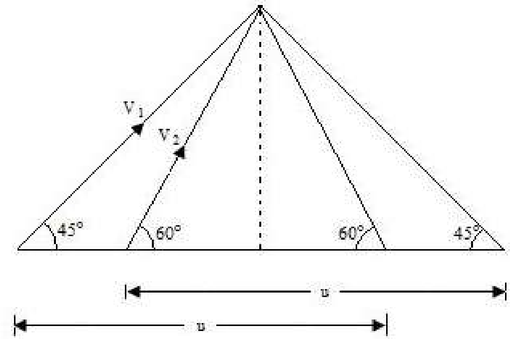
Velocity diagram for reaction turbine blade

IAS-23. **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]**



IAS-23.Ans. (c)

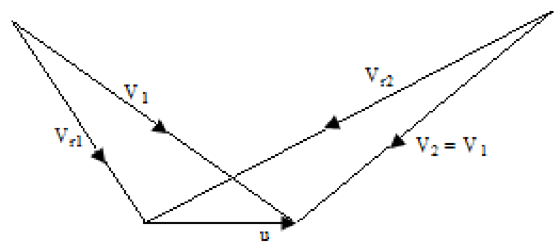
IAS-24. **The given figure represents velocity diagram for a tubomachine stage. The stage in question is**
(a) power absorbing and 50%reaction
(b) power absorbing and impulse
(c) power generating and 50% reaction
(d) power generating and impulse



[IAS-1999]

IAS-24.Ans. (c)

IAS-25. **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?**



[IAS-1997]

(a) Pure impulse (b) Pure reaction
(c) 50% reaction (d) 25% reaction

IAS-25. Ans. (b)

Optimum velocity ratio

IAS-26. **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

IAS-26. Ans. (c) The impulse turbine rotor efficiency, $\eta = (1+kc)\dfrac{\cos^2\alpha_1}{2}$

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

Diagram work (Blading Work)

IAS-27. **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

IAS-27. 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

IAS-28. **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]**

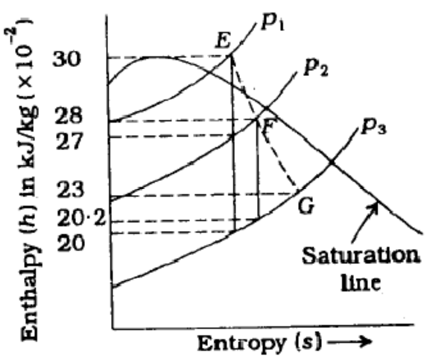
(a) 352 kW (b) 347 kW (c) 338 kW (d) 332 kW

IAS-28. Ans. (c) $W = (\Delta h)_{total} \times \eta_{nozzle} \times \eta_{rotor}$ or $(\Delta h)_{total} = \frac{280}{0.92\times 0.9} = 338\,KW$

'State Point Locus' and 'Reheat Factor'

IAS-29. **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]

IAS-29. Ans. (a) R.F = $\frac{(30-27)+(28-20.2)}{(30-20)} = 1.08$

IAS-30. **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.** $\frac{\text{Adiabatic heat drop}}{\text{Heat supplied}}$
B. Internal efficiency	**2.** $\frac{\text{Total work done on the rotor}}{\text{Total adiabatic heat drop}}$
C. Degree of reaction	**3.** $\frac{\text{Cumulative heat drop of all stages}}{\text{Total adiabatic heat drop}}$
D. Rankine efficiency	**4.** $\frac{\text{Enthalpy drop in moving blades}}{\text{Enthalpy drop in the stage}}$

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

IAS-30. Ans. (a)

Nozzle governing

IAS-31. **In the case of nozzle governed steam turbines, stage efficiencies vary very little when compared with those with full steam flow because [IAS-1997]**
(a) Mass flow rate does not affect the stage efficiency
(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
IAS-31. Ans. (*)

Blading and Fastening

IAS-32. **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
IAS-32. Ans. (c) both increases impact between blade and droplet of water.

Condensers

IAS-33. **An Important parameter to be monitored continuously for safeguarding turbine rotor in a steam power plant is [IAS-1997]**
(a) Steam inlet pressure (b) steam inlet temperature
(c) Shaft vibration level (d) beaming temperatures**]**
IAS-33. Ans. (d)

Condenser Efficiency

IAS-34. **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]**
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true
IAS-34. Ans. (a)

IAS-35. **The presence 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
IAS-35. Ans. (a)

IAS-36. **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

IAS-36. Ans. (a) Condenser pressure = partial pressure of steam + partial pressure of air = 0.06 + 0.07 = 0.067 bar

Cooling Towers

IAS-37. 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.

IAS-37. Ans. (d)

5. Flue Gas Analysis

Previous Years GATE Questions

Combustion (Stoichiometric Air)

GATE-1. 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). [GATE-1995]

(a) 3 (b) 4 (c) 5 (d) 6

GATE-1. Ans. (b)

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

16 kg 64 kg

16 kg of CH_4 requires 64 kg of oxygen

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

Pulverized coal furnace for fine particle

GATE-2. 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

GATE-2. Ans. (c)

Previous Years IES Questions

Coal Analysis

IES-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

IES-1. Ans. (d)

IES-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

IES-2. **Ans. (d)** LPG is a predominant mixture of propane and Butane with a small percentage of unsaturates (Propylene and Butylene) and some lighter C_2 as well as heavier C_5 fractions. Included in the LPG range are propane (C_3H_8), Propylene (C_3H_6), normal and iso-butane (C_4H_{10}) and Butylene (C_4H_8).

Proximate Analysis

IES-3. **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

IES-3. Ans. (a)

Ultimate Analysis

IES-4. **Volumetric analysis of sample of dry products -of combustion gave the following results: [IES-1993]**

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

Their proportions by weight will be

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

IES-4. 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).

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

IES-5. **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

IES-5. Ans. (d)

IES-6. **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

IES-6. Ans. (b)

IES-7. **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]**
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-7. Ans. (d) The higher heating value is experimentally determined in a bomb calorimeter by concealing a stoichiometric mixture of fuel and oxidizer (e.g., two moles of hydrogen and one mole of oxygen) in a steel container at 25 °C. Then the exothermic reaction is initiated by an ignition device and the combustion reactions completed. When hydrogen and oxygen react during combustion, water vapor emerges. Subsequently, the vessel and its content are cooled down to the original 25 °C and the higher heating value is determined as the heat released between identical initial and final temperatures.

IES-8. **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

IES-8. Ans. (d)

HHV and LHV

IES-9. **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

IES-9. Ans. (c) Since CO does not have hydrogen content; the HCV and LCV are same

IES-10. **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

IES-10. Ans. (c) 2 is wrong therefore correct choice will be (c)

IES-11. **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) 1 alone is correct (b) 1 and 3 are correct
(c) 2 and 4 are correct (d) 3 and 4 are correct

IES-11. Ans. (b)

Combustion (Stoichiometric Air)

IES-12. **Consider the following:**
Carbon **Carbon-monoxide**
Hydrogen, **Sulphur**
What is the amount of oxygen (in kg) required for complete combustion of each one of the above respectively? **[IES-2008]**
(a) 1, 8, 8/3, 4/7 (b) 4/7, 1, 8, 8/3
(c) 8/3, 4/7, 8, 1 (d) 8, 1, 4/7, 8/3

IES-12. Ans. (c)

$$C + O_2 \rightarrow CO_2$$
$$12\,kg + 32Kg = 44Kg$$
$$2CO + O_2 \rightarrow 2CO_2$$
$$56\,kg + 32Kg = 88Kg$$
$$2H_2 + O_2 \rightarrow 2H_2O$$
$$4\,kg + 32Kg = 36Kg$$
$$S + O_2 \rightarrow SO_2$$
$$32\,kg + 32Kg = 64Kg$$

IES-13. **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

IES-13. Ans. (a)

IES-14. **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]**

IES-14. Ans. (d)

$$12\text{kg of C} + 32\text{ kg of } O_2 \rightarrow 44\text{ kg of } CO_2$$
$$\text{Or } 1\text{ kg of C} + \frac{8}{3}\text{kg of } O_2 \rightarrow \frac{11}{3}\text{kg of } CO_2$$

IES-15. **Methane burns with stoichiometric quantity of air. The air/fuel ratio by weight is** **[IES-1999]**
(a) 4 (b) 14.7 (c) 15 (d) 17.16

IES-15. Ans. (d)

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

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

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

Since air contains 23% ofoxygen by weight,

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

IES-16. 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) $11.6C-34.8\left(H-\frac{O}{8}\right)+4.35S$

IES-16. 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 = $\frac{100}{23}\left[\frac{8}{3}C+8\left(H_2-\frac{O_2}{8}\right)+S\right]$

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

IES-17. 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.1152C + 0.3456 (H - 0.125 O) + 0.0432S
(d) 0.1152C + 0.3456 (H + 0.125) + 0.0432S.

IES-17. Ans. (c) Mass of air for complete combustion is 0.1152C + 0.3456 (H - 0.125 O) + 0.0432 S.

IES-18. 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

IES-18. Ans. (d)

Pulverized coal furnace for fine particle

IES-19. Match List I with List II and select the correct answer. [IES-1994]

List I	**List II**
A. Bin system	**1. Dust collection.**
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

IES-19.Ans.(b)

Cyclone Furnaces: Cyclone furnaces were developed after pulverized coal systems and require less processing of the coal fuel. They can burn poorer grade coals with higher moisture contents and ash contents to 25%. The crushed coal feed is either stored temporarily in bins or transported directly to the cyclone furnace. The furnace is basically a large cylinder jacketed with water pipes that absorb the some of the heat to make steam and protect the burner itself from melting down. A high powered fan blows the heated air and chunks of coal into one end of the cylinder. At the same time additional heated combustion air is injected along the curved surface of the cylinder causing the coal and air mixture to swirl in a centrifugal "cyclone" motion. The whirling of the air and coal enhances the burning properties producing high heat densities (about 4700 to 8300kW/m^2) and high combustion temperatures.

The hot combustion gases leave the other end of the cylinder and enter the boiler to heat the water filled pipes and produce steam. Like in the pulverized coal burning process, all the fuel that enters the cyclone burns when injected once the furnace is at its operating temperature. Some slag remains on the walls insulating the burner and directing the heat into the boiler while the rest drains through a trench in the bottom to a collection tank where it is solidified and disposed of. This ability to collect ash is the biggest advantage of the cyclone furnace burning process. Only 40% of the ash leaves with the exhaust gases compared with 80% for pulverized coal burning. Cyclone furnaces are not without disadvantages. The coal used must have a relatively low sulfur content in order for most of the ash to melt for collection. In addition, high power fans are required to move the larger coal pieces and air forcefully through the furnace, and more nitrogen oxide pollutants are produced compared with pulverized coal combustion. Finally, the actual burner requires yearly replacement of its liners due to the erosion caused by the high velocity of the coal.

IES-20. 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

IES-20. Ans. (c)

IES-21. Coal fired power plant boilers manufactured in India generally use:
(a) Pulverised fuel combustion **[IES-1997]**
(b) Fluidised bed combustion
(c) Circulating fluidised bed combustion
(d) Moving stoker firing system

IES-21. 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.

Fluidized bed furnace for crushed small particle

IES-22. Consider the following statements regarding the fluidized bed combustion boilers:
1. The combustion temperatures are low, around 900^{o}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

IES-22. Ans. (b)

IES-23. Which one of the following statements is *not* correct? In a fluidized-bed boiler? [IES-2001]
(a) The combustion temperatures are higher than those in the conventional boilers
(b) Inferior grade of coal can be used without slagging problems
(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

IES-23. Ans(a). Fluidized bed combustion has emerged as a viable alternative and has significant advantages over conventional firing system and offers multiple benefits – compact boiler design, fuel flexibility, higher combustion efficiency and reduced emission of noxious pollutants such as SO_x and NO_x. The temperature of about 870°C is reasonably constant throughout the process because of the high turbulence and circulation of solids. The low combustion temperature also results in minimal NO_x formation.

IES-24. In fluidized bed combustion velocity of fluid is proportion of (r =radius of the particle) as [IES-1992]
(a) $\frac{1}{r}$ (b) $\frac{1}{\sqrt{r}}$ (c) $\sqrt{r}$ (d) r

IES-24. 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)

IES-25. 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: [IES 2007]

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:	**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

IES-25. Ans. (c)

IES-26. **The combustion analysis carried out by the Orsat Apparatus renders which one of the following? [IES 2007]**
(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-26. 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.

IES-27. **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 1 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

IES-27. 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

IES-28. **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? [IES-2004]**
(a) Potassium hydroxide solution - alkaline solution of Pyrogallic acid - cuprous chloride solution
(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

IES-28. Ans. (a)

IES-29. **Orsat apparatus is used to determine products of [IES-2003]**
(a) All constituents 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

IES-29. Ans. (d)

IES-30. **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%

IES-30. Ans. (c)

IES-31. **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

IES-31. Ans. (d)

IES-32. **In the Orsat flue gas analyser, ammoniacal cuprous chloride is used to absorb.** **[IES-1995]**
(a) CO_2 (b) CO (c) O_2 (d) N_2

IES-32. Ans. (b)

IES-33. **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

IES-33. Ans. (c)

IES-34. **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

IES-34. Ans. (c)

IES-35. **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

IES-35. Ans. (b) Air contains 23 % oxygen by weight and 21 % oxygen by volume.

IES-36. **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%.

IES-36. Ans. (b) when solid fuels are burnt, the nitrogen content of flue gas by volume is about 70%.

Excess Air

IES-37. **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.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-37. Ans. (c)

IES-38. **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]**

IES-38. Ans. (d) Greater surface area per unit mass of coal allows faster combustion reactions because more carbon becomes exposed to heat and oxygen, This reduces the excess air needed to complete combustion. The excess air required for combustion of pulverised coal is of the order of 5 to 10%

IES-39. **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.

IES-39. Ans. (a) O_2 = 9.6 means excess air is used

IES-40. **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.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-40. Ans. (d) Excess air up to a limit increases efficiency, but beyond that the efficiency decreases for the reason given in R

Fan

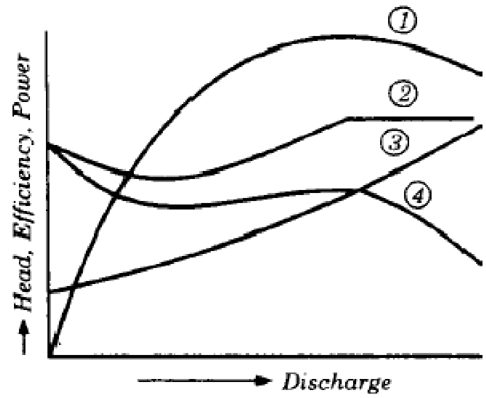
IES-41. **Consider the following statements:** **[IES-2006]**
1. Forward swept blade impeller is used in draft fans.
2. Forward swept blade impeller is used in room air-conditioners.
3. Radial tipped blade impeller is used in draft fans.
4. Forward swept blade impeller is used in exhaust fans.
Which 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

IES-41. Ans. (b)

IES-42. **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

IES-42. 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.

IES-43. 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]

IES-43. Ans. (d)

IES-44. 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

IES-44. Ans. (b)

IES-45. 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.

IES-45. Ans. (a) Induced draught fans of a large steam generator have backward curved blades

IES-46. Or 15 m³/s air flow at 10 mm Hg head, which one of the following would be the best choice? [IES-1994]
(a) Centrifugal fan with forward curved blades.
(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.

IES-46. Ans. (a)

IES-47. 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.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-47. Ans. (a)

IES-48. 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

IES-48. Ans. (d)

IES-49. 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)

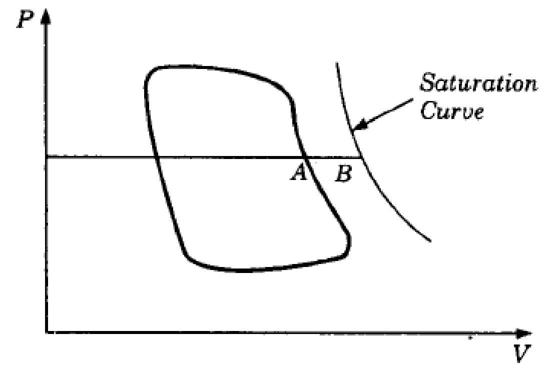
(a) $\left(\dfrac{Q_1}{Q_2}\right) = \left(\dfrac{N_1}{N_2}\right)^2$ (b) $\left(\dfrac{Q_1}{Q_2}\right) = \left(\dfrac{N_1}{N_2}\right)^3$

(c) $\left(\dfrac{Q_1}{Q_2}\right) = \left(\dfrac{D_1}{D_2}\right)^2$ (d) $\left(\dfrac{Q_1}{Q_2}\right) = \left(\dfrac{D_1}{D_2}\right)^3$

IES-49. Ans. (d)

Steam Engine

IES-50. 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]

IES-50. Ans. (c) The length AB in the figure represents the missing quantity.

IES-51. 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.

IES-51. Ans. (d) Ratio of actual indicated work to hypothetical indicated work in a steam engine is the diagram factor.

IES-52. 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

IES-52. 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.

IES-53. 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

IES-53. Ans. (b) The expansion ratio = $\dfrac{1}{\text{cut off ratio}} = \dfrac{1}{0.35} = 2.85$

Previous Years IAS Questions

Coal Analysis

IAS-1. 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

IAS-1. Ans. (b)

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

IAS-2. Which one of the following fuels is used to determine the water equivalent of a bomb calorimeter? [IAS-1997]
(a) Benzoic acid (b) Octane (c) Coke (d) Cetane

IAS-2. Ans. (a)

Combustion (Stoichiometric Air)

IAS-3. Amount of oxygen needed to completely burn l1lg of methane (CH_4) is
(a) 2 kg (b) 4 kg (c) 16 kg (d) 22 kg **[IAS-2001]**

IAS-3. Ans. (b)

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

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

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

Excess Air

IAS-4. 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

IAS-4. Ans. (d) pulverized coal combustion required less amount of excess air as it burns fine particles.

IAS-5. 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.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false
(d) A is false but R is true

IAS-5. 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

IAS-6. Inside a large power boiler, the flue gas pressure will be above the atmospheric pressure [IAS-2000]

(a) At the furnace
(b) near superheater region
(c) At the base of the chimney
(d) after the forced draught fan

IAS-6. Ans. (d)

IAS-7. 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

IAS-7. Ans. (b)

IAS-8. 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/m³) [IAS-1997]

(a) 10.97MW (b) 9.87MW (c) 9.21 MW (d) 8.78MW

IAS-8. Ans. (a)

$$P_1 = 101.325\,\text{kPa} = 10.33\,\text{m of } H_2O$$

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

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

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

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

6. Gas Turbine

Previous Years GATE Questions

Optimum pressure ratio

GATE-1. 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 **[GATE-2004]**

(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) $\left(\frac{T_{min}}{T_{max}}\right)^{\frac{\gamma-1}{\gamma}}$

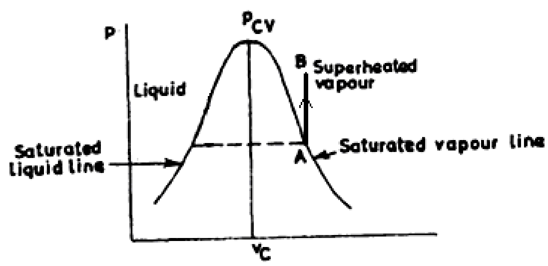
GATE-1. Ans. (a)

Number of stages etc

GATE-2. Isentropic compression of saturated vapour of all fluids leads to superheated vapour. **[GATE-1994]**

(a) True (b) False (c) Neither true not false (d) cant say

GATE-2. Ans. (a)



Reheating

GATE-3. A gas turbine cycle with heat exchanger and reheating improves

(a) Only the thermal efficiency **[GATE-1993]**
(b) Only the specific power output
(c) Both thermal efficiency and specific power output
(d) Neither thermal efficiency nor specific power output

GATE-3. Ans. (c)

Previous Years IES Questions

Advantages and disadvantages of Gas turbine

IES-1. Which one of the following is correct? **[IES-2007]**

(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

IES-1. Ans. (b)

IES-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
2. Gas turbine plants are heavier and larger in size than steam turbine plants
3. Gas turbines require 'cooling water for its operations
4. 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

IES-2. Ans. (c)

IES-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.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-3. Ans. (a)

IES-4. **Consider the following statements pertaining to gas turbines:** **[IES-2009]**
1. The degree of reaction of a reaction turbine is the ratio of energy transfer in fixed blade to the overall energy transfer across a stage.
2. The overall pressure drop in a turbine is the product of pressure drop per stage and number of stages.
3. Gas turbine cycle (Brayton cycle) is not as efficient as Rankine cycle for steam. Which of the above statements is/are correct?
(a) 1 only (b) 2 only (c) 2 and 3 (d) 3 only

IES-4. Ans. (d)

IES-5. **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.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-5. **Ans. (d)** A is false and R is true.

IES-6. **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]**
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false
(d) A is false but R is true

IES-6. Ans. (c) The air-fuel ratio might vary from about **60:1** to 120:**1** for simple **gas** turbines
and from 100:**1** to 200:**1** if a heat-exchanger is **employed**.

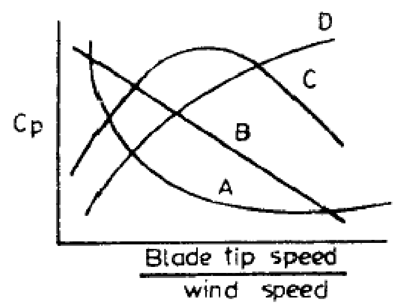
IES-7. **Assertion (A):** Gas turbines use very high air fuel ratio. **[IES-1995]**
Reason (R): The allowable maximum temperature at the turbine inlet is limited by available material considerations.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-7. Ans. (b) Though A and R are true, but R is not correct reason for A.

IES-8. **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

IES-8. Ans. (a) Low grade fuel can't be burnt in gas turbine since it leads to poor life of turbine blades, etc.

IES-9. **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]

IES-9. Ans. (d)

Joule cycle or Brayton cycle

IES-10. **A Bell-Coleman air refrigeration cycle works as a reversed:** **[IES-2005]**
(a) Stirling cycle (b) Otto cycle (c) Diesel cycle (d) Brayton cycle

IES-10. Ans. (d)

IES-11. **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.

(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-11. Ans. (b)

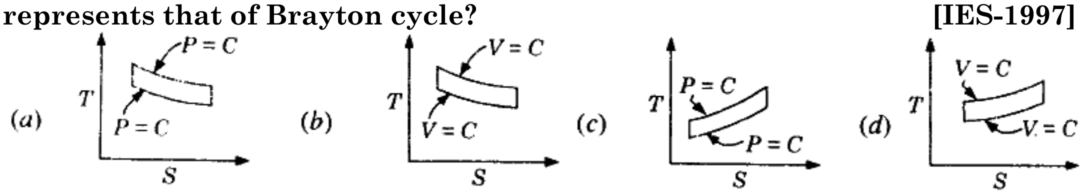
IES-12. **Assertion (A):** The thermal efficiency of Brayton cycle with regeneration decreases as the compressor ratio increases. **[IES-1999]**
Reason (R): As the compression ratio of compressor increases, the range of temperature in the regenerator decreases and the amount of heat recovered reduces.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-12. Ans. (a) $\eta_{th} = 1 - \left(\frac{T_{\min}}{T_{\max}}\right) r_p^{\frac{\gamma-1}{\gamma}}$

IES-13. A gas turbine works on which one of the following cycles? [IES-1998]
(a) Brayton (b) Rankine (c) Stirling (d) Otto

IES-13. Ans. (a)

IES-14. Which one of the thermodynamic cycles shown in the following figures represents that of Brayton cycle? [IES-1997]



IES-14. Ans. (c)

IES-15. For a Brayton cycle, match the following using codes given below: [IES-1992]

List I	List II
A. Compression	**1. Isothermal**
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	2	3	2

IES-15. Ans. (d)

IES-16. Use of maximum pressure ratio, corresponding to maximum to minimum cycle temperature ratio in case of Joule cycle gives which one of the following? [IES 2007]
(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-16. Ans. (a)

IES-17. Consider the following statements relating to a closed gas turbine cycle:
1. The cycle can employ monatomic gas like helium instead of air to

3. **The turbine blades suffer higher corrosion damages.**
4. **Higher output can be obtained for the same size.**

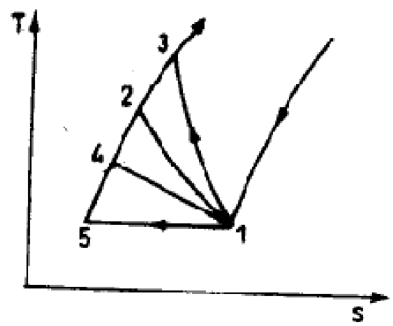
Which of these statements are correct? [IES-1999]

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

IES-17. Ans. (b) Item 3 is not correct and other items are correct.

IES-18. Consider the T-s diagram shown in the following figure: Actual compression process in gas turbines is indicated by the process.

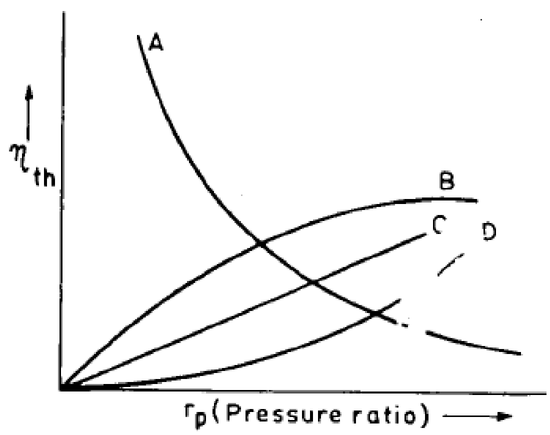
(a) 1-2
(b) 1-3
(c) 1-4
(d) 1-5



[IES-1994]

IES-18. Ans. (b) Curve 1-3 is actual compression process in gas turbine.

IES-19. 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 labelled

IES-19. Ans. (b)

Efficiency

IES-20. Consider the following statements in respect of gas turbines: [IES 2007]

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-20. Ans. (b)

IES-21. 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? [IES 2007]

(a) 61% (b) 16% (c) 18% (d) None of the above

IES-21. Ans. (b) take air = 80 kg so fuel = 1 kg

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

IES-22. 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: [IES-1997]

(a) 80% (b) 60% (c) 40% (d) 20%

IES-22. Ans. (d) $\frac{W_T - W_C}{Heat} = \frac{600-400}{1000} = 20\%$

Optimum pressure ratio

IES-23. 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

IES-23. Ans. (b)

IES-24. 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

IES-24. Ans. (b)

Maximum possible pressure ratio, (Rr)max

Maximum possible pressure ratio, $(R_p)_{max} = \left(\frac{T_2}{T_1}\right)^{\gamma/\gamma-1} = \left(\frac{1000}{300}\right)^{1.4/(1.4-1)} = \left(\frac{10}{3}\right)^{3.5}$

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

IES-25. 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 [IES-2001]

(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-25. Ans. (a)

Number of stages etc

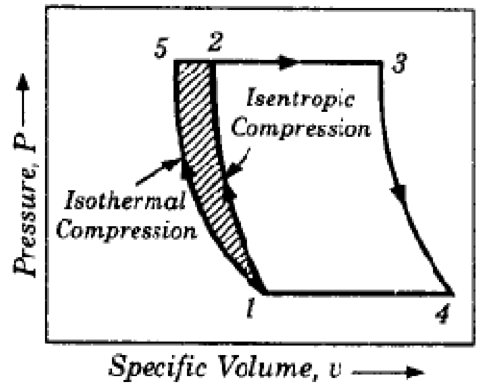
IES-26. In a single-stage open-cycle gas turbine, the mass flow through the turbine is higher than the mass flow through compressor, because [IES-1997]

(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

IES-26. Ans. (c) Due to combustion of fuel in combustion chamber, mass flow through turbine is higher than compressor

IES-27. 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 are (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]

IES-27. Ans. (a) Shaded area corresponds to increment in the compression work

IES-28. Which one of the following statements is correct? Increasing the number of reheating stages a gas turbine to infinity, makes the expansion tending: [IES-2009]

(a) Reversible adiabatic (b) Isothermal (c) Isobaric (d) Adiabatic

IES-28. Ans. (b)

- Increasing the number of Reheating stages in a gas turbine to infinity makes the expansion tending to isothermal.
- Increasing the intercooling in compressor to infinity also makes the compression tending to isothermal.
- This is known as Erecessionisation of the Brayton cycle.

Regeneration

IES-29. Which one of the following is correct? [IES-2008]
In a gas turbine cycle with regeneration,

(a) Pressure ratio increases (b) work output decreases
(c) Thermal efficiency increases (d) heat input increases

IES-29. Ans. (c)

IES-30. 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

IES-30. Ans. (b)

IES-31. A gas turbine plant working on Joule cycle produces 4000 kW of power. If its work ratio is 40%, what is the power consumed by the compressor?

(a) 2000 kW (b) 4000 kW (c) 6000 kW (d) 8000 kW **[IES-2008]**

IES-31. Ans. (c)

$$0.4 = \frac{W_{net}}{W_T} = \frac{4000}{W_T} \Rightarrow W_T = 10000\,kW$$

$$\therefore W_C = W_T - W_{Net} = 10000 - 4000 = 6000\,kW$$

IES-32. **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%

IES-33. Ans. (a) $\eta = \dfrac{120-60}{200} = \dfrac{60}{200} = 30\%$

Heat in exhaust gas = 200 – 120 + 60 = 140 kJ

Heat recovery in regenerator = 0.4 x 140 = 56 kJ

Thus heat supply will reduce by 56 kJ, i.e. heat supply = 200 - 56 = 144 kJ ;

$\eta = \dfrac{120-60}{144} = \dfrac{60}{144} = 40.2\% \quad \therefore \eta \ \text{ increased by } \ 10.2\%$

IES-34. **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

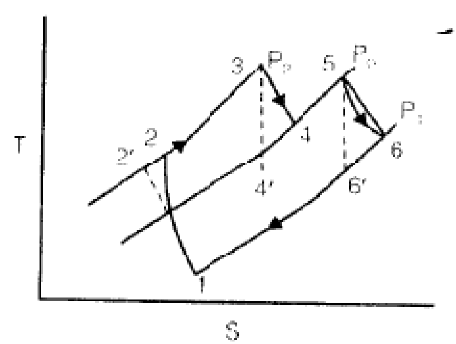
(c) Increases both efficiency and output

(d) Increases efficiency but decreases output

IES-34. 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

IES-35.



The above T-S diagram for a gas turbine plant is drawn for the case where:

(a) Compression of air is done in two stages incorporating an intercooler between two.

(b) Expansion of gases is done in two stages followed by regeneration.

(c) Expansion of gases is done in two stages with a reheater between the two.

(d) Expansion of gases is done in two stages with a reheater between the two followed by regeneration. **[IES-2009]**

IES-35. Ans. (c)

IES-36. **Consider the following statements in respect of gas turbines:** **[IES 2007]**

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-36. Ans. (a) In gas power plant reheat always decrease thermal efficiency.

IES-37. **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.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-37. Ans. (d) A is false but R is true

IES-38. **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

IES-38. Ans. (c)

Inter cooling

IES-39. **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

IES-39. 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.

IES-40. **Consider the following 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
3. 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.

IES-40. Ans. (d)

IES-41. **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

IES-41. Ans. (d)

IES-42. 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) l and 3 (d) 1, 2 and 3

IES-42. Ans. (b)

IES-43. 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]**
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-43. Ans. (c)

IES-44. 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

IES-44. Ans. (d)

IES-45. 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

IES-45. Ans. (d)

IES-46. 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

IES-46. Ans. (a)

IES-47. In a simple single stage gas turbine plant, if T_1 is the minimum temperature and T_3 is the maximum temperature then what is the work ratio in terms of r_p? [IES-2009]

(a) $1-\frac{T_3}{T_1} r_\rho^{\frac{\gamma-1}{\gamma}}$ (b) $1-\frac{T_1}{T_3} r_\rho^{\frac{\gamma-1}{\gamma}}$ (c) $1-\frac{T_1}{T_3} r_\rho^{\frac{\gamma}{\gamma-1}}$ (d) $1-\frac{T_1}{T_3} r_\rho^{\frac{1}{\gamma}}$

IES-47. Ans. (b)

Previous Years IAS Questions

Advantages and disadvantages of Gas turbine

IAS-1. 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

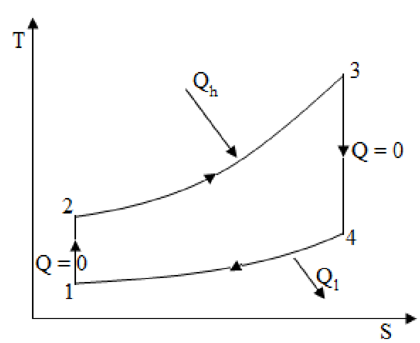
IAS-1. Ans. (c) Gas turbine is more compact than I.C. engine & steam turbine for same power output.

IAS-2. 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.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IAS-2. Ans. (a)

Joule cycle or Brayton cycle

IAS-3. Which cycle is represented in the diagram given above?
(a) Miller cycle
(b) Ericsson cycle
(c) Atkinson cycle
(d) Brayton cycle



[IAS-2007]

IAS-3. 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.

IAS-4. **Assertion (A):** Brayton cycle is not suitable for reciprocating engines.
Reason (R): A reciprocating engine cannot have complete expansion. **[IAS-1999]**
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IAS-4. Ans. (a)

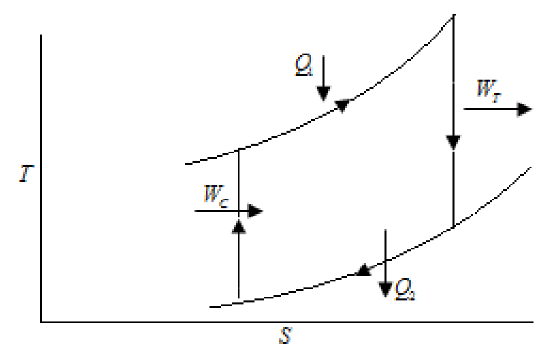
IAS-5. For air standard Brayton cycle, increase in the maximum temperature of the cycle, while keeping the pressure ratio the same would result in
(a) Increase in air standard efficiency
(b) Decrease in air standard efficiency
(c) No change in air standard efficiency
(d) Increase in the efficiency but reduction in net work **[IAS-1998]**

IAS-5. Ans. (c) air standard efficiency of Brayton cycle (η) = $1-\frac{1}{r_p^{\frac{\gamma-1}{\gamma}}}$

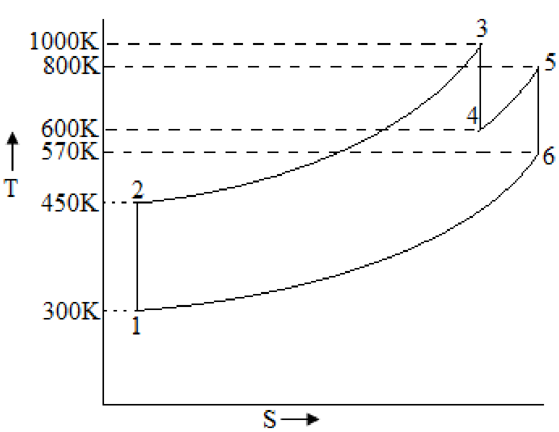
IAS-6. In a simple gas turbine power plant operating on standard Brayton cycle power needed to drive the compressor is 175 kW, rate of heat supplied during constant pressure heat addition process is 675 kW. Turbine output obtained during expansion is 425 kW. What is the rate of heat rejection during constant pressure heat rejection? **[IAS-2004]**
(a) 75 kW (b) 425 kW (c) 500 kW (d) 925 kW

IAS-6. Ans. (b) $\Sigma dQ = \Sigma dW$

$$or\ \ Q_1 - Q_2 = W_T - W_C$$
$$or\ \ 675 - Q_2 = 675 - 425$$
$$or\ \ Q_2 = 425kW$$



IAS-7. 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]

IAS-7. Ans. (b)

Heat addition (Q1) $= C_p(T_3 - T_2) + C_p(T_5 - T_4) = C_p[1000 - 450 + 800 - 600] = 750C_p$

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 = $480C_p$ $\therefore \eta = \dfrac{480}{750} = 64\%$

Optimum pressure ratio

IAS-8. 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 [IAS-1995]

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

IAS-8. Ans. (a)

Open and closed cycle

IAS-9. Assertion (A): The open 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]**

IAS-9. Ans. (b) Both A and R are true but R is NOT the correct explanation of A

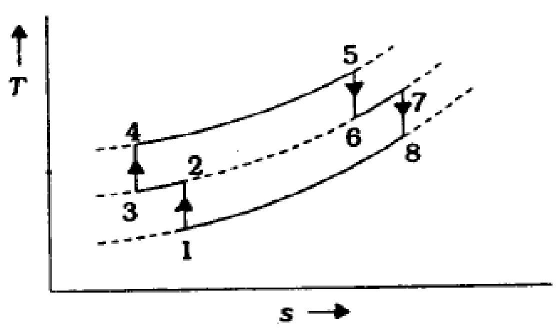
Inter cooling

IAS-10. 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

IAS-10. Ans. (a)

IAS-11. 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

(c)	III	IV	V	II	(d)	II	V	IV	I

IAS-11. Ans. (b)

7. Nuclear Power Plant

Theory at a Glance (For IES, GATE & PSUs)

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 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) $= \frac{1}{12} \times mass$ of one C^{12} *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
8. 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, g-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 $\times10^{10}$ 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

    $$\Delta E = \Delta m.c^2$$

    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

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

    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.

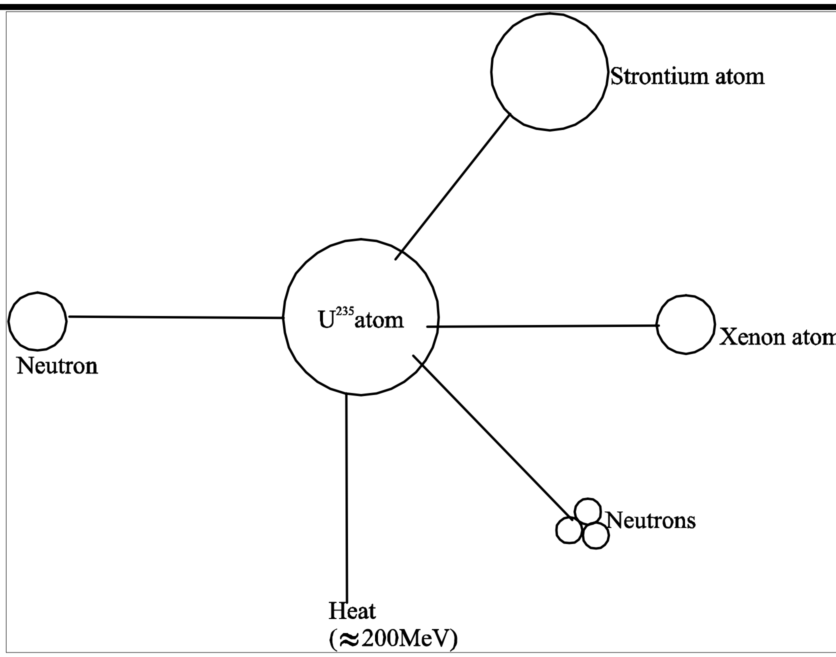
15. Each fission of U^{235} Produces $2\frac{1}{2}$ neutrons of fast neutrons per fission.

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 g'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. Stationary power plants
      Central station
      Package reactors
   B. Mobile reactors
      Naval reactors
      Aircraft reactors
      Merchant Ship reactors

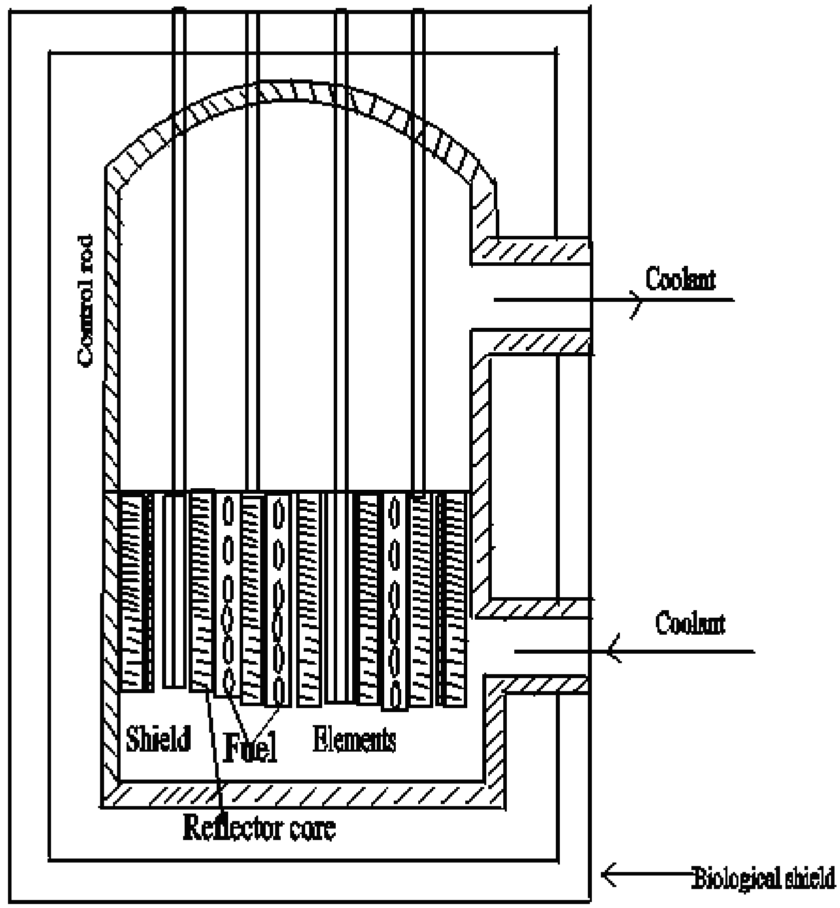
1. The efficiency of a nuclear power plant in comparsion to a conventional thermal power plant is less. The average thermal efficiency of a modern nuclear power plant is about 30%
2. India's first nuclear power plant was started at tarapur (Mumbai) and has boiling water reactor.

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. [IAS-2000; IES-2004]

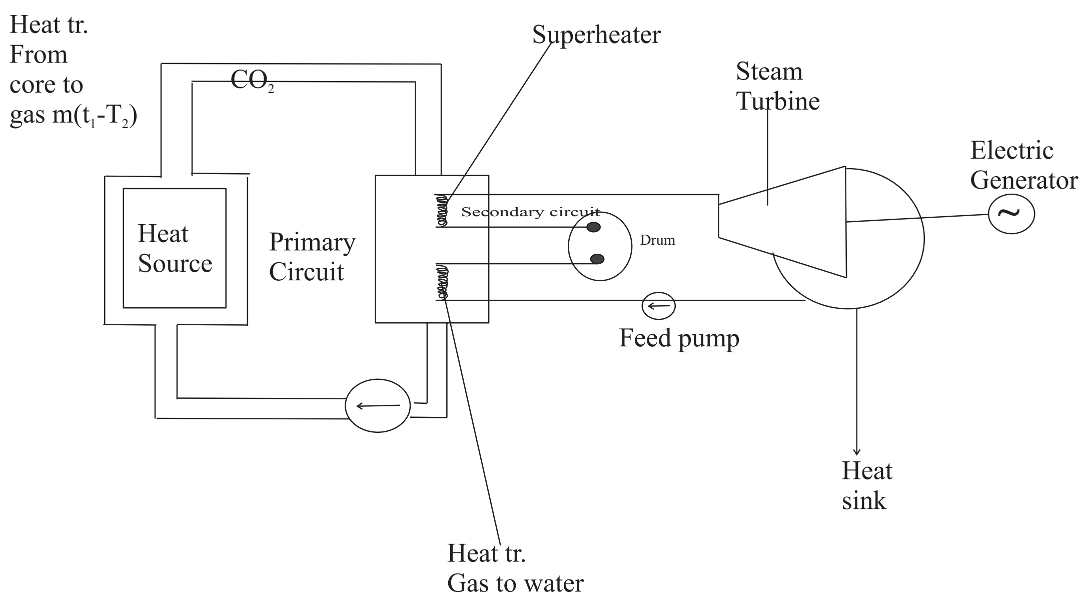
6. **Shielding:** The reactor is a source of intense radioactivity which is quite harmful to human life. The common radiations from the reactor **are α-rays, β-rays,** γ-rays and fast neutrons. Shielding (concrete and steel) absorbs them before the harmful radiations are emitted to the atmosphere.
   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 are that material which contain light weight atoms. In boiling water reactor. Moderator is coolant 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.

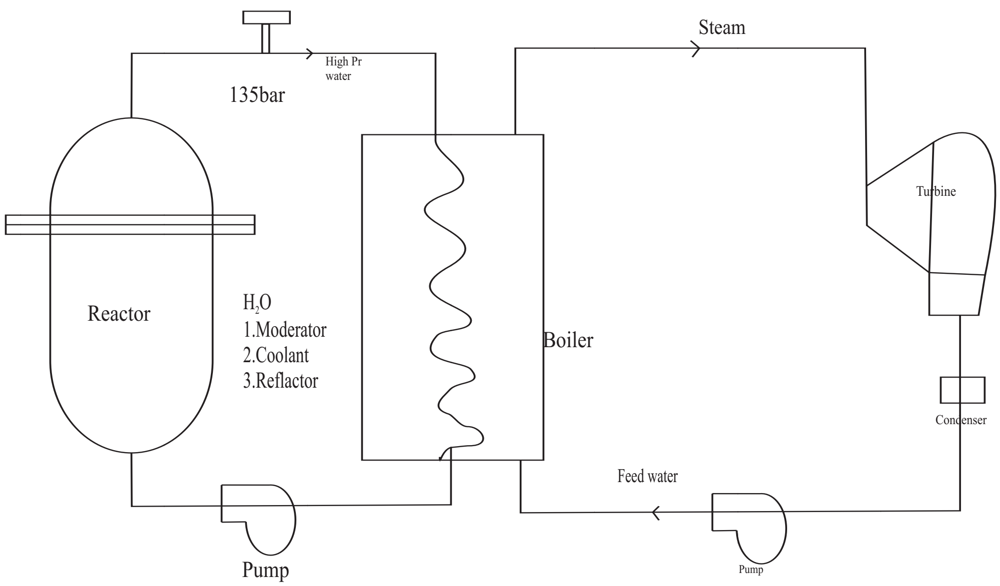
Such reactors can be classified according to the type of fuel, the moderator and the coolant. The most practical fuel the moderator and the coolant. The most practical fuel for a thermo-nuclear reactor, both from economical and nuclear consideration is deuterium.

Reactors Types:

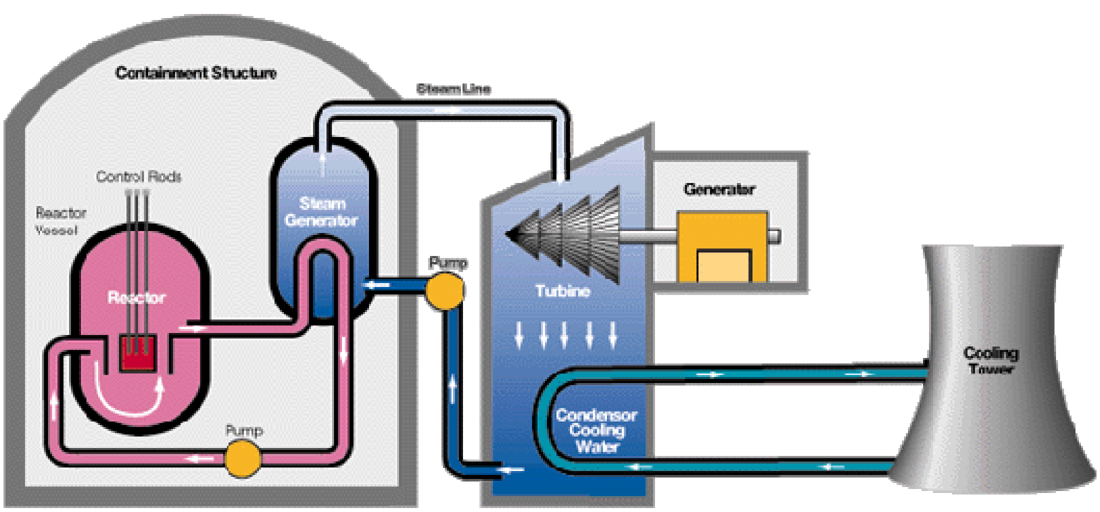
1.Pressurized water Rector:(PWR) (ESE-98)

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.

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.

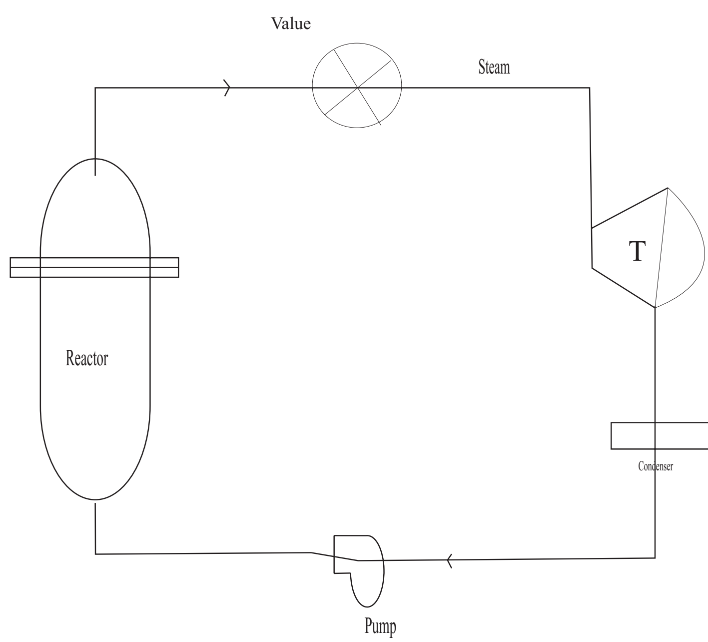


Fig: Boiling water reactor:

1. Reactor water cleans 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 Containment cooling function and 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:

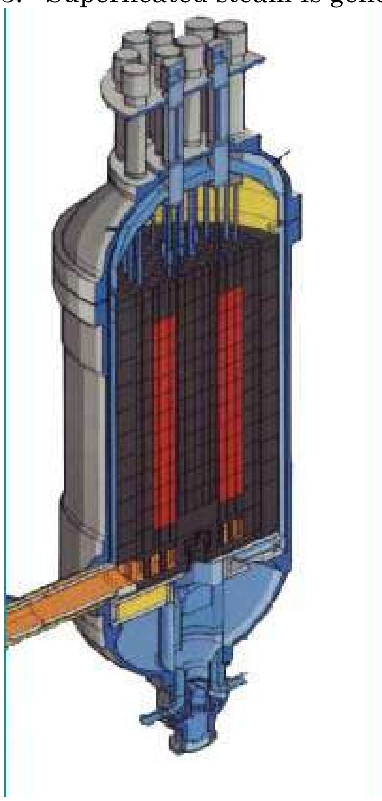
It uses high-energy neutrons. In it the average neutron yield of a fission is greater than in thermal reactors and accordingly all absorption cross-sections are much reduced. Plutonium is the fissile material for fast reactors. Liquid metal coolants are used.

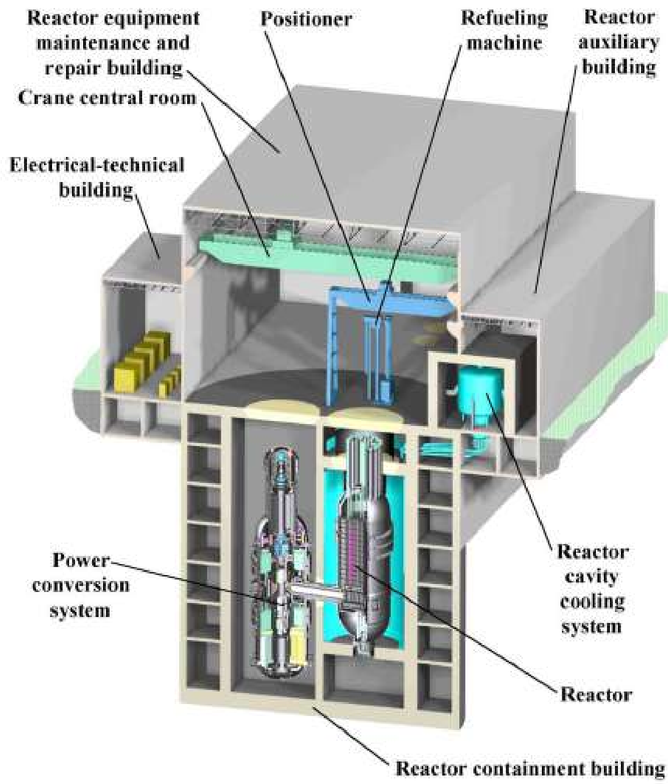
1. Breeder reactor has a conversion ratio of more than unity.
2. Fast breeder reactor uses double circuit system of coolant cycle.
3. In fast breeder reactors moderator is dispensed with.
4. The breeding gain in case of thermal breeder reactor as compared fast breeder reactor is lower.
5. The fast breeder reactor uses the following moderator ® 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 has no moderator.
11. A fast breeder reactor uses highly enriched fuel i.e 90% U^{235}
12. Fast breeder reactors are best suited for India because of large thorium deposits.

4. Advanced a Gas Cooled Reactors (AGR):

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. CANDU (CANadian Deuterium Uranium):

It uses heavy water as moderator and coolant, and UO_2 as fuel.

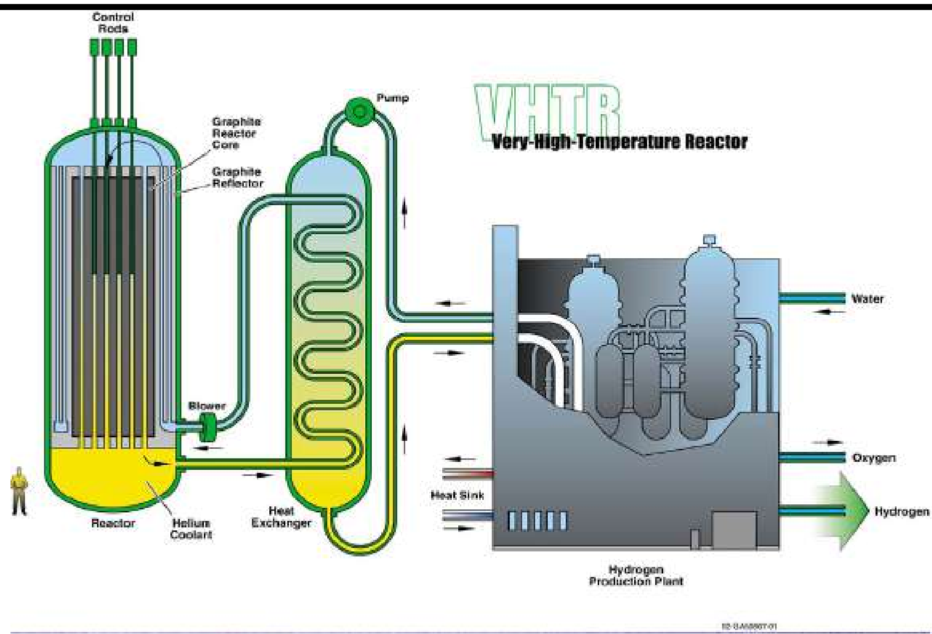
6. (SGHW) Steam Generating Heavy water Reactor:

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.

It 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 $99.282\%U^{238}, 0.712\%U^{235}, 0.006\%U^{234}$
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)

Previous Years IES Questions

Basic concept

IES-1. Uranium-238 is represented by $_{92}U^{238}$. What does it represent? [IES-2008]
(a) 92 neutrons and 238 protons (b) 92 protons and 238 neutrons
(c) 92 neutrons and 146 protons (d) 92 protons and 146 neutrons

IES-1. Ans. (d)

IES-2. 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

IES-2. Ans. (c)

IES-3. Consider the following nuclear fuels:
1. Pu^{239} 2. U^{235} 3. U^{233} 4. Th^{232}
What is the correct sequence of the above nuclear fuels in order of increasing half life? [IES-2008]
(a) 1-2-3-4 (b) 1-3-2-4 (c) 2-4-3-1 (d) 4-1-2-3

IES-3. Ans. (b)

IES-4. 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

IES-4. Ans. (b)

Units of radioactivity

IES-5. S.l. unit for radioactivity is [IES-1992]
(a) Joule (b) amu (c) Curie (d) becquerel

IES-5. Ans. (d)

Nuclear Fission

IES-6. 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

IES-6. Ans. (c)

IES-7. The energy released during the fission of one atom of Uranium-235 in million electron volts is about [IES-1993, 1995]
(a) 100 (b) 200 (c) 300 (d) 400

IES-7. Ans. (b) Energy released during fission of U-235 is 200 million electron volt

Basic Nuclear power reactor

IES-8. 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

IES-8. Ans. (c)

IES-9. The most commonly used moderator in nuclear power plants is [IES-2000]
(a) Heavy water (b) concrete and bricks (c) steel (d) graphite

IES-9. Ans. (a)

IES-10. With natural uranium, which of the following is used as moderator?
(a) Heavy water (b) Graphite
(c) Beryllium (d) All the above **[IES-2009]**

IES-10. Ans. (d) Type of moderator used:
A. Graphite B. Light water C. Heavy water
D. Beryllium E. Organic liquid

IES-11. Shielding in a nuclear reactor is generally done to protect against
(a) Excess electrons (b) X-rays **[IES-2000]**
(c) α-and β-rays (d) neutron and gamma rays

IES-11. Ans. (d)

IES-12. Which one of the following statements is correct? [IES-2009]
The nuclear radiators produced in a reactor, which must be shielded, are:
(a) Electrons only (b) Alpha, Beta and Gamma rays
(c) Neutrons and Gamma rays (d) Electrons and Gamma rays

IES-12. Ans. (b)

IES-13. Which one of the following pairs of materials is used as moderators in nuclear reactors? [IES-1995]
(a) Heavy water and zirconium (b) Zirconium and beryllium
(c) Cadmium and beryllium (d) Beryllium and heavy water.

IES-13. Ans. (d) Moderator in nuclear reactor is Beryllium and heavy water.

IES-14. Match List I with List II and select the correct answer (these pertain to nuclear reactors). [IES-1994]

List I	List II
A. Coolant	**1. Carbon dioxide**
B. Control rod	**2. Zirconium**
C. Poison	**3. Cadmium**
D. Cladding	**4. Graphite**
	5. Hafnium

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

IES-14. Ans. (c)

IES-15. 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

IES-15. Ans. (d)

IES-16. 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

IES-16. Ans. (d)

IES-17. 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

IES-17. Ans. (a)

IES-18. Match List-I (Material) with List-II (Use) and select the correct answer using the codes given below the lists: [IES-2001]

List-I (Material)	List-II (Use)
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

IES-18. Ans. (c)

IES-19. 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

IES-19. Ans. (c)

Critical

IES-20. 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

IES-20. Ans. (a)

IES-21. Which one of the following is correct? [IES-2008]
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
(b) Decreasing from a specific value
(c) Reduced to zero
(d) constant

IES-21. Ans. (d)

Pressurised water reactor (PWR)

IES-22. **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]**
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-22. Ans. (d) Pressurized water reactor (PWR) nuclear power plants doesn't use superheated steam.

IES-23. **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.
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. **[IES-1999]**
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-23. Ans. (b) Both A and R are individually true but R is **not** the correct explanation of A. Because low pressure and temperature in secondary loop results in poor thermodynamic efficiency in PWR.

IES-24. Match List I with List II and select the correct answer using the codes given below the lists: [IES-1993]

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**

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

IES-24. 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.

Fast breeder reactor

IES-25. **Assertion (A):** A breeder reactor does not require moderator. **[IES-1992]**
Reason (R): The parasite absorption of neutrons is low.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-25. Ans. (b)

Advanced Gas cooled reactor (AGR)

IES-26. 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

IES-26. Ans. (d)

CANDU (CANadian Deuterium Uranium) reactor

IES-27. 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

IES-27. Ans. (b)

IES-28. 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) 1 and 2 are correct (d) 3 and 4 are correct

IES-28. Ans. (a)

IES-29. Consider the following statements:
1. Gas cooled thermal reactors use CO_2 or helium as coolant and require no separate moderator. [IES-1996]
2. Fast reactors use heavy water as moderator and coolant.
3. Liquid metal fast breeder reactors use molten sodium as coolant.
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

IES-29. Ans. (c) 1. Gas cooled thermal reactors use CO_2 or helium as coolant and require graphite as separate moderator.
2. Fast reactors use no moderator.

IES-30. Which of the following statements are true about CANDU reactors?
1. Fuel elements contain natural-uranium dioxide [IES-1992]
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

IES-30. Ans. (a)

Nuclear Fuel

IES-31. 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.

IES-31. Ans. (c)

IES-32. Which one of the following statements is correct? [IES-2008]
The mass defect is
(a) A characteristic of certain elements
(b) A term used to prove the relationship between mass and energy of fission energy
(c) A measure
(d) The difference between mass of the nucleus and sum of the masses of the nucleons

IES-32.Ans. (d)

IES-33. 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.

IES-33. Ans. (a) U-233 is not a fertile material.

IES-34. 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

IES-34. Ans. (a) Atomic weight (238) = number of protons + number of neutrons.

Previous Years IAS Questions

Nuclear Fission

IAS-1. The energy released during the fission of one atom of Uranium-235 in million electron volts is about [IAS- 1999]
(a) 100 (b) 200 (c) 300 (d) 400

IAS-1. Ans. (b) Energy released during fission of U-235 is 200 million electron volt

IAS-2. 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

IAS-2. Ans. (b)

Advantages and limitation of Nuclear power plant

IAS-3. 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

IAS-3. Ans. (d)

IAS-4. 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.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IAS-4. Ans. (a)

Type of Nuclear Reactor

IAS-5. 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

IAS-5. Ans. (a)

Basic Nuclear power reactor

IAS-6. 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 ß and γ rays
(d) Absorb excess neutrons in the reactor

IAS-6. Ans. (b)

IAS-7. **The function of the moderator in a nuclear reactor is to [IAS-2003]**
(a) stop chain reaction (b) reduce the speed of the neutrons
(c) absorb neutrons (d) reduce temperature

IAS-7. Ans. (b)

IAS-8. **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

IAS-8. Ans. (c)

IAS-9. **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

IAS-9. Ans. (a)

IAS-10. **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

IAS-10. Ans. (b)

IAS-11. **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

IAS-11. Ans. (b)

IAS-12. **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. Zirconium**							
	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

IAS-12. Ans. (c)

IAS-13. 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

IAS-13. Ans. (b)

IAS-14. 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

IAS-14. Ans. (a)

Critical

IAS-15. A nuclear reactor is said to be "critical" when the neutron population in the reactor core is [IAS-1995]

(a) Rapidly increasing leading to the point of explosion
(b) Decreasing from the specified value
(c) constant
(d) Reduced to zero

IAS-15. Ans. (c)

IAS-16. 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 [IAS-2003]

(a) k= 0 (b) 0<k<l (c) k = 1 (d) k> 1

IAS-16. Ans. (c)

Boiling Water reactor (BWR)

IAS-17. 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

IAS-17. Ans. (a) BWR is similar to the thermal power plant. So condenser is used no heat exchanger.

IAS-18. The boiler used in the Nuclear Power Station at Tarapore, is of the **[IAS-1998]**
(a) Pressurized water type (b) boiling water type
(c) Gas cooled type (d) liquid metal cooled type

IAS-18. Ans. (b)

Fast breeder reactor

IAS-19. The moderator used in a fast breeder nuclear reactor is **[IAS 1994]**
(a) Graphite or liquid sodium
(b) Graphite or beryllium oxide.
(c) Graphite, liquid sodium or beryllium oxide
(d) None of the above

IAS-19. Ans. (d)

IAS-20. A fast breeder reactor uses which one of the following as fuel? **[IAS-2007]**
(a) Thorium (b) U^{235} (c) Plutonium (d) Enriched uranium

IAS-20. Ans. (b)

IAS-21. 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

IAS-21. Ans. (d)

IAS-22. Consider the following statements regarding the features of a Breeder reactor: **[IAS-1995]**
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:
(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

IAS-22. Ans. (b) A fast breeder reactor has no moderator.

Magnox

IAS-23. Match List I with List II and select the correct answer using the codes given below the Lists: **[IAS-2002]**

List I	List II
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

IAS-23. Ans. (b)

Nuclear Fuel

IAS-24. 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}

IAS-24. Ans. (c)

IAS-25. 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

IAS-25. Ans. (c) composition of Uranium ore
U-238 is abundant Uranium up to 99.282%
U-235=0.712%
U-233=0.006%

IAS-26. 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

IAS-26. 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.

IAS-27. 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

IAS-27. Ans. (a)

Answer with Explanation