**DEPARTMENT OF MECHANICAL ENGINEERING**

**ME8595 – THERMAL ENGINEERING - II**

**QUESTION BANK**

| | |
|---|---|
| **UNIT 1 - STEAM NOZZLE**<br>Types and Shapes of nozzles - Flow of steam through nozzles, Critical pressure ratio-Variation of mass flow rate with pressure ratio-Effect of friction- Metastable flow. | |
| **PART-A (2 Marks)** | |
| 1. | Define critical pressure ratio in steam flow through Nozzles. |
| 2. | If the enthalpy drop in a steam nozzle of efficiency 92% is 100 kJ/kg. Determine the exit velocity of steam. |
| 3. | What is the effect of super saturation in the nozzles? |
| 4. | Draw the Shape of Supersonic Nozzle. |
| 5. | Express the effects of friction on the flow through a steam nozzle. |
| 6. | Name the various types of nozzles and their function. |
| 7. | Analyze the effects of super saturation in a nozzle. |
| 8. | Define nozzle efficiency. |
| 9. | Where is nozzle control governing is used? |
| 10. | If the enthalpy drop in a steam nozzle of efficiency 88% is 95 kJ/kg.Determine the exit velocity of steam. |
| 11. | Explain various types of nozzles. |
| 12. | Define the term steam nozzle. |
| 13. | What is the effect of friction on the flow through a stream nozzle? |
| 14. | What you mean by a supersaturated flow? |
| 15. | Explain what is meant by critical pressure ratio of a nozzle. |
| 16. | The dry and saturated steam at a pressure of 5 bar is expanded isentropic ally in a nozzle to a pressure of 0.2 bar. Find the velocity of steam leaving the nozzle. |
| 17. | What are the effects of super saturation on discharge and heat drop? |
| 18. | What is meant by overexpansion and under expansion? |
| 19. | State the relation between the velocity of steam and heat during any Part of a steam nozzle. |
| 20. | Give the five applications of steam nozzles. |

| PART-B (13 Marks) | |
|---|---|
| 1. | (a) Mention the types of nozzles you know, Where are these used? |
| | (b) Steam having pressure of 10.5 bar and 0.95 dryness is expanded through a convergent-divergent nozzle and the pressure of steam leaving the nozzle is 0.85 bar. Find the velocity at the throat for maximum discharge conditions. Index of expansion may be assumed as 1.135. Calculate mass rate of flow of steam through the nozzle. |
| 2. | (a) Dry saturated steam enters a frictionless adiabatic nozzle with negligible velocity at a temperature of 300°C. It is expanded to pressure of 5000 KPa. The mass flow rate is 1 kg/s. Calculate the exit velocity of the steam. |
| | (b) Steam is expanded in a set of nozzles from 10 bar and 200°C to 5 bar. What type of Nozzle is it? Neglecting the initial velocity find minimum area of the nozzle required to allow a flow of 3 kg/s under the given conditions. Assume that expansion of steam to be isentropic. |
| 3. | In a steam nozzle, the steam expands from 4 bar to 1 bar. The initial velocity is 60 m/s and the initial temperature is 200°C. Determine the exit velocity if the nozzle efficiency is 92%. |
| 4. | Describe (Derive) the expression for critical pressure ratio in terms of index of expansion. |
| 5. | Dry saturated steam enters a steam nozzle at a pressure of 15 bar and is discharged at a pressure of 2 bar. If the dryness fraction of discharge steam is 0.96, what will be the final velocity of steam? Neglect initial velocity of steam. If 10% of heat drop is lost in friction, Examine (find) the percentage reduction in the final velocity. |
| 6. | Dry saturated steam at a pressure of 11 bar enters a convergent-divergent nozzle and leaves at a pressure of 2 bar. If the flow is adiabatic and frictionless, determine: (i) The exit velocity of steam. (ii) Ratio of cross section at exit and that at throat. Assume the index of adiabatic expansion to be 1.135. |
| 7. | The nozzles of De-Laval stream turbine are supplied with dry saturated steam at a pressure of 9 bar. The pressure at the outlet is 1 bar. The turbine has two nozzles with a throat diameter of 2.5 mm. Assuming nozzle efficiency as 90% and that of turbine rotor 35%, find the quality of steam used per hour and the power developed. |
| 8. | Dry saturated steam at a pressure of 8 bar enters a convergent divergent nozzle and leaves it at a pressure of 1.5 bar. If the flow is isentropic and if the corresponding expansion index is 1.33, find the ratio of cross-sectional area at exit and throat for maximum discharge. |
| 9. | Air at a pressure of 20 bar and at a temperature of 18°C is supplied to a convergent divergent nozzle having a throat diameter of 1.25 cm and discharging to atmosphere. The adiabatic index for air is 1.4 and the characteristic constant is 287. Find the weight of air discharged per minute. |
| 10. | Derive an expression for maximum discharge through convergent divergent nozzle for steam. |
| 11. | Steam initially dry and saturated is expanded in a nozzle from 15 bar 300°C at 1 bar. if the friction loss in the nozzle is 12% of the total head drop calculate the mass of steam discharged when exit diameter of the nozzle is 15 mm. |
| 12. | (a) Define critical pressure ratio of a nozzle and discuss why attainment of sonic velocity determines the maximum mass rate of flow through steam nozzle. |
| | (b) Air enters a frictionless adiabatic converging nozzle at 10 bar 500 K with negligible velocity. The nozzle discharges to a region at 2 bar. If the exit area of the nozzle is 2.5 $cm^2$, find the flow rate of air through the nozzle. Assume for air Cp = 1005 J/kg K and Cv= 718 J/kg K. |

| | |
|---|---|
| 14 | Steam enters a group of convergent-divergent nozzles at a pressure of 22 bar and with a temperature of 240°C. The exit pressure is 4 bar and 9% of the total heat drop is lost in friction. The mass flow rate is 10kg/s and the flow upto throat may be assumed friction less. Calculate 1.The throat and exit velocities, and 2. The throat and exit areas. |
| **PART-C (15 Marks)** | |
| 1 | A convergent-Divergent nozzle is required to discharge 2kg of steam per second. The nozzle is supplied with steam at 6.9 bar and180°C and discharge takes place against a back pressure of 0.98 bar. Expansion up to throat is isentropic and the frictional resistance between the throat and exit is equivalent to 62.76 kJ/kg of steam. Taking approach velocity of 75 m/s andthroat pressure 3.9 bar, estimate:<br>(i) Suitable areas for the throat and Exit<br>(ii) Overall efficiency of the nozzle based on the enthalpy drop between the actual inletpressure, and temperature and the exit pressure. |
| 2 | (a) Define Critical pressure ratio of nozzle and discuss why attainment of sonic velocity determines the maximum mass rate of flow through steam nozzle. |
| | (b) Explain the metastable expansion of steam in a nozzle with help of h-s diagram. |
| 3 | In an installation 5 kg/s of steam at 30 bar and 300°C is supplied to group of six nozzles ina wheel chamber maintained at 7.5 bar. (a) Determine the dimensions of the nozzles of rectangular cross- sectional flow area with aspect ratio 3: 1. The expansion may be consideredmeta-stable and friction is neglected.<br>(b) Also calculate:(i) degree of under-cooling and super-saturation ; (ii) loss in available drop due to irreversibility; (iii) increases in entropy (iv) Ratio of mass flow rate with meta- stable expansion to that if expansion is in thermal equilibrium. |
| 4 | A gas expands in a convergent-divergent nozzle from 5 bar to 1.5 bar, the initial temperature being 700°C and the nozzle efficiency is 90%. All the losses take place after the throat. For 1 kg/s mass flow rate of the gas, find throat and exit areas. Take n = 1.4 and R = 287 J/kg K. |
| 5 | A convergent divergent nozzle is required to discharge 2kg of steam per second. The nozzle is supplied with steam at 7 bar and 180oC and discharge takes place against a back pressure of 1 bar. The expansion up to throat is isentropic and frictional resistance between the throat and exitis equivalent to 63 kJ/kg of steam. Taking approach velocity of 75 m/s and throat pressure of 4 bar, estimate (1) suitable areas for the throat and exit and (2) overall efficiency of the nozzle based on the enthalpy drop between actual inlet pressure and temperature and exit pressure. |
| 6 | Dry saturated steam at a pressure of 8 bar enters a convergent divergent nozzle and leaves it at a pressure of 1.5 bar. If the steam flow process is isentropic and the corresponding expansion indexis 1.135, find the ratio of cross sectional area at exit and throat for maximum discharge. |
| 7 | In a test on a steam nozzle, the issuing steam jet impinges on a stationary flat plate which is perpendicular to the direction of flow and the force on the plate is measured. With convergent-divergent nozzle supplied with steam at 10 bar dry saturated and discharge at 1 bar, the force is experimentally measured to be 600N. The area of nozzle at throat measures 5cm2 and the exit area is such that the complete expansion is achieved under these conditions. Determine (i) the flow rate of steam (ii) efficiency of the nozzle assuming that all the losses occur after the throat. Assume n=1.135 for Isentropic expansion. |
| 8 | Dry saturated steam at a pressure of 11 bar enters a convergent – divergent nozzle and leaves at a pressure of 2 bar. If the flow is adiabatic and frictionless, Find the (i) exit velocity of steam (ii) ratio of cross section of exit and that at throat |

| UNIT II – BOILERS<br>Types and comparison. Mountings and Accessories. Fuels - Solid, Liquid and Gas. Performance calculations, Boiler trial. | |
|---|---|
| **PART-A (2 Marks)** | |
| 1. | What is water level indicator? |
| 2. | Define boiler efficiency. |
| 3. | Define equivalent evaporation from and at $100^0$C. |
| 4. | Define boiler thermal efficiency. |
| 5. | Discuss chemical fuel. |
| 6. | Types of Boiler Fuel. |
| 7. | What are primary fuels? List some important fuels. |
| 8. | Define heating value of fuel. |
| 9. | Explain the function of the boiler chimney. |
| 10. | Why is there no chimney in the case of a locomotive boiler? |
| 11. | What is safety valve? And define safety valve. |
| 12. | Explain various types of draughts used in usual practice. |
| 13. | Merits and demerits of the dead weight safety valve. |
| 14. | Define fusible plug. |
| 15. | How to working boiler injector? |
| 16. | Write the draught losses. |
| 17. | Discuss steam jet draught. |
| 18. | Write the power of F.D & I.D fan equations. |
| 19. | Write short notes on bomb calorimeter. |
| 20. | What is Junkers gas calorimeter? |



| **PART-B (13 Marks)** | |
|---|---|
| 1. | Explain the function of boiler mountings. Can a boiler work without mountings. |
| 2. | Explain in detail about how accessories differ from mountings. |
| 3. | Enumerate the various accessories normally used in a steam generating plant. |
| 4. | Discuss the function of a safety value. State the minimum number of safety value to be used in boiler. |

| | |
|---|---|
| 5. | Explain fusible plug and state where it is located in a boiler |
| 6. | Explain with neat sketch any three of the following mounting:<br>i) Water level indicator ii) Pressure gauge iii) Feed check value iv) Blow of cock<br>v) High steam and low water safety value vi) Junction or stop value |
| 7. | Give a schematic sketch of a boiler plant. What are the observations to be recorded during a boiler trial? |
| 8. | Explain what the sources of heat losses in boiler plants are. What are the methods used to reduce these losses? |
| 9. | With the help of neat sketch, explain and injector for feeding water to the boiler drum. Why it is not used for large capacity boilers? Explain its location in boiler installation. |
| 10. | Explain with neat sketches any two of the following boiler accessories:<br>i) Injector ii) super heater iii) Air preheated iv) Economizer. |
| 11. | Explain with neat sketch expansion type of steam trap. |
| 12. | Explain the function of steam separator. Discuss with a neat sketch anyone types of steam separators. |
| 13. | A boiler generates 13000 kg of steam at 7 bars during a period of 24 hrs and consume 1250 kg of coal whose CV. = 30000 kJ/kg. Taking the enthalpy of steam coming out of boiler = 2507.7 kJ/kg and water is supplied to the boiler at $40^{o}$C. Find: (a) efficiency of the boiler<br>(b) Equivalent evaporation per kg of coal. |
| 14. | The following data were obtained in a boiler trial: coal used = 250 kg ; calorific value = 29800kJ/kg ; water evaporated = 2000 kg ; steam pressure = 11.5 bar ; dryness fraction of steam = 0.95 ; feed water temperature = 34 OC. Find the equivalent evaporation " from and at 100 OC " per kg of coal and the efficiency of the boiler. |
| **PART-C (15 Marks)** | |
| 1. | (a)Describe with a neat diagram, the construction and working of a Babcock and Wilcox water tube boiler. |
| | (b) Describe with a neat line sketch of a Benson boiler mentioning its distinguishing features. State the advantages for this type of boilers. |
| 2. | Discuss, briefly, the working of an economizer in a boiler plant giving a neat sketch. |
| 3. | (a)A coal fired boiler plant consumes 400 kg of coal per hour. The boiler evaporates 3200 kg of water at $44.5^{o}$C into superheated steam at a pressure of 12 bar and $274.5^{o}$C. If the calorific value of fuel is 32760 kJ/kg of coal, determine: 1. Equivalent evaporation "from and at $100^{o}$C,'' and 2. Thermal efficiency of the boiler. Assume specific heat of superheated steam as 2.1 kJ/kg K. (10) |
| | (b) Discuss briefly the term boiler efficiency. (5) |
| 4. | The following data were obtained in a boiler trial: Feed water supply per hour = 690 kg at 28 $^{o}$C ; steam produced = 0.97dry at 8 bar ; coal fired per hour = 91kg of calorific value 27255 kJ/kg ; ash and unburnt coal collected beneath fire bars = 7.5 kg/hr of calorific value 3700 kJ/kg ; mass of the flue gasses per kg of coal burnt = 17.4kg ; temperature of flue gases 325OC ; room temperature = 17 $^{o}$C; specific heat of flue gases 1.005 kJ/kgK. Estimate the boiler efficiency and draw up a heat balance sheet |

| **UNIT III-STEAM TURBINES** |
|---|
| Types, Impulse and reaction principles, Velocity diagrams, Work done and efficiency – optimal operating conditions. Multi-staging, compounding and governing. |

| **PART-A (2 Marks)** | |
|---|---|
| 1. | Distinguish between impulse and reaction principle. |
| 2. | Discuss the importance of compounding of steam turbine. |
| 3. | Define stage efficiency. |
| 4. | Discuss the importance of compounding of steam turbine. |
| 5. | What is meant by Pressure Compounding? |
| 6. | Summarize the different losses involved in steam turbines. |
| 7. | Define Diagram efficiency. |
| 8. | Explain 'Degree of Reaction' in a steam turbine. |
| 9. | Define a steam turbine and state its fields of application. |
| 10. | How are the steam turbines classified? |
| 11. | Discuss the advantages of a steam turbine over the steam engines. |
| 12. | What you mean by compounding of steam turbines? |
| 13. | What methods are used in reducing the speed of the turbine rotor? |
| 14. | Define the term degree of reaction used in reaction turbines. |
| 15. | Write a short note on bleeding of steam turbines. |
| 16. | Explain reheat factor. Why is its magnitude always greater than unity? |
| 17. | Give the classification of steam turbines. |
| 18. | Explain the principle of impulse turbines. |
| 19. | What are the different losses that occur in a steam turbine? |
| 20. | State the advantages and disadvantages of reheating steam. |



| **PART-B (13 Marks)** | |
|---|---|
| 1. | In a certain stage of an impulse turbine, the nozzle angle is 20° with the plane of the wheel. The mean diameter of the ring is 2.8 meters. It develops 55 kW at 2400 rpm. Four nozzles, each of 10 mm diameters expand steam isentropic ally from 15 bar and 250°C to 0.5 bar. The axial thrust is 3.5 N. Calculate: 1. Blade angles at entrance and exit, and 2.power lost in blade friction. |
| 2. | The velocity of steam exiting the nozzle of the impulse stage of a turbine is 400 m/s. The blades operate close to the maximum blading efficiency. The nozzle angle is 20°. Considering equiangular blades and neglecting blade friction, calculate for a steam flow of 0.6 kg/s, the diagram power and the diagram efficiency. |

| | |
|---|---|
| 3. | The blade speed of a single ring impulse blading is 250 m/s and nozzle angle is 20°. The heat drop is 550 kJ/kg and nozzle efficiency is 0.85. The blade discharge angle is 30° and the machine develops 30 kW, when consuming 360 kg of steam per hour. Draw the velocity diagram and calculate: 1. Axial thrust on the blading and 2.the heat equivalent per kg of steam friction of the blading. |
| 4. | At a stage of reaction turbine, the mean diameter of the rotor is 1.4 m. The speed ratio is 0.7. Determine the blade inlet angle if the blade outlet angle is 20°. The rotor speed is 3000 rpm. Also find the diagram efficiency. Find the percentage increase in diagram efficiency and rotor speed if the rotor is designed to run at the best theoretical speed, the exit angle being 20°. |
| 5. | In a single stage impulse turbine the blade angles are equal and the nozzle angle is 20°. The velocity coefficient for the blade is 0.83. Find the maximum blade efficiency possible. If the actual blade efficiency is 90% of maximum blade efficiency, find the possible ratio of blade speed to steam speed. |
| 6. | A single stage impulse turbine rotor has a diameter of 1.2 m running at 3000 rpm. The nozzle angle is 18°. Blade speed ratio is 0.42. The ratio of the relative velocity at outlet to relative velocity at inlet in 0.9. The outlet angle of the blade is 3° smaller than the inlet angle. The steam flow rate is 5 kg/s. Draw the velocity diagram and find the following : (i) Velocity of whirl (ii) Axial thrust on the bearing (iii) Blade angles (iv) Power developed |
| 7. | A de-Laval turbine it supplied with dry steam and works on a pressure range from 10.5 bar to 0.3 bar. The nozzle angle is 20° and the blade exit angle is 30°.The mean blade speed is 270 m/s. If there is a 10% loss due to friction in the nozzle and blade velocity coefficient 0.82, find the thrust on the shaft per kW power developed. |
| 8. | Explain with a neat sketch of velocity compounding, pressure compounding, pressure-velocity compounding. |
| 9. | A 50 % reaction turbine (with symmetrical velocity triangles) running at 400 rpm has the exit angle of the blades as 20° C and the velocity of steam relative to the blades at the exit is 1.35 times the mean speed of the blade. The steam flow rate is 8.33 Kg/s and at a particular stage the specific volume is 1.381 m3/Kg. Evaluate for this stage. (i) A suitable blade height, assuming the rotor mean diameter 12 times the blade height, and (ii) The diagram work |
| 10. | A single row impulse turbine develops 132.4 kW at a blade speed of 175 m/s, using 2 kg of steam per sec. Steam leaves the nozzle at 400 m/s. Velocity coefficient of the blades is 0.9. Steam leaves the turbine blades axially. Calculate nozzle angle, blade angles at entry and exit, assuming no shock. |
| 11. | A single-stage impulse turbine is supplied steam at 5 bar and 200°C at the rate of 50 kg/min and it expands into a condenser at a pressure of 0.2 bar. The blade speed is 400 m/s and nozzles are inclined at 20°C to the plane of the wheel. The blade angle at the exit of the moving blade is 30°C. Neglecting friction losses in the moving blade, Evaluate (i) Velocity of the steam entering the blades (ii) Power developed, (iii). Blade efficiency and (iv) Stage efficiency. |
| 12. | In a stage of impulse reaction turbine operating with 50% degree of reaction, the blades are identical in shape. The outlet angle of the moving blades in 19o and the absolute discharge velocity of steam is 100 m/s in the direction 70o to the motion of the blades. If the rate of flow through the turbine is 15000 kg/hr., calculate the power developed by the turbine. |
| 13. | A stage of a steam turbine is supplied with steam at a pressure of 50 bar and 350oC, and exhausts at a pressure of 5 bar. The isentropic efficiency of the stage is 0.82 and the steam consumption is 2270 kg/min. Determine the power of the stage. |
| 14. | The velocity of steam exiting the nozzle of the impulse stage of a turbine is 400 m/s. The blades operate close to maximum blading efficiency. The nozzle angle is 20o.Considering equiangular blades and neglecting blade friction, calculate for a steam flow of 0.6 kg/s, the diagram power and the diagram efficiency. |

| PART-C (15 Marks) | |
|---|---|
| 1. | In a De-Laval turbine steam issues from the nozzle with a velocity of 1200 m/s. The nozzle angle is 20°, the mean blade velocity is 400 m/s and the inlet and outlet angles of blades are equal. The mass of steam flowing through the turbine per hour is 1000 kg. Find the (i) blade angles (ii) relative velocity of steam entering the blades (iii) tangential force on the blades (iv) power developed (v) blade efficiency. Take the blade velocity coefficient as 0.8 |
| 2. | In a stage of impulsive reaction turbine, steam enters with a speed of 250 m/s at an angle of 30° in the direction of blade motion. The mean speed of the blade is 150 m/s when the rotor is running at 3000 r.p.m. The blade height is 10 cm. The specific volume of steam at nozzle outlet and blade outlet are 3.5 $m^3$/kg and 4 $m^3$/kg respectively. The turbine develops 250 kW. Assuming the efficiency of nozzle and blades combined considered is 90% and carryover coefficient is 0.8, find (i) The enthalpy drop in each stage, (b) Degree of reaction and (iii) Stage efficiency. |
| 3. | A simple impulse turbine has one ring of moving blades running at 150 m/s. the absolute velocity of steam at exit from the stage is 85 m/s at an angle of 80° from the tangential direction. Blade velocity co-efficient is 0.82 and the rate of steam flowing through the stage is 2.5 kg/s. if the blades are equiangular, determine: (i) Blade angles (ii) Nozzle angle (iii) Absolute velocity of the steam issuing from the nozzle (iv) Axial thrust. |
| 4. | In a De-Laval turbine steam issues from the nozzle with a velocity of 1200 m/s. The nozzle angle is 20o, the mean blade velocity is 400 m/s, the inlet and outlet angles of blades are equal. The mass of steam flowing through the turbine per hour is 1000 kg. Calculate:<br>(i)Blade angles, (ii)Relative velocity of steam entering the blades, (iii)Tangential force on the blades, (iv)Power developed (v)Blade efficiency, Take blade velocity co-efficient as 0.8. |
| 5 | A single stage impulse turbine 1 m in diameter rotates at 3000 rpm. Steam is supplied from the nozzles with a velocity of 300 m/s and nozzle angle is 20°C. The blades are equiangular. Assuming that the friction loss in the blade passages is 33% of the K.E corresponding to the relative velocity at inlet to the blade, find the power developed by the turbine. The axial thrust on the bearing of turbine is 150 N. |
| 6 | Steam enters the blade row of an impulse turbine with a velocity of 600 m/s at an angle of 25° to the plane of rotation of the blades. The mean blade speed is 250 m/s. The blade angle on the exit side is 30°. The blade friction coefficient is 10%. Determine the (i) Blade angle at inlet (ii) Work done per kg of steam (iii) Diagram efficiency (iv) axial thrust per kg of steam per second. |
| 7 | In a De-Laval turbine steam issues from the nozzle with a velocity of 1200 m/s. The nozzle angle is 20°, the mean blade velocity is 400 m/s and the inlet and outlet angles of blades are equal. The mass of steam flowing through the turbine per hour is 1000 kg. Find the (i) blade angles (ii) relative velocity of steam entering the blades (iii) tangential force on the blades (iv) power developed (v) blade efficiency. Take the blade velocity coefficient as 0.8 |
| 8 | The blade speed of a single ring impulse blading is 300m/s and nozzle angle is 20o. The heat drop is 625 kJ/kg and nozzle efficiency is 0.85. The blade discharge angle is 30o and the machine develops 30kW, when consuming 300 kg of steam per hour. Draw velocity diagram and determine, 1) axial thrust on blading and 2) heat equivalent per kg of steam friction of blading. |
| 9 | Explain the working of velocity and pressure velocity compounding methods with neat sketch. |

| UNIT IV COGENERATION AND RESIDUAL HEAT RECOVERY | |
|---|---|
| Cogeneration Principles, Cycle Analysis, Applications, Source and utilization of residual heat. Heat pipes, Heat pumps, Recuperative and Regenerative heat exchangers. Economic Aspects. | |
| **Part-A (2 Marks)** | |
| **S.No** | **Questions** |
| 1 | Explain the term cogeneration. |
| 2 | Explain how cogeneration is advantageous over conventional power plant. |
| 3 | Describe briefly about heat wheels. |
| 4 | What is meant by combined cycle cogeneration? |
| 5 | Explain the term topping cycle with examples. |
| 6 | Explain the term bottoming cycle with examples. |
| 7 | Explain the term heat-to-power ratio. |
| 8 | Mention any three commercial waste heat recovery devices. |
| 9 | List at least five applications of heat pipe. |
| 10 | Explain the principle of metallic recuperator. |
| 11 | Evaluate the importance of absorption refrigeration cycle in heat pumps. |
| 12 | Point out the advantage of plate heat exchanger over shell and tube heat exchanger. |
| 13 | Give two examples of usage of heat exchanger. |
| 14 | Write about closed-cycle heat pumps. |
| 15 | Write short notes on cycle analysis. |
| 16 | List the circumstances under which cogeneration will become attractive. |
| 17 | List out the sources of waste heat in a diesel engine. |
| 18 | Explain about pressure cogeneration system. |
| 19 | Write short notes on Direct Contact Heat Exchanger. |
| 20 | Explain the principle of heat pump. |

| PART – B (13 Marks) | |
|---|---|
| **S.No** | **Questions** |
| 1 | Steam at 40 bar, 500º C flowing at the rate of 5500 Kg/hr expands in a hp turbine to 2 bar with an isentropic efficiency of 83%. A continuous supply of steam at 2 bar, 0.87 qualities and a flow rate of 2700 Kg/h are available from a geothermal energy source. This steam is mixed adiabatically with the hp turbine exhaust steam and the combined flow then expands in a lp turbine to 0.1 bar with an isentropic efficiency of 78%. Determine the power output and the thermal efficiency of the plant. Assume that 5500 Kg/h of steam is generated in the boiler at 40 bar, 500 deg C from the saturated feed water at 0.1 bar. Calculate the power output without geothermal steam. (Neglect pump work) |
| 2. | A large food processing plant requires 8 kg/s of saturated or slightly superheated steam at 50 bar which is extracted from the turbine of a cogeneration plant. The boiler generates steam at 120 bar and 400° C at a rate of 18 kg/s and the condenser pressure is 12 bar. Steam leaves the process heater as a saturated liquid. It is then mixed with the feed water at the same pressure and this mixture is pumped to the boiler pressure. Assuming that both pumps and turbine have isentropic efficiencies of 92%, Determine the (a) rate of heat transfer to the boiler, (b) power output of the cogeneration plant and (c) utilization factor. |
| 3 | A cogeneration plant is to generate power and 8500 kW of process heat. Consider an ideal cogeneration steam plant. Steam enters the turbine from the boiler at 10 MPa and 450° C. One-third of the steamis extracted from the turbine at 800 KPa pressure for process heating. The remainder of the steam continues to expand and exhausts to the condenser at 8 KPa. The steam extracted for the process heater is condensed in the heater and mixed with the feedwater at 800 KPa. The mixture is pumped to the boiler pressure of 10 MPa. Show the cycle on a T-s diagram with respect to saturation lines, and Determine the (a) mass flow rate of steam that must be supplied by the boiler (b) net power produced by the plant and (c) utilization factor. |
| 4. | Steam enters the turbine of a cogeneration plant at 8MPa and 500oC. Two third of steam is extracted from the turbine at 660 kPa pressure for process heating. The remaining steam continues to expand to 8kPa. The extracted steam is then condensed and mixed with feed water at constant pressure and mixture is pumped to the boiler pressure of 8kPa. The mass flow rate of steam through the boiler is 25 kg/s. Disregarding any pressure drop and heat losses in the piping and assuming the turbine and the pump to be isentropic, determine net power produced and utilization factor of plant. |
| 6. | a). Explain any three types of recuperators.<br>b). What are waste heat recovery boilers? Explain the need and benefits? |
| 7. | Explain the principle of operation of heat pipe. Discuss three examples of its industrial application. |
| 8. | List out in detail the factors for selection of cogeneration system. |
| 9. | Explain in detail about low temperature Energy Recovery Options and Technologies. |
| 10 | Discuss about Vapour compression and absorption heat pumps. |
| 11. | Derive the general equation for maximum economic lift for heat pumps. |
| 12. | Explain about Kalina cycle, heat pump and heat pipe with neat sketch |
| 13. | Explain the impact of cyclic analysis in heat exchangers. |
| 14. | List out the various economic aspects of heat recovery devices and their efficiency in different applications. |
| **PART – C (15 Marks)** | |
| 1. | Analyze the different contemporary applications of cogenerations principles. |

| | |
|---|---|
| 2. | Steam at 60 bar, 450 deg C flowing at the rate of 4500 Kg/h expands in a h.p turbine to 2 bar with an isentropic efficiency of 79%. A continuous supply of steam at 2 bar, 0.87 qualities and a flow rate of 2700 Kg/h is available from a geothermal energy source. This steam is mixed adiabatically with the h.p turbine exhaust steam and the combined flow then expands in a l.p turbine to 0.1 bar with an isentropic efficiency of 78%. Determine the power output and the thermal efficiency of the plant. Assume that 5500 Kg/h of steam is generated in the boiler at 40 bar, 500 deg C from the saturated feed water at 0.1 bar. Calculate the power output without geothermal steam. Evaluate the measured power output in contrast to a typical IC engine. |
| 3. | In a process, low pressure and high pressure steam is available. Describe how can this steam be reused industry? Which equipment is used for recovery of this? Explain with a neat sketch the principle of operation of such system. |
| 4. | Explain the cost - benefit ratio of waste heat recovery devices. |

| UNIT V - REFRIGERATION AND AIR – CONDITIONING | |
|---|---|
| Vapour compression refrigeration cycle, Effect of Superheat and Sub-cooling, Performance calculations, Working principle of air cycle, vapour absorption system, and Thermoelectric refrigeration. Air conditioning systems, concept of RSHF, GSHF and ESHF, Cooling load calculations. Cooling towers – concept and types. | |
| **Part-A (2Marks)** | |
| **S. No** | **Questions** |
| 1 | Define refrigeration effect. |
| 2 | Draw the electrolux refrigeration system. |
| 3 | Explain the working principle of air cycle. |
| 4 | What is the function of the throttling valve in vapour compression refrigeration system? |
| 5 | Write down four important properties of a good refrigerant. |
| 6 | Define super heating. |
| 7 | Brief the necessity of refrigeration. |
| 8 | Estimate the effect of super heat and sub cooling on .the vapour compression cycle. |
| 9 | Compare vapour compression and vapour absorption system |
| 10 | Point out the unit of refrigeration, with an example. |
| 11 | Evaluate the functions of Cooling load calculations. |
| 12 | Define thermoelectric refrigeration. . |
| 13 | Compare RSHF, GSHF and ESHF. |
| 14 | Define GSHF. |
| 15 | Define RSHF. |
| 16 | Define ESHF. |
| 17 | Give the concept of cooling towers. |
| 18 | Name the types of cooling towers. |
| 19 | How are air-conditioning systems classified? |
| 20 | Point out the various sources of heat gain of an air-conditioned space. |

| PART – B (13 Marks) | |
|---|---|
| **S. No.** | **Questions** |
| 1. | Explain the working of a simple vapour compression refrigeration system with neat diagram. |
| 2. | A Refrigerating machine working between the temperature limits of 13 ºC and 37 deg C and has 90% relative COP. It consumes 4.8 kW power. Determine TR capacity. For same TR capacity, how much power will be consumed by Carnot refrigerator? Also for the same power consumption, determine TR capacity of Carnot refrigerator operating between same temperature limits. |
| 3. | A cold storage room has walls made of 0.23 m of brick on the outside, 0.08 m of plastic foam and finally 15 mm of wood on the inside. The outside and inside temperature is 22ºC and 2ºC respectively. If the inside and outside heat transfer coefficient are 29 and 12 $W/m^2$ K respectively the thermal conductivities of bricks, foam and wood are 0.98, 0.02 and 0.17 W/m K respectively. Determine rate of heat removal by refrigeration per unit area of wall. |
| 5. | Air at 25 ºC WBT 25% RH is to be conditioned to 22 º C. DBT and 11 gm / kg d.a. specific humidity. Determine heat transfer per kg of dry air referring the psychrometric chart. Represent the process on chart by sketch. |
| 6. | Carnot refrigeration cycle absorbs heat at 270 K and rejects heat at 300K. (a) Calculate the coefficient of performance of this refrigeration cycle.(b) If the cycle is absorbing 1130 kJ/min at 270 K, how many kJ of work is required per second.(c) If the Carnot heat pump operates between the same temperatures as the above refrigeration cycle, what is the coefficient of performance. (d) How many kJ/min will the heat pump deliver at 300 K if it absorbs 1130 kJ/min at 270 K. |
| 7. | The capacity of a refrigerator is 200 TR when working between – 6°C and 25oC. Determine the mass of ice produced per day from water at 25°C.Also find the power required to drive the unit. Assume that the cycle operates on reversed Carnot cycle and latent heat of ice is 335kJ/kg. |
| 8. | Five hundred kgs of fruits are supplied to a cold storage at 20ºC. The cold storage is maintained at 5°C and the fruits get cooled to the storage temperature in10 hours. The latent heat of freezing is 105 kJ/kg and specific heat of fruit is 1.256 kJ/kg K. Find the refrigeration capacity of the plant. |
| 9. | A cold storage plant is required to store 20 tons of fish. The fish is supplied at a temperature of 30°C. The specific heat of fish above freezing point is 2.93 kJ/kg K. The specific heat offish below freezing point is 1.26 kJ/kg K. The fish is stored in cold storage which is maintained at –8ºC. The freezing point of fish is –4°C. The latent heat of fish is 235 kJ/kg. If the plant requires 75Kw to drive it, find (a)The capacity of the plant, and (b)Time taken to achieve cooling. Assume actual C.O.P. of the plant as 0.3 of the Carnot C.O.P. |
| 10. | Explain the following Counter flow induced draft; Counter flow forced draft and Cross flow induced draft. |
| 11. | Describe the factors affecting cooling tower performance in detail. |
| 12. | Describe the efficient system operation in cooling towers. |
| 13. | Elaborate the flow control strategies used in fans of cooling tower. |
| | SHF, GSHF and ESHF, with suitable examples. |

| | |
|---|---|
| 1. | Evaluate the working of Vapour compression refrigeration cycle with respect to the following refrigerants: CFCs (Chlorofluorocarbons) HCFCs (Hydro chlorofluorocarbons) |
| 2. | Explain about Cooling load calculations in refrigeration and air- conditioning systems. |
| 3. | Elaborate the effect of superheat and sub-cooling in refrigeration and air-conditioning systems. |
| 4. | Explain unitary and central air conditioning systems and their application in contemporary industries. |

5 An ammonia refrigerator produces 20 tons of ice per day from and at 0°C. The condensation and evaporation takes at 20°C and -20°C respectively. The temperature of the vapour at the end of isentropic compression is 50°C and there is no undercooling of the liquid. The actual COP is 70% of the theoretical COP. **Determine** the (i) rate of NH3 circulation and (ii) size of single acting compressor when running at 240 rpm assuming L=D and volumetric efficiency of 80%. Take latent heat of ice is 335 kJ/kg, specific heat of superheated vapour is 2.8 kJ/kgK and specific volume of saturated vapour at -20°C is 0.624 $m^3$/kg

| **Sat. Temp. (°C)** | **$h_f$(kJ/kg)** | **$h_g$ (kJ/kg)** | **$S_f$(kJ/kg k)** | **$S_g$ (kJ/kg k)** |
|---|---|---|---|---|
| 20 | 274.98 | 1461.58 | 1.0434 | 5.0919 |
| -20 | 89.72 | 1419.05 | 0.3682 | 5.6204 |

6 An NH3 refrigerator produces 30 tonnes of ice from and at 0°Cin a day of 24 hours. The temperature range in compressor is from 25°C to -15°C. The vapour is dry saturated at end of compression. Assume a COP of 60% theoretical. **Calculate** power required to drive the compressor. Assume latent heat of ice 335 kJ/kg. For properties of $NH_3$ refer table or charts.

| **Temp (°C)** | **$h_f$(kJ/kg)** | **$h_g$ (kJ/kg)** | **$S_f$(kJ/kg k)** | **$S_g$ (kJ/kg k)** |
|---|---|---|---|---|
| 25 | 298.9 | 1465.8 | 1.124 | 5.039 |
| -15 | 112.34 | 1426.5 | 0.4572 | 5.549 |

| | |
|---|---|
| 7 | A sling psychrometer in a laboratory test recorded the following readings. Dry bulb temperature = 303 K, Wet bulb temperature = 298 K. Calculate the following: (i) Vapour pressure (ii) Specific humidity (ii) Relative humidity (iii) Degree of saturation (iv) Dew point temperature(v) Enthalpy of mixture per kg of dry air. Take atmospheric pressure = 1.0132 bar. |
| 8 | Air enters compressor of an aircraft system at 100kPa, 277 K and is compressed to 300kPa with an isentropic efficiency of 72%. After being cooled to 328 K at constant pressure in a heat exchanger, the air then expands in a turbine to 100kPa with an isentropic efficiency of 78%. Low temperature air absorbs a cooling load of 3 tons of refrigeration at constant pressure before re entering compressor which is driven by turbine. Find the COP of refrigerator, driving power and air mass flow rate. |
| 9 | A simple R-12 plant is to develop 5 tonnes of refrigeration. The condenser and evaporator temperatures are to be 40oC and -10oC respectively. Determine refrigerant flow rate in kg/s, volume flow rate handled by compressor in m3/s, compressor discharge temperature, heat rejected to condenser in kW, COP and power required to drive compressor. |
| 10 | Describe the following refrigeration systems with layout: (i) Ammonia water system (ii) Lithium-bromide water system |