TEST ID: 302

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ESE- 2020 (Prelims) - Offline Test Series Test - 3

MECHANICAL ENGINEERING

SUBJECT: IC Engines, Refrigeration and Air conditioning + Power Plant Engineering — SOLUTIONS

01. Ans: (a)

Sol: Due to incomplete combustion the maximum temperature is lower than expected value obtained from stoichiometric calculation during odiabatic combustion in SI engine.

02. Ans: (a)

Sol: In Loffler boiler superheated steam is used for evaporation of feed water (heating).

03. Ans: (c)

Sol: Heat Rejection Ratio, HRR = $\frac{Q_R}{RE}$

RE = Refrigeration effect ,

Q_R = heat rejected by condenser

$\Rightarrow Q_R = RE + W$

$$\frac{RE + W}{RE} = HRR$$

$$1 + \frac{1}{COP} = HRR$$

$\Rightarrow$ HRR = 1.5

04. Ans: (d)

Sol: Temperature, turbulent and time are the factors responsible for good combustion.

05. Ans: (a)

Sol: The available heat drop in supersaturated flow of steam through nozzle decreases as compared to that in stable flow.

06. Ans: (c)

Sol: At a given evaporator temperature, the saturation pressure should be above atmospheric to prevent air or moisture ingress into system and ease of leak detection. High suction pressure is better as it leads to smaller compressor displacement.

Discharge pressure: At a given condenser temperature, the discharge pressure should be as small as possible to allow light-weight construction of compressor, condenser etc.

07. Ans: (b)

Sol: The pre-ignition concept is applied to SI engines only.

08. Ans: (d)

Sol: Scotch Marine is the boiler whose tubes are bent at the back to reduce the length.

09. Ans: (c)

Sol: $T_R = -23 + 273 = 250$ K ,

$T_O = 27 + 273 = 300$ K

$$(COP)_{carnot} = \frac{T_R}{T_o - T_R} = \frac{250}{300 - 250} = 5$$

Now, RC = 150 kJ/min

$$COP = \frac{RC}{P}$$

$$\Rightarrow \quad P = \frac{150}{5} = 30\,kJ/min$$

10. Ans: (d)

Sol: Octane number (ON) is related to performance number (PN) by

$$ON = \frac{1}{3}(PN - 100)$$

11. Ans: (b)

Sol: Excess air contributes to significant loss of energy.

12. Ans: (a)

Sol: The chemical formula of R11 is CCl_3F .

For, fully saturated halogenated compounds. The refrigerants are designated by R XYZ where

X+1 indicates, no.of carbon (C) atoms

Y–1 indicates, no.of Hydrogen (H) atoms

Z indicates, no. of Fluorine atoms

The balance indicates the number of Chlorine atoms.

here, X = 0

$\therefore$ X + 1 = 0 + 1 = 1

$\therefore$ The number of Carbon atoms is 1.

Y – 1 = 1 – 1 = 0

The number of Hydrogen atoms is 0

Z = 1

The number of Fluorine atoms is 1

Since the number of carbon atoms is 1, it is a derivative of methane (CH_4). The no. of Hydrogen atom is 0 and Fluorine is 1.

$\therefore$ The number of Chlorine atoms = 4 – 1 = 3

$\therefore$ Chemical Formula for R11 is CCl_3F

13. Ans: (d)

Sol: The design of combustion chamber of SI engine should take into account the following to avoid knock.:

- small bore
- short ratio of flame path to bore
- Absence of hot surface at end of region of charge

14. Ans: (d)

Sol: The components of total draught loss in a chimney draught system are:

- Velocity head loss at chimney exit
- Fuel bed resistance loss
- Head loss in economizer and air preheater
- Head loss in chimney and ducts

15. Ans: (b)

Sol: Cascade refrigeration system is used when very low refrigeration temperature is to be attained. Thus, it is used for applications requiring large temperature lifts.

16. Ans: (a)

Sol: Mean effective pressure for dual cycle increases with higher pressure ratio and lower cut off ratio.

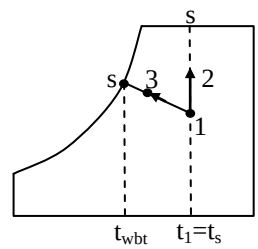
17. Ans: (d)

Sol: Admirably brass is the material of pipes commonly used in condensers.

18. Ans: (c)

Sol: Air washer involves flow of air through spray of water during course of flow air may be cooled or heated, humidified or dehumidified or simply adiabatically saturated depending on the mean surface temperature of water.

- If mean surface temperature at which water is sprayed is equal to dry bulb temperature ($t_1 = t_s$) then humidification of air takes place as shown in the figure.



t_1 = dry bulb temperature of air ,

t_s = mean surface temperature at which water is sprayed.

In process 1-2, the enthalpy of air increases. Thus water has to be heated externally.

- In process 1-3, which is adiabatic saturation process. The mean surface temperature of water is equal to wet bulb temperature ($t_{wbt} = t_s$) then the process is adiabatic saturation. In this process the enthalpy of air remains constant. Therefore, no external heating or cooling of water is done and water is simply re-circulated.

19. Ans: (d)

Sol: Over-cooling results in

- Difficulty in starting
- Poor combustion
- Condensation of Sulphurous and sulphuric acids

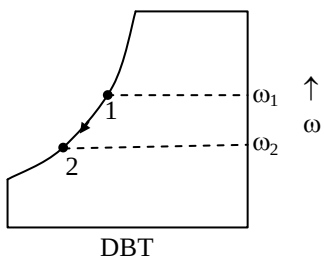
20. Ans: (a)

Sol: In regenerative steam cycle:

- As net work decreases steam rate increases.
- As thermal efficiency increases heat rate reduces.

21. Ans: (b)

Sol:



From the figure, it is clear that when warm saturated air is cooled

- excess moisture is condensed.
- specific humidity decreases.
- as air remains saturated, i.e., relative humidity remains unchanged.

22. Ans: (b)

Sol: Average speed during stage 2 combustion is called flame speed.

23. Ans: (c)

Sol:

- Large gas turbines use radial in flow turbines. ----------FALSE
- Gas turbines have blades similar to steam turbines. -------FALSE
- Gas turbines blade will appear as impulse section at hub and as reaction section at tip.-----TRUE
- Gas turbines use both air and liquid cooling.----------FALSE

24. Ans: (b)

Sol: For dehumidification process

(Coil temperature) < (DPT) for vapour in air to condense

(Coil temperature) > Freezing point of water so that ice does not form.

25. Ans: (d)

Sol: The increase in compression of SI engine decreases the temperature at beginning of exhaust.

26. Ans: (c)

27. Ans: (a)

Sol: $P_{atm} = 1.03$ bar

$P_{air} = 1$ bar

$P_{vap} = P_{atm} - P_{air} = 1.03 - 1 = 0.03$ bar

P_{sat} at DBT for vapor = 0.05 bar

$$\text{Relative humidity} = \frac{P_V}{P_{sat}} = \frac{0.03}{0.05} = 0.6$$

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28. Ans: (c)

Sol: In circulating fluidized bed combustion boilers No_x emissions are 50 - 150 ppm because of low furnace temperatures.

29. Ans: (d)

Sol: To keep boiling point of water at 100°C in high altitude operations.

30. Ans: (a)

Sol: The correct sequence of passing the flue gases through different absorbents during analysis in Orsat apparatus is Potassium hydroxide solution-alkaline solution of pyrogallic acid-cuprous chloride solution.

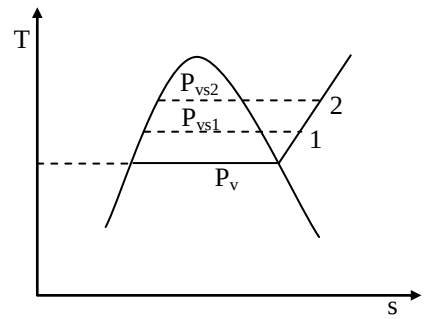
31. Ans: (b)

Sol: By increasing condenser pressure, the mean temperature of heat addition in a steam plant can be increased.

32. Ans: (c)

Sol:

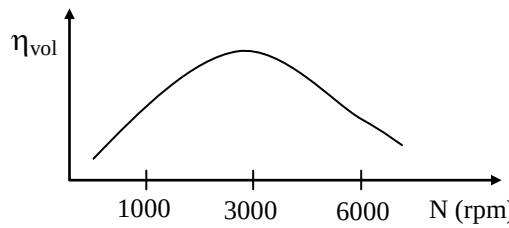
- As temperature changes, the partial vapour pressure remains constant and hence, its specific humidity also.
- If temperature changes, its dry bulb temperature also changes and due to this saturation vapour pressure changes and hence relative humidity also changes.



- Partial pressure of vapour is very low and at low pressure water vapour can be treated as ideal gas irrespective of temperature.

33. Ans: (c)

Sol:



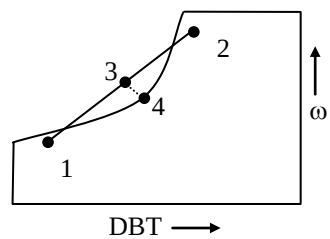
34. Ans: (d)

Sol: The correct steam turbine arrangements are:

- Cross compound
- Tandem compound
- Vertical double flow

35. Ans: (c)

Sol:



The figure in the problem shows the process of mixing with condensation. When large quantity of cold air mixes with warm air with high relative humidity, some amount of water vapour condenses.

36. Ans: (b)

37. Ans: (a)

Sol: Nozzles used in high pressure impulse stage turbine are called reamed nozzles.

38. Ans: (d)

Sol: $\text{COP} = \dfrac{\text{RE (kJ/kg)}}{\text{W (kJ/kg)}}$

$$4 = \frac{80}{W}$$

$W = 20$ kJ/kg

Q_R = Heat rejected in condenser

$= RE + W = 80 + 20$

$Q_R = 100$ KJ/kg

$Q_R\,(\text{kW}) = \dot{m}(\text{kg/sec})Q_R(\text{kJ/kg})$

$= 2 \times 100 = 200$ kW

39. Ans: (a)

Sol: In cross scavenging of two stroke engine, intake and exhaust ports are on opposite side of cylinder walls.

40. Ans: (c)

Sol: Increase in pump work is not a consequence of irreversible expansion in a Rankine cycle.

41. Ans: (b)

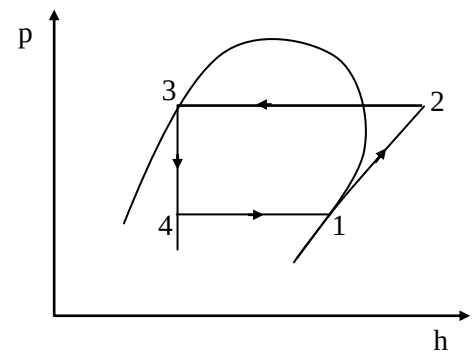
Sol: $(\text{COP})_R = \dfrac{RC}{W} = \dfrac{10}{5} = 2$

$(\text{COP})_{HP} = (\text{COP})_R + 1 = 2 + 1 = 3$

$\dfrac{(\text{COP})_{HP}}{(\text{COP})_R} = \dfrac{3}{2} = 1.5$

42. Ans: (a)

Sol:



$$\text{COP} = \frac{RC}{P_{in}} = \frac{h_1 - h_4}{(h_2 - h_1)}$$

where, RC = refrigeration capacity (in kW)

P_{in} = power input (in kW)

$$W = \frac{RC(h_2 - h_1)}{(h_1 - h_4)} = \frac{5 \times 3.5 \times (210 - 183)}{(183 - 75)}$$

$= 4.375$

Mass flow rate of the refrigerant

$$= \frac{5 \times 3.5}{(183 - 75)} = 0.162\,\text{kg/sec}$$

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43. Ans: (a)

Sol: In evaporative type of condenser, steam flows in pipes which are surrounded by water.

44. Ans: (b)

Sol:

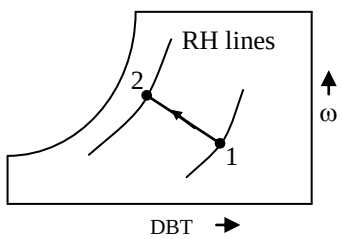
- Due to regeneration heat required is less and hence η_{th} increases.
- Reheating has no effect on compressor work.
- Supersonic flow leads to decrease in efficiency.

45. Ans: (d)

Sol: All the instruments given are used in the control and supervision of turbine.

46. Ans: (a)

Sol:



As cooling and humidification occurs relative humidity increases, dew point temperature increases and specific humidity also increases as shown in the figure.

47. Ans: (c)

Sol: Radial inward motion of gas mixture is called squish. As piston reaches TDC a squish motion generates secondary rotational flow called tumble.

48. Ans: (a)

Sol: $\dot{W}_P = \dot{m}v\Delta P = \dot{m}v_{f@100kPa}\left(P_1 - P_5\right)$

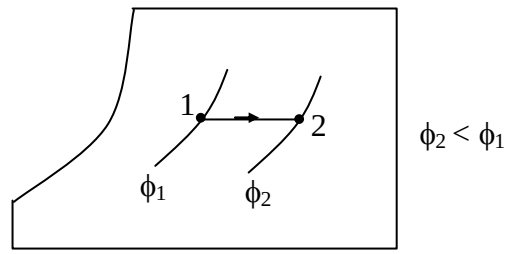
$= 1.74 \times 0.001043\ (15\times10^3 - 100)$

$= 27.04$ kW

49. Ans: (d)

50. Ans: (c)

Sol:



1-2 Heating process

51. Ans: (c)

52. Ans: (b)

Sol: Degree of saturation (μ) = $\dfrac{\omega}{(\omega_s)}$

53. Ans: (d)

Sol: $\text{Back work ratio} = \dfrac{\text{Pump work}}{\text{Turbine work}}$

Since the pump handles only liquid phase, back work ratio for a Rankine cycle with superheater and reheater is very small.

54. Ans: (c)

55. Ans: (a)

Sol: HC emissions in SI engine are 6000 ppm.

56. Ans: (c)

Sol: Total Heat Load = THL = 5 kJ/min

Sensible Heat Factor = SHF = 0.8

$$SHF = \frac{SHL}{THL}$$

$$0.8 = \frac{SHL}{5} \text{ ; } SHL = 4 \text{ kJ/min}$$

SHL + LHL = THL

4 + LHL = 5

$\Rightarrow$ LHL = 5 – 4 = 1 kJ/min

57. Ans: (d)

Sol: Given $\frac{\text{Net work}}{\text{Turbine work}} = 0.56$

$$\frac{\text{Turbine work} - \text{Compressor work}}{\text{Turbine work}} = 0.56$$

$$\frac{W_T - W_C}{W_T} = 0.56$$

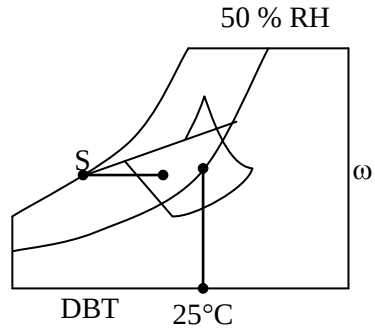
$$1 - \frac{W_C}{W_T} = 0.56$$

Or, $\frac{W_C}{W_T} = 0.44$

$$\Rightarrow W_T = \frac{W_C}{0.44} = \frac{161.5}{0.44} = 367.0501 \text{ kJ/kg of air}$$

58. Ans: (c)

Sol:



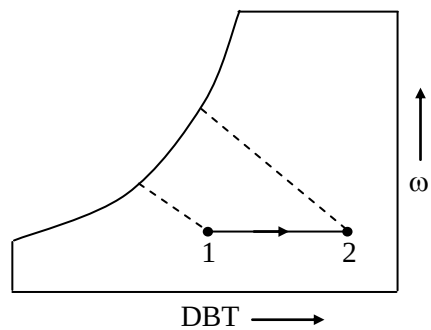
Lower DBT and higher relative humidity has less load.

59. Ans: (d)

Sol: The effect of supplementary firing in a combined cycle when two power producing cycles are connected in series, is to reduce the overall cycle efficiency.

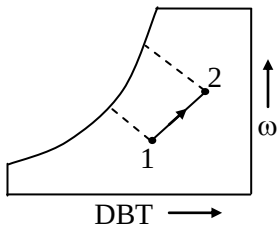
60. Ans: (c)

Sol: **Sensible heating process :**



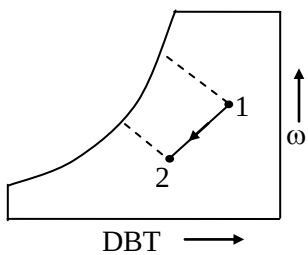
WBT increases.

Heating and Humidification process :



DBT increases.

Cooling and Dehumidification process :



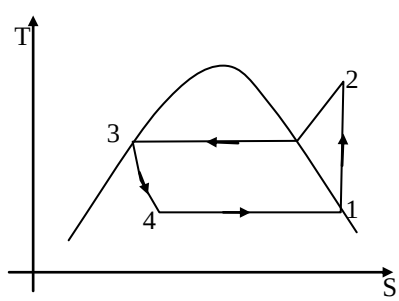
Specific humidity decreases.

61. Ans: (a)

Sol: Since condenser is a part of bottoming cycle, gas turbine power output will be independent of the condenser temperature.

62. Ans: (d)

Sol:



$h_1 = 100$ kJ/kg;

$h_2 = 120$ kJ/kg

$h_3 = 40$ kJ/kg $= h_4$

NRE (kJ/kg) $= h_1 - h_4 = 100 - 40 = 60$ kJ/kg

W_c (kJ/kg) $= h_2 - h_1 = 120 - 100 = 20$ kJ/kg

$$\text{COP} = \frac{\text{NRE(kJ/kg)}}{\text{Wc(kJ/kg)}} = \frac{60}{20} = 3$$

63. Ans: (c)

64. Ans: (b)

Sol: In a three stage Curtis turbine the workdone is in the ratio 5:3:1. Workdone in the last stage of a three stage velocity compounded impulse turbine is $1/9^{th}$ of the total work.

$$\Rightarrow \quad \frac{1}{9} \times 1800 = 200\,\text{kW}$$

65. Ans: (d)

Sol: Critical temperature of refrigerant, should be very high so the condenser temperature line on p-h diagram is for removed from critical point. Refrigeration effect becomes very small if state of liquid before expansion is near the critical point. Therefore COP becomes low.

66. Ans: (a)

67. Ans: (B)

68. Ans: (a)

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69. Ans: (b)

Sol:

- $\eta_v = 1 - C\left[\left(\frac{P_2}{P_1}\right)^{\frac{1}{n}} - 1\right]$

  From above equation when clearance ratio C increases, volumetric efficiency decreases
- As the clearance increases flow capacity decreases. Therefore reciprocating compressors are built with minimum clearance in order to get maximum flow capacity.

70. Ans: (b)

71. Ans: (b)

Sol: Regenerative cycle is preferred at low pressure ratios and Brayton cycle is preferred at high pressure ratios.

72. Ans: (d)

73. Ans: (d)

74. Ans: (a)

Sol: In summer air conditioning the cooling and humidification is required. Because the outside air temperature and humidity are both high, therefore room gains heat as well as moisture.

75. Ans: (b)