TEST ID: 403

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ESE- 2019 (Prelims) - Offline Test Series Test – 5

MECHANICAL ENGINEERING

IC ENGINES, REFRIGERATION and AIR CONDITIONING + POWER PLANT ENGINEERING ___ SOLUTIONS

01. Ans: (c)

Sol: Total heat loss area = Heat loss from cylinder surface + Heat loss from cylinder head + Heat loss through piston

$$= \pi DL + \frac{\pi}{4}D^2 + \frac{\pi}{4}D^2$$

$$= \pi \times 3 \times 3 + \frac{\pi}{4} \times 3 \times 3 + \frac{\pi}{4} \times 3 \times 3$$

$$= 9\pi + \frac{9}{4}\pi + \frac{9}{4}\pi$$

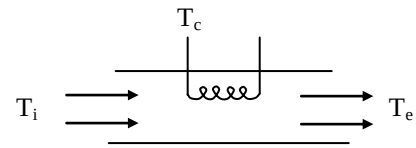
$$= \frac{27}{2}\pi$$

02. Ans: (c)

Sol: Pulse jet engine can be idealised to follow Lenoir cycle. it consists of constant volume heat addition, reversible adiabatic expansion and constant pressure heat rejection.

03. Ans: (c)

Sol: When SHF = 1 (sensible cooling)



$$BPF = \frac{T_e - T_c}{T_c - T_i} = 0$$

$T_e - T_c = 0$

$T_e = T_c$

Room dew point temperature will be equal to the coil dew point temperature.

04. Ans: (a)

Sol: Disadvantages of gas turbine power plant in utility system are :

- Low cycle efficiency, due to large exhaust loss, large compressor work and inefficiencies.
- Large compressor work input, since power required to drive the compressor is considerably higher.

- Large exhaust loss, since exhaust gas temperature is quite high.
- Machine inefficiencies, since with decreases in compressor efficiency take work input to compressor increases and with decreases in turbine efficiency work output from turbine decreases.
- Gas turbine plants respond quickly to load changes.

05. Ans: (d)

Sol:

- The ultimate analysis gives the chemical elements that comprise coal substance together with ash and moisture. It is used to determine percentage of carbon, hydrogen, oxygen, sulphur, nitrogen, moisture and ash on mass basis.
- Some types of coal during and after release of volatile matter become soft and pasty and form agglomerate. These are called caking coal. Swelling index is a property used to determine the extent of caking of coal.

06. Ans: (a)

Sol: $T_E = 7°C = 280\ K$

$T_G = 87°C = 360\ K$

$T_O = 37°C = 310\ K$

$$COP = \frac{T_E(T_G - T_O)}{T_G(T_O - T_E)}$$

$$= \frac{280(87-37)}{360\times(37-7)} = \frac{280\times 50}{360\times 30} = 1.29$$

07. Ans: (c)

Sol:

- Due to shortcomings of distribution and limited intermixing of fuel CI engine are operated at high air fuel ratios than stoichiometric requirements.
- α-methyl naphthalene is a hydrocarbon with poor ignition quality. It is assigned zero centene number.

08. Ans: (c)

Sol: For a constant velocity of flow, if the duct diameter is increased

- The flow through duct will increase
- The friction pressure drop in the duct will decrease

09. Ans: (b)

Sol: In CI engine detonation occurs at the beginning of combustion.

10. Ans: (c)

Sol:

- Reheating and intercooling decreases turbine efficiency.
- Regeneration improves thermal efficiency of gas turbine by increasing mean temperature of heat addition.

11. Ans: (a)

Sol:

- Crank case dilution and evaporation loss are effected by tail end volatility.
- Engine warm up is effected by mid range volatility.

12. Ans: (b)

Sol:

- Increase in injection advance increases delay period, because pressure and temperature are lower when injection begins.
- Increase in jacket water temperature increases compressed air temperature and hence delay period is reduced.

13. Ans: (d)

Sol: COP of heat pump = $\frac{T_H}{T_H - T_L} = \frac{Q_H}{W_{net}}$

$$\frac{300}{27-7} = \frac{20}{W_{net}}$$

$$W_{net} = \frac{20 \times 20}{300} = \frac{4}{3}\text{kW}$$

From first law of thermodynamics

$Q_L + W_{net} = Q_H$

$$Q_L = 20 - \frac{4}{3} = \frac{56}{3} = 18.67\,\text{kW}$$

14. Ans: (c)

Sol: Air has 79 % Nitrogen by volume, Nitrogen does not participate in chemical reaction.

15. Ans: (b)

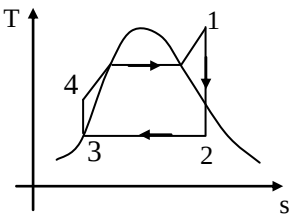
Sol: $\text{COP} = \frac{\text{Refrigerating eff}}{W_{net}} = \frac{3.5}{\frac{2N}{\text{COP}}}$

(as 1 TR = 3.5 kW)

$$N = \frac{3.5}{2} = 1.75\,\text{kW}$$

16. Ans: (b)

Sol:



$W_T = (h_1 - h_2)$

$= 2904 - 1900$ kJ/kg

$= 1004$ kJ/kg

Pump work = 4 kJ/kg

$W_{net} = 1004 - 4 = 1000$ kJ/kg

$\therefore$ Specific steam consumption

$$= \frac{3600}{1000}\text{kg/kw-hr}$$

= 3.6 kg/kW-hr

17. Ans: (d)

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

18. Ans: (b)

Sol: Due to reheating of steam in steam turbine power plant

- Efficiency improves marginally
- Specific work output increases
- Blade erosion reduces

19. Ans: (b)

Sol: Regenerative feed water heating increases the mean temperature of heat addition. Hence, cycle efficiency increases.

20. Ans: (b)

Sol: Economiser heats the feed water to the saturated temperature corresponding to the boiler pressure.

21. Ans: (b)

Sol: $W_{max} = c_p\left(\sqrt{T_{max}} - \sqrt{T_{min}}\right)^2$

$= 1\left(\sqrt{1225} - \sqrt{400}\right)^2$

$= (35 - 20)^2 = 225$ kJ/kg

22. Ans: (a)

Sol: Specific humidity (ω) $= \frac{m_v}{m_a} = \frac{0.622\,P_v}{P_t - P_v}$

$\frac{0.5}{40} = \frac{0.622\,P_v}{100 - P_v}$

$0.5 = \frac{24.88\,P_v}{100 - P_v}$

$100 - P_v = 49.76\,P_v$

$P_v = 1.97$ kPa

Relative humidity (ϕ) $= \frac{P_v}{P_{vs}} = \frac{1.97}{3}$

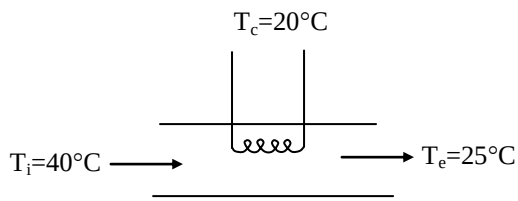
$= 0.6566 = 65.66\ \%$

23. Ans: (a)

Sol: Approach of cooling tower is difference between cold water outlet temperature and wet bulb temperature.

24. Ans: (b)

Sol:



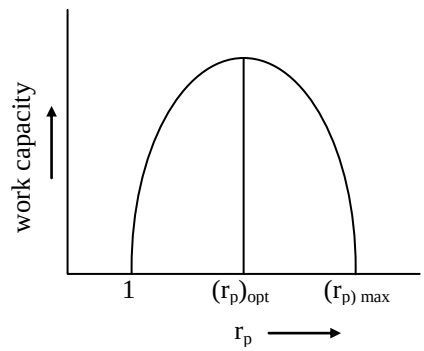
$\text{Contact factor} = 1 - \text{BPF}$

$= 1 - \frac{25 - 20}{40 - 20}$

$= 1 - \frac{5}{20} = 0.75$

25. Ans: (c)

Sol:



If pressure ratio increases, the work capacity of Brayton cycle first increases, becomes maximum and then decreases.

Work capacity is zero when r_p is unity ; becomes maximum when $(r_p)_{opt} = \left(\frac{T_{max}}{T_{min}}\right)^{\frac{\gamma}{2(\gamma-1)}}$, and again becomes zero when $(r_p)_{max} = \left(\frac{T_{max}}{T_{min}}\right)^{\frac{\gamma}{(\gamma-1)}}$ as shown in the figure below. At maximum pressure ratio the efficiency of Brayton cycle becomes equal to Carnot efficiency and work output become zero.

26. Ans: (d)

Sol: Thermostatic expansion valve maintains a constant degree of super heat.

27. Ans: (a)

Sol:

- The air fuel ratio in gas turbine is kept very high. It varies from 60 / 1 to 120 / 1. Because of high air fuel ratio used, gases entering HP turbine contain high percentage of oxygen and therefore if reheating is performed, the additional fuel can be burnt in the HP turbine.
- Reheating in gas turbine increases turbine work.
- Intercooling and reheating in gas turbine decreases thermal efficiency.

28. Ans: (b)

Sol:

- Risers installed all around the furnace walls act as cooling tubes or a water wall and carry away heat from furnace at the same rate at which heat is released in it by the burning of fuel.
- If circulation is inadequate the rate at which heat is carried away will be less than heat released. The difference will be stored in riser tubes leading to their overheating and rupturing.
- Riser located in the corners of furnace are relatively cooler. So these will have more circulation ratio than other riser tubes.
- Circulation ratio

$$= \frac{\text{flow of saturated water in downcomer}}{\text{flow of steam released from drum}}$$

$$= \frac{m}{m_g} = \frac{m_g + m_\ell}{m_g}$$

29. Ans: (c)

Sol: Use of condenser increases the work output and efficiency of steam power plant.

30. Ans: (c)

Sol: The following are the reasons for the pressure drop :

1. Friction, due to fluid velocity, resulting in frictional pressure drop.
2. Acceleration, due to the flashing off the liquid refrigerant into vapour, resulting in momentum pressure drop.

31. Ans: (c)

Sol: Benson boiler is a drumless once through boiler. This boiler can operate at super critical pressure.

32. Ans: (d)

Sol: Proximate analysis indicate behaviour of coal when it is heated. It is used to determine percentage of fixed carbon, ash, volatile matter and moisture.

33. Ans: (c)

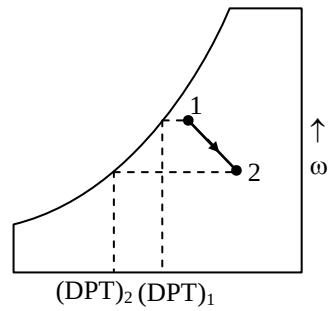
Sol: Function of high steam and low water safety valve is two fold :

1. It blows out if the steam pressure is higher than the working pressure.
2. It blows out steam when water level in the boiler is low.

34. Ans: (b)

Sol:

- During cooling and dehumidification process, relative humidity may increases, decreases or remain constant.
- Chemical dehumidification process



$(DPT)_2 < (DPT)_1$

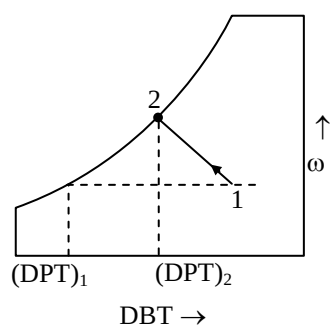
35. Ans: (c)

Sol:

- Bomb calorimeter is used to determine higher calorific value of fuels by volume.
- Orsat apparatus is used to determine products of only dry constituents of combustion by volume.

36. Ans: (b)

Sol:



During adiabatic saturation process :

- $\omega \uparrow$
- DPT $\uparrow$
- Process is cooling and humidification
- WBT = constant
- Enthalpy = constant

37. Ans: (c)

Sol: $t = \frac{\theta}{6N} = \frac{9}{6 \times 1200} \text{sec}$

$= 0.00125$ sec

38. Ans: (a)

Sol: Compressed gas enters the tube tangentially not normally.

39. Ans: (d)

Sol: The component which is used to recover heat of exhaust gases before boiler furnace is air preheater.

40. Ans: (b)

Sol:

- In shell tube surface condenser for convenience of cleaning and maintenance cooling water flows through tubes and steam condenses outside the tube.
- Spray condenser is a direct contact type condenser in which cooling water is sprayed into the steam mixes directly with cold water and gets condensed.
- Jet condenser, spray condenser and barometric condenser are direct contact type condenser.

41. Ans: (a)

Sol: Absorption system is not a reversible refrigerating machine. Because of the mixing process of refrigerant and absorbent, a degree of irreversibility is involved.

42. Ans: (c)

Sol: Efficiency of Otto cycle is given by $1 - \frac{1}{r^{\gamma - 1}}$

where r is compression ratio

Adiabatic index, γ for Helium is 1.67, Air is 1.4 and CO_2 is 1.3.

$\therefore$ η_{otto} (Helium) > η_{otto} (Air) > η_{otto} (Carbon dioxide)

43. Ans: (b)

Sol: For maximum power the fuel-air mixture should be 10% rich.

44. Ans: (a)

Sol: The third fluid remains mainly in the evaporator thus reducing the partial pressure of the refrigerant to enable it to evaporate at low pressure and hence low temperature.

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45. Ans: (b)

Sol: For maximum work output in two stage expansion turbine with perfect reheating, the intermediate pressure is $p_i = \sqrt{p_d p_s}$.

46. Ans: (a)

Sol: The octane number in a single cylinder CFR diesel engine, the engine speed and jacket water temperature are 900 rpm and 100°C respectively.

47. Ans: (c)

Sol: From the energy balance : **M – W = Q + S**

48. Ans: (a)

Sol: As engine speed increases in terms of crank angle hence ignition delay increases. Because of retarding due to increased heat loss ignition delay increases. Due to ignition advance, as pressure and temperature are low ignition delay increases. Due to engine size increases, ignition delay decreases in terms of crank angle.

49. Ans: (b)

Sol: The delay period decreases with cetane number of the fuel because it reduces the self ignition temperature of the fuel.

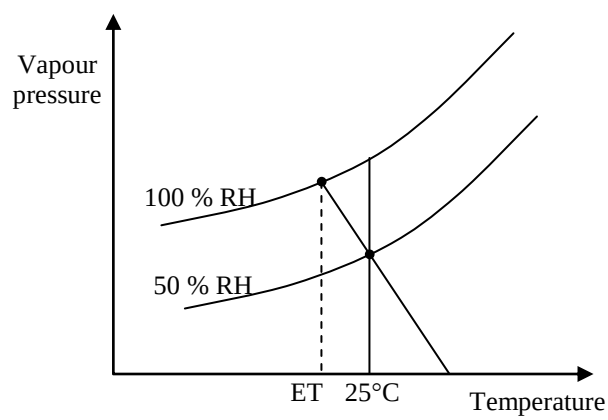
50. Ans: (a)

Sol: If the inlet pressure is low temperature at the end of compression is low, temperature at the end of heat supply is low, low peak pressure and temperatures, reduce knocking. Hence, statement 4 is wrong.

51. Ans: (b)

Sol:

- Effective temperature is the temperature saturated air (100 % RH) at which the subject would experience the same feeling of comfort as experienced in the actual unsaturated environment.
- Vapour pressure corresponding to effective temperature is more than that of actual comfort condition.



where, ET = effective temperature

52. Ans: (d)

Sol: Fuel is injected on to the hot piston. Slow rate of pressure rise takes place resulting in less noise. Cold starting is difficult as the piston is cold.

53. Ans: (a)

Sol: EGR displaces some incoming air and also heats the air, lowering its density. The volumetric efficiency is thus reduced by EGR.

54. Ans: (c)

Sol: Due to the expansion of the refrigerant, temperature of the refrigerant decreases in the capillary tube.

For cooling process :

Joule-Thomson coefficient (μ) > 0

55. Ans: (a)

Sol: The main objective of supercharging is to obtain more power by burning the large amount of fuel or to reduce the weight and the size of the engine for a given power output.

56. Ans: (d)

Sol: A method usually employed for starting the engine from the cold is to shut off most of the main air supply to the main jets and thus produce rich mixture necessary for cold starting.

57. Ans: (b)

Sol: COP of the Bell-Coleman cycle = $\dfrac{1}{\left(r_p\right)^{\frac{\gamma-1}{\gamma}}-1}$

when $r_p \uparrow \Rightarrow$ COP $\downarrow$

where, r_p = pressure ratio

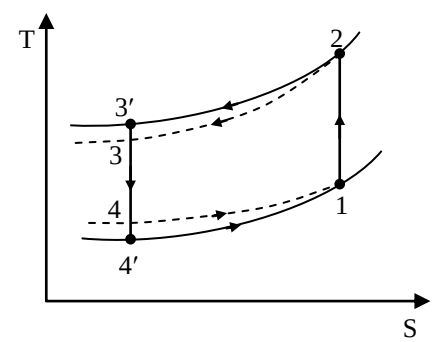
$$\gamma = \frac{c_p}{c_v} = \text{ratio of specific heats}$$

58. Ans: (a)

Sol: Knocking tendency in SI engine is reduced by decreasing the compression ratio.

59. Ans: (c)

Sol:



Actual gas refrigeration cycle :

Actual cycle $\rightarrow 1 - 2 - 3 - 4 - 1$

Ideal cycle $\rightarrow 1 - 2 - 3' - 4'$

Pressure, $P_1 > P_4$

$P_2 > P_3$

$1 \rightarrow$ entry to compressor

$2 \rightarrow$ exit from compressor

$3 \rightarrow$ entry to turbine

$4 \rightarrow$ exit from turbine

60. Ans: (b)

Sol:

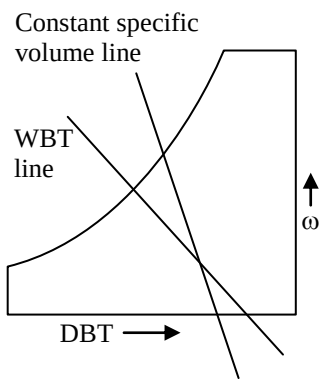
- Volumetric efficiency of four stroke engine is higher than two stroke engine due to greater time of induction.
- In two stroke engine cycle is completed in two stroke of piston cylinder in one revolution of crankshaft. Thus, more uniform turning moment than four stroke engine.

61. Ans: (b)

Sol: For better starting 10% of the fuel should evaporate at low temperatures. In winter, as atmospheric temperature are low, volatility curve should be lower.

62. Ans: (c)

Sol:



For constant specific volume line, specific humidity changes. (i.e., moisture content changes).

63. Ans: (a)

Sol: Thermal efficiency of combined cycle plant is higher than individual cycles. Thus, higher conversion efficiency from fuel to electricity can be achieved.

64. Ans: (b)

Sol: In SI engines supercharging increases the tendency to detonate and pre-ignite whereas in CI engines supercharging tend to prevent knocking.

65. Ans: (b)

Sol: When the body temperature is less than the air temperature. Heat will not be transfer from the body by convection, conduction and radiation. The heat will be transferred by evaporative cooling.

66. Ans: (d)

Sol: As the number of cylinders increases, the dwell angle decreases as the firings are more for every two revolutions.

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67. Ans: (a)

Sol: Joule -Thomson coefficient for an ideal gas

$(\mu) = 0$

$$\left(\frac{dT}{dP}\right)_h = 0$$

$$dT = 0$$

$$T_2 = T_1$$

If we use throttling valve, there will not be change in the temperature.

68. Ans: (a)

Sol: Net work is practically unity

$$\frac{W_T - W_p}{W_T} \approx 1 \qquad \because W_T >> W_P$$

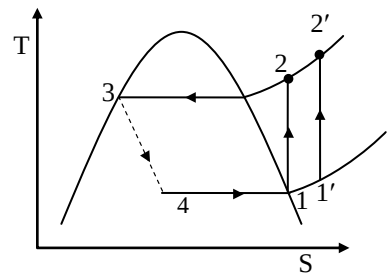
Pump work is very small compared to turbine work because pump compresses the saturated liquid which has small specific volume.

69. Ans: (a)

Sol: Fuel level in the compensating well decreases with the increase in air flow rate. For compensating jet or double jet engine, the compensating jet supplies leaner mixture and the main jet makes richer mixture and both together maintain constant air fuel ratio at all speeds.

70. Ans: (b)

Sol: V-C cycle :



$T_2' > T_2$

T_2' = New peak temperaure of the cycle

71. Ans: (b)

Sol:

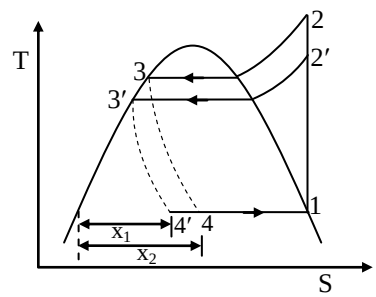
- Octane rating of gasoline is based on iso-octane and normal-heptane.
- Tetraethyl lead is added to gasoline to increase octane number.

72. Ans: (a)

Sol: In diesel engine, cut off ratio depends on load. Hence, unlike Otto cycle the air standard efficiency of diesel cycle depends on load and increase as the load is increased.

73. Ans: (d)

Sol:



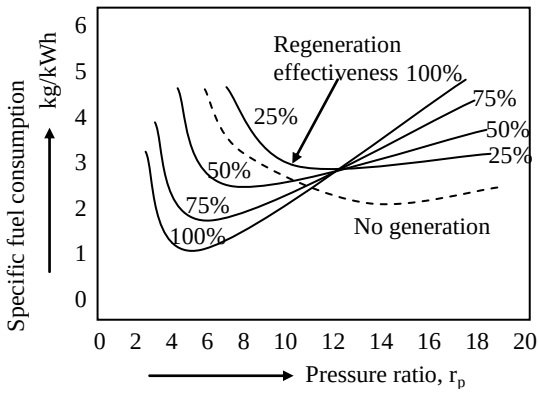
$x_1 < x_2$

Where x = quality of the mixture.

- As condenser temperature decrease, refrigerating effect increases and power input decreases. Because of this COP will increases.

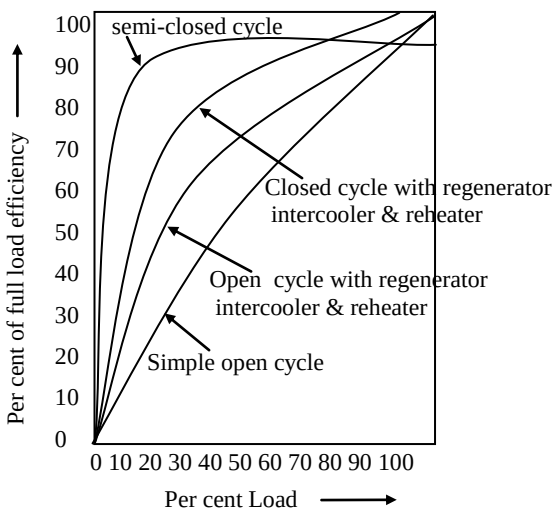
74. Ans: (b)

Sol:



(a)

Fig. (a) shows, variation of specific fuel consumption with pressure ratio with different degree of regeneration. It is clear that there is a optimum pressure ratio for each degree of regeneration.



(b)

Fig. (b) shows the variation of percentage of fuel load efficiency with part load. It is clear that for semi-closed cycle the part load efficiency is the best.

75. Ans: (b)

Sol:

- At high engine speed vacuum at the throat is high and we get too rich mixtures.
- In multicylinder engines, the mixture passing through the intake many fold generally contains a certain amount of petrol in the droplet form. These droplets have greater inertia then gaseous mixture and, hence, whenever the direction of flow is changed abruptly, the droplets tend to continue in their original direction of movement. As a result, there is a variation in the A/F ratio between cylinders, the outer cylinders getting richer mixture than the inner cylinders, the outer cylinders getting richer mixture than the inner cylinders.

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