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Engineering Academy

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ESE- 2018 (Prelims) - Offline Test Series Test - 9

MECHANICAL ENGINEERING

SUBJECT: IC ENGINES, REFRIGERATION AND AIR CONDITIONING + POWER PLANT ENGINEERING – SOLUTIONS

01. Ans: (c)

Sol: Vortex tube refrigeration:

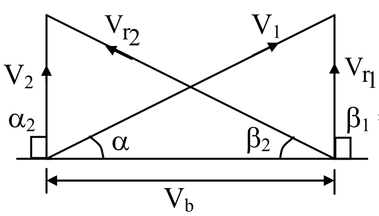
- It is a device which develops hot and cold streams simultaneously at its two ends by using compressed air.
- It has no moving parts.
- Its COP is very low thus it is used in small capacity refrigeration.
- Nozzle is used to develop a high tangential velocity in the chamber. Hence, it has to tangential to the chamber and the losses in the nozzle should be reduced to minimum.

02. Ans: (a)

Sol: As static head remains same in the float chamber, the compensating jet in the carburettor supplies constant fuel.

03. Ans: (c)

Sol:



For a Parson's reaction turbine with maximum efficiency, the velocity diagram is shown as above

$V_b = V\cos\alpha = V_{w1}$ and $V_{w2} = 0$

where V_{w1} and V_{w2} are whirl velocities at inlet and exit to the turbine respectively

Workdone, $W = (V_{w1} + V_{w2})V_b$

$= V_{w1} \times V_b = V_b^2$

$(\therefore V_{w1} = V_b \text{ and } V_{w2} = 0)$

$= 100^2$

$= 10000$ J/kg or 10 kJ/kg

04. Ans: (a)

Sol: The process in cooling tower is close to adiabatic saturation process where minimum possible temperature is wet bulb temperature.

05. Ans: (d)

Sol: A good combustion chamber for compression ignition engine should have such a design that it creates turbulent motion for the fuel and air mixture when fuel is injected for better combustion.

06. Ans: (c)

Sol: The optimum blade velocity ratio for Curtis stage having n-rows of moving blades is given by

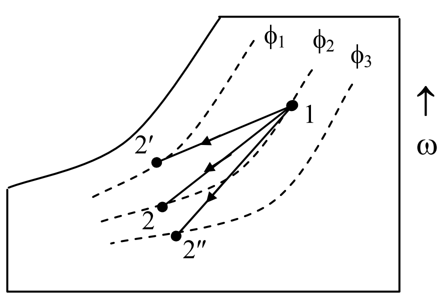
$$\rho_{opt} = \frac{V_b}{V} = \frac{\cos\alpha}{2n}$$

where, V_b = blade velocity

V = absolute velocity of steam at inlet to moving blades.

07. Ans: (d)

Sol:



$$\phi_1 > \phi_2 > \phi_3$$

For the cooling and dehumidification process the final state (2) can be on the line of constant relative humidity (as shown in figure 1-2) or it can be above (1-2′) or below (1-2″) that line. Thus during cooling and dehumidification process the relative humidity may increase, decrease or remain same.

08. Ans: (a)

Sol: For a fuel to be suitable for diesel engine, its cetane number should be high to promote auto ignition.

09. Ans: (A)

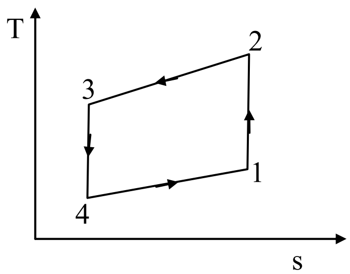
Sol:

- Compounding is done to reduce turbine speed. If entire enthalpy drop occurs in single stage, they would have very high rotational speed (N). Such high speeds cannot be properly utilised and entails large frictional losses. Centrifugal stress also becomes very large.
- In pressure compounding entire enthalpy drop does not occur in single row of nozzles but enthalpy drop occurs in row of nozzles at each stage. The enthalpy drop is equally divided among the stages.

- Curtis staging is less efficient than rateau stages because velocity of steam in Curtis staging is high. Thus frictional losses are more.

10. Ans: (d)

Sol:



Consider the T-s diagram for ideal Bell-Coleman cycle

$$COP = \frac{\text{Refrigeration effect}}{\text{Net work}}$$

$$= \frac{c_p(T_1 - T_4)}{c_p(T_2 - T_1) - c_p(T_3 - T_4)}$$

$$= \frac{T_1 - T_4}{(T_2 - T_3) - (T_1 - T_4)}$$

$$= \frac{1}{\left(\frac{T_2 - T_3}{T_1 - T_4}\right) - 1}$$

$$= \frac{1}{\frac{T_2}{T_3}\frac{\left(1 - \frac{T_3}{T_2}\right)}{\left(1 - \frac{T_4}{T_2}\right)} - 1}$$

Now $\frac{T_2}{T_1} = \frac{T_3}{T_4} = r_p^{\frac{\gamma-1}{\gamma}}$

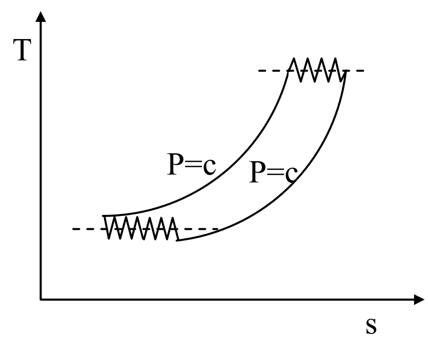
$$\frac{T_3}{T_2} = \frac{T_1}{T_4}$$

$$COP = \frac{1}{\frac{T_2}{T_3} - 1} = \frac{T_1}{T_2 - T_1}$$

or $$COP = \frac{1}{\frac{T_3}{T_4} - 1} = \frac{T_4}{T_3 - T_4}$$

11. Ans: (c)

Sol:



If the number of compression and expansion stages are infinite in Brayton cycle, if approaches to Ericson cycle as shown in T-s diagram.

12. Ans: (c)

Sol: The maximum blading efficiency for a single stage impulse turbine is given by,

$$\frac{(1 + k_b)}{2}\cos^2\alpha$$

13. Ans: (c)

Sol: Contact factor $= \frac{T_{in} - T_{out}}{T_{in} - T_{coil}}$

$$= \frac{30 - 15}{30 - 10} = 0.75$$

14. Ans: (d)

Sol: NO_2 + sun light → NO + O + smog

15. Ans: (b)

Sol: Workdone $= \frac{V_1^2 - V_2^2}{2}$

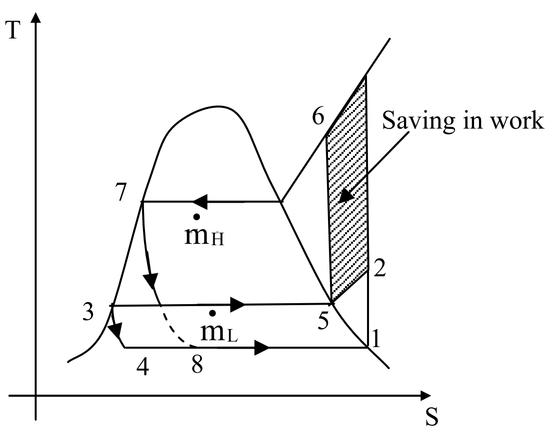
where V_1 = 50 m/s at nozzle exit

V_2 = 10 m/s at blade exit

$$= \frac{50^2 - 10^2}{2} = 1200 \text{ Nm}$$

16. Ans: (a)

Sol: Cascade Refrigeration System :



Due to cascading:

i. Net refrigeration effect increases
ii. W_c decreases
iii. COP increases
iv. Compressor discharge temperature decreases, dryness fraction decreases
v. Pressure ratio(r_p) decreases
vi. volumetric efficiency(η_{vol}) increases

17. Ans: (a)

Sol: In cold region, the condenser temperature is lower due to lower cooling water temperature which results in increase in specific output and efficiency.

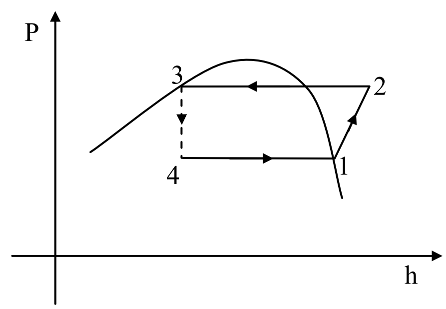
18. Ans: (b)

Sol: $\text{BMEP} = \frac{\text{Power}}{\text{L.A.}\frac{N}{2}}$

$$= \frac{45}{1.5\times10^{-3}\times\frac{3000}{2\times60}} = 1200 \text{ kN/m}^2$$

19. Ans: (b)

Sol:



h_2 = 200 kJ/kg,

$h_3 = h_4$ = 80 kJ/kg

$$h_1 = h_2 - \frac{W_c}{\dot{m}}$$

$$= 200 - \frac{3}{\left(\frac{6}{60}\right)} = 170 \text{ kJ}$$

$$\text{COP} = \frac{h_1 - h_4}{h_2 - h_1}$$

$$= \frac{170-80}{200-170} = \frac{90}{30} = 3$$

20. Ans: (b)

Sol: Refrigeration capacity = mass flow rate × refrigeration effect

$\Rightarrow 2\times 3.5\times 3600 = \dot{m}\times c\times \Delta T$

$\Rightarrow 7\times 3600 = \dot{m}\times 4.2\times (29-15)$

$\Rightarrow \dot{m} = \frac{6000}{14} = 428.57\,\text{kg/hr}$

21. Ans: (a)

Sol: They require single pump for main feed water stream regardless of no. of heaters.

22. Ans: (c)

Sol: $\eta_{otto} = 1-\frac{1}{r^{\gamma-1}} = 1-\frac{1}{r^{0.4}}$

Where, r is the compression ratio

$\eta_{diesel} = 1-\frac{(C^{1.4}-1)}{1.4(C-1)r^{0.4}}$

For $\eta_{otto} = \eta_{diesel}$:

$= \frac{1}{r^{0.4}} = \frac{(C^{1.4}-1)}{1.4(C-1)r^{0.4}}$

$C^{1.4} - 1 = 1.4\,C - 1.4$

$C^{1.4} - 1.4C + 0.4 = 0$

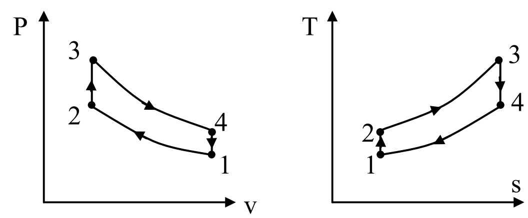
23. Ans: (c)

Sol: Following are the desirable properties of a refrigerant :

- High latent heat of vaporization to have high refrigeration effect.
- Low specific volume at the inlet of compressor to have low compressor work.
- High thermal conductivity for faster heat transfer during condensation and evaporation.
- In order to have large range of isothermal energy transfer, the refrigerant should have critical temperature above the condensing temperature.

24. Ans: (a)

Sol: Standard Otto Cycle



Heat supplied = $C_v\,(T_3 - T_2)$

$\Rightarrow 717 = 0.717\,(1650 - T_2)$

$\Rightarrow T_2 = 650$ K

${}_1W_2 = u_2 - u_1 = C_v(T_2 - T_1)$

$= 0.717\,(650 - 290)$

$= 258.12$ kJ/kg

25. Ans: (B)

Sol: For maximum work,

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

$$\eta = 1 - \frac{1}{(r_p)^{\frac{\gamma-1}{\gamma}}} = 1 - \sqrt{\frac{T_{min}}{T_{max}}}$$

$$= 1 - \sqrt{\frac{300}{1200}} = 50\%$$

26. Ans: (d)

Sol:

- NH_3 attacks copper, so iron or steel is used. So, (1) is correct.
- NH_3 is the cheapest refrigerant. The operation costs are lower with ammonia than R22. So, (2) is correct.
- In VAC, heat is rejected to condenser and absorber. So, (3) is correct.

27. Ans: (a)

Sol: Work from mean effective pressure,

$$M.E.P = \frac{W_{net}}{V_{max} - V_{min}}$$

$$\Rightarrow W_{net} = M.E.P(V_{max} - V_{min})$$

The displacement is

$\Delta V = \pi \times bore^2 \times 0.25 \times stroke$

$= 22/7 \times 0.1^2 \times 0.25 \times 0.14$

$= 0.0011 m^3$

Work per cylinder per power stroke

$W = P_{meff}(V_{max} - V_{min})$

$= 1400 \times 0.0011$ kPa m^3

$= 1.54$ kJ/cycle

28. Ans: (b)

Sol: When the pressure ratio of Brayton cycle becomes $\left(\frac{T_{max}}{T_{min}}\right)^{\frac{\gamma}{(\gamma-1)}}$, the work capacity of the cycle becomes zero.

29. Ans: (c)

Sol: Sensible heat factor (SHF)

$$= \frac{\text{Room sensible heat(RSH)}}{\text{RSH} + \text{Room latent heat}(\text{RLH})}$$

$$\Rightarrow 0.8 = \frac{48}{48 + \text{RLH}}$$

$$\Rightarrow 48 + \text{RLH} = \frac{48}{0.8} = 60$$

$\Rightarrow$ RLH = 12 kW

30. Ans: (b)

Sol: $IP = 3B - \{B_1 + B_2 + B_3\}$

$= 3 \times 12 - \{6.45 + 7.95 + 6.6\}$

$= 36 - 21 = 15$ kN

$$\Rightarrow \eta_{mean} = \frac{12}{15} = 0.8 \text{ or } 80\%$$

31. Ans: (a)

Sol: $R_{11} \Rightarrow C = 1, H = 0, F = 1$

$R_{11} \rightarrow CCl_3F$

$R_{12} \rightarrow C = 1, H = 0, F = 2$

$R_{12} \rightarrow CCl_2F_2$

$R_{123} \rightarrow C = 2, H = 1, F = 3$

$R_{123} \rightarrow C_2HCl_2F_3$

$R_{134a} \rightarrow C = 2, H = 2, F = 4$

$R_{134a} \rightarrow C_2H_2F_4$

32. Ans: (d)

33. Ans: (b)

Sol: $$H_2 + \frac{1}{2}O_2 + \frac{1}{2}(3.76N_2) \rightarrow H_2O + \frac{1}{2} \times 3.76N_2$$

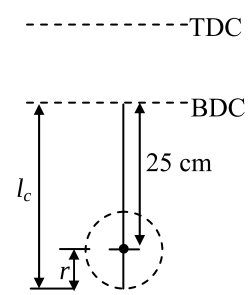
$$A/F = \frac{m_a}{m_f} = \frac{\frac{1}{2}(1 + 3.76)}{1} = 2.38$$

34. Ans: (c)

Sol: Scotch-marine boiler is an internally fired fire tube boiler. Others are externally fired fire tube boilers.

35. Ans: (c)

Sol:



$\Rightarrow l_c - r = 25$ cm

$$\frac{\pi}{4} d^2 L = V_s$$

$$\frac{22}{7} \times \frac{1}{4} \times 64 \times L = 880$$

$$L = 4 \times \frac{280}{64} = 17.5\text{cm}$$

$L = 17.5 \Rightarrow r = 8.75$ cm

$\Rightarrow l_c = 25 + 8.75 = 33.75$ cm

36. Ans: (d)

Sol:

- Solenoid valve is used to turn refrigerant flow on and off.
- Thermostatic valve maintains the constant degree of superheat
- Float valve maintains constant level of refrigerant in the evaporator
- Automatic expansion valve maintains constant pressure in evaporator

37. Ans: (a)

Sol: Advantages of fire tube boiler are

- Less draught required
- Quick response to load change
- Low initial cost
- Skilled labour is not required
- It cannot handles high pressure and capacity. It is suitable for small steam requirements.

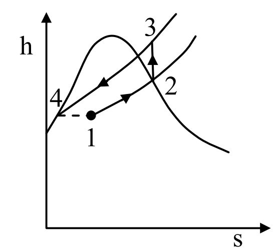
38. Ans: (a)

Sol:

- Humidity ratio is the ratio of actual mass of water vapour in moist air to the mass of the dry air.
- Partial pressure of vapour equals to the partial pressure of saturated air, so statement 3 is incorrect.

39. Ans: (b)

Sol: h-s diagram of vapour compression refrigeration cycle,



Throttling process (4-1) is isenthalpic and compression process (2-3) is isentropic.

40. Ans: (d)

Sol: Once through boilers operate above critical temperatures. At this pressure water directly converts to steam. Hence, no steam drum is required.

There is no circulation pump used in once through boilers. The energy supplied for the circulation is provided by feed pump

41. Ans: (b)

Sol: Maximum COP of cycle = Carnot COP

$$= \frac{T_L}{T_H - T_L} = \frac{250}{300 - 250} = 5$$

Actual COP = 0.8 × Maximum COP

$$= 0.8 \times 5 = 4$$

COP = 4

$$COP = \frac{\text{Desired effect}}{\text{Energy input}}$$

$$4 = \frac{5}{(W)_{in}}$$

$$W_{in} = \frac{5}{4} = 1.25\ kW$$

42. Ans: (c)

Sol: Sump is situated at the bottom of the engine. From given options, crank shaft will be at the bottom of the engine.

43. Ans: (a)

Sol: Boiler mountings are different fillings mounted on boiler for proper functioning and safety of boiler. Different Boiler mountings are

1. Safety valve
2. Fusible plug
3. Water level indicator
4. Blow off cock
5. Mud box
6. Man-hole
7. Steam stop valve
8. Pressure gauge

Boiler accessories are used to increase efficiency of boiler. They are

1. Superheater
2. Economiser
3. Air preheater
4. Steam ejector
5. Steam trap

44. Ans: (a)

Sol:

- Condenser and evaporator temperature difference (T_H – T_L) is less in air conditioning plant as compared to household refrigerator and COP is inversely proportional to temperature difference. Thus COP of air conditioning plant is greater than that of refrigerator.

  For example: In India, generally air conditioning plant works between 45°C and 15°C where as refrigerator works between 45°C and –15°C

$$(COP)_{air\ conditioning} = \frac{T_L}{T_H - T_L} = \frac{288}{(318-288)} = 19.2$$

$$(COP)_{refrigerator} = \frac{T_L}{T_H - T_L} = \frac{258}{318-258} = 4.3$$

$$(COP)_{air\ conditioning} > (COP)_{refrigerator}$$

- For throttling of an ideal gas

$$\mu = 0$$

$$\left(\frac{\partial T}{\partial P}\right)_h = 0$$

$$\partial T = 0$$

$$\therefore\ T_1 = T_2\ \text{(Constant)}$$

- Subcooling increases the net refrigerating effect.

  No effect of subcooling on work input.

45. Ans: (d)

Sol:

- Salts are mixed with coolant to lower the freezing point and to increase the boiling point.
- Anti freezing agent is mixed with coolant to lower the freezing point and increase the boiling point.
- Heat is transferred from block to coolant even with conduction.

46. Ans: (a)

Sol: The advantages of centrifugal compressor is air craft are:

1. high durability
2. ease of manufacture
3. good operation under adverse circumstances
4. small foreign particles are inhaled in inlet duct

Axial direction of flow is preferred in jet engine for compact size of the engine.

47. Ans: (a)

Sol:

- In $NH_3.H_2O$ refrigeration system

  $H_2O \rightarrow$ absorbent

  $NH_3 \rightarrow$ refrigerant

- In $LiBr_2.H_2O$ refrigeration system

  $H_2O \rightarrow$ refrigerant

  $LiBr_2 \rightarrow$ absorbent

48. Ans: (d)

Sol: High wall temperature in CI engine increases the temperature of the inlet charge which reduces knock and larger size of cylinder promotes proper mixing of air and fuel. Tendency of knock in SI engine decreases with increase in speed of engine and decrease in mass of charge inducted.

49. Ans: (c)

Sol: Maximum pressure rise is obtained for forward curved blades.

50. Ans: (c)

Sol: Evaporative cooling is commonly used when the outdoor conditions are very dry. This means that wet bulb depression of air is very large. In a dry climate, evaporative cooling can give same relief by removing the sensible heat from the room, but the humidity cannot be control.

51. Ans: (c)

Sol: While using SFEE, we assume that flow is adiabatic.

For calculating the enthalpy and temperature conditions at the throat, we assume flow to be isentropic.

52. Ans: (a)

Sol: Degree of reaction

$$= \frac{\text{enthalpy drop in moving blades}}{\text{enthalpy drop in stage}}$$

53. Ans: (d)

Sol: By pass factor $= \frac{40-30}{40-20} = \frac{10}{20} = 0.5$

54. Ans: (d)

Sol: Voltage at spark plug depends on the nature and amount of charge to be ignited for useful work. It also depends on the time of combustion. Hence depends on the engine running speed.

55. Ans: (a)

Sol:

- Backward curved blades when compared to radial and forward curved blades have
  1. better efficiency
  2. are stable over a wide range of flows
- Forward curve blades give highest pressure ratio

56. Ans: (b)

Sol: Brake Power = 80 kW

Brake Thermal η = 32 %

IP = 100 kW

Indicate thermal, η = ?

$$\eta_{mech} = \frac{BP}{IP} = \frac{Br.Th.\eta}{I.Th.\eta} = \frac{80}{100} = \frac{32}{I.TH.\eta}$$

Indicate thermal efficiency,

(I. Th.η) = 40 %

57. Ans: (b)

Sol: $\eta_o = RF \times \eta_{stage}$

$$\eta_{stage} = \frac{\eta_o}{RF} = \frac{80}{1.05} = 76.2\%$$

58. Ans: (c)

Sol: An increase in intake temperature and pressure increases flame speed an increase in compression ratio increases flame speed (odd man out)

59. Ans: (a)

Sol: As the temperature difference between condenser and evaporator increases during the starting the corresponding pressure difference will also increase. Hence compressor work input will increase continuously until steady state is reached.

60. Ans: (c)

Sol: Some energy loss takes place as steam flows from one stage to the next. The kinetic energy leaving one stage and available to the next is given by $\eta_{CO}\left(V_2^2/2\right)$, where η_{CO} is the carry-over efficiency.

61. Ans: (c)

Sol: Hydrocarbon emissions are due to the incomplete combustion of fuel. Absorption and desorption of fuel by oil also depend on pressure and it is predominant in compression and suction stroke.

62. Ans: (b)

Sol: At TDC and BDC even though velocity is zero, frictional force is not zero. The static friction is present even though kinetic friction is zero.

63. Ans: (a)

Sol: During high speed conditions, valves are opened and closed at very high frequency. So, valves are made to open and close slowly to provide quiet operation under high speed conditions.

64. Ans: (d)

Sol: Aluminium is used for piston for its high thermal conductivity.

65. Ans: (b)

Sol: The volumetric efficiency is given by

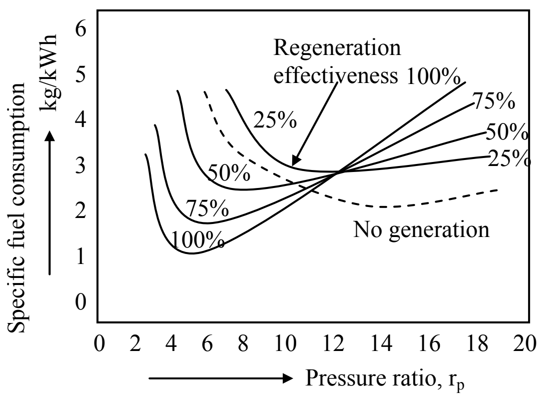
$$\eta_v = 1 + c - c\left(\frac{P_2}{P_1}\right)^{1/n}$$

66. Ans: (a)

Sol: In ideal impulse turbine there is no friction in moving blades. The entire enthalpy drop occurs in nozzle. There is no enthalpy drop in moving blades. Hence, the relative velocity at the inlet of moving blades is equal to that at the outlet.

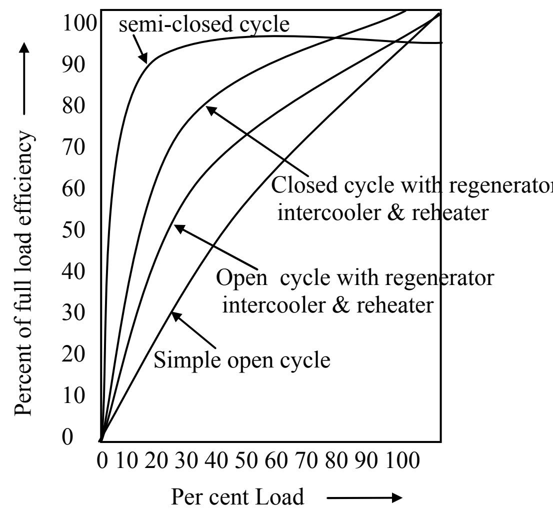
67. Ans: (b)

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 percent of fuel load efficiency with part load. It is clear that for semi-closed cycle the part load efficiency is the best.*

68. Ans: (a)

Sol: Net work is practically unity

$$\frac{W_T - W_P}{W_T} \quad [\because W_T >> W_P]$$

$\therefore$ Work ratio ≈ 1

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

69. Ans: (d)

Sol: $$\text{Heat rejection ratio} = \frac{\text{condenser load}}{\text{evaporator load}} = \frac{Q_C}{Q_E}$$

$$= \frac{Q_C - Q_E + Q_E}{Q_E}$$

$$= \frac{Q_C - Q_E}{Q_E} + \frac{Q_E}{Q_E}$$

$$= \frac{W_{net}}{Q_E} + 1$$

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

COP ↑– Heat rejection ratio ↓

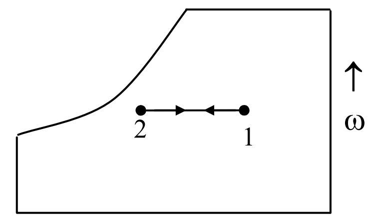
70. Ans: (c)

Sol:

Specific humdity (ω)

$$= \frac{\text{mass of water vapour in a specific volume}}{\text{mass of dry air in the same specified volume}}$$

So, statement (I) is incorrect.



As clearly seen in the figure, specific humidity remains constant during sensible heating / cooling. So, statement (II) is correct.

71. Ans: (d)

Sol:

- In gas refrigeration, we use isentropic expansion because in this there is a temperature drop and hence during this expansion as the refrigeration temperature is low it can absorb heat from storage space.
- If throttling is used, there is no temperature change i.e., there it can't pick up heat from storage. So, statement I is incorrect.

72. Ans: (c)

Sol: To calculate pressure drop in non-circular ducts the equivalent diameter (hydraulic diameter) is defined as

$$D_h = \frac{4A}{P}$$

$$= \frac{4(ab)}{(a+b)\times 2}$$

$$D_h = \frac{2ab}{a+b}$$

73. Ans: (c)

Sol: Carnot COP for VCRS operating between evaporator temperature (T_E) and condenser temperature (T_C) is

$$(COP)_{VCRS} = \frac{T_E}{T_C - T_E}$$

For the same condenser and evaporator temperature, if VARS takes heat energy from generator at temperature (T_G) then its COP is given by

$$(COP)_{VARS} = \left(1 - \frac{T_C}{T_G}\right) \times \frac{T_E}{(T_C - T_E)}$$

As $T_G > T_C$

$(COP)_{VARS} < (COP)_{VCRS}$

Hence Statement – I is correct. Statement – II wrong because VCRS uses high grade energy (electrical energy) to drive the compressor.

74. Ans : (b)

Sol: For pure reaction turbines enthalpy drop is only in moving blades which are difficult to construct.

75. Ans: (d)

Sol: $\frac{L}{D} < 1 \Rightarrow$ Lower stroke length.

So, $U_{avg} = 2LN \Rightarrow$ Lower piston speed

Frictional force is independent of the velocity but frictional power loss is directly proportional to the velocity.

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6 IN RAMESH KAMULLA
6 PI PINAL KUMAR RANA
7 IN PANKAJ MISHRA
8 ME DIVYANSHU JHA
8 PI
9 EC Anand Uppada
9 CS
9 ME DHRUV KUMAR JHA
10 EC AMIT RAWAT
10 ME
10 EE SURAJ DASH
10 IN
10 IN
ESE TOPPERS
ESE 2017
CE
1 CE NAMIT JAIN
2 CE PRAVIND SINGH
3 CE ANKIT
6 CE RISHABH DANGAYACH
8 CE ADITYA SINGH
9 CE HIMANSHU GAUTAM
10 CE AYUSH DUBEY
7 IN TOP 10 RANKS
7 All India 1st Rank in ESE.
E&T
2 E&T SUDHANSHU CHAUDHARY
3 E&T
5 E&T AMIT GAUTAM
6 E&T SUBHRANGINI MISHRA
7 E&T DEVADURGAM PAVAN KUMAR
8 E&T DEEPALI GOYAL
9 E&T ABHISHEK PRATAP SINGH
10 E&T UMESH
8 IN TOP 10 RANKS
EE
2 EE PREETI KUMARI
3 EE
4 EE HARSHIT KUMAR SINGH
5 EE NIKHIL KUMAR
6 EE DUSHYANT SINGH
8 EE APOORVA GUPTA
9 EE KIRAN BABU KONERU
7 IN TOP 10 RANKS
and many more...
ME
3 ME SAURABH
4 ME AMIT KUMAR RAI
6 ME ANKAN GUPTA
7 ME DHRUW JHA
9 ME ACHARAJ GUPTA
5 IN TOP 10 RANKS
27 Ranks in Top 10 in ESE-2017
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