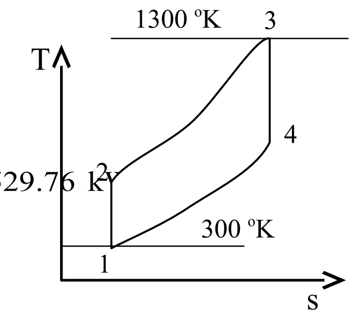
INDUSTRIAL & POWER PLANT DESIGN ELEMENTS MODULE

1. In Refrigeration, how do you call a heat exchanger in which low-pressure refrigerant boils or vaporizes, thus absorbing heat that was removed from the refrigerated area by the cooling medium (water)?
   a) Evaporator b) Chiller c) Cooler d) Flooded Evaporator

   Answer: b) Chiller. In refrigeration application, the appropriate term used for evaporator is chiller.

2. In an ideal standard Brayton cycle, 1.5 kg/s of air at 101 kPaa and 27 ºC is compressed isentropically to a certain pressure and temperature after which the is added until the temperature becomes 1027 ºC. Isentropic expansion occurs in the turbine. Determine the net power produced by the cycle.
   a) 629.56 kW b) 592.65 kW c) 529.76 kW d) 579.26 kW

   Answer: c) 529.76 kW



   Solution: $T_2 = T_4 = \sqrt{T_1 T_4} = \sqrt{(300)(1300)} = 624.5\ ^{o}K$

$$W_{net} = mc_p(T_3 - 2T_2 + T_1) = (1.5)(1.0062)[1300 - 2(624.5) + 300] = 529.76\ kW$$

3. In an air standard Otto cycle, the clearance volume is 12 % of the displacement volume. What is the thermal efficiency?
   a) 57 % b) 59 % c) 58 % d) 60 %

   Answer: b) Thermal efficiency = 59 %

   Solution:

$$V_2 = 0.12V_D \qquad r_k = \frac{V_1}{V_2} = \frac{V_2 + V_D}{V_2} = \frac{0.12V_D + V_D}{0.12V_D} = \frac{1.12}{0.12} = 9.33$$

$$e_{th} = \left[1 - \frac{1}{(r_k)^{k-1}}\right](100\ \%) = \left[1 - \frac{1}{(9.33)^{0.4}}\right](100\ \%) = 59.08\ \%$$

4. In an air-standard Brayton cycle, air enters compressor at 1 bar and 15 ºC. The pressure leaving the compressor is 0.6 MPaa and maximum temperature of the cycle is 1000 ºC. What is the maximum net work, in kJ/kg?
   a) 319.52 b) 392.51 c) 315.29 d) 352.19

   Answer: d) Max W_{net} = 352.19 kJ/kg

   Solution: $T_2 = \sqrt{T_1\ T_3} = \sqrt{(15+273)(1000+273)} = 605.49\ ^{o}K$

$$\text{Max } w_{net} = c_p(T_3 - 2T_2 + T_1) = (1.0062)[1273 - 2(605.49) + 288] = 352.19\ kJ/kg$$

5. What is the clearance volumetric efficiency of an ammonia compressor designed with 4 % clearance and operating between condenser temperature of 30 ºC (p_{sat} = 1.1672 MPaa) and evaporator temperature of 4 ºC (p_{sat} = 497.48 kPaa)?
   a) 93.61 % b) 93.68 % c) 96.31 % d) 96.83 %

   Answer: c) Volumetric Efficiency = 96.31 %

   Solution: $\eta_v = \left[1 + c - c\left(\frac{p_d}{p_s}\right)^{\frac{1}{k}}\right](100\ \%) = \left[1.04 - 0.04\left(\frac{1167.2}{497.48}\right)^{\frac{1}{1.304}}\right](100\%) = 96.31\ \%$

Note: k = 1.304, for ammonia (R-717) k = 1.30, for R-134a

6. The percent rating of water tube boiler is 200 %, factor of evaporation is 1.10, and heating surface is 400 ft^2. Determine the rate of evaporation, in kg/hr.
a) 1831 b) 1831 c) 1138 d) 1813

Answer: c) Rate of evaporation = 1138 kg/hr

Solution: $\text{Rated Bo. Hp} = \dfrac{\text{H.S.}}{10} = \dfrac{400}{10} = 40$

$$\text{Dev. Bo. Hp} = \text{Percent Rating}\left(\text{Rated Bo. Hp}\right) = 2\left(40\right) = 80$$

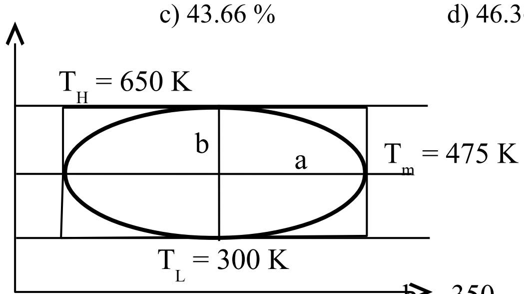
$$\text{Dev. Bo. Hp} = m_s\left(h_1 - h_B\right) = m_s\left(2257\right)\text{F.E.}$$

$$m_s = \frac{\text{Dev. Bo. Hp}}{2257\ \text{FE}} = \frac{80\left(35314\right)}{2257(1.1)} = 1138\ \text{kg/hr}$$

7. A Carnot cycle is represented by a rectangle in a Ts diagram that operates between temperature limits of 300 °K and 650 °K. Inscribed within a rectangle is a ellipse of maximum major and minor axes, represents a cycle and operating at the same temperature limits. Considering that the major axis of the ellipse is two times that of its minor axis. Determine the thermal efficiency of the cycle represented by an ellipse.
a) 44.88 % b) 48.48 % c) 43.66 % d) 46.36 %

Answer: a) 44.88 %

Solution:



a = 2b = 650 – 300 = 350 °K $\qquad b = \dfrac{a}{2} = \dfrac{350}{2} = 175\ ^{\circ}K$

$A = \pi ab = \pi\left(350\right)\left(175\right) = 61\ 250\pi = W_{net}$ $\qquad \Delta S = 2a = 700$

$$Q_A = T_m\left(\Delta S\right) + \frac{W_{net}}{2} = 475\left(700\right) + \frac{61250\pi}{2} = 428711.275\ \text{kJ}$$

$$e = \frac{W_{net}}{Q_A}\ \text{x}\ 100\% = \frac{61250\pi}{428711.275}\left(100\ \%\right) = 44.88\ \%$$

8. Determine the critical radius in cm for an asbestos-cement covered pipe [k_{asb} = 0.208 W/m-°K]. The external heat-transfer coefficient is 1.5 Btu/h-ft^2-°F.
a. 2.44 cm b. 2.55 cm c. 2.66 cm d. 2.22 cm

Solution: a) Critical radius = 2.44 cm

Solution: $r_c = \dfrac{k}{h_c} = \dfrac{0.208\ \dfrac{W}{m\cdot{}^{o}K}}{\left(1.5\ \dfrac{Btu}{hr\cdot ft^2\cdot{}^{o}F}\right)\left(5.675\right)} = 0.0244\ m = 2.44\ cm$

Note: $1\ \dfrac{Btu}{hr\cdot ft^2\cdot{}^{o}F} = 5.675\ \dfrac{W}{m^2\cdot{}^{o}F}$

9. A hiker carried an Aneroid barometer from the foot of Mount Banahaw to the camp of the NPA leader Ka Roger. On the foot of the mountain, the barometer reads 30.150 inches of Hg, and on the camp, which is nearly at the top of the mountain it reads

28.607 inches of Hg. Assume that the average air density (atmospheric) was 0.075 pcf, estimate the height of the mountain, in ft.

a) 1455.54 b) 1545.54 c) 1554.54 d) 1455.55

Answer: a) 1455.54 ft

Solution:

$$h = \frac{p_1 - p_2}{\rho g} = \frac{(30.150 - 28.607\text{" Hg})\left(\frac{14.7 \text{ psi}}{29.92\text{" Hg}}\right)(144)}{0.075} = 1455.54$$

10. In a geothermal power plant, the mass flow rate of ground water is 4000 kg/s and the quality after throttling is 20%. If the turbine power is 80 MW, what is the change in enthalpy of steam at the inlet and outlet of the turbine?

a) 120 kJ/kg b) 100 kJ/kg c) 200 kJ/kg d) 150 kJ/kg

Answer: b) Change of enthalpy = 100 kJ/kg

Solution: $m_s = x_3 \, m_c = (0.20)(4000) = 800 \text{ kg/s} \qquad \Delta h = \frac{W_t}{m_s} = \frac{80\,000}{800} = 100 \text{ kJ/kg}$

11. Determine the partial pressure of CO_2 for the following analysis of gas mixture by weight at 101 kPaa and 25 ºC: CO_2 = 35 % and N_2 = 65 %.

a) 25.75 kPaa b) 27.55 kPaa c) 52.75 kPaa d) 52.57 kPaa

Answer: a) partial pressure of CO_2 = 25.75 kPaa

Solution: For 100 kg of the mixture, total number of moles,

$$n_T = \frac{CO_2}{44} + \frac{N_2}{28} = \frac{35}{44} + \frac{65}{28} = 0.7955 + 2.3214 = 3.12 \text{ kgmoles}$$

From the equation, $pv = n\overline{R}T \qquad \frac{\overline{R}T}{v} = \frac{p_{CO_2}}{n_{CO_2}} = \frac{P_T}{n_T}$

$$p_{CO_2} = \left(\frac{n_{CO_2}}{n_T}\right) p_T = \left(\frac{0.7955}{3.12}\right)(101) = 25.75 \text{ kPaa}$$

12. A certain coal has the following ultimate analysis by weight. C = 67 %, Ash = 5 %, Moisture = 8 %, N = 6 %, H = 3 %, Sulfur = 7 %, O = 4 %. Calculate the higher heating value in Btu/lb.

a) 15 179 b) 11 579 c) 17 519 d) 19 517

Answer: b) 11 579 Btu/lb

Solution:

$$HHV = 14\,544\,C + 62\,028\left(H_2 - \frac{O_2}{8}\right) + 4\,050\,S = (14544)(0.67) + (62028)\left(0.03 - \frac{0.04}{8}\right) + (4050)(0.07)$$

HHV = 11 578.68 Btu/lb

13. Determine the heating value of a certain fuel with a SG = 0.997.

a) 42 975 kJ/kg b) 42 597 kJ/kg c) 42 795 kJ/kg d) 42 579 kJ/kg

Answer: a) 42 975 kJ/kg

Solution: $HHV = 51716 - 8793.8(SG)^2 = 51716 - 8793.8(0.997)^2 = 42\,975 \text{ kJ/kg}$

14. If an airplane is flying at an altitude of 5 800 ft, what is the approximate atmospheric pressure at the said altitude?

a) 12.34 psi b) 14.7 psi c) 13.24 psi d) 14.32 psi

Answer: a) 12.34 psi

Solution: $p = 29.92 \text{ in Hg} - \left(\frac{1\text{" Hg}}{1000 \text{ ft}}\right)(4800 \text{ ft}) = 25.12 \text{ in Hg} = 12.34 \text{ psia}$

Note: Barometric pressure reduces by 1 inch Hg per 1000 ft rise in elevation or 83.312 mm Hg per 1000 m rise in elevation.

Barometric temperature reduces by 3.566 ºF per 1000 ft rise in elevation, or 6.5 ºC per 1000 m rise in elevation.

15. It the maximum temperature of any gas or vapor at which it may be condensed into a liquid; above this temperature, it is impossible to condense regardless of the pressure applied. How do you call this temperature?
    a) Saturation temperature b) Superheated temperature
    c) Critical temperature d) Dew point temperature

    Answer: Critical temperature

16. Calculate the energy transfer rate across 6" wall of firebrick with a temperature difference across of 50 ºC. the thermal conductivity of the firebrick is 0.65 Btu/hr-ft-ºF.
    a) 369 W/m² b) 369 Btu/hr-Ft² c) 639 W/m² d) 639 Btu/hr-Ft²

    Answer: a) Heat Transfer = 369 W/m²

    Solution: $$\frac{q}{A}=\frac{k}{L}(\Delta T)=\frac{(0.65\ \text{Btu/hr}\cdot\text{ft}\cdot{}^{o}\text{F})}{\left(\frac{6}{12}\ \text{ft}\right)}\left[\frac{9}{5}(50)\right]=117\ \text{Btu/Hr}\cdot\text{ft}^2$$

    $$\frac{q_k}{A}=(117\ \text{Btu/Hr}\cdot\text{ft}^2)(1055\ \text{J/Btu})\left(\frac{1\ \text{Hr}}{3600\text{s}}\right)\left(\frac{3.28\ \text{ft}}{1\ \text{m}}\right)^2=368.88\ \frac{\text{W}}{\text{m}^2}$$

17. What is the specific gravity of a fuel at 28º Baume?
    a) 0.868 0.688 c) 0.886 d) 0.986

    Answer: c) SG = 0.886

    Solution: $$\text{SG}@15.6\ {}^{o}\text{C}=\frac{140}{{}^{o}\ \text{Baume}+130}=\frac{140}{28+130}=0.886$$

18. Air at 1 MPaa and 310 ºC is expanded to 250 kPaa in accordance with the relation $pV^{1.25}=C$. Determine the work done.
    a) + 162.11 kJ/kg b) – 162.11 kJ/kg c) + 126.11 kJ/kg d) – 126.11 kJ/kg

    Answer: a) Work done, W = + 162.11 kJ/kg

    Solution: $$T_2=T_1\left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}=(310+273)\left(\frac{250}{1000}\right)^{\frac{0.25}{1.25}}=441.83\ {}^{o}\text{K}$$

    $$W=\frac{p_2v_2-p_1v_1}{1-n}=\left(\frac{R}{1-n}\right)(T_2-T_1)=\left(\frac{0.28708}{-0.25}\right)(441.83-583)=+162.11\ \text{kJ/kg}$$

    Note: Work is positive (+), if work is done by the system; and work is negative (-) if work is done to the system.

19. A Rankine cycle operates with a thermal efficiency of 40 % and the factor of evaporation of the boiler is 1.15. Determine the mass flow rate of steam if the cycle power output is 5.5 MW.
    a) 5.3 kg/s b) 4.3 kg/s c) 3.5 kg/s d) 6.3 kg/s

    Answer: a) Steam mass flow rate, m_s = 5.3 kg/s

    Solution: $$Q_A=\frac{W_{net}}{e_{th}}=\frac{5500}{0.40}=13\ 750\ \text{kW}$$ $$m_s=\frac{Q_A}{h_1-h_B}=\frac{Q_A}{2257(\text{FE})}=\frac{13750}{2257(1.15)}=5.3\ \text{kg/s}$$

20. This refrigeration system component combines the functions of a cooling tower and a condenser. It consists of a casing enclosing a fan or blower section, water eliminators, refrigerant condensing coil, water pan, float valve, and spray pump outside the casing. How do you call this component?
    a) Water-cooled condenser b) Evaporative condenser c) Atmospheric condenser d) Chiller

Answer: b) Evaporative condenser

21. A boiler operates at 82 % efficiency while the mass of steam generated is 490 200 kg in 6 hours. The enthalpy of steam is 3187 kJ/kg and feed is 604.83 kJ/kg while the fuel used for boiler has a heating value of 32 567.85 kJ/kg. Find the mass of fuel needed per day in metric tons.
a) 179.6 b) 189.6 c) 198.6 d) 169.8

Answer: b) Fuel consumption per day = 189.6 metric tons

Solution: $m_s = \frac{490\,200}{6} = 81\,700 \text{ kg/hr}$

$$Q_F = \frac{m_s(h_2 - h_1)}{E_B} = \frac{81\,700(3187 - 604.83)}{0.82} = 257\,272\,303.7 \text{ kg/hr}$$

$$m_F = \frac{Q_F}{q_h} = \frac{257\,272\,303.7}{32\;567.85} = 7\;899.58 \text{ kg/hr} = 189\,589.8958 \text{ kg/day} = 189.6 \text{ Metric tons/day}$$

22. It refers to a factor used in calculating the over-all heat transfer through the tube walls of a condenser tube or other heating surface. It includes the sum of the heat-transfer rate of the layer of dirt and foreign material that builds up on the water side of the tube. What is this factor?
a) Cooling factor b) Contact factor c) By-pass factor d) Fouling factor

Answer: d) Fouling Factor

23. A 10 kg/s of air enters the theater at 16 ºC. The theater is to be maintained at 27 ºC DB and 20 ºC WB. If the sensible heat ratio is 0.71, what is the latent heat load of the theater?
a) 45.21 kW b) 54.21 kW c) 110.682 kW d) 42.51 kW
Answer: a) atent heat load, q_L = 45.21 kW

Solution: $q_s = 1.0062m(t_r - t_s) = (1.0062)(10)(27 - 16) = 110.682 \text{ kW}$

$$q_L = \frac{q_s}{SHR} - q_s = \frac{110.682}{0.71} - 110.682 = 45.21 \text{ kW}$$

24. A 80 MW power plant has an average load of 34 500 kW and a load factor of 0.75. Find the reserve power over a peak load power.
a) 14 000 kW b) 34 000 kW c) 24 000 kW d) 4 000 kW

Answer: b) Reserve Power = 34 000 kW

Solution: $\text{Load Factor} = \frac{\text{Average Load}}{\text{Peak Load}}$ $\text{Peak Load} = \frac{\text{Average Load}}{\text{Load Factor}} = \frac{34\,500}{0.75} = 46\,000 \text{ kW}$

$$\text{Reserve Power} = \text{Plant Capacity} - \text{Peak Load} = 80000 - 46000 = 34\;000 \text{ kW}$$

25. What is the standardized term used by the industry to describe any device that meters or regulates the flow of liquid refrigerant to an evaporator?
a) Refrigerant control b) Expansion valve c) Throttling valve d) Capillary tube

Answer: b) Expansion Valve

26. A steam generator burns fuel oil with 25 % excess air. Fuel may be represented by $C_{14}H_{30}$. Calculate the actual-air fuel ratio.
a) 17.63 b) 18.63 c) 16.63 d) 15.63

Answer: b) Actual A/F ratio = 18.63 kg air per kg fuel

Solution: $$A:F = \frac{137.28(n+0.25m)(1+e)}{12n+m} = \frac{137.28[14+0.25(30)]}{12(14)+30}(1.25) = 18.63$$

Note: Equation above is used for hydro-carbon fuels, C_nH_m.

27. A container filled with helium is dropped 3000 m above the ground, find the change of temperature?
a) 12.43 ºC b) 9.43 ºC c) 15.43 ºC d) 8.43 ºC

Answer: b) The change of temperature, ΔT = 9.43 ºC

Solution: $$\Delta P = \Delta KE = \Delta U \quad \frac{mg(\Delta z)}{1000} = mc_v(\Delta T) = m\left(\frac{R}{k-1}\right)(\Delta T) \qquad \Delta T = \frac{(k-1)g(\Delta z)}{1000R}$$ k = 1.666

$$R = \frac{\overline{R}}{M} = \frac{8.3143}{4} = 2.078575\ kJ/kg\cdot{}^oK \qquad \Delta T = \frac{0.666(9.8066)(3000)}{1000(2.078575)} = 9.43\ {}^oC$$

Note: For Helium, k = 1.666 and M = 4 kg/kgmole

28. A 3153-lb car is accelerated from 32 fps to 55 fps in 10 seconds. Determine the work done, in Btu.
a) 125.92 b) 192.52 c) 152.92 d) 129.52

Answer: a) Work done, W = 125.92 Btu

Solution: $$W = \Delta K = \left(\frac{m}{2}\right)(V_2^2 - V_1^2) = \frac{3153[(55)^2-(32)^2]}{2(32.2)(778)} = 125.92\ Btu$$

Note: 1 Btu = 778 ft-lb & 1 lb_f = 32.2 lb_m-fps^2
Work = Kinetic energy

29. A turbine has a peripheral coefficient of 0.6. Find the runner diameter of the turbine if it operates at 450 rpm and a head of 60 m.
a) 0.874 m b) 0.784 m c) 0.478 m d) 0.748 m

Answer: a) Water runner diameter, D_r = 0.874 m

Solution: Peripheral Coefficient, $$\Phi = \frac{\text{Periperal velocity}}{\text{Velocity of jet}} = \frac{\pi D_r N}{60\sqrt{2gH_{eff}}}$$

$$D_r = \frac{\Phi\left(60\sqrt{2gH_{eff}}\right)}{\pi N} = \frac{(0.60)(60)\sqrt{2(9.8066)(60)}}{\pi(450)} = 0.874\ m$$

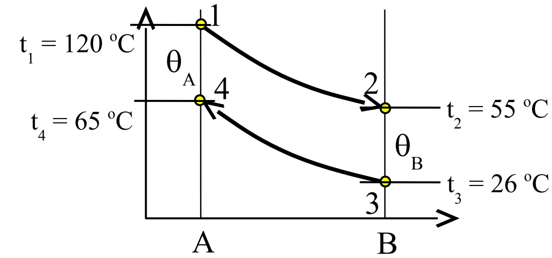
30. Heat is transferred from hot water to an oil in a double-pipe counter-flow heat exchanger. Water enters the outer pipe at 120 ºC and exits at 55 ºC while the oil enters the inner pipe at 26 ºC and exits at 65 ºC. What is the log-mean temperature difference (LMTD)?
a) 42.60 ºC b) 40.62 ºC c) 46.20 ºC d) 42.06 ºC

Answer: b) Log Mean Temperature Difference, LMTD = 40.62 ºC

Solution:

$$\theta_A = t_1 - t_4 = 120 - 65 = 55\ {}^oC = \theta_{max}$$

$$\theta_B = t_2 - t_3 = 55 - 26 = 29\ {}^oC = \theta_{min}$$



$$LMTD = \frac{\theta_{max} - \theta_{min}}{\ln\left(\frac{\theta_{max}}{\theta_{min}}\right)} = \frac{55 - 29}{\ln\left(\frac{55}{29}\right)} = 40.62 \ ^{o}C$$

31. In a Rankine cycle, steam enters the turbine at 2.5MPa and a condenser pressure of 50KPa. What is the quality of steam at the turbine exhaust? Steam Properties: @ 2.5Mpaa, h = 2803.1 kJ/kg & s = 6.2575 kJ/kg-^{O}K; @ 50kPaa, h_f = 340.49 kJ/kg, h_{fg} = 2305.4 kJ/kg, v_f = 0.00103 m^3/kg, s_f = 1.0910 kJ/kg-^{O}K, s_{fg} = 6.5029 kJ/kg-^{O}K.
a) 79.45 % b) 97.45 % c) 59.75 % d) 95.55 %

Answer: a) Steam Quality, x_2 = 79.45 %

Solution: $$x_2 = \left(\frac{s_2 - s_{f2}}{s_{fg}}\right)100\% = \left(\frac{6.2575 - 1.0910}{6.5029}\right)(100\ \%) = 79.45\ \%$$

32. An adiabatic turbine steam generating plant receives steam at a pressure of 7.0 MPa and 550^{O}C (h = 3531 kJ/kg) and exhausts at a condenser pressure of 20kPa (h = 2290 kJ/kg). The turbine inlet is 3 meters higher than the turbine exit, inlet steam velocity is 15m/s and the exit is 300m/s. Calculate the turbine work in kJ/kg.
a) 1296.14 b) 1196.24 c) 1619.42 d) 1294.16

Answer: b) The turbine work, W_t = 1196.24 kJ/kg

Solution: $$W_t = -(\Delta h + \Delta k + \Delta P) = (h_1 - h_2) + \frac{(V_1^2 - V_2^2)}{2000} + \frac{g(z_2 - z_1)}{1000}$$

$$W_t = (3531 - 2290) + \frac{(15)^2 - (300)^2}{2000} + \frac{9.8066(3)}{1000} = 1196.24\ kJ/kg$$

33. Determine the indicated power of a four-cylinder, 4-stroke, Diesel engine with 20-cm bore and 30-cm stroke running at 1000 rpm and has a reading of 450 kPa mean effective pressure in the indicator diagram.
a) 159.83 Hp b) 189.53 Hp c) 158.93 Hp d) 198.53 Hp

Answer: b) Indicated power, IP = 189.53 Hp

Solution: Volume displacement,

$$V_D = \frac{\pi}{4}D^2 L\, N\, n_c = \frac{\pi}{4}D^2\ L\left(\frac{n}{2}\right)n_c / 60 = \left(\frac{\pi}{4}\right)(0.20)^2(0.30)\left(\frac{1000}{2}\right)\left(\frac{4}{60}\right) = 0.3142\, m^3/s$$

Indicated Power, $W_I = p_I V_D = (450)(0.3142) = 141.4\ kW = 189.53\ Hp$

34. The approach and efficiency of cooling tower are 10 ºC and 65 %, respectively. If the temperature of water leaving the tower is 27 ºC, determine the temperature of water entering the tower.
a) 54.57 ºC b) 55.47 ºC c) 45.57 ºC d) 54.75 ºC

Answer: c) Temperature of water entering the tower, t_3 = 45.57 ºC

Solution: $t_{wb1} = t_4 - CA = 27 - 10 = 17\ ^{o}C$

Tower Efficiency, $$e_t = \frac{ACR}{TCR} = \frac{t_3 - t_4}{t_3 - t_{wb1}}$$

$$t_3 = \frac{t_4 - et_{wb1}}{1 - e} = \frac{27 - 0.65(17)}{1 - 0.65} = 45.57\ ^{o}C$$

35. An air-vapor mixture has a dry bulb temperature of 30 ºC and a humidity ratio of 0.015 kg/kg d.a., calculate the enthalpy of the moist air.

a) 68.527 kJ/kg d.a b) 86.527 kJ/kg d.a c) 65.827 kJ/kg d.a. d) 67.528 kJ/kg d.a

Answer: a) Enthalpy, h = 68.527 kJ/kg d.a.

Solution: Using the IHVE formula, h = 1.007t – 0.026 + W(2501 + 1.84t)

$$h = 1.007(30) - 0.026 + (0.015)[2501 + 1.84(30)] = 68.527 \text{ kJ/kg da}$$

36. Determine the equivalence ratio of the following mixture: 4 grams of butane, C_4H_{10}, and 75 grams of air.
a) 0.72 b) 0.92 c) 0.62 d) 0.82

Answer: d) Equivalence ratio = 0.82

Solution: Theoretical air-fuel ratio, $W_a = \dfrac{137.28(n + 0.25m)}{12n + m} = \dfrac{137.28[4 + 0.25(10)]}{12(4) + 10} = 15.385 \text{ kg/kg}$

Actual Air-fuel ratio, $W_{aa} = \dfrac{75}{4} = 18.75 \text{ kg/kg}$

$$\text{Equivalence ratio} = \frac{W_a}{W_{aa}} = \frac{1}{1+e} = \frac{15.385}{18.75} = 0.82$$

37. Find the air Hp of an industrial fan that delivers 25 m^3/s of air through a 900 mm by 1200 mm outlet. Static pressure is 127 mm of water gage and air density is 1.18 kg/m^3.
a) 52.3 Hp b) 35.2 Hp c) 42.3 Hp d) 34.2 Hp

Answer: a) Fan power, W_F = 52.3 Hp

Solution: $V = \dfrac{Q}{A} = \dfrac{25}{(0.9)(1.2)} = 23.15 \text{ m/s}$ $\quad h_s = \dfrac{\rho_w}{\rho_a} h_w = \left(\dfrac{1000}{1.18}\right)(0.127) = 107.63 \text{ m air}$

$h_v = \dfrac{V^2}{2g} = \dfrac{(23.15)^2}{2(9.8066)} = 27.32 \text{ m air}$ $\quad h_t = h_s + h_v = 107.63 + 27.32 = 134.95 \text{ m air}$

$$W_F = \frac{\rho g Q h_t}{1000} = \frac{1.18(9.8066)(25)(134.95)}{1000} = 39.04 \text{ kW} = 52.3 \text{ Hp}$$

38. Determine the indicated mean effective pressure of an engine, in psi, having a brake mean effective pressure of 750 kPa and 80 % mechanical efficiency.
a) 138 b) 137 c) 136 d) 135

Answer: c) Indicated mean effective pressure, p_I = 136.01 psi

Solution: $\eta_m = \dfrac{W_B}{W_I}(100\ \%) = \dfrac{p_B}{p_I}(100\ \%)$ $\quad p_I = \dfrac{p_B}{\eta_m} = \dfrac{750}{0.80} = 937.5 \text{ kPa} = 136.01 \text{ psi}$

39. The indicator card (actual p-V diagram) of an engine in a Diesel power plant indicates an area of 0.06 m^2 and length of 300 mm, and with a spring scale of 2500 kPa/m. The engine was tested using Prony brake with lever arm of 3 m and tare weight of 8 kN. Determine the mechanical efficiency if the engine is running at 600 rpm. The engine is 2-stroke and has 12 cylinders, 300 mm bore, and 450 mm stroke.
a) 78.01 % b) 79.01 % c) 82.01 % d) 76.01 %

Answer: b) Engine mechanical Efficiency = 79.01 %

Solution: $W_B = \dfrac{\pi n T}{30} = \dfrac{\pi(600)(8 \text{ kN})(3 \text{ m})}{30} = 1507.96 \text{ kW}$ $\quad h = \dfrac{A}{b} = \dfrac{0.06 \text{ m}^2}{0.3 \text{ m}} = 0.2 \text{ m}$

$p_I = k_s h = (2500 \text{ kPa/m})(0.2 \text{ m}) = 500 \text{ kPa}$

$$V_D = \frac{\pi}{4} D^2 L n n_c / 60 = \left(\frac{\pi}{4}\right)(0.3)^2 (0.45)(600)(12)/60 = 3.817 \ m^3/s$$

$$W_I = p_I \ V_D = (500)(3.817) = 1908.5 \ kW$$

$$\eta_m = \frac{W_B}{W_I}(100 \ \%) = \left(\frac{1507.96}{1908.5}\right)(100 \ \%) = 79.01\%$$

40. A 2-kg steam at 2.5 MPaa and 260 ºC undergoes a constant pressure until the quality becomes 70 %. Determine the heat rejected, in Btu. At 2.5 MPaa and 260ºC: h = 2907.4 kJ/kg; and at 2.5 MPaa and 70 % quality: h_f = 962.11 kJ/kg and h_g = 2803.1 kJ/kg.
a) 1244.7 Btu b) 1424.7 Btu c) 1442.7 Btu d) 1274.4 Btu

Answer: a) Heat rejected = 1244.73 Btu

Solution: $h_2 = h_f + x_2(h_g - h_f) = 962.11 + (0.70)(2803.1 - 962.11) = 2250.803 \ kJ/kg$

$$Q = m(\Delta h) = m(h_2 - h_1) = 2(2250.803 - 2907.4) = -\ 1313.19 \ kJ = -\ 1244.73 \ Btu$$

41. Are steam traps required to pass air?
    a) Steam traps should not pass air under any circumstances
    b) Only when the trap has passed all the condensate
    c) Air should be removed as soon as it reaches the trap
    d) Only on high pressure steam system

    Answer: c) Air should be removed as soon as it reaches the trap

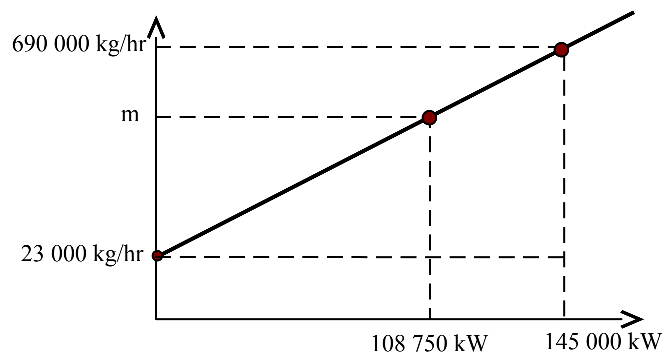
42. A 145 000-kW turbo-generator requires 690 000 kg/hr of steam at rated load and 23 000 kg/hr of steam at zero load. Determine the steam rate, in kg/kW-hr, at 75 % of its rated load.
a) 4.81 kg/kW-hr b) 3.81 kg/kW-hr c) 5.81 kg/kW-hr d) 2.81 kg/kW-hr

Answer: a) Rated load = 4.811 kg/kW-Hr

Solution: $\frac{m - 23\,000}{108\,750} = \frac{690\,000 - 23\,000}{145\,000}$

m = 523 250 kg/hr

$$\omega_{75} = \frac{523\,250}{108\,750} = 4.811 \ kg/kW \cdot hr$$



43. The combustion gases of a furnace are separated from its surrounding or ambient air which is 29 ºC. The brick wall is 130 mm and has a thermal conductivity of 1.23 W/m-ºC with a surface emissivity of 0.81. The outer surface temperature of the wall is 130 ºC and with surface air conductance of 15 W/m^2-ºC. For steady state conditions, what is the total heat transmitted for a surface area of 30 m^2?
a) 70.33 kW b) 73.30 kW c) 33.07 kW d) 37.30 kW

Answer: a) 70.33 kW

Solution: $q_k = A h_c(\Delta T) + \varepsilon \sigma A (T_s^4 - T_\infty^4)$

$$q_k = (30)(15)(130 - 29) + (0.81)(5.669 \ x \ 10^{-8})(30)\left[(130 + 273)^4 - (29 + 273)^4\right]$$

q_k = 70326.81 W = 70.33 kW

44. Which of the following ranges of humidity ratio is used for comfort air conditioning?
a) 50 to 55 % b) 55 to 60 % c) 60 to 65 % d) 45 to 50 %

Answer: b) RH = 55 % to 60 %

45. When adding the refrigerant in a refrigeration system, it shall be charge into which of the following parts of the system?
a) High pressure side
b) Low pressure side
c) Low and high pressure side
d) Compressor discharge line

Answer: b) Low pressure side

46. A 1.5 MW Diesel power generating unit has a generator efficiency of 85 %. Determine the volume flow rate, in lps, of cooling water required for the engine at 18 ºC temperature rise.
a) 21 lps
b) 19 lps
c) 22 lps
d) 23 lps

Answer: a) Volume flow = 21 lps

Solution: $$BP = \frac{W_k}{\eta_g} = \frac{1500}{0.85} = 1764.71 \text{ kW}$$

Heat Balance for a Typical Diesel Engine at Full Load

Brake Power	34 %
Cooling System Losses	30 %
Exhaust Losses	26 %
Friction, Radiation, etc	10 %

$$Q_{cw} = \frac{BP}{0.34}(0.30) = \left[\frac{1500}{0.85(0.34)}\right](0.30) = 1557.1 \text{ kW}$$

$$m_{cw} = \frac{Q_{cw}}{c_p(\Delta T)} = \frac{1557.1}{4.187(18)} = 20.66 \text{ kg/s}$$

$$V_{cw} = \frac{20.66 \text{ kg/s}}{1 \text{ kg/li}} = 20.66 \text{ lps}$$

47. Why is a boiler feed tank heated to approximately 85 ºC?
a) To reduce the energy required to raise steam
b) To reduce the content of total dissolved solids in the water supplied to the boiler
c) To reduce the gas content of the water
d) To reduce the content of suspended solids in the water

Answer: c) To reduce the gas content of the water

48. What is used to dry air?
a) A separator
b) A strainer
c) A steam trap
d) A tee piece

Answer: a) A separator

49. A Carnot refrigerator is to remove heat from a cooled space at a rate of 18 000 kJ/hr to maintain the temperature at – 8 ºC. If the air surrounding the refrigerator is 25 ºC, determine the minimum power required for the refrigerator.
a) 0.723 kW
b) 0.523 kW
c) 0.623 kW
d) 0.423 kW

Answer: c) 0.623 kW

Solution: $$W = \frac{Q_L(T_H - T_L)}{T_L} = \frac{18000(25+8)}{(273-8)} = 2241.51 \text{ kJ/hr} = 0.623 \text{ kW}$$

50. A Pelton wheel has a capacity of 25 000 kW with head of 290 m. What is the number of jet needed for this turbine if the jet if the nozzle jet diameter is 200 mm.
a) 3
b) 4
c) 2
d) 1

Answer: b) Number of Jets or Nozzles = 4

Solution: $Q = \frac{1000\,W_t}{\rho g H_T} = \frac{(25\,000)(1000)}{(1000)(9.8066)(290)} = 8.79\,m^3\ /\ s$

$A = \left(\frac{\pi}{4}\right)D^2 = \left(\frac{\pi}{4}\right)(0.20)^2 = 0.03142\ m^2$

$V = \sqrt{2gH} = \sqrt{2(9.8066)(290)} = 75.42\ m/s$ $A_T = \frac{Q}{V} = \frac{8.79}{75.42} = 0.1165\,m^2$

No. of jets: $N_j = \frac{0.1165\ m^2}{0.03142\ m^2\ /\ jet} = 3.71\ \text{jets}$ Use 4 jets