1. Find the work possess for a helium gas at 20°C.

A. 609 kJ/kg B. 168 kJ/kg C. 229 kJ/kg D. 339 kJ/kg

Solution:

$$W = mRT = m\left(\frac{8.314}{MW}\right)T$$

$$\text{For Helium}, MW = 4$$

$$\frac{W}{m} = \frac{8.314}{4}(20 + 273) = \mathbf{609\ kJ/kg}$$

2. Two kilogram of gas is confined in a 1 m^3 tank at 200 kPa and 88°C. What type of gas is in the tank?

A. Helium B. Ethane C. Methane D. Ethene

Solution:

$$PV = mRT$$

$$200(1) = 2\left(\frac{8.314}{MW}\right)(88 + 273)$$

$$MW = 30$$

$$\therefore \text{the gas is } \mathbf{Ethane}\ (C_2H_6)$$

3. Find the enthalpy of Helium if its internal energy is 200 kJ/kg.

A. 144 kJ/kg B. 223.42 kJ/kg C. 333.42 kJ/kg D. 168 kJ/kg

Solution:

$$\text{For helium}, k = 1.667$$

$$U = mC_vT \text{ and } H = mC_pT$$

$$\frac{H}{U} = \frac{C_p}{C_v} = k$$

$$H = 200(1.667) = \mathbf{333.42\ kJ/kg}$$

4. Compute the mass of a 2 m^3 propane at 280 kPa and 40°C.

A. 6.47 kg B. 5.1 kg C. 10.20 kg D. 9.47 kg

Solution:

$$\text{Propane is } C_3H_3, MW = 3(12) + 8(1) = 44$$

$$PV = mRT$$

$$280(2) = m\left(\frac{8.314}{44}\right)(40 + 273)$$

$$m = \mathbf{9.47\ kg}$$

5. Compute the air flow in ft^3/min of mechanical ventilation required to exhaust an accumulation of refrigerant due to leaks of the system capable of revolving air from the machinery for a mass of 4 lbs refrigerant.

A. 200 B. 210 C. 220 D. 230

Solution:

$$Q = 100 \times \sqrt{G}, \text{ft}^3/\text{min}$$
$$Q = 100 \times \sqrt{4} = \mathbf{200} \text{ ft}^3/\text{min}$$

6. Compute the free aperture cross section in m^3 for the ventilation of a machinery room if the mass of refrigerant is 9 kg.

A. 0.314 B. 0.414 C. 0.514 D. 0.614

Solution:

$$F = 0.138G^{0.5}, \text{m}^2$$
$$F = 0.138\sqrt{9} = \mathbf{0.414} \text{ m}^2$$

7. A 29.53" x 39.37" pressure vessel contains ammonia with f = 0.041. Compute the minimum required discharge capacity of the relief device in kg/hr.

A. 106.71 kg/hr B. 108.71 kg/hr C. 110.71 kg/hr D. 112.71 kg/hr

Solution:

$$C = \text{fDL}, \text{kg/s (D and L are in meters)}$$
$$C = f\left(\frac{29.53}{39.37}\right)\left(\frac{39.37}{39.37}\right) = 0.03705(3600) = \mathbf{110.71\ kg/hr}$$

8. Compute the maximum length of the discharge pipe installed on an outlet of a pressure-relief device in feet for internal pipe diameter of 0.5 inch and rated discharge capacity is 8 lb/min of air. The rated pressure of relief valve is 10 psig.

A. 0.286 ft B. 0.386 ft C. 0.486 ft D. 0.586 ft

Solution:

$$P_{abs} = P_{gage} + P_{atm} = 16(1.1) + 14.7 = 32.3 \text{ psia}$$
$$L = \frac{9P^2d^5}{16C_r^2} = \frac{9(32.3)^2(0.5)^5}{16(8)^2} = \mathbf{0.286\ ft}$$

9. A thermal power plant has the heat rate of 11,363 Btu/kW-hr. Find the thermal efficiency of the plant.

A. 28% B. 30% C. 34% D. 40%

Solution:

$$e = \frac{3412}{\text{heat rate}} = \frac{3412}{11363} = 0.30 = \mathbf{30\%}$$

10. What is the hydraulic gradient of a 1 mile, 17 inches inside diameter pipe when 3300 gal/min of water flow with f = 0.03?

A. 0.00714 B. 0.00614 C. 0.00234 D. 0.00187

Solution:

$$v = \frac{Q}{A} = \frac{\frac{3300}{7.48}}{\frac{\pi}{4} \times \left(\frac{17}{12}\right)^2} \times 60 = 4.66 \text{ ft/s}$$

$$L = 1 \text{ mile} = 5280 \text{ ft}$$

$$h_L = \frac{fLV^2}{2GD} = \frac{0.03(5280)(4.66)^2}{2(32.2)(\frac{17}{12})} = 37.7 \text{ ft} = \mathbf{0.00714} \text{ miles}$$

11. Find the loss of head in the pipe entrance if speed of flow is 10 m/s.

A. 5.10 m B. 10.2 m C. 17.4 m D. 2.55 m

Solution:

$$\text{Loss at entrance} = 0.5\left(\frac{v^2}{2G}\right) = 0.5\left[\frac{10^2}{2(9.81)}\right] = \mathbf{2.55\ m}$$

12. Wet material, containing 220% moisture (dry basis), is to be dried at a rate of 1.5 kg/s in a continuous dryer to give a product containing 10% (dry basis). Find the moisture removed in kg/hr.

A. 3543.75 kg/hr B. 3513.75 kg/hr C. 3563.75 kg/hr D. 3593.75 kg/hr

Solution:

$$\text{Solid in wet feed} = \text{Solid in dried product}$$

$$1.5\left(\frac{1}{1+2.2}\right) = x\left(\frac{1}{1+0.1}\right)$$

$$x = 0.5156 \text{ kg/s (total dried product)}$$

$$\text{Moisture removed} = 1.5 - 0.5156 = 0.984\,\frac{kg}{s} = \mathbf{3543.75\ kg/hr}$$

13. Copra enters a dryer containing 70% moisture and leaves 7% moisture. Find the moisture removed on each pound of solid in the final product.

A. 6.258 lbs B. 1.258 lbs C. 4.258 lbs D. 2.258 lbs

Solution:

$$\text{Solid in wet feed} = \text{solid in dried product}$$

$$0.3x = 1$$

$$x = 3.333 \text{ lbs}$$

$$1 = 0.93y$$

$$y = 1.07527 \text{ lb}$$

$$\text{Moisture removed} = x - y = 3.333 - 1.07527 = \mathbf{2.258\ lbs}$$

14. A 1 m x 1.5 m cylindrical tank is full of oil with SG = 0.92. Find the force acting at the bottom of the tank in dynes.

A. 106.33 x 10^3 dynes C. 106.33 x 10^5 dynes

B. 106.33 x 10^4 dynes D. 106.33 x 10^6 dynes

Solution:

$$P = \gamma h = 0.92 \times 9.81 \times 1.5 = 13.5378 \text{ kPa}$$

$$F = PA = 13.5378 \text{ kPA} \times \left(\frac{\pi}{4} \times 1^2\right) = 10.632 \text{ kN} = 10{,}632 \text{ N}$$

$$= \mathbf{106.33 \times 10^6\, dynes}$$

15. Find the pressure at the 100 fathom depth of water in kPa.

A. 1,793.96 kPa B. 1,893.96 kPa C. 1,993.96 kPa D. 1,693.96 kPa

Solution:

$$H = 100 \text{ fathom} \times \frac{6 \text{ ft}}{\text{fathom}} = 600 \text{ ft}$$

$$P = \gamma H = 9.81\left(\frac{600}{3.281}\right) = \mathbf{1793.96\ kPag}$$

16. Find the depth in furlong of the ocean (SG = 1.03) if the pressure at the sea bed is 2,032.56 kPa.

A. 1 B. 2 C. 3 D. 4

Solution:

$$P = \gamma h$$

$$2032.56 = 1.03 \times 9.81h$$

$$h = 201.158 \text{ m}\left(\frac{3.281 \text{ ft}}{1 \text{ m}}\right)\left(\frac{1 \text{ yd}}{3\text{ft}}\right)\left(\frac{1 \text{ furlong}}{220 \text{ yd}}\right) = \mathbf{1} \text{ furlong}$$

17. Find the mass of 10 quartz of water.

A. 10.46 kg B. 9.46 kg C. 11.46 kg D. 8.46 kg

Solution:

$$V = 10 \text{ quartz}\left(\frac{1 \text{ gal}}{4 \text{ quartz}}\right)\left(\frac{3.785 \text{ L}}{1 \text{ gal}}\right)\left(\frac{1 \text{ m}^3}{1000 \text{ L}}\right) = 0.0094625 \times 10^{-3} \text{ m}^3$$

$$m = \rho V = 1000\left(0.0094625 \times 10^{-3}\right) = \mathbf{9.46\ kg}$$

18. Find the mass of carbon dioxide having a pressure of 20 psia at 200°F with 10 ft^3 volume.

A. 1.04 lbs B. 1.14 lbs C. 1.24 lbs D. 1.34 lbs

Solution:

$$PV = mRT$$

$$(20 \times 144)(10) = m\left(\frac{1545}{44}\right)(200 + 460)$$

$$m = \mathbf{1.24\ lbs}$$

19. Find the heat needed to raise the temperature of water from 30°C to 100°C with 60% quality. Consider an atmospheric pressure of 101.325 kPa. Use the approximate enthalpy formula of liquid.

A. 293.09 kJ/kg B. 1,772.90 kJ/kg C. 1,547.90 kJ/kg D. 1,647.29 kJ/kg

Solution:

@ 100°C:

$$h_f = C_p T = 4.187\ (100) = 418.7 \text{ kJ/kg}$$

$$h_{fg} = 2257 \text{ kJ/kg}$$
$$h_2 = h_f = xh_{fg} = 418.7 + 0.6(2257) = 1772.9 \text{ kJ/kg}$$
$$Q = mC\Delta T + m\Delta h = 4.187(100 - 30) + (1772.9 - 418.7)$$
$$= \mathbf{1647.29\ kJ/kg}$$

20. Find the enthalpy of water at 212°F and 14.7 psi if the dryness factor is 30%. Use the approximate enthalpy formula of liquid.

A. 461 Btu/lb B. 471 Btu/lb C. 481 Btu/lb D. 491 Btu/lb

Solution:

$$h_f = F - 32 = 212 - 32 = 180 \text{ Btu/lb}$$
$$h_{fg} = 970 \text{ Btu/lb}$$
$$h = h_f + xh_{fg} = 180 + 0.3(970) = \mathbf{471\ Btu/lb}$$

21. An air compressor consumed 1200 kW-hr per day of energy. The electric motor driving the compressor has an efficiency of 80%. If indicated power of compressor is 34 kW, find the mechanical efficiency of the compressor.

A. 117.65% B. 75% C. 85% D. 90%

Solution:

$$P_{in} = 1200 \frac{\text{kW}-\text{hr}}{\text{day}} \left(\frac{\text{day}}{24 \text{ hrs}}\right) = 50 \text{ kW}$$
$$P_{brake} = 0.8(50 \text{ kW}) = 40 \text{ kW}$$
$$e = \frac{34}{40} = 0.85 = \mathbf{85\%}$$

22. A refrigeration system consumed 28,800 kW-hr per month of energy. There is 20% of energy lost due to the cooling system of the compressor and the motor efficiency is 90%. If the COP of the system is 6, find the mechanical efficiency of the compressor.

A. 43.15 TR B. 46.15 TR C. 49.15 TR D. 41.15 TR

Solution:

$$P_{in} = 28{,}800 \frac{\text{kW}-\text{hr}}{\text{mo}} \left(\frac{1 \text{ mo}}{30 \text{ days}}\right)\left(\frac{1 \text{ day}}{24 \text{ hrs}}\right) = 40 \text{ kW}$$
$$P_{brake} = 0.9\ (40) = 36 \text{ kW}$$
$$\dot{W}_{compressor} = 36(1 - 0.2) = 28.8 \text{ kW}$$
$$COP = \frac{RE}{W_c}$$
$$RE = COP \times \dot{W}_c = 6\ (28.80 \text{ kW}) = 172.8 \text{ kW} = \mathbf{49.15\ TR}$$

23. A 23 ton refrigeration system has a heat rejected of 100 kW. Find the energy efficiency ratio of the system.

A. 13.42 B. 14.42 C. 15.42 D. 16.42

Solution:

$\dot{Q}_H = RE + \dot{W}_c$
$100 = 23(3.516) + \dot{W}_c$
$\dot{W}_c = 19.132 \text{ kW}$
$COP = \frac{RE}{W_c} = \frac{23\,(3.516)}{19.132} = 4.23$
$EER = 3.412COP = 3.412(4.23) = \mathbf{14.42}$

24. A 200 mm x 250 mm, 8-cylinder, 4-stroke diesel engine has a brake power of 150 kW. The mechanical efficiency is 80%. If two of the cylinders were accidentally cut off, what will be the new friction power?

A. 31.50 kW B. 33.50 kW C. 35.50 kW D. 37.50 kW

Solution:

$e_m = \frac{P_{brake}}{P_{ind}}$
$P_{ind} = \frac{150}{0.8} = 187.5 \text{ kW}$
$P_{friction} = P_{ind} - P_{brake} = 187.5 - 150 = 37.5 \text{ kW}$
Friction power will not change even if the two cylinders were cut off.
$\therefore P_f = \mathbf{37.50\ kW}$

25. If the energy efficiency ratio of the refrigeration system is 12.6, what is the COP of the system?

A. 3.69 B. 4.23 C. 5.92 D. 6.83

Solution:

$COP = \frac{EER}{3.412} = \frac{12.6}{3.412} = \mathbf{3.69}$

26. An air compressor has a power of 40 kW at 4% clearance. If the clearance will increase to 7%, what is the new power?

A. 70 kW B. 40 kW C. 53 kW D. 60 kW

Solution:

The power of compressor will not be affected with the changes in clearance.
$\therefore$ the power will still be **40 kW**.

27. What is the approximate value of temperature of water having enthalpy of 208 Btu/lb?

A. 138.67°C B. 115.55°C C. 258.67°C D. 68.67°C

Solution:

$\Delta Btu/lb = \Delta°F$
$h = F - 32$
$208 = F - 32$
$F = 240°F = \mathbf{115.55°C}$

28. Convert 750°R to K.

A. 390.33 K　　B. 395.33 K　　C. 410.33 K　　D. 416.33 K

Solution:

$$\Delta°R = 1.8\Delta K$$
$$750 = 1.8K$$
$$K = 416.67 \approx \mathbf{416.33\ K}$$

29. An Otto cycle has a compression ratio of 8. Find the pressure during compression.

A. 18.38　　B. 16.38　　C. 14.38　　D. 12.28

Solution:

$$P_1V_1^k = P_2V_2^k$$
$$\left(\frac{P_2}{P_1}\right) = \left(\frac{V_1}{V_2}\right)^k = r_k^k = 8^{1.4} = \mathbf{18.38}$$

30. A diesel cycle has a cut off ratio of 2.5 and expansion ratio of 4. Find the clearance of the cycle.

A. 9.11%　　B. 5.55%　　C. 11.11%　　D. 15.15%

Solution:

$$r_k = r_c r_e = 2.5(4) = 10$$
$$c = \frac{1}{r_k - 1} = \frac{1}{10-1} = 0.1111 = \mathbf{11.11\%}$$

31. A dual cycle has an initial temperature of 30°C. The compression ratio is 6 and the heat addition at constant volume process is 600 kJ/kg. If the cut-off ratio is 2.5, find the maximum temperature of the cycle.

A. 3638.50°C　　B. 3365.50°C　　C. 3565.50°C　　D. 3965.50°C

Solution:

$$T_2 = T_1\left(\frac{V_2}{V_1}\right)^{1-k} = T_1\left(\frac{1}{r_k}\right)^{1-k} = (30+273)\left(\frac{1}{6}\right)^{1-1.4} = 620.75\ K$$
$$Q_{cv} = 600\frac{kJ}{kg} = mC_v\Delta T = (1)(0.718)(T_3 - T_2) = 0.718(T_3 - 620.75)$$
$$T_3 = 1456.4\ K$$
$$\frac{P_3}{T_3} = \frac{P_4}{T_4}$$
$$T_4 = T_3\left(\frac{P_4}{P_3}\right) = 1456.4(2.5) = 3641\ K + 273 = 3367.9 \approx \mathbf{3365.50℃}$$

32. A 3-stage air compressor compresses air from 100 kPa to 1000 kPa. Find the intercooler pressure between the 1st and 2nd stage.

A. 505.44 kPa　　B. 108.44 kPa　　C. 316.23 kPa　　D. 215.44 kPa

Solution:

$$P_{intercooler} = (P_S^{n-r}\,P_D^{r})^{\frac{1}{n}} = (100^{3-1}\,1000^{1})^{\frac{1}{3}} = \mathbf{215.44\ kPa}$$

33. A 10-stage air compressor compresses air from 100 kPa to 800 kPa. Find the intercooler pressure between the 1st and 2nd stage.

A. 282.84 kPa B. 113.21 kPa C. 123.11 kPa D. 333.51 kPa

Solution:

$$P_{1-2} = \sqrt[n]{P_1^{n-r}P_2^{r}} = \sqrt[10]{100^{10-1}\,800^{1}} = \mathbf{123.11\ kPa}$$

34. A 3-stage air compressor compresses air from 100 kPa to 700 kPa. Find the intercooler pressure between the 2nd and 3rd stage.

A. 365.88 kPa B. 375.88 kPa C. 385.88 kPa D. 395.88 kPa

Solution:

$$P_{intercooler} = (P_S^{n-r}\,P_D^{r})^{\frac{1}{n}} = (100^{3-2}\,700^{2})^{\frac{1}{3}} = 365.93 \approx \mathbf{365.88\ kPa}$$

35. Carnot cycle A, B and C are connected in series so that the heat rejected from A will be the heat added to B. and heat rejected from B will be added to C. Each cycle operates between 30°C and 400°C. If heat added to A is 1000 kW, find the work output of C.

A. 111.44 kW B. 549.78 kW C. 247.53 kW D. 141.89 kW

Solution:

$$e_A = e_B = e_C = \frac{400-30}{400+273} = 54.98\%$$

$$e = \frac{\dot{W}}{\dot{Q}_A} = \frac{\dot{Q}_A - \dot{Q}_R}{\dot{Q}_A}$$

$$0.5498 = \frac{1000 - \dot{Q}_{R,A}}{1000}$$

$$\dot{Q}_{R,A} = \dot{Q}_{A,B} = 450.22$$

$$0.5498 = \frac{450.22 - \dot{Q}_{R,B}}{450.22}$$

$$\dot{Q}_{R,B} = \dot{Q}_{A,C} = 202.69$$

$$0.5498 = \frac{\dot{W}_C}{\dot{Q}_{A,C}}$$

$$\dot{W}_C = \mathbf{111.44\ kW}$$

36. Air compressed adiabatically from 30°C to 100°C. If the mass of air being compressed is 5 kg, find the change of entropy.

A. 1.039 kJ/K B. 0.746 kJ/K C. 0 D. 1.245 kJ/K

Solution:

$$\text{For adiabatic compression}, S = \text{constant}.$$

$$\therefore \Delta S = \mathbf{0}$$

37. Two kilogram of air in a rigid tank changes its temperature from 32°C to 150°C. Find the work done during the process.

A. 236　　B. 170　　C. 195　　D. 0

Solution:

$$\text{For rigid tank, V} = \text{constant}$$
$$\text{For constant volume process, } \mathrm{W} = \mathbf{0}$$

38. Determine the atmospheric pressure at a location where barometric reading is 740 mm Hg and gravitational acceleration is g = 9.7 m/s^2. Assume the temperature of mercury to be 10°C, at which the density is 13,570 kg/m^3.

A. 99.45 kPa　　B. 97.41 kPa　　C. 95.44 kPa　　D. 98.66 kPa

Solution:

$$\mathrm{P} = \rho\mathrm{gh} = 13570(9.7)(0.74\ \mathrm{m\ Hg}) = 97405.46\ \mathrm{Pa} = \mathbf{97.41\ kPa}$$

39. The barometer of a mountain hiker reads 930 mbars at the beginning of a hiking trip and 780 mbars at the end. Neglecting the effect of altitude on local gravitational acceleration, determine the vertical distance climbed. Assume g = 9.7 m/s^2.

A. 1274.21 m　　B. 1289.00 m　　C. 1267.34 m　　D. 1583.34 m

Solution:

$$\Delta\mathrm{P} = \rho\mathrm{gh}$$
$$(0.93 - 0.78)\left(\frac{100{,}000\ \mathrm{Pa}}{1\ \mathrm{bar}}\right) = 1.2\ (9.7)(\mathrm{h})$$
$$\mathrm{h} = 1288.66 \approx \mathbf{1289.00\ m}$$

40. The lower half of a 10 m high cylindrical container is filled with water and the upper half with oil that has SG = 0.85. Determine the pressure difference between the top and bottom if the cylinder.

A. 90.74 kPa　　B. 92.74 kPa　　C. 83.38 kPa　　D. 98.10 kPa

Solution:

$$\Delta\mathrm{P} = \mathrm{P_{oil}} + \mathrm{P_{water}} = (0.85 \times 9.81)(5) + 9.81(5) = \mathbf{90.74\ kPa}$$

41. An ideal gas at 0.80 atmospheres and 87°C occupies 0.450 liter. How many moles are in the sample? (R = 0.0821 liter-atm/mole-K).

A. 0.0002 mole　　B. 0.0378 mole　　C. 0.0122 mole　　D. 0.0091 mole

Solution:

$$\mathrm{PV} = \mathrm{nRT}$$
$$0.8\ (0.45) = \mathrm{n}(0.0821)(87 + 273)$$
$$\mathrm{n} = 0.0121752 \approx \mathbf{0.0122\ mole}$$

42. A certain gas at 101.325 kPa and 10°C whose volume is 2.83 m^3 capacity. Before admission, the storage vessel contained gas at a pressure and temperature of 137.8 kPa and 26°C; after admission, the pressure increased to 1171.8 kPa. What should be the final temperature of the gas in the vessel in Kelvin?

A. 298.0 B. 319.8 C. 180.0 D. 314.2

Solution:

Solving for the mass of gas which is to be compressed:

$$PV = mRT$$

$$m_1 = \frac{101.325(2.83)}{R(10+273)} = \frac{1.01325}{R}$$

Solving for the mass of gas initially contained in the vessel:

$$PV = mRT$$

$$m_2 = \frac{137.8(0.31)}{R(26+273)} = \frac{0.14286}{R}$$

Solving for the final temperature:

$$m_3 = m_1 + m_2 = \frac{1.01325}{R} + \frac{0.014286}{R} = \frac{1.156}{R}$$

$$P_3V_3 = m_3RT_3$$

$$T_3 = \frac{1171.8(0.31)}{\frac{1.156}{R}R} = \mathbf{314.2}\ \mathrm{K}$$

43. A perfect gas has a value of R = 58.8 ft-lb/lb-°R and k = 1.26. If 20 Btu are added to 10 lbs of this gas at constant volume when initial temperature is 90°F, find the final temperature.

A. 97°F B. 104°F C. 154°F D. 185°F

Solution:

$$Q = mC_V\Delta T$$

$$C_V = \frac{R}{k-1} = \frac{58.8}{1.26-1}\left(\frac{1}{778}\right) = 0.29086\ \mathrm{Btu/lb\text{-}°F}$$

$$20 = 10(0.29086)(T_2 - 90)$$

$$\mathbf{T_2} = 96.88 \approx \mathbf{97°F}$$

44. Ammonia weighing 22 kg is confirmed inside a cylinder equipped with a piston has an initial pressure of 413 kPa at 38°C. If 3200 kJ of heat is added to the ammonia until its final pressure and temperature is 413 kPa and 100°C, respectively. What is the amount of work done by the fluid in kJ?

A. 667 B. 304 C. 420 D. 502

Solution:

$$\text{Molecular Weight of Ammonia, MW} = 17$$

$$P_1V_1 = m_1RT_1$$

$$V_1 = \frac{22\left(\frac{8.314}{17}\right)(38+273)}{413} = 8.106\ \mathrm{m^3}$$

$$P_2V_2 = m_2RT_2$$

$$V_2 = \frac{22\left(\frac{8.314}{17}\right)(100+273)}{413} = 9.72\ m^3$$
$$W = P\Delta V = 413(9.72 - 8.106) = 666.58 \approx \mathbf{667}\ kJ$$

45. A tank contains 90 ft^3 of air at a pressure of 350 psig; if the air is cooled until its pressure and temperature decreases at 200 psig and 70°F respectively, what is the decrease in internal energy?

A. 6232.09 Btu B. -5552 Btu C. 5552 Btu D. -6232.09 Btu

Solution:

$$P_2V_2 = mRT_2$$
$$m = \frac{P_2V_2}{RT_2} = \frac{90(200+14.7)\left(\frac{12\ in}{ft}\right)^2}{53.35(70+460)} = 98.5\ lbs$$
$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$
$$T_1 = \frac{P_1}{P_2}T_2 = \frac{350+14.7}{200+14.7}(530) = 900°R$$
$$\Delta U = mC_v\Delta T = 98.5(0.171)(530 - 900) = -6232.095 \approx \mathbf{-6232.09\ Btu}$$

46. A large mining company was provided with a 3 m^3 of compressed air tank. Air pressure in the tank drops from 700 kPa to 150 kPa while the temperature remains constant at 28°C. What percentage has the mass of air in the tank been reduced?

A. 74.09 B. 72.45 C. 76.56 D. 78.57

Solution:

$$\text{Percent of mass reduced} = \frac{700-150}{700} = \mathbf{78.57}\%$$

47. A 4 m^3/hr pump delivers water to a pressure tank. At the start, the gage read 138 kPa until it reads 276 kPa and then the pump was shut off. The volume of the tank is 180 liters. At 276 kPa, the water occupied 2/3 of the tank volume. Determine the volume of the water that can be taken out until the gage reads 138 kPa.

A. 31.20 liters B. 34.59 liters C. 16.87 liters D. 29.50 liters

Solution:

Consider the air pressure:

$$V_2 = \frac{1}{3}(180) = 60\ \text{liters}$$
$$P_1V_1 = P_2V_2$$
$$(138 + 101.325)V_1 = (276 + 101.325)(60)$$
$$V_1 = 94.59\ \text{liters}$$
$$\text{Amount of water to be removed} = \frac{2}{3}(180) - (180 - 94.59) = \mathbf{34.59\ liters}$$

48. A refrigeration plant is rated at 15 tons capacity. How many pounds of air per hour will it cool from 70°F to 90°F at constant temperature?

A. 50,000 lb/hr B. 37,500 lb/hr C. 52,000 lb/hr D. 45,000 lb/hr

Solution:

$$\dot{Q} = \dot{m}C_p\Delta T$$

$$15\ \text{TOR}\left(12000\frac{\frac{\text{BTU}}{\text{hr}}}{\text{TOR}}\right) = \dot{m}(0.24)(90-70)$$

$$\dot{m} = \mathbf{37,500\ lb/hr}$$

49. An air standard engine has a compression ratio of 18 and a cut-off ratio of 4. If the intake air pressure and temperature are 100 kPa and 27°C, find the work in kJ per kg.

A. 2976 B. 2166 C. 1582 D. 2751

Solution:

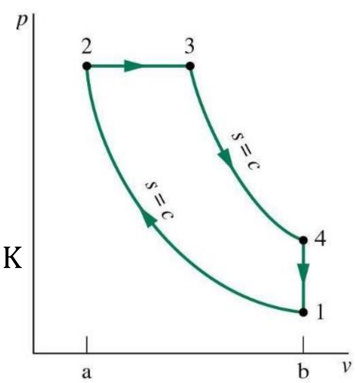
$$e = 1 - \frac{B}{A}$$

$$A = r_k^{k-1}$$

$$B = \frac{r_c^k - 1}{k(r_c - 1)}$$

$$e = 0.5531 = 55.31\%$$

$$T_2 = T_1\left(\frac{V_1}{V_2}\right)^{k-1} = 300(18)^{1.4-1} = 953.3\ \text{K}$$



In constant pressure heat addition:

$$T_3 = \frac{V_3}{V_2}T_2 = 4(953.3) = 3813.2\ \text{K}$$

$$Q_{2\text{-}3} = mC_p\Delta T = 1(1)(3813.2 - 953.3) = 2859.9\ \text{kJ/kg}$$

$$e = \frac{W}{Q}$$

$$W = eQ = 0.5531(2859.9) = 1581.6 \approx \mathbf{1582\ kJ/kg}$$

50. Determine the air-standard efficiency of an engine operating on the diesel cycle with a clearance of 6% when the suction pressure is 99.7 kPa and the fuel is injected for 7% of the stroke. Assume k = 1.4.

A. 62.11% B. 51.20% C. 73.58% D. 60.02%

Solution:

$$V_3 - V_2 = 0.07V_D$$

$$V_2 = 0.06V_D$$

$$V_3 = 0.07V_D + V_2 = 0.07V_D + 0.06V_D = 0.13V_D$$

$$r_c = \frac{V_3}{V_2} = \frac{0.13V_D}{0.06V_D} = 2.167$$

$$r_k = \frac{1+c}{c} = \frac{1+0.06}{0.06} = 17.667$$

$$e = 1 - \left(\frac{1}{r_k^{k-1}}\right)\left(\frac{r_c^k - 1}{k(r_c - 1)}\right) = 0.6211 = \mathbf{62.11\%}$$

51. Steam at 2 MPa and 250°C in a rigid cylinder is cooled until the quality is 30%. Find the heat rejected from the cylinder.

@ 2 Mpa and 250°C: $\upsilon = 0.11144\ m^3/kg$ $u = 2679.6\ kJ/kg$

@ 2 Mpa, (saturated): $\upsilon_f = 0.0011767\ m^3/kg$ $\upsilon_g = 0.09963\ m^3/kg$

$u_f = 906.44 kJ/kg$ $u_g = 1693.8\ kJ/kg$

A. -423.23 kJ/kg B. -926.26 kJ/kg C. -1265.02 kJ/kg D. 1082.34 kJ/kg

Solution:

$$Q = U_2 - U_1$$

$$U_1 = 2679.6\ kJ/kg$$

$$U_2 = U_f + xU_{fg} = 906.44 + 0.30(1693.8) = 1414.58\ kJ/kg$$

$$Q = 1414.58 - 2679.6 = \mathbf{-1265.02\ kJ/kg}$$

52. At 1.3 MPa, a mixture of steam and water has an entropy of 3 kJ/kg-K, Find the enthalpy of the mixture.

@ 1.3MPa: $s_f = 2.2515\ kJ/kg\text{-}K$ $s_g = 6.4952\ kJ/kg\text{-}K$

$h_f = 814.93\ kJ/kg$ $h_{fg} = 1972.7\ kJ/kg$

A. 1627.71 kJ/kg B. 1533.33 kJ/kg C. 1234.45 kJ/kg D. 1162.40 kJ/kg

Solution:

$$s = s_f + xs_{fg}$$

$$3 = 2.2515 + x(6.4952 - 2.2515)$$

$$x = 0.1764$$

$$h = h_f + xh_{fg} = 814.93 + 0.176(1972.7) = 1162.91 \approx \mathbf{1162.40\ kJ/kg}$$

53. A mixture with 70% quality at 500 kPa is heated isothermally until its pressure is 300 kPa. Find the heat added during the process.

@ 600 kPa: $s_f = 1.8607\ kJ/kg\text{-}K$ $s_{fg} = 4.9606\ kJ/kg\text{-}K$

@ 300 kPa and 151.86°C: $s = 7.0888\ kJ/kg\text{-}K$

A. 745.92 kJ/kg B. 535.16 kJ/kg C. 982.44 kJ/kg D. 765.34 kJ/kg

Solution:

$$s = s_f + xs_{fg} = 1.8607 + 0.70(4.9606) = 5.333$$

$$s_2 = 7.0888$$

For an isothermal process:

$$Q = T\Delta s = (151.86 + 273)(7.0888 - 5.333) \approx \mathbf{745.92\ kJ/kg}$$

54. A tank contains exactly one kilogram of water consisting of liquid and vapor in equilibrium at 1 MPa. If the liquid contains one-third and the remaining is vapor of the volume of the tank, what is the enthalpy of the contents of the tank?

@ 1MPa: υ_f = 0.0011273 m^3/kg υ_{fg} = 0.19444 m^3/kg

h_f = 762.81 kJ/kg h_{fg} = 2015.3 kJ/kg

A. 644.40 kJ/kg B. 774.40 kJ/kg C. 785.92 kJ/kg D. 435.29 kJ/kg

Solution:

$$\text{Let V} = \text{total volume of the tank}$$

$$m_l = \frac{V_l}{\upsilon_l} = \frac{\frac{1}{3}V}{0.0011273} = 295.69V$$

$$m_v = \frac{V_v}{\upsilon_v} = \frac{\frac{2}{3}V}{0.1944} = 3.429V$$

$$x = \frac{m_v}{m_v + m_l} = \frac{3.429V}{3.429V + 295.69V} = 0.01146$$

$$h = h_f + xh_{fg} = 762.81 + 0.01146(2015.3) = \mathbf{785.92\ kJ/kg}$$

55. Water substance at 70 bar and 65°C enters a boiler tube of constant inside diameter of 25 mm. The water leaves the boiler tube at 50 bar and 700 K at velocity of 150 m/s. Calculate the inlet velocity (m/s).

From steam tables:

@ 70 bar (7Mpa) and 65°C: υ_1 = 0.001017 m^3/kg

@ 50 bar (5Mpa) and 700 K (427°C): υ_2 = 0.06081 m^3/kg

A. 1.56 B. 2.51 C. 1.672 D. 3.230

Solution:

$$\dot{m}_1 = \dot{m}_2$$

$$\frac{Q_1}{\upsilon_1} = \frac{Q_2}{\upsilon_2}$$

$$\frac{AV_1}{\upsilon_1} = \frac{AV_2}{\upsilon_2}$$

$$\frac{AV_1}{0.001017} = \frac{A(100)}{0.06081}$$

$$\mathbf{V_1} = \mathbf{2.51}\ \text{m/s}$$

56. Water substance at 70 bar and 65°C enters a boiler tube of constant inside diameter of 35 mm. The water leaves the boiler tube at 50 bar and 700 K at velocity of 150 m/s. Calculate the inlet volume flow (liters/s).

From steam tables:

@ 70 bar (7Mpa) and 65°C: υ_1 = 0.001017 m^3/kg

@ 50 bar (5Mpa) and 700 K (427°C): υ_2 = 0.06081 m^3/kg

A. 0.821 B. 1.261 C. 0.344 D. 1.609

Solution:

$$\dot{m}_1 = \dot{m}_2$$

$$\frac{Q_1}{\upsilon_1} = \frac{Q_2}{\upsilon_2}$$
$$\frac{AV_1}{\upsilon_1} = \frac{AV_2}{\upsilon_2}$$
$$\frac{AV_1}{0.001017} = \frac{A(150)}{0.06081}$$
$$V_1 = 1.672 \text{ m/s}$$
$$Q_1 = AV = \frac{\pi}{4}(0.035)^2(1.672) = 1.609 \times 10^{-3}\frac{m^3}{s} = \mathbf{1.609} \text{ L/s}$$

57. Steam leaves an industrial boiler at 827.4 kPa and 171.6°C. A portion of the steam is passed through a throttling calorimeter and is exhausted to the atmosphere when the calorimeter pressure is 101.4 kPa. How much moisture is leaving the boiler container if the temperature of the steam at the calorimeter is 115.6°C?

@ 827.4 kPa and 171.6°C: h_f = 727.25 kJ/kg h_{fg} = 2043.2 kJ/kg
@ 101.4 kPa and 115.6°C: h_2 = 2707.6 kJ/kg

A. 3.78% B. 3.08% C. 4.56% D. 2.34%

Solution:

$$\text{Let x = quality of steam entering the throttling calorimeter}$$
$$h_1 = h_2$$
$$27076 = 727.25 + x(2043.2)$$
$$x = 0.9692$$
$$y = 1 - 0.9692 = 0.0308 = \mathbf{3.08\%}$$

58. A throttling calorimeter is connected to a desuperheated steam line supplying steam to the auxiliary feed pump on a ship. The line pressure measures 2.5 MPa. The calorimeter pressure is 110 kPa at 150°C. Determine the entropy of the steam line.

@ 110 kPa and 150°C: h_2 = 2775.6 kJ/kg
@ 2.5 MPa: h_f = 962.11 kJ/kg h_{fg} = 1841 kJ/kg
s_f = 2.5547 kJ/kg-K s_{fg} = 3.7028 kJ/kg-K

A. 6.8 kJ/kg-K B. 6.2 kJ/kg-K C. 6.6 kJ/kg-K D. 7.5 kJ/kg-K

Solution:

For throttling process:
$$h_1 = h_2 = h_f + xh_{fg}$$
$$2775.6 = 962.11 + x(1841)$$
$$x = 0.985$$
$$s = s_f + xs_{fg} = 2.5457 + 0.985(3.7028) = \mathbf{6.2\ kJ/kg\text{-}K}$$

59. Atmospheric pressure boils at 212°F. At the vacuum pressure at 24 in Hg, the temperature is 142°F. Find the boiling temperature when the pressure is increased by 40 psia from atmospheric.

A. 449.42°F B. 536.34°F C. 479.13°F D. 263.45°F

Solution:

$$P_1 = P_g + P_{atm} = \text{-24 in Hg}\left(\frac{14.7\text{ psi}}{29.92\text{ in Hg}}\right) + 14.7 = 2.908\text{ psia}$$

$$P_2 = P_g + P_{atm} = 40 + 14.7 = 54.7\text{ psia}$$

By interpolation:

$$\frac{t_2 - 212}{t_2 - 142} = \frac{54.7 - 14.7}{54.7 - 2.908}$$

$$\mathbf{t_2 = 449.42°F}$$

60. A certain coal has the following ultimate analysis:

C = 69% N_2 = 5% H = 2.5% S =7%

Determine the amount of oxygen if the heating value of fuel is 26,961.45 kJ/kg.

A. 1.5% B. 2.5% C. 3.5% D. 4.5%

Solution:

$$Q_H = 26{,}961.45 = 33{,}820C + 144{,}212\left(H - \frac{O}{8}\right) + 9{,}304S$$

$$26{,}961.45 = 33{,}820(0.69) + 144{,}212\left(0.025 - \frac{O}{8}\right) + 9{,}304(0.07)$$

$$\mathbf{O = 3.5\%}$$

61. A diesel engine consumed 945 liters of fuel per day at 35°C. If the fuel was purchased at 15.6°C and 30°API at P29.00/li. Determine the cost of fuel to operate the engine per day.

A. P5,677.50 B. P4,677.50 C. P48,088.90 D. P27,127.76

Solution:

$$°API = \frac{141.5}{SG_{15.6°C}} - 131.5$$

$$30 = \frac{141.5}{SG_{15.6°C}} - 131.5$$

$$SG_{15.6°C} = 0.87616$$

$$SG_{35°C} = SG_{15.6°C}CF = 0.87616[1 - 0.0007(30 - 15.6)] = 0.8673$$

$$\frac{V_{35°C}}{V_{15.6°C}} = \frac{SG_{15.6°C}}{SG_{30°C}}$$

$$V_{15.6°C} = 935.44\text{ li}$$

$$\text{Cost} = \frac{P29.00}{li}(935.44\text{ li}) = \mathbf{P27{,}127.76}$$

62. A cylindrical tank 4 m long and 3 m diameter is used for oil storage. How many days can the tank supply the engine having 27°API with fuel consumption of 60 kg/hr?

A. 17.53 B. 5.84 C. 12.84 D. 19.84

Solution:

$$V = Ah = \frac{\pi}{4}D^2h = \frac{\pi}{4}(3)^2(2) = 28.27\text{ m}^3$$

$$°\mathrm{API} = \frac{141.5}{SG_{15.6℃}} - 131.5$$
$$27 = \frac{141.5}{SG_{15.6℃}} - 131.5$$
$$SG_{15.6℃} = 0.8927$$
$$\rho_{oil} = SG_{15.6℃}\rho_w = 0.8927 \times 1000\,\frac{\mathrm{kg}}{\mathrm{m^3}} = 892.7\ \mathrm{kg/m^3}$$
$$\dot{V} = \dot{m}\upsilon = 60\,\frac{\mathrm{kg}}{\mathrm{hr}}\left(\frac{1}{892.7}\,\frac{\mathrm{m^3}}{\mathrm{kg}}\right) = 0.0672\ \mathrm{m^3/hr}$$
$$\dot{V} = \frac{V}{t}$$
$$t = \frac{V}{\dot{V}} = \frac{28.27}{0.0672} = 420.6845\ \mathrm{hr}\left(\frac{1\ \mathrm{day}}{24\ \mathrm{hours}}\right) = \mathbf{17.53}\ \mathrm{days}$$

63. A logging firm in Isabella operates a Diesel Electric Plant to supply its electric energy requirements. During a 2 hour period, the plant consumed 250 gallons of fuel at 80°F and produced 2900 kW-hrs. Industrial fuel is used at 30°API and was purchased at P30/li at 60°F. Determine the overall thermal efficiency of the plant.

A. 26.08% B. 34.23% C. 28.00% D. 18.46%

Solution:

$$Q_H = 41{,}130 + 139.6(°\mathrm{API}) = 41{,}130 + 139.6(30) = 45{,}318\ \mathrm{kJ/kg}$$
$$60°\mathrm{F} = 15.6℃$$
$$80°\mathrm{F} = 26.6℃$$
$$°\mathrm{API} = \frac{141.5}{SG_{15.6℃}} - 131.5$$
$$SG_{15.6℃} = \frac{141.5}{131.5+30} = 0.876$$
$$SG_{26.67} = SG_{15.6℃}CF = 0.876[1 - 0.00072(26.67 - 15.6)] = 0.869$$
$$\rho_{oil} = SG_{26.67℃}\rho_w = 0.869\left(1000\,\frac{\mathrm{kg}}{\mathrm{m^3}}\right) = 869\ \mathrm{kg/m^3}$$
$$\dot{m}_f = \frac{250\ \mathrm{gal}}{24\ \mathrm{hour}}\left(\frac{3.7854\ \mathrm{liter}}{1\ \mathrm{gal}}\right)\left(\frac{1\ \mathrm{m^3}}{1000\ \mathrm{liter}}\right) = 0.039427\,\frac{\mathrm{m^3}}{\mathrm{hr}}\left(869\,\frac{\mathrm{kg}}{\mathrm{m^3}}\right)\left(\frac{1\ \mathrm{hr}}{3600\ \mathrm{s}}\right)$$
$$= 0.00952\ \mathrm{kg/s}$$
$$\text{Overall Efficiency} = \frac{\text{Power Output}}{\dot{m}_f Q_h} = \frac{2900\,\frac{\mathrm{kW\text{-}hr}}{\mathrm{day}}\left(\frac{1\ \mathrm{day}}{24\ \mathrm{hrs}}\right)}{0.00953\,\frac{\mathrm{kg}}{\mathrm{s}}\left(45{,}318\,\frac{\mathrm{kJ}}{\mathrm{kg}}\right)} = 0.2800 = \mathbf{28.00\%}$$

64. The dry exhaust gas from the oil engine has the following gravimetric analysis:

CO_2 = 21.6% O_2 = 4.2% N = 74.2%

Specific heats at constant pressure for each component of the exhaust gas in kCal/kg-°C are:

CO_2 = 0.203 O_2 = 0.219 N = 0.248

Calculate the specific gravity if the molecular weight of air is 28.97 kg/kg-mol.

A. 0.981 B. 1.244 C. 1.055 D. 0.542

Solution:

Converting the gravimetric analysis to volumetric:

$CO_2 = \frac{0.216}{44} = 0.004909$

$O_2 = \frac{0.042}{32} = 0.001312$

$N_2 = \frac{0.742}{28} = 0.0265$

$\sum \text{volumetric} = 0.032721 \text{ mol/kg-mol}$

$\text{Molecular Weight} = \frac{1}{0.032721} = 30.56 \text{ mol/kg-mol}$

$SG = \frac{MW_{\text{exhaust gas}}}{MW_{\text{air}}} = \frac{30.56}{28.97} = \mathbf{1.055}$

65. A bituminous coal has the following composition:

C = 71.5% H = 5.0% O = 7.0% N = 1.3% S = 3% Ash = 7.6%
W = 3.4%

Determine the theoretical weight of Nitrogen in lb/lb of coal.

A. 2.870 B. 7.526 C. 2.274 D. 6.233

Solution:

$\left(\frac{A}{F}\right)_{\text{theo}} = 11.5C + 34.5\left(H - \frac{O}{8}\right) + 4.3S$

$= 11.5(0.715) + 34.5\left(0.05 - \frac{0.07}{8}\right) + 4.3(0.036)$

$\left(\frac{A}{F}\right)_{\text{theo}} = 9.8\frac{lb_{\text{air}}}{lb_{\text{coal}}}$

$N_2 \text{ in air by weight} = 76.8\ \%$

$\text{Theoretical weight of } N_2 = 0.768(9.8) = \mathbf{7.526}\ lb/lb_{\text{coal}}$

66. A gaseous fuel mixture has a molal analysis:

H_2 = 14% CH_4 = 3% CO = 27% O_2 = 0.6% CO_2 = 4.5% N_2 = 50.9%

Determine the air-fuel ratio for complete combustion on molal basis.

A. 2.130 B. 3.230 C. 1.233 D. 1.130

Solution:

Chemical reaction with oxygen:

$0.14H_2 + 0.070O_2 = 0.14H_2O$

$0.93CH_4 + 0.0600O_2 = 0.03CO_2 + 0.06H_2O$

$0.27CO + 0.135O_2 = 0.27CO_2$

$\sum O_2 = 0.265O_2$

$\text{Actual } O_2 \text{ in product} = 0.265O_2 - 0.006O_2 = 0.259O_2$

$\text{Molal } \frac{A}{F} = \frac{0.259 + 0.259(3.76)}{1} = \mathbf{1.233}\ mol_{\text{air}}/mol_{\text{fuel}}$

67. A volumetric analysis of a gas mixture is a follows:

CO_2: 12% O_2: 4% N_2: 80% CO: 4%

What percentage of CO_2 on a mass basis?

A. 17.55% B. 15.55% C. 12.73% D. 19.73%

Solution:

Converting to mass basis:

$$CO_2 = 0.12 \times 44 = 5.28$$

$$O_2 = 0.04 \times 32 = 1.28$$

$$N_2 = 0.82 \times 28 = 22.96$$

$$CO = 0.02 \times 28 = 0.56$$

$$\sum \text{mass of product} = 5.28 + 1.28 + 22.96 + 0.56 = 30.08 \text{ kg}$$

$$\%\text{mass of } CO_2 = \frac{5.28}{30.08} = 0.1755 = \mathbf{17.55\%}$$

68. The following coal has the following ultimate analysis by weight:

C = 70.5% H_2 = 4.5% O_2 = 6.0% N_2 = 1.0% S = 3.0% Ash = 11%

Moisture = 4%

A stocker fired boiler of 195,000 kg/hr steaming capacity uses this coal as fuel. Calculate volume of air in m^3/hr with air at 60°F and 14.7 air pressure if the boiler efficiency is 70% and FE = 1.10.

A. 234,019 m^3/hr B. 215,830 m^3/hr C. 213,830 m^3/hr D. 264,830 m^3/hr

Solution:

$$\left(\frac{A}{F}\right)_{theo} = 11.5C + 34.5\left(H - \frac{O}{8}\right) + 4.3S$$

$$= 11.5(0.705) + 34.5\left(0.045 - \frac{0.06}{8}\right) + 4.3(0.03) = 9.53$$

$$\left(\frac{A}{F}\right)_{actual} = \left(\frac{A}{F}\right)_{theo}\left(1 + \frac{\%\text{ excess}}{100}\right) = 9.53\left(1 + \frac{30}{100}\right)$$

$$= 12.389 \text{ kg}_{air}/\text{kg}_{fuel}$$

$$FE = \frac{h_s - h_f}{2257}$$

$$h_s - h_f = FE \times 2257 = 1.1 \times 2257$$

$$Q_H = 33820C + 141212\left(H - \frac{O}{8}\right) + 9304S$$

$$= 33820(0.705) + 141212\left(0.045 - \frac{0.06}{8}\right) + 9304(0.03)$$

$$= 29{,}930 \text{ kJ/kg}$$

$$\eta = \frac{\dot{m}_{s(h_s - h_f)}}{\dot{m}_f Q_H} = \frac{\dot{m}_{s(FE\times 2257)}}{\dot{m}_f Q_H}$$

$$0.7 = \frac{195{,}000(1.1\times 2257)}{\dot{m}_f(29{,}930)}$$

$$\dot{m}_f = 23107.56\frac{kg}{hr}(12.389) = 286{,}279.57 \text{ kg}_{air}/\text{hr}$$

$$P\dot{V} = \dot{m}RT$$

$$101.325\dot{V} = 286{,}279.57(0.287)(15.6 + 273)$$

$$\dot{V} = \mathbf{234{,}019\ m^3/hr}$$

69. 23.5 kg of steam per second at 5 MPa and 400°C is produced by a steam generator. The feedwater enters the economizer at 145°C and leaves at 205°C. The steam leaves the boiler drum with a quality of 98%. The unit consumes 3 kg of coal per second as received having value of 25,102 kJ/kg. What would be the overall efficiency of the unit in percent?

Steam properties:

@ 5 MPa and 400°C:	h = 3195.7 kJ/kg	
@ 5 MPa:	h_f = 1154.23 kJ/kg	h_{fg} = 1640.1 kJ/kg
@ 205°C:	h_f = 875.04 kJ/kg	
@ At 145°C:	h_f = 610.63 kJ/kg	

A. 65.72 B. 80.67 C. 88.28 D. 78.82

Solution:

$$\eta_b = \frac{\dot{m}_s(h_s - h_f)}{\dot{m}_f Q_H} = \frac{23.5(3195.7 - 610.63)}{3(25{,}102)} = \mathbf{80.67}\ \%$$

70. In a Rankine cycle steam enters the turbine at 2.5 MPa (enthalpies & entropies given) and condenser of 50 kPa (properties given), what is the thermal efficiency of the cycle?

@ 2.5 MPa:	h_g = 2803.1 kJ/kg	s_g = 6.2575 kJ/kg-K
@ 50 kPa:	s_f = 1.0910 kJ/kg-K	s_{fg} = 6.5029 kJ/kg-K
	h_f = 340.49 kJ/kg	h_{fg} = 2305.4 kJ/kg
	υ_f = 0.00103 m^3/kg	

A. 25.55% B. 45.23% C. 34.23% D. 12.34%

Solution:

$$h_f = 2803.1 \text{ kJ/kg}$$

Solving for h_2:

$$s = s_f + xs_{fg}$$

$$6.2575 = 1.0910 + x(6.5029)$$

$$x = 0.7945$$

$$h_2 = h_f + xh_{fg} = 340.49 + 0.7945(2305.4) = 2172.13$$

$$h_3 = 340.49 \text{ kJ/kg}$$

$$h_4 = h_f + v_f(P_2 - P_1) = 340.49 + 0.00103(2500 - 50) = 342.93$$

$$\text{efficiency} = \frac{(h_f - h_2) - (h_4 - h_3)}{h_1 - h_4} = \frac{(2803.1 - 2172.11) - (342.98 - 340.49)}{2803.1 - 342.98} = \mathbf{25.55\%}$$

71. A thermal power plant generates 5 MW and the heat generated by fuel is 13,000 kJ/s. If the thermal efficiency is 36.15%, find the power needed for the auxiliaries.

A. 310 kW B. 300 kW C. 400 kW D. 350 kW

Solution:

$$\text{eff} = \frac{BP - P_{aux}}{P_{in}}$$

$$0.3615 = \frac{5000 - P_{aux}}{13000}$$

$$P_{aux} = 300.5 \approx \mathbf{300\ kW}$$

72. A superheat steam Rankine cycle has turbine inlet conditions of 17.5 MPa and 530°C expands in a turbine to 0.007 MPa. The turbine and pump polytropic efficiencies are 0.85 and 0.75 respectively. Pressure losses between the pump and turbine inlet are 1.5 MPa. What should be the pump work in kJ/kg?

A. 17.34 B. 27.32 C. 25.32 D. 47.33

Solution:

Using density of water $= 1000\ kg/m^3$

$$\upsilon_3 = \frac{1}{\rho} = \frac{1}{1000} = 0.001\ m^3/kg$$

$$P_4 = 17.5 + 1.5 = 19\ MPa = 19{,}000\ kPa$$

$$P_3 = 0.007\ MPa = 7\ kPa$$

$$W = \frac{\upsilon_3(P_4 - P_3)}{\eta_p} = \frac{0.001\,(19{,}000 - 7)}{0.75} = \mathbf{25.32}\ kJ/kg$$

73. In an open feedwater heater for a steam plant, saturated steam at 7 bar is mixed with subcooled liquid at 7 bar and 25°C. Just enough steam is supplied to ensure that the mixed steam leaving the heater will be saturated liquid at 7 bar when heater efficiency is 95%. Calculate the mass flow rate of the subcooled liquid if steam flow rate is 0.865 kg/s.

Steam properties:

@ 7 bar, saturated vapor:	h_g = 2763.5 kJ/kg
@ 7 bar and 25°C:	h_f = 105.5 kJ/kg
@ 7 bar, saturated liquid:	h_f = 697.22 kJ/kg

A. 2.725 kg/s B. 3.356 kg/s C. 2.869 kg/s D. 3.948 kg/s

Solution:

$$\text{Efficiency} = \frac{\text{Heat Absorbed}}{\text{Heat Supplied}} = \frac{\dot{m}_L(h_3 - h_2)}{\dot{m}_s(h_1 - h_3)}$$

$$0.95 = \frac{\dot{m}_L(697.22 - 105.5)}{0.865\,(2763.5 - 697.22)}$$

$$\dot{m}_L = \mathbf{2.869\ kg/s}$$

74. A steam condenser receives 10 kg/s of steam with an enthalpy of 2770 kJ/kg. Steam condenses and leaves with an enthalpy of 160 kJ/kg. Cooling water passes through the condenser with temperature increases from 13°C to 24°C. Calculate the water flow rate in kg/s.

A. 583 B. 567 C. 523 D. 528

Solution:

By heat balance in the condenser:

Heat rejected by steam = heat absorbed by water

$$\dot{m}_s(h_f - h_2) = \dot{m}_w c_p(t_2 - t_1)$$

$$10(2770 - 160) = \dot{m}_w(4.187)(24 - 13)$$

$$\dot{m}_w = \mathbf{567}\ \text{kg/s}$$

75. Steam expands adiabatically in a turbine from 2000 kPa, 400°C to 400 kPa, 250°C. What is the effectiveness of the process in percent assuming an atmospheric pressure of 18°C? Neglect changes in kinetic and potential energy.

Steam properties:

@ 2000 kPa and 400°C:	h = 3247.6 kJ/kg	s = 7.1271kJ/kg-K
@ 400 kPa and 250°C:	h = 2964.2 kJ/kg	s = 7.3789 kJ/kg-K

A. 82 B. 84 C. 79.60 D. 79.46

Solution:

$$Q_m = h_1 - h_2 = 3247.6 - 2964.2 = 283.4\ \text{kJ/kg}$$
$$Q_s = T(s_1 - s_2) = (18 + 273)(7.3789 - 7.1271) = 73.27\ \text{kJ/kg}$$
$$\text{Effectiveness} = \frac{283.4}{283.4 + 73.27} = 0.7946 = \mathbf{79.46}\%$$

76. A heat exchanger was installed purposely to cool 0.50 kg of gas per second. Molecular weight is 32 and k = 1.32. The gas is cooled from 150°C to 80°C. Water is available at the rate of 0.30 kg/s and at a temperature of 15°C. Calculate the exit temperature of the water in °C.

A. 44.86 B. 42.86 C. 46.45 D. 40.34

Solution:

$$R = \frac{8.314}{32} = 0.2598\ \text{kJ/kg-K}$$
$$C_p = \frac{kR}{k-1} = \frac{1.32(0.2598)}{1.32-1} = 1.0717\ \text{kJ/kg-K}$$

By heat balance:

$$Q_{gain} = Q_{loss}$$
$$\dot{m}_w c_p (t_b - t_a) = \dot{m}_g c_{pg} (t_2 - t_1)$$
$$0.3(4.187)(t_b - 15) = 0.5(1.0717)(150 - 80)$$
$$t_b = \mathbf{44.86}°\text{C}$$

77. A 350 mm x 450 mm steam engine running at 280 rpm has a clearance steam condition of 2 MPa and 230°C and exits at 0.1 MPa. The steam consumption is 2000 kg/hr and mechanical efficiency is 85%. If indicated mean effective pressure is 600 kPa, determine brake thermal efficiency.

@ 2 MPa and 230°C:	h_1 = 2849.6 kJ/kg	s_1 = 6.4423 kJ/kg-K	
@ 0.1 MPa:	s_f = 1.3026 kJ/kg-K	h_f = 417.46kJ/kg	s_{fg} = 6.0568 kJ/kg-K
	h_{fg} = 2258 kJ/kg	h_{f2} = 417.46 kJ/kg	

A. 23.34% B. 15.25% C. 14.16% D. 27.34%

Solution:

$$BP = PLANck$$

$$= 600 \text{ kPa}(0.45 \text{ m})\left[\left(\frac{\pi}{4}\right)(0.35)^2\right](280 \text{ rpm})\left(\frac{1 \text{ min}}{60 \text{ s}}\right)(2)(1)(0.85)$$
$$= 206.08 \text{ kW}$$
$$\text{eff} = \frac{\text{BP}}{\dot{m}_S(h_1-h_2)} = \frac{206.08}{2000\left(\frac{1}{3600}\right)(2849.6-417.46)} = 0.1525 = \mathbf{15.25\%}$$

78. A steam turbine receives 5,000 kg/hr of steam at 5 MPa and 400°C and velocity of 30 m/s. It leaves the turbine at 0.006 MPa and 85% quality and velocity of 15 m/s. Radiation loss is 10,000 kJ/hr. Find the kW developed.

@5 MPa and 400°C:	h_1 = 3195.7 kJ/kg	s_1 = 6.6459 kJ/kg-K
@ 0.006 Mpa:	h_f = 151.53 kJ/kg	h_{fg} = 2415.9 kJ/kg

A. 1273.29 B. 2173.29 C. 1373.60 D. 7231.29

Solution:

$$h_2 = h_f + xh_{fg} = 151.53 + 0.85(2415.9) = 2205.045 \text{ kJ/kg}$$
$$\dot{KE}_1 = \frac{1}{2}\dot{m}V^2 = \frac{1}{2}\left(\frac{5{,}000}{3600}\right)(30)^2 = 625 \text{ W} = 0.625 \text{ kW}$$
$$\dot{KE}_2 = \frac{1}{2}\dot{m}V^2 = \frac{1}{2}\left(\frac{5{,}000}{3600}\right)(15)^2 = 156.25 \text{ W} = 0.15625 \text{ kW}$$

By energy balance:

$$\dot{KE}_1 + \dot{m}h_1 = \dot{KE}_2 + \dot{m}h_2 + \dot{Q} + \dot{W}$$
$$\dot{W} = \left(\dot{KE}_1 - \dot{KE}_2\right) + \dot{m}(h_1 - h_2) - \dot{Q}$$
$$= (0.625 - 0.156) + \frac{5{,}000}{3600}(3195.7 - 2205.045) - \frac{10{,}000}{3600}$$
$$= \mathbf{1373.60} \text{ kW}$$

79. A steam turbine with 85% stage efficiency receives steam at 7 MPa and 550°C and exhausts at 20 kPa. Determine the turbine work.

@ 7 MPa and 550°C:	h_1 = 3530.9 kJ/kg	s_1 = 6.9486 kJ/kg-K
@ 20 kPa (0.020 MPa):	s_f = 0.8320 kJ/kg-K	h_f = 251.40 kJ/kg
	s_{fg} = 7.0766 kJ/kg-K	h_{fg} = 2358.3 kJ/kg

A. 1,117 kJ/kg B. 1,132 kJ/kg C. 1,123.34 kJ/kg D. 1,054.95 kJ/kg

Solution:

$$s_1 = s_2 = s_f + xs_{fg}$$
$$6.9486 = 0.8320 + x(7.70766)$$
$$x = 0.8643$$
$$h_2 = 251.40 + 0.8643(2358.3) = 2289.78 \text{ kJ/kg}$$
$$\eta_{ST} = \frac{h_1 - h_{2_s}}{h_1 - h_2}$$
$$0.85 = \frac{3530.9 - h_{2_s}}{3530.9 - 2289.78}$$
$$h_{2_s} = 2475.95 \text{ kJ/kg}$$
$$W_T = h_1 - h_{2_s} = 3530.9 - 2475.95 = \mathbf{1{,}054.95 \text{ kJ/kg}}$$

80. A steam turbine with 80% stage efficiency receives steam at 7 MPa and 550°C and exhausts at 20 kPa. Determine the quality at exhaust.

@ 7 MPa and 550°C: h_1 = 3530.9 kJ/kg s_1 = 6.9486 kJ/kg-K

@ 20 kPa (0.020 MPa): s_f = 0.8320 kJ/kg-K h_f = 251.40 kJ/kg

s_{fg} = 7.0766 kJ/kg-K h_{fg} = 2358.3 kJ/kg

A. 96.96% B. 76.34% C. 82.34% D. 91.69%

Solution:

$$s_1 = s_2 = s_f + xs_{fg}$$
$$6.9486 = 0.8320 + x(7.0766)$$
$$x = 0.8643$$
$$h_2 = 251.40 + 0.8643(2358.3) = 2289.78\ \text{kJ/kg}$$
$$\eta_{ST} = \frac{h_1 - h_{2_s}}{h_1 - h_2}$$
$$0.80 = \frac{3530.9 - h_{2_s}}{3530.9 - 2289.78}$$
$$h_{2_s} = 2538.004\ \text{kJ/kg}$$
$$h_{2_s} = h_f + xh_{fg}$$
$$2538.004 = 251.40 + x(2358.3)$$
$$x = 0.9696 = \mathbf{96.96\%}$$

81. An 18,000 kW geothermal plant has a generator efficiency of 90% and 80% respectively. If the quality after throttling is 20% and each well discharges 400,000 kg/hr, determine the number of wells required to produce if the change of enthalpy at entrance and exit of turbine is 500 kJ/kg.

A. 4 wells B. 2 wells C. 6 wells D. 8 wells

Solution:

$$\dot{W}_T = \dot{m}_s(h_3 - h_4)$$
$$\frac{18{,}000}{0.9(0.8)} = \dot{m}_s(500)$$
$$\dot{m}_s = 44.44\ \text{kg/s} = 160{,}000\ \text{kg/hr}$$
$$160{,}000 = 0.20\dot{m}_g$$
$$\dot{m}_g = 800{,}00\ \text{kg/hr}$$
$$\text{No. of wells} = \frac{800{,}000}{400{,}000} = \mathbf{2\ wells}$$

82. A liquid dominated geothermal plant with a single flash separator receives water at 204°C. The separator pressure is 1.04 MPa. A direct contact condenser operates at 0.034 MPa. The turbine has a polytropic efficiency of 0.75. For cycle output of 60 MW, what is the mass flow rate of the well water in kg/s?

@ 204°C: h_f = 870.51 kJ/kg

@ 1.04 MPa: h_f = 770.38 kJ/kg h_{fg} = 2009.2 kJ/kg h_g = 2779.6 kJ/kg

s_g = 6.5729 kJ/kg-K

@ 0.034 MPa: h_f = 301.40 kJ/kg h_{fg} = 2328.8 kJ/kg s_f = 0.09793 kJ/kg-K

s_{fg} = 6.7463 kJ/kg-K

A. 2,933 B. 2,100 C. 1,860 D. 2,444

Solution:

$$h_3 = h_g \text{ @ } 1.04 \text{ MPa} = 2779.6 \text{ kJ/kg}$$

Solving for h_4:

$$s_g = s_4 = s_f + x_4 s_{fg}$$
$$6.5729 = 0.9793 + x_4(6.7463)$$
$$x_4 = 0.829$$
$$h_4 = 301.4 + 0.829(2328.8) = 2232.3 \text{ kJ/kg}$$
$$\dot{W}_T = \dot{m}_s(h_3 - h_4)\eta$$
$$60{,}000 = \dot{m}_s(2279.6 - 2232.3)(0.75)$$
$$\dot{m}_s = 146.17 \text{ kg/s}$$

Solving for x_2: $(h_1 = h_2)$

$$h_1 = h_2 = h_f + x_2 h_{fg}$$
$$870.51 = 770.38 + x_2(2009.2)$$
$$x_2 = 0.049836$$
$$\dot{m}_s = x_2 \dot{m}_g$$
$$146.17 = 0.049836\dot{m}_g$$
$$\dot{m}_g = \mathbf{2,933} \text{ kg/s}$$

83. An engine-generator rated 9000 kVA at 80% power factor, 3 phase, 4160 V has an efficiency of 90%. If the overall plant efficiency is 28%, what is the heat generated by the fuel?

A. 18,800 kW B. 28,800 kW C. 7,500 kW D. 25,714 kW

Solution:

$$\text{Gen. Output} = \text{pf} \times \text{KVA} = 0.8 \times 9000 = 7200 \text{ kW}$$
$$e_{overall} = \frac{\text{Gen. Output}}{\dot{Q}_g}$$
$$0.28 = \frac{7200}{\dot{Q}_g}$$
$$\dot{Q}_g = \mathbf{25,714 \text{ kW}}$$

84. The indicated thermal efficiency of a two stroke diesel engine is 60%. If friction power is 15% of heat generated, determine the brake thermal efficiency of the engine.

A. 43% B. 45% C. 36% D. 37%

Solution:

$$e_i = \frac{P_{in}}{Q_h}$$

$$60 = P_{in}\dot{Q}_h$$
$$BP = P_{in} - P_f = 0.60\dot{Q}_h - 0.15\dot{Q}_h = 0.45\dot{Q}_h$$
$$e_b = \frac{BP}{\dot{Q}_h} = \frac{0.45\dot{Q}_h}{\dot{Q}_h} = \mathbf{45\%}$$

85. A 305 mm x 457 mm four stroke single acting diesel engine is rated at 150 kW at 260 rpm. Fuel consumption at rated load is 0.56 kg/kW-hr with a heating value of 43,912 kJ/kg. Calculate the break thermal efficiency.

A. 10.53% B. 27.45% C. 14.64% D. 18.23%

Solution:

$$\dot{m}_f = 0.56\frac{\text{kg}}{\text{kW-hr}} \times 150\text{ kW} = 84\frac{\text{kg}}{\text{hr}} = 0.0233\text{ kg/s}$$
$$\text{Brake thermal efficiency} = \frac{\text{Brake Power}}{m_f Q_h} = \frac{150}{0.0233\,(43{,}912)} = \mathbf{14.64\%}$$

86. A waste heat recovery boiler produces 4.8 MPa (dry saturated) steam from 104°C feedwater. The boiler receives energy from 7 kg/s of 954°C dry air. After passing through a waste heat boiler, the temperature of the air has been reduced to 343°C. How much steam in kg is produced per second? Note: @ 4.80 MPa dry saturated, h = 2796 kJ/kg.

A. 1.30 B. 0.92 C. 1.81 D. 3.43

Solution:

$$h_f = \text{approximate enthalpy of feedwater}$$
$$h_f = c_p t = 4.187(104) = 435.45\text{ kJ/kg}$$
$$\text{Heat loss} = \text{Heat gain}$$
$$\dot{m}_g c_p(t_1 - t_2) = \dot{m}_s(h_s - h_f)$$
$$7(1.0)(954 - 343) = \dot{m}_s(2796.0 - 435.45)$$
$$\dot{m}_s = \mathbf{1.81}\text{ kg/s}$$

87. A diesel electric power plant supplies energy for Meralco. During a 24-hour period, the plant consumed 240 gallons of fuel at 28°C and produced 3930 kW-hr. Industrial fuel used is 28°API and was purchased at P30 per liter at 15.6°C. What is the cost of fuel to produce one kW-hr?

A. P6.87 B. P1.10 C. P41.07 D. P5.00

Solution:

$$SG_{15.6°C} = \frac{141.5}{131.5+28} = 0.887$$
$$\text{Density @ 15.6°C} = 0.887\left(1\frac{\text{kg}}{\text{li}}\right) = 0.887\text{ kg/li}$$
$$SG_{28°C} = 0.887[1 - 0.0007(t - 15.6)] = 0.879$$
$$\text{Density @ 28°C} = 0.879\left(1\frac{\text{kg}}{\text{li}}\right) = 0.879\text{ kg/li}$$

$$\frac{V_{28°C}}{V_{15.6°C}} = \frac{SG_{15.6°C}}{SG_{28°C}}$$

$$\frac{240}{V_{15.6°C}} = \frac{0.887}{0.879}$$

$$V_{15.6°C} = 237.835 \text{ gallons} \times 3.7854 \frac{\text{li}}{\text{gal}} = 900.21 \text{ li}$$

$$\text{Cost} = \frac{30(900.21)}{3930} = \mathbf{P6.87}/\text{kW-hr}$$

88. In a gas unit, air enters the combustion chamber at 550 kPa, 227°C and 43 m/s. The products of combustion leave the combustor at 511 kPa, 1004°C and 180 m/s. Liquid fuel enters with a heating value of 43,000 kJ/kg. For fuel-air ratio of 0.0229, what is the combustor efficiency in percent?

A. 70.38% B. 79.38% C. 75.38% D. 82.38%

Solution:

$$\text{Heat supplied by fuel} = m_f Q_h = 0.0229(43{,}000) = 984.7 \text{ kJ/kg}_{air}$$

$$Q = \text{heat absorbed by fuel}$$

$$\frac{Q}{m} = c_p(T_2 - T_1) + \frac{1}{2}\frac{V_2^2 - V_1^2}{1000} = 1.0(1004 - 277) + \frac{1}{2}\left(\frac{180^2 - 43^2}{1000}\right)$$

$$= 742.28 \text{ kJ/kg}_{air}$$

$$\text{Combustor Efficiency} = \frac{742.28}{984.7} = 0.7538 = \mathbf{75.38\%}$$

89. The specific speed of turbine is 85 rpm and running at 450 rpm. If the head is 20 m and generator efficiency is 90%, what is the maximum power delivered by the generator?

A. 450.51 kW B. 354.52 kW C. 650.53 kW D. 835.57 kW

Solution:

$$N_s = \frac{N\sqrt{HP}}{h^{5/4}}$$

$$85 = \frac{450\sqrt{HP}}{(20 \times 3.281)^{5/4}}$$

$$HP = 1244.52$$

$$\text{Generator Output} = 1244.52 \times 0.746(0.9) = \mathbf{835.57\ kW}$$

90. In Francis turbine, the pressure gage leading to the turbine casing reads 380 kPa. The velocity of water entering the turbine is 8 m/s. If net head of the turbine is 45 m, find the distance from the center of the spiral casing to the tailrace.

A. 3.0 m B. 3.5 m C. 4.0 m D. 4.5 m

Solution:

$$h = \frac{P}{\gamma} + \frac{V^2}{2g} + z$$

$$45 = \frac{380}{9.81} + \frac{8^2}{2(9.81)} + z$$

$z = \mathbf{3.0\ m}$

91. A turbine has a mechanical efficiency of 93%, volumetric efficiency of 95% and total efficiency of 82%. If the effective head is 40 m, find the total head.

A. 48.72 m B. 40.72 m C. 36.22 m D. 34.72 m

Solution:

$$e_T = e_m e_h e_v$$
$$0.8 = 0.93e_h(0.95)$$
$$e_h = 0.9055$$
$$\text{Total head} = he_h = 40(0.9055) = \mathbf{36.22\ m}$$

92. A Pelton type turbine has 25 m head friction loss of 4.5 m. The coefficient of friction head loss (Morse) is 0.00093 and penstock length of 80 m. What is the penstock diameter?

A. 1,355.73 mm B. 3476.12 mm C. 6771.23 mm D. 1686.73 mm

Solution:

$$h = 25 - 4.5 = 20.5\ \text{m}$$
$$V = \sqrt{2gh} = \sqrt{2(9.81)(20.5)} = 20.055\ \text{m/s}$$
$$h_L = \frac{2fLV^2}{gD}$$
$$4.5 = \frac{2(0.00093)(80)(20.055)^2}{9.81D}$$
$$D = 1.35573\ \text{m} = \mathbf{1{,}355.73\ mm}$$

93. In a 9,000 kW hydro-electric plant, the overall efficiency is 88% and the actual power received by the costumer is 110,000 kW-hrs for that day. What is the secondary power that this plant could deliver during the entire day?

A. 58,960 kW-hrs B. 80,080 kW-hrs C. 65,960 kW-hrs D. 70,960 kW-hrs

Solution:

$$\text{Plant Capacity} = 9{,}000(0.88)(24) = 190{,}080\ \text{kW-hrs}$$
$$\text{Secondary Power} = 190{,}080 - 110{,}000 = \mathbf{80{,}080\ kW\text{-}hrs}$$

94. A Pelton type turbine was installed 30 m below the head gate of the penstock. The head loss due to friction is 12 percent of the given elevation. The length of the penstock is 100 m and the coefficient of friction is 0.00093. Determine the power output in kW. (Use Morse equation).

A. 22,273 B. 23,234 C. 32,345 D. 34,452

Solution:

$$h_L = 0.12(30) = 3.6\ \text{m}$$
$$h = 30 - 3.6 = 26.40\ \text{m}$$

$$V = \sqrt{2gh} = \sqrt{2(9.81)(26.4)} = 22.759 \text{ m/s}$$
$$h_L = \frac{2fLV^2}{gD}$$
$$3.6 = \frac{2(0.00093)(100)(22.759)}{9.81D}$$
$$D = 2.728 \text{ m}$$
$$Q = AV = \frac{\pi}{4}(2.728)^2(22.759) = 133.03 \text{ m}^3/\text{s}$$
$$\text{Power} = \gamma Q h = 9.81(133.03)(26.4) = \mathbf{34,452} \text{ kW}$$

95. Water flows steadily with a velocity of 3.05 m/s in a horizontal pipe having a diameter of 25.24 cm. At one section of the pipe, the temperature and pressure of the water are 21°C and 689.3 kPa respectively. At a distance of 304.8 m downstream, the pressure is 516.9 kPa. What is the friction factor?

A. 0.134 B. 0.0050 C. 0.0307 D. 0.641

Solution:

$$h_L = \frac{P_d - P_s}{\gamma} = \frac{689.3 - 516.9}{9.81} = 17.574 \text{ m}$$
$$h_L = \frac{fLV^2}{2gD}$$
$$17.574 = \frac{f(304.8)(3.05)^2}{2(9.81)(0.2524)}$$
$$f = \mathbf{0.0307}$$

96. A hydro-electric plant having 30 sq. km reservoir area and 100 m head is used to generate power. The energy utilized by the consumers whose load is connected to the power plant during a five-hour period is 13.5x10^6 kWh. The overall generation efficiency is 75%. Find the fall in the height of water in the reservoir after the 5-hour period.

A. 5.13 m B. 1.32 m C. 3.21 m D. 2.20 m

Solution:

$$\text{Energy Output} = \text{Power} \times \text{time} = \eta\gamma Q h \times \text{time}$$
$$13.5 \times 10^6 = 0.75(9.81)Q(100)(5)$$
$$Q = 3669.725 \text{ m}^3/\text{s}$$
$$\text{Volume after 5 hrs} = 3669.725(5 \times 3600) = 66{,}055{,}050 \text{ m}^3$$
$$66{,}055{,}050 = 30 \times 10^6 h$$
$$h = \mathbf{2.20 \text{ m}}$$

97. The gas density of chimney is 0.75 kg /m^3 and air density of 1.15 kg /m^3. Find the driving pressure if the height of the chimney is 63.71 m.

A. 0.15 kPa B. 0.25 kPa C. 0.35 kPa D. 0.45 kPa

Solution:

$$h_w = H(\rho_a - \rho_d) = 63.71(1.15 - 0.75)(0.00981) = \mathbf{0.25\ kPa}$$

98. The actual velocity of gas entering in a chimney is 8 m/s. The gas temperature is 25°C with a gas constant of 0.287 kJ/kg-K. Determine the gas pressure for a mass of a gas is 50,000 kg/hr and chimney diameter of 1.39 m.

A. 95 kPa B. 98 kPa C. 101 kPa D. 92 kPa

Solution:

$$\dot{V}_g = AV = \frac{\pi}{4}(1.39)^2(8) = 12.139\ m^3/s$$

$$P_g\dot{V}_g = \dot{m}_g R_g T_g$$

$$P(12.139) = \frac{50{,}000}{3600}(0.278)(25 + 273)$$

$$P = 97.85 \approx \mathbf{98\ kPa}$$

99. A steam generator with economizer and air heater has an overall draft loss of 25.78 cm of water. If the stack gases are at 177°C and if the atmosphere is at 101.3 kPa and 26°C, what theoretical height of stack in meters is needed when no draft fan is used? Assume that the gas constant for the flue gases is the same as that for air.

A. 611.10 B. 631.10 C. 651.10 D. 671.10

Solution:

$$\rho_a = \frac{P}{RT} = \frac{101.325}{0.287(26+273)} = 1.180\ kg/m^3$$

$$\rho_g = \frac{101.3}{0.287(177+273)} = 0.784\ kg/m^3$$

$$\text{Draft} = 0.2578(1000) = 257.80\ kg/m^2$$

$$\text{Draft} = H(\rho_a - \rho_g)$$

$$257.80 = H(1.18 - 0.784)$$

$$H = \mathbf{651.10}\ m$$

100. A foundation measures 12 ft x 14 ft x 16 ft. Find the number of sacks of cement needed for a 1:2:4 mixture.

A. 302 B. 404 C. 356 D. 598

Solution:

$$V = 12 \times 14 \times 16 = 2{,}688\ ft^3\left(\frac{1\ yd^3}{3^3\ ft^3}\right) = 99.55\ yd^3 \text{ of concrete}$$

For every 1 yd^3 concrete, it needs 6 sacks of cement.

$$\therefore \text{No. of sacks} = 6(99.55) = 597.33 \text{ sacks or } \mathbf{598} \text{ sacks}$$

101. A rectangular foundation cross-section has a bed plate dimension of 8 ft x 10 ft. The uniform clearance on each side is 1 ft. The height of the foundation is 4.5 ft. If the weight of the

steel bar reinforcements needed is ½% of weight of foundation, find the weight of the steel bars. Use concrete density of 2400 kg/m^3.

A. 173.47 kg B. 183.47 kg C. 163.47 kg D. 153.47 kg

Solution:

$$A = (8+2)(10+2) = 120\ \text{m}^2$$
$$V = Ah = 120(4.5) = 540\ \text{ft}^3 = 15.29\ \text{m}^3$$
$$m = \rho V = 2400(15.29) = 36{,}693.26\ \text{kg}$$
$$\text{Weight of steel bars} = \tfrac{1}{2}\%m = 0.005(36{,}693.26) = \mathbf{183.47\ kg}$$

102. A steam pipe having a surface temperature of 250°C passes through a room where the temperature is 27°C. The outside diameter of the pipe is 100 mm and emissivity factor is 0.8. Calculate the radiated heat loss for 3 m pipe length.

A. 1434.47 W B. 3746.35 W C. 2851.82 W D. 3546.45 W

Solution:

$$A_o = \pi DL = \pi(0.10)(3) = 0.9425\ \text{m}^2$$

Solving for heat due to radiation:

$$T_1 = 250 + 273 = 523\ \text{K}$$
$$T_2 = 27 + 273 = 300\ \text{K}$$
$$Q_R = \varepsilon\sigma A_o(T_1^4 - T_2^4)$$
$$= 0.8\left(5.67 \times 10^{-8}\frac{\text{W}}{\text{m}^2\text{-K}^4}\right)(0.9425\ \text{m}^2)(523^2 - 300^2)\text{K}$$
$$= 2852.32 \approx \mathbf{2851.82\ W}$$

103. Brine enters a circulating brine cooler at the rate of 60 m^3/hr at -8°C and leaves at -18°C. Specific heat of brine is 1.072 kJ/kg-K and a specific gravity of 1.12. Determine the tons of refrigeration.

A. 53.5 TR B. 65.3 TR C. 33.5 TR D. 56.9 TR

Solution:

$$\text{Density of brine} = 1.12\left(1000\frac{\text{kg}}{\text{m}^3}\right) = 1120\ \text{kg/m}^3$$
$$\dot{m} = \frac{1120(60)}{3600} = 18.67\ \text{kg/s}$$
$$\dot{Q} = \dot{m}c_p\Delta t = 18.67(1.072)(-8+18) = 200.11\ \text{kW}$$
$$\text{TR} = \frac{200.11}{3.516} = \mathbf{56.9\ TR}$$

104. A turbo-charged, 16 cylinder, Vee-type diesel engine has an air consumption of 3,000 kg/hr per cylinder at rated load and speed. This air is drawn in through a filter by a centrifugal compressor directly connected to the exhaust gas turbine. The temperature of the air from the

compressor is 135°C and a counter flow air cooler reduces the air temperature to 45°C before it goes to the engine suction header. Cooling water enters the air cooler at 30°C and leaves at 40°C. Calculate the log mean temperature difference.

A. 47.23°C B. 87.82°C C. 43.34°C D. 65.24°C

Solution:

$$\Delta t_A = 45 - 30 = 15°C$$
$$\Delta t_B = 135 - 40 = 95°C$$
$$\Delta t_{mean} = \frac{\Delta t_A - \Delta t_B}{\ln\frac{\Delta t_A}{\Delta t_B}} = \frac{95-15}{\ln\frac{95}{15}} = \mathbf{43.34°C}$$

105. Water is flowing in a pipe with radius of 30 cm at a velocity of 5 m/s at the temperature in the pipe. The density and viscosity of the water are as follows: density = 997.9 kg/s viscosity = 1.131 Pa-s. What is the Reynolds number for this situation?

A. 2647 B. 96.2 C. 3100 D. 1140

Solution:

$$N_R = \frac{DV_o}{\nu}$$
$$D = 2(0.30) = 0.60 \text{ m}$$
$$V_o = 5 \text{ m/s}$$
$$\nu = \frac{1.131}{997.9} = 0.0011334 \text{ m}^2/\text{s}$$
$$N_R = \frac{0.60\,(5)}{0.0011334} = \mathbf{2647}$$

106. Compute the amount of condensate formed during a 10 minute warm-up of 180 meter pipe conveys the saturated steam with enthalpy of vaporization, h_{fg} = 1947.8 kJ/kg. The minimum external temperature of pipe is 2°C. The final temperature of pipe is 195°C. The specific heat of pipe material is 0.6 kJ/kg-°C. The specific weight is 28 kg/m.

A. 240.69 kg B. 982.45 kg C. 299.64 kg D. 423.45 kg

Solution:

$$m = \text{mass of pipe} = 28(180) = 5{,}040 \text{ kg}$$
$$\text{Heat loss by steam} = \text{Heat loss from pipe}$$
$$m_s(h_g - h_f) = m_p c_p (T_2 - T_1)$$
$$m_s(1947.8) = 5040(0.6)(195-2)$$
$$m_s = \mathbf{299.64\ kg}$$

107. The discharge pressure of an air compressor is 5 times the suction pressure. If volume flow at suction is 0.1 m^3/s, what is the suction pressure if compressor work is 19.57 kW (use n = 1.35).

A. 97 kPa B. 98 kPa C. 99 kPa D. 100 kPa

Solution:

$$\dot{W} = \frac{nP_1V_1}{n-1}\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$$

$$19.57 = \frac{1.35P_1(0.1)}{1.35-1}\left[5^{\frac{1.35-1}{1.35}} - 1\right]$$

$$P_1 = \mathbf{98\ kPa}$$

108. The initial condition of air in an air compressor is 98 kPa and 27 °C and discharges air at 450 kPa. The bore and stroke are 355 mm and 381 mm, respectively with percent clearance of 8% running at 300 rpm. Find the volume of air at suction.

A. 541.62 m^3/hr B. 551.62 m^3/hr C. 561.62 m^3/hr D. 571.62 m^3/hr

Solution:

$$e = 1 + c - c\left(\frac{P_2}{P_1}\right)^{\frac{1}{n}} = 1 + 0.08 - 0.08\left(\frac{450}{98}\right)^{\frac{1}{1.4}} = 0.842$$

$$V_D = \frac{\pi}{4}D^2LN = \frac{\pi}{4}(0.355)^2(0.381)\left(\frac{300}{60}\right)0.1885\ m^3/s$$

$$V_1 = 0.1885(0.842) = 0.15878\ m^3/s = \mathbf{571.62\ m^3/hr}$$

109. An air compressor has a suction volume of 0.35 m^3/s at 97 kPa and discharges at 650 kPa. How much power is saved by the compressor if there are two stages?

A. 18.27 kW B. 16.54 kW C. 13.86 kW D. 11.58 kW

Solution:

$$\dot{W}_1 = \frac{nP_1V_1}{n-1}\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right] = \frac{1.4(97)(0.35)}{1.4-1}\left[\left(\frac{650}{97}\right)^{\frac{1.4-1}{1.4}} - 1\right] = 85.79\ kW$$

For two stages:

$$P_x = \sqrt{P_1P_2} = \sqrt{97(650)} = 251.097\ kPa$$

$$\dot{W}_2 = \frac{2nP_1V_1}{n-1}\left[\left(\frac{P_x}{P_1}\right)^{\frac{n-1}{n}} - 1\right] = \frac{2(1.4)(97)(0.35)}{1.4-1}\left[\left(\frac{251.097}{97}\right)^{\frac{1.4-1}{1.4}} - 1\right]$$

$$= 74.208\ kW$$

$$\text{Power Saved} = 85.79 - 74.208 = \mathbf{11.58\ kW}$$

110. A two stage air intercooler has an intercooler pressure of 4 kg/cm^2. What is the discharge pressure if suction pressure is 1 kg/cm^2?

A. 3 kg/cm^2 B. 9 kg/cm^2 C. 12 kg/cm^2 D. 16 kg/cm^2

Solution:

$$P_x = \sqrt{P_1P_2}$$

$$P_x^2 = P_1P_2$$

$$4^2 = 1P_2$$
$$P_2 = \mathbf{16\ kg/cm^2}$$

111. A two-stage air compressor at 100 kPa and 22°C discharges to 750 kPa. If the intercooler intake is 105°C, determine the value of n.

A. 1.400 B. 1.326 C. 1.345 D. 1.288

Solution:

$$P_x = \sqrt{100(750)} = 273.86\ \text{kPa}$$
$$\frac{T_x}{T_1} = \left(\frac{P_x}{P_1}\right)^{\frac{n-1}{n}}$$
$$\frac{105+273}{22+273} = \left(\frac{273.86}{100}\right)^{\frac{n-1}{n}}$$
$$1.281 = 2.6268^{\frac{n-1}{n}}$$
$$n = \mathbf{1.326}$$

112. A single acting compressor has a volumetric efficiency of 89%, operates at 500 rpm. It takes in air at 100 kPa and 30°C and discharges it at 600 kPa. The air handled is 8 m^3/min measured at discharged condition. If compression is isentropic, find the effective mean pressure in kPa.

A. 233.34 B. 973.17 C. 198.34 D. 204.82

Solution:

$$P_1V_1^k = P_2V_2^k$$
$$100V_1^{1.4} = 600(8)^{1.4}$$
$$V_1 = 28.768\ \text{m}^3/\text{min}$$
$$V_D = \frac{28.768}{0.89} = 32.32\ \text{m}^3/\text{min}$$
$$\dot{W} = \frac{nP_1V_1}{n-1}\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right] = \frac{1.4(100)(32.32)}{1.4-1}\left[\left(\frac{600}{100}\right)^{\frac{1.4-1}{1.4}} - 1\right]$$
$$= 7562.19\ \text{kJ/min}$$
$$\dot{W} = P_m \times V_D$$
$$7562.19 = P_m \times 32.2$$
$$P_m = \mathbf{233.34}\ \text{kPa}$$

113. A water-jacketed air compressor handles 0.343 m^3/s of air entering at 96.5 kPa and 21°C and leaving at 480 kPa and 132°C; 10.9 kg/hr of cooling water enters the jacket at 15°C and leaves at 21°C. Determine the compressor brake power.

A. 23.163 kW B. 62.65 kW C. 34.44 kW D. 19.33 kW

Solution:

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}$$

$$\frac{132+273}{21+273} = \left(\frac{480}{96.5}\right)^{\frac{n-1}{n}}$$

$$n = 1.249$$

$$\dot{W} = \frac{nP_1V_1}{n-1}\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right] = \frac{1.249(96.5)(0.343)}{1.249-1}\left[\left(\frac{480}{96.5}\right)^{\frac{1.249-1}{1.249}} - 1\right] = 82.57 \text{ kW}$$

$$\dot{Q} = \text{heat loss} = \dot{m}c_p(T_2 - T_1) = \frac{10.9}{3600}(4.187)(21-15) = 0.076 \text{ kW}$$

$$\text{Brake power} = \dot{W} + \dot{Q} = 62.57 + 0.076 = \mathbf{62.65\ kW}$$

114. A double suction centrifugal pump delivers 20 ft^3/s of water at a head of 12 m and running at 650 rpm. What is the specific speed of the pump?

A. 5014.12 rpm B. 6453.12 rpm C. 2770.73 rpm D. 9968.73 rpm

Solution:

$$N_s = \frac{N\sqrt{Q}}{h^{3/4}}$$

$$Q = \frac{20}{2}\frac{ft^3}{s} \times \frac{7.481 \text{ gal}}{1 \text{ ft}^3} \times \frac{60 \text{ s}}{1 \text{ min}} = 4{,}488.6 \text{ gal/min}$$

$$h = 12 \times 3.281 = 39.37 \text{ ft}$$

$$N_s = \frac{650\sqrt{4{,}488.6}}{39.37^{3/4}} = \mathbf{2770.73\ rpm}$$

115. Determine the number of stages needed for a centrifugal pump if it is used to deliver 400 gal/min of water and pump power of 15 hp. Each impeller develops a head of 30 ft.

A. 6 B. 4 C. 5 D. 7

Solution:

$$\dot{W}_p = \gamma Q h$$

$$15 \times 0.746 = 9.81\left(400\frac{\text{gal}}{\text{min}} \times \frac{0.00785 \text{ m}^3}{1 \text{ gal}} \times \frac{1 \text{ min}}{60 \text{ s}}\right)h$$

$$h = 45.20 \text{ m} \times \frac{1 \text{ ft}}{0.3048 \text{ m}} = 148.294 \text{ ft}$$

$$\text{Number of stages} = \frac{148.294}{30} = 4.94 \approx \mathbf{5}$$

116. The suction pressure of a pump reads 3 in. of mercury vacuum and discharge pressure reads 140 psi is used to deliver 120 gpm of water with specific volume of 0.0163 ft^3/lb. Determine the pump work.

A. 4.6 kW B. 5.7 kW C. 7.4 kW D. 8.4 kW

Solution:

$$P_1 = \text{-3 in Hg} \times \frac{101.325}{29.92} = \text{-10.16 kPa}$$

$$P_2 = 140\text{ psi} \times \frac{101.325}{14.7} = 965\text{ kPa}$$

$$\gamma = \frac{g}{\upsilon} = \frac{\frac{9.81}{62.4}}{0.0163} = 9.645\text{ kN/m}^3$$

$$h = \frac{P_2 - P_1}{\text{-}\gamma} = \frac{965 + 10.16}{9.645} = 101.105\text{ m}$$

$$Q = 120\,\frac{\text{gal}}{\text{min}} \times \frac{3.7854\text{ li}}{1\text{ gal}} \times \frac{1\text{ m}^3}{1000\text{ li}} \times \frac{1\text{ min}}{60\text{ s}} = 0.00757\text{ m}^3/\text{s}$$

$$P = \gamma Q h = 9.645(0.00757)(101.105) = 7.38 \approx \mathbf{7.4\ kW}$$

117. A submersible pump delivers 350 gpm of water to a height of 5 ft from the ground. The pump where installed 150 ft below the ground level and a drawdown of 8 ft during the operation. If water level is 25 ft above the pump, determine the pump power.

A. 7.13 kW B. 4.86 kW C. 7.24 kW D. 9.27 kW

Solution:

$$h = 5 + 150 - (25 - 8) = \frac{138}{3.281} = 42.06\text{ m}$$

$$Q = 350\,\frac{\text{gal}}{\text{min}} \times \frac{0.003785\text{ m}^3}{1\text{ gal}} \times \frac{1\text{ min}}{60\text{ s}} = 0.02246\text{ m}^3/\text{s}$$

$$\dot{W}_p = \gamma Q h = 9.81(0.02246)(42.06) = \mathbf{9.27\ kW}$$

118. A vacuum pump is used to drain a flooded mine shaft of 20°C water. The pump pressure of water at this temperature is 2.34 kPa. The pump is incapable of lifting the water higher than 16 m. What is the atmospheric pressure?

A. 159.30 B. 132.33 C. 196.22 D. 171.9

Solution:

Using Bernoulli's Theorem:

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2$$

$$\frac{P_1}{\gamma} = \frac{P_2}{\gamma} + \frac{V_2^2 - V_1^2}{2g} + (z_2 - z_1)$$

$$\frac{P_1}{9.81} = \frac{2.34}{9.81} + 0 + 16$$

$$P_1 = \mathbf{159.30}\text{ kPa}$$

119. A submersible, multi-stage, centrifugal deep well pump 260 gpm capacity is installed in a well 27 ft below the static water level and running at 3000 rpm. Drawdown when pumping at rated capacity is 10 feet. The pump delivers the water into a 25,000 gallons capacity overhead storage tank. Total discharge head developed by pump, including friction in piping is 243 ft. Calculate the diameter of the impeller of this pump in inches if each impeller diameter developed a head of 38 ft.

A. 3.28 B. 5.33 C. 3.71 D. 6.34

Solution:

$$V = \pi DN$$

$$V = \sqrt{2gh}$$

$$\pi D\left(\frac{3000}{60}\right) = \sqrt{2(32.2)(38)}$$

$$D = 0.315\ \text{ft} \times \frac{12\ \text{in}}{1\ \text{ft}} = 3.708 \approx \mathbf{3.71}\ \text{in}$$

120. A fan draws 1.42 m^3 per second of air at a static pressure of 2.54 cm of water through a duct 300 mm diameter and discharges it through a duct of 275 mm diameter. Determine the static fan efficiency if total fan is 75% and air is measured at 25°C and 760 mm Hg.

A. 50.11% B. 53.69% C. 65.67% D. 45.34%

Solution:

$$P\upsilon_a = RT$$

$$\upsilon_a = \frac{P}{RT} = \frac{101.325}{0.287(25+273)} = 1.18\ \text{kg/m}^3$$

$$h_s = \frac{h_w \rho_w}{\rho_a} = \frac{0.254(1000)}{1.18} = 21.52\ \text{m}$$

$$V_1 = \frac{1.42}{\frac{\pi}{4}(0.3)^2} = 20.09\ \text{m/s}$$

$$V_2 = \frac{1.42}{\frac{\pi}{4}(0.275)^2} = 23.9\ \text{m/s}$$

$$h_v = \frac{23.9^2 - 20.09^2}{2(9.81)} = 8.54\ \text{m}$$

$$h = h_s + h_v = 21.52 + 8.54 = 30.06\ \text{m}$$

$$e_T = \frac{\gamma_a Q h}{Bp}$$

$$0.75 = \frac{1.18 \times 0.00981(1.42)(30.06)}{BP}$$

$$BP = 0.6588\ \text{kW}$$

$$e_s = \frac{\gamma Q h_s}{BP} = \frac{1.18 \times 0.00981(1.42)(21.52)}{0.6588} = 0.5369 = \mathbf{53.69\%}$$

121. A water cooler uses 50 lb/hr of melting ice to cool running water from 80°F to 42°F. Based on the inside coil area, U_i = 110 Btu/hr-ft^2-°F. Find the gpm of water cooled.

A. 0.10 GPM B. 0.21 GPM C. 0.38 GPM D. 0.45 GPM

Solution:

$$\dot{Q} = \dot{m}_i L_f = \dot{m}_w c_{p_w}(T_1 - T_2)$$

$$50(144) = \dot{m}_w(1)(80 - 42)$$

$$\dot{m}_w = 189.474\ \text{lb/hr}$$

$$V = \frac{189.474}{62.4}\left(\frac{7.481}{60}\right) = \mathbf{0.38\ GPM}$$

122. The charge in a Diesel engine consists of 18.34 grams of fuel, with lower heating value of 42,571 kJ/kg, and 409 grams of fuel and products of combustion. At the beginning of compression, T_1 = 60°C. Let r_k = 14. For constant c_p = 1.11 kJ/kg-°C, what should be the cut-off ratio in the corresponding ideal cycle?

A. 2.05 B. 2.34 C. 5.34 D. 2.97

Solution:

$$Q_A = m_f Q_h = 0.01834(42{,}571) = 780.752 \text{ kJ}$$
$$\frac{T_2}{T_1} = r_k^{k-1}$$
$$T_2 = (60 + 273)^{1.4-1} = 956.964 \text{ K}$$
$$m_f + m_g = 409$$
$$m_f + m_a + m_f = 409$$
$$m_a = 409 - 2(18.34) = 372.32 \text{ grams} = 0.37232 \text{ kg}$$
$$Q_A = m_a c_p (T_3 - T_2)$$
$$780.752 = 0.37232(1.11)(T_3 - 956.969)$$
$$T_3 = 2846.146°\text{C}$$
$$r_o = \frac{T_3}{T_2} = \frac{2846.146}{956.969} = \mathbf{2.97}$$

123. The gain of entropy during isothermal nonflow process of 5 lb of air at 60°F is 0.462 Btu/°R. Find the V_1/V_2.

A. 3.85 B. 0.259 C. 1.0 D. 0.296

Solution:

$$\Delta s = mR \ln \frac{V_2}{V_1}$$
$$0.462 = 5\left(\frac{53.33}{778}\right) \ln \frac{V_2}{V_1}$$
$$\frac{V_2}{V_1} = 3.85$$
$$\frac{V_1}{V_2} = \frac{1}{3.85} = \mathbf{0.259}$$

124. An auditorium seating 1500 people is to be maintained at 80°F dry bulb and 60°F wet bulb temperature when outdoor air is at 91°F dry bulb and 75°F wet bulb. Solar heat load is 110,000 Btu/hr and supply air is at 60°F, determine the amount of supply air.

A. 93,229.17 lb/hr B. 83,229.17 lb/hr C. 73,229.17 lb/hr D. 63,229.17 lb/hr

Solution:

$$\text{Sensible heat per person} = 225 \text{ Btu/hr}$$
$$\dot{Q}_s = 225(1500) + 110{,}000 = 447{,}500 \text{ Btu/hr}$$
$$\dot{Q}_s = \dot{m} c_p (t_1 - t_2)$$
$$447{,}500 = \dot{m}(0.24)(80 - 60)$$

$$\dot{m} = \mathbf{93,229.17\ lb/hr}$$

125. In a Brayton cycle that operates between temperature limits of 300 K and 1773 K with k = 1.4, determine the temperature at the end of compression (isentropic) for maximum work of the cycle.

A. 780 K B. 690.5 K C. 730 K D. 350 K

Solution:

For maximum work:

$$T = (300 \times 1773)^{1/2} = \mathbf{730\ K}$$

126. A 35% solution leaves the absorber and 30% solution enters the absorber. The heat removed from the absorber by cooling water is 547.6 Btu and ammonia is superheated by 10°. Find the pound per pound of ammonia gas from the evaporating coils.

A. 11 B. 12 C. 13 D. 14

Solution:

$$n = \frac{\text{lb}}{\text{lb}} \text{ of ammonia gas from the coils} = \frac{1-x_2}{x_1-x_2} - 1 = \frac{1-0.3}{0.35-0.3} - 1 = \mathbf{13}$$

127. A Carnot refrigeration system operates at T_{max}/T_{min} = 1.5. Find the kW per ton of refrigeration.

A. 1.91 B. 2.15 C. 1.76 D. 1.55

Solution:

$$\frac{\dot{W}}{TR} = \frac{3.516}{COP} = \frac{3.516}{\frac{T_{min}}{T_{max}-T_{min}}} = 3.516\left(\frac{T_{max}-T_{min}}{T_{min}}\right) = 3.516\left(\frac{T_{max}}{T_{min}} - 1\right)$$

$$= 3.516(1.5 - 1) = 1.758 \approx \mathbf{1.76}\ \text{kW/TR}$$

128. Assume 8 ft^3 of air at 100 psi and 100°F are compressed isothermally to a volume of 2 ft^3. For each end state of the process, find the bulk modulus.

A. 400 and 100 psi B. 400 and 110 psi C. 400 and 120 psi D. 400 and 130 psi

Solution:

$$BM = \text{bulk modulus} = -V\left(\frac{P_2-P_1}{V_2-V_1}\right)$$

For $V_1 = 8\ ft^3$

$$P_1V_1 = P_2V_2$$

$$8(100) = P_2(2)$$

$$P_2 = 400\ psi$$

$$BM = -8\left(\frac{400-100}{2-8}\right) = \mathbf{400\ psi}$$

For $V_2 = 2\ ft^3$

$$\text{BM} = -2\left(\frac{400-100}{2-8}\right) = \mathbf{100\ psi}$$

129. Predict the pressure of nitrogen gas at T = 200 K and υ = 0.00385 L/g and b = 0.00141 L/g; a = 0.178 L^2-kPa/g^2. Use Van der Waals equation.

A. 15,331 kPa B. 14,331 kPa C. 13,331 kPa D. 12,331 kPa

Solution:

$$P = \frac{RT}{(\upsilon - b)} - \frac{a}{\upsilon^2} = \frac{\frac{8.314}{28}(200)}{0.00385 - 0.00141} - \frac{0.178}{0.00385^2} = \mathbf{12,331\ kPa}$$

130. A Francis turbine is to be operated at a speed of 600 rpm and with discharge of 4 m^3/s. If r_1 = 0.6 m, β = 110°, and the blade height B is 10 cm, what should be the guide vane angle α_1 for nonseparating flow condition at the runner entrance?

A. 14.4° B. 15.4° C. 16.4° D. 17.4°

Solution:

$$\alpha_1 = \cot^{-1}\left(\frac{r_1\omega}{V_{r_1}} + \cot\beta_1\right)$$

$$r_1\omega = 0.6\left(\frac{600}{60}\right)(2\pi) = 37.7\ \text{m/s}$$

$$V_{r_1} = \frac{Q}{2\pi r_1 B} = \frac{4}{2\pi(0.6)(0.1)} = 10.61\ \text{m/s}$$

$$\alpha_1 = \cot^{-1}\left(\frac{37.7}{10.61} + \cot 110°\right) = \mathbf{17.4°}$$

131. The total head of fan is 187 m and has a static pressure of 210 mm of water gage, what is the velocity of air flowing if the density of air is 1.15 kg/m^3?

A. 6.85 m/s B. 3.45 m/s C. 4.39 m/s D. 9.28 m/s

Solution:

$$h_a = 0.21\left(\frac{1000}{1.15}\right) = 182.61\ \text{m}$$

$$187 = 182.61 + h_v$$

$$h_v = 4.39\ \text{m}$$

$$4.39 = \frac{V^2}{2(9.81)}$$

$$V = \mathbf{9.28\ m/s}$$

132. A fan delivers 5.7 m^3/s at a static pressure of 5.08 cm of water when operating at a speed of 400 rpm. The power input required is 2.963 kW. If 7.05 m^3/s are desired in the same fan and installation, find the pressure in cm of water.

A. 7.77 B. 17.14 C. 11.43 D. 5.08

Solution:

$$\frac{Q_1}{Q_2} = \frac{N_1}{N_2}$$
$$\frac{5.7}{7.05} = \frac{400}{N_2}$$
$$N_2 = 494.74 \text{ rpm}$$
$$\frac{h_1}{h_2} = \left(\frac{N_1}{N_2}\right)^2$$
$$\frac{5.08}{h_2} = \left(\frac{400}{494.74}\right)^2$$
$$h_2 = \mathbf{7.77} \text{ cm of water}$$

133. A rigid container is closed at one end and measures 8 in diameter by 12 in long. The container is held vertical and is slowly moved downward until the pressure in the container is 17 psia. What will be the depth of the top of the container from the free water surface?

A. 42.36 in B. 59.29 in C. 63.69 in D. 69.82 in

Solution:

$$P_{atm} = P_{gage} + P_{atm}$$
$$17 = P_{gage} + 14.7$$
$$P_{gage} = 2.30 \text{ psi}$$
$$2.30(144) = 62.4h$$
$$h = 5.3077 \text{ ft} \times 12 = \mathbf{63.69\ in}$$

134. An empty, open can is 30 cm high with a 15 cm diameter. The can, with the open end down, is pushed under water with a density of 1000 kg/m^3. Find the water level in the can when the top of the can is 50 cm below the surface.

A. 17.20 cm B. 2.12 cm C. 4.20 cm D. 5.87 cm

Solution:

$$P_w = \gamma h + 101.325 = 9.81(0.8 - x) + 101.325 = 109.173 - 9.81x$$

Consider the air pressure:

$$P_1V_1 = P_2V_2$$
$$101.325(A \times 0.3) = P_2[A(0.3 - x)]$$
$$P_2 = \frac{30.3795}{0.3 - x}$$
$$P_w = P_2$$
$$109.173 - 9.81x = \frac{30.3795}{0.3 - x}$$
$$9.81x^2 - 112.116x + 2.3705 = 0$$

By quadratic formula:

$$x = 0.02118 \text{ m} = \mathbf{2.12\ cm}$$

135. A cylindrical pipe with water flowing downward at 0.03 m^3/s having top diameter of 0.08, bottom diameter of 0.04 m and height of 1.5 m. Find the pressure inside the pipe.

A. 154.63 kPa B. 197.93 kPa C. 252.44 kPa D. 243.92 kPa

Solution:

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2$$

$$\frac{P_1 - P_2}{\gamma} = \frac{V_2^2 - V_1^2}{2g} + (z_2 - z_1)$$

$$z_1 - z_2 = 1.5 \text{ m}$$

$$z_2 - z_1 = \text{-}1.5 \text{ m}$$

$$V_1 = \frac{0.03}{\frac{\pi}{4}(0.08)^2} = 5.968 \text{ m/s}$$

$$V_2 = \frac{0.03}{\frac{\pi}{4}(0.04)^2} = 23.87 \text{ m/s}$$

$$\frac{P_1 - P_2}{9.81} = \frac{23.87^2 - 5.968^2}{2(9.81)} + (\text{-}1.5)$$

$$P_1 - P_2 = \mathbf{252.44\ kPa}$$

136. Determine the size of pipe which will deliver 8 liters of medium oil ($\nu = 6.10 \times 10^{-6}$ m^2/s) assuming laminar flow conditions.

A. 622 mm B. 754 mm C. 950 mm D. 835 mm

Solution:

$$V = \frac{Q}{A} = \frac{0.008}{\frac{\pi}{4}D^2} = \frac{0.010186}{D^2}$$

$$Re = \frac{DV}{\nu}$$

$$\text{For laminar flow}, Re = 2000$$

$$2000 = D\left(\frac{\frac{0.010186}{D^2}}{6.10 \times 10^{-6}}\right)$$

$$D = 0.835 \text{ m} = \mathbf{835\ mm}$$

137. The type of flow occupying in a 1 cm diameter pipe which water flows at a velocity of 2.50 m/s. Use $\nu = 1.13 \times 10^{-6}$ m^2/s for water.

A. turbulent B. constant C. laminar D. none of these

Solution:

$$Re = \frac{DV}{\nu} = \frac{0.01(2.50)}{1.13} \times 10^{-6} = 22{,}124$$

Since it is greater than 2000, then it is **turbulent** flow

138. What force is exerted by a water jet, 60 mm in diameter, if it strikes a wall at the rate of 15 m/s?

A. 636.17 N B. 442.62 N C. 764.23 N D. 563.34 N

Solution:

$$F = \rho QV$$

$$Q = AV = \left[\frac{\pi}{4}(0.06)^2\right](15) = 0.0424\ m^3/s$$

$$F = (1000)(0.0424)(15) = \mathbf{636.17\ N}$$

139. A 300 mm diameter pipe discharges water at a rate of 200 li/s. Point 1 on the pipe has a pressure of 260 kPa and 3.4 m below point 1 is point 2 with a pressure of 300 kPa. Compute the head loss between points 1 and 2.

A. 4.29 m B. 2.59 m C. 6.32 m D. 1.87 m

Solution:

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_L$$

$$h_L = \frac{P_1 - P_2}{\gamma} + (z_1 - z_2) = \frac{285 - 300}{9.81} + 3.40 = \mathbf{1.87\ m}$$

140. Water flowing at the rate of 10 m/s from an orifice at bottom of a reservoir. Find the pressure at the bottom of reservoir.

A. 30 kPa B. 40 kPa C. 50 kPa D. 60 kPa

Solution:

$$h = \frac{V^2}{2g} = \frac{10^2}{2(9.81)} = 5.0968\ m$$

$$P = \gamma h = 9.81(5.0968) = \mathbf{50\ kPa}$$

141. Steam flows through a nozzle at 400°C and 1 MPa (h = 3263.9 kJ/kg) with velocity of 300 m/s. Find the stagnation enthalpy.

A. 3300 kJ/kg B. 3290 kJ/kg C. 3320 kJ/kg D. 3309 kJ/kg

Solution:

$$h_o = h + \frac{V^2}{2000} = 3263.9 + \frac{300^2}{2000} = \mathbf{3309\ kJ/kg}$$

142. Air flows through a nozzle at a speed of 350 m/s. Find the stagnation temperature if the entrance temperature is 200°C.

A. 241.25°C B. 251.25°C C. 261.25°C D. 271.25°C

Solution:

$$T_o = T_1 + \frac{V^2}{2000c_p} = (200 + 273) + \frac{350^2}{2000(1)} = 534.25\ K - 273 = \mathbf{261.25℃}$$

143. Carbon dioxide flows through a nozzle with a speed of 400 m/s. Compute the dynamic temperature.

A. 92.56 K B. 94.56 K C. 96.56 K D. 98.56 K

Solution:

$$\text{For } CO_2: c_p = 0.846 \text{ kJ/kg-K}$$

$$\text{Dynamic temperature} = \frac{V^2}{2000 c_p} = \frac{400^2}{2000(0.846)} = \mathbf{94.56\ K}$$

144. Carbon dioxide flows through a nozzle with speed of 380 m/s. The entrance condition of nozzle is 250°C and 1200 kPa. Find the stagnation pressure.

A. 2,136.34 kPa B. 2,146.34 kPa C. 2,156.34 kPa D. 2,166.34 kPa

Solution:

$$T_1 = 250 + 273 = 523 \text{ K}$$

$$T_o = T_1 + \frac{V^2}{2000} = 523 + \frac{380^2}{2000} = 595.2 \text{ K}$$

$$P_1 = 1200 \text{ kPa}$$

$$\frac{T_1}{T_o} = \left(\frac{P_1}{P_o}\right)^{\frac{k-1}{k}}$$

$$\text{For } CO_2: k = 1.289$$

$$\frac{523}{595.2} = \left(\frac{1200}{P_o}\right)^{\frac{1.289-1}{1.289}}$$

$$P_o = \mathbf{2{,}136.34\ kPa}$$

145. Air enters a diffuser with a velocity of 200 m/s. Determine the velocity of sound if air temperature is 30°C.

A. 349 m/s B. 359 m/s C. 369 m/s D. 379 m/s

Solution:

$$C = \sqrt{kRT \times 1000} = \sqrt{1.4(0.287)(30+273)(1000)} = \mathbf{349\ m/s}$$

146. Air flows through a nozzle with temperature of entrance of 420 K stagnation temperature of 468 K. Find the Mach number.

A. 0.744 B. 0.754 C. 0.764 D. 0.774

Solution:

$$T_e = T_f + \frac{V^2}{2000 c_p}$$

$$468 = 420 + \frac{V^2}{2000}$$

$$V = 309.839 \text{ m/s}$$

$$C = \sqrt{kRT \times 1000} = \sqrt{1.4(0.287)(420)(1000)} = 410.8 \text{ m/s}$$

$$M = \frac{V}{C} = \frac{309.839}{410.8} = \mathbf{0.754}$$

147. Air at 300 K and 200 kPa is heated at constant pressure to 600 K. Determine the change of internal energy.

A. 245.58 kJ/kg B. 235.58 kJ/kg C. 225.58 kJ/kg D. 215.58 kJ/kg

Solution:

$$\Delta U = mc_v(T_2 - T_1) = 1(0.7186)(600 - 300) = \mathbf{215.58\ kJ/kg}$$

148. An insulated rigid tank initially contains 1.5 lb of helium at 80°F and 50 psia. A paddle wheel with power rating of 0.02 hp is operated within the tank for 30 min. Determine the final temperature.

A. 159.22°F B. 169.22°F C. 179.22°F D. 189.22°F

Solution:

$$W = \Delta U = mc_v(T_2 - T_1)$$

$$0.02\ \text{hp}(0.50\ \text{hr})\left(2545\,\frac{\frac{\text{Btu}}{\text{hr}}}{\text{hp}}\right) = 1.5(0.171)(T_2 - 80)$$

$$T_2 = \mathbf{179.22°F}$$

149. A 4 m^2 asphalt pavement with emissivity of 0.85 has a surface temperature of 50°C. Find the maximum rate of radiation that can be emitted from the surface.

A. 2,068 .32 watts B. 2,078.32 watts C. 2,088.32 watts D. 2,098.32 watts

Solution:

$$\dot{Q} = \varepsilon\sigma AT^4 = 0.85\left(5.67 \times 10^{-8}\right)(4)(50 + 273)^4 = \mathbf{2{,}098.32\ watts}$$

150. Air at 10°C and 80 kPa enters a diffuser of a jet engine steadily with a velocity of 200 m/s. The inlet area of diffuser is 0.40 m^2. Determine the mass flow rate of air.

A. 72.79 kg/s B. 74.79 kg/s C. 76.79 kg/s D. 78.79 kg/s

Solution:

$$\rho = \frac{P}{RT} = \frac{80}{0.287\,(10+273)} = 0.985\ \text{kg/m}^3$$

$$\dot{m} = \rho VA = 0.985(200)(0.40) = \mathbf{78.79\ kg/s}$$

151. Consider a refrigerator whose 40 watts light bulb remains on continuously as a result of a malfunction of the switch. If the refrigerator has a COP of 1.3 and the cost of electricity is 8 cents per kW-hr, determine the increase in the energy consumption of the refrigerator and its cost per year if the switch is not fixed.

A. P 49.59 B. P 47.59 C. P 45.59 D. P 43.59

Solution:

$$\text{COP} = \frac{\text{RE}}{\text{W}_{\text{ref}}}$$
$$1.3 = \frac{40}{\text{W}_{\text{ref}}}$$
$$\dot{\text{W}}_{\text{ref}} = 30{,}769 \text{ watts}$$
$$\dot{\text{W}} = \dot{\text{W}}_{\text{b}} + \dot{\text{W}}_{\text{ref}} = 40 + 30.769 = 70.77 \text{ watts}$$
$$\dot{\text{W}} = 0.07077 \text{ kW}$$
$$\text{Cost} = 0.07077(8760)(\text{P } 0.08) = \mathbf{P\ 49.59}$$

152. A 75 hp motor that has an efficiency of 91% is worn out and is replaced by a high-efficiency motor that has an efficiency of 95.4%. Determine the reduction in heat gain of the room due to higher efficiency under full-load conditions.

A. 2.24 kW B. 2.44 kW C. 2.64 kW D. 2.84 kW

Solution:

$$\text{P}_1 = 75 \times 0.746(0.91) = 50.91 \text{ kW}$$
$$\text{P}_2 = 75 \times 0.746(0.954) = 53.376 \text{ kW}$$
$$\dot{\text{Q}}_{\text{reduced}} = 53.376 - 50.91 = \mathbf{2.44\ kW}$$

153. A household refrigerator that has a power input of 450 watts and a COP of 2.5 is to cool five large watermelons, 10 kg each, to 8°C. If the watermelons are initially at 20°C, determine how long it will take for the refrigerator to cool them. The watermelons can be treated as water whose specific heat is 4.2 kJ/kg-K.

A. 2220 seconds B. 2230 seconds C. 2240 seconds D. 2250 seconds

Solution:

$$\text{COP} = \frac{\text{RE}}{\text{W}}$$
$$2.5 = \frac{\text{RE}}{450}$$
$$\text{RE} = 1{,}125 \text{ watts} = 1.125 \text{ kilowatts}$$
$$\text{RE} = \text{mc}_{\text{p}}(\text{T}_2 - \text{T}_1)$$
$$1.125\text{t} = 10 \times 5(4.2)(20 - 8)$$
$$\text{t} = \mathbf{2240\ seconds}$$

154. When a man returns to his wall-sealed house on a summer day, he finds that the house is at 32°C. He returns on the air conditioner which cools the entire house to 20°C in 15 minutes. If COP is 2.5, determine the power drawn by the air conditioner. Assume the entire mass within the house is 800 kg of air for which c_v = 0.72 kJ/kg-K, c_p = 1.0 kJ/kg-K.

A. 1.072 kW B. 2.072 kW C. 3.072 kW D. 4.072 kW

Solution:

$$RE = \dot{m}c_v(T_2 - T_1) = \left(\frac{800}{15\times60}\right)(0.72)(32-20) = 7.68 \text{ kW}$$

$$P = \frac{RE}{COP} = \frac{7.68}{2.5} = \mathbf{3.072\ kW}$$

155. A heat source at 800 K losses 2000 kJ of heat to a sink at 500 K. Determine the entropy generated during this process.

A. 1.5 kJ/K B. 2.5 kJ/K C. -2.5 kJ/K D. 4 kJ/K

Solution:

$$\Delta s_{source} = \frac{-Q}{T_{source}} = \frac{-2000}{800} = -2.5$$

$$\Delta s_{sink} = \frac{Q}{T_{sink}} = \frac{2000}{500} = 4$$

$$\Delta s_{gen} = -2.5 + 4 = \mathbf{1.5\ kJ/K}$$

156. Helium gas is compressed in an adiabatic compressor from an initial state of 14 psia and 50°F to a final temperature of 320°F in a reversible manner. Determine the exit pressure of Helium.

A. 38.5 psia B. 40.5 psia C. 42.5 psia D. 44.5 psia

Solution:

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}$$

$$\frac{320+460}{50+460} = \left(\frac{P_2}{14}\right)^{\frac{1.667-1}{1.667}}$$

$$P_2 = \mathbf{40.5\ psia}$$

157. Air passes thru a nozzle with efficiency of 90%. The velocity of air at the exit is 600 m/s. Find the actual velocity at the exit.

A. 382 m/s B. 540 m/s C. 458 m/s D. 568 m/s

Solution:

$$e = \left(\frac{V_a}{V_t}\right)^2$$

$$0.9 = \left(\frac{V_a}{600}\right)^2$$

$$V_a = \mathbf{568\ m/s}$$

158. A 50 kg block of iron casting at 500 K is thrown into a large lake that is at a temperature of 285 K. The iron block eventually reaches thermal equilibrium with the lake water. Assuming average specific heat of 0.45 kJ/kg-K for the iron, determine the entropy generated during this process.

A. -12.65 kJ/K B. 16.97 kJ/K C. 4.32 kJ/K D. 6.32 kJ/K

Solution:

$$\Delta s_{iron} = mc \ln \frac{T_2}{T_1} = 50(0.45) \ln \frac{285}{500} = \text{-}12.65 \text{ kJ/kg}$$

$$\Delta s_{lake} = \frac{Q}{T} = \frac{50(0.45)(500-285)}{285} = 16.97 \text{ kJ/kg}$$

$$\Delta s_{gen} = \text{-}12.65 + 16.97 = \mathbf{4.32\ kJ/K}$$

159. A windmill with a 12 m diameter rotor is to be installed at a location where the wind is blowing at an average velocity of 10 m/s. Using standard condition of air (1 atm, 25°C), determine the maximum power that can be generated by the windmill.

A. 68 kW B. 70 kW C. 72 kW D. 74 kW

Solution:

$$\rho = \frac{R}{RT} = \frac{101.325}{0.287(25+273)} = 1.1847 \text{ kg/m}^3$$

$$\dot{m} = \rho AV = 1.1847\left(\frac{\pi}{4} \times 12^2\right)(10) = 1{,}339.895 \text{ kg/s}$$

$$KE = \frac{V^2}{2000} = \frac{10^2}{2000} = 0.05 \text{ kJ/kg}$$

$$\text{Power} = \dot{m}KE = 1{,}339.895(0.05) = \mathbf{70\ kW}$$

160. Consider a large furnace that can supply heat at a temperature of 2000°R at a steady rate of 3000 Btu/s. Determine the exergy of this energy. Assume an environment temperature of 77°F.

A. 2305.19 kW B. 2315.19 kW C. 2325.19 kW D. 2335.19 kW

Solution:

$$e = \frac{T_H - T_L}{T_H} = \frac{2000-(77+460)}{2000} 0.71315$$

$$\dot{W} = e\dot{Q} = 0.7135(3000) = 2194.5 \text{ Btu/s} = \mathbf{2315.19\ kW}$$

161. A heat engine receives heat from a source at 1200 K at a rate of 500 kJ/s and rejects the waste heat to a medium at 300 K. The power output of the engine is 180 kW. Determine the irreversibility rate for this process.

A. 190 kW B. 195 kW C. 200 kW D. 205 kW

Solution:

$$e = \frac{T_H - T_L}{T_H} = \frac{1200-300}{1200} = 0.75$$

$$\dot{W} = e\dot{Q} = 375 \text{ kW}$$

$$\text{Irreversibilities} = \dot{W} - P = 375 - 180 = \mathbf{195\ kW}$$

162. A dealer advertises that he has just received a shipment of electric resistance heaters for residential buildings that have an efficiency of 100 percent. Assuming an indoor temperature of 21°C and outdoor temperature of 10°C, determine the second law efficiency of these heaters.

A. 8.74% B. 6.74% C. 3.74% D. 4.74%

Solution:

$$\mathrm{COP_1} = 100\% \text{ efficient} = 1$$

$$\mathrm{COP_2} = \frac{21+273}{21-10} = 26.73$$

$$\mathrm{e} = \frac{\mathrm{COP_1}}{\mathrm{COP_2}} = \frac{1}{26.73} = 0.0374 = \mathbf{3.74\%}$$

163. A thermal power plant has a heat rate of 11,363 Btu/kW-hr. Find the thermal efficiency of the plant.

A. 34% B. 24% C. 26% D. 30%

Solution:

$$\mathrm{e} = \frac{3412}{\text{Heat rate}} = \frac{3412}{11363} = 0.30 = \mathbf{30\%}$$

164. A rigid tank contains 2 kmol of N_2 and 6 kmol of CO_2 gases at 300 K and 115 MPa. Find the tank volume using the ideal gas equation.

A. 7.33 m^3 B. 5.33 m^3 C. 3.33 m^3 D. 1.33 m^3

Solution:

$$\mathrm{PV} = \mathrm{NRT}$$

$$15{,}000\mathrm{V} = (6+2)(8.324)(300)$$

$$\mathrm{V} = \mathbf{1.33\ m^3}$$

165. A spherical balloon with a diameter of 6 m is filled with helium at 20°C and 200 kPa. Determine the mole number.

A. 9.28 kmol B. 10.28 kmol C. 11.28 kmol D. 13.28 kmol

Solution:

$$\mathrm{PV} = \mathrm{NRT}$$

$$200\left[\frac{4}{3}\pi\left(\frac{6}{2}\right)^3\right] = \mathrm{N}(8.314)(20+273)$$

$$\mathrm{N} = \mathbf{9.28\ kmol}$$

166. The air in an automobile tire with a volume of 0.53 ft^3 is at 90°F and 20 psig. Determine the amount of air that must be added to raise the pressure to the recommended value of 30 psig. Assume the atmospheric pressure to be 14.7 psia and the temperature and the volume to remain constant.

A. 0.026 lb B. 0.046 lb C. 0.066 lb D. 0.086 lb

Solution:

$$P_1V_1 = m_1R_1T_1$$
$$(20 + 14.7)(144)(0.53) = m_1(53.3)(90 + 460)$$
$$m_1 = 0.09034 \text{ lb}$$
$$P_2V_2 = m_2R_2T_2$$
$$(30 + 14.7)(144)(0.53) = m_2(53.3)(90 + 460)$$
$$m_2 = 0.11634 \text{ lb}$$
$$m_{added} = m_2 - m_1 = 0.11634 - 0.09034 = \mathbf{0.026\ lb}$$

167. A rigid tank contains 20 lb_m of air at 20 psia and 70°F. More air is added to the tank until the pressure and temperature rise to 35 psia and 90°F, respectively. Determine the amount of air added to the tank.

A. 11.73 lb B. 13.73 lb C. 15.73 lb D. 17.73 lb

Solution:

$$P_1V_1 = m_1R_1T_1$$
$$20 \times 144V_1 = 20(50.3)(70 + 460)$$
$$V_1 = 196.17 \text{ ft}^3$$
$$P_2V_2 = m_2R_2T_2$$
$$35 \times 144(196.17) = m_2(53.3)(90 + 460)$$
$$m_2 = 33.73 \text{ lb}$$
$$m_{added} = m_2 - m_1 = 33.73 - 20 = \mathbf{13.73\ lb}$$

168. A rigid tank contains 5 kg of an ideal gas at 4 atm and 40°C. Now a valve is opened, and half of mass of the gas is allowed to escape. If the final pressure in the tank is 1.5 atm, the final temperature in the tank is?

A. -38°C B. -30°C C. 40°C D. 53°C

Solution:

$$P_1V_1 = m_1R_1T_1$$
$$4 \times 9.81V_1 = 5(0.287)(40 + 273)$$
$$V_1 = 11.446 \text{ m}^3$$
$$P_2V_2 = m_2R_2T_2$$
$$1.5 \times 9.81(11.446) = \tfrac{5}{2}(0.287)T_2$$
$$T_2 = 234.74 \text{ K} - 273 = -38.26 \approx \mathbf{-38°C}$$

169. The pressure of an automobile tire is measured to be 200 kPa (gage) before the trip end 220 kPa (gage) after the trip at a location where the atmospheric pressure is 90 kPa. If the temperature of the air in the tire before the trip is 25°C, the air temperature after the trip is?

A. 45.6°C B. 54.8°C C. 27.5°C D. 26.7°C

Solution:

$$\frac{T_2}{T_1} = \frac{P_2}{P_1}$$

$$\frac{T_2}{25+273} = \frac{220+90}{200+90}$$

$$T_2 = 318.55\ K - 273 = 45.55 \approx \mathbf{45.6℃}$$

170. Water is boiling at 1 atm pressure in a stainless steel pan on an electric range. It is observed that 2 kg of liquid water evaporates in 30 min. The rate of heat transfer to the water is?

A. 2.07 kW B. 0.47 kW C. 2.51 kW D. 3.12 kW

Solution:

$$\dot{Q} = \dot{m}L_v = \frac{2}{30(60)}(2257) = \mathbf{2.51\ kW}$$

171. Consider a person standing in a breezy room at 20°C. Determine the total rate of heat transfer from this person if the exposed surface area and the average outer surface temperature of the person are 1.6 m^2 and 29°C, respectively, and the convection heat transfer coefficient is 6 W/m^2 with emissivity factor of 0.95.

A. 86.40 watts B. 81.70 watts C. 198.1 watts D. 168.1 watts

Solution:

$$\dot{Q}_o = hA(t_2 - t_1) = 6(1.6)(29.20) = 86.40\ \text{watts}$$

$$\dot{Q}_r = 0.95\left(5.67 \times 10^{-6}\right)(1.6)[(29+273)^4 - (20+273)^4] = 81.7\ \text{watts}$$

$$\dot{Q} = \dot{Q}_o + \dot{Q}_r = 86.40 + 81.7 = \mathbf{168.1\ watts}$$

172. Water is boiler in a pan on a stove at sea level. During 10 minutes of boiling, it is observed that 200 grams of water has evaporated. Then the rate of heat transfer to the water is:

A. 0.84 kJ/min B. 45.1 kJ/min C. 41.8 kJ/min D. 53.5 kJ/min

Solution:

$$\dot{Q} = \dot{m}L_v = \frac{0.2}{10}(2257) = \mathbf{45.1\ kJ/min}$$

173. An aluminum pan whose thermal conductivity is 237 W/m-°C has a flat bottom whose diameter is 20 cm and thickness of 0.4 cm. Heat is transferred steadily to boiling water in the pan through its bottom at a rate of 500 watts. If the inner surface of the bottom of the pan is 105°C, determine the temperature of the surface of the bottom of the pan.

A. 95.27°C B. 105.27°C C. 115.27°C D. 125.27°C

Solution:

$$A = \frac{\pi}{4}(0.20)^2 = 0.0314 \text{ m}^2$$
$$\dot{Q} = \frac{kA(t_2 - t_1)}{x}$$
$$500 = \frac{237\,(0.0314)\,(t_2 - 105)}{0.004}$$
$$t_2 = \mathbf{105.27°C}$$

174. For heat transfer purposes, a standing man can be modeled as a 30 cm diameter, 170 cm long vertical cylinder with both the top and bottom surfaces insulated and with the side surface at an average temperature of 34°C. For a convection heat transfer coefficient of 15 W/m^2-°C, determine the rate of heat loss from this man by convection in an environment at 20°C.

A. 316.46 watts B. 326.46 watts C. 336.46 watts D. 346.46 watts

Solution:

$$\dot{Q} = kA(t_2 - t_1) = 15(\pi \times 0.30 \times 1.7)(34 - 20) = \mathbf{336.46\ watts}$$

175. A 5 cm diameter spherical ball whose surface is maintained at a temperature of 70°C is suspended in the middle of a room at 20°C. If the convection heat transfer coefficient is 15 W/m^2-°C and the emissivity of the surface is 0.8, determine the total heat transfer from the ball.

A. 23.56 watts B. 32.77 watts C. 9.22 watts D. 43.45 watts

Solution:

$$A = 4\pi r^2 = 4\pi(0.05)^2 = 0.0314 \text{ m}^2$$
$$\dot{Q}_o = hA(t_2 - t_1) = 15(0.0314)(70 - 20) = 23.56 \text{ watts}$$
$$\dot{Q}_r = 0.80\left(5.67 \times 10^{-8}\right)(0.0314)[(70 + 273)^4 - (50 + 273)^4] = 9.22 \text{ watts}$$
$$\dot{Q} = \dot{Q}_o + \dot{Q}_r = 23.56 + 9.22 = \mathbf{32.77\ watts}$$

176. A frictionless piston-cylinder device and a rigid tank contain 1.2 kmol of an ideal gas at the same temperature, pressure and volume. Now heat is transferred, and the temperature of both systems is raised by 15°C. The amount of extra heat that must be supplied to the gas in the cylinder that is maintained at constant pressure is?

A. 0 B. 50 kJ C. 100 kJ D. 150 kJ

Solution:

$$Q = mc_p(t_2 - t_1) = 1.2 \times 8.314(1)(15) = \mathbf{150\ kJ}$$

177. A supply of 50 kg of chicken at 6°C contained in a box is to be frozen to -18°C in a freezer. Determine the amount of heat that needs to be removed. The latent heat of the chicken is 247 kJ/kg, and its specific heat is 3.32 kJ/kg-°C above freezing and 1.77 kJ/kg-°C below freezing. The

container box is 1.5 kg, and the specific heat of the box material is 1.4 kJ/kg-°C. Also the freezing temperature of chicken is -2.8°C.

A. 15,206.4 kJ B. 50.4 kJ C. 15,156 kJ D. 1,863 kJ

Solution:

$$Q_{chicken} = 50[3.32(6 + 2.8) + 247 + 1.77(-2.8 + 18)] = 15{,}156 \text{ kJ}$$
$$Q_{box} = 1.5(1.4)(6 + 18) = 50.4 \text{ kJ}$$
$$Q = 15{,}156 + 50.4 = \mathbf{15{,}206.4\ kJ}$$

178. Water is being heated in a closed pan on top of a range while being stirred by a paddle wheel. During the process, 30 kJ of heat is transferred to the water, and 5 kJ of heat is lost to the surrounding air. The paddle wheel work amounts to 500 N-m. Determine the final energy of the system if its initial energy is 10 kJ.

A. 35.5 kJ B. 40.5 kJ C. 25.5 kJ D. 14.5 kJ

Solution:

$$\text{Final energy} = Q_A + \Delta U - Q_{loss} + W = 30 + 10 - 5 + 0.50 = \mathbf{35.5\ kJ}$$

179. A classroom that normally contains 40 people is to be air-conditioned with window air-conditioning units of 5 kW cooling capacity. A person at rest may be assumed to dissipate heat at a rate about 360 kJ/hr. There are 10 light bulbs in the room, each with a rating of 100 watts. The rate of heat transfer to the classroom through the walls and the windows is estimated to be 15,000 kJ/hr. If the room is to be maintained at a constant temperature of 21°C, determine the number of window air-conditioning units required.

A. 1 units B. 2 units C. 3 units D. 4 units

Solution:

$$\dot{Q} = \text{total heat load} = 40(360)(3600) + 10(0.100) + \frac{15{,}000}{3600} = 9.167 \text{ kW}$$
$$\text{No. of air} - \text{conditioning} = \frac{9.167}{5} = 1.833 = \mathbf{2\ units}$$

180. A 4 m x 5 m x 6 m room is to be heated by a baseboard resistance heater. It is desired that the resistance heater be able to raise the air temperature in the room from 7 to 23°C within 15 minutes. Assuming no heat losses from the room and an atmospheric pressure of 100 kPa, determine the required power of the resistance heater. Assume constant specific heats at room temperature.

A. 2.34 kW B. 1.91 kW C. 4.56 kW D. 6.34 kW

Solution:

$$\upsilon = \frac{P}{RT} = \frac{100}{0.287(7+273)} = 1.244 \text{ kg/m}^3$$
$$m = 1.244(4 \times 5 \times 6) = 149.28 \text{ kg}$$

$$Q = mc_v(t_2 - t_1) = 149.28(0.7186)(23 - 7) = 1{,}716.36 \text{ kJ}$$
$$\text{Power} = 1{,}716.36(15 \times 60) = \mathbf{1.91\ kW}$$

181. A student living in a 4 m x 6 m x 6 m dormitory room turns on her 150 watts fan before she leaves the room on a summer day, hoping that the room will be cooler when she comes back in the evening. Assuming all the doors and windows are tightly closed and disregarding any heat transfer through the walls and the windows, determine the temperature in the room when she comes back 10 hours later. Use specific heat values at room temperature, and assume the room to be at 100 kPa and 15°C in the morning when she leaves.

A. 28.13°C B. 38.13°C C. 48.13°C D. 58.13°C

Solution:

$$\upsilon = \frac{P}{RT} = \frac{100}{0.287(15+273)} = 1.2098 \text{ kg/m}^3$$
$$m = 1.2098(4 \times 6 \times 6) = 174.216 \text{ kg}$$
$$Q = mc_v(t_2 - t_1)$$
$$0.15(10 \times 3600) = 174.216(0.7186)(t_2 - 15)$$
$$t_2 = \mathbf{58.13℃}$$

182. A piston-cylinder device whose piston is resting on top of a set of stops initially contains 0.50 kg of helium gas at 100 kPa and 25°C. The mass of the piston is such that 500 kPa of pressure is required to raise it. How much heat must be transferred to the helium before the piston starts rising?

A. 1557.13 kJ B. 1657.13 kJ C. 1757.13 kJ D. 1857.13 kJ

Solution:

For helium:

$$c_v = \frac{R}{k-1} = \frac{\frac{8.314}{4}}{1.667 - 1} = 3.116 \text{ kJ/kg-K}$$
$$T_2 = (25 + 273)\left(\frac{500}{100}\right) = 1{,}490 \text{ K}$$
$$T_1 = 25 + 273 = 298 \text{ K}$$
$$Q = mc_v(T_2 - T_1) = 0.50(3.116)(1490 - 298) = \mathbf{1857.13\ kJ}$$

183. In order to cool 1 ton (1000 kg) of water at 20°C in an insulated tank, a person pours 80 kg of ice at -5°C into the water. Determine the final equilibrium temperature in the tank. The melting temperature and the heat of fusion of ice at atmospheric pressure are 0°C and 333.7 kJ/kg, respectively.

A. 12.43°C B. 14.43°C C. 16.43°C D. 18.43°C

Solution:

$$Q_{water} = Q_{ice}$$

$$1000(4.187)(20 - t_e) = 80(2.09)(0 + 5) + 80(333.7) + 80(4.187)(t_e - 0)$$
$$t_e = \mathbf{12.43℃}$$

184. A fan is powered by 0.5 hp motor and delivers air at a rate of 85 m^3/min. Determine the highest value for the average velocity of air mobilized by the fan. Take the density of air to be 1.18 kg/m^3.

A. 18.23 m/s B. 21.12 m/s C. 25.34 m/s D. 32.23 m/s

Solution:

$$P = \gamma Q h$$
$$0.50(0.746) = 1.18 \times 0.00981\left(\frac{85}{60}\right)h$$
$$h = 22.74 \text{ m}$$
$$V = \sqrt{2(9.81)(22.74)} = \mathbf{21.12\ m/s}$$

185. An Ocean-Thermal Energy Conversion power plant generates 10,000 kW using a warm surface water inlet temperature of 26°C and cold deep-water temperature of 15°C. On the basis of a 3°C drop in the temperature of the warm water and a 3°C rise in the temperature of the cold water due to removal and addition of heat, calculate the power required in kW to pump the cold-deep water to the surface and through the system heat exchanger if the required pumping pressure increase is 12 kPa. Assume a Carnot cycle efficiency and density of cold water to be 100 kg/m^3.

A. 108 B. 250 C. 146 D. 160

Solution:

$$e = \frac{T_H - T_L}{T_H} = \frac{26 - 15}{26 + 273} = 0.03679$$
$$e = \frac{\dot{W}}{\dot{Q}_A}$$
$$0.03679 = \frac{10{,}000}{\dot{Q}_A}$$
$$\dot{Q}_A = 271{,}812.99 \text{ kW}$$
$$\dot{Q}_R = \dot{Q}_A - \dot{W} = 271{,}812.99 - 10{,}000 = 261{,}813 \text{ kW}$$
$$\dot{Q}_R = \dot{m}c_p\Delta t$$
$$261{,}813 = \dot{m}(4.187)(3)$$
$$\dot{m} = 20{,}843.32 \text{ kg/s or } 20{,}843.32 \text{ li/s} = 20.843 \text{ m}^3\text{/s} = Q$$
$$h = \frac{P}{\gamma} = \frac{12}{9.81} = 1.223 \text{ m}$$
$$P = \gamma Q h = 9.81(20.843)(1.223) = \mathbf{250} \text{ kW}$$

186. A plate-type solar energy collector with an absorbing surface covered by a glass plate is to receive an incident radiation of 800 W/m^2. The glass plate has a reflectivity of 0.12 and a

transmissivity of 0.85. The absorbing surface has an absorptivity of 0.90. The area of the collector is 5 m^2. How much solar energy in watts is absorbed by the collector?

A. 2500 B. 2880 C. 3510 D. 3060

Solution:

$$\dot{Q} = \text{heat absorbed from the sun} = 800\frac{W}{m^2}(5\ m^2)(0.85)(0.90) = \mathbf{3060}\ W$$

187. A tank contains liquid nitrogen at -190°C is suspended in a vacuum shell by three stainless steel rods of 0.80 cm in diameter and 3 meters long with a thermal conductivity of 16.3 W/m^2-°C. If the ambient air outside the vacuum shell is 15°C, calculate the magnitude of the conductive heat flow in watts along the support rods.

A. 0.168 B. 0.0587 C. 0.182 D. 0.176

Solution:

$$\dot{Q} = hA\Delta t = 16.3\left(\frac{\pi}{4}\times 0.008^2\right)\left[15-(\text{-}190)\right] = \mathbf{0.168}\ \text{watts}$$

188. An elastic sphere containing gas at 120 kPa has a diameter of 1.0 m. Heating the sphere causes it to expand to a diameter of 1.3 m. During the process the pressure is proportional to the sphere diameter. Calculate the work done by the gas in kJ.

A. 41.8 B. 50.6 C. 87.5 D. 35.4

Solution:

$$P \propto D$$
$$P = kD$$
$$120 = k(1)$$
$$k = 120$$
$$P = 120D$$
$$V = \frac{4}{3}\pi\left(\frac{D}{2}\right)^3 = \frac{4}{24}\pi D^3$$
$$dV = \frac{12}{24}\pi D^2\,dD$$
$$W = \int_{D_1}^{D_2} P\,dV = \int_1^{1.3} 120D\left(\frac{12}{24}\pi D^2\,dD\right) = \int_1^{1.3}\frac{1440}{24}\pi D^3\,dD = 87.47 \approx \mathbf{87.5}\ kJ$$

189. An ideal gas with a molecular weight of 7.1 kg/kg mol is compressed from 600 kPa and 280 K to a final specific volume of 0.5 m^3/kg. During the process the pressure varies according to P = 620 + 150υ + 95 $υ^2$ where p is in kPa and υ in m^3/kg. Calculate the work of compression in kJ/kg.

A. 32.8 B. 28.7 C. 35.6 D. 33.3

Solution:

$$\upsilon_1 = \frac{RT}{P} = \frac{8.314}{7.1}\left(\frac{280}{600}\right) = 0.546\ m^3/kg$$

$$W = \int_{V_1}^{V_2} P\, d\upsilon = \int_{0.546}^{0.5} (620 + 150\upsilon + 95\upsilon^2)\, d\upsilon = \mathbf{33.3}\ \text{kJ}$$

190. A one cubic meter container contains a mixture of gases composed of 0.02 kg-mol of oxygen and 0.04 kg-mol of helium at a pressure of 220 kPa. What is the temperature of this ideal gas mixture in Kelvin?

A. 441 B. 350 C. 400 D. 450

Solution:

$$V_T = V_1 + V_2 = \frac{m_1 R_1 T_1}{P_1} + \frac{m_2 R_2 T_2}{P_2} = \frac{0.02 \times 32\left(\frac{8.314}{32}\right)T}{220} + \frac{0.04 \times 4\left(\frac{8.314}{4}\right)T}{220} = \mathbf{441}\ \text{K}$$

191. Methyl alcohol (CH_3OH) is burned with 25% excess air. How much unburned oxygen in kg-mol$_{oxygen}$/kg-mol$_{fuel}$ will there be in the products if the combustion is complete?

A. 0.35 B. 0.45 C. 0.37 D. 0.65

Solution:

$$CH_3OH + O_2 + 3.76N_2 = CO_2 + H_2O + 3.76N_2$$

$$CH_3OH + 1.5O_2 + 1.5(3.76)N_2 = 1CO_2 + 2H_2O + 1.5(3.76)N_2$$

Consider 25% excess air:

$$CH_3OH + 1.25(1.5) + 1.25(1.5)(3.76)N_2$$

$$= 1CO_2 + 2H_2O + 1.25(1.5)(3.76)N_2 + 0.25(1.5)O_2$$

$$\text{Unburned O} = 0.25(1.5) = 0.375 \approx \mathbf{0.37}$$

192. A 12 DC electrical motor draws a current of 15 amps. How much work in kJ does this motor produce over a 10-minute period of operation?

A. 108.0 B. 129.6 C. 216.0 D. 318.2

Solution:

$$W = E = QA = (15 \times 10 \times 60)(12) = 108{,}000\ \text{J} = \mathbf{108.0}\ \text{kJ}$$

193. A 4 liter (2-liter per revolution at standard pressure and temperature) spark ignition engine has a compression ratio of 8 and 2200 kJ/kg heat addition by the fluid combustion. Considering a cold air-standard Otto cycle model, how much power will the engine produce when operating at 2500 rpm?

A. 166.53 hp B. 73.12 hp C. 97.4 hp D. 148 hp

Solution:

$$\rho = 1.2\ \text{kg/m}^3\ \text{(standard density of air)}$$

$$\dot{m} = 2\frac{\text{l}}{\text{rev}} \times \frac{1\ \text{m}^3}{1000\ \text{l}} \times 2500\frac{\text{rev}}{\text{min}} \times \frac{1\ \text{min}}{60\ \text{s}} \times 2\frac{\text{kg}}{\text{m}^3} = 0.10\ \text{kg/s}$$

$$e = \frac{W}{Q_A} = 1 - \frac{1}{r_k^{k-1}} = 1 - \frac{1}{8^{1.4-1}} = 0.5647$$

$$W = eQ_A = 0.5647(2200)$$
$$\dot{W} = 1242.34\frac{\text{kJ}}{\text{kg}}\left(0.10\frac{\text{kg}}{\text{s}}\right) = 124.23\text{ kW} = \mathbf{166.53\ hp}$$

194. A simple Rankine cycle produces 40 MW of power, 50 MW of process heated and rejects 50 MW of heat to the surroundings. What is the utilization factor of this cogeneration cycle neglecting the pump work?

A. 50% B. 60% C. 64% D. 80%

Solution:

$$\dot{Q}_A = \dot{W}_t + \dot{Q}_{process} + \dot{W}_p = 40 + 50 + 50 = 140\text{ kW}$$
$$\frac{\dot{Q}_{process} + \dot{W}_t}{\dot{Q}_A} = \frac{50+40}{140} = \mathbf{64\%}$$

195. The rate of heat transfer to the surroundings from a person at rest is 400 kJ/hr. Suppose that the ventilation system fails in an auditorium containing 120 people and assuming that the energy goes into the air of volume 1500 m^3 initially at 300 K and 101 kPa, calculate the rate in °C /min of air temperature change.

A. 0.81 B. 0.53 C. 0.63 D. 1.0

Solution:

$$\dot{Q} = \dot{m}c_v\Delta t$$
$$P\dot{V} = \dot{m}RT$$
$$101(1500) = \dot{m}(0.287)(300)$$
$$\dot{m} = 1759.58\text{ kg/min}$$
$$120\left(\frac{400}{60}\right) = 1759.58(0.7186)\Delta t$$
$$\Delta t = \mathbf{0.63}\text{°C/min}$$

196. An insulated box containing helium gas falls from a balloon 4.5 km above the earth's surface. Calculate the temperature rise in °C of the helium when box hits the ground.

A. 15.2 B. 12.6 C. 25.3 D. 14.1

Solution:

$$C_v\text{ of helium} = 3118.9\text{ J/kg-°C}$$
$$mgh = mc_v\Delta t$$
$$m(9.81)(4500) = m(3118.9)\Delta t$$
$$\Delta t = 14.15 \approx \mathbf{14.1°C}$$

197. Consider two Carnot heat engines operating in series. The first engine receives heat from the reservoir at 2400 K and rejects the waste heat to another reservoir at temperature T. The second engine receives heat by the first one, convert some of it to work, and rejects the rest to

a reservoir at 300 K. If thermal efficiencies of both engines are the same, determine the temperature T.

A. 849 K B. 578 K C. 763 K D. 978 K

Solution:

$$e_1 = e_2$$
$$\frac{2400 - T}{2400} = \frac{T - 300}{T}$$
$$T = \mathbf{849\ K}$$

198. An ideal gas mixture consists of 2 kmol of N_2 and 6 kmol of CO_2. The mass fraction of CO_2 is?

A. 0.175 B. 0.250 C. 0.825 D. 0.750

Solution:

$$\text{Mass fraction of } CO_2 = \frac{6(44)}{6(44) + 2(28)} = \mathbf{0.825}$$

199. An ideal gas mixture consists of 2 kmol of N_2 and 6 kmol of CO_2. The apparent gas constant of mixture is?

A. 0.208 B. 0.231 C. 0.531 D. 0.825

Solution:

$$M = \frac{2}{8}(28) + \frac{6}{8}(44) = 40$$
$$R = \frac{8.314}{M} = \frac{8.314}{40} = \mathbf{0.208}\ \text{kJ/kg-K}$$

200. A Carnot cycle operates between the temperature limits of 300 K and 1500 K, and produces 600 kW of net power. The rate of entropy change of the working fluid during heat addition process is?

A. 0 B. 0.4 C. 0.5 D. 2.0

Solution:

$$\dot{W} = \Delta s(T_H - T_L)$$
$$600 = \Delta s(1500 - 300)$$
$$\Delta s = \mathbf{0.5}\ \text{kW/K}$$

201. Air in an ideal Diesel cycle is compressed from 3 L to 0.15 L and then it expands during the constant pressure heat addition process to 0.3 L. Under cold air standard conditions, the thermal effieciency of this cycle is?

A. 35% B. 44% C. 65% D. 70%

Solution:

$$r_k = \frac{3}{0.15} = 20$$
$$r_c = \frac{0.3}{0.15} = 2$$
$$e = 1 - \frac{1}{r_k^{k-1}}\left[\frac{r_c^k - 1}{k(r_c - 1)}\right] = 1 - \frac{1}{20^{1.4-1}}\left[\frac{2^{1.4} - 1}{1.4(2-1)}\right] = 0.6467 = 64.67 \approx \mathbf{65\%}$$

202. Helium gas in an ideal Otto cycle is compressed from 20°C and 2 L to 0.25 L and its temperature increases by an additional 800°C during the heat addition process. The temperature of Helium before the expansion process is?

A. 1700°C B. 1440°C C. 1240°C D. 880°C

Solution:

$$r_k = \frac{V_1}{V_2} = \frac{2}{0.25} = 8$$
$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{k-1}$$
$$T_2 = T_1 r_k^{k-1} = (20 + 273)(8)^{1.667-1} = 1172\ \text{K}$$
$$T_3 = T_2 + 800 = 1172 + 800 = 1972\ \text{K} - 273 = 1699 \approx \mathbf{1700℃}$$

203. In an ideal Otto cycle, air is compressed from 1.20 kg/m^3 and 2.2 L to 0.26 L and the net work output of the cycle is 440 kJ/kg. The mean effective pressure for the cycle is?

A. 612 kPa B. 599 kPa C. 528 kPa D. 416 kPa

Solution:

$$V_D = V_2 - V_1 = 2.2 \times 10^{-3}\text{m}^3 - 0.26 \times 10^{-3}\text{m}^3 = 1.94 \times 10^{-3}\text{m}^3$$
$$W = 440\ \text{kJ/kg}\left(1.2\frac{\text{kg}}{\text{m}^3} \times 2.2 \times 10^{-3}\text{m}^3\right) = 1.1616\ \text{kJ}$$
$$P_m = \frac{W}{V_D} = \frac{1.1616}{1.94 \times 10^{-3}} = 598.76 \approx \mathbf{599\ kPa}$$

204. An ideal Brayton cycle has a net work output of 150 kJ/kg and backwork ratio of 0.4. if both the turbine and the compressor had an isentropic efficiency of 80%, the net work output of the cycle would be?

A. 60 kJ/kg B. 75 kJ/kg C. 98 kJ/kg D. 120 kJ/kg

Solution:

$$\text{Backwork ratio} = \frac{w_c}{wt}$$
$$0.40 = \frac{w_c}{w_t}$$
$$w_c = 0.40 w_t$$
$$w_{net} = w_t - w_o$$
$$150 = w_t - 0.4 w_t$$
$$w_t = 250\ \text{kJ/kg}$$

$$w_t' = 250(0.8) = 200 \text{ kJ/kg}$$
$$w_p = 0.40(200) = 100 \text{ kJ/kg}$$
$$w_p' = \frac{100}{0.80} = 125 \text{ kJ/kg}$$
$$w_{net}' = w_t' - w_o' = 200 - 125 = \mathbf{75\ kJ/kg}$$

205. Air enters a turbojet engine at 200 m/s at a rate of 20 kg/s and exits at 800 m/s relative to the aircraft. The thrust developed by the engine is?

A. 6 kN B. 12 kN C. 16 kN D. 20 kN

Solution:

$$\text{Thrust developed} = m(V_2 - V_1) = 20(800 - 200) = 12{,}000 \text{ N} = \mathbf{12\ kN}$$

206. A thermal power has a net power of 10 MW. The backwork ratio of the plant is 0.005. Determine the compressor work.

A. 50.15 kW B. 50.35 kW C. 50.25 kW D. 50.45 kW

Solution:

$$\dot{W}_{net} = \dot{W}_t + \dot{W}_p$$
$$BW = \frac{\dot{W}_p}{W_t}$$
$$0.005 = \frac{\dot{W}_p}{W_t}$$
$$\dot{W}_p = 0.005\dot{W}_t$$
$$\dot{W}_{net} = \dot{W}_t - \dot{W}_p$$
$$10{,}000 = \dot{W}_t - 0.005\dot{W}_t$$
$$\dot{W}_t = 10{,}050.25 \text{ kW}$$
$$\dot{W}_c = 0.005(10{,}050.25) = \mathbf{50.25\ kW}$$

207. A heat engine receives heat from a source at 1200 K at a rate of 500 kJ/s and rejects the wasted heat to a sink at 300 K. If the power output of the engine is 200 kW, the second law efficiency of this heat engine is?

A. 35% B. 40% C. 53% D. 75%

Solution:

$$e_a = \frac{200}{500} = 0.40$$
$$e_b = \frac{T_H - T_L}{T_H} = \frac{1200 - 300}{1200} = 0.75$$
$$e_c = \frac{0.40}{0.75} = \mathbf{53\%}$$

208. A water reservoir contains 100,000 kg of water at an average elevation of 60 m. The maximum amount of electric power that can be generated from this water is?

A. 8 kWh B. 16 kWh C. 1630 kWh D. 58,800 kWh

Solution:

$$P = mh = 100{,}000 \times 0.00981(60) = 58{,}860 \text{ kJ} \times \frac{\text{kWh}}{3600 \text{ kJ}} = 16.35 \approx \mathbf{16\ kWh}$$

209. A house is maintained at 22°C in winter by electric resistance heaters. If the outdoor temperature is 5°C, the second law efficiency of the resistance heaters is?

A. 0% B. 5.8% C. 34% D. 77%

Solution:

$$e_a = 100\% \text{ of resistance heaters}$$

$$e_b = \frac{T_H - T_L}{T_H} = \frac{22-5}{22+273} = 0.058 = 5.8\%$$

$$e_c = \frac{5.8}{100} = 0.058 = \mathbf{5.8\%}$$

210. A thermoelectric refrigerator that resembles a small ice chest is powered by a car battery, and has a COP of 0.10. If the refrigerator cools a 0.350 L canned drink from 20°C to 4°C in 30 min, determine the average electric power consumed by the thermoelectric refrigerator.

A. 130 watts B. 110 watts C. 120 watts D. 140 watts

Solution:

$$\dot{Q} = \dot{m}c_p(t_2 - t_1) = \frac{1\times0.35}{30\times60}(4.187)(20-4) = 13 \text{ watts} = \text{RE}$$

$$\text{COP} = \frac{\text{RE}}{\text{W}} = \frac{13}{0.10} = \mathbf{130\ watts}$$

211. A Carnot refrigerator operates in a room in which the temperature is 25°C and consumes 2 kW of power when operating. If the food compartment of the refrigerator is to be maintained at 3°C, determine the rate of heat removal from the food compartment.

A. 1504.8 kJ/min B. 12.86 kJ/min C. 1625 kJ/min D. 9.57 kJ/min

Solution:

$$\text{COP} = \frac{T_L}{T_H - T_L} = \frac{3+273}{(25+273)-(3+273)} = 12.54$$

$$\dot{Q}_L = \text{COP} \times \dot{W} = 12.54 \times 2(60) = \mathbf{1504.8\ kJ/min}$$

212. A household refrigerator with EER 8.0 removes heat from the refrigerated space at a rate of 90 kJ/min. Determine the rate of heat transfer to the kitchen air.

A. 101.25 kJ/min B. 63.05 kJ/min C. 128.46 kJ/min D. 80 kJ/min

Solution:

$$\text{COP} = \frac{\text{EER}}{3.412} = \frac{8}{3.412} = 2.34$$

$$\text{COP} = \frac{\dot{Q}_L}{\dot{Q}_H - \dot{Q}_L} 2.34 = \frac{90}{\dot{Q}_H - 90}$$

$$\dot{Q}_H = \mathbf{128.46\ kJ/min}$$

213. An air-conditioning system is used to maintain a house at 75°F when the temperature outside is 95°F. The house is gaining the heat through the walls and windows at a rate of 1250 Btu/min, and the heat generation rate within the house from people, lights, and appliances amounts to 350 Btu/min. Determine the minimum power input required for this air-conditioning system.

A. 10.06 hp B. 1.36 hp C. 1.41 hp D. 7.94 hp

Solution:

$$\dot{Q}_L = 1250 + 350 = 1600\ \text{Btu/min}$$

$$\text{COP} = \frac{T_L}{T_H - T_L} = \frac{75+460}{(95+460)-(75+460)} = 26.75$$

$$\dot{W} = \frac{\dot{Q}_L}{\text{COP}} = \frac{\frac{1600}{26.75}}{42{,}4} = \mathbf{1.41\ hp}$$

214. A refrigeration system is to cool bread loaves with an average mass of 450 g from 22°C to -10°C at a rate of 500 loaves per hour by refrigerated air. Taking the average specific and latent heats of bread to be 2.93 kJ/kg-°C and 109.3 kJ/kg, respectively, determine the product load.

A. 541.7 kJ/min B. 351.6 kJ/min C. 761.5 kJ/min D. 409.9 kJ/min

Solution:

$$\dot{m}_{\text{bread}} = 500\frac{\text{breads}}{\text{h}}\left(0.45\frac{\text{kg}}{\text{bread}}\right) = 225\ \text{kg/h}$$

$$\dot{Q}_{\text{total}} = \dot{Q}_{\text{bread}} + \dot{Q}_{\text{freezing}} = \left(\dot{m}c_p\Delta T\right)_{\text{bread}} + (\dot{m}h_{\text{latent}})_{\text{bread}}$$

$$= 225(2.93)\left[22 - \left(\text{-}10\right)\right] + 225(109.3) = 45{,}688.5\ \text{kJ/h}$$

$$= \mathbf{761.5\ kJ/min}$$

215. A house that was heated by electric resistance heaters consumed 1200 kWh of electric energy in a winter month. If this house were heated instead by a heat pump that has an average performance factor, PF of 2.4, determine how much money the homeowner would be saved that month. Assume a price of 0.085 $/kWh for electricity.

A. $42.5 B. $59.50 C. $102 D. $97.75

Solution:

$$\dot{W} = \frac{\dot{Q}}{\text{PF}} = \frac{1200\ \text{kWh}}{2.4} = 500\ \text{kWh}$$

$$\$\ \text{savings per month} = (1200 - 500)(0.085) = \mathbf{\$59.50}$$

216. An ammonia simple saturation cycle operates with a suction pressure of 291.6 kPa and a condenser pressure of 1204 kPa develops 15 tons of refrigeration. Determine the theoretical horsepower of the compressor. The following enthalpies have been found: condenser entrance = 1653 kJ/kg, exit = 346.6 kJ/kg; compressor entrance = 1450.2 kJ/kg, exit = 1653 kJ/kg.

A. 7.23 hp B. 13 hp C. 15 hp D. 8.23 hp

Solution:

$$\dot{m} = \frac{\dot{Q}}{h_1 - h_4} = \frac{15 \times 3.52}{1450.2 - 346.6} = 0.0478 \text{ kg/s}$$

$$\dot{W} = \dot{m}(h_2 - h_1) = \frac{0.0478(1653 - 1450.2)}{0.746} = \mathbf{13\ hp}$$

217. An ammonia ice plant operates between a condenser temperature of 35°C and evaporator of -15°C. It produces 10 metric tons of ice per day from water at 30°C to ice at -5°C. Assuming simple saturation cycle, determine the horsepower of the motor if the adiabatic efficiency of the compressor n_c = 0.85 and mechanical efficiency n_m = 0.95. The specific heat of ice is 2.094 kJ/kg-°C and the latent heat is 335 kJ/kg. From the table for ammonia the following enthalpies are: condenser entrance = 1703 kJ/kg, exit = 366.1 kJ/kg; compressor entrance = 1443.9 kJ/kg, exit = 1703 kJ/kg.

A. 17.68 hp B. 18.61 hp C. 15.5 hp D. 21.9 hp

Solution:

$$q = c_{p_a}(t_e - t_f) + h_{latent} + c_{p_b}(t_g - t_h)$$

$$= 4.187(30 - 0) + 335 + 2.094[0 - (-5)] = 471.08 \text{ kJ/kg}$$

$$\dot{Q} = \frac{10 \times 1000(471.08)}{24} = 196{,}283.33 \frac{\text{kJ}}{\text{hr}} = 54.523 \text{ kJ/s}$$

$$\dot{m} = \frac{\dot{Q}}{h_1 - h_4} = \frac{54.523}{1443.9 - 366.1} = 0.0509 \text{ kg/s}$$

$$\dot{W} = \dot{m}(h_2 - h_1) = \frac{0.0509(1703 - 1443.9)}{0.746} = 17.68 \text{ hp}$$

$$\dot{W}_{motor} = \frac{17.68}{0.85(0.95)} = \mathbf{21.9\ hp}$$

218. A Freon 22 air conditioning under standard operating conditions of 35°C condensing and 5°C evaporating temperatures. The volume flow rate entering the compressor is 23.72 L/s. Determine the refrigerating capacityif the refrigerating effect is 164 kJ/kg. From the table for R22 the specific volume at the compressor entrance is 40.46 L/kg.

A. 339.3 TR B. 79.3 TR C. 96.4 TR D. 27.4 TR

Solution:

$$m = \frac{V_1}{\upsilon_1} = \frac{23.72}{40.36} = 0.5877 \text{ kg/s}$$

$$Q_c = mq_c = \frac{0.5877(164)}{3.52} = \mathbf{27.4\ TR}$$

219. The refrigerant volume flow rate at the entrance of compressor were obtained from a test on a twin cylinder, single acting 15 cm x 20 cm, 320 rpm compressor ammonia refrigerating plant to be 33 L/s. Determine the volumetric efficiency of the compressor.

A. 77.65% B. 87.6% C. 97.6% D. 65.65%

Solution:

$$V_D = \left(\frac{\pi}{4}D^2L\right)N = \frac{\pi}{4}(0.15)^2(0.2)(320)(2) = 2.26\text{ m}^3/\text{min}$$

$$\eta_v = \frac{V_1}{V_D} = \frac{33}{2.26\left(\frac{1000}{60}\right)} = 0.876 = \mathbf{87.6\%}$$

220. A twin cylinder ammonia compressor with volume displacement of 14,726 cm^3 operates at 300 rpm. Condenser and evaporator pressure are 1200 kPa and 227 kPa respectively. Specific volume of refrigerant at the entrance of compressor is 528.26 L/kg. Compression process is polytropic with n = 1.20 and clearance factor of compressor is 2 percent. Determine the horsepower required.

A. 60 hp B. 70 hp C. 80 hp D. 90 hp

Solution:

$$\eta_V = 1 + c - c\left(\frac{P_2}{P_1}\right)^{\frac{1}{n}} = 1 + 0.02 - 0.02\left(\frac{1200}{227}\right)^{1.2} = 0.8725$$

$$V_D = \left(\frac{\pi}{4}D^2L\right)N = 0.014726(320)(2) = 9.424\text{ m}^3/\text{min}$$

$$V_1 = \eta_V V_D = 0.8725(9.424) = 8.2224\text{ m}^3/\text{min}$$

$$\dot{W} = \frac{nP_1V_1}{1-n}\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right] = \frac{1.20(227)(8.2224)}{1-1.20}\left[\left(\frac{1200}{227}\right)^{\frac{1.2-1}{1.2}} - 1\right] = 3582\text{ kJmin}$$

$$= \frac{3582}{60(0.746)} = \mathbf{80\ hp}$$

221. A reversed Carnot has a refrigerating COP of 2.5. Determine the ratio TH/TL.

A. 1.4 B. 1.5 C. 1.25 D. 1.2

Solution:

$$\text{COP} = \frac{T_L}{T_H - T_L}$$

$$\frac{1}{\text{COP}} = \frac{T_H - T_L}{T_L} = \frac{T_H}{T_L} - 1$$

$$\frac{T_H}{T_L} = 1 + \frac{1}{\text{COP}} = 1 + \frac{1}{2.5} = \mathbf{1.4}$$

222. Three thousand cubic feet per minute of air are circulated over an air-cooled condenser. If the load on the condenser is 64,800 Btu/hr, compute the temperature rise of the air passing over the condenser. Specific volume of standard air (13.34 ft^3/lb).

A. 10°F B. 15°F C. 20°F D. 25°F

Solution:

$$Q_c = m_{air} c_{p_{air}} \Delta t_{air}$$

$$\Delta t_{air} = \frac{\dot{Q}_c}{\dot{m}_{air} c_{p_{air}}} = \frac{64{,}800}{\frac{3000\,(60)}{13.34}}(0.24) = \mathbf{20°F}$$

223. Saturated vapor ammonia at -16°C (h_T = 1442.60 kJ/kg) leaves the evaporator and enters the compressor at -6°C (h_1 = 1465 kJ/kg). The refrigerant leaves the condenser as saturated liquid at 40°C (h_4 = 390.6 kJ/kg) and enters the expansion valve at 35°C (h_5 = 366.1 kJ/kg). Heat rejected from the condenser amount to 50 kW. The work to compressor is 208 kJ/kg, while the heat loss from compressor is 33 kJ/kg. If 95 kJ/kg of heat are lost in the piping between the compressor discharge and condenser inlet, determine the refrigerating capacity of the system.

A. 49.5 TR B. 46.61 TR C. 12.88 TR D. 13.24 TR

Solution:

Solving for the enthalpy at the exit of compressor using energy balance about the compressor:

$$h_2 = h_1 + w - q_{wj} = 1465 + 208 - 33 = 1640 \text{ kJ/kg}$$

Solving for the enthalpy at the entrance of condenser using energy balance about the piping from compressor exit to condenser entrance:

$$h_3 = h_2 - q_{2\text{-}3} = 1640 - 95 = 1545 \text{ kJ/kg}$$

Solving for the heat rejected in the condenser using energy balance about the condenser:

$$q_c = h_3 - h_4 = 1545 - 390.6 = 1154.4 \text{ kJ/kg}$$

$$m = \frac{\dot{Q}_c}{q_c} = \frac{50}{1154.4} = 0.0433 \text{ kg/s}$$

Solving for the refrigerating effect using energy balance about the evaporator:

$$h_5 = h_6 = 366.1 \text{ kJ/kg}$$

$$q_s = h_T - h_6 = 1442.6 - 366.1 = 1076.5 \text{ kJ/kg}$$

∴ the refrigerating capacity,

$$\dot{Q}_s = \dot{m} q_s = 0.0433\left(\frac{1076.5}{3.52}\right) = \mathbf{13.24\ TR}$$

224. In an actual refrigeration cycle using R12 as working fluid, the refrigerant flow rate is 0.05 kg/s. Vapor enters the expansion valve at 1.15 MPa, 40°C (h = 238.5 kJ/kg) and leaves the evaporator at 175 kPa, -15°C (h = 345 kJ/kg). The electric iput to motor driving the compressor is measured and found 3.0 kW. Motor efficiency at this load 92% and mechanical efficiency 82%. Determine the actual coefficient of performance for this cycle.

A. 1.58 B. 2.36 C. 1.78 D. 1.34

Solution:

$$\dot{Q}_e = 0.05(345 - 238.5) = 5.325 \text{ kW}$$
$$\dot{W} = 3(0.92)(0.82) = 2.26 \text{ kW}$$
$$\text{COP}_{\text{actual}} = \frac{5.325}{2.26} = \mathbf{2.36}$$

225. In an ammonia refrigeration system, the temperature in the evaporator is -12°C and the ammonia at the evaporator entry 0.1511 dry while at exit is 0.95 dry. If the rate of ammonia circulation is 5.64 kg/min, determine the refrigerating capacity of the system. Enthalpy of saturated liquid and vapor at -12°C is 144.929 kJ/kg and 1447.74 kJ/kg respectively.

A. 17.82 B. 34.82 C. 27.82 D. 4.82

Solution:

$$h_4 = h_{f_4} + x_4\left(h_{g_4} - h_{f_4}\right) = 144.929 + 0.1511(1447.74 - 144.929)$$
$$= 341.78 \text{ kJ/kg}$$
$$h_1 = h_{f_1} + x_1\left(h_{g_1} - h_{f_1}\right) = 144.929 + 0.95(1447.74 - 144.929)$$
$$= 1382.6 \text{ kJ/kg}$$
$$\dot{Q}_e = \dot{m}(h_1 - h_4) = \frac{5.64(1382.6 - 341.78)}{211} = \mathbf{27.82\ TR}$$

226. A two stage cascade vapor compression refrigeration system uses ammonia in the low-temperature loop and R-12 in the high-temperature loop. The ammonia provides 15 tons of cooling. If the high-loop temperature requires 10.12 kW compressor power and low loop 15.93 kW, determine the COP of the system.

A. 2.027 TR B. 5.22 TR C. 3.314 TR D. 9.1 TR

Solution:

$$\dot{W}_{\text{Total}} = 10.12 + 15.93 = 26.05 \text{ kW}$$
$$\text{COP} = \frac{15(3.52)}{26.05} = \mathbf{2.027\ TR}$$

227. When a man returns to his well-sealed house on a summer day, he finds that the house is at 32°C. He turns on the air conditioner, which cools the entire house to 20°C in 15 min. If COP of the air conditioner system is 2.5, determine the power drawn by the air conditioners. Assume the entire mass within the house is equivalent to 800 kg of air for which c = 0.72 kJ/kg-°C.

A. 7.08 kW B. 3.07 kW C. 19.2 kW D. 12.08 kW

Solution:

$$\dot{Q}_e = \frac{m_{air}c(t_1 - t_2)}{\Delta_{time}} = \frac{800(0.72)(32 - 20)}{15(60)} = 7.68 \text{ kW}$$
$$\dot{W} = \frac{\dot{Q}_e}{\text{COP}} = \frac{7.68}{2.5} = \mathbf{3.07\ kW}$$

228. It is desired to double the COP of a reversed Carnot engine for cooling from 5.0 by raising the temperature of heat addition while keeping the temperature of heat rejection constant. By what percentage must the temperature of heat addition be raised?

A. 10.1% B. 9.1% C. 8.1% D. 7.1%

Solution:

$$\text{Percent Increase of Temperature} = \frac{T_L' - T_L}{T_L} = \frac{T_L'}{T_L} - 1 \text{ of heat addition}$$

Original COP: Doubling the COP:

$$5 = \frac{T_L}{T_H - T_L} \qquad 10 = \frac{T_L'}{T_H - T_L'}$$

$$\frac{1}{5} = \frac{T_H - T_L}{T_L} \qquad \frac{1}{10} = \frac{T_H - T_L'}{T_L'}$$

$$\frac{1}{5} = \frac{T_H}{T_L} - 1 \qquad \frac{1}{10} = \frac{T_H}{T_L'} - 1$$

$$\frac{T_H}{T_L} = 1.2;\ \text{eq.}1 \qquad \frac{T_H}{T_L'} = 1.1;\ \text{eq.}2$$

Dividing eq. 1 and eq. 2:

$$\frac{\frac{T_H}{T_L}}{\frac{T_H}{T_L'}} = \frac{1.2}{1.1} = 1.091 = \frac{T_L'}{T_L}$$

$$\text{Percent Increase of heat addition} = 1.091 - 1 = 0.091 = \mathbf{9.1\%}$$

229. An ammonia water-cooled compressor receives the refrigerant at specific volume 62 L/kg. It has a piston displacement rate of 5 m^3/min. If a squirrel cage motor running at 1200 rpm drives the compressor and average piston speed is 490 m/min, calculate size of cylinder bore.

A. 20.4 cm B. 26.0 cm C. 16.13 cm D. 13.6 cm

Solution:

$$\text{Piston speed} = 2LN$$

$$490 = 2L(1200)$$

$$L = 0.204\text{ m} = 20.4\text{ cm}$$

$$V_D = \frac{\pi}{4}D^2LN = \frac{\pi}{4}D^2(0.204)(1200) = 5$$

$$D = 0.1613\text{ m} = \mathbf{16.13\ cm}$$

230. If the initial volume of an ideal gas is compressed the one-half its original volume and to twice its temperature, the pressure:

A. Doubles B. Quadruples C. Remains constant D. Halves

Solution:

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{P_1V_1}{T_1} = \frac{P_2\left(\frac{1}{2}V_1\right)}{2T_1}$$
$$P_2 = 4P_1$$
$\therefore$ The pressure **quadruples**.

231. If the gage pressure of a medium is 30 kPa (vacuum) and the atmospheric pressure is 101.3 kPa, the absolute pressure will be?

A. 131.3 kPa B. -71.3 kPa C. 71.3 kPa D. -131.3 kPa

Solution:

$$P_{abs} = P_{atm} - P_{vac} = 101.3 \text{ kPa} - 30 \text{ kPa} = \mathbf{71.3\ kPa}$$

232. If a particle has a velocity of 4 meters per second and a kinetic energy of 144 Joules, then the mass, in kilograms of this particle must be?

A. 44 B. 16 C. 18 D. 24

Solution:

$$KE = \frac{1}{2}mV^2$$
$$144 = \frac{1}{2}m(4)^2$$
$$m = \mathbf{18}\text{ kg}$$

233. A condenser vacuum gauge reads 715 mm Hg when the barometer stands at 757 mm Hg. State the absolute pressure in the condenser in kN/m^2 or kPa.

A. 5.6 kPa B. 5.9 kPa C. 6.5 kPa D. 5.2 kPa

Solution:

$$P_{abs} = P_{atm} - P_{vac} = 757 - 715 = 42 \text{ mm Hg}\left(\frac{101.325 \text{ kPa}}{760 \text{ mm Hg}}\right) = \mathbf{5.6\ kPa}$$

234. Determine the force in newton in a piston of 465 mm^2 area with a pressure of 0.172 MPa.

A. 65 N B. 72 N C. 80 N D. 111 N

Solution:

$$F = PA = 0.172 \text{ MPa}\left(\frac{10^6 \text{ Pa}}{1 \text{ MPa}}\right)(465 \text{ mm}^2)\left(\frac{1 \text{ m}^2}{10^6 \text{ mm}^2}\right) = 79.98 \approx \mathbf{80\ N}$$

235. One piston of a hydraulic press has an area of 1 cm^2. The other piston has an area of 25 cm^2. If a force of 150 N is applied on the smaller piston, what will be the total force on the larger piston if both piston surfaces are on the same level?

A. 6 N B. 175 N C. 3750 N D. 4250 N

Solution:

$$\frac{A_1}{F_1} = \frac{A_2}{F_2}$$
$$\frac{150}{1} = \frac{F_2}{25}$$
$$F_2 = \mathbf{3750\ N}$$

236. The work done on air is 10.86 kJ/kg, determine the compressor power if it is receiving 272 kg/min of air.

A. 36.72 hp B. 49.23 hp C. 2954 hp D. 66 hp

Solution:

$$W = 10.86\left(\frac{272}{60}\right) = 49.232\frac{\text{kJ}}{\text{s}}\text{ or kW}\left(\frac{1\text{ hp}}{0.746\text{ kW}}\right) = \mathbf{66\ hp}$$

237. A water tank 18 ft wide, 14 ft long, and 4 ft high, calculate the pressure at the bottom of the tank.

A. 1.733 psi B. 1.999 psi C. 2.337 psi D. 3.773 psi

Solution:

$$P = 62.4\frac{\text{lb}_f}{\text{ft}^3}(4\text{ ft})\left(\frac{1\text{ ft}^2}{144\text{ in}^2}\right) = \mathbf{1.733\ psi}$$

238. What is the pressure of 750 mm Hg in kN/m^2?

A. 90 B. 100 C. 103 D. 110

Solution:

$$P = 750\text{ mm Hg}\left(\frac{101.325\text{ kPa}}{760\text{ mm Hg}}\right) = \mathbf{100}\text{ kPa}$$

239. A double purpose tank 18 ft wide, 24 ft long and 4 ft depth is filled with water. What is the weight of water in the tank in long tons?

A. 49 tons B. 48 tons C. 54 tons D. 50 tons

Solution:

$$W = 62.4\frac{\text{lb}_f}{\text{ft}^3}[18(24)(4)]\text{ft}^3 = 107{,}827.2\text{ lb}_f\left(\frac{1\text{ ton}}{2200\text{ lb}_f}\right) = \mathbf{49\ tons}$$

240. Oil flows through a 16 tube single cooler with a velocity of 2 m/s. The internal diameter of the tube is 30 mm and oil density is 0.85 g_m/ml. Find the volume flow in liters per sec.

A. 22.62 B. 32.22 C. 62.22 D. 42.62

Solution:

$$\text{Volume flow rate} = \pi(0.015)^2(2)(16) = 0.02262\frac{\text{m}^3}{\text{s}} = \mathbf{22.62}\text{ liters/s}$$

241. A substance temperature was 620°R. What is the temperature in °C?

A. 50.7 B. 45.54 C. 71.11 D. 91.44

Solution:

$$T, ^\circ C = [(620 - 460) - 32]\left(\frac{5}{9}\right) = \mathbf{71.11}^\circ C$$

242. An unknown volume of container gas of 1 atmosphere is allowed to expand to another container of 10 m^3 volume at 500 mmHg at constant temperature. Find the unknown volume.

A. 6.58 m^3 B. 6.75 m^3 C. 5.67 m^3 D. 7.65 m^3

Solution:

$$P_1V_1 = P_2V_2$$
$$760V_1 = 500(10)$$
$$V_1 = \mathbf{6.58\ m^3}$$

243. An iron block weighs 5 Newton and has a volume of 200 cm^3. What is the density of the block?

A. 2458 kg/m^3 B. 2485 kg/m^3 C. 2584 kg/m^3 D. 2549 kg/m^3

Solution:

$$\text{Density} = \text{specific weight (At sea level or near the surface of the earth)}$$
$$= \frac{5\ N}{200\ cm^3}\left(\frac{10^6\ cm^3}{1\ m^3}\right)\left(\frac{1\ kg}{9.8066\ N}\right) = \mathbf{2549\ kg/m^3}$$

244. If air is at a pressure of 22.22 psia and at a temperature of 800°R, what is the specific volume?

A. 11.3 ft^3/lb_m B. 33.1 ft^3/lb_m C. 13.3 ft^3/lb_m D. 31.3 ft^3/lb_m

Solution:

$$P\upsilon = RT$$
$$\upsilon = \frac{53.34(800)}{22.22(144)} = \mathbf{13.3\ ft^3/lb_m}$$

245. The Specific gravity of mercury is 13.55. What is the specific weight of mercury?

A. 123.9 kN/m^3 B. 139.2 kN/m^3 C. 132.9 kN/m^3 D. 193.2 kN/m^3

Solution:

$$\gamma = 13.55(9.8066) = \mathbf{132.9\ kN/m^3}$$

246. The equivalent weight of mass 10 kg at a location where the acceleration of gravity is 9.77 m/s^2?

A. 97.7 N B. 79.7 N C. 77.9 N D. 977 N

Solution:

$$\text{Weight} = \frac{mg}{k} = \frac{10(9.77)}{1} = \mathbf{97.7\ N}$$

247. A transportation company specializes in the shipment of pressurized gaseous materials. An order is received from 100 liters of a particular gas at STP (32°F and 1 atm). What minimum volume tank is necessary to transport the gas at 80°F and maximum pressure of 8 atm?

A. 16 liters B. 14 liters C. 10 liters D. 12 liters

Solution:

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{1(100)}{(32+460)} = \frac{8(V_2)}{(80+460)}$$

$$V_2 = 13.72 \approx \mathbf{14\ liters}$$

248. 100 g of water are mixed with 150 g of alcohol (density = 790 kg/m^3). What is the specific volume of the resulting mixtures, assuming that the fluids mixed completely?

A. 0.82 x 10^{-3} m^3/kg B. 0.88 x 10^{-3} m^3/kg C. 0.63 x 10^{-3} m^3/kg D. 1.16 x 10^{-3} m^3/kg

Solution:

$$\text{Mass of mixtures} = 100 + 150 = 250\ \text{g}$$

$$\text{Volume of mixture} = \frac{0.100}{1000} + \frac{0.150}{790} = 0.0029\ \text{m}^3$$

$$\text{Specific Volume of mixture} = \frac{0.00029}{0.250} = \mathbf{1.16\ \times 10^{-3}\ m^3/kg}$$

249. How much does 30 lb_m weigh on the moon? (g_{moon} = 5.47 ft/s^2).

A. 2.0 lb_f B. 3.2 lb_f C. 3.4 lb_f D. 5.096 lb_f

Solution:

$$\text{Weight} = \frac{mg_m}{k} = \frac{30(5.47)}{32.2} = \mathbf{5.096\ lbf}$$

250. A 10 kg block is raised vertically 3 meters. What is the change in potential energy?

A. 320 J B. 350 km-m^2/s^2 C. 294 J D. 350 N-m

Solution:

$$\text{PE} = \frac{mgz}{k} = \frac{10(9.8066)(3)}{1} = \mathbf{294\ J}$$

251. How many cubic meters is 100 gallons of liquid?

A. 3.7850 m^3 B. 0.1638 m^3 C. 0.3785 m^3 D. 1.638 m^3

Solution:

$$100\ \text{gal}\left(3.785\frac{\text{liters}}{\text{gal}}\right)\left(\frac{1\ \text{m}^3}{1000\ \text{liters}}\right) = \mathbf{0.3785\ m^3}$$

252. Steam turbine is receiving 1014 lb_m/hr of steam, determine the horsepower output of the turbine if the work done by steam is 251 Btu/lbm.

A. 100 hp B. 462.7 hp C. 200 hp D. 600 hp

Solution:

$$\dot{W} = 251\frac{\text{Btu}}{\text{lb}_\text{m}}\left(1014\frac{\text{lb}_\text{m}}{\text{hr}}\right)\left(\frac{1\text{hp}}{2545\frac{\text{Btu}}{\text{hr}}}\right) = \mathbf{100\ hp}$$

253. What is the resulting pressure when one pound of air at 15 psia and 200°F is heated at constant volume to 800°F?

A. 32.1 psia B. 15 psia C. 28.6 psia D. 36.4 psia

Solution:

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$P_2 = \left(\frac{800+460}{200+460}\right)(15) = \mathbf{28.6\ psia}$$

254. A bicycle tire has a volume of 600 cm^3. It is inflated with carbon dioxide to pressure of 551.43 kPa, 20°C. How many grams of CO_2 are contained in the tire? R_{CO2} = 0.18896 kJ/kg.K.

A. 5.98 g B. 6.43 g C. 4.63 g D. 3.83 g

Solution:

$$m = \frac{PV}{RT} = \frac{\frac{551.43(600)}{10^6}}{0.18896(20+273)} = 0.00598 = \mathbf{5.98\ g}$$

255. The absolute pressure at the bottom of a vertical column of water is 15.5 psia. What is the height of this column?

A. 22 in B. 9.2 in C. 12 in D. 9.8 in

Solution:

$$h = \frac{(15.5-14.7)(144)}{62.4} = 1.846\text{ ft} \approx \mathbf{22\ in}$$

256. A water temperature rise of 18°F in the water cooled condenser is equivalent to what in °C?

A. 7.78°C B. 10°C C. 263.56 K D. -9.44°C

Solution:

$$\Delta T = 18°\text{F}\left(\frac{1°\text{C}}{1.80°\text{F}}\right) = \mathbf{10°C}$$

257. An oil storage tank contains oil with specific gravity of 0.88 and depth of 20 meters. What is the hydrostatic pressure at the bottom of the tank in kg/cm^2?

A. 1.67 B. 1.76 C. 1.56 D. 1.87

Solution:

$$P = 0.88(9{,}8066)(20) = 172.60\,\frac{\text{kN}}{\text{m}^2}\left(\frac{1\ \text{m}^2}{10^4\ \text{cm}^2}\right)\left(\frac{10^3\ \text{N}}{1\ \text{kN}}\right)\left(\frac{1\ \text{kg}}{9.8066\ \text{N}}\right) = \mathbf{1.76}\ \text{kg/cm}^2$$

258. A vertical column of water will be supported to what height by standard atmospheric pressure?

A. 34 ft B. 36 ft C. 24 ft D. 26 ft

Solution:

$$h = \frac{14.7(144)}{62.4} = \mathbf{34\ ft}\ \text{of water}$$

259. The specific weight of liquid is 60 lb/ft^3. What is the equivalent to kN/m^3?

A. 9.334 B. 9.249 C. 9.643 D. 9.420

Solution:

$$60\,\frac{\text{lb}}{\text{ft}^3}\left(\frac{1\ \text{kg}}{2.205\ \text{lb}}\right)\left(\frac{0.0098066\ \text{kN}}{1\ \text{kg}}\right)\left[\frac{(3.28\ \text{ft})^3}{(1\ \text{m})^3}\right] = \mathbf{9.420}\ \text{kN/m}^3$$

260. A cylinder weighs 150 lb_f. Its cross-sectional area is 40 square inches. When the cylinder stands vertically on one end, what pressure does the cylinder exert on the floor?

A. 14.1 kPa B. 58.2 kPa C. 0.258 bar D. 0.141 bar

Solution:

$$P = \frac{F}{A} = \frac{150}{40} = 3.75\ \text{psi}\left(\frac{6.895\ \text{kPa}}{1\ \text{psi}}\right)\left(\frac{1\ \text{bar}}{100\ \text{kPa}}\right) = 0.2586 \approx \mathbf{0.258\ bar}$$

261. What is the absolute pressure exerted on the surface of a submarine cruising 300 ft below the free surface of the sea? Assume specific gravity of sea water is 1.03.

A. 133.9 psia B. 148.6 psia C. 100.7 psia D. 103.7 psia

Solution:

$$P_{abs} = \frac{62.4(1.03)(300)}{144} + 14.7 = \mathbf{148.6\ psia}$$

262. Air enters a nozzle steadily at 2.21 kg/m^3 and 30 m/s. What is the mass flow rate through the nozzle if the inlet area of the nozzle is 80 cm^2?

A. 0.35 kg/s B. 3.5 kg/s C. 5.3 kg/s D. 0.53 kg/s

Solution:

$$\text{Mass flow rate} = \left(\frac{80}{10^4}\right)(30)(2.21) = \mathbf{0.53\ kg/s}$$

263. What is the work required to accelerate an 800-kg car from rest to 100 km/h on a level road?

A. 308.6 kJ B. 806.3 kJ C. 608.3 kJ D. 386 kJ

Solution:

$$W = KE = \frac{1}{2}(800)\left[100\ \frac{\text{km}}{\text{h}}\left(\frac{1000\ \text{m}}{1\ \text{km}}\right)\left(\frac{1\ \text{h}}{3600\ \text{s}}\right)\right]^2[1(1000)] = \mathbf{308.6\ kJ}$$

264. Assuming that there are no heat effects and no friction effects, find the speed of a 3220-lb_m body after it falls 778 ft from rest.

A. 422 ft/s B. 424 ft/s C. 224 ft/s D. 424 ft/s

Solution:

$$\text{Velocity} = [2(32.174)(778)]^{1/2} = \mathbf{224\ ft/s}$$

265. What is the flow rate through a pipe 4 inches in diameter carrying water at a velocity of 11 ft/s?

A. 430.84 gpm B. 7.18 gpm C. 340.28 gpm D. 39.16 gpm

Solution:

$$\text{Volumetric flow rate} = 3.1416\left(\frac{2}{12}\right)^2(11) = 0.96\frac{\text{ft}^3}{\text{s}}\left(7.48\frac{\text{gal}}{\text{ft}^3}\right)\left(\frac{60\ \text{s}}{\text{min}}\right)$$
$$= \mathbf{430.84\ gpm}$$

266. If the specific weight of a liquid is 58.5 lb_f per cubic foot, what is the specific volume of the liquid in cm^3/g?

A. 0.5321 cm^3/g B. 0.6748 cm^3/g C. 0.9504 cm^3/g D. 1.0675 cm^3/g

Solution:

$$\text{Density} = \text{specific weight}$$
$$= 58.50\ \text{lb}_\text{f}/\text{ft}^3\ \text{(At sea level or near the surface of the earth)}$$
$$\text{Specific Volume} = \left(\frac{1}{58.50}\right) = 0.0171\frac{\text{ft}^3}{\text{lb}_\text{m}}\left(\frac{1\ \text{lb}_\text{m}}{453.6\ \text{g}}\right)[(30.48)^3\text{cm}^3/\text{ft}^3]$$
$$= \mathbf{1.0675\ cm^3/g}$$

267. What is the resulting pressure when one pound of air at 0.3 psig and 200°F is heated at constant volume to 800°F?

A. 0.572 psig B. 28.6 psia C. 7.857 psia D. 1.2 psig

Solution:

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$
$$\frac{0.30 + 14.70}{200 + 160} = \frac{P_2}{800 + 460}$$
$$P_2 = \mathbf{28.6\ psia}$$

268. A small pump serving as model, when tested in laboratory using water at 3600 rpm, delivered 30 cfs at a head of 125 ft. If the efficiency of this model pump is 84%, predict the

horsepower input to the prototype pump if it is to develop the same head as model pump and the model pump has a scale ratio of 1:10. Assume the efficiency of the prototype pump is 90%.

A. 50.6 hp B. 4730 hp C. 3740 hp D. 60.5 hp

Solution:

$$P_m = \frac{\gamma Q_m h_m}{550\eta_m} = \frac{62.4(3)(125)}{550\,(0.84)} = 50.6 \text{ hp}$$

$$\eta_p = \eta_m \left(\frac{h_p}{h_m}\right)^{1/2}\left(\frac{D_m}{D_p}\right) = 3600(1)^{1/2}\left(\frac{1}{10}\right) = 360 \text{ rpm}$$

$$Q_p = \frac{Q_m\left(\frac{D_p}{D_m}\right)^3 \eta_p}{\eta_m} = \frac{3(10^3)(360)}{3600} = 300 \text{ cfs}$$

$$P_p = \frac{\gamma Q_p h_p}{550\eta_p} = \frac{62.4(300)(125)}{550(0.90)} = \mathbf{4730\ hp}$$

269. Pump at is best efficiency point (BEP) has a capacity of 10,500 gpm while developing a head of 60 ft at a rotative speed of 1450 rpm. What is the specific speed of the pump?

A. 2760 B. 1450 C. 2476 D. 6892

Solution:

$$N_s = \frac{(n,\text{rpm})\,(Q,\text{gpm})^{1/2}}{(h,\text{ft})^{3/4}} = \frac{1450\,(10{,}500)^{1/2}}{60^{3/4}} = \mathbf{6892}$$

270. A pump will be installed below the reservoir water surface with a required net positive suction head ($NPSH_R$) of 50 ft. The barometric pressure is 14.3 psia, and the vapor pressure is 0.5 psia. Assume friction losses in the intake piping are 5 ft. Find the maximum allowable elevation of the pump relative to the water surface intake to avoid cavitation.

A. 45 ft B. 55 ft C. 18.2 ft D. 23.2 ft

Solution:

$$\frac{p_{atm}}{\gamma} = \frac{14.3(144)}{62.4} = 33.0 \text{ ft}$$

$$\frac{p_v}{\gamma} = \frac{0.5(144)}{62.4} = 1.154\text{ft}$$

$$NPSH_A = \left(\frac{p_{atm}}{\gamma} - \frac{p_v}{v}\right) + z_s - h_L$$

To avoid cavitation, net positive suction head available ($NPSH_A$) should be greater than the net positive suction head required ($NPSH_R$). To determine the maximum elevation of the pump let ($NPSH_A$) = ($NPSH_R$).

$$\therefore (z_s)_{max} = NPSH_R - \left(\frac{p_{atm}}{\gamma} - \frac{p_v}{\gamma}\right) + h_L = 50 - (33.0 - 1.154) + 5 = \mathbf{23.2\ ft}$$

271. A centrifugal pump is at best efficiency point (BEP). Assume the pump characteristic are head, h = 7 m, flow rate, Q = 19 liters/s, and rotative speed n = 1170 rpm. Find the specific speed in SI units.

A. 0.4 B. 0.71 C. 10.41 D. 3.94

Solution:

$$N_s = \frac{(n_s,\frac{rad}{s})(Q,\frac{m^3}{s})^{1/2}}{\left(g,\frac{m}{s^2}\right)^{3/4}(h,m)^{3/4}}$$

$$n = \frac{1170\,(2\pi)}{60} = 123\ rad/s$$

$$N_s = \frac{123\left(\frac{19}{1000}\right)^{1/2}}{(9.81)^{3/4}(7)^{3/4}} = \mathbf{0.71}$$

272. The pressure of a confined gas at a constant temperature is tripled, what will happen to the volume?

A. The volume will be tripled

B. The volume will be reduced to one-third of its original value

C. The volume will remain unchanged

D. The volume is constant

Solution:

$$P_1V_1 = P_2V_2$$
$$P_1V_1 = 3P_1V_2$$
$$V_2 = \frac{1}{3}V_1$$

The volume will be reduced to one-third of its original value.

273. A 15 in. diameter fan operates at 1600 rpm and develops a head of 6 in. of water and delivers 120 cfm. What volumetric capacity for geometrically similar fan will develop 6 in of water at 1300 rpm?

A. 147.7 cfm B. 181.8 cfm C. 97.5 cfm D. 79.2cfm

Solution:

$$\frac{H_1}{N_1^2 D_1^2} = \frac{H_2}{N_2^2 D_2^2} \quad \text{For: } H_1 = H_2 \quad \frac{D_2}{D_1} = \frac{N_1}{N_2}$$

$$\frac{Q_1}{N_1 D_1^3} = \frac{Q_2}{N_2 D_2^3}; \quad Q_2 = Q_1\left(\frac{N_2 D_2^3}{N_1 D_1^3}\right)$$

$$Q_2 = Q_1\left(\frac{N_1^2}{N_2^2}\right) = Q_1\left(\frac{N_1}{N_2}\right)^2$$

$$Q_2 = 120\ cfm\left(\frac{1600}{1300}\right)^2 = \mathbf{181.8\ cfm}$$

274. A radial-flow pump operating at maximum efficiency at a specific speed of 2500 is to deliver 260 gpm against a head of 129 ft at a rotative speed of 2100 rpm. Find the required number of stages (i.e., impellers).

A. 2 stages B. 3 stages C. 4 stages D. 5 stages

Solution:

$$N_s = \frac{nQ^{0.5}}{H^{0.75}} = 2500 = \frac{2100(2600)^{0.5}}{H^{0.75}}$$

$$H = 32.29 \text{ ft; number of stages} = \frac{129}{32.29} = \mathbf{4\ stages} \text{ will be needed}$$

275. How many identical turbines, operating at 139.0 rpm and 91% efficiency (specific speed = 5.4), are needed to exploit a head of 1200 ft and a flow of 1660 ft^3/s?

A. 2 turbines B. 3 turbines C. 4 turbines D. 5 turbines

Solution:

$$N_s = \frac{n\left(\frac{bhp}{\text{number of runner}}\right)^{0.5}}{H^{5/4}}$$

$$bhp = \frac{\eta Q\gamma H}{550} = \frac{0.91(1660)(62.4)(1200)}{550} = 206{,}000 \text{ bhp}$$

$$5.4 = \frac{139\left(\frac{206{,}000}{\text{number of runner}}\right)^{0.5}}{1200^{5/4}}$$

$$\text{number of runner} = 2.7; \text{ use } \mathbf{3\ turbines}$$

276. How many poles should a 60-Hz generator have, if it is connected to a turbine operating under a design head of 3000 ft with a flow of 82 cfs? Assume turbine specific speed and efficiency 3 and 84 percent respectively.

A.10-pole B. 12-pole C. 14-pole D. 16-pole

Solution:

$$N_s = \frac{n\left(\frac{bhp}{\text{number of runner}}\right)^{0.5}}{H^{5/4}}$$

$$bhp = \frac{\eta Q\gamma H}{550} = \frac{0.84(82)(62.4)(3000)}{550} = 23{,}444 \text{ bhp}$$

$$3 = \frac{n(23{,}444)^{0.5}}{3000^{5/4}} \qquad n = 435 \text{ rpm}$$

$$N_{poles} = 120\frac{f}{n} = \frac{120(60)}{435} = 16.55 \text{ use } \mathbf{16\text{-}pole} \text{ generator}$$

277. It is proposed to build a dam in a river where the flow rate is 10 m^3/s and a 32-m drop in elevation can be achieved for flow through a turbine. If a turbine is 82 percent efficient, what is the maximum power that can be achieved? Specific gravity of river is 0.998.

A. 2570 kW B. 3133 kW C. 3820 kW D. 262 kW

Solution:

$$P = \eta Q\gamma H = 0.82(10)[(0.998)(9.81)](32) = \mathbf{2570\ kW}$$

278. What type of turbine delivers 25,000 bhp at 500 rpm under a net head of 5350 ft?

A. Impulse turbine B. Francis turbine C. Kaplan turbine D. Propeller turbine

Solution:

$$N_s = \frac{n\left(\frac{bhp}{\text{number of runner}}\right)^{0.5}}{H^{5/4}} = \frac{500\,(25{,}000)^{0.5}}{5350^{5/4}} = 1.73$$

$$2 < N_s < 10\ (\textbf{Impulse turbine})$$

279. A 26-hp pump delivers 475 gpm of gasoline (γ = 42.5 lb/ ft^3) at 20 C with 78% efficiency. What pressure rise result across the pump?

A. 30.2 psi B. 32.7 psi C. 120.3 psi D. 73.2 psi

Solution:

$$P = \frac{Q\gamma H}{\eta} = \frac{Q\Delta p}{\eta}\ \frac{475(0.002228)}{0.78} = 26(550)$$

$$\Delta p = 10{,}540\ \text{lb/ft}^3\ =\ \mathbf{73.2\ psi}$$

280. A model pump delivering water at 180°F (γ = 60.6 lb/ ft^3; p_{vapor} = 7.54 psia) at 900 gpm and 2500 rpm begins to cavitate when the inlet pressure and velocity are 13 psia and 22 fps. Find the required NPSH of a prototype which is 4 times larger and runs at 1100 rpm.

A. 63.5 ft B. 20.49 ft C. 6.61 ft D. 36 ft

Solution:

$$NPSH = \frac{p_{inlet} - p_{vapor}}{\gamma} + \frac{V_{inlet}^2}{2g}$$

$$NPSH_{model} = \frac{[13(144) - 7.54(144)]}{60.6} + \frac{22^2}{2(32.2)} = 20.49\ \text{ft}$$

$$NPSH_{prototype} = NPSH_{model}\left(\frac{N_p}{N_m}\right)^2\left(\frac{D_p}{Dm}\right)^2 = 20.49\left(\frac{1100}{2500}\right)^2(4)^2 = \mathbf{63.5\ ft}$$

281. The diameter of the discharge pipe is 8 in. and that of the intake pipe is 10 in. The pressure gage at discharge reads 32 psi, and vacuum gage at the intake reads 12 in. Hg. If the discharge flow rate = 4.0 ft^3/s of water and the brake horsepower is 49.0, find the efficiency. The intake and the discharge are at the same elevation.

A. 82.2% B. 80.9% C. 55.8% D. 58.46%

Solution:

$$V_s = \frac{Q}{A_s} = \frac{4.0}{\left(\frac{\pi\left(\frac{10}{12}\right)^2}{4}\right)} = 7.33\text{ft/s} \quad V_d = \frac{Q}{A_d} = \frac{4.0}{\left(\frac{\pi\left(\frac{8}{12}\right)^2}{4}\right)} = 11.46\text{ft/s}$$

$$H = \frac{p_d}{\gamma} + \frac{V_d^2}{2g} - \left(\frac{p_s}{\gamma} + \frac{V_s^2}{2g}\right) = \frac{32(144)}{62.4} + \frac{(11.46)^2}{2(32.2)} - \frac{(-12)(0.491)(144)}{62.4} + \frac{7.33^2}{2(32.2)}$$

$$= 88.67\ \text{ft}$$

$$P = \frac{Q\gamma H}{\eta} = \frac{4.0(62.4)(88.67)}{\eta(550)} = 49; \quad \eta = 82.1 \approx \mathbf{82.2\%}$$

282. A piston positive-displacement pump (PDP) has a 6-in diameter and a 2.5-in stroke. Its crankshaft rotates at 300 rpm. Calculate its output at 94 percent volumetric efficiency.

A. 12.27 cfm B. 13.5 cfm C. 10 cfm D. 11.53 cfm

Solution:

$$V_{displaced} = \frac{\pi D^2}{4} LN\eta_v = \frac{\pi\left(\frac{6}{12}\right)^2}{4}\left(\frac{2.5}{12}\right)(300)(0.94) = \mathbf{11.53\ cfm}$$

283. A centrifugal pump (efficiency 88%) lifts water through a total height of 40 m from a reservoir to discharge. Pumping is through 300 m of 75 mm diameter pipe at the rate of 20 liter/s. If pipe friction, f = 0.025, what horsepower is required?

A. 28.4 kW B. 32.2 kW C. 25kW D. 9kW

Solution:

$$V = \frac{Q}{A_s} = \frac{0.02}{\left(\frac{\pi(0.075)^2}{4}\right)} = 4.53\ m/s$$

$$h_f = \frac{fLDV^2}{2g} = 0.025\left(\frac{300}{0.075}\right)\left[\frac{4.53^2}{2(9.81)}\right] = 104.6\ m$$

$$P = \frac{Q\gamma H}{\eta} = \frac{0.02(9.81)(144.6)}{0.88} = \mathbf{32.2\ kW}$$

284. In order to predict the behaviour of a small oil pump, tests are to be made on a model using air. The pump is to be driven by a 1/20-hp motor at 1800 rpm and a ¼-hp motor is available to drive the air at 600 rpm. Using specific gravity of oil at 0.912 and density of air constant at 0.076 lb/ ft^3, what size model should be built?

A. The model should be 2 times as large as the oil pump.

B. The model should be 5 times as large as the oil pump.

C. The model should be 8 times as large as the oil pump.

D. The model should be 10 times as large as the oil pump.

Solution:

$$\left(\frac{P}{\rho_{oil} D_p^5 N^3}\right)_{prototype} = \left(\frac{P}{\rho_{air} D_m^5 N^3}\right)_{model}$$

$$\frac{\frac{1}{20}}{0.912(62.4)(D_p^5)(1800)^3} = \frac{\frac{1}{4}}{0.0766(D_m^5)(600)^3}$$

$$D_m = 10D_p$$

The model should be 10 times as large as the oil pump.

285. A double-overhung impulse turbine installation is to develop 20,000 hp at 275 rpm under a net head of 1100 ft. Determine the specific speed.

A. 4.34 B. 6.14 C. 203.61 D. 144

Solution:

$$N_s = \frac{NP^{0.5}}{H^{5/4}} = \frac{275\left(\frac{20,000}{2}\right)^{0.5}}{1100^{5/4}} = \mathbf{4.34}$$

286. An impulse wheel at best produces 125 hp under a head of 210 ft. By what percent should the speed be increased for a 290-ft head?

A. 82.25% B. 17.5% C. 72.41% D. 27.59%

Solution:

For same wheel: $\frac{N_1}{N_2} = \left(\frac{H_1}{H_2}\right)^{1/2}$

$$N_2 = N_1\left(\frac{H_2}{H_1}\right)^{1/2} = N_1\left(\frac{290}{210}\right)^{1/2} = 1.175N_1$$

Thus, the speed should be increased $\mathbf{17.5\%}$.

287. What is the power ratio of a pump and its 1/5 scale model if the ratio of heads is 4 to 1?

A. 20 B. 200 C. 12.5 D. 125

Solution:

$$D_p = 5D_m;\ 4H_p = H_m;\ \rho_p = \rho_m$$

$$\frac{P_p}{P_m} = \left(\frac{D_p}{D_m}\right)^5\left(\frac{N_p}{N_m}\right)^3 \text{ and } \frac{N_p}{N_m} = \left(\frac{H_p}{H_m}\right)^{\frac{1}{2}}\left(\frac{D_m}{D_p}\right)$$

$$\frac{P_p}{P_m} = \left(\frac{H_p}{H_m}\right)^{\frac{3}{2}}\left(\frac{D_m}{D_p}\right)^2 = (4)^{3/2}(5)^2 = \mathbf{200}$$

288. The speed of a centrifugal pump is doubled. By what factor does the pump head change?

A. 0.125 B. 0.25 C. 4 D. 8

Solution:

For $D_1 = D_2$: $\frac{H_1}{H_2} = \left(\frac{N_1}{N_2}\right)^2$ & $N_2 = 2N_1$

$$H_2 = \left(\frac{N_2}{N_1}\right)^2 H_1 = (2)^2H_1 = \mathbf{4}H_1$$

289. Compute the specific volume of an air-vapor mixture in cubic meter per kg of dry air when the following conditions prevail: t = 40°C, w = 0.015 kg/kg, and P_t = 90 kPa.

A. 0.99 m^3/kg B. 0.89 m^3/kg C. 0.79 m^3/kg D. 0.69 m^3/kg

Solution:

$$\upsilon = \frac{R_aT}{P_t - P_v}$$

Solving for P_v:

$$w = \frac{0.622\,P_v}{P_t - P_v}$$

$$0.015 = \frac{0.622 P_v}{90 - P_v}$$

$$P_v = 2.12 \text{ kPa}$$

thus;

$$\upsilon = \frac{0.287(40+273)}{90-2.12} = 1.02 \approx \mathbf{0.99\ m^3/kg}$$

290. A coil has an inlet temperature of 70°F and outlet of 80°F. If the mean temperature of the coil is 130°F, find the bypass factor of the coil.

A. 0.28 B. 1.2 C. 0.82 D. 0.83

Solution:

$$\text{Bypass factor} = \frac{t_{mean} - t_{db \text{ of outlet air}}}{t_{mean} - t_{wb \text{ of inlet air}}}$$

$$BF = \frac{130-80}{130-70} = \mathbf{0.83}$$

291. Compute the pressure drop of 35°C air flowing with a mean velocity of 5m/s in a circular sheet-metal duct 400mm in diameter and 25 m long. Use friction factor, f = 0.04, and ρ_{air} = 1.3799 kg/m^3.

A. 431.22 Pa B. 221.34 Pa C. 312.24 Pa D. 422.31 Pa

Solution:

$$\Delta P = \frac{fLV^2 \rho}{2D} = \frac{0.04(25)(5)^2(1.3799)}{2(0.35)} = \mathbf{431.22\ Pa}$$

292. Pressure difference of 400 Pa is available to force 20°C air through a circular sheet-metal duct 450 mm in diameter and 25 m long. At 20°C, ρ = 1.204 kg/m^3 and take friction factor, f = 0.016. Determine the velocity.

A. 27.34 ft/s B. 43.72ft/s C. 89.68 ft/s D. 86.98 ft/s

Solution:

$$\Delta P = \frac{fLV^2 \rho}{2D}$$

$$400 = \frac{0.016(25)V^2(1.204)}{2(0.450)}$$

$$V = \mathbf{27.34\ ft/s}$$

293. A rectangular duct has a dimension of 0.25 m by 2 m. Determine the equivalent diameter of the duct.

A. 0.50 m B. 0.60 m C. 0.70 m D. 0.40 m

Solution:

$$D_{eq} = \frac{2ab}{a+b} = \frac{2(0.25)(2)}{0.25+2} = \mathbf{0.40\ m}$$

294. To what height will a barometer column rise if the atmospheric conditions are 13.9 psia and 68°F and barometer fluid is mercury?

A. 3.56 ft B. 5.36 ft C. 2.36 ft D. 3.26 ft

Solution:

$$h = \frac{P_{atm} - P}{\gamma} = \mathbf{2.36\ ft}$$

295. To what height will a barometer column rise if the atmospheric conditions are 13.9 psia and 68°F and barometer fluid is ethyl alcohol? Note: @ 68°F; P_v =138.5 lb_f/ft^3 and specific gravity of 0.79 for ethyl alcohol:

A. 79.37 in B. 37.79 in C. 353.54 in D. 453.53 in

Solution:

$$h = \frac{P_{atm} - P}{\gamma} = \frac{13.9(144) - 138.5}{0.79(62.4)} = 37.794\ \text{ft} = \mathbf{453.53\ in}$$

296. What is the pressure 7000 ft below the water surface of the ocean? Neglect compressibility.

A. 512,000 psf B. 324,500 psf C. 447,000 psf D. 213,000 psf

Solution:

$$P = (SG)\rho h = 1.023\left(62.4\,\frac{lb_f}{ft^3}\right)(7000\ \text{ft}) \approx \mathbf{447{,}000\ lbf/ft^2\ (psfg)}$$

297. If atmospheric air 14.7 psia and 60°F at sea level, what is the pressure at 14212 ft altitude if air is incompressible? Note: @ 60°F, the density of air is 0.0763 lb_m/ft^3; P_1 = 14.7 psia.

A. 5.4674 psia B. 7.5304 psia C. 7.1696 psia D. 7.1966 psia

Solution:

$$\text{air is incompressible: } \Delta P = P_2 - P_1$$

$$\Delta P = \gamma h = 0.0763(14.212)\left(\frac{1}{144}\right) = 7.5304\ \text{psia}$$

$$P_2 = P_1 - \Delta P = 14.7 - 7.5304 = \mathbf{7.1696\ psia}$$

298. Water (ρ = 62.4 lb_m/ft^3) is flowing through a pipe. A pitot-static gage registers 3.0 inches of mercury. What is the velocity of the water in the pipe? Note: ρ_{Hg} = 848.6 lb_m/ft^3.

A. 14.7 ft/s B. 41.7 ft/s C. 71.4 ft/s D. 74.1 ft/s

Solution:

$$V = \sqrt{\frac{2gh(\rho_{Hg} - \rho)}{\rho}} = \sqrt{\frac{2(32.2)\left(\frac{3}{12}\right)(848.6 - 62.4)}{62.4}} = \mathbf{14.7 ft/s}$$

299. The mass of an outside air at 50°C in an air conditioning unit is 60 kg. Find the temperature after mixing if the outside air mixed with 40 kg with recirculated air at 35°C.

A. 44°C B. 39°C C. 52°C D. 47°C

Solution:

$$m_o t_o + m_r t_r = m_s t_s$$
$$60(50) + 40(35) = (60 + 40)t_s$$
$$t_s = \mathbf{44°C}$$

300. A creamery must cool 20,000 liters of milk received each day from an initial temperature of 29°C to a final temperature of 2°C in 5 hours. If refrigeration losses amount to 10 percent of the cooling load, what must be the capacity of their refrigerating machine? Note: specific heat of milk is 3.9 kJ/kg-K and SG = 1.05.

A. 38.5 TOR B. 36.5 TOR C. 37.5 TOR D. 39.5 TOR

Solution:

The total Refrigeration Capacity with 10% refrigeration losses:

$$\dot{Q}_t = 1.10\dot{Q}$$
$$= 1.10\dot{m}C_p\Delta t$$

where:

$$\dot{m} = V\rho = \frac{20{,}000\text{L}}{5(3600)\text{s}}\left(\frac{1.05\text{kg}}{\text{L}}\right) = 1.17\text{ kg/s}$$

then;

$$\dot{Q}_T = 1.10[1.17(3.9)(29 - 2)] = 135.52\text{ kW} = \mathbf{38.5\ TOR}$$

301. How many tons of refrigeration is required to produce 10 metric tons of ice per day at -10°C from raw water at 22°C if miscellaneous losses are 15% of the chilling and freezing load?

A. 17 TOR B. 20 TOR C. 15 TOR D. 24 TOR

Solution:

Phase change of water transformed into ice:

$$\dot{Q}_T = \dot{Q}_1 + \dot{Q}_2 + \dot{Q}_3 + \dot{Q}_L$$

where:

$$\dot{Q}_1 = \dot{m}_w C_{pw}\Delta t_w$$
$$\dot{Q}_1 = \left(\frac{10{,}000\text{kg}}{24(3600)\text{s}}\right)\left(4.187\frac{\text{kJ}}{\text{kg-°C}}\right)(22 - 0)°\text{C} = 10.66\text{ kJ/s}$$
$$\dot{Q}_2 = \left(\frac{10{,}000\text{kg}}{24(3600)\text{s}}\right)\left(335\frac{\text{kJ}}{\text{kg}}\right) = 38.773\text{ kW}$$
$$\dot{Q}_3 = \left(\frac{10{,}000\text{kg}}{24(3600)\text{s}}\right)\left(2.098\frac{\text{kJ}}{\text{kg-°C}}\right)(0 + 10)°\text{C} = 2.428\text{ kW}$$
$$\dot{Q}_L = 0.15(10.66 + 38.773 + 2.428) = 7.779\text{ kW}$$
$$\dot{Q}_T = 10.66 + 38.773 + 2.428 + 7.779 = 59.64\text{ kW} = \mathbf{17\ TOR}$$

302. Five hundred kilograms of poultry enter a chiller at 8°C and are frozen and chilled to a final temperature of 18°C for storage in 15 hours. The specific heat above and below freezing are 3.18 kJ/kg-°C and 1.55 kJ/kg-°C respectively. The latent heat is 246 kJ/kg and the freezing temperature is -5°C. Compute the product load.

A. 2.75 kW B. 2.85 kW C. 2.95 kW D. 3.15 kW

Solution:

$$\dot{Q}_T = \dot{Q}_1 + \dot{Q}_2 + \dot{Q}_3$$

$$\dot{Q}_1 = \left(\frac{500\,\text{kg}}{15(3600)\,\text{s}}\right)\left(3.18\,\frac{\text{kJ}}{\text{kg-°C}}\right)(8+5)\text{°C} = 0.38\ \text{kW}$$

$$\dot{Q}_2 = \left(\frac{500\,\text{kg}}{15(3600)\,\text{s}}\right)\left(246\,\frac{\text{kJ}}{\text{kg}}\right) = 2.28\ \text{kW}$$

$$\dot{Q}_3 = \left(\frac{500\,\text{kg}}{15(3600)\,\text{s}}\right)\left(1.55\,\frac{\text{kJ}}{\text{kg-°C}}\right)(-5+18)\text{°C} = 0.19\ \text{kW}$$

$$\dot{Q}_T = \mathbf{2.85\ kW}$$

303. Fish weighing 11,000 kg with a temperature of 20°C is brought to a cold storage and which shall be cooled to -10°C in 11 hours. Find the required plant refrigerating capacity in tons of refrigeration if the specific heat of fish is 0.7 kCal/kg-°C above freezing point and 0.30 kCal/kg-°C below freezing point. The freezing point is -3°C. The latent heat of freezing is 55.5 kCal/kg.

A. 25.26 TOR B. 15.26 TOR C. 14.38 TOR D. 24.38 TOR

Solution:

$$\dot{Q}_T = \dot{Q}_1 + \dot{Q}_2 + \dot{Q}_3$$

$$\dot{Q}_1 = \left(\frac{11{,}000\,\text{kg}}{11(3600)\,\text{s}}\right)\left(0.7\,\frac{\text{kCal}}{\text{kg-°C}}\right)(20+3)\text{°C} = 4.47\ \text{kCal/s}$$

$$\dot{Q}_2 = \left(\frac{11{,}000\,\text{kg}}{11(3600)\,\text{s}}\right)\left(55.5\,\frac{\text{kJ}}{\text{kg}}\right) = 15.24\ \text{kCal/s}$$

$$\dot{Q}_3 = \left(\frac{11{,}000\,\text{kg}}{11(3600)\,\text{s}}\right)\left(0.3\,\frac{\text{kCal}}{\text{kg-°C}}\right)(-3+10)\text{°C} = 0.58\ \text{kCal/s}$$

then;

$$\dot{Q}_T = 20.47\,\frac{\text{kCal}}{\text{s}} = 85.71\text{kW} = \mathbf{24.38\ TOR}$$

304. The power requirement of a Carnot refrigerator in maintaining a low temperature region at 300 K is 1.5 kW per ton. Find the heat rejected.

A. 4.02 kW B. 7.02 kW C. 5.02 kW D. 6.02 kW

Solution:

$$\dot{Q}_R = T_2 \Delta s$$

where:

$$T_2 = \frac{T_1}{\text{COP}} + T_1$$

Solving for COP:

$$COP = \frac{\dot{Q}_A}{W_C} = \frac{3.516\ kW}{1.5\ kW} = 2.34$$

then;

$$T_2 = \frac{300}{2.34} + 300 = 427.99\ K$$

$$\Delta S = \frac{\dot{W}_C}{T_2 - T_1} = \frac{1.5}{427.99 - 300} = 0.01172\frac{kW}{K}$$

thus;

$$\dot{Q}_R = 427.99(0.01172) = \mathbf{5.02\ kW}$$

305. A vapor compression refrigeration system is designed to have a capacity of 150 tons of refrigeration. It produces chilled water from 22°C to 2°C. Its actual coefficient of performance is 5.86 and 35% of the power supplied to the compressor is lost in the form of friction and cylinder cooling losses. Determine the condenser cooling water required for a temperature rise of 10°C.

A. 14.75 kg/s B. 15.65 kg/s C. 18.65 kg/s D. 13.75 kg/s

Solution:

By Energy Balance:

$$\dot{Q}_R = \dot{W}_C + RE = \dot{m}_w C_{pw} \Delta t_w$$

where:

$$RE = 150(3.516) = 527.4\ kW$$

from:

$$COP = \frac{RE}{W_C}$$

$$5.86 = \frac{527.4}{W_C}$$

$$\dot{W}_C = 90\ kW$$

then:

$$\dot{Q}_R = 527.4 + 90 = 617.4$$

$$617.4 = \dot{m}_w C_{pw} \Delta t_w = \dot{m}_w (4.187)(10)$$

thus;

$$\dot{m}_w = \mathbf{14.75\ kg/s}$$

306. Determine the heat extracted from 2000 kg of water from 25°C to ice at -10°C.

A. 621,150 kJ B. 721,150 kJ C. 821,150 kJ D. 921,150 kJ

Solution:

$$Q_T = Q_1 + Q_2 + Q_3$$

where:

$$Q_1 = 2000(4.187)(25 - 0) = 209{,}350\ kJ$$

$$Q_2 = 2000(335) = 670{,}000\ kJ$$

$$Q_3 = 2000(2.09)(0+10) = 41{,}800$$

thus;

$$Q_T = 209{,}350 + 670{,}000 + 41{,}800 = \mathbf{921{,}150\ kJ}$$

307. A single acting, twin cylinder, Ammonia compressor with bore equal to stroke is driven by an engine at 250 rpm. The machine is installed in a chilling plant to produce 700 kW of refrigeration at -18°C evaporating temperature. At this temperature the cooling effect per kg mass is 1160 kJ. The specific volume of vapor entering the compressor is 0.592 m^3 per kilogram. Assume 85% volumetric efficiency, determine the bore in mm.

A. 400 mm B. 300 mm C. 450 mm D. 500 mm

Solution:

$$V_D = \frac{\pi D^2}{4} LNC = \frac{\pi D^2}{4} D\left(\frac{250}{60}\right)(2) = 6.545D^3$$

Solving for the piston displacement, V_D:

$$V_D = \frac{V_1}{e_{va}} = \frac{m\upsilon_1}{0.85} = \frac{m(0.592)}{0.85}$$

from:

$$Q_A = m(h_1 - h_4) = m(1160) = 0.603\ \text{kg/s}$$

then;

$$V_D = 0.42 m^3/s$$

thus;

$$0.42 = 6.545D^3$$

$$D = 0.40\ \text{m} = \mathbf{400\ mm}$$

308. An iron block weighs 7 Newtons and has a volume of 200 cubic centimeters. What is the density the block?

A. 3465 kg/m^3 B. 3565 kg/m^3 C. 1255 kg/m^3 D. 2550 kg/m^3

Solution:

$$\rho = \frac{m}{V} = \frac{\frac{W}{g}}{V} = \frac{\frac{7\ N}{9.8066\ \frac{m}{s^2}}}{200\ cm^3} \times \left(\frac{1\ kg\text{-}\frac{m}{s^2}}{1\ N}\right)\left[\frac{(100\ cm)^3}{(1\ m)^3}\right] = 3569 \approx \mathbf{3565\ kg/m^3}$$

309. If the density of the gas is 0.003 slugs per cubic foot, what is the specific weight of the gas?

A. 9.04 N/m^3 B. 15.2 N/m^3 C. 76.3 N/m^3 D. 98.2 N/m^3

Solution:

$$\gamma = \rho g = 0.003\frac{slug}{ft^3}\left(32.2\frac{ft}{s^2}\right) \times \left(\frac{1\frac{lb_f\text{-}s^2}{ft}}{1\ slug}\right)\left(\frac{4.4482\ N}{1\ lb_f}\right)\left[\frac{(1\ ft)^3}{(0.3048\ m)^3}\right]$$

$$= \mathbf{15.2\ N/m^3}$$

310. The specific gravity of mercury relative to water is 13.55. What is the specific weight of mercury? (The specific weight of water is 62.4 lb_f per cubic foot.)

A. 82.2 kN/m^3 B. 102.3 kN/m^3 C. 132.9 kN/m^3 D. 150.9 kN/m^3

Solution:

$$S.G._{Hg} = \frac{\gamma_{Hg}}{\gamma_{H_2O}} = \frac{\gamma_{Hg}}{62.4\frac{lb_f}{ft^3}} \times \frac{1}{\left(\frac{4.4482\ N}{1\ lb_f}\right)\left(\frac{1\ kN}{1000\ N}\right)\left[\frac{(1\ ft)^3}{(0.3048\ m)^3}\right]} = 13.55$$

$$\gamma_{Hg} = 132.82 \approx \mathbf{132.9\ kN/m^3}$$

311. If the specific weight of a liquid is 58.5 lb_f per cubic foot, what is the specific volume of the liquid in cm^3/g?

A. 0.5321 cm^3/g B. 0.6748 cm^3/g C. 0.9504 cm^3/g D. 1.0675 cm^3/g

Solution:

$$\upsilon = \frac{1}{\rho} = \frac{g}{\gamma} = \frac{32.2\frac{ft}{s^2}}{58.5\frac{lb_f}{ft^3}}$$

$$= 0.5504\frac{ft^3}{slug} \times \left[\frac{(0.3048\ m)^3}{(1\ ft)^3}\right]\left[\frac{(100\ cm)^3}{(1\ m)^3}\right]\left(\frac{1\ slug}{14.5938\ kg}\right)\left(\frac{1\ kg}{1000\ g}\right)$$

$$= 1.0680 \approx \mathbf{1.0675\ cm^3/g}$$

312. Which of the following is not a unit of pressure?

A. Pa B. bars C. $kg/m\text{-}s^2$ D. kg/m^2

Solution:

$\mathbf{kg/m\text{-}s^2}$ is not a unit of pressure

313. A cylinder weighs 150 lb_f. Its cross-sectional area is 40 square inches. When the cylinder stands vertically on one end, what pressure does the cylinder exert on the floor?

A. 14.1 kPa B. 25.8 kPa C. 63.2 kPa D. 89.7 kPa

Solution:

$$P = \frac{F}{A} = \frac{150\ lb_f}{40\ in^2} = 3.75\ psia \times \left(\frac{101.325\ kPa}{14.7\ psia}\right) = \mathbf{25.8\ kPa}$$

314. What pressure is a column of water 100 centimeters high equivalent to?

A. 9810 $dyne/cm^2$ B. 9810 N/m^2 C. 0.1 bars D. 0.1 atm

Solution:

$$P = 100\ cm\ H_2O \times \left(\frac{1\ m\ H_2O}{100\ cm\ H_2O}\right)\left(\frac{1\ ft\ H_2O}{0.3048\ m\ H_2O}\right)\left(\frac{101.325\ kPa}{33.9\ ft\ H_2O}\right)\left(\frac{1000\ Pa}{1\ kPa}\right)\left(\frac{1\ N/m^2}{1\ Pa}\right)$$

$$= 9806.23 \approx \mathbf{9810\ N/m^2}$$

315. Water is flowing in a pipe with a radius of 10” at a velocity of 5 m/s. At the temperature in the pipe, the density and viscosity of the water are as follows:

ρ = 997.9 kg/m^3 and μ = 1.131 Pa-s.

What is the Reynold's number for this situation?

A. 44.1 B. 88.2 C. 1140 D. 2241

Solution:

$$\mathrm{Re} = \frac{\mathrm{VD}\rho}{\mu} = \frac{\mathrm{V(2R)}\rho}{\mu} = \frac{\left(5\frac{\mathrm{m}}{\mathrm{s}}\right)[2(10\ \mathrm{in})]\left(997.9\frac{\mathrm{kg}}{\mathrm{m}^3}\right)\times\left(\frac{1\ \mathrm{ft}}{12\ \mathrm{in}}\right)\left(\frac{0.3048\ \mathrm{m}}{1\ \mathrm{ft}}\right)}{1.131\ \mathrm{Pa\text{-}s}\left(\frac{1\frac{\mathrm{N}}{\mathrm{m}^3}}{1\ \mathrm{Pa}}\right)\left(\frac{1\ \mathrm{kg\text{-}}\frac{\mathrm{m}}{\mathrm{s}^2}}{1\ \mathrm{N}}\right)} = \mathbf{2241}$$

316. How long must a current of 5.0 amperes pass through a 10 ohm resistor until a charge of 1200 coulombs passes through?

A. 1 min B. 2 min C. 3 min D. 4 min

Solution:

$$\mathrm{T} = \frac{\mathrm{C}}{\mathrm{I}} = \frac{1200\ \mathrm{A\text{-}s}}{5\ \mathrm{A}} = 240\ \mathrm{s}\left(\frac{1\ \mathrm{min}}{60\ \mathrm{s}}\right) = \mathbf{4\ min}$$

317. A car moving at 70 km/hr has a mass of 1700 kg. What force is necessary to decelerate it at a rate of 40 cm/s^2?

A. 0.680 N B. 42.5 N C. 680 N D. 4250 N

Solution:

$$\mathrm{F} = \mathrm{ma} = 1700\ \mathrm{kg}(40\ \mathrm{cm/s^2}) \times \frac{1\ \mathrm{m}}{100\ \mathrm{cm}} = \mathbf{680\ N}$$

318. One hundred milliliters of water in a plastic bag of negligible mass is to be catapulted upwards with an initial acceleration of 20.0 m/s^2. What force is necessary to do this? Assume gravity is 9.81 m/s^2 and the density of the water is 1 g/cm^3.

A. 2.00 N B. 2.98 N C. 15.0 N D. 2.00 kN

Solution:

$$\mathrm{F} = \mathrm{ma} = (\rho\mathrm{V})\mathrm{a}$$

$$= \left[1\frac{\mathrm{g}}{\mathrm{cm}^3}(100\ \mathrm{ml})\right]\left[(9.81+20)\frac{\mathrm{m}}{\mathrm{s}^2}\right] \times \left(\frac{1\ \mathrm{kg}}{1000\ \mathrm{g}}\right)\left(\frac{1\ \mathrm{cm}^3}{1\ \mathrm{ml}}\right)\left(\frac{1\ \mathrm{N}}{1\ \mathrm{kg\text{-}}\frac{\mathrm{m}}{\mathrm{s}^2}}\right) = \mathbf{2.98\ N}$$

319. A boy pulls a sled with a mass of 20 kg horizontally over a surface with a coefficient of friction of 0.20. It takes him 10 minutes to pull the sled 100 yards. What is his average power output over these 10 minutes?

A. 4 W B. 6 W C. 8 W D. 10 W

Solution:

$$P = \frac{W}{t} = \frac{F_f d}{t} = \frac{\left[0.20(20\ \text{kg})\left(9.81\frac{\text{m}}{\text{s}^2}\right)\right](100\ \text{yards})}{10\ \text{min}} \times \left(\frac{0.9144\ \text{m}}{1\ \text{yards}}\right)\left(\frac{1\ \text{min}}{60\ \text{s}}\right)$$
$$= 5.9802 \approx \mathbf{6\ W}$$

320. A force of 200 lb_f acts on a block at an angle of 28° with respect to horizontal. The block is pushed 2 feet horizontally. What is the work done by this force?

A. 215 J B. 320 J C. 480 J D. 540 J

Solution:

$$W = (F\cos\theta)d = (200\cos 28°)\text{lb}_f(2\ \text{ft}) \times \left(\frac{4.4482\ \text{N}}{1\ \text{lb}_f}\right)\left(\frac{0.3048\ \text{m}}{1\ \text{ft}}\right) = 478.84 \approx \mathbf{480\ J}$$

321. Two particles collide, stick together and continue their motion together. Each particle has a mass of 10 g and their respective velocities before the collision were 10 m/s and 100 m/s. What is the energy of the system after the collision?

A. 21.8 J B. 30.2 J C. 42.8 J D. 77.9 J

Solution:

$$m_1 v_1 + m_2 v_2 = (m_1 + m_2)v_3$$
$$10\ \text{g}(10\ \text{m/s}) + 10\ \text{g}(100\ \text{m/s}) = [(10+10)\text{g}]v_3$$
$$v_3 = 55\ \text{m/s}$$
$$W = \frac{1}{2}(m_1 + m_2)v_3^2 = \frac{1}{2}[(10+10)\text{g}]\left(55\ \frac{\text{m}}{\text{s}}\right)^2 \times \left(\frac{1\ \text{kg}}{1000\ \text{g}}\right) = 30.25 \approx \mathbf{30.2\ J}$$

322. A copper bar is 90 centimeters long at 86°F. What is the increase in its length when the bar is heated to 95°F? The linear expansion coefficient for copper, α, is 1.7 x 10^{-5}/°C.

A. 2.12 x 10^{-5} m B. 3.22 x 10^{-5} m C. 5.25 x 10^{-5} m D. 7.65 x 10^{-5} m

Solution:

$$\delta = \alpha L \Delta T = \frac{1.7\times10^{-5}}{°\text{C}}(90\ \text{cm})[(95-86)°\text{F}] \times \left(\frac{1\ \text{m}}{100\ \text{cm}}\right)\left(\frac{1\ \Delta°\text{C}}{1.8\ \Delta°\text{F}}\right)$$
$$= 0.000075\ \text{m} = \mathbf{7.65 \times 10^{-5}\ m}$$

323. Calculate the energy transfer rate across a 6" wall of firebrick with a temperature difference across the wall of 50°C. The thermal conductivity of firebrick is 0.65 BTU/hr-ft-°F at the temperature of interest.

A. 112 W/m^2 B. 285 W/m^2 C. 369 W/m^2 D. 429 W/m^2

Solution:

$$\frac{Q}{A} = \frac{k\Delta t}{x} = \frac{0.65\frac{\text{Btu}}{\text{hr-ft-°F}}(50°\text{C})}{6\ \text{in}} \times \left(\frac{1\ \text{kW}}{3412\frac{\text{Btu}}{\text{hr}}}\right)\left(\frac{1000\ \text{W}}{1\ \text{kW}}\right)\left(\frac{1.8\ \Delta°\text{F}}{\Delta°\text{C}}\right)\left(\frac{1}{\frac{1\ \text{ft}}{12\ \text{in}}}\right)\left\{\frac{1}{\left[\frac{(0.3048\ \text{m})^2}{(1\ \text{ft})^2}\right]}\right\}$$
$$= \mathbf{369\ W/m^2}$$

324. A house has brick walls 15 millimeters thick. On a cold winter day, the temperature of the inner and outer layers of the walls are measured and found to be 20°C and -12°C, respectively. If there is 120 m^2 of exterior wall of race, and the thermal conductivity of bricks is 0.711 J/m-s-°C, how much heat is lost through the walls per hour?

A. 182 J B. 12.5 kJ C. 655 kJ D. 655 MJ

Solution:

$$Q = \frac{kA\Delta t}{x} = \frac{0.711\ \frac{J}{m\text{-}s\text{-}°C}(120\ m^2)\{[20-(-12)]°C\}}{15\ mm} \times \left(\frac{3600\ s}{1\ hr}\right)\left(\frac{1}{\frac{1\ m}{1000\ mm}}\right) = 655257600\ J$$

$$= \mathbf{655\ MJ}$$

325. If a $\frac{1}{3}$ horsepower pump runs for 20 minutes, what is the energy used?

A. 0.06 ergs B. 0.25 kW C. 0.30 MJ D. 0.11 kW-h

Solution:

$$W = Pt = \frac{1}{3}\ hp(20\ min) \times \left(\frac{746\ W}{1\ hp}\right)\left(\frac{1\ \frac{J}{s}}{1\ W}\right)\left(\frac{60\ s}{1\ min}\right) = 298{,}400\ J = \mathbf{0.30\ MJ}$$

326. A power of 6 kW is supplied to the motor of a crane. The motor has an efficiency of 90%. With what constant speed does the crane lift the 800 lb_f weight?

A. 0.09 m/s B. 0.32 m/s C. 0.98 m/s D. 1.52 m/s

Solution:

$$P = \frac{FV}{e}$$

$$6\ kW\left(\frac{1000\ W}{1\ kW}\right) = \frac{(800\ lb_f)V}{0.90} \times \left(\frac{4.4482\ N}{1\ lb_f}\right)$$

$$V = \mathbf{1.52\ m/s}$$

327. An engine has an efficiency of 26%. It uses 2 gallons of gasoline per hour. Gasoline has a heating value of 20,500 BTU/lb_m and a specific gravity of 0.8. What is the power output of the engine?

A. 0.33 kW B. 20.8 kW C. 26.0 kW D. 41.7 kW

Solution:

$$e = \frac{P}{m_f Q_H}$$

$$m_f = \dot{V}_f\rho_f = \dot{V}_f\rho_w S.G._f = 2\ \frac{gal}{hr}\left(1000\frac{kg}{m^3}\right)(0.8) \times \left(\frac{3.7854\ l}{1\ gal}\right)\left(\frac{1\ m^3}{1000\ l}\right)\left(\frac{1\ hr}{3600\ s}\right)$$

$$= 0.0016824\ kg/s$$

$$0.26 = \frac{P}{0.0016824\frac{kg}{s}\left(20{,}500\ \frac{Btu}{lb_m}\right)} \times \left(\frac{1}{\frac{1055\ J}{1\ Btu}}\right)\left(\frac{1}{\frac{2.2\ lb_m}{1\ kg}}\right)$$

$$P = 20{,}811.71\ \text{W} = \mathbf{20.8\ kW}$$

328. Two liters of an ideal gas at a temperature of T_1 = 25°C and a pressure of P_1 = 0.101 MPa, are in a 10 cm diameter cylinder with a piston at one end. The piston is depressed so that the cylinder is shortened by 10 centimeters. The temperature increases by 2°C. What is the change in pressure?

A. 0.156 MPa B. 0.167 MPa C. 0.251 MPa D. 0.327 MPa

Solution:

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{(0.101\ \text{MPa})(2\ \text{liters})}{(25+273)\text{K}} = \frac{P_2\left\{2\ \text{liters} - \left[\frac{\pi}{4}(10\ \text{cm})^2(10\text{cm})\right]\times\frac{0.001\ \text{liters}}{1\ \text{cm}^3}\right\}}{(25+2+273)\text{K}}$$

$$P_2 = \mathbf{0.167\ MPa}$$

329. The average power output of a cylinder in a combustion engine is given by:

$$\overline{P} = pLAN$$

where:

p = average pressure on the piston during the stroke

L = length of the piston stroke

A = area of the piston head

N = number of strokes per second

An 8-ylinder engine has the following specifications

p = 283 kPa

L = 14 cm

d = diameter of piston head = 12 cm

N = 1500 strokes/min

What is the average power output of this engine?

A. 89.5 N/s B. 89.5 kW C. 89.5 x 10^3 J-m/s D. 89.5 kJ

Solution:

$$\overline{P} = 8 \times pLAN$$

$$= 8(283\ \text{kPa})(14\ \text{cm})\left[\frac{\pi}{4}(12\ \text{cm})^2\right]\left(1500\frac{\text{strokes}}{\text{min}}\right)\times\frac{(1\ \text{m})^3}{(100\ \text{cm})^3}\left(\frac{1\ \text{min}}{60\ \text{s}}\right)$$

$$= 89.62 \approx \mathbf{89.5\ kW}$$

330. What is the power required to transfer 97,000 coulombs of charge through a potential rise of 50 volts in one hour?

A. 0.5 kW B. 0.9 kW C. 1.3 kW D. 2.8 kW

Solution:

$$P = VI = \frac{VC}{t} = \frac{50\text{ V}(97{,}000\text{ A-s})}{1\text{ hr}\times\left(\frac{3600\text{ s}}{1\text{ hr}}\right)} = 1347\text{ W} \approx \mathbf{1.3\ kW}$$

331. A current of 7 amperes passes through a 12 ohm resistor. What is the power dissipated in the resistor?

A. 84 w B. 0.59 hp C. 0.79 hp D. 7 hp

Solution:

$$P = I^2R = (7\text{ A})^2(12\ \Omega) = 588\text{ W}\times\frac{1\text{ hp}}{746\text{ W}} = \mathbf{0.79\ hp}$$

332. What is the pressure at point A in the tank if h = 2 feet? ($g = 32.2\text{ ft/s}^2$ and $\rho = 1.94\text{ slug/ft}^3$)

A. 75 lb_f/ft^2 B. 85 lb_f/ft^2 C. 100 lb_f/ft^2 D. 125 lb_f/ft^2

Solution:

$$P = \gamma h = \rho g h = 1.94\frac{\text{slug}}{\text{ft}^3}\left(32.2\frac{\text{ft}}{\text{s}^2}\right)(2\text{ ft})\times\left(\frac{1\frac{\text{lb}_f\text{-s}^2}{\text{ft}}}{1\text{ slug}}\right) = \mathbf{125\ lb_f/ft^2}$$

333. Determine the average velocity through a circular section in which the velocity distribution is given by $v = v_{max}\left[1-\left(\frac{r}{r_o}\right)^2\right]$. The distribution is symmetric with respect to the longitudinal axis, r = 0, r_o is the outer radius, v_{max} is the velocity along the longitudinal axis. Assume flow is laminar.

A. $\frac{v_{max}}{4}$ B. $\frac{v_{max}}{3}$ C. $\frac{v_{max}}{2}$ D. v_{max}

Solution:

For a fully developed laminar pipe flow, V_{avg} is half of the maximum velocity.

$$\therefore v_{avg} = \frac{\mathbf{v_{max}}}{\mathbf{2}}$$

334. A pipe has a diameter 4" at section AA, and a diameter of 2" at section BB. For an ideal fluid flow, the velocity given is 1 ft/s at section AA. What is the flow velocity at section BB?

A. 4 ft/s B. 0.5 ft/s C. 1.0 ft/s D. 2.0 ft/s

Solution:

$$A_{AA}V_{AA} = A_{BB}V_{BB}$$
$$\frac{\pi}{4}(4\text{ in})^2(1\text{ ft/s}) = \frac{\pi}{4}(2\text{ in})^2V_{BB}$$
$$V_{BB} = \mathbf{4\ ft/s}$$

335. A mixing tank mixes two inlet streams containing salt. The salt concentration in stream 1 is 5% by weight, at stream 2 it is 15% by weight. Stream 1 flows at 25 kg/s, and stream 2 flows at 10 kg/s. There is only one exit stream. Find the salt concentration in the exit stream.

A. 5% B. 8% C. 11% D. 13%

Solution:

$$x_1v_1 + x_2v_2 = x_3v_3$$
$$0.05\text{m}(25\text{ kg/s}) + 0.15\text{m}(10\text{ kg/s}) = x\text{m}(25\text{ kg/s})$$
$$x = 0.11 = \mathbf{11\ \%}$$

336. Water is pumped at 1 m^3/s to an elevation 5 meters through a flexible hose using a 100% efficient pump rated at 100 kilowatts. Using the same length of hose, what size motor is needed to pump 1 m^3/s of water to the tank, with no elevation gain? In both cases, both ends of the hose are at the same temperature and pressure. Neglect kinetic energy effects.

A. 51 kW B. 22 kW C. 36 kW D. 43 kW

Solution:

@5 m elevation:

$$\frac{P_1}{\gamma} + \cancel{\frac{V_1^2}{2g}} + z_1 + h_p = \frac{P_2}{\gamma} + \cancel{\frac{V_2^2}{2g}} + z_2, P = \gamma Q h \ \therefore h_p = \frac{P}{\gamma Q}$$
$$\frac{P_1}{\gamma} + 0 + \frac{100\text{ kW}}{9.81\frac{\text{kN}}{\text{m}^3}\left(1\frac{\text{m}^3}{\text{s}}\right)} = \frac{P_2}{\gamma} + 5$$
$$\frac{P_2}{\gamma} - \frac{P_1}{\gamma} = 5.2\text{ m}$$

@0 m elevation:

$$\frac{P_1}{\gamma} + 0 + h_p = \frac{P_2}{\gamma} + 0$$
$$h_p = \frac{P_2}{\gamma} - \frac{P_1}{\gamma} = 5.2\text{ m}$$
$$P = 9.81\frac{\text{kN}}{\text{m}^3}\left(1\frac{\text{m}^3}{\text{s}}\right)(5.2\text{ m}) = \mathbf{51\ kW}$$

337. A fluid with kinetic viscosity of 2.5 x 10^{-5} ft^2/s is flowing at 0.1 ft/s from an orifice 3" in diameter. How can the fluid be described?

A. The fluid is completely turbulent.

B. The fluid is in transition zone.

C. The fluid is laminar.

D. Turbulent cannot be calculated, it must be measured.

Solution:

$$\text{Re} = \frac{VD}{\mu_k} = \frac{0.1\frac{\text{ft}}{\text{s}}(3\text{ in})}{2.5\times10^{-5}\frac{\text{ft}^2}{\text{s}}} \times \left(\frac{1\text{ ft}}{12\text{ in}}\right) = 1000 < 2000$$

$\therefore$**The fluid is laminar**.

338. The Reynold's number of a sphere falling in air is 1x10^6. If the sphere's radius is 1 ft, what is its velocity? (ρ = 0.00234 slug/ft^3, μ_{air} = 3.8x10^{-7} lb_f-s/ft^2).

A. 2.5 ft/s B. 5.1 ft/s C. 40.6 ft/s D. 81.2 ft/s

Solution:

$$\mathrm{Re} = \frac{V D \rho}{\mu}$$

$$1000000 = \frac{V[2(1\ \mathrm{ft})]\left(0.00234\frac{\mathrm{slug}}{\mathrm{ft}^3}\right)}{3.8\times10^{-7}\frac{\mathrm{lb_f\text{-}s}}{\mathrm{ft}^2}} = \mathbf{81.2\ ft/s}$$

339. The flow rate of water through a cast iron is 5000 gallons per minute. The diameter of the pipe is 1 foot, and the coefficient of friction is f = 0.0173. What is the pressure drop over a 100 foot length of pipe?

A. 21.078 $\mathrm{lb_f/ft^2}$ B. 23.78 $\mathrm{lb_f/ft^2}$ C. 337.26 $\mathrm{lb_f/in^2}$ D. 337.26 $\mathrm{lb_f/ft^2}$

Solution:

$$Q = AV$$

$$5000\frac{\mathrm{gal}}{\mathrm{min}} \times \left(\frac{3.7854\ \mathrm{L}}{1\ \mathrm{gal}}\right)\left(\frac{1\ \mathrm{m}^3}{1000\ \mathrm{L}}\right)\left[\frac{(1\ \mathrm{ft})^3}{(0.3048\ \mathrm{m})^3}\right]\left(\frac{1\ \mathrm{min}}{60\ \mathrm{s}}\right) = \frac{\pi}{4}(1\ \mathrm{ft})^2 V$$

$$V = 14.1839\ \mathrm{ft/s} = V_1 = V_2;\ z_1 = z_2$$

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_f;\ h_f = fL\frac{V^2}{2gD}$$

$$\frac{P_2 - P_1}{62.4\frac{\mathrm{lb_f}}{\mathrm{ft}^3}} = 0.0173(100\ \mathrm{ft})\left[\frac{\left(14.1839\frac{\mathrm{ft}}{\mathrm{s}}\right)^2}{2\left(32.2\frac{\mathrm{ft}}{\mathrm{s}^2}\right)(1\ \mathrm{ft})}\right]$$

$$\Delta P = 337.24 \approx \mathbf{337.26\ lb_f/ft^2}$$

340. A cylindrical flash tank mounted with its axis horizontal is used to separate liquid ammonia from ammonia vapor. The ammonia bubbles through the liquid with 70 m^3/min leaving the disengaging surface. The disengaging rate is limited to 60 m/min and the liquid level is to operate with the liquid level one-third to the diameter from the top. Determine the diameter if the tank is 1.5 m long.

A. 830 mm B. 730 mm C. 860 mm D. 760 mm

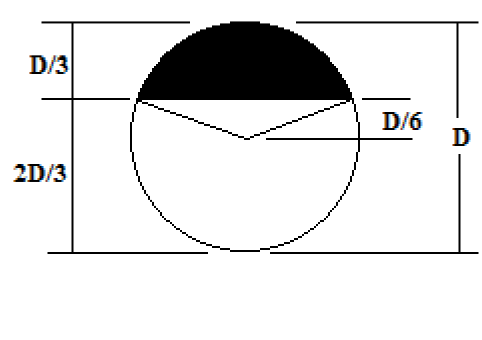
Solution:

Let

Q = rate of separation

A = disengaging area

V = disengaging rate



then; $Q = AV$

$$70 = 60\ A$$

$$A = 1.17\ \mathrm{m}^2 = 2bL$$

from fig:

$$b^2 = \left(\frac{D}{2}\right)^2 - \left(\frac{D}{6}\right)^2$$

$$b = \frac{\sqrt{2}}{3}D$$

$$A = 2\left(\frac{\sqrt{2}}{3}D\right)L$$

$$1.17 = 2\left(\frac{\sqrt{2}}{3}D\right)(2)$$

thus;

$$D = 0.83\text{ m} = \mathbf{830\ mm}$$

341. A 150 Hp motor is used to drive the compressor. If the heat loss from the compressor is 25 kW and the mass flow rate of the refrigerant entering the compressor is 0.50 kg/s, determine the difference of the enthalpies between the inlet and outlet of the compressor.

A. 143.80 kJ/kg B. 153.80 kJ/kg C. 173.80 kJ/kg D. 183.80 kJ/kg

Solution:

$$W_C = m\Delta h$$

where:

$$W_C = P_{motor} - \text{Heat Loss} = 150(0.746) - 25 = 86.9\text{ kW}$$

then;

$$86.9 = 0.50(\Delta h)$$

$$\Delta h = \mathbf{173.80\ kJ/kg}$$

342. To cool farm products, 300 kg of ice at -4.4°C are placed in bunker. Twenty four hours later the ice has melted into water at 7.2°C. What is the average rate of cooling provided by the ice in kJ/hr?

A. 2679.28 kJ/hr B. 5679.28 kJ/hr C. 3679.28 kJ/hr D. 4679.28 kJ/hr

Solution:

$$\dot{Q} = \dot{Q}_1 + \dot{Q}_2 + \dot{Q}_3$$

$$\dot{Q} = \frac{300\text{ kg}}{24\text{ hr}}[2.09(0 + 4.4) + 335 + 4.187(7.2 - 0)]\frac{\text{kJ}}{\text{kg}}$$

$$\dot{Q} = \mathbf{4679.28\ kJ/hr}$$

343. Determine the estimated condenser load for an open-type compressor having a cooling capacity of 16,500 Btu/hr and a heat rejection factor of 1.32.

A. 22,280 Btu/hr B. 20,780 Btu/hr C. 21,780 Btu/hr D. 19,780 Btu/hr

Solution:

$$\text{Condenser Load} = \text{Compressor Capacity} \times \text{heat rejection factor}$$

$$= 16{,}500(1.32) = \mathbf{21{,}780\ Btu/hr}$$

344. If the load on water-cooled condenser is 150,000 Btu/hr and the temperature rise of the water in the condenser is 10°F, what is the quantity of water circulated in gpm?

A. 30 GPM B. 40 GPM C. 20 GPM D. 50 GPM

Solution:

$$\dot{Q} = \dot{m}C_p t$$
$$150{,}000 = \dot{m}(1)(10)$$
$$\dot{m} = 15{,}000 \text{ lb/hr}$$

Solving for V in gpm:

$$V = \frac{\dot{m}}{\rho} = \frac{15{,}000 \text{ lb/hr}}{8.33 \text{ lb/gal}} = 1800.72 \text{ gal/hr} = \mathbf{30\ GPM}$$

345. The load on a water-cooled condenser is 90,000 Btu/hr. if the quantity of water circulated through the condenser is 15 gpm, determine the temperature rise of the water in the condenser.

A. 12°F B. 14°F C. 16°F D. 18°F

Solution:

$$\dot{Q} = \dot{m}C_p\Delta t$$
$$90{,}000\frac{\text{Btu}}{\text{hr}} = \dot{m}\left(1\,\frac{\text{Btu}}{\text{lb-°F}}\right)(\Delta t)$$

where:

$$\dot{m} = \rho V = 8.33\frac{\text{lb}}{\text{gal}\left(15\frac{\text{gal}}{\text{min}}\right)\left(60\frac{\text{min}}{\text{hr}}\right)} = 7497 \text{ lb/hr}$$

thus;

$$90{,}000 = 7497(1)\Delta t$$
$$\Delta t = \mathbf{12°F}$$

346. The weight of ammonia circulated in a machine is found to be 21.8 lb/hr. if the vapor enters the compressor with a specific volume of 9.6 ft^3/lb, calculate the piston displacement, assuming 80% percent volume efficiency.

A. 261.6 ft^3/hr B. 271.6 ft^3/hr C. 281.8 ft^3/hr D. 291.6 ft^3/hr

Solution:

$$\text{Actual volumetric efficiency} = \frac{\text{Volume flow rate at suction}}{\text{Piston displacement}}$$
$$e_{va} = \frac{V_1}{V_D} = \frac{21.8(9.6)}{V_D}$$
$$V_D = \mathbf{261.6\ ft^3/hr}$$

347. A single-stage ammonia compressor is producing 10 tons of refrigeration and the power consumed is 15 Hp. Suction pressure is 25 psi, condensing pressure is 180 psi. Brine temperature is 20°F off brine cooler. Determine the actual coefficient of performance.

A. 10.14 B. 11.14 C. 12.14 D. 13.14

Solution:

$$\text{COP} = \frac{\text{refrigeration capacity}}{\text{compressor power}} = \frac{10(3.516)}{15(0.746)} = 3.14;\text{ANS } \mathbf{13.14}$$

348. In an ammonia condensing machine (compressor plus condenser) the water used for condensing is 55°F and the evaporator is at 15°F. Calculate the ideal COP.

A. 11.875 B. 12.875 C. 10.875 D. 13.875

Solution:

$$\text{COP} = \frac{T_1}{T_2 - T_1}$$

where:

$$T_1 = 15 + 460 = 475°\text{R}$$
$$T_2 = 55 + 460 = 515°\text{R}$$

then;

$$\text{COP} = \frac{475}{515 - 475} = \mathbf{11.875}$$

349. How much refrigeration capacity is required to cool 2000 cfm of air from 85°F to 70°F?

A. 2.7 TOR B. 3.7 TOR C. 1.7 TOR D. 4.7 TOR

Solution:

$$\dot{Q} = \dot{m}C_p\Delta t$$

where:

$$C_p = 0.24 \text{ Btu/lb-°R}$$
$$\dot{m} = 2000\frac{\text{ft}^3}{\text{min}}\left(0.075\frac{\text{lb}}{\text{ft}^3}\right)\left(60\frac{\text{min}}{\text{hr}}\right) = 9000 \text{ lb/hr}$$

then;

$$\dot{Q} = 9000(0.24)(85 - 70) = \left(32{,}400\frac{\text{Btu}}{\text{hr}}\right)\left(\frac{1 \text{ TOR}}{12{,}000\frac{\text{Btu}}{\text{hr}}}\right) = \mathbf{2.7\ TOR}$$

350. Determine the coil face area required to maintain a face velocity 400 ft/min if the air flow rate over the coil is 2100 ft^3/min.

A. 3.25 ft^2 B. 4.25 ft^2 C. 5.25 ft^2 D. 6.25 ft^2

Solution:

$$\text{Velocity} = \frac{\text{Air quantity}}{\text{Face area}}$$

$$400\,\frac{\text{ft}}{\text{min}} = \frac{2100\,\frac{\text{ft}^3}{\text{min}}}{\text{Face area}}$$
$$\text{Face area} = \mathbf{5.25\ ft^2}$$

351. Calculate the heat transfer per hour through a solid brick wall 6 m long, 2.9 m high, and 225 mm thick, when the outer surface is at 5°C and the inner surface 17°C, the coefficient of thermal conductivity of the brick being 0.6 W/m-K.

A. 2,004.48 kJ B. 3,004.48 kJ C. 2,400.48 kJ D. 3,400.48 kJ

Solution:

$$Q = \frac{kA\Delta t}{x} = \frac{0.60[(6)(2.9)](17-5)}{0.225}$$
$$Q = 556.8\text{ W} = 556.8\,\frac{\text{J}}{\text{s}}\left(\frac{3600\text{s}}{1\text{hr}}\right)\left(\frac{1\text{ kJ}}{1000\text{ J}}\right) = 2{,}004.48\text{ kJ/hr}$$
$$\text{The heat transfer per hour is } \mathbf{2{,}004.48\ kJ}$$

352. A vertical furnace wall is made up of an inner wall of firebrick 20 cm thick followed by insulating brick 15 cm thick and an outer wall of steel 1 cm thick. The surface temperature of the wall adjacent to the combustion chamber is 1200°C while that of the outer surface of steel is 50°C. The thermal conductivities of the wall material in W/m-K are: firebrick, 10; insulating brick, 0.26; and steel, 45. Neglecting the film resistances and contact resistance of joints, determine the heat loss per sq.m. of wall area.

A. 1.93 W/m^2 B. 2.93 W/m^2 C. 1.55 W/m^2 D. 2.55 W/m^2

Solution:

$$\frac{\dot{Q}}{A} = \frac{t_1 - t_4}{\frac{x_{12}}{k_{12}} + \frac{x_{23}}{k_{23}} + \frac{x_{34}}{k_{34}}} = \frac{1200-50}{\frac{0.20}{10} + \frac{0.15}{0.26} + \frac{0.01}{45}} = \mathbf{1.93\ W/m^2}$$

353. A composite wall is made up of an external thickness of brickwork 110 mm thick inside which is a layer of fiberglass 75 mm thick. The fiberglass is faced internally by an insulating board 25 mm thick. The coefficients of thermal conductivity are as follow:

Brickwork	1.5 W/m-K
Fiberglass	0.04 W/m-K
Insulating board	0.06 W/m-K

The surface transfer coefficients of the inside wall is 3.1 W/m^2-K while that of the outside wall is 2.5 W/m^2-K. Take the internal ambient temperature as 10°C and the external temperature is 27°C. Determine the heat loss through such wall 6m high and 10 m long.

A. 330.10 W B. 230.10 W C. 430.10 W D. 530.10 W

Solution:

$$\dot{Q} = \frac{A\Delta t}{R_t}$$

$$R_t = \frac{1}{h_i} + \frac{x_{12}}{k_{12}} + \frac{x_{23}}{k_{23}} + \frac{x_{34}}{k_{34}} + \frac{1}{h_o} = \frac{1}{3.1} + \frac{0.110}{1.5} + \frac{0.075}{0.04} + \frac{0.025}{0.06} + \frac{1}{2.5} = 3.09\,\frac{m^2\text{-°C}}{W}$$

$$\dot{Q} = \frac{[6(10)](27-10)}{3.09} = \mathbf{330.10\ W}$$

354. One insulated wall of a cold-storage compartment is 8 m long by 2.5 m high and consists of an outer steel plate 18 mm thick. An inner wood wall is 22.5 m thick. The steel and wood are 90 mm apart to form a cavity which is filled with cork. If the temperature drop across the extreme faces of the composite wall is 15°C. Calculate the heat transfer per hour through the wall and the temperature drop across the thickness of the cork. Take the coefficients of thermal conductivity for steel, cork and wood as 45, 0.045, and 0.18 W/m-K respectively.

A. 408.24 kJ, 12.12°C
C. 608.24 kJ, 13.12°C
B. 708.24 kJ, 11.12°C
D. 508.24 kJ, 14.12°C

Solution:

$$\dot{Q} = \frac{A\Delta t}{R_T}$$

where:

$$R_T = \frac{x_{12}}{k_{12}} + \frac{x_{23}}{k_{23}} + \frac{x_{34}}{k_{34}} = \frac{0.018}{45} + \frac{0.09}{0.045} + \frac{0.0225}{0.18} = 2.125$$

then:

$$\dot{Q} = \frac{[8(2.5)](15)}{2.125} = 141.176\ \text{W or J/s} = \mathbf{508.24\ kJ/hr}$$

thus; the heat transfer per hour is 508.24kJ

Solving for the temperature drop across the Cork:

$$\dot{Q} = \frac{A\Delta t}{\frac{x_{23}}{k_{23}}} = \frac{20(\Delta t)}{\frac{0.09}{0.045}}$$

$$\Delta t = \mathbf{14.12℃}$$

355. A cubical tank of 2 m sides is constructed of metal plate 12 mm and contains water at 75°C. The surrounding air temperature is 16°C. Calculate the overall heat transfer coefficient from water to air. Take the coefficient of thermal conductivity of the metal as 48 W/m-K, the coefficient of heat transfer of water is 2.5 kW/m^2-K and the coefficient of heat transfer of the air is 16 W/m^2-K.

A. 15.84 W/m^2-°C B.14.84 W/m^2-°C C. 16.84 W/m^2-°C D. 13.84 W/m^2-°C

Solution:

$$\text{Let U} = \text{overall heat transfer coefficient} = \frac{1}{R_T}$$

where:

$$R_T = \frac{1}{h_{water}} + \frac{x_{12}}{k_{12}} + \frac{1}{h_{air}} = \frac{1}{2.5\times10^3} + \frac{0.012}{48} + \frac{1}{16} = 0.063\ m^2\text{-°C/W}$$

then:

$$U = \frac{1}{0.063}\frac{W}{m^2\,°C} = \mathbf{15.84\ W/m^2\text{-}°C}$$

356. A cold storage compartment is 4.5 m long by 4 m wide by 2.5 m high. The four walls, ceiling and floor are covered to a thickness of 150 mm with insulating material which has a coefficient of thermal conductivity of 5.8×10^{-2} W/m-K. Calculate the quantity of heat leaking through the insulation per hour when the outside and inside face temperature of the material is 15°C and -5°C respectively.

A. 2185.44 kJ B. 2285.44 kJ C. 3185.44 kJ D. 4185.44 kJ

Solution:

$$\dot{Q} = \frac{kA\Delta t}{x}$$

where:

$$A = 2[4.5(2.5) + 4(2.5) + 4.5(4)] = 78.50\ m^2$$

then;

$$\dot{Q} = \frac{(5.8\times10^{-2})(78.50)(15+5)}{0.15} = 607.07\ W\ or\ \frac{J}{s} = \mathbf{2185.44\ kJ/hr}$$

357. A furnace wall consists of 35 cm firebrick (k = 1.557 W/m-K), 12 cm insulating refractory (k = 0.346) and 20 cm common brick (k = 0.692) covered with 7 cm steel plate (k = 45). The temperature at the inner surface of the firebrick is 1,230°C and at the outer face of the steel plate is 60°C. Atmosphere is 27°C. What is the value of the combined coefficient for convection and radiation from the outside wall?

A. 31.13 W/m^2-K B. 30.13 W/m^2-K C. 41.3 W/m^2-K D. 40.13 W/m^2-K

Solution:

$$\frac{\dot{Q}}{A} = \frac{\Delta t}{R_T}$$

where:

$$R_T = \frac{k_{12}}{x_{12}} + \frac{k_{23}}{x_{23}} + \frac{k_{34}}{x_{34}} + \frac{k_{45}}{x_{45}} = \frac{0.35}{1.557} + \frac{0.12}{0.346} + \frac{0.20}{0.692} + \frac{0.07}{45} = 0.8621\frac{W}{m^2\,K}$$

then;

$$\frac{\dot{Q}}{A} = \frac{(1230-60)\,K}{0.8621\frac{m^2 K}{W}} = 1356.99\ W/m^2$$

$$\frac{\dot{Q}}{A} = \frac{\dot{Q}_{5-0}}{A} = \frac{t_5 - t_0}{\frac{1}{h_o}}$$

$$1356.99 = \frac{60-27}{\frac{1}{h_o}}$$

$$h_o = 41.12 \approx \mathbf{41.3\ W/m^2\text{-}K}$$

358. Hot gases at 280°C flow on one side of the metal plate 10 mm thickness and air at 35°C flows on the other side. The heat transfer coefficient of the gases is 31.5 W/m^2-K and that of the air is 32 W/m^2-K. Calculate the over-all heat transfer coefficient.

A. 15.82 W/m^2-K B. 16.82 W/m^2-K C. 14.82 W/m^2-K D. 17.82 W/m^2-K

Solution:

$$U = \frac{1}{R_T}$$

where:

$$R_T = \frac{1}{h_1} + \frac{k_{12}}{x_{12}} + \frac{1}{h_2} = \frac{1}{31.5} + \frac{0.01}{50} + \frac{1}{32} = 0.0632$$

thus;

$$U = \frac{1}{0.06032} = \mathbf{15.82\ W/m^2\text{-}K}$$

359. The surface temperature of the hot side of the furnace wall is 1200°C. It is desired to maintain the outside of the wall at 38°C. A 152 mm of refractory silica is used adjacent to the combustion chamber and 10 mm of steel covers the outside. What thickness of insulating bricks is necessary between refractory and steel, if the heat loss should be kept at 788 W/m^2? Use k = 13.84 W/m-K for refractory silica; 0.15 for insulating brick, and 45 for steel.

A. 220 mm B. 240 mm C. 260 mm D. 280 mm

Solution:

Solving for R_T:

$$788 = \frac{\Delta t}{R_T}$$

$$788 = \frac{1200 - 38}{R_T}$$

$$R_T = 1.475 = \frac{0.152}{13.84} + \frac{x_{23}}{0.15} + \frac{0.010}{45}$$

thus;

$$x_{23} = 0.22\ \text{m} = \mathbf{220\ mm}$$

360. An insulated steam pipe located where the ambient temperature is 32°C, has an inside diameter of 50 mm with 10 mm thick wall. The outside diameter of corrugated asbestos insulation is 125 mm and the surface coefficient of still air, h_o = 12 W/m^2-K. Inside the pipe is steam having a temperature of 150°C with film coefficient h_i = 6000 W/m^2-K. Thermal conductivity of pipe and asbestos insulation are 45 and 0.12 W/m-K respectively. Determine the heat loss per unit length of pipe.

A. 110 W B. 120 W C. 130 W D. 140 W

Solution:

$$\dot{Q} = \frac{\Delta t}{x}$$

where:

$$R_T = \frac{1}{A_1 h_1} + \frac{\ln\left(\frac{r_2}{r_1}\right)}{2\pi L k_1} + \frac{\ln\left(\frac{r_3}{r_2}\right)}{2\pi L k_2} + \frac{1}{A_o h_o}$$

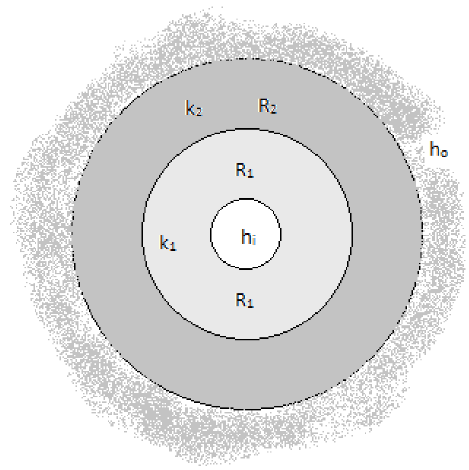
$$= \frac{1}{[\pi(0.05)L](6000)} + \frac{\ln\left(\frac{35}{25}\right)}{2\pi L(45)} + \frac{\ln\left(\frac{62.5}{35}\right)}{2\pi L(0.12)} + \frac{1}{[\pi(0.125)L](12)}$$

$$= 0.98345/L$$

then;

$$\dot{Q} = \frac{150-32}{\frac{0.98345}{L}}$$

$$\frac{\dot{Q}}{L} = \mathbf{120\ W} \text{ per meter length}$$



361. How many watts will be radiated from a spherical black body 15 cm in diameter at a temperature of 800°C?

A. 5.34 kW B. 4.34 kW C. 6.34 kW D. 3.34 kW

Solution:

$$P = \sigma A T^4$$

where:

$$\sigma = 5.7 \times 10^{-12} \text{W/cm}^2\text{-K}^4$$
$$A = 4\pi(7.5)^2 = 706.86 \text{ cm}^2$$
$$T = 800 + 273 = 1073 \text{ K}$$

then;

$$P = \left(5.7 \times 10^{-12}\right)(706.86)(1073)^4 = 5{,}340 \text{ W} = \mathbf{5.34\ kW}$$

362. A wall with an area of 10 m^2 is made of a 2 cm thickness of white pine (k = 0.133 W/m-°C) followed by a 10 cm of brick (k = 0.649 W/m-°C). The pine is on the inside where the temperature is 30°C while the outside temperature is 10°C. Assuming equilibrium conditions exist, what is the temperature at the interface between the two metals?

A. 15.65 °C B. 17.64 °C C. 18.21 °C D. 19.31 °C

Solution:

$$\dot{Q} = \frac{A\Delta t}{R_T}$$

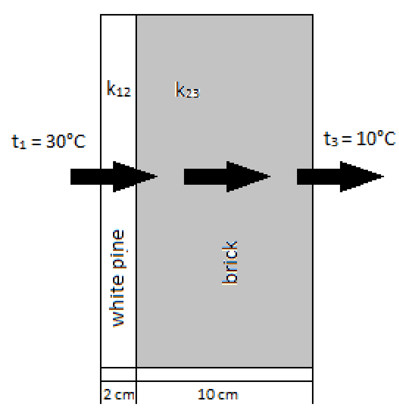
where:

$$R_T = \frac{0.12}{0.113} + \frac{0.10}{0.649} = 0.331 \text{ m}^2\text{-°C/W}$$

then;

$$\dot{Q} = \frac{10(30-10)}{0.331} = 604.23 \text{ W}$$

Solving for the temperature at the interface between the two materials:



$$\dot{Q} = \dot{Q}_{12} = \frac{k_{12} A(t_1 - t_2)}{x_{12}} = \frac{0.113(10)(30 - t_2)}{0.02}$$
$$t_2 = \mathbf{19.31°C}$$

363. A counter-flow heat exchanger is designed to heat a fuel oil from 45°C to 100°C while the heating fluid enters at 150°C and leaves at 115°C. Calculate the arithmetic mean temperature difference.

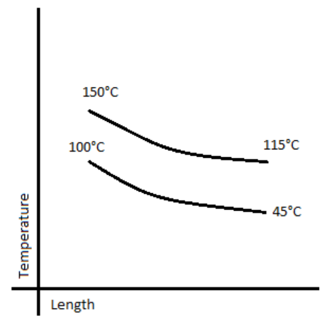
A. 40°C B. 50°C C. 60°C D. 70°C

Solution:

$$\text{AMTD} = \frac{\Delta t_{max} + \Delta t_{min}}{2}$$

where:

$$\Delta t_{max} = 115 - 45 = 70°C$$
$$\Delta t_{min} = 150 - 100 = 50°C$$
$$\text{AMTD} = \frac{70 + 50}{2} = \mathbf{60°C}$$



364. With three different quantities x, y, and z of the same kind of liquid of temperatures 9, 21 and 38°C respectively, it is found that when x and y are mixed together the resultant temperature is 17°C and when y and z are mixed together the resultant temperature is 28°C. Find the resultant temperature if x and z were mixed.

A. 25.87°C B. 25.92°C C. 20.85°C D. 24.86°C

Solution:

Mixing of x and y:
$$Q_x = Q_y$$
$$m_x(17 - 9) = m_y(21 - 17)$$
$$m_x = 0.50 m_y$$

Mixing of y and z:
$$Q_y = Q_z$$
$$m_y(28 - 21) = m_z(38 - 28)$$
$$m_z = 0.70 m_y$$

Mixing of x and z:
$$Q_x = Q_z$$
$$m_x(t - 9) = m_z(38 - t)$$
$$0.5 m_y(t - 9) = 0.70 m_y(38 - t)$$
$$t = \mathbf{25.92°C}$$

365. The journals of a shaft are 380 mm diameter, it runs at 105 rpm and the coefficient of friction between journals and bearings is 0.02. If the average load on the bearings is 200 kN, find the heat generated per minute at the bearings.

A. 501.375 kJ B. 505.575 kJ C. 401.375 kJ D. 501.575 kJ

Solution:

Friction Force at journal surface:

$$F = \mu N = 0.02(200) = 4 \text{ kN}$$

Work done to overcome friction per revolution: (W)

$$W = \text{circumference} \times \text{friction force}$$

$$= [\pi(0.38)](4) = 4.775 \text{ kN-m or kJ}$$

The Power Loss: (P_{Loss})

$$P_{Loss} = \left(4.775 \frac{\text{kJ}}{\text{s}}\right)\left(105 \frac{\text{rev}}{\text{min}}\right)\left(\frac{1\text{min}}{60 \text{ s}}\right) = 8.357 \text{ kW}$$

The Heat Energy generated per minute at the bearings: (Q)

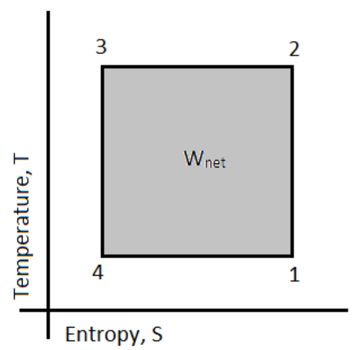
$$\dot{Q} = \left(8.357 \frac{\text{kJ}}{\text{s}}\right)\left(\frac{60\text{s}}{\text{min}}\right)(1 \text{ min}) = \mathbf{501.375 \text{ kJ}}/\text{min}$$

366. A reverse Carnot cycle requires 3 Hp and extracts energy from a lake to heat a house. If the house is kept at 70°F and requires 2000 Btu per minute, what is the temperature of the lake?

A. 35.29°F B. 36.29°F C. 39.29°F D. 40.29°F

Solution:

$$\dot{Q}_A = T_1(S_1 - S_4)$$



Solving for Q_A:

$$\dot{W} = \dot{Q}_R - \dot{Q}_A$$

where:

$$\dot{W} = 3 \text{ Hp} = 127.20 \text{ Btu/min}$$

$$\dot{Q}_R = 2000 \text{ Btu/min}$$

then;

$$127.2 = 2000 - Q_A$$

$$\dot{Q}_A = 1872.80 \text{ Btu/min}$$

Solving for $S_1 - S_4$:

$$\dot{Q}_A = T_2(S_2 - S_3) = T_2(S_1 - S_4)$$

$$2000 = (70 + 460)(S_1 - S_4)$$

$$S_1 - S_4 = 3.77$$

from;

$$\dot{Q}_A = T_1(S_1 - S_4)$$

$$1872.80 = T_1(3.77)$$

$$T_1 = 496.29°\text{R} = \mathbf{36.29°F}$$

367. An oxygen cylinder of volume 2.3 ft^3 has a pressure of 2200 psig and is at 70°F. Determine the mass of oxygen in the cylinder.

A. 25.66 lbs B. 26.66 lbs C. 27.66 lbs D. 28.66 lbs

Solution:

$$PV = mRT$$

where:

$$P = 2000 + 14.7 = 2214.7 \text{ psi}$$
$$T = 70 + 460 = 530°R$$
$$R = 48.291 \text{ (oxygen)}$$

then;

$$2214.7(2.3)(144) = m(48.291)(530)$$
$$m = \mathbf{28.66\ lbs}$$

368. A group of 50 persons attend a secret meeting in a room which is 12 m wide by 10 m long and a ceiling height of 3 m. The room is completely sealed off and insulated. Each person gives off 150 kCal per hour of heat and occupies a volume of 0.20 m^3. The room has an initial pressure of 101.3 kPa and temperature of 16°C. Calculate the room temperature after 10 minutes. Use R = 0.287 kJ/kg-K and C_v = 0.171 kCal/kg-K.

A. 33.1°C B. 37.7°C C. 38.7°C D. 31.7°C

Solution:

$$Q = mC_v\Delta T$$

where:

$$Q = 150(50) = 7{,}500 \text{ kCal/hr} = 125\text{kCal/min}$$

After 10 minutes:

$$Q = 125\ \frac{\text{kCal}}{\text{min}}(10 \text{ min}) = 1250 \text{ kCal}$$

Solving for m:

$$PV = mRT$$

where:

$$P = 101.325 \text{ kPa}$$
$$V_{air} = V_{room} - V_{persons}$$
$$V_{air} = [12(10)(3) - 0.20(50)] = 50 \text{ m}^3$$

then;

$$101.3(350) = m(0.287)(16 + 273)$$
$$m = 427.46 \text{ kg}$$

thus;

$$1250 = 427.46(0.171)(T_2 - 16)$$
$$T_2 = \mathbf{33.1℃}$$

369. One kilogram of wet steam at a pressure of 8 bar (υ_g = 0.2404 m^3/kg, υ_f = 0.0011148 m^3/kg) and dryness of 0.94 is expanded until the pressure is 4 bar (υ_g = 0.4625 m^3/kg, υ_f = 0.0010836 m^3/kg). If expansion follows the law PV^n = C, where n = 1.12, find the dryness fraction of the steam at the lower pressure.

A. 0.9072 B. 0.4197 C. 0.2260 D. 0.2404

Solution:

$$\upsilon_2 = x\upsilon_{g_2} + y\upsilon_{f_2}$$
$$\upsilon_1 = x(0.4625) + (1 - x)(0.0010836)$$

Solving for υ_2:

$$P_1\upsilon_1 = P_2\upsilon_2$$

where:

$$\upsilon_1 = x\upsilon_{g_1} + y\upsilon_{f_1} = 0.94(0.2404) + 0.06(0.0011148) = 0.2260$$

then;

$$8(0.2260)^{1.12} = 4(\upsilon_2)^{1.12}$$
$$\upsilon_2 = 0.4197 \text{ m}^3/\text{kg}$$

thus;

$$0.4197 \text{ m}^3/\text{kg} = x(0.4625) + (1 - x)(0.0010836)$$
$$x = \mathbf{0.9072}$$

370. 2.5 liters of superheated steam at 25 bar and 400°C (υ = 0.1252 m^3/kg) is expanded in an engine to a pressure of 0.1 bar (υ_g = 14.674 m^3/kg, υ_f = 0.0010102 m^3/kg) when its dryness fraction is 0.9. Find the final volume of the steam.

A. 163.74 liters B. 263.74 liters C. 363.74 liters D. 463.74 liters

Solution:

The mass of steam expanded:

$$m = \frac{0.0025 \text{ m}^3}{0.1252\frac{\text{m}^3}{\text{kg}}} = 0.01997 \text{ kg}$$

The volume of steam at 0.10 bar and dryness 0.9.

$$\upsilon_2 = x\upsilon_{g_2} + y\upsilon_{f_2} = 0.9(14.674) + 0.1(0.0010102) = 13.21 \text{ m}^3/\text{kg}$$
$$V_2 = m\upsilon_2 = (0.01997 \text{ kg})(13.21 \text{ m}^3/\text{kg}) = 0.26374 \text{ m}^3 = \mathbf{263.74 \text{ liters}}$$

371. A 1.5 kg of wet steam at a pressure of 5 bar (h_f = 640 kJ/kg, h_{fg} = 2109 kJ/kg) dryness 0.95 is blown into 70 liters of water 12°C (h = 50.4 kJ/kg). Find the final enthalpy of the mixture.

A. 74.80 kJ/kg B. 84.80 kJ/kg C. 94.80 kJ/kg D. 104.80 kJ/kg

Solution:

$$\text{Enthalpy before mixing} = \text{Enthalpy after mixing}$$

where:

$$\text{Enthalpy before mixing} = H(1.5 \text{ kg steam}) + H(70 \text{ kg water})$$

$$= 1.50[640 + 0.95(2109)] + 70(50.4)$$
$$= 7493.33 \text{ kJ}$$
$$\text{Enthalpy after mixing} = H(71.5 \text{ kg water}) = 71.5h$$

then;

$$71.5h = 7493.33$$
$$h = \mathbf{104.80 \ kJ/kg}$$

372. A 650 BHP diesel engine uses fuel oil of 28°API gravity, fuel consumption is 0.65 lb/BHP-hr. Cost of fuel is P7.95 per liter. For continuous operation determine the minimum volume of cubical day tank in cm^3, ambient temperature is 45° C.

A. 4,372,890 cm^3 B. 5,987,909 cm^3 C. 5,291,880 cm^3 D. 7,352,789 cm^3

Solution:

$$V = \frac{m}{\rho}$$

Solving for m:

$$m = 0.65(650) = 422.50 \text{ lb/hr} = 191.61 \text{ kg/hr}$$

Solving for ρ:

$$S.G._{15.6°C} = \frac{141.5}{°API + 131.5} = \frac{141.5}{28 + 131.5} = 0.887$$
$$S.G._{45°C} = S.G._{15.6°C}[1 - 0.0007(t - 15.6)]$$
$$= 0.887[1 - 0.0007(45 - 15.6)] = 0.869$$
$$\rho = 0.869(1000 \text{ kg/m}^3) = 869 \text{ kg/m}^3$$

then;

$$V = \frac{191.61}{869} = 0.220495\frac{m^3}{hr} = \mathbf{5,291,880 \ cm^3}/\text{day}$$

373. A typical industrial fuel oil, $C_{16}H_{32}$ with 20% excess air by weight. Assuming complete oxidation of the fuel, calculate the actual air-fuel ratio by weight.

A. 17.56 kg_{air}/kg_{fuel} C. 16.75 kg_{air}/kg_{fuel}
B. 15.76 kg_{air}/kg_{fuel} D. 17.65 kg_{air}/kg_{fuel}

Solution:

The theoretical reaction equation:

$$\underbrace{C_{16}H_{32}}_{\text{Fuel}} + \underbrace{O_2 + 3.76aN_2}_{\text{Air}} = \underbrace{bCO_2 + cH_2O + 3.76aN_2}_{\text{Products}}$$

Material Balance:

$$C: 16 = b(1) \qquad b = 16 \text{ kgmol}$$
$$H: 32 = 2C \qquad c = 16 \text{ kgmol}$$
$$O: 2a = 2b + c \qquad a = 24\text{kgmol}$$
$$N: 3.76a = 90.24 \text{ kgmol}$$

then, the theoretical reaction equation:

$$C_{16}H_{32} + 24O_2 + 90.24N_2 \rightarrow 16CO_2 + 16H_2O + 90.24N_2$$

The actual reaction equation with 20% excess air:

$$C_{16}H_{32} + 1.2(24O_2 + 90.24N_2) \rightarrow 16CO_2 + 16H_2O + dO_2 + 1.2(90.24)N_2$$

Material Balance of Oxygen:

$$O: 1.2(24)(1) = 16(2) + 16 + 2d \qquad d = 4.8 \text{ kgmol}$$

The actual reaction equation:

$$\underbrace{C_{16}H_{32}}_{\text{Fuel}} + \underbrace{28.8O_2 + 108.28N_2}_{\text{Air}} \rightarrow \underbrace{16H_2O + 16CO_2 + 4.8O_2 + 108.28N_2}_{\text{Gaseous Products}}$$

The actual air − fuel ratio:

$$\left(\frac{A}{F}\right)_a = \frac{28.8(32) + 108.28(28)}{12(16) + 1(32)} = \mathbf{17.65\ kg_{air}/kg_{fuel}}$$

374. Fuel oil in a day tank for use of an industrial boiler is tested with hydrometer. The hydrometer reading indicates a SG = 0.924 when the temperature of the oil in the tank is 35°C. Calculate the higher heating value of the fuel.

A. 43,852.13 kJ/kg B. 53,852.13 kJ/kg C. 58,352.13 kJ/kg D. 48,352.13 kJ/kg

Solution:

$$Q_h = 41{,}130 + 139.6(°API)$$

Solving for °API:

$$S.G._{35°C} = S.G._{15.6°C} = S.G._{15.6°C}\,[1 - 0.00072(35 - 15.6)]$$

$$S.G._{15.6} = 0.937$$

$$°API = \frac{141.5}{S.G._{15.6°C}} - 131.5 = \frac{141.5}{0.937} - 131.5 = 19.50$$

thus;

$$Q_h = 41{,}130 + 139.6(19.50) = \mathbf{43{,}852.13\ kJ/kg}$$

375. A diesel electric plant supplies energy for Meralco. During a 24 hr Period, the plant consumed 200 gallons of fuel at 28°C and produced 3930 Kw-hr. Industrial fuel used is 28°API and was purchased at P5.50 per liter at 15.6°C. What should the cost of fuel be produce one kw-hr.?

A. P 1.05 B. P 1.10 C. P 1.069 D. P 1.00

Solution:

Solving for density at 15.6°C:

$$S.G._{15.6°C} = \frac{141.5}{28 + 131.5} = 0.887$$

$$\rho =_{15.6°C} = 0.887(1\text{ kg/L}) = 0.887\text{ kg/L}$$

Solving for density at 28°C:

$$S.G._t = S.G._{15.6°C}\,[1 - 0.00072(t - 15.6)]$$

$$\text{S.G.}_{28°C} = 0.887[1 - 0.00072(28 - 15.6)] = 0.879$$
$$\rho_{28°C} = 0.879(1\ \text{kg/L}) = 0.879\ \text{kg/L}$$
$$\text{Price per kg} = \frac{5.50}{0.887} = \text{P } 6.20 \text{ per kg}$$

Cost per kW-hr:

$$C = \left(\frac{200\ \text{gal}}{3930\ \text{kW-hr}}\right)\left(\frac{3.7854\ \text{L}}{1\ \text{gal}}\right)\left(0.879\frac{\text{kg}}{\text{L}}\right)\left(\frac{\text{P } 6.20}{\text{kg}}\right) = \mathbf{P\ 1.05} \text{ per kw-hr}$$

376. A certain coal has the following ultimate analysis:

C = 70.5%	H = 4.5%	O_2 = 6%	N_2 = 1.0%
S = 3.0%	Ash = 11%	Moisture = 4%	

A stoker fired boiler of 175,000 kg/hr steaming capacity uses this coal as fuel. Calculate the volume of air in m^3/hr with air at 60°F (15.6°F) and 14.7 psia (101.325 kPa) the coal is burned with 30% excess air. Boiler efficiency is 70% and factor of evaporation of 1.10.

A. 212,861.04 m^3/hr B. 221,861.04 m^3/hr C. 218,261.04 m^3/hr D. 281,261.04 m^3/hr

Solution:

$$\dot{V} = \frac{\dot{m}(0.287)(15.6+273)}{101.325}$$

Solving for mass of air:

$$\left(\frac{A}{F}\right)_t = 11.5C + 34.5\left(H - \frac{O}{8}\right) + 4.3S = 11.5(0.705) + 34.5\left(0.045 - \frac{0.06}{8}\right)$$
$$= 9.53 \text{ kg air/kg coal}$$
$$Q_h = 33{,}820C + 144{,}212\left(H - \frac{O}{8}\right) + 9{,}304S$$
$$= 33{,}820(0.705) + 144{,}212\left(0.045 - \frac{0.06}{8}\right) + 9{,}304(0.03)$$
$$= 29{,}530.17 \text{ kJ/kg}$$
$$\eta = \frac{\dot{m}_s(h_s - h_f)}{\dot{m}_f Q_h} = \frac{\dot{m}_s(2257)\text{F.E.}}{\dot{m}_f Q_h} = \frac{175{,}000(2257)(1.10)}{\dot{m}_f(29{,}530.17)}$$
$$0.70 = \frac{175{,}000(2482.7)}{\dot{m}_f(29{,}530.17)}$$
$$\dot{m}_f = 21{,}018.335 \text{ kg coal/hr}$$
$$\dot{m}_a = \dot{m}_f\left(\frac{A}{F}\right)_t(\text{excess air}) = 21{,}018.335\frac{\text{kg coal}}{\text{hr}}\left(9.53\frac{\text{kg air}}{\text{kg coal}}\right)(1.3)$$
$$= 260{,}396.15 \text{ kg air/hr}$$

thus;

$$\dot{V}_{air} = \frac{260{,}396.15(0.287)(15.6+273)}{101.325} = \mathbf{212{,}861.04\ m^3/hr}$$

377. A diesel power plant consumed 1 m^3 of fuel with 30°API at 27°C in 24 hrs. Calculate the fuel rate in kg/hr.

A. 36.21 B. 26.25 C. 29.34 D. 39.42

Solution:

$$\dot{m} = \rho\dot{V}$$

Solving for density (ρ):

$$S.G._{15.6°C} = \frac{141.5}{°API + 131.5} = \frac{141.5}{30 + 131.5} = 0.876$$

$$S.G._{27°C} = 0.876[1 - 0.00072(27 - 15.6)] = 0.869$$

$$\rho_{fuel} = 0.869\left(1000\frac{kg}{m^3}\right) = 869\ kg/m^3$$

thus;

$$\dot{m} = 869\frac{kg}{m^3}\left(\frac{1\ m^3}{24\ hrs}\right) = \mathbf{36.21\ kg/hr}$$

378. A diesel power plant uses fuel with heating value of 43,000 kJ/kg. What is the density of the fuel at 25°C?

A. 840 kg/m^3 B. 873 kg/m^3 C. 970 kg/m^3 D. 940 kg/m^3

Solution:

$$\rho_{fuel} = S.G._{fuel}\,\rho_w$$

Solving for $S.G._{fuel}$ @ 30°C:

$$S.G._{15.6°C} = \frac{141.5}{°API + 131.5}$$

from:

$$Q_h = 41{,}130 + 139.6°API$$

$$43{,}000 = 41{,}130 + 139.6°API$$

$$°API = 13.395$$

$$S.G._{15.6°C} = \frac{141.5}{13.395 + 131.5} = 0.98$$

$$S.G._{25°C} = 0.98[1 - 0.00072(25 - 15.6)] = 0.97$$

thus;

$$\rho_{fuel} = 0.97(1000\ kg/m^3) = \mathbf{970\ kg/m^3}$$

379. A water tube boiler has a capacity of 1000 kg/hr of steam. The factor of evaporation is 1.3, boiler rating is 200%, boiler efficiency is 65% and heating surface area is 0.91 m^2 per bo.Hp. And the heating value of fuel is 18,400 kCal/kg. The total coal available in the bunker is 50,000 kg. Determine the no. of hrs. to consume the available fuel.

A. 853.36 hrs B. 706.57 hrs C. 979.46 hrs D. 100.75 hrs

Solution:

Let t = no. of hrs to consume the available fuel.

$$t = \frac{50{,}000}{\dot{m}_f}$$

Solving for mass of fuel, m_f:

$$F.E. = \frac{h_s - h_f}{2257}$$

$$h_s - h_f = 2257\ F.E. = 2257(1.3)$$

$$e_{bo.} = \frac{m_s(h_s - h_f)}{m_s Q_h} = \frac{1000[1000(1.3)]}{m_f[18,400(4.187)]}$$

$$\dot{m}_f = 58.592 \text{ kg/hr}$$

thus;

$$t = \frac{50,000}{58.592} = \mathbf{853.36\ hrs}$$

380. Two boilers are operating steadily on 91,000 kg of coal contained in a bunker. One boiler is producing 1591 kg of steam per hour at 1.2 factor of evaporation and an efficiency of 65% and another boiler produced 1364 kg of steam per hour at 1.15 factor of evaporation and an efficiency of 60%. How many hrs will the coal in the bunker run the boilers if the heating value of coal is 7,590 kCal/kg?

A. 230.80 hrs B. 280.54 hrs C. 350.35 hrs D. 300.54 hrs

Solution:

Let t = total number of hours the coal in the bunker run the boilers

$$t = \frac{91,000}{\dot{m}_t}$$

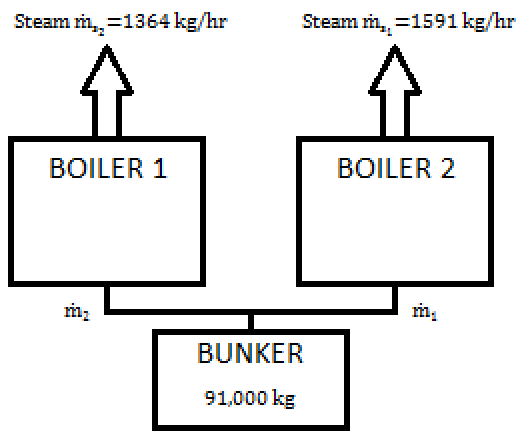
Solving for the total fuel consumed, m_t:

For Boiler ←:

$$e_{bo.1} = \frac{\dot{m}_{s_1}(h_s - h_f)}{\dot{m}_{f_1} Q_h} = \frac{\dot{m}_{s_1}[F.E._1(2257)]}{\dot{m}_{f_1} Q_h}$$

$$0.65 = \frac{1591[1.2(2257)]}{\dot{m}_{f_1}[7590(4.187)]}$$

$$\dot{m}_{f_1} = 208.605 \text{ kg/hr}$$



For Boiler ↑:

$$e_{bo.2} = \frac{\dot{m}_{s_2}[F.E._2(2257)]}{\dot{m}_{f_2} Q_h}$$

$$0.60 = \frac{1364[1.15(2257)]}{\dot{m}_{f_2}[7590(4.187)]}$$

$$\dot{m}_{f_1} = 185.673 \text{ kg/hr}$$

then;

$$\dot{m}_t = \dot{m}_1 + \dot{m}_2 = 208.605 + 185.673 = 394.278 \text{ kg/hr}$$

thus;

$$t = \frac{91,000 \text{ kg}}{394.278 \frac{\text{kg}}{\text{hr}}} = \mathbf{230.80\ hrs}$$

381. The heating value of fuel supplied in a boiler is 40,000 kJ/kg. If the factor of evaporation is 1.10 and the actual specific evaporation is 10, what is the efficiency of the boiler?

A. 62.07% B. 53.08% C. 78.05% D. 54.97%

Solution:

$$e_{bo.} = \frac{\dot{m}_s(h_s - h_f)}{\dot{m}_f Q_h} = \frac{\text{A.S.E.}[\text{F.E.}(2257)]}{Q_h} = \frac{10[1.10(2257)]}{40{,}000} = 0.6207 = \mathbf{62.07\%}$$

382. What is the rate of evaporation of a water tube boiler if the factor of evaporation is 1.10, percent rating of 200% and the heating surface area is 250 m^2?

A. 7,817.16 kg/hr B. 7,898.67 kg/hr C. 6,789.45 kg/hr D. 5,768.54 kg/hr

Solution:

$$\text{Dev. Bo. Hp.} = \frac{\dot{m}_s(h_s - h_f)}{35{,}322} = \frac{\dot{m}_s[\text{F.E.}(2257)]}{35{,}322}$$

Solving for the Developed Bo. Hp.:

$$\text{Rated Bo. Hp.} = \frac{250}{0.91} = 274.725$$

$$\%\ \text{Rating} = \frac{\text{Dev. Bo. Hp.}}{\text{Rated Bo. Hp.}} \times 100$$

$$200 = \frac{\text{Dev. Bo. Hp.}}{274.725} \times 100$$

$$\text{Dev. Bo. Hp.} = 549.45\ \text{Hp}$$

then;

$$549.45 = \frac{\dot{m}_s[1.10(2257)]}{35322}$$

$$\dot{m}_s = \mathbf{7{,}817.16\ kg/hr}$$

383. Steam is admitted to the cylinder of an engine in such a manner the average pressure is 120 psi. The diameter of the piston is 10 in. and the length of a stroke is 12 in. What is the Hp of the engine when it is making 300 rpm?

A. 171.4 Hp B. 175 Hp C. 173.2 Hp D. 174.4 Hp

Solution:

$$P_{in} = P_{mi} V_d$$

Solving for the piston displacement, V_d:

$$V_d = 2\left(\frac{\pi D^2 LN}{4}\right) = 2\left[\frac{\pi\left(\frac{10}{12}\right)^2(1)(300)}{4}\right] = 327.25\ \text{ft}^3/\text{min}$$

then;

$$P_{in} = \frac{120(144)(327.25)}{33{,}000} = \mathbf{171.4\ Hp}$$

384. Steam enters a turbine stage with an enthalpy of 3628 kJ/kg at 70 m/s and leaves the same stage with an enthalpy of 2846 kJ/kg and a velocity of 124 m/s. Calculate the power if there are 5 kg/s steam admitted at the turbine throttle?

A. 4597.45 kW B. 3976.55 kW C. 3883.81 kW D. 1675.42 kW

Solution:

$$\dot{W} = \dot{m}_s(h_1 - h_2) + \frac{1}{2}\dot{m}_s(V_1^2 - V_2^2) = 5(3628 - 2846) + \frac{1}{2}(5)\left(\frac{70^2 - 124^2}{1000}\right)$$
$$\dot{W} = \mathbf{3883.81\ kW}$$

385. Steam with an enthalpy of 800 kCal/kg enters a nozzle at a velocity of 80 m/s. Find the velocity of the steam at the exit of the nozzle if its enthalpy is reduced to 750 kCal/kg, assuming the nozzle is horizontal and disregarding heat losses. Take g = 9.81 m/s^2 and J constant = 427 kg m/kCal.

A. 452.37 m/s B. 245.45 m/s C. 651.92 m/s D. 427.54 m/s

Solution:

$$\text{Energy Entering} = \text{Energy Leaving}$$
$$h_1 + KE_1 = h_2 + KE_2$$
$$KE_2 - KE_1 = h_1 - h_2$$
$$\frac{V_2^2 - V_1^2}{2} = (800 - 750)\frac{\text{kCal}}{\text{kg}} \times \frac{4186\ \text{J}}{1\ \text{kCal}}$$
$$\frac{V_2^2 - 80^2}{2} = 418600$$
$$V_2 = \mathbf{651.92\ m/s}$$

386. Steam is expanded through a nozzle and the enthalpy drop per kg of steam from the initial pressure to the final pressure of 60 kJ. Neglecting friction, find the velocity of discharge and the exit area of the nozzle to pass 0.20 kg/s if the specific volume of the steam at exit is 1.5 m^3/kg.

A. 346.4 m/s, 879 mm^2

B. 356.7 m/s, 278 mm^2

C. 765.6 m/s, 467 mm^2

D. 346.4 m/s, 866 mm^2

Solution:

The velocity of discarge, V_d:
$$V_d = \sqrt{2\Delta h} = \sqrt{2(\text{specific enthalpy drop})} = \sqrt{2(60{,}000)}$$
thus;
$$V_d = \mathbf{346.4\ m/s}$$
The exit area of the nozzle:
$$\text{Area} \times \text{Velocity} = \text{mass flow} \times \text{specific volume}$$
$$A(346.4) = 0.20(1.5)$$
$$A = 0.000866 = \mathbf{866\ mm^2}$$

387. A 6 MW steam turbine generator power plant has a full-load steam rate of 8 kg/kW-hr. Assuming that no-load steam consumption as 15% of full-load steam consumption, compute for the hourly steam consumption at 75% load, in kg/hr.

A. 37,800 kg/hr B. 38,700 kg/hr C. 30,780 kg/hr D. 30,870 kg/hr

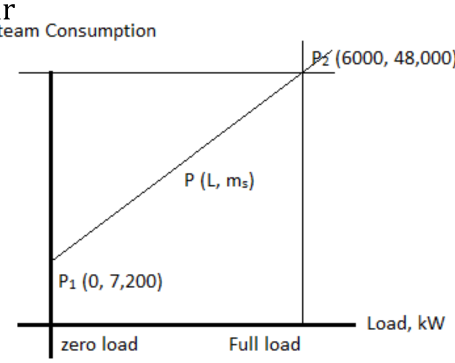
Solution:

Steam consumption at full-load:

$$\dot{m}_2 = 6000\ \text{kW}\left(8\,\frac{\text{kg}}{\text{kW-hr}}\right) = 48{,}000\ \text{kg/hr}$$

Steam consumption at no-load (m_1):

$$\dot{m}_1 = 0.15(48{,}000) = 7{,}200\ \text{kg/hr}$$



Using two-point form:

$$\frac{y - y_1}{x - x_1} = \frac{y_2 - y_1}{x_2 - x_1}$$

where:

$$P_1(x_1,\ y_2) = P_1(0, 7200)$$
$$P_2(x_2,\ y_2) = P_2(6000,\ 48{,}000)$$
$$P(x,\ y) = P(L,\ m_s)$$

then:

$$\frac{\dot{m}_s - 7200}{L - 0} = \frac{48{,}000 - 7{,}200}{6000 - 0}$$
$$\dot{m}_s - 7{,}200 = 6.8L$$
$$\dot{m}_s = 6.8L + 7{,}200$$

At 75% Load:

$$L = 0.75(6000) = 4500\ \text{kW}$$

then;

$$\dot{m}_s = 6.8L + 7200 = 6.8(45000) + 7200 = \mathbf{37{,}800\ kg/hr}$$

388. A 4 kg of air enters a turbine with enthalpy of 600 kJ and velocity of 250 m/s. The enthalpy at exit is 486 kJ and velocity of 170 m/s. What is the work developed if there is a heat loss of 10 kJ?

A. 122.83 kJ B. 171.2 kJ C. 80.2 kJ D. 28.3 kJ

Solution:

$$H_1 + KE_1 = H_2 + \dot{Q} + \dot{W}_t$$
$$600\ \text{kJ} + \left[\frac{1}{2}(4)(250)^2\right]\text{J} \times \frac{1\ \text{kJ}}{1000\ \text{J}} = 486\ \text{kJ} + \left[\frac{1}{2}(4)(170)^2\right]\text{J} \times \frac{1\ \text{kJ}}{1000\ \text{J}} + 10 + W_t$$
$$W_t = \mathbf{171.2\ kJ}$$

389. Calculate the drive horsepower for pumping 1703 L/min cold water to a tank suction at 127 mmHg vacuum, delivery at 5.3 kg/cm^2 ga., both measured close to pump, e_p = 0.65.

A. 31.42 Hp B. 20.42 Hp C. 35.42 Hp D. 23.02 Hp

Solution:

Let

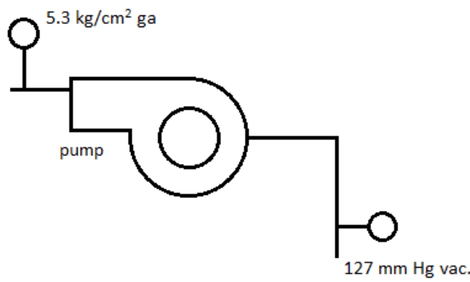
$$h_d = \text{total head at discharge}$$
$$h_s = \text{total head at suction}$$
$$h = \text{pump head}$$

By Bernoulli's Equation:

$$h = h_d - h_s$$

or;

$$h = \frac{P_d - P_s}{\gamma} + \cancel{\frac{V_d^2 - V_s^2}{2g}} + \cancel{(Z_d - Z_s)}$$



where:

$$P_d = 5.3 \text{ kg/cm}^2 \text{ ga}$$

$$P_s = \text{-}127 \text{ mm Hg} = \text{-}0.1727 \text{ kg/cm}^2$$

$$h = \frac{(5.3 + 0.1721)\frac{\text{kg}}{\text{cm}^2}\left(100\frac{\text{cm}}{\text{m}}\right)^2}{100\frac{\text{kg}}{\text{m}^3}} = 54.72 \text{ m}$$

where:

$$P_{brake} = \gamma Q h = 1703\frac{\text{L}}{\text{min}}\left(\frac{1 \text{ m}^3}{1000 \text{ L}}\right)\left(1000\frac{\text{kg}}{\text{m}^3}\right)(54.72)$$

$$= 93{,}188.16\frac{\text{kg-m}}{\text{min}}\left(\frac{1 \text{ kW}}{6116.3\frac{\text{kg-m}}{\text{min}}}\right) = 15.24 \text{ kW} = 20.42 \text{ Hp}$$

Drive Hp for pump:

$$\text{Hp} = \frac{20.42}{0.65} = \mathbf{31.42\ Hp}$$

390. Find the length of a suspension bunker to contain 181 tons of coal without surcharge; width = 4.6 m, depth = 4.3 m. The level capacity of a suspension bunker is 5/8 wdL where: w = width, d = depth and L = length. Density of coal is 800 kg/m^3.

A. 18.30 m B. 15.80 m C. 17.61 m D. 12.61 m

Solution:

$$V = \frac{5}{8}\text{WdL}$$

Solving for the total volume:

$$V = \frac{181(1000)\text{ kg}}{800\frac{\text{kg}}{\text{m}^3}} = 226.25 \text{ m}^3$$

then;

$$226.25 = \frac{5}{8}(4.6)(4.3)L$$

$$L = \mathbf{18.30\ m}$$

391. A 305 mm x 457 mm four stroke single acting diesel engine is rated at 150 kW at 260 rpm. Fuel consumption at rated load is 0.26 kg/kW-hr with a heating value of 43,912 kJ/kg. Calculate the brake thermal efficiency.

A. 31.63% B. 41.63% C. 21.63% D. 35.63%

Solution:

$$e_{tb} = \frac{P_b}{m_f Q_h}$$

Solving for m_f:

$$\dot{m}_f = 0.26\frac{kg}{kW\text{-}hr}(150\ kW) = 39\frac{kg}{hr} = 0.0108 kg/s$$

then;

$$e_{tb} = \frac{150}{0.0108\,(43{,}912)} = 0.3163 = \mathbf{31.63\%}$$

392. The brake thermal efficiency of a 1 MW diesel electric plant is 36%. Find the heat generated by fuel in kW if the generator efficiency is 89%.

A. 3,121.10 kW B. 3,528.64 kW C. 4,121.10 kW D. 4,528.64 kW

Solution:

$$e_{tb} = \frac{P_b}{Q_s}$$

Solving for brake power, P_b:

$$e_{gen} = \frac{1000}{P_b}$$

$$P_b = \frac{1000}{0.89} = 1{,}123.60\ kW$$

then;

$$0.36 = \frac{1{,}123.60}{Q_s}$$

$$Q_s = \mathbf{3{,}121.10\ kW}$$

393. In an air-standard Brayton cycle, the compressor receives air at 101.325kPa, 21°C and it leaves at 600 kPa at the rate of 4 kg/s. Determine the turbine work if the temperature of the air entering the turbine is 1000°C.

A. 3000 kW B. 2701 kW C. 2028 kW D. 3500 kW

Solution:

$$\dot{W}_t = \dot{m}C_p(T_3 - T_4)$$

Solving for T_4:

$$\frac{T_4}{T_3} = \left(\frac{P_4}{P_3}\right)^{\frac{k-1}{k}}$$

$$\frac{T_4}{1000+273} = \left(\frac{101.325}{600}\right)^{\frac{1.4-1}{1.4}}$$

$$T_4 = 765.83\ K = 492.88°C$$

thus;

$$\dot{W}_t = 4(1)(1000 - 492.83) = \mathbf{2028\ kW}$$

394. Kerosene is the fuel of a gas turbine plant: fuel-air ratio, m_f = 0.012, T_3 = 972 K, pressure ratio, r_p = 4.5, exhaust to atmosphere. Find the available energy in kJ per kg air flow. Assume k = 1.34 and C_p = 1.13.

A. 352.64 kJ/kg B. 452.64 kJ/kg C. 252.64 kJ/kg D. 552.64 kJ/kg

Solution:

The available Energy, Q:

$$Q = (1 + m_f)C_p(T_3 - T_4)$$

Solving for T_4:

$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{k-1}{k}}$$

$$\frac{972}{T_4} = (4.5)^{\frac{k-1}{k}}$$

$$T_4 = 663.63 \text{ K}$$

then;

$$Q = (1 + 0.012)(1.13)(972 - 663.63) = \mathbf{352.64\ kJ/kg}$$

395. An ideal gas turbine operates with a pressure ratio of 10 and the energy input in the high temperature heat exchanger is 300 kW. Calculate the air flow for temperature limits of 30°C and 1200°C.

A. 0.25 kg/s B. 0.34 kg/s C. 0.41 kg/s D. 0.51 kg/s

Solution:

$$\dot{Q}_A = \dot{m}C_p(T_3 - T_2)$$

Solving for T_2:

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}$$

$$\frac{T_2}{30+273} = 10^{\frac{k-1}{k}}$$

$$T_2 = 585 \text{ K}$$

then;

$$300 = \dot{m}(1)(1473 - 585)$$

$$\dot{m} = \mathbf{0.34\ kg/s}$$

396. In an air-standard Brayton cycle the inlet temperature and pressure are 20°C and 101.325 kPa. The turbine inlet conditions are 1200 kPa and 900°C. Determine the air flow if the turbine produces 12 MW.

A. 21.41 kg/s B. 20.20 kg/s C. 19.25 kg/s D. 18.10 kg/s

Solution:

$$W_t = \dot{m}C_p(T_3 - T_4)$$

Solving for T_4:

$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{k-1}{k}}$$

$$\frac{900+273}{T_4} = \left(\frac{1200}{101.325}\right)^{\frac{1.4-1}{1.4}}$$

$$T_4 = 578.89\ K$$

then;

$$12{,}000 = \dot{m}(1)(1173 - 578.89)$$

$$\dot{m} = \mathbf{20.20\ kg/s}$$

397. A gas turbine power plant operating on the Brayton cycle delivers 15 MW to a standby electric generator. What are the mass flow rate and the volume flow rate of air if the minimum and maximum pressures are 100 kPa and 500 kPa respectively and temperature of 20°C and 1000°C?

A. 31.97 kg/s, 26.88 m^3/s

B. 36.98 kg/s, 28.99 m^3/s

C. 41.97 kg/s, 26.88 m^3/s

D. 46.98kg/s, 28.99 m^3/s

Solution:

$$P\dot{V} = \dot{m}RT$$

Solving for m:

$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{k-1}{k}}$$

$$\frac{1000+273}{T_4} = \left(\frac{500}{100}\right)^{\frac{1.4-1}{1.4}}$$

$$T_4 = 803.75\ K$$

$$\dot{W}_t = \dot{m}C_p(T_3 - T_4)$$

$$15{,}000 = \dot{m}(1)(1273 - 803.75)$$

$$\dot{m} = \mathbf{31.97\ kg/s}$$

then;

$$100\dot{V} = 31.97(0.287)(20 + 273)$$

$$\dot{V} = \mathbf{26.88\ m^3/s}$$

398. In a hydraulic plant the difference in elevation between the surface of the water at intake and the tailrace is 650 ft when the flow is 90 cfs, the friction loss in the penstock is 65 ft and the head utilized by the turbine is 500 ft. The mechanical friction in the turbine is 110 Hp, and the leakage loss is 4 cfs. Find the hydraulic efficiency.

A. 87.45% B. 84.57% C. 85.47% D. 78.54%

Solution:

Hydraulic Efficiency: , e_h:

$$e_h = \frac{500}{650 - 65} = 0.8547 = \mathbf{85.47\%}$$

399. A hydro-electric power plant consumes 60,000,000 kW-hr per year. What is the net head if the expected flow is 1500 m^3/min and over-all efficiency is 63%?

A. 34.34 m B. 43.43 m C. 44.33 m D. 33.44 m

Solution:

$$P_w = \gamma Q h$$

Solving for water power, P_w:

$$e_{net} = \frac{\text{Generator Output}}{\text{Water Power}}$$

$$0.63 = \frac{\frac{60{,}000}{8760}}{P_w}$$

$$P_w = 10{,}871.93 \text{ kW}$$

then; subtituting:

$$10{,}871.93 = 9.81\left(\frac{1500}{60}\right)h$$

$$h = \mathbf{44.33\ m}$$

400. A pelton type turbine has a gross head of 40 m and a friction head loss 6 m. What is the penstock diameter if the penstock length is 90 m and the coefficient of friction head loss is 0.001 (Morse)?

A. 2040 mm B. 3120 mm C. 2440 mm D. 2320 mm

Solution:

$$h_L = \frac{2fLV^2}{gD}$$

Solving for V:

$$V = \sqrt{2gh} = \sqrt{2(9.81)(40-6)} = 25.83 \text{ m/s}$$

then; substituting:

$$6 = \frac{2(0.001)(90)(25.83)^2}{9.81D}$$

$$D = 2.04 = \mathbf{2040\ mm}$$

401. The water velocity of a 5 m x 1 m channel is 6 m/s. What is the annual energy produced if the net head is 120 m and the over-all efficiency is 80%?

A. 494,247,258 kW-hrs C. 247,494,528 kW-hrs

B. 247,497,582 kW-hrs D. 472,497,582 kW-hrs

Solution:

$$\text{Annual Energy Produced} = 0.80P_w(8760)$$

Solving for water Power (P_w):

$$Q = AV = (5 \times 1)(6) = 30\ m^3/s$$
$$P_w = 9.81(30)(120) = 35{,}316\ kW$$
then; substituting:
$$\text{Annual Energy Produced} = 0.80(35{,}316)(8760)$$
$$= \mathbf{247{,}494{,}528\ kW\text{-}hrs}$$

402. A hydro-electric impulse turbine is directly coupled to a 24 pole, 60 Hz alternator. It has a specific speed of 60 rpm and develops 3000 Hp. What is the required diameter assuming a peripheral speed ratio of 0.45?

A. 0.661 m B. 0.552 m C. 0.443 m D. 0.773 m

Solution:
$$\phi = \frac{\pi DN}{\sqrt{2gh}}$$
Solving for h:
$$N = \frac{120f}{p} = \frac{120\,(60)}{24} = 300\ rpm$$
$$N_s = \frac{N\sqrt{HP}}{h^{5/4}}$$
$$60 = \frac{300\sqrt{3000}}{h^{5/4}}$$
$$h = 89.13\ ft = 27.17\ m$$
then; Substituting:
$$0.45 = \frac{\pi D\left(\frac{300}{60}\right)}{\sqrt{2(9.81)(27.17)}}$$
$$D = \mathbf{0.661\ m}$$

403. In a hydroelectric power plant the tailwater elevation is at 500 m. What is the head water elevation if the net head is 30 m and the head loss is 5% of the gross head?

A. 785.25 m B. 582.57 m C. 528.57 m D. 758.25 m

Solution:
$$h_g = h_{hw} - h_{tw}$$
Solving for h_g:
$$h = h_g + h_L = h_g + 0.05h_g = 1.05h_g$$
$$30 = 1.05h_g$$
$$h_g = 28.57\ m$$
then; substituting:
$$28.57 = h_{hw} - 500$$
$$h_{hw} = \mathbf{528.57\ m}$$

404. The tailwater and headwater of a hydro-electric plant are 150 m and 200 m respectively. What is the water power if the flow is 15 m^3/s and a head loss of 10% of the gross head?

A. 6,621.75 kW B. 7,621.65 kW C. 5,621.76 kW D. 4,621.56 kW

Solution:

$$P_w = \gamma Q h$$

Solving for h:

$$h_g = h_{hw} - h_{tw} = 200 - 150 = 50 \text{ m}$$

$$h = h_g - h_L = 50 - 0.10(50) = 45$$

$$P_w = 9.81(15)(45) = \mathbf{6,621.75\ kW}$$

405. In a hydro-electric plant, water flows at 10 m/s in a penstock of 1 m^3 cross-sectional area. If the net head of the plant is 30 m and the turbine efficiency is 85%, what is the turbine output?

A. 2,501.55 kW B. 2,100.21 kW C. 3,626.34 kW D. 3,124.65 kW

Solution:

$$\text{Turbine Output} = 0.85 P_w$$

Solving for P_w:

$$Q = AV = 1(10) = 10 \text{ m}^3/\text{s}$$

$$P_w = \gamma Q h = 9.81(10)(30) = 2{,}943 \text{ kW}$$

then; substituting:

$$\text{Turbine Output} = \mathbf{2,501.55\ kW}$$

406. A 75 MW power plant has an average load of 35,000 kW and a load factor of 65%. Find the reserve over peak.

A. 21.15 MW B. 23.41 MW C. 25.38 MW D. 18.75 MW

Solution:

$$\text{Reserve over peak} = \text{Plant Capacity} - \text{Peak Load}$$

Solving for Peak Load:

$$\text{Load Factor} = \frac{\text{Average Load}}{\text{Peak Load}}$$

$$0.65 = \frac{35000}{\text{Peak Load}}$$

$$\text{Peak Load} = 53{,}846.15 \text{ kW} = 53.846 \text{ MW}$$

then;

$$\text{Reserve Over Peak} = 75 - 53.846 = \mathbf{21.15\ MW}$$

407. A power plant is said to have/had a use factor of 48.5% and a capacity factor of 42.4%. How many hrs. did it operate during the year?

A. 6,600.32 hrs B.7,658.23 hrs C. 8,600.32 hrs D. 5,658.23 hrs

Solution:

$$\text{Plant Use Factor} = \frac{\text{Annual kW-hrs}}{\text{kW Plant Capacity} \times \text{No.of Hrs.Operation}}$$

$$\text{Plant Capacity Factor} = \frac{\text{Annual Energy Produced}}{\text{kW Plant Capacity} \times 8760 \text{ hrs}}$$

Derived Formula:

$$\text{No. of hrs. of Operation} = 8760\left(\frac{\text{Capacity Factor}}{\text{Use Factor}}\right) = 8760\left(\frac{0.424}{0.485}\right)$$

$$= \mathbf{7,658.23 \ hrs} \text{ per year}$$

408. A 50,000 kW steam plant delivers an annual output of 238,000,000 kW-hr with a peak load of 42,860 kW. What is the annual load factor and capacity factor?

A. 0.634, 0.534 B. 0.643, 0.534 C. 0.634, 0.543 D. 0.643, 0.534

Solution:

$$\text{Load Factor} = \frac{\text{Ave.Load}}{\text{Peak Load}}$$

Solving for the Average Load;

$$\text{Ave. Load} = \frac{\text{kW-hrs Energy}}{\text{No.of hrs in one year}} = \frac{238{,}000{,}000 \text{ kW-hr/yr}}{8760 \text{ hr/yr}} = 27{,}168.94 \text{ kW}$$

$$\text{Load Factor} = \frac{27{,}168.94}{42{,}860} = \mathbf{0.634}$$

$$\text{Annual Capacity Factor} = \frac{\text{Annual Energy Produced}}{\text{kW Plant Capacity} \times 8760 \text{ hrs}}$$

$$= \frac{238{,}000{,}000 \text{ kW-hrs/year}}{50{,}000 \text{ kW} \times 8760 \text{ hrs}} = \mathbf{0.543}$$

409. Calculate the use factor of a power plant if the capacity factor is 35% and it operates 8000 hrs during the year?

A. 38.325% B. 33.825% C. 35.823% D. 32.538%

Solution:

$$\text{No. of Hrs of Operation} = 8760\left(\frac{\text{Capacity Factor}}{\text{Use Factor}}\right)$$

$$8000 = 8760\left(\frac{0.35}{\text{Use Factor}}\right)$$

$$\text{Use Factor} = 0.38325$$

thus;

$$\text{Use Factor} = \mathbf{38.325\%}$$

410. If the air required for combustion is 20 kg per kg of coal and the boiler uses 3000 kg of coal per hr, determine the mass of gas entering the chimney. Assume an ash loss of 15%.

A. 40,664 kg/hr B. 70,200 kg/hr C. 62,550 kg/hr D. 50,500 kg/hr

Solution:

$$\dot{m}_g + \dot{m}_{ash} = \dot{m}_a + \dot{m}_f$$

where:

$$\frac{\dot{m}_a}{\dot{m}_f} = 20$$

$$\dot{m}_a = 20\dot{m}_f$$

$$\dot{m}_g + 0.15\dot{m}_f = 20\dot{m}_f + \dot{m}_f$$

$$\dot{m}_g = 20.85\dot{m}_f = 20.85(3000) = \mathbf{62{,}550\ kg/hr}$$

411. A 15 kg gas enters a chimney at 10 m/s. If the temperature and pressure of a gas are 26°C and 100 kPa respectively, what is the diameter of the chimney? Use R = 0.287 kJ/kg-K.

A. 1.57 m B. 2.65 m C. 2.22 m D. 1.28 m

Solution:

$$Q = AV_{actual}$$

Solving for Q:

$$Q = \dot{V}_g = \frac{\dot{m}_g R_g T_g}{P_g} = \frac{15(0.287)(26+273)}{100} = 12.87\ m^3/s$$

then, substituting:

$$12.87 = \frac{\pi D^2}{4}(10)$$

$$D = \mathbf{1.28\ m}$$

412. A two-stage air compressor at 90 kPa and 20°C discharges at 700 kPa. Find the polytropic exponent n if the intercooler intake temperature is 100°C.

A. 1.29 B. 1.33 C. 1.4 D. 1.25

Solution:

$$\frac{T_x}{T_y} = \left(\frac{P_x}{P_y}\right)^{\frac{n-1}{n}}$$

Solving for P_x:

$$P_x = \sqrt{P_1 P_2} = \sqrt{90(700)} = 250.40\ kPa$$

then;

$$\frac{100+273}{20+273} = \left(\frac{250.40}{90}\right)^{\frac{n-1}{n}}$$

$$n = \mathbf{1.29}$$

413. A two-stage compressor receives 0.35 kg/s of air at 100 kPa and 269 K and delivers it at 5000 kPa. Find the heat transferred in the intercooler.

A. 70.49 kW B. 80.49 kW C. 90.49 kW D. 100.49 kW

Solution:

$$\dot{Q} = \dot{m}C_p(T_x - T_1)$$

Solving for T_x:

$$P_x = \sqrt{100(5000)} = 707.11 \text{ kPa}$$

$$\frac{T_x}{T_1} = \left(\frac{P_x}{P_1}\right)^{\frac{k-1}{k}}$$

$$\frac{T_x}{269} = \left(\frac{707.11 \text{ kPa}}{100}\right)$$

$$T_x = 470.40 \text{ K}$$

thus;

$$\dot{Q} = 0.35(1)(470.40 - 269) = \mathbf{70.49\ kW}$$

414. A centrifugal pump discharged 20 L/s against a head of 17 m when the speed is 1500 rpm. The diameter of the impeller was 30 cm and the brake horsepower was 6.0. A geometrically similar pump 40 cm in diameter is to run at 1750 rpm. Assuming equal efficiencies, what brake horsepower is required?

A. 51.55 HP B. 50.15 HP C. 40.14 HP D. 45.15 HP

Solution:

New brake horsepower required:

$$\frac{P_1}{D_1^5 N_1^3} = \frac{P_2}{D_2^5 N_2^3}$$

$$\frac{6}{0.30^5\,(1500)^3} = \frac{P_2}{0.40^5\,(1750)^3}$$

$$P_2 = \mathbf{40.14\ HP}$$

415. A pump delivers 20 cfm of water having a density of 62 lb/ft^3. The suction and discharge gage reads 5 in. Hg vacuum and 30 psi respectively. The discharge gage is 5 ft above the suction gage. If pump efficiency is 70%, what is the motor power?

A. 5.31 HP B. 3.31 HP C. 4.31 HP D. 6.31 HP

Solution:

$$P_{motor} = \frac{P_{water}}{0.70}$$

Solving for P_{water}:

$$H = \frac{P_d - P_s}{\gamma} + \frac{V_d^2 - V_s^2}{2g} + (Z_d - Z_s) = \frac{\left[30-(\text{-}5)\left(\frac{14.7}{29.92}\right)\right]144}{62} + 0 + 5 = 80.38 \text{ ft}$$

$$P_{water} = 62\frac{\text{lb}_f}{\text{ft}^3}\left(20\frac{\text{ft}^3}{\text{min}}\right)(30.38 \text{ ft}) = 99674.87\frac{\text{ft-lb}}{\text{min}}\left(\frac{1 \text{ Hp}}{33{,}000\frac{\text{ft-lb}}{\text{min}}}\right)$$

$$= 3.02 \text{ Hp}$$

$$P_{motor} = \frac{3.02}{0.70} = \mathbf{4.31\ HP}$$

416. Calculate the air power of a fan that delivers 1200 m^3/min of air through a 1 m x 1.5 m outlet. Static pressure is 120 mm WG and density of air is 1.18.

A. 20.45 kW B. 25.64 kW C. 30.45 kW D. 35.64 kW

Solution:

$$P_{air} = \gamma Q h$$

$$h_s = \frac{h_w \rho_w}{\rho_a} = 0.120\left(\frac{1000}{1.18}\right) = 101.695 \text{ m of air}$$

from:

$$Q = AV$$

$$\frac{1200}{60} = [1(1.5)]V$$

$$V = 13.33 \text{ m/s}$$

$$h_v = \frac{V^2}{2g} = \frac{13.33^2}{2(9.81)} = 9.06 \text{ m of air}$$

$$h = h_s + h_v = 101.695 + 9.06 = 110.756 \text{ m of air}$$

thus;

$$P_{air} = [1.18(0.00981)]\left(\frac{1200}{60}\right)(110.756) = \mathbf{25.64\ kW}$$

417. Determine the temperature for which a thermometer with degrees Fahrenheit is numerically twice the reading of the temperature in degrees Celsius.

A. -24.6 B. 320 C. 160 D. -12.3

Solution:

$$°C = \frac{°F}{2} \qquad \text{equation-1}$$

$$°C = \frac{5}{9}(°F - 32) \qquad \text{equation-2}$$

Substitute eq.1 to eq.2

$$\frac{°F}{2} = \frac{5}{9}(°F - 32)$$

$$\left[\frac{°F}{2} = \frac{5}{9}(°F - 32)\right] \times 18$$

$$9\ °F = 10°F - 320$$

$$320 = 10°F - 9°F$$

$$°F = 320$$

$$°C = \frac{°F}{2} = \frac{320}{2} = \mathbf{160}$$

418. During takeoff in a spaceship, an astronaut is subjected to acceleration equal to 5 times the pull of the earth's standard gravity. If the astronaut is 180 lb_m and the takeoff is vertical, what force does he exert on the seat?

A. 4810.9 N B. 4414.5 N C. 8829 N D. 9620 N

Solution:

$$\Sigma F_{VERTICAL} = 0$$

$$F = m(5)g + mg$$

$$g = 9.8\frac{m}{s^2}, k = 9.8\ m/s^2$$

$$F = \left(\frac{180\ lb_m}{2.2}\right) kg(5)(9.8\ m/s^2) + \left(\frac{180\ lb_m}{2.2}\right) kg(9.8\ m/s^2) = \mathbf{4810.9\ N}$$

419. A pressure cooker operates by cooking food at a higher pressure and temperature possible at atmospheric conditions. Steam is contained in the sealed pot, with vent hole in the middle of the cover, allowing steam to escape. The pressure is regulated by covering the vent hole with a small weight, which is displaced slightly by escaping steam. Atmospheric pressure is 100 kPa, the vent hole area is 7-mm^2, and the pressure inside should be 250 kPa. What is the mass of the weight?

A. 0.107 kg B. 1.05 kg C. 1.75 kg D. 0.1783 kg

Solution:

$$\Delta P = P_{press\ cooker} - P_{atm} = 250\ kPa - 100\ kPa = 150\ kPa$$

$$\Delta P = \frac{F}{A}$$

$$150 = \frac{F}{7\ mm^2} \times \left(\frac{1000\ mm}{1\ m}\right)^2$$

$$F = 1.05 \times 10^{-3}\ kN\left(\frac{1000\ N}{1\ kN}\right) = 1.05\ N\left(\frac{1\ kg}{9.81\ N}\right) = \mathbf{0.107\ kg}$$

420. A barometer can be used to measure an airplane's altitude by comparing the barometric pressure at a given flying altitude to that on the ground. Determine an airplane's altitude if the pilot measures the barometric pressure at 700 mm-Hg, the ground reports it at 758 mm-Hg, and the average air density is 1.19 kg/m^3, g = 9.81 m/s^2.

A. 636 m B. 633 m C. 366 m D. 663 m

Solution:

$$\Delta P = P_{GROUND} - P_{ABOVE\ GROUND} = (758 - 700)\text{mm-Hg}\left(\frac{101.325\ kPa}{760\ \text{mm-Hg}}\right)$$

$$= 7.732\ kPa = \gamma h$$

$$\gamma = \text{Gamma (specific weight, } kN/m^3) = \rho g$$

$$7.732\ kN/m^3 = 1.19 kg/m^3\left(\frac{9.8\ N}{1\ kg}\right)\left(\frac{1\ kN}{1000\ N}\right) \times h$$

$$h = \mathbf{663}$$

421. A mixture of 0.4 lb_m of helium and 0.2 lb_m of oxygen is compressed polytropically from 14.7 psia and 60°F to 60 psia according to n = 1.4. Determine the final temperature, T_2.

A. 727.7°R B. 777.2°R C. 722.7°R D. 277.7°R

Solution:

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}$$

$$T_2 = T_1\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} = 520°R\left(\frac{60}{14.7}\right)^{\frac{0.4}{1.4}} = \mathbf{777.2°R}$$

422. A mixture of 0.4 lb_m of helium and 0.2 lb_m of oxygen is compressed polytropically from 14.7 psia and 60°F t0 60 psia according to n = 1.4. Determine the polytropic work.

A. 139 Btu B. 239 Btu C. 339 Btu D. 539 Btu

Solution:

$$R = \text{Gas constant, ft-lb}_f/\text{lb}_m\text{-°R}$$

Solving for the gas constant of mixture, R_m

$$R_m = \Sigma x_1 R_1$$

$$X_{He} = \frac{0.4}{0.6} = 0.667$$

$$X_{H_2O} = \frac{0.2}{0.6} = 0.333$$

$$R_m = \left(0.667\ \text{lb}_{m_{He}}/\text{lb}_{m_{mix}}\right)\left(386.04\ \text{ft-lb}_f/\text{lb}_m\text{-°R}\right) + \left(0.333\ \text{lb}_{m_{H_2O}}/\text{lb}_{m_{mix}}\right)\left(46.29\ \text{ft-lb}_f/\text{lb}_m\text{-°R}\right)$$

$$R_m = 273.6\frac{\text{ft-lb}_f}{\text{lb}_m\text{-°R}}\left(\frac{1\ \text{Btu}}{778\ \text{ft-lb}_f}\right) = 0.3516\ \text{Btu/lb}_m\text{-°R}$$

Solving for the Polytropic Work,

$$W = \frac{mR_m(T_2 - T_1)}{1-n} = 0.6\frac{\text{lb}_m\left(0.3516\ \text{Btu/lb}_m\text{-°R}\right)(777.2°R - 520°R)}{1-1.4} = \mathbf{139\ Btu}$$

423. A pump in a municipality's water-supply system receives water from the filtration beds and pumps it up to the top of a water tower. The tower's height is 35 m, and the inlet piping to the pump is 2 m below the pump's intake. The water temperature is 20°C, measured at both the inlet and the discharge from the pump. The mass flow rate through the pump is 100 kg/s, the diameter of the inlet piping is 25 cm, and the diameter of the discharge piping is 15 cm. Determine the power required by the pump.

A. 77.3 kW B. 33.77 kW C. 34.42 kW D. 42.34 kW

Solution:

$$\dot{W}_p = \text{pump work, kW}$$

$$\dot{W}_p = Q\gamma(\text{TDH})$$

$$\text{TDH} = \left(\frac{v_2^2 - v_1^2}{2g}\right) + (z_2 - z_1) + \Delta h, \text{m}$$

$$\rho = \frac{m_{\text{flow rate}}}{V_{\text{flow rate}}}$$

$$1000\frac{\text{kg}}{\text{m}^3} = \frac{100\frac{\text{kg}}{\text{s}}}{V_{\text{flow rate}}}$$

$$Q = 0.1\ \text{m}^3/\text{s}$$

$$0.1\frac{\text{m}^3}{\text{s}} = \frac{\pi}{4}(0.25\ \text{m})^2 v_1$$

$$v_1 = 2.037 \text{ m/s}$$

$$0.1\frac{m^3}{s} = \frac{\pi}{4}(0.15 \text{ m})^2 v_2$$

$$v_2 = 5.658 \text{ m/s}$$

$$\text{TDH} = \left(\frac{5.658^2 - 2.037^2}{2(9.81)}\right) + (35 - 2) = 34.42$$

$$\dot{W}_p = 0.1\frac{m^3}{s}\left(9.81\frac{kN}{m^3}\right)(34.42 \text{ m}) = \mathbf{33.77\ kW}$$

424. An adiabatic tank containing air is used to power an air turbine during times of peak power demand. The tank has a volume of 500 m^3 and contains air at 1000 kPa and 500 K. Determine the mass remaining when the pressure reaches 100 kPa.

A. 273.37 kg B. 672.73 kg C. 772.73 k D. 227.73 kg

Solution:

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}$$

$$\frac{T_2}{500 \text{ K}} = \left(\frac{100 \text{ kPa}}{1000 \text{ kPa}}\right)^{\frac{1.4-1}{1.4}}$$

$$T_2 = 258.97 \text{ K}$$

$$PV_2 = m_2 RT_2$$

$$100 \text{ kPa}(500 \text{ m}^3) = m_2\left(0.287 \text{ kJ/kg-K}\right)(258.97 \text{ K})$$

$$m_2 = \mathbf{672.73\ kg}$$

425. Determine the air-fuel ratio on a molar basis for the complete combustion of octane, with theoretical amount of air.

A. 95.5 kg_{air}/kg_{fuel} B. 59.9 kg_{air}/kg_{fuel} C.59.5 kg_{air}/kg_{fuel} D. 55.9 kg_{air}/kg_{fuel}

Solution:

Molar basis means that the $\frac{A}{F}$ ratio will be for 1 mol of fuel.

$$C_8H_{18} + a(O_2 + 3.76N_2) \rightarrow bCO_2 + cH_2O + dN_2$$

$$a = x + 0.25y$$

$$a = 8 + 0.25(18) = 12.5$$

$$\left(\frac{A}{F}\right)_{molar} = \frac{[12.5 + 12.5(3.76)] \text{ mol air}}{1 \text{ mol fuel}} = \mathbf{59.5\ kg_{air}/kg_{fuel}}$$

426. During a steady state operation, a gearbox receives 60 kW throughout the input shaft and delivers power through the output shaft. For the gearbox as the system, the rate of energy transfer is by convection, h = 0.171 kW/m^2-K is the heat transfer coefficient, A = 1.0 m^2 is the outer surface area of the gearbox, T_b = 300 K (27°C) is the temperature at the outer surface, T_f = 293 K (20°C) is the temperature of the surroundings away from the immediate vicinity of the

gearbox. Determine the power delivered to the output shaft in kW if the heat transfer rate is -1.2 kW.

A. 98.8 kW B. 78.8 kW C. 68.8 kW D. 58.8 kW

Solution:

$$\frac{dE}{dt} = \dot{Q} - \dot{W} \text{ or } \dot{W} = \dot{Q}$$

$$\dot{W} = \dot{W}_1 + \dot{W}_2 = \dot{Q}$$

$$\dot{W}_1 = \text{-}60\text{kW}$$

$$\dot{Q} = \text{-}1.2 \text{ kW}$$

$$\dot{W}_2 = \text{power delivered to the output shaft, kW} = \text{-}1.2 \text{ kW} - (\text{-}60 \text{ kW})$$

$$= \mathbf{58.8\ kW}$$

427. A single acting air compressor with a clearance of 6% takes in air at atmospheric pressure and temperature of 85°F and discharges it at a pressure of 85 psia. The air handled is 0.25 ft^3/cycle measured at discharge pressure. If the compression is isentropic, find the piston displacement per cycle, if the compressor is running at 750 rpm.

A. 0.0750 ft^3/cycle B. 0.025 ft^3/cycle C. 1.030 ft^3/cycle D. 1.090 ft^3/cycle

Solution:

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}$$

$$T_2 = T_1\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} = 545\left(\frac{85}{14.7}\right)^{\frac{1.4-1}{1.4}} = 900°\text{R}$$

$$m = \frac{P_2V_2}{RT_2} = \frac{85(144)(0.25)}{53.34(900)} = 0.06374 \text{ lb/cycle}$$

$$V_1 = \frac{mRT_1}{P_1} = \frac{0.06374(53.34)(545)}{14.7(144)} = 0.8754 \text{ ft}^3\text{/cycle}$$

$$\eta_v = 1 + c - c\left(\frac{P_2}{P_1}\right)^{\frac{1}{k}} = 1 + 0.06 - 0.06\left(\frac{85}{14.7}\right)^{\frac{1}{1.4}} = 0.8499$$

$$V_D = \frac{V_1}{\eta_v} = \frac{0.8754}{0.8499} = \mathbf{1.030\ ft^3/cycle}$$

428. A single acting air compressor with a clearance of 6% takes in air at atmospheric pressure and temperature of 85°F and discharges it at a pressure of 85 psia. The air handled is 0.25 ft^3/cycle measured at discharge pressure. If the compression is isentropic, find the air hp of the compressor if rpm is 750.

A. 16 hp B. 96 hp C. 69 hp D. 61 hp

Solution:

$$\dot{V}_1 = V_1N = \left(0.8754\frac{\text{ft}^3}{\text{cycle}}\right)(750 \text{ rpm}) = 656.55 \text{ ft}^3\text{/min}$$

$$\dot{W} = \frac{kP_1\dot{V}_1}{1-k}\left[\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} - 1\right] = \frac{1.4(14.7)(656.55)(144)}{33{,}000\,(1-1.4)}\left[\left(\frac{85}{14.7}\right)^{\frac{1.4-1}{1.4}} - 1\right] = \mathbf{96\ hp}$$

429. A nozzle receives 0.5 kg/s of air at a pressure of 2700 kPa and a velocity of 30 m/s and with an enthalpy of 923 kJ/kg, and the air leaves at a pressure of 700 kPa and with an enthalpy of 660 kJ/kg. Determine the exit velocity from the nozzle.

A. 923 m/s B. 726 m/s C. 700 m/s D. 660 m/s

Solution:

$$\mathrm{ENERGY_{IN}} = \mathrm{ENERGY_{OUT}}$$

$$\cancel{m}(h_1 + PE_1 + \cancel{KE_1}) + \cancel{Q} = W_{MAX} + \cancel{m}(h_2 + PE_2 + KE_2)$$

$$h_1 + KE_1 = h_2 KE_2$$

$$\text{since, } KE = \frac{V^2}{2000}\ \text{kJ}$$

$$h_1 + \frac{V_1^2}{2000} = h_2 + \frac{V_2^2}{2000}$$

$$923\frac{\text{kJ}}{\text{kg}} + \frac{\left(30\frac{\text{m}}{\text{s}}\right)^2}{2000} = 660\frac{\text{kJ}}{\text{kg}} + \frac{V_2^2}{2000}$$

$$V_2 = 725.87 \approx \mathbf{726\ m/s}$$

430. A two-stage, double acting compressor is to deliver 90 lb/min of air from 14.3 psia to 90°F to a final pressure of 185 psia. The normal barometer is 29.8 in-Hg and the temperature is 80°F. The pressure drop in the intercooler is 3 psi and the speed is 210 rpm and $pV^{1.34}$ = C during compression and expansion. The clearance is 5% for both cylinders. Find the volume of free air if the temperature of the cooling water increased by 18°F.

A. 1282 CFM B. 1230 CFM C. 1320 CFM D. 1822 CFM

Solution:

$$\dot{V}_1 = \frac{\dot{m}RT_1}{P_1} = \frac{90(53.34)(550)}{14.3(144)} = 1282\ \text{CFM}$$

Solving for the volume of free air, $\dot{V}_o$:

$$\frac{P_1\dot{V}_1}{T_1} = \frac{P_2\dot{V}_2}{T_2}$$

$$\dot{V}_2 = \frac{P_1\dot{V}_1T_2}{T_1P_2} = \frac{14.3\ \text{psia}(1282\ \text{CFM})[(80+460)°\text{R}]}{(90+460)°\text{R}\left[29.8\ \text{in-Hg}\left(\frac{14.7\ \text{psia}}{29.92\ \text{in-Hg}}\right)\right]} = \mathbf{1230\ CFM}$$

431. Consider 4800 lb of steam per hour flowing through a pipe at 100 psia pressure. Assume a velocity of 5280 ft/min. What size of pipe is required? Specific volume of steam at 100 psia υ = 4.432 ft^3/lb.

A. 3 in B. 5 in C. 4 in D. 6 in

Solution:

$$Q = 4.432\left(\frac{4800}{60}\right) = 345.56\ \text{ft}^3/\text{min (steam)}$$

$$D = \sqrt{\frac{144(354.56)}{5280\,(0.7854)}} = 3.509\ \text{in},$$

refer to page 575, Chapter 13 (Auxillary Steam Plant Equipment) Steam Plant Operation by E. Woodruff, H. Lammers, T. Lammers, Sixth edition

$\therefore$ use **4 in** diameter pipe.

432. A boiler plant generates 225,000 lb of steam and burns 13.9 tons of coal per hour. The coal has a heating value of 11,400 Btu/lb. A test of the particulates leaving the boiler shows that 3804 lb of particulate is being discharged per hour. What is the particulate discharged per million Btu heat input to the furnace?

A. 12 lb/10^6 Btu B. 14 lb/10^6 Btu C. 15 lb/10^6 Btu D. 16 lb/10^6 Btu

Solution:

$$\text{Furnace heat input} = 13.9 \times 2000 \times 11{,}400 = 317 \times 10^6\ \text{Btu/hr}$$

$$\text{Particulate released from boiler per Btu} = \frac{3804}{317 \times 10^6} = \mathbf{12\ lb/10^6\ Btu}$$

433. A turbine receives 150 lb_m/s of air at 63 psia and 2450°R and expands it polytropically to 14.7 psia. The exponent n is equal to 1.45 for the process. Determine the power.

A. 52,343.16 BTU/s

B. 52,343.16 kW

C. 53.343.16 HP

D. 53,343.16 ft-lb/s

Solution:

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}$$

$$\frac{T_1}{2450°R} = \left(\frac{14.7\ \text{psia}}{63\ \text{psia}}\right)^{\frac{1.45-1}{1.45}}$$

$$T_1 = 1559.62°R$$

For Polytropic Work, W_T

$$\dot{W}_{TURBINE} = \frac{mR(T_2 - T_1)}{n-1} = \frac{150\frac{lb}{s}\left(53.34\frac{\text{ft-lb}}{\text{lb-°R}}\right)[(2450-1559.62)°R]}{n-1}$$

$$= 40{,}722{,}956.40\ \frac{\text{ft-lb}}{s}\left(\frac{1\ \text{Btu}}{778\ \text{ft-lb}}\right) = \mathbf{52{,}343.16\ Btu/s}$$

434. Find the thrust and efficiency of two 2-m diameter propellers through which flows a total of 600 m^3/s of air to 11.3 N/m^3. The propellers are attached to an airplane moving at 250 kph through still air. Neglect eddy losses.

A. 36,077 N, 73% B. 77,630 N, 37% C. 66,033 N, 33% D. 77,330 N, 77%

Solution:

Velocity of air relative to airplane is:

$$V_1 = 250 \text{ km/hr} = \frac{250(1000)}{60(60)} = 69.4 \text{ m/s}$$

Velocity of air through the actuating disk is:

$$V = \frac{Q}{A} = \frac{\frac{600}{2}}{\frac{\pi}{4}(2)^2} = 95.5 \text{ m/s}$$

$$\Delta V = 2(95.5 - 69.4) = 52.2 \text{ m/s}$$

Thrust of both propellers

$$F_T = \frac{11.3(600)(52.2)}{9.81} = \mathbf{36{,}077\ N}$$

Efficiency of Propellers,

$$\eta = \frac{1}{1+\frac{\Delta V}{2V_1}} = \frac{1}{1+\frac{52.2}{138.9}} = 0.73 = \mathbf{73\%}$$

435. A liquid with a specific gravity of 1.26 is being pumped in a pipeline from A to B. At A, the pipe diameter is 60 cm and the pressure is 300 kN/m^2. At B, the pipe diameter is 30 cm and the pressure is 330 kN/m^2. Point B is 1.0 m lower than A. Find the flow rate if the pump puts 16 kW into the flow. Neglect head loss.

A. 4.2 m^3/s B. 0.42 m^3/s C. 2.4 m^3/s D. 0.24 m^3/s

Solution:

$$\text{kW} = 16 = \frac{1.26(9.810)Qh_p}{1000}$$

$$h_p = \frac{1.29}{Q}$$

$$0 + \frac{300}{1.26(9.81)} + \frac{\left[\frac{Q}{\pi(0.3)^2}\right]^2}{2(9.81)} + \frac{1.29}{Q} = -1.0 + \frac{330}{1.26(9.81)} + \frac{\left[\frac{Q}{\pi(0.15)^2}\right]^2}{2(9.81)}$$

$$Q = \mathbf{0.42\ m^3/s}$$

436. A reciprocating compressor handles 1,400 cfm of air measured at intake where P_1 = 18 psia and T_1 = 90°F. The discharge pressure is 92 psia. Calculate the work if the process of the compression is isothermal.

A. -180.5 hp B. -179.5 hp C. -227.6 hp D. -228.6 hp

Solution:

$$\dot{W} = P_1V_1 \ln\frac{P_1}{P_2} = \frac{18\frac{\text{lb}}{\text{in}^2}\left(144\frac{\text{in}^2}{\text{ft}^2}\right)\left(1{,}400\frac{\text{ft}^3}{\text{min}}\right)}{778\frac{\text{ft-lb}}{\text{Btu}}\left(42.4\frac{\text{Btu}}{\text{min-hp}}\right)}\left(\ln\frac{18}{92}\right) = \mathbf{-179.5\ hp}$$

437. The fuel oil has the ff. analysis:

C = 89% N_2 = 2% H_2 = 8% S = 1%

With 3% excess air, what is the actual amount of air needed to burn the fuel oil?

A. 13.17 kg_{air}/kg_{fuel} C. 14.47 kg_{air}/kg_{fuel}
B. 13.47 kg_{air}/kg_{fuel} D. 14.17 kg_{air}/kg_{fuel}

Solution:

$$m_{ta} = 11.5C + 34.5\left(H_2 + \frac{O_2}{8}\right) + 4.3S$$
$$= 11.5(0.89) + 34.5(0.08) + 4.32(0.01) = 13.1232\ kg_{air}/kg_{fuel}$$
$$m_{aa} = (1 + 0.10)(13.1232) = \mathbf{14.17\ kg_{air}/kg_{fuel}}$$

438. A pump discharges 550 gpm of water to a height of 35 ft. With an efficiency of 80%, what is the power input?

A. 6.09 hp B. 6.32 hp C. 4.74 hp D. 4.94 hp

Solution:

$$P_{output} = Q\gamma H = \frac{\frac{500\ gal}{min}\left(\frac{1\ ft^3}{7.48\ gal}\right)\left(62.4\frac{lb}{ft^3}\right)(35\ ft)}{778\frac{ft\text{-}lb}{Btu}\left(42.4\frac{Btu}{min\text{-}hp}\right)} = 4.87\ hp$$

$$Efficiency = \frac{P_{output}}{P_{input}}$$

$$P_{input} = \frac{4.87}{0.80} = \mathbf{6.09\ hp}$$

439. A room contains air at 20°C and 96 kPa at a relative humidity of 75%. Determine the enthalpy of moist air.

where:

($P_{sat\ @\ 20°C}$ = 2.339 kPa)

($h_{g\ @\ 20°C}$ = 2538.1 kJ/kg_{da})

Given:

Unsaturated air (0% < Ø <100%)

t_d = 20°C

P_t = 96 kPa

Ø = 75%

A. 45.919 kJ/kg_{da} B. 45.515 kJ/kg_{da} C. 49.515 kJ/kg_{da} D. 41.815 kJ/kg_{da}

Solution:

$$P_d = P_{sat\ @\ 20°C} = 2.339\ kPa$$
$$P_s = ØP_d = 0.75(2.339) = 1.7543\ kPa$$
$$P_t = P_a + P_s$$
$$P_a = 96 - 1.7543 = 94.2457$$
$$W = \frac{m_s}{m_a} = 0.622\left(\frac{P_s}{P_a}\right) = 0.622\left(\frac{1.7543}{94.2457}\right) = 0.01158\ kg_{wv}/kg_{da}$$
$$h = 1.0062t_d + W\left(h_{g\ @\ t_d}\right) = 1.0062(20) + 0.01158(2538.1)$$
$$= \mathbf{49.515\ kJ/kg_{da}}$$

440. A piston moves inside a cylinder at a velocity of 6.0 m/s. The 160 mm diameter piston is centrally located within the 160.2 mm inside diameter cylinder. The film of oil is separating the piston from the cylinder has an absolute viscosity of 0.4 N-s/m^2. Assuming a linear velocity profile, find the shear stress in the oil. (T = μ (v/H))

Given:

μ = 0.40 N-s/m^2

v = 5 m/s

H = thickness of oil film = 160.2 – 160/2 = 0.1 mm

A. 50,000 N/m^2 B. 40,000 N/m^2 C. 24,000 N/m^2 D. 34,000 N/m^2

Solution:

$$\mathrm{T} = 0.40\,\frac{\mathrm{N\text{-}s}}{\mathrm{m}^2}\left(\frac{5\frac{\mathrm{m}}{\mathrm{s}}}{0.0001\ \mathrm{m}}\right) = \mathbf{24{,}000\ N/m^3}$$

441. A centrifugal pump with a 3 ft impeller diameter operates at 800 rpm. If the speed is to be increased to 1200 rpm, determine the impeller diameter that should be used so that the same shaft input power would be required.

A. 5.32 ft B. 2.35 ft C. 5.23 ft D. 2.93 ft

Solution:

$$\frac{\mathrm{P}_1}{\mathrm{P}_2} = \frac{(\rho \mathrm{N}^3 \mathrm{D}^5)_1}{(\rho \mathrm{N}^3 \mathrm{D}^5)_2} = \left(\frac{\mathrm{N}_1}{\mathrm{N}_2}\right)^3 \left(\frac{\mathrm{D}_1}{\mathrm{D}_2}\right)^5$$

$$\mathrm{D}_2 = \mathrm{D}_1\left(\frac{\mathrm{N}_1}{\mathrm{N}_2}\right)^{3/5} = 3\left(\frac{800}{1200}\right)^{3/5} = \mathbf{2.35\ ft}$$

442. Determine the mass of water vapor contained in a 150 m^3 room at 100 kPa, 23°C and 40% relative humidity. From Steam Tables: $P_{sat\ @\ 23°C}$ = 2.810 kPa.

A. 1.6342 kg B. 1.9342 kg C. 1.2342 kg D. 2.2342 kg

Solution:

$$\mathrm{P_s} = \mathrm{ØP_d} = 0.4 \times 2.810 = 1.124\ \mathrm{kPa}$$

$$\mathrm{P_sV_s} = \mathrm{M_sR_sT_s}$$

$$\mathrm{M_s} = \frac{\mathrm{P_sV_s}}{\mathrm{R_sT_s}} = \frac{1.124(150)}{0.4615(296)} = \mathbf{1.2342\ kg}$$

443. What is the power of the pump, HP, if it delivers 925 gal/min of water against a head of 15 m?

A. 15.38 HP B. 16.38 HP C. 10.5 HP D. 11.5 HP

Solution:

$$P = Q\gamma h = \frac{\left[925\frac{\text{gal}}{\text{min}}\times\left(\frac{1\text{ ft}^3}{7.48\text{ gal}}\right)\right]\left(62.4\frac{\text{lb}}{\text{ft}^3}\right)(15\text{ m})\times\left(\frac{100\text{ cm}}{1\text{ m}}\right)\left(\frac{1\text{ in}}{2.54\text{ cm}}\right)\left(\frac{1\text{ ft}}{12\text{ in}}\right)}{778\frac{\text{ft-lb}}{\text{Btu}}\times42.4\frac{\text{Btu}}{\text{min-Hp}}} = \mathbf{11.5\ HP}$$

444. Kerosene is pumped into an aircraft fuel tank through a hose that has an inside diameter of 4 cm. If the velocity of the kerosene is 8 m/s through the hose, determine the mass flow rate. Assume that the kerosene has a density of 800 kg/m³.

A. 7.06 kg/s B. 7.56 kg/s C. 8.06 kg/s D. 8.56 kg/s

Solution:

$$A = \pi r^2 = \pi(2\text{ cm})^2 = 12.6\text{ cm}^2 = 0.00126\text{ m}^2$$

$$\dot{m} = \rho A\dot{V} = 800\frac{\text{kg}}{\text{m}^3}(0.00126\text{ m}^2)\left(8\frac{\text{m}}{\text{s}}\right) = \mathbf{8.06\ kg/s}$$

445. During the working stroke of an engine the heat transferred out of the system was 150 kJ/kg of working substance. The internal energy also decreased by 400 kJ/kg of working substance. Determine the work done.

A. 250 kJ/kg B. 550 kJ/kg C. 600 kJ/kg D. 350 kJ/kg

Solution:

$$Q = \Delta U + W_n \text{ (Nonflow energy equation)}$$

$$W_n = Q - \Delta U = -150 - (-400) = -150 + 400 = \mathbf{250\ kJ/kg}$$

446. During the experiment on Charles Law, the volume of the gas trapped in the apparatus is 10000 mm³ when the temperature is 18°C. The temperature of the gas was then raised to 85°C. Determine the new volume of the gas trapped in the apparatus if the pressure exerted on the gas remained constant.

A. 12302.41 mm³ B. 8128.49 mm³ C. 70833.33 mm³ D. 2117.64 mm³

Solution:

$$\text{Charles Law: } P = \text{constant and } \frac{V}{T} = C$$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$T_1 = 18 + 273 = 291\text{ K}$$

$$T_2 = 85 + 273 = 358\text{ K}$$

$$V_2 = V_1 \times \frac{T_2}{T_1} = 1000 \times \frac{358}{291} = \mathbf{12302.41\ mm^3}$$

447. Find the density of oil with a specific gravity of 1.6 in-g/cm³.

A. 15.68 g/cm³ B. 99.84 g/cm³ C. 0.8 g/cm³ D. 1.6 g/cm³

Solution:

$$SG = \frac{\rho_{fluid}}{\rho_{water}}$$

$$\rho_{fluid} = SG \times \rho_{water} = 1.6 \times \frac{1\ g}{cm^3} = \mathbf{1.6\ g/cm^3}$$

448. What is the absolute pressure if the gauge pressure reading is 9 bar and the atmospheric pressure is 0.9 bar?

A. 6.3 bar B. 7.8 bar C. 9.9 bar D. 8.1 bar

Solution:

$$P_{abs} = P_{gage} + P_{atm} = 9\ bar + 0.9\ bar = \mathbf{9.9\ bar}$$

449. The tank of an air compressor has a volume of 3 ft^3 and is filled with air at a temperature of 40°F. If a gage on the tank reads 150 psig, what is the mass of the air in the tank?

A. 1.78 lbs B. 2.00 lbs C. 2.67 lbs D. 1.98 lbs

Solution:

$$R_{air} = 53.3\ ft\text{-}lb_f/lb_m\text{-}°R$$

$$PV = mRT$$

$$m = \frac{PV}{RT} = \frac{(150 + 14.7)\frac{lb_f}{in^2}(3\ ft^3)\left(\frac{144\ in^2}{1\ ft^2}\right)}{53.3\frac{ft\text{-}lb_f}{lb_m\text{-}°R}(40+460)°R} = \mathbf{2.67\ lbs}$$

450. What is the mass of acetylene gas, V = 0.94 cu. ft., R = 59.35 ft-lb/lb-°R, T = 90°F, P = 200 psia?

A. 0.816 lb B. 0.841 lb C. 0.829 lb D. 0.852 lb

Solution:

$$m = \frac{PV}{RT} = \frac{200\ (0.94)\ (144)}{59.35\ (90+460)} = \mathbf{0.829\ lb}$$

451. Specific volume is the number of cubic meters of mixture per kilogram of dry air. If dry air has these following properties: R_a = 287 J/kg-K, T = 303 K, Pa = 99.604 kPa. Solve for the specific volume.

A. 0.873 m^3/kg B. 0.853 m^3/kg C. 0.953 m^3/kg D. 0.783 m^3/kg

Solution:

$$\text{specific volume} = \frac{R_a \times T}{P_a} = \frac{0.287(303)}{99.604} = \mathbf{0.873\ m^3/kg}$$

452. A refrigerating system operates on the reversed Carnot Cycle. The higher temperature of the refrigerant in the system is 120°F and the lower is 10°F. The capacity is 20 tons. Neglect losses. Determine the coefficient of performance.

A. 2.732 B. 5.373 C. 7.372 D. 4.273

Solution:

$$\text{COP} = \frac{T_1}{T_2 - T_1} = \frac{10+460}{(120+460)+(10+460)} = \mathbf{4.273}$$

453. At a pressure of 60°F, a motorbike Ire is inflated to 33 psig. As it is driven along the C-5 road, the temperature rose to 76°F. Assuming the volume remains constant, determine the final gauge pressure.

Given:

P_1 = 33 psig + 14.7 psig = 47.7 psig

T_1 = 60°F + 460 = 520°R

T_2 = 76°F + 460 = 536°R

A. 34.47 psig B. 49.17 psig C. 35.00 psig D. 34.30 psig

Solution:

$$\text{At constant volume}, V = C:$$

$$\frac{T_2}{T_1} = \frac{P_2}{P_1}$$

$$P_2 = P_1 \times \frac{T_2}{T_1} = 47.7 \text{ psig} \times \frac{536°\text{R}}{520°\text{R}} = 49.17 \text{ psia} - 14.7 \text{ psig} = \mathbf{34.47\ psig}$$

454. Steam enters a turbine stage with an enthalpy of 3700 kJ/kg and a velocity of 80 m/s and leaves with an enthalpy of 2864 kJ/kg with a velocity of 12.8 m/s. If the rate of a steam flow through the turbine is 0.44 kg/s, what is the work done in kW?

A. 365 kW B. 365.64 kW C. 366.0 kW D. 366.50 kW

Solution:

$$H_1 + KE_1 = H_2 + KE_2 + W$$

$$KE_1 = \frac{v_1^2}{2K} = \frac{\left(80\frac{m}{s}\right)^2}{\left(2\times 1000\frac{\text{kg-m}}{\text{kN-s}^2}\right)} = 3.2 \text{ kJ/kg}$$

$$KE_2 = \frac{v_2^2}{2K} = \frac{\left(128\frac{m}{s}\right)^2}{\left(2\times 1000\frac{\text{kg-m}}{\text{kN-s}^2}\right)} = 8.192 \text{ kJ/kg}$$

$$3700\frac{\text{kJ}}{\text{kg}} + 3.2\frac{\text{kJ}}{\text{kg}} = 2864\frac{\text{kJ}}{\text{kg}} + 8.192\frac{\text{kJ}}{\text{kg}} + W$$

$$W = 3703.2\frac{\text{kJ}}{\text{kg}} - 2872.2\frac{\text{kJ}}{\text{kg}}$$

$$= 831\frac{\text{kJ}}{\text{kg}} \times 0.44\frac{\text{kg}}{\text{s}} = \mathbf{365.64\ kW}$$

455. Aluminum has a specific heat of 0.902 J/g-°C. How much heat is lost when a piece of aluminum with a mass of 23.984 g cools from a temperature of 415.0°C to a temperature of 22.0°C?

A. 8500 J B. 6000 J C. 80000 J D. 7500 J

Solution:

$$Q = mC_p(t_2 - t_1) = 23.984(0.902)(415 - 22) = 8502 \approx \mathbf{8500\ J}$$

456. If the temperature of an air parcel is -20.5°C, and its density is 0.690 kg/m^3, what is the pressure of the air parcel?

A. 40 kPa B. 50 kPa C. 60 kPa D. 70 kPa

Solution:

$$P = \rho RT$$

$$T = \text{-}20.5\ ℃ + 273\ K = 252.5\ K$$

$$\rho = 0.690\ kg/m^3$$

$$R = 287\ J/kg\text{-}K$$

$$P = 0.690\frac{kg}{m^3} \times 252.5\ K \times 287\frac{J}{kg\text{-}K} = 50000\ Pa = \mathbf{50\ kPa}$$

457. A 35.0 mL sample of gas is enclosed in a flask at 22 degrees Celsius. If the flask was placed in an ice bath at 0 degrees Celsius, what would the new gas volume be if the pressure is held constant?

A. 34.1 mL B. 32.1 mL C. 32.39 mL D. 33.1 mL

Solution:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$V_1 = 35.0\ ml$$

$$T_1 = 22℃ + 273 = 295\ K$$

$$V_2 = ?$$

$$T_2 = 0℃ + 273 = 273K$$

$$\frac{35.0\ mL}{295\ K} = \frac{V_2}{273\ K}$$

$$V_2 = \mathbf{32.39\ ml}$$

458. A car engine with a power output of 65 hp has a thermal efficiency of 24%. Determine the fuel consumption rate of this car if the fuel has a heating value of 19,000 Btu/lb$_m$.

A. 36.28 lb$_m$/hr B. 37.28 lb$_m$/hr C. 37.28 lb$_m$/hr D. 35.30 lb$_m$/hr

Solution:

$$e = \frac{\dot{W}}{\dot{Q}_A}$$

$$\dot{Q}_A = \frac{\dot{W}}{e} = \frac{65\ hp}{0.24}\left(\frac{2545\frac{Btu}{hr}}{1\ hp}\right) = 689{,}270.83\ Btu/hr$$

$$\dot{Q}_A = \dot{m}_{fuel}(\text{Heating value})$$

$$\dot{m} = \frac{689{,}270.83\frac{Btu}{hr}}{19{,}000\frac{Btu}{lb_m}} = \mathbf{36.28\ lb_m/hr}$$

459. The thermal efficiency of a Carnot cycle operating between 170°C and 620°C is closest to:

A. 44% B. 50% C. 63% D. 73%

Solution:

$$T_{high} = 620°C + 273 = 893\ K$$

$$T_{low} = 170°C + 273 = 443\ K$$

$$e = \frac{T_{high} - T_{low}}{T_{high}} = \frac{893 - 443}{893} = 0.5039 = 50.39 \approx \mathbf{50\%}$$

460. Compute the humidity ratio of air at 70% relative humidity and 25°C when the barometric pressure is 101.325 kPa. From the steam tables: $P_{sat\ @\ 34\ °C}$ = 3.169 kPa.

A. 0.014 $kg_{water\ vapor}/kg_{dry\ air}$ C. 1.4 $kg_{water\ vapor}/kg_{dry\ air}$

B. 0.14 $kg_{water\ vapor}/kg_{dry\ air}$ D. 0.0014 $kg_{water\ vapor}/kg_{dry\ air}$

Solution:

$$P_s = \text{saturation pressure at } 34°C = 3.169\ kPa$$

$$P_v = ØP_s = 0.70(3.169) = 2.2183\ kPa$$

$$W = 0.622\left(\frac{2.2183}{101.325 - 2.2183}\right) = \mathbf{0.014\ kg_{water\ vapor}/kg_{dry\ air}}$$

461. A pressure gauge registers 50 psig in a region where the barometer reads 14.8 psia. Find the absolute pressure in kPa.

A. 666.66 kPa B. 556.66 kPa C. 446.66 kPa D. 336.66 kPa

Solution:

$$P_{abs} = P_o + P_g = 14.8\ psia + 50\ psig = 64.8\ psia \times \frac{101.325\ kPa}{14.70\ psi} = \mathbf{446.66\ kPa}$$

462. Consider 1 kg of air at 32°C that expanded by a reversible polytropic process with n = 1.25 until the pressure is halved. Determine the heat transfer. Specific heat at constant volume for air is 0.1786 kJ/kg-K.

A. 17.02 kJ heat rejected C. 17.02 kJ heat added

B. 7.05 kJ heat rejected D. 7.05 kJ heat added

Solution:

$$T_1 = 32 + 273 = 305\ K$$

$$T_2 = T_1\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} = 305\left(\frac{1}{2}\right)^{\frac{1.25-1}{1.25}} = 265.52\ K$$

$$c_p = c_v\left(\frac{k-n}{1-n}\right) = 0.1786\left(\frac{1.4-1.25}{1-1.25}\right) = \text{-}0.4312\ kJ/kg\text{-}K$$

$$Q = mc_p(T_2 - T_1) = 1\ kg\left(\text{-}0.4312\frac{kJ}{kg\text{-}K}\right)(265.52\ K - 305\ K)$$

$$= \mathbf{17.02\ kJ\ heat\ added}$$

463. A Carnot cycle uses nitrogen (k = 1.399) as the working substance. The heat supplied is 54 kJ and the adiabatic expansion ratio is 10. Determine the heat rejected.

A. 10 kJ B. 32.4 kJ C. 21.6 kJ D. 54 kJ

Solution:

$$e == 1 - \frac{1}{A} = 1 - \frac{1}{r_k^{k-1}} = 1 - \frac{1}{10^{1.399-1}} = 0.60$$

$$W = eQ_A = 0.60(54) = 32.4 \text{ kJ}$$

$$Q_R = W - Q_A = 32.4 - 54 = \mathbf{21.6\ kJ} \text{ or } 21.6 \text{ (heat rejected)}$$

464. A tank contains 20 kg of air at 200 kPa (gage) and 23°C. During the heating process the temperature of air rises. For safety purposes a technician installed a relief-type valve so that pressure of air inside the tank never exceeds 260 kPa (gage). At what air temperature the relief valve will start releasing air?

A. 112°C B. 92°C C. 82°C D. 102°C

Solution:

$$T_1 = 23 + 273 = 296 \text{ K}$$

$$P_1 = 200 + 101.325 = 301.325 \text{ kPa (abs)}$$

$$P_2 = 260 + 101.325 = 361.325 \text{ kPa (abs)}$$

$$T_2 = T_1\left(\frac{P_2}{P_1}\right) = 296\left(\frac{361.125}{301.125}\right) = 355 \text{ K} - 273 = \mathbf{82℃}$$

465. An air compressor takes in 9 kg/min of air at 98 kPa; υ_1 = 0.125 m^3/kg and discharges it at 680 kPa; υ_2 = 0.03 m^3/kg. The increase of internal energy is 93 kJ/kg and the work done on air is 163 kJ/kg; the change in potential and kinetic energy are neglected. How much heat is transferred per kg of air?

A. 264.15 kJ/kg B. 61.85 kJ/kg C. 288.65 kJ/kg D. 78.15 kJ/kg

Solution:

$$w_1 = P_1\upsilon_1 = 98(0.125) = 12.25 \text{ kJ/kg}$$

$$w_2 = P_2\upsilon_2 = 680(0.03) = 20.4 \text{ kJ/kg}$$

$$Q = \Delta u + \Delta w + w = 93 + (20.4 - 12.25) + (\text{-}163)$$

$$= \text{-}\mathbf{61.85\ kJ/kg} \text{ (heat rejected)}$$

466. During a reversible process, there are abstracted 317 kJ/s from 1.134 kg/s of a certain gas while the temperature remains constant at 26.7°C. For this gas c_p = 2.232 and c_v = 1.713 kJ/kg-K. The initial pressure is 586 kPa. Determine the final volume flow rate.

A. 0.301 m^3/s B. 0.03 m^3/s C. 0.5 m^3/s D. 0.05 m^3/s

Solution:

$$R = c_p - c_v = 2.232 - 1.713 = 0.519\frac{kJ}{kg\text{-}K};\ T_1 = 26.7 + 273 = 299.7\ K$$
$$\dot{Q} = P_1\dot{V}_1 \ln\frac{V_2}{V_1} = -317 = 586(0.301)\ln\frac{V_2}{0.301}$$
$$\dot{V}_2 = \mathbf{0.05\ m^3/s}$$

467. Flow of water in a pipe has a velocity at 10 meters per second. Determine the velocity head of the water.

A. 50.1 meters B. 5.10 meters C. 8.20 meters D. 100 meters

Solution:

$$\text{Velocity head} = \frac{v^2}{2g} = \frac{10^2}{2(9.8066)} = \mathbf{5.1\ meters}$$

468. A Diesel cycle has a cut-off ratio of 2.20 and a compression ratio of 10. Find the cycle efficiency.

A. 55.10% B. 59.735% C. 52.23% D. 62.37%

Solution:

$$e = 1 - \frac{1}{r_k^{k-1}}\left[\frac{r_c^k - 1}{k(r_c - 1)}\right] = 1 - \frac{1}{10^{1.40-1}}\left[\frac{2.20^{1.4} - 1}{1.4(2.20-1)}\right] = \mathbf{52.23\%}$$

469. A diesel cycle has an initial temperature of 27°C. If the cut-off ratio is 2.50 and compression ratio is 12, find the maximum cycle temperature.

A. 1634.4°C B. 1753.44°C C. 2010.3°C D. 1983.4°C

Solution:

$$T_2 = T_1 r_k^{k-1} = 300(12)^{1.40-1} = 810.58\ K$$
$$\frac{V_2}{T_2} = \frac{V_3}{T_3}$$
$$\frac{T_3}{T_2} = \frac{V_3}{V_2} = r_c$$
$$T_3 = T_2 r_c = 810.58(2.50) = 2026.44\ K = \mathbf{1753.44℃}$$

470. A diesel cycle, which takes in air at 1 bar and 26°C, has a compression ratio of 19. Calculate the operating clearance in percent.

A. 8.08 B. 8.56 C. 7.52 D. 5.55

Solution:

$$r_k = \frac{1+c}{c}$$
$$19 = \frac{1+c}{c}$$
$$c = \mathbf{5.55\%}$$

471. An Otto cycle has an initial pressure of 100 kPa and has a pressure of 400 kPa after adiabatic compression. Find the cycle efficiency.

A. 32.70% B. 34.70% C. 36.70% D. 38.70%

Solution:

$$P_1V_1^k = P_2V_2^k$$

$$r_k = \frac{V_1}{V_2} = \left(\frac{P_2}{P_1}\right)^{1/k} = \left(\frac{400}{100}\right)^{1/1.4} = 2.692$$

$$e = 1 - \frac{1}{r_k^{k-1}} = 1 - \frac{1}{2.692^{1.40-1}} = 0.3270 = \mathbf{32.70\%}$$

472. An Otto cycle has a clearance of 8% and heat added of 1000 kJ. Find the heat rejected.

A. 564 kJ B. 353 kJ C. 709 kJ D. 867 kJ

Solution:

$$r_k = \frac{1+c}{c} = \frac{1+0.08}{0.08} = 13.50$$

$$e = 1 - \frac{1}{r_k^{k-1}} = 1 - \frac{1}{13.50^{1.40-1}} = 0.6469 = 64.69\%$$

$$e = \frac{W}{Q_A}$$

$$W = eQ_A = 0.6469(1000) = 649.9 \text{ kJ}$$

$$Q_R = Q_A - W = 1000 - 646.90 = \mathbf{353\ kJ}$$

473. An Otto cycle has a heat rejected of 300 kJ and work of 700 kJ. Find the cycle efficiency.

A. 56% B. 60% C. 70% D. 50%

Solution:

$$Q_A = W_{net} + Q_R = 700 + 300 = 1000 \text{ kJ}$$

$$e = \frac{W_{net}}{Q_A} = \frac{700}{1000} = 0.70 = \mathbf{70\%}$$

474. An Otto cycle has a pressure ratio of 7. What is the cycle compression ratio?

A. 5.18 B. 6.34 C. 7.34 D. 4.01

Solution:

$$P_1V_1^k = P_2V_2^k$$

$$r_k = \frac{V_1}{V_2} = \left(\frac{P_2}{P_1}\right)^{1/k} = 7^{1/1.40} = \mathbf{4.01}$$

475. Find the power of a rotating shaft which develops a torque of 188 N-m at 1350 rpm.

A. 101.54 hp B. 53.63 hp C. 63.35 hp D. 35.63 hp

Solution:

$$P = 2\pi TN = 2\pi(0.188)\left(\frac{1350}{60}\right) = 26.58 \text{ kW}\left(\frac{1 \text{ hp}}{0.746 \text{ kW}}\right) = \mathbf{35.63\ hp}$$

476. Determine the pressure exerted on a diver at 30 m below the free surface of the sea. Assume a barometric pressure of 101 kPa and the specific gravity of sea water is 1.03.

A. 404 kPa B. 410 kPa C. 420 kPa D. 430 kPa

Solution:

$$\mathrm{P} = 101 + 9.8066(1.03)(30) = \mathbf{404\ kPa}$$

477. An air compressor has an inlet enthalpy of 35 Btu/lb and an exit enthalpy of 70 Btu/lb. The mass flow rate of air is 3 lb/s. If the heat loss is 466.62 Btu/min, find the work input to the compressor.

A. 139.59 hp B. 149.59 hp C. 159.59 hp D. 169.59 hp

Solution:

$$\dot{\mathrm{Q}} = \Delta\mathrm{H} + \dot{\mathrm{W}}$$

$$-466.62 = 3(60)(70 - 35) + \dot{\mathrm{W}}$$

$$\dot{\mathrm{W}} = -6766.62\,\frac{\mathrm{Btu}}{\mathrm{min}}\left(\frac{1\ \mathrm{hp}}{42.4\frac{\mathrm{Btu}}{\mathrm{min}}}\right) = \mathbf{-159.59\ hp}$$

478. An automobile tire is inflated to 35 psig at 54°F. After being driven, the temperature rises to 80°F. Determine the final gage pressure assuming that the tire is inflexible.

A. 36.51 psig B. 37.51 psig C. 38.51 psig D. 39.51 psig

Solution:

$$\frac{\mathrm{P}_2}{\mathrm{P}_1} = \frac{\mathrm{T}_2}{\mathrm{T}_1}$$

$$\mathrm{P}_2 = \mathrm{P}_1\left(\frac{\mathrm{T}_2}{\mathrm{T}_1}\right) = (35 + 14.7)\left(\frac{540}{514}\right) = 52.21\ \mathrm{psia}$$

$$\mathrm{P}_\mathrm{g} = 52.21\ \mathrm{psia} - 14.7\ \mathrm{psia} = \mathbf{37.51\ psig}$$

479. A condenser vacuum gauge reads 600 mm Hg when the barometer reads 760 mm Hg. What is the absolute condenser pressure in bar?

A. 0.0213 B. 0.061 C. 0.213 D. 0.610

Solution:

$$\mathrm{P}_{\mathrm{abs}} = \mathrm{P}_{\mathrm{atm}} - \mathrm{P}_{\mathrm{vac}} = (760 - 600)\ \mathrm{mm\ Hg} \times \left(\frac{1.013\ \mathrm{bar}}{760\ \mathrm{mm\ Hg}}\right) = \mathbf{0.213}$$

480. Water flows in a pipe at the rate of 10 kg/s. If the velocity of flow is 10 m/s, find the pipe diameter.

A. 30.23 mm B. 35.68 mm C. 38.39 mm D. 42.39 mm

Solution:

$$\dot{\mathrm{m}} = \mathrm{AV}\rho$$

$$10 = \frac{\pi}{4}D^2(10)(1000)$$

$$D = 0.03568 \text{ m or } \mathbf{35.68\ mm}$$

481. What is the resulting pressure when one kilogram of air at 104 kPa and 98°C is heated at constant volume to 450°C?

A. 202.67 kPa B. 194.67 kPa C. 186.53 kPa D. 198.65 kPa

Solution:

$$\frac{P_2}{T_2} = \frac{P_1}{T_1}$$

$$P_2 = \frac{450+273}{98+273}(104) = \mathbf{202.67\ kPa}$$

482. Determine the degrees of superheat of steam at 101.325 kPa and 170°C.

A. 50°C B. 70°C C. 60°C D. 80°C

Solution:

$$°SH = 170℃ - t_{sat\ @101.325\ kPa} = 170℃ - 100℃ = \mathbf{70℃}$$

483. Calculate the approximate enthalpy of water at 90°C.

A. 366.83 kJ/kg B. 376.83 kJ/kg C. 386.83 kJ/kg D. 396.83 kJ/kg

Solution:

$$h = c_p(t - t_{ref}) = 4.187(90 - 0) = \mathbf{376.83\ kJ/kg}$$

484. A Carnot cycle operates between 30°C and 350°C. Find the cycle efficiency.

A. 51.36% B. 63.45% C. 45.37% D. 76.45%

Solution:

$$e = \frac{T_{max} - T_{min}}{T_{max}} = \frac{350-30}{350+273} = 0.5136 = \mathbf{51.36\%}$$

485. A Carnot cycle has a maximum temperature of 550°F and minimum temperature of 100°F. If the heat added is 4200 Btu/min, find the horsepower output of the engine.

A. 34.53 B. 40.56 C. 44.13 D. 65.40

Solution:

$$e = \frac{550-100}{550+460} = 0.4455 = 44.55\%$$

$$\dot{W} = e\dot{Q}_A = 0.4455(4200) = 1871.1\frac{\text{Btu}}{\text{min}}\left(\frac{1\text{ hp}}{42.4\frac{\text{Btu}}{\text{min}}}\right) = \mathbf{44.13}\text{ hp}$$

486. A Carnot cycle has a sink temperature of 100°F and a cycle efficiency of 70%. Find the temperature of the heat souce.

A. 1306.70°F B. 1406.70°F C. 1506.70°F D. 1606.70°F

Solution:

$$e = \frac{T_{max} - T_{min}}{T_{max}}$$

$$0.70 = \frac{T_{max} - 560}{T_{max}}$$

$$T_{max} = 1866.67°R - 460 \approx \mathbf{1406.70°F}$$

487. The quality of steam is 20%. This means that:

A. mass of liquid is 20%, mass of vapor is 80%

B. mass of liquid is 20%, mass of vapor is 0%

C. mass of liquid is 80%, mass of vapor is 20%

D. none of the above

Solution:

$$\mathbf{mass\ of\ liquid\ is\ 80\%, mass\ of\ vapor\ is\ 20\%}$$

488. Fifty kilograms of cooling water per second enter the condenser at 25°C and leaves at 50°C. Find the heat carried away by water.

A. 1234.45 kW B. 5233.75 kW C. 2340.53 kW D. 3140.25 kW

Solution:

$$\dot{Q} = \dot{m}c\Delta T = 50(4.187)(50 - 25) = \mathbf{5233.75\ kW}$$

489. Ten kilograms per second of steam enter the turbine with an enthalpy of 3200 kJ/kg and enter the condenser with an enthalpy of 2500 kJ/kg in a Rankine cycle. If the turbine efficiency is 80% and the generator efficiency is 90%, determine the power plant output.

A. 4320 kW B. 3213 kW C. 4056 kW D. 5040 kW

Solution:

$$\dot{W} = 10(3200 - 2500)(0.80)(0.90) = \mathbf{5040\ kW}$$

490. Determine the quality of steam in a vessel containing 2 kg of saturated vapor and 8 kg of saturated liquid.

A. 100% B. 20% C. 80% D. 60%

Solution:

$$\text{Quality}, x = \frac{m_v}{m_v + m_l} = \frac{2}{2+8} = 0.20 = \mathbf{20\%}$$

491. The condenser of a reheat power plant rejects heat at the rate of 600 kW. The mass flow rate of cooling water is 5 kg/s and the inlet cooling water temperature is 35°C. Calculate the condenser cooling water exit temperature.

A. 43.45°C | B. 53.45°C | C. 63.66°C | D. 74.34°C

Solution:

$$600 = 5(4.187)(T_{final} - 308)$$
$$T_{final} = 336.66\ K - 273 = \mathbf{63.66^\circ C}$$

492. A heat engine has a thermal efficiency of 50%. How much power does the engine produce when heat is transferred at a rate of 10^9 kJ/hr?

A. 50 MW | B. 75 MW | C. 139 MW | D. 147 MW

Solution:

$$\dot{Q}_A = 1{,}000{,}000{,}000\frac{kJ}{hr}\left(\frac{1\ hr}{3600\ s}\right) = 277{,}777.78\ kW = 277.78\ MW$$
$$\dot{W}_{net} = eQ_A = 0.50(277.78) = 138.89 \approx \mathbf{139\ MW}$$

493. One kilogram of air is compressed adiabatically and in a steady-flow manner. The compression efficiency is 80% and the work done on the air is 265 kJ/kg. Compute the heat.

A. 212 kJ/kg | B. 100 kJ/kg | C. 0 kJ/kg | D. 331.25 kJ/kg

Solution:

$$Q = \mathbf{0\ kJ/kg}\ \text{(adiabatic)}$$

494. Three-hundred kilojoules of heat flow by conduction from the outside to the inside of a cold storage in one hour. If the temperature and all other conditions are the same, what is the heat flowing through the cold storage room in two hours?

A. 600 kJ | B. 900 kJ | C. 300 kJ | D. 1,200 kJ

Solution:

$$Q = 300\frac{kJ}{hr}(2\ hr) = \mathbf{600\ kJ}$$

495. Determine the density of air at 760 mmHg absolute and 22°C?

A. 1.014 kg/m³ | B. 1.316 kg/m³ | C. 1.197 kg/m³ | D. 1.266 kg/m³

Solution:

$$\rho = \frac{P}{RT} = \frac{760\ mmHg}{\left(0.287\frac{kJ}{kg\text{-}K}\right)(22^\circ C + 273)} \times \frac{101.325\ kPa}{760\ mmHg} = \mathbf{1.197\ kg/m^3}$$

496. A refrigerating machine that is classified as a one-ton machine has the capacity to produce a cooling effect of?

A. 3.516 kW | B. 12,000 Btu/hr | C. 211 kJ/min | D. All of the above

Solution:

$$1\ TOR = 3.516\ kW = 12{,}000\frac{Btu}{hr} = \frac{211 kJ}{min}\ \therefore\ \textbf{All of the above}$$