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PROBLEM 19

APPLICATIONS SYSTEMS & COMPONENTS

A primary-secondary chilled water pumping system consists of a primary pump designed to supply 500 GPM at 20 feet head and a secondary pump designed to supply 500 GPM at 100 feet head. The chiller has a minimum flow of 200 GPM. During part load conditions, the air handlers require a total of 300 GPM. At this time, which of the following is true? Assume only the secondary pump has variable flow control.

(A) Primary pump: 500 GPM; Secondary pump: 500 GPM; Bypass: 0 GPM

(B) Primary pump: 300 GPM; Secondary pump: 300 GPM; Bypass: 0 GPM

(C) Primary pump: 500 GPM; Secondary pump: 300 GPM; Bypass: 200 GPM

(D) Primary pump: 300 GPM; Secondary pump: 500 GPM; Bypass: 200 GPM

PROBLEM 20

APPLICATIONS SUPPORTIVE KNOWLEDGE

A vibration isolator system is designed for a HVAC equipment with a disturbing frequency of 30 HZ. The system achieves a transmissibility of 10%. If the disturbing frequency is doubled, then what will most likely be the new transmissibility? Assume the vibration isolator system remains the same and the HVAC equipment mass remains the same. Assume zero damping.

$$Transmissibility = \left| \frac{1}{1 - \left(\frac{f_d}{f_n}\right)^2} \right|$$

(A) 1.2%

(B) 2.3%

(C) 5.0%

(D) 10.0%

PROBLEM 25

PRINCIPLES – HEAT TRANSFER

A wall section consists of 10 inch concrete, 1” air gap (R-3), R-12 insulation (6 inch thickness) and another 6 inches of concrete. Assume 150 lb/ft^3 concrete with conductivity of 10 Btu-in/hr-ft^2-F. The design heating space conditions are 68 F DB/50% RH. The design outdoor conditions are 40 F DB/30 F WB. What is the heating load due to the exterior walls? The total area of the walls is 5,200 square feet.

(A) 2,020 Btu/h

(B) 5,160 Btu/h

(C) 8,344 Btu/h

(D) 11,180 Btu/h

PROBLEM 26

Principles – Fluid mechanics

A pump is currently supplying 150 GPM at 125 feet of head. If a second identical pump is turned on then what will each pump provide? Assume the pumps are arranged in parallel and there are identical pressure drops to/from each pump to/from the common pipes.

(A) 150 gpm and 62.5 feet of head

(B) 75 gpm and 62.5 feet of head

(C) 75 gpm and 125 feet of head

(D) 300 gpm and 125 feet of head

PROBLEM 37

APPLICATIONS SYSTEMS & COMPONENTS

The density of a chilled water-glycol mixture is 70 lbs/ft^3. The viscosity is 7.5 centipoise. A pump is used to pump 100 GPM of this fluid through the cooling system that has a total pressure drop of 100 ft of head. What is the mechanical horsepower required to pump this fluid?

(A) 2.5 HP

(B) 2.8 HP

(C) 3.2 HP

(D) 3.6 HP

PROBLEM 38

Principles – Systems

A chilled water system consists of (2) chillers each with a volume of 100 gallons. The chilled water piping consists of 1,000 feet of 6" Sch 40 steel. There are 10 air handlers each with a volume of 25 gallons. The chilled water design temperatures are 45 F minimum and 85 F maximum. At the location of the expansion tank there will be a minimum pressure of 50 psig and a maximum of 100 psig. What is most nearly the size of the diaphragm expansion tank? Do not include any credit for the expansion of the piping in the system and assume the pre-charge pressure is 18 psig. The expansion tank equation is shown below, since it isn't included in the handbook.

$$V_{tank} = V_{system} * \frac{\left(\left(\frac{v_{hot}}{v_{cold}} - 1\right) - 3\alpha(T_h - T_c)\right)}{\frac{P_{min}}{P_{pre}} - \frac{P_{min}}{P_{max}}}$$

(A) 6 gallons

(B) 33 gallons

(C) 67 gallons

(D) 195 gallons

PROBLEM 39

APPLICATIONS SYSTEMS & COMPONENTS

A condenser water system consists of an outdoor cooling tower, indoor reservoir, 3-way diverting valve, condenser and condenser water pump. If the cooling tower fans are at minimum speed and the condenser water temperature continues to fall, then which of the following should most likely occur to keep the condenser water temperature entering the condenser above the minimum required temperature?

(A) The cooling tower fans should slow down

(B) The pump should slow down.

(C) The diverting valve should direct water to the indoor reservoir.

(D) The diverting valve should direct water to the cooling tower.

PROBLEM 40

APPLICATIONS SUPPORTIVE KNOWLEDGE

An outdoor air cooled chilled water plant consists of (2) air cooled chillers and (2) chilled water pumps. The air cooled chillers both have a sound rating of 90 db and the chilled water pumps both have a sound rating of 80 db. What is the combined sound rating?

(A) 50 db

(B) 68 db

(C) 86 db

(D) 93 db

PROBLEM 45

PRINCIPLES – HEAT TRANSFER

A 6” steel, schedule 40 pipe carries steam at 300 °F. The exterior surface of the insulation must be kept below 120 °F. The ambient temperature is 80 °F. What equivalent thickness insulation is required?

Insulation: k = 0.20 Btu-in/h-ft^2-°F

Insulation Surface Convective Heat Transfer Coefficient: h = 1.0 Btu/h-ft^2-°F

(A) 0.9 inches

(B) 1.5 inches

(C) 1.8 inches

(D) 2.4 inches

PROBLEM 46

Principles – Fluid mechanics

A compressor provides 150 CFM at 100 psig. What is the standard CFM entering the compressor? The ambient air is 68 °F/36% RH and the output temperature of the compressor is 200 °F.

(A) 636 CFM

(B) 935 CFM

(C) 1,229 CFM

(D) 2,647 CFM

(B) The pump should slow down.

(C) The diverting valve should direct water to the indoor reservoir.

(D) The diverting valve should direct water to the cooling tower.

The correct answer is most nearly, (C). The diverting valve should direct water to the indoor reservoir. This will bypass the cooling tower, where it is most likely too cold outdoors.

SOLUTION 40

APPLICATIONS SUPPORTIVE KNOWLEDGE

An outdoor air cooled chilled water plant consists of (2) air cooled chillers and (2) chilled water pumps. The air cooled chillers both have a sound rating of 90 db and the chilled water pumps both have a sound rating of 80 db. What is the combined sound rating at a distance of 25 feet away? Assume there are no walls or sound barriers and the equipment is located on the ground.

First, combine the sound levels.

$$Total\ Sound\ Level(DB) = 10\text{LOG}[10^{\frac{L1}{10}} + 10^{\frac{L1}{10}} + 10^{\frac{L1}{10}} + 10^{\frac{L1}{10}}]$$

$$Total\ Sound\ Level(DB) = 10\text{LOG}[10^{\frac{90}{10}} + 10^{\frac{90}{10}} + 10^{\frac{80}{10}} + 10^{\frac{80}{10}}]$$

$$Total\ Sound\ Level(DB) = 93.42\ db$$

The correct answer is most nearly, (D) 93 db.

(A) 50 db

(B) 68 db

(C) 86 db

(D) 93 db

PROBLEM 45

PRINCIPLES – HEAT TRANSFER

A 6" steel, schedule 40 pipe carries steam at 300 °F. The exterior surface of the insulation must be kept below 120 °F. The ambient temperature is 80 °F. What equivalent thickness insulation is required?

Insulation: k = 0.20 Btu-in/h-ft^2-°F

Insulation Surface Convective Heat Transfer Coefficient: h = 1.0 Btu/h-ft^2-°F

(A) 0.9 inches

(B) 1.5 inches

(C) 1.8 inches

(D) 2.4 inches

PROBLEM 46

Principles – Fluid mechanics

A compressor provides 150 CFM at 100 psig. What is the actual CFM entering the compressor? The ambient air is 68 °F/36% RH and the output temperature of the compressor is 200 °F.

(A) 636 CFM

(B) 935 CFM

(C) 1,229 CFM

(D) 2,647 CFM

PROBLEM 49

APPLICATION – HEATING/COOLING LOADS

A food storage refrigerator will contain 500 pounds of food at an initial temperature of 75 °F. The food has the properties shown below. The refrigerator must be sized to cool the food down to 0 °F in a maximum of 2 hours. Assume a safety factor of 25%. What is the size of the refrigerator? Specific heat at all temperatures: 0.5 Btu/lb-°F; Latent heat of fusion: 133 Btu/lb. Freezing point: 10 °F.

(A) 3.6 tons

(B) 4.4 tons

(C) 7.1 tons

(D) 8.9 tons

PROBLEM 50

APPLICATIONS EQUIPMENT & COMPONENTS

A 100-ton, 480 V, 3 PH, 60 HZ, HVAC equipment has the following efficiencies at various loading conditions. The HVAC equipment operates at 100% load for 20 hours/year, 75% load for 2,000 hours/year, 50% load for 4,000 hours/year and 25% load for the remaining hours. What is the total electricity usage per year?

100% load: 3.0 COP

75% load: 3.3 COP

50% load: 2.5 COP

25% load: 2.2 COP

(A) 2,400 kWh/year

(B) 109,400 kWh/year

(C) 378,400 kWh/year

(D) 550,000 kWh/year

PROBLEM 61

PRINCIPLES BASIC ENGINEERING PRACTICE

A fan provides 1,000 CFM at 2.0 in wg. The fan is 70% efficient at this operating point. The motor is 95% efficient. What is the total kW provided? Assume sea level.

(A) 0.17 kW

(B) 0.35 kW

(C) 0.47 kW

(D) 0.91 kW

PROBLEM 62

PRINCIPLES – THERMODYNAMICS

A refrigerant cycle uses R-410a at a condenser temperature of 102°F and an evaporator temperature of 20°F. What is the quality of the refrigerant entering the evaporator? Assume no sub-cooling, no superheating and an ideal expansion valve.

(A) 0.3

(B) 0.6

(C) 0.8

(D) 1.0

$$Q_{ventilation} = 1.08 * 300\ CFM * (85°F - 34°F) = 16{,}524\ Btuh$$

$$Q_{heating} = Q_{envelope} + Q_{ventilation} = 90{,}000\ Btuh + 16{,}524\ Btuh = 106{,}524\ Btuh$$

Find the steam flow rates, using the heat of vaporization at 220°F. The maximum steam flow rate occurs when steam is supplied at saturated vapor and returns at saturated liquid.

$$Q_{heating} = \dot{m}(h_g - h_f) = \dot{m}\left(1154.05\frac{Btu}{lb} - 188.40\frac{Btu}{lb}\right) = 106{,}524\ Btuh$$

$$\dot{m} = 110\ lb/hr$$

The correct answer is most nearly, (B) 105 lb/hr.

(A) 80 lb/hr

(B) 105 lb/hr

(C) 135 lb/hr

(D) 175 lb/hr

SOLUTION 29

APPLICATION – HEATING/COOLING LOADS

What is the total cooling load for a dance room with 30 occupants and a lighting load of 1.0 watts per square foot. The total area is 400 square feet. Assume the lights have a usage factor of 1.0, special allowance factor of 1.1 and a space fraction of 0.7.

$$Q_{lights} = 1.0\frac{W}{ft^2} * 400\ ft^2 * \frac{3.412\frac{Btu}{h}}{W} * (1.0) * (1.1) * 0.7) = 1{,}050.9\ Btu/h$$

$$Q_{people} = 30 * 850\frac{Btu}{h}\ per\ person\ (ASHRAE\ Fundamentals\ Ch18) = 25{,}500\frac{Btu}{h}$$

$$Total\ load = Q_{people} + Q_{lights} = 26{,}551\frac{Btu}{h}$$

The correct answer is most nearly, (D) 26,550 Btu/h.

(A) 1,050 Btu/h

(B) 15,770 Btu/h

(C) 25,500 Btu/h

(D) 26,550 Btu/h

$$Q_{sensible} = 50{,}000 \frac{Btu}{h} = 1.08 * 2{,}000 * (72 - T_{DB})$$

$$T_{DB} = 48.9\ F\ DB$$

$$Q_{sensible} = 50{,}000 \frac{Btu}{h} = 1.08 * 3{,}000 * (72 - T_{DB})$$

$$T_{DB} = 56.6\ F\ DB$$

Then plot the 0.9 sensible heat ratio line from 72 F DB/45% relative humidity. Find out where this line intersects the 57 F and 49 F dry bulb lines.

The correct answer is most nearly, (D) 3,000 CFM, 57 F DB, 52 F WB.

(A) 2,000 CFM, 49 F DB, 41 F WB

(B) 2,000 CFM, 49 F DB, 45 F WB

(C) 3,000 CFM, 57 F DB, 48 F WB

(D) 3,000 CFM, 57 F DB, 52 F WB

SOLUTION 25

PRINCIPLES – HEAT TRANSFER

A wall section consists of 10 inch concrete, 1" air gap (R-3), R-12 insulation (6 inch thickness) and another 6 inches of concrete. Assume 150 lb/ft^3 concrete with conductivity of 10 Btu-in/hr-ft^2-F. The design heating space conditions are 68 F DB/50% RH. The design outdoor conditions are 40 F DB/30 F WB. What is the heating load due to the exterior walls? The total area of the walls is 5,200 square feet.

First find the R values for the inner and outer concrete section.

$$k_{concrete} = 10 \frac{Btu - in}{hr - ft - °F} * \frac{1\ ft}{12\ in} = 0.0833\ \frac{Btu}{hr - ft - °F}$$

$$R_{concrete,6\ inches} = \frac{0.5\ ft}{0.0833\ \frac{Btu}{hr - ft - °F}} = 0.6\ \frac{hr - ft - °F}{Btu}$$

$$R_{concrete,10\ inches} = \frac{0.833\ ft}{0.0833\ \frac{Btu}{hr - ft - °F}} = 1\ \frac{hr - ft - °F}{Btu}$$

Lookup the surface film resistance from the NCEES handbook for winter design conditions on a vertical surface.

The incoming air enthalpy from the psychrometric chart is shown below.

$$h_{in} = 45.52 \frac{Btu}{lb}$$

Since the process is assumed to be adiabatic then the outgoing enthalpy will be the same. Find the intersection of this enthalpy line with the dew point line of -20 F.

$$h_{out} = 45.52 \frac{Btu}{lb}; T = 187.5\ F\ DB$$

The correct answer is most nearly, (D) 188 °F.

(A) 116 °F

(B) 138 °F

(C) 153 °F

(D) 188 °F

SOLUTION 45

PRINCIPLES – HEAT TRANSFER

A 6” steel, schedule 40 pipe carries steam at 300 °F. The exterior surface of the insulation must be kept below 120 °F. The ambient temperature is 80 °F. What equivalent thickness insulation is required?

Insulation: k = 0.20 Btu-in/h-ft^2-°F

Insulation Surface Convective Heat Transfer Coefficient: h = 1.0 Btu/h-ft^2-°F

Normally the radial surface equation requires iterations to solve for the insulation thickness, due to the complexity of the equation. The vertical surface equation can be used in lieu of the radial surface as an estimate for purposes of this problem. Note that the question asks for the “equivalent thickness.”

$$Q_{through\ insulation} = Q_{surface\ of\ insulation\ to\ ambient}$$

$$\frac{k}{thickness} * A * (T_{pipe} - T_{surface}) = h_{surface} * A * (T_{surface} - T_{ambient})$$

SOLUTION 61

PRINCIPLES BASIC ENGINEERING PRACTICE

A fan provides 1,000 CFM at 2.0 in wg. The fan is 70% efficient at this operating point. The motor is 95% efficient. What is the total kW provided? Assume sea level.

$$Power\ (HP) = \frac{CFM * in\ wg}{6{,}356 * Fan\ Efficiency * Motor\ Efficiency}$$

$$Power\ (HP) = \frac{1{,}000\ CFM * 2.0\ in\ wg}{6{,}356 * 0.7 * 0.95} = 0.47\ HP * \frac{0.7457\ kW}{1\ HP} = 0.35\ kW$$

The correct answer is (B) 0.35 kW

(A) 0.17 kW

(B) 0.35 kW

(C) 0.47 kW

(D) 0.91 kW

SOLUTION 62

PRINCIPLES – THERMODYNAMICS

A refrigerant cycle uses R-404a at a condenser temperature of 102°F and an evaporator temperature of 20°F. What is the quality of the refrigerant entering the evaporator? Assume no sub-cooling, no superheating and an ideal expansion valve.

$$NCEES\ 410a\ Refrigeration\ tables$$

Find 102 °F at the saturated liquid. The exit of the condenser enthalpy will be the same enthalpy as the refrigerant entering the evaporator.

$$Lvg\ Condenser \rightarrow \left(102\ °F, 52.31\frac{Btu}{lb}\right)$$

$$Entering\ Evaporator \rightarrow \left(20\ °F, 52.31\frac{Btu}{lb}\right)$$

Use the quality equation and the saturated liquid and vapor at 20 F.

$$h_{ent\ evaporator} = h_{sat\ liquid} + x * h_{fg}$$

$$52.31 = 20.91 + x * (119.26 - 20.91)$$

$$x = 0.32$$

The correct answer is (A) 0.3

(A) 0.3

(B) 0.6

(C) 0.8

(D) 1.0

SOLUTION 63

PRINCIPLES – PSYCHROMETRICS

An evaporative cooler is used to cool 10,000 CFM of air at 100°F DB, 70°F WB. If 0.4 gpm of 60°F water is added to the airstream, what is most nearly the dry bulb temperature leaving the cooler? Assume the specific volume of the air is 14.0 cu ft/lb.

Find the leaving dry bulb temperature of the air by first finding the change in humidity ratio.

$$\frac{lb_{dry}}{min} = 10{,}000\frac{ft^3}{min} * \frac{1\ lb}{14\ ft^3} = 714\frac{lb_{dry}}{min}$$

$$\frac{lb_{wet}}{min} = 0.4\frac{gal}{min} * \frac{8.345\ lb_{wet}}{gal} = 3.338\frac{lb_{wet}}{min}$$

$$\Delta W = \frac{3.338\frac{lb_{wet}}{min}}{714\frac{lb_{dry}}{min}} = 0.00467\frac{lb_{wet}}{lb_{dry}}$$

From the psychrometric chart, the humidity ratio at the entering air conditions (100F DB/70F WB) is 0.0091 lb/lb. Find the leaving humidity ratio.

$$W_{leaving} = 0.0091\frac{lb_{wet}}{lb_{dry}} + 0.00467\frac{lb_{wet}}{lb_{dry}} = 0.0138\frac{lb_{wet}}{lb_{dry}}$$

On the psychrometric chart, start form the entering conditions (100F DB/70F WB) and follow the constant enthalpy line (up and left) until it intersects the leaving humidity ratio. Evaporative cooling is adiabatic, adds moisture (up) and reduces sensible heat (left).

The leaving dry bulb temperature at this point is 79°F.

The correct answer is most nearly (C) 80°F.

(A) 70°F