Thermal & Fluids PE Full Exam Errata

This product has been re-issued to incorporate all changes shown in the comments on the webpage and email comments as of January 1, 2020. If you have purchased this product prior to this date and wish for the latest version then please email Justin Kauwale at contact@engproguides.com.

The following changes have been made after January 1st, 2020.

PROBLEM 9

A 100 GPM condenser water pump is supplied with water by a cooling tower basin that is 5 ft above the centerline of the pump. The pressure loss due to friction is 2 feet of head. Condenser water pump serves a cooling tower with entering and leaving conditions of 95 F and 85 F. What is the net positive suction head available at the condenser water pump?

(A) 7 ft of head

(B) 31 ft of head

(C) 35 ft of head

(D) 37 ft of head

PROBLEM 10

A feedwater pump circulates 500 GPM of water through a system consisting of a heat exchanger (pressure drop = 10 feet of head) and 100 feet of 6" standard schedule 40 steel pipe with twenty 6" standard elbows. What is the total pressure loss due to the piping, elbows and the heat exchanger?

(A) 31 ft of head

(B) 23 ft of head

(C) 15 ft of head

(D) 7 ft of head

PROBLEM 15

A new solar hot water heating system has two loops, (1) solar hot water loop and a (2) domestic hot water loop. The loops are separated by a plate frame heat exchanger. If the solar hot water fluid enters the heat exchanger at 160 F and leaves at 130 F and the domestic hot water enters at 80 F and leaves at 120 F, then what is the LMTD? Assume a parallel flow heat exchanger.

(A) 30 F

(B) 31.3 F

(C) 33.7 F

(D) 35 F

PROBLEM 16

32 F Chilled water passes through a 4" schedule 40 steel pipe at a flow rate of 100 GPM. What is the Prandtl number? The viscosity is $4.31(\frac{lbm}{ft-hr})$ and the thermal diffusivity is 1.54 x 10^{-6} ft^2/s. The heat capacity of chilled water is 1.01 $\left(\frac{Btu}{lbm*°F}\right)$ and the thermal conductivity is $0.32\ \frac{Btu}{h*ft*°F}$.

(A) 1.4

(B) 5.2

(C) 13.7

(D) 15.1

PROBLEM 17

A 4” schedule 40 steel pipe carries 100 GPM of chilled water. The chilled water is at a temperature of 45 F. The exterior of the pipe is measured at a temperature of 50 F. The thermal conductivity of steel is 30 $\left[\frac{Btu}{hr*ft*°F}\right]$. What is the chilled water total heat loss from 100 feet of pipe? Assume there is no convective or radiative heat loss.

(A) 400,000 Btu/hr

(B) 800,000 Btu/hr

(C) 1,000,000 Btu/hr

(D) 1,800,000 Btu/hr

PROBLEM 18

There is 125 GPM of 45 °F water flowing through a 4” diameter pipe that is located in the ceiling of a building. The temperature in the ceiling is 85 °F and the temperature of the outer surface of the pipe is 49 °F. Calculate the convective heat transfer at the fluid inside the pipe. Assume the water in the pipe is not under extreme pressure and assume the Reynolds number is 1,700,000.

At 45°F, water has the following properties:

$$\mu = 3.75 \, \frac{lbm}{ft-hr}, dynamic\ viscosity$$

$$c_p = 1.005 \, \frac{Btu}{lbm*°F}, specific\ heat$$

$$k = 0.332 \, \frac{Btu*ft}{hr*ft^2*°F}, thermal\ conductivity$$

(A) $25 \frac{Btu}{h*ft^2*°F}$

(B) $5{,}000 \frac{Btu}{h*ft^2*°F}$

(C) $36{,}000 \frac{Btu}{h*ft^2*°F}$

(D) $71{,}000 \frac{Btu}{h*ft^2*°F}$

PROBLEM 53

Background: A fan has an output of 10 mechanical horsepower and operates for 4000 hours in the year. The fan is 85% efficient and the motor is 85% efficient. Energy cost is $0.25 per kilowatt-hour.

Problem: How much does it cost to operate the fan in one year?

(A) $7,460

(B) $8,770

(C) $10,320

(D) $12,140

SOLUTION 10

A feedwater pump circulates 500 GPM of water through a system consisting of a heat exchanger (pressure drop = 10 feet of head) and 100 feet of 6” standard schedule 40 steel pipe with twenty 6” standard elbows. What is the total pressure loss due to the piping, elbows and the heat exchanger?

First, check the NCEES Mechanical PE Reference Handbook for the pressure drop per 100 ft, for 6" Schedule 40 steel pipe and 500 GPM.

$$Pressure\ Drop = 3.2\ ft\ of\ head/100'$$

$$Velocity = 5.55\ fps$$

Next, find the total equivalent length which is found by adding the total length of pipes and the total equivalent length of the elbows in the fluids section of the NCEES Mechanical PE Reference Handbook.

$$20\ standard\ 90°\ 6"\ elbows * (16\ feet\ per\ elbow) = 320\ feet$$

Find the total equivalent length of piping.

$$Total\ length = 100 + 320 = 420\ ft$$

Multiply the pressure drop factor per length of pipe by the total equivalent length of pipe:

$$P_{fric} = 3.2\ \frac{ft\ of\ head}{100'} * 420' = 13.4\ ft\ of\ head$$

Don’t forget the 10 ft of head from the heat exchanger.

$$P_{fric} = 13.4\ ft\ of\ head + 10' = 23.4\ ft\ of\ head$$

Correct answer is most nearly **(B) $\mathbf{23\ ft\ of\ head}$**

SOLUTION 11

Water at 50 °F flows through a 6" schedule 40 steel pipe at a volumetric flow rate of 200 gallons per minute. What is the Reynolds number?

First, find the kinematic viscosity of water at 50 F [refer to your Mechanical Engineering Reference Manual]

$$v = 1.410\ x\ 10^{-5}\ ft^2/sec$$

Next find the velocity of water through the 6" schedule 40 steel pipe.

$$Internal\ Area_{6"\ Sch\ 40\ pipe} = 0.2006\ ft^2$$

$$LMTD = \frac{\Delta T_a - \Delta T_b}{\ln(\frac{\Delta T_a}{\Delta T_b})}$$

$$\Delta T_a = temperature\ difference\ at\ entrance = 160 - 80 = 80\ F$$

$$\Delta T_b = temperature\ difference\ at\ exit = 130 - 120 = 10\ F$$

$$LMTD = \frac{80 - 10}{\ln(\frac{80}{10})} = 33.7\ F$$

The correct answer is most nearly, **(C) 33.7 F.**

SOLUTION 16

32 F Chilled water passes through a 4" schedule 40 steel pipe at a flow rate of 100 GPM. What is the Prandtl number? The viscosity is $4.31(\frac{lbm}{ft-hr})$ and the thermal diffusivity is 1.54 x 10^{-6} ft^2/s. The heat capacity of chilled water is 1.01 $\left(\frac{Btu}{lbm*°F}\right)$ and the thermal conductivity is 0.32 $\frac{Btu}{h*ft*°F}$.

In this problem, you must know the Prandtl number equation and the conversion of centistokes to ft^2/s.

$$Pr = \frac{\mu * c_p}{k}$$

$$c_p = 1.01\left(\frac{Btu}{lbm * °F}\right);$$

$$Given \rightarrow k = 0.32\ \frac{Btu}{h * ft * °F}$$

$$Given \rightarrow \mu = 1.79\ centipoise * 2.41\frac{\frac{lbm}{ft-hr}}{cP} = 4.31\frac{lbm}{ft-hr}$$

$$Pr = \frac{4.31\ \frac{\cancel{lbm}}{\cancel{ft-hr}} * 1.01\frac{\cancel{Btu}}{\cancel{lbm * °F}}}{0.32\ \frac{\cancel{Btu}}{\cancel{h * ft * °F}}} = 13.5$$

The correct answer is most nearly, **(C) 13.7.**

$$Pr = \frac{\mu * c_p}{k}$$

Use the tables in the NCEES Handbook to find the properties of water. Because the properties of water do not change drastically under minor pressure differences, water at atmospheric pressure can be used as a close estimate.

At 45°F, water has the following properties:

$$\mu = 3.75\ \frac{lbm}{ft-hr}, dynamic\ viscosity$$

$$c_p = 1.005\ \frac{Btu}{lbm*°F}, specific\ heat$$

$$k = 0.332\ \frac{Btu*ft}{hr*ft^2*°F}, thermal\ conductivity$$

Therefore,

$$Pr = \frac{\mu * c_p}{k} = \frac{3.75\ \frac{lbm}{ft-hr} * 1.005\ \frac{Btu}{lbm * °F}}{0.332\ \frac{Btu * ft}{hr * ft^2 * °F}} = 11.35$$

Solve for the convective heat transfer:

$$h_{conv} = \frac{.023 * Re^{.8} * Pr^{.333} * k}{D} = \frac{.023 * 1{,}700{,}000^{.8} * 11.35^{.33} * 0.332\ \frac{Btu * ft}{h * ft^2 * °F}}{0.3355\ ft}$$

$$h_{conv} = 4933 \frac{Btu}{hr * ft^2 * °F}$$

The correct answer is most nearly,**(B)** $\mathbf{5{,}000}\ \frac{Btu}{hr*ft^2*°F}$

SOLUTION 19

What is the air to fuel ratio? Assume the equation is balanced.

$$C_4H_{10} + 6.5(O_2 + 3.76N_2) \rightarrow 4CO_2 + 5H_2O + 24.44N_2$$

$$First\ find\ the\ mass\ of\ air, 6.5(O_2 + 3.76N_2)$$

$$6.5 * (16 * 2 + 3.76 * 14 * 2) = 892$$

$$C_4H_{10} + 6.5O_2 + 24.4N_2 \rightarrow 4(CO_2) + 5(H_2O) + 24.4N_2$$

In this problem fuel is represented by C_4H_{10} and air is $6.5(O_2 + 3.76N_2)$.

The first step is to calculate the molecular weight of both fuel and air.

$$C_4H_{10} = 4 * 12 + 1 * 10 = 58\ MW$$

$$6.5O_2 + 24.4N_2 = 6.5 * (16 * 2) + 24.4 * (2 * 14) = 891\ MW$$

The air to fuel ratio is as follows:

$$Air\ to\ fuel\ ratio = \frac{891\ lbm\ air}{58\ lbm\ fuel}$$

Since you need 100 pounds of fuel, then multiple this number by the air to fuel ratio to get air.

$$100\ lbm\ fuel * \frac{891\ lbm\ air}{58\ lbm\ fuel} = 1{,}536\ lbm\ air$$

But you need 15% excess air.

$$1{,}536\ lbm\ air * 1.15 = 1{,}767\ lbm\ air$$

The correct answer is most nearly, **(D) 1,800 lbm air.**

SOLUTION 22

An air handler has 10,000 CFM of air at 80° F DB/60 % Rel. Hum pass through its cooling coil with an apparatus dew point of 53° F. The resulting discharge air temperature from the coil is 55° F DB/ 54° F WB. What is the total amount of condensate produced? Assume sea level.

In order to determine the amount of condensate produced, the change in humidity ratio must first be determined.

$$\Delta W_{LB} = W_{initial} - W_{final} = 0.0130 - 0.0088 \frac{lbm\ of\ H20}{lbm\ of\ DA}$$

$$\Delta W_{LB} = 0.0042 \frac{lbm\ of\ H20}{lbm\ of\ DA}$$

$$0.0042 \frac{lbm\ of\ H20}{lbm\ of\ DA} * 10{,}000\ \cancel{CF}M\ of\ dry\ air * 0.074 \frac{lbm\ of\ DA}{ft^3} = 3.108 \frac{lbm\ of\ H20}{minute}$$

$$3.1 \frac{\cancel{lbm\ of\ H20}}{minute} * \frac{\cancel{ft^3}}{62.4\ \cancel{lbm\ of\ H20}} * \frac{7.48\ gallons}{1\ \cancel{ft^3}} = 0.37 \frac{gallons}{minute}$$

SOLUTION 53

Background: A fan has an output of 10 mechanical horsepower and operates for 4000 hours in the year. The fan is 85% efficient and the motor is 85% efficient. Energy cost is $0.25 per kilowatt-hour.

Problem: How much does it cost to operate the fan in one year?

Convert fan brake horsepower to mechanical horsepower to fan horsepower.

$$P_{fan[HP]} = \frac{P_{output[MHP]}}{\varepsilon_{fan}}$$

$$P_{fan[HP]} = \frac{10\ BHP}{0.85} = 11.8\ HP$$

Determine the amount of power supplied to the motor, use motor efficiency.

$$P_{supplied\ to\ motor} = \frac{P_{motor[HP]}}{\varepsilon_{motor}} = \frac{11.8\ HP}{0.85} = 13.8\ HP$$

Find the kilowatt-hours (kwh) consumed.

$$13.8\ HP * \frac{0.7457\ KW}{HP} * 4{,}000\frac{hrs}{year} = 41{,}267.8\ kwh$$

Find the cost ($) with the electricity cost.

$$41{,}267.8\ kwh * \frac{\$0.25}{kwh} = \$10{,}317$$

The correct answer is most nearly. **(C), $10,320**

SOLUTION 54

A new 480 Volt, 3-phase motor is provided to serve the following pump with the design conditions shown in the below figure. If the pump's impeller diameter is decreased by 25% and the speed of the pump remains the same, then what will be the resulting flow rate?