This product has been updated to incorporate all changes shown in the comments on the webpage and email comments as of July 30, 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.

All new changes from July 30, 2020 are included in this document.

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1.4 Societal Considerations

Engineers must also consider the societal impacts of their design. An engineering design may have economic and/or environmental impacts. Although an engineering design may meet the appropriate engineering design standard, the engineering design may have a longer term impact that isn't covered by the standard. The engineer should always consider the way the design will perform over the lifetime of the design. This includes ongoing maintenance, utility usage cost and the sustainability of the design.

2.0 Practice Exam Problems

2.1 Practice Problem 1 – Codes of Ethics

An engineer has submitted a large donation to a public official to secure a state funded condominium project. Which section of the *Model Rules* code of ethics does this violate?

(A) Licensee's Obligation to the Public

(B) Licensee's Obligation to Other Licensees

(C) Licensee's Obligation to Employers and Clients

(D) Licensee's Obligation to Engineering Etiquette

2.2 Practice Problem 2 – Agreements and Contracts

You are seeking to secure a contract to design a new fuel facility and distribution system for the local gas company. Based on the Model Rules, which of the following would not allow you to proceed with the project?

(A) You sit on the board of directors for the local gas company, but you have disclosed all affiliations with the gas company.

7.0 Solutions

7.1 Solution 1 - Motors

Background: A 460 V, 1 phase, 60 HZ, 20 BHP pump. The motor has an efficiency of 75%. There is a power factor of 0.85.

Problem: What is the current in amperes supplied to the motor?

Convert pump brake horsepower to motor horsepower.

$$P_{motor[HP]} = \frac{P_{pump[BHP]}}{\varepsilon_{motor}}$$

$$P_{motor[HP]} = \frac{20\ BHP}{0.75} = 26.7\ HP$$

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

$$S_{supplied\ to\ motor} = \frac{P_{motor[HP]}}{PF} = \frac{26.7\ HP}{} * \frac{0.7457\ KW}{HP} * \frac{1}{0.85} = 23.42\ KVA$$

Find the current supplied to the motor through the below equation.

$$S_{supplied\ to\ motor,watts} = I * V$$

Make sure to convert horsepower to watts.

$$S_{supplied\ to\ motor,watts} = 23.42\ KVA * \frac{1000\ volt - amperes}{KW} = 23{,}423\ VA$$

$$23{,}423\ VA = I * 460\ V$$

$$50.9\ amps = I$$

Correct Answer: (D) 51 Amperes.

7.2 Solution 2 - Motors

Background: A 10 BHP fan operates for 4000 hours in the year. The motor is 85% efficient and the power factor is 0.85. 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 motor horsepower.

$$P_{motor[HP]} = \frac{P_{pump[BHP]}}{\varepsilon_{motor}}$$

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

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

Find the kilowatt-hours (kwh) consumed.

$$P_{supplied\ to\ motor,watts} = I * V$$

$$11.8\ HP * \frac{0.7457\ KW}{HP} * 4{,}000 \frac{hrs}{year} = 35{,}092\ kwh$$

Find the cost ($) with the electricity cost.

$$35{,}092\ kwh * \frac{\$0.25}{kwh} = \$8{,}772$$

Correct Answer: (B) $8,770

7.3 Solution 3 – Series Circuit

Background: A new electrical circuit has 3 resistors in series. Each resistor has a resistance of 4 Ω. The circuit is powered by a 12 V battery.

Problem: What is the current through the circuit?

$$R_{eq,series} = 4 + 4 + 4 = 12$$

$$I = \frac{12}{12} = 1\ amp$$

Correct Answer: (B), 1 amp

7.4 Solution 4 – Parallel Circuit

Background: A new electrical circuit has 2 resistors in parallel. One resistor has a resistance of 4 Ω. The resistance of the other resistor is unknown. The circuit is powered by a 12 V battery.

Moment describes the force on a body that causes the body to rotate about an axis. Moment can also be called Torque. The most difficult part in completing problems with Moment or Torque is drawing the free body diagram. You must be able to imagine forces being applied to a body's axis at different distances from the axis in such a way to rotate the body about its axis.

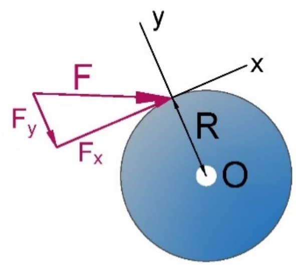


Figure 26: The moment is the multiplication of the tangential force times the perpendicular distance to the rotational axis.

$$M = F_x * R$$

$$M = Moment\ (lbf \cdot ft \quad or \quad N \cdot m);\ \ F = Force\ (lbf \quad or \quad N);\ \ R = Distance\ (ft \quad or \quad m)$$

7.1 Free Body Diagram

On the FE exam you will be given scenarios and diagrams without forces and moments shown. It will be up to you to draw the moments acting upon the objects.

The magnitude of the moment of a force at the circumference of the above circle, is equal to the perpendicular distance R, multiplied by the magnitude of the force: M = F*R.

7.2 Equilibrium

If an object is not rotating, then the object is in equilibrium. This means that the moments at a point will sum to equal zero. On the exam, you can use these equilibrium equations to solve for the unknowns. When constructing an equilibrium equation you need to assign positive and negative moments, similar to positive and negative forces. For example, it is most commonly assumed that any moment acting in the clockwise direction is assigned a positive value and a negative value for counterclockwise moments.

$$\sum M_x^{axis\ 1} = 0;\ \sum M_y^{axis\ 1} = 0;\ \sum M_z^{axis\ 1} = 0$$

7.3 Calculating Moments of Inertia

Moment of inertia describes an object's resistance to rotation. It can be classified either as area moment of inertia or mass moment of inertia. Area moments of inertia, also known as the second moment of area, are associated with cross sectional areas, while mass moments of

$$0 + \frac{1}{2}50 * \left(5\frac{m}{s}\right)^2 + 0 = 0 + 0 + (\frac{1}{2} * 1{,}000 * x^2)$$

$$x = 1.1\ m$$

The correct answer is most nearly (A) 1 m.

14.7 Solution 7 – Impulse Momentum

For this problem, you need to use the impulse momentum equation.

$$F * \Delta t = m v_f$$

$$20\ N * 0.01\ s = 50\ kg * v_f$$

$$20\ kg\frac{m}{s^2} * 0.01\ s = 50\ kg * v_f$$

$$v_f = 0.004\ m/s$$

The correct answer is most nearly (B) 4 mm/s.

14.8 Solution 8 – Impulse Momentum

For this problem, you need to use the impulse momentum equation.

$$F * \Delta t = m v_f$$

$$100\ N * \cos(40°) * 0.1\ s = 50\ kg * v_f$$

$$6.669\ N - s = 50\ kg * v_f$$

$$v_f = 0.15\ m/s$$

The correct answer is most nearly (A) 0.15 m/s.

14.9 Solution 9 – Vibration

In order to complete this problem, you should use the frequency equation shown below.

$$f_n = \frac{1}{2\pi}\sqrt{\frac{k g_c}{m}}$$

$$R_1 = R_2 = \frac{W}{2}\ (N\ \ or\ \ lbf)$$

The next figure shows the shear force diagram. The shear force acting at any point “x” on the beam is governed by the below equation. The shear force is at its maximum at the supports. You can see that when 0 and L are inserted into the equation for x, the value will be of magnitude equal to ½ the weight.

$$V_x = w * \left(\frac{L}{2} - x\right) \quad [N\ \ or\ \ lbf]$$

$$V(0) = w * \left(\frac{L}{2} - x\right) = W\frac{1}{2} and\ V(L) = -W\frac{1}{2} \quad [N\ \ or\ \ lbf]$$

The bending moment acting at any point “x” on the beam is governed by the following equation. The moment is at its maximum at the center. The moment will be equal to zero when “x” is equal to “L” or “0”.

$$M_x = \frac{Wx}{2}(L - x) \qquad [N \cdot m \quad or \quad lbf \cdot in]$$

$$Maximum\ Moment \rightarrow M_{L/2} = \frac{WL^2}{8} \quad [N \cdot m \quad or \quad lbf \cdot in]$$

The deflection at any point “x” on the beam is governed by the following equation. The deflection is at its maximum at the center.

$$\Delta_x = \frac{Wx}{24 * E * I} * (L^3 - 2 * L * x^2 + x^3) \quad [m\ \ or\ \ in]$$

$$where\ E = modulus\ of\ elasticity\ (Pa\ \ or\ \ psi) and\ L = \ length\ (m\ \ or\ \ in)$$

$$\Delta_{center} = \frac{5WL^4}{384 * E * I}[m\ \ or\ \ in]$$

The moment can then be used to find the maximum stress in the beam. The maximum stress in the beam will help to influence the beam dimensions and material choices. The maximum stress will be discussed in the bending topic.

The equation for axial stress is shown below. Remember that the area used for this equation is the area that is perpendicular to the force vector.

$$\sigma_{axial} = \frac{Force}{Axial\ Area}; \sigma_{axial} = \frac{lbf}{in^2}; F = lb; A = in^2$$

$$\sigma_{axial} = \frac{Force}{Axial\ Area}; \sigma_{axial} = Pa\ or\ \frac{N}{m^2}; F = N; A = m^2$$

3.2 SHEAR

Shear stresses are the opposite of axial stresses. These stresses are caused by unaligned forces acting in parallel to a cross sectional area. The equation for shear stress is the same as axial stress, except the area is the area parallel to the force vector.

$$\tau_{shear} = \frac{Force}{Shear\ Area}; \tau_{shear} = \frac{lbf}{in^2}; F = lbf; A = in^2$$

$$\tau_{shear} = \frac{Force}{Shear\ Area}; \tau_{shear} = Pa\ or\ \frac{N}{m^2}; F = N; A = m^2$$

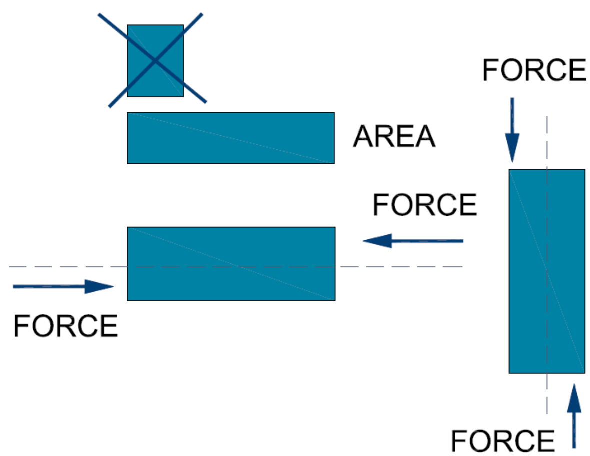


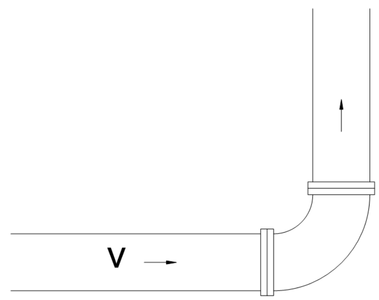
Figure 9: The shear stress is found by dividing the force by the area that is in parallel to the force vector.

3.3 BENDING

Bending stresses are discussed more in the beam topic. Bending stress can also be called a flexure stress. Bending stresses put the top half of an object in compression and the bottom half in tension. So the stress varies depending on the location in the object. In the previous topics on shear and axial stresses, the stress is consistent throughout the entire object's cross section. The equation for bending stress is shown below. Bending stress is a function of the moment, distance from the neutral axis and the moment of inertia.

13.9 Practice Problem 9 – Impulse Momentum

Water flows through a 50 cm pipe at a flow rate of 190 kg/s and pressure of 4kPa. As the water flows, it hits a 90 degree elbow. What is the force needed to restrain the elbow?



(a) 35 N

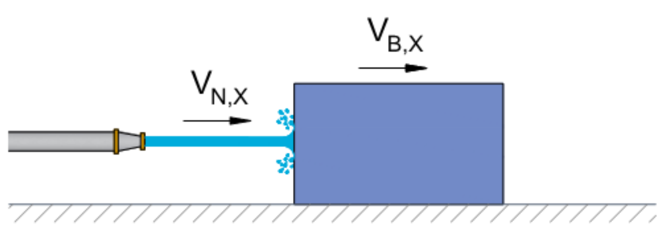
(b) 70 N

(c) 706 N

(d) 986 N

13.10 Practice Problem 10 – Impulse Momentum

Water flows out of a nozzle in a 60 m/s horizontal jet stream towards the vertical surface of a box on the ground, as shown below. The jet stream has a cross sectional area of 0.01 sq m and water disperses after hitting the box. If the nozzle pushes the box horizontally at velocity of 5 m/s, what is the force of the water on the box?



(a) 30 kN

(b) 33 kN

(c) 36 kN

(d) 40 kN

13.7 Practice Problem 7 – Fatigue

A material undergoes a cyclical stress with a tensile stress of 50 MPa and a compressive stress of 10 MPa. What is the stress amplitude?

a) 30 MPa

b) 40 MPa

c) 50 MPa

d) 60 MPa

13.8 Practice Problem 8 – Fatigue

A rod undergoes a cyclical force, with a tensile force of 10,000 lbs and a compressive force of 50,000 lbs. What is the minimum diameter to ensure that the mean stress is less than 1,600 psi?

a) 1.4 in

b) 2.7 in

c) 4.1 in

d) 6.0 in

13.9 Practice Problem 9 – Fatigue

A beam is loaded with a compressive stress of 100 MPa. Upon initial loading, the beam undergoes a strain of 0.002 mm/mm. At an average temperature of 27 C, the creep rate is 10 x 10^{-7}/hr. What is the total change in length of the 1 meter beam after 365 days? Assume the compressive stress is constant for the entire time.

a) 2 mm

b) 5 mm

c) 8 mm

d) 11 mm

13.10 Practice Problem 10 – Poisson's Ratio

A rod is subject to a tensile stress of 12 x 10^6 psi. The modulus of elasticity of the material is 50,000 ksi. The diameter of the rod is reduced by 1 inches. The diameter of the rod is originally 9 inches. What is the Poisson's Ratio?

a) -0.23

b) 0.003

c) 0.16

d) 0.46

13.13 PROBLEM 13 - STEAM AIR COILS

0.00623 kg/s of steam (saturated vapor) enters a heating coil at a pressure of 101 KPa and leaves as a saturated liquid. 700 CFM of air enters the coil at 60 F. Assume 100% efficient heat transfer. What is the resulting exiting temperature of the air?

a) 105 °F

b) 110 °F

c) 115 °F

d) 125 °F

13.14 PROBLEM 14 - STEAM - HOT WATER COILS

A hot water coil has an incoming water temperature of 70 F and an outgoing temperature of 140 F. Hot water is flowing through the coil at a rate of 40 GPM. What steam flow rate is required to properly heat the water [lb/hr]? Assume saturated steam at a pressure of 101 KPa, with no super heat and sub-cooling and 100% effective heat exchange.

(a) 0.111 kg/s

(b) 0.149 kg/s

(c) 0.174 kg/s

(d) 0.182 kg/s

13.17 Problem 17 – Combustion

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

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

(a) 10.1

(b) 12.9

(c) 14.8

(d) 15.4

13.18 Problem 18 – Rankine Cycle

Background: A steam power plant boiler operates at a pressure of 1 MPa. Steam exits the turbine at 14.7 psi (101.4 kPa). If the boiler heats the steam to 200 C, then what is the enthalpy of the steam leaving the turbine? Assume an isentropic turbine.

The answer is most nearly,

(a) 417 KJ/kg

(b) 1975 KJ/kg

(c) 2427 KJ/kg

(d) 2791 KJ/kg

$$W_{compressor}\ [Btuh] = (125 - 110) = 15$$

$$Q_{net\ refrigeration\ effect}\ [Btuh] = (H_1 - H_4)\left[\frac{Btu}{lb}\right] * (Refrig\ Flow\ Rate)\left[\frac{lb}{min}\right] * (60)\left[\frac{min}{hr}\right]$$

$$Q_{net\ refrigeration\ effect}\ [Btuh] = (110 - 50.5) = 59.5$$

$$COP\ = \frac{59.5}{15} = 3.97$$

Correct Answer: A

14.12 Solution 12: Steam Production

Water (120 F, 50 lbm/hr) is converted to saturated steam (no super-heat) at a pressure of 15 PSIA. What is the total production of the boiler (Btu/hr)?

The enthalpy of the incoming feed-water at 120 F and a pressure of 15 PSIA is shown below.

$$h_{feedwater} = 88.10\frac{Btu}{lb}$$

The enthalpy of the outgoing steam at 15 PSIA, saturated is equal to 1,150.76 Btu/lb.

$$h_{steam} = 1{,}150.76\frac{Btu}{lb}$$

The total production of the boiler (Btu/hr) is found by multiplying the difference between the incoming and outgoing boiler enthalpies by the mass flow rate of the steam.

$$Q = \dot{m} * (h_{steam} - h_{feedwater})$$

$$Q = 50\frac{lbm}{hr} * (1150.76 - 88.10)$$

$$Q = 53{,}133\frac{Btu}{hr}$$

14.13 Solution 13: Steam Air Coils

0.00623 kg/s of steam (saturated vapor) enters a heating coil at a pressure of 101 KPa and leaves as a saturated liquid. 700 cubic feet per minute of air enters the coil at 60 F. Assume 100% efficient heat transfer. What is the resulting exiting temperature of the air?

Steam at 101 KPa has an enthalpy of vaporization of 2,257 kJ/kg.

$$Q = \dot{m}_{steam} * h_{fg} = 0.075 \frac{lbm}{ft^3} * 700 \frac{ft^3}{min} * 60 \frac{min}{hr} * 0.24 \frac{Btu}{lbm - F} * \Delta T$$

$$0.00623 \frac{kg}{s} * 2{,}257 \frac{kJ}{kg} = 756 \frac{Btu}{lbm - F} * \Delta T$$

$$14.06 \frac{kJ}{s} * \frac{Btu}{1.055\ kJ} * \frac{3600\ s}{hr} = 756 * \Delta T$$

$$\Delta T = 63.5\ °\mathrm{F}$$

The final temperature of the air is 124 F.

$$60°\mathrm{F} + 64\ °\mathrm{F} = 124\ °\mathrm{F}$$

14.14 SOLUTION 14: STEAM - HOT WATER COILS

A hot water coil has an incoming water temperature of 70 F and an outgoing temperature of 140 F. Hot water is flowing through the coil at a rate of 40 GPM. What steam flow rate is required to properly heat the water [lb/hr]? Assume saturated steam at a pressure of 101 KPa, with no super heat and sub-cooling and 100% effective heat exchange.

Steam at 101 KPa has an enthalpy of evaporation of 2,257 kJ/kg..

An energy balance is conducted on the heat loss through condensing the steam and the heat gained by the water.

$$Heat\ loss\ through\ steam\ condensation = Heat\ gained\ by\ water$$

$$\dot{m}_{steam} * h_{fg} = \dot{m} * c_p * \Delta T$$

$$\dot{m}_{steam} * 2{,}257 \frac{\mathrm{kJ}}{\mathrm{kg}} = \frac{8.34\ lbm}{gal} * 40 \frac{gal}{min} * 60 \frac{min}{hr} * \frac{1.0\ Btu}{lbm - F} * 70\ F$$

$$\dot{m}_{steam} * 2{,}257 \frac{\mathrm{kJ}}{\mathrm{kg}} = 1{,}401{,}120 \frac{Btu}{hr} * \left(\frac{1\ hr}{3600\ s}\right) * \left(\frac{1.055\ kJ}{Btu}\right)$$

$$\dot{m}_{steam} = 0.182 \frac{kg}{s}$$

14.15 SOLUTION 15 – BRAYTON CYCLE

Background: Air is compressed at a gas turbine from 14.7 psi and 77 degrees F to 73.5 psi. The resulting temperature is most nearly? Assume isentropic compression.

14.17 SOLUTION 17 – COMBUSTION

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

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

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

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

$$Second\ find\ the\ mass\ of\ fuel, C_4H_{10}$$

$$4 * 12 + 10 * 1 = 58$$

$$Air\ to\ fuel\ ratio = \frac{m_{air}}{m_{fuel}} = \frac{892}{58} = 15.4$$

The answer is most nearly, D, 15.4.

14.18 SOLUTION 18 – RANKINE CYCLE

Background: A steam power plant boiler operates at a pressure of 1 MPa. Steam exits the turbine at 14.7 psi (101.4 kPa). If the boiler heats the steam to 200 C, then what is the enthalpy of the steam leaving the turbine? Assume an isentropic turbine.

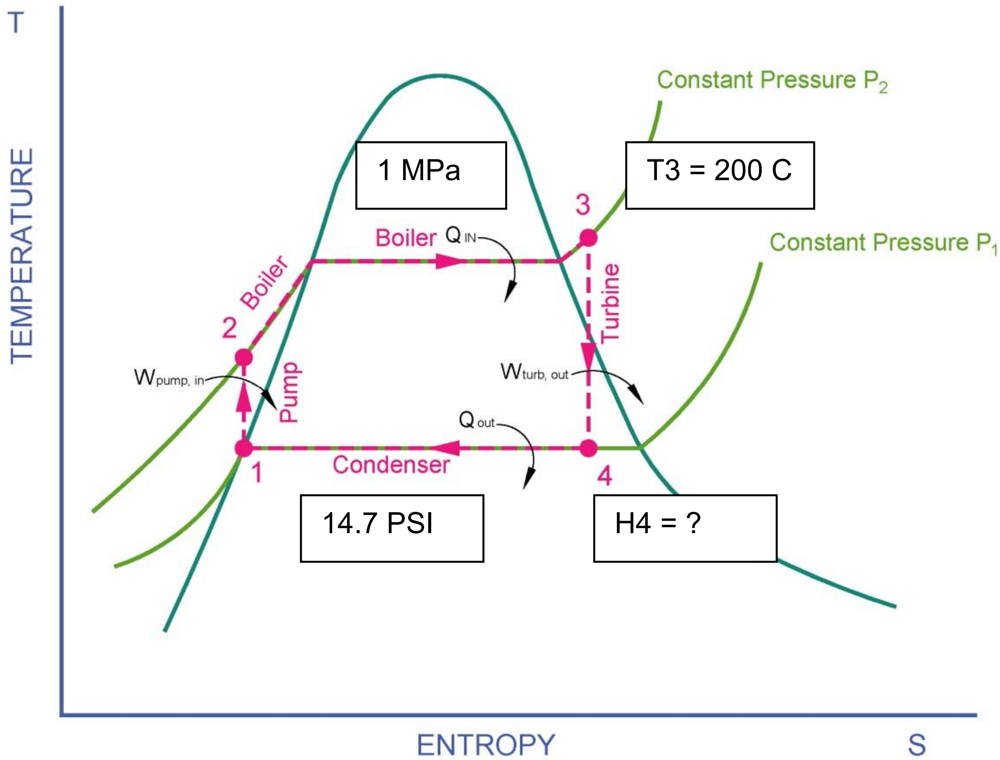
The answer is most nearly,

(a) 417 KJ/kg

(b) 1975 KJ/kg

(c) 2427 KJ/kg

(d) 2791 KJ/kg



The first step is to find the entropy of h_3 with the steam tables. If we look at the standard steam tables

In your NCEES FE Reference Handbook, we find that at a pressure of 1 MPa, saturated steam is at a temperature of 180 C.

Therefore we must use the superheated steam tables, we find that

$$h_3 = 2827.9\ kj/kg; s_3 = 6.6940$$

$$Since\ the\ turbine\ process\ is\ isentropic, s_4 = s_3 = 6.6940$$

$$We\ also\ know\ that\ the\ pressure\ at\ step\ 4\ is\ 101\ kPa\ and\ according\ to\ the\ steam\ tables$$

$$s_f = 1.3069\ and\ s_g = 7.3549, but\ s_4 = 6.6940; so\ s_4 is\ governed\ by\ the\ following\ equation$$

$$s_4 = s_f + x * s_{fg}; where\ s_{fg} = entropy\ of\ evaporation\ at\ 6.0480\ amd\ x =\ steam\ quality$$

$$s_4 = 6.6940 = 1.3069 + x * 6.0480$$

$$Solving\ for\ x$$

$$x = 0.89$$

$$now\ that\ we\ have\ x, we\ can\ use\ a\ similar\ equation\ to\ find\ h_4$$

$$h_4 = h_f + x * h_{fg};$$

$$h_4 = 419 + .89 * 2257$$

$$h_4 = 2{,}427\ kJ/kg$$

The answer is most nearly (C), 2,382 kJ/kg.

9.3 Problem 3 - Calculate the Reynolds number

250 GPM (15.7725 L/s) of 120°F (48.9 °C) water flows through a 4” (101.6 mm) inner diameter pipe that is located in the ceiling of a building. Assume the water in the pipe is not under extreme pressure. Calculate the Reynolds number of the fluid inside the pipe.

a) 57,734

b) 295,941

c) 355,745

d) 136,836,344

9.4 Problem 4 - Calculate the Convective Heat Transfer Coefficient

250 GPM of 120°F water flows through a 4” diameter pipe that is located in the ceiling of a building. Calculate the convective heat transfer at the fluid inside the pipe. Assume the water in the pipe is not under extreme pressure.

120°F, water properties: $\mu = 1.36\ \frac{lbm*ft}{hr}, c_p = 0.999\ \frac{Btu}{lbm*°F}, k = 0.378\ \frac{Btu*ft}{h*ft^2*°F}, thermal\ conductivity$

a) $1{,}067 \frac{Btu}{h*ft^2*°F}$

b) $5{,}182 \frac{Btu}{h*ft^2*°F}$

c) $6{,}738 \frac{Btu}{h*ft^2*°F}$

d) $12{,}784 \frac{Btu}{h*ft^2*°F}$

9.9 PROBLEM 9 – NTU METHOD

Water enters a heat exchanger at 1 kg/s and 200 K. Air enters the heat exchanger at 0.5 kg/s at an unknown temperature. The overall heat transfer coefficient for the heat exchanger is 150 W/m^2-K. If the NTU value is 1.2, then what is the area of heat exchange?

(A) 1 m^2

(B) 2 m^2

(C) 3 m^2

(D) 4 m^2

9.10 PROBLEM 10 - TRANSIENT

A motor is modeled as a box with dimensions, 3' x 5' x 1'. The motor is turned off and is at a temperature of 300 K. Assume the properties for the motor as shown below. Assume the motor is raised with an open platform. The motor is located in a room that is at a temperature of 300 K. The convective heat transfer coefficient is also shown below. What is the Biot number?

$$k_{motor} = 30\frac{W}{m-K}; p_{motor} = 5{,}000\frac{kg}{m^3}; h_{air} = 15\frac{W}{m^2-K}$$

(A) 0.01

(B) 0.10

(C) 0.44

(D) 1.21

9.11 Problem 11 - Radiation

A motor is modeled as a box with dimensions, 1 m x 2 m x 0.5 m. The motor is turned off and is at a temperature of 300 K. Assume the motor has an emissivity of 0.8. Assume the motor is raised with an open platform. The motor is located in a room that is at a temperature of 300 K. What is the heat loss from the motor due to radiation?

$$\sigma = 0.1713\ x\ 10^{-8}\left(\frac{Btu}{h * ft^2 * R^4}\right)\ or\ \ 5.67\ x\ 10^{-8}\left(\frac{W}{m^2 * K^4}\right);$$

(A) 100 W

(B) 900 W

(C) 1,300 W

(D) 2,600 W

9.12 Problem 12 – Radiation & Convection

A 4" diameter copper pipe carries hot water from the heater to the equipment. The surface temperature of the pipe is 200 F. The ambient temperature is 75 F. Assume that the convective heat transfer coefficient is 1.85 Btu/(hr-ft2-F). What is the total heat loss per 100 feet of pipe? Assume black body radiation.

$$\sigma = 0.1713\ x\ 10^{-8}\left(\frac{Btu}{h * ft^2 * R^4}\right)\ or\ \ 5.67\ x\ 10^{-8}\left(\frac{W}{m^2 * K^4}\right);$$

(A) 24,300 Btuh

(B) 31,900 Btuh

(C) 43,600 Btuh

(D) 67,100 Btuh

$$h_{conv} = \frac{.023 * Re^{.8} * Pr^{.3} * k}{D} = \frac{.023 * 355{,}745^{.8} * 3.6^{.3} * 0.378 \frac{Btu * ft}{h * ft^2 * °F}}{0.33\, ft}$$

$$h_{conv} = 1{,}067 \frac{Btu}{h * ft^2 * °F}$$

The correct answer is most nearly, **(A) 1,067.**

10.5 SOLUTION 5 – HEAT EXCHANGER

Air enters a heat exchanger at 10 lbs/hr and water enters a heat exchanger at an unknown mass flow rate. The entering temperature of the air is 200 F and the air leaves at 150 F. Water enters the heat exchanger at 75 F and leaves at 100 F. What is the mass flow rate of the water?

In order to complete this problem, you must conduct an energy balance on the hot and cold sides of the heat exchanger.

$$Hot \rightarrow Q_{hot} = \dot{m} * c_{p,air} * (T_{in} - T_{out}) = 10 \frac{lbm}{hr} * 0.24 \frac{Btu}{lbm\ °F} * (200 - 150) = 120 \frac{Btu}{hr}$$

$$Cold \rightarrow Q_{cold} = \dot{m} * c_{p,water} * (T_{out} - T_{in}) = x \frac{lbm}{hr} * 1.00 \frac{Btu}{lbm\ °F} * (100 - 75) = 120 \frac{Btu}{hr}$$

$$x = 4.8 \frac{lbm}{hr}$$

The correct answer is (A) $\mathbf{4.8 \frac{lbm}{hr}}$

10.6 SOLUTION 6 – HEAT EXCHANGER

$$k_{motor} = 30\frac{W}{m-K}; p_{motor} = 5{,}000\frac{kg}{m^3}; h_{air} = 15\frac{W}{m^2-K}$$

Use the Biot equation below and solve for the volume and surface area of the box. But remember to convert from feet to meters.

$$3' = 0.914\,m; 5' = 1.524\,m; 1' = 0.305\,m$$

$$Bi = \frac{hV}{kA}$$

$$Bi = \frac{15\frac{W}{m^2-K} * (0.914m * 1.524m * 0.305m)}{30\frac{W}{m-K} * (2 * (0.914m * 1.524m + 1.524m * 0.305m + 0.914m * 0.305m)}$$

$$Bi = 0.099$$

The correct answer is most nearly, **(A) 0.01.**

10.11 Solution 11 - Radiation

A motor is modeled as a box with dimensions, 1 m x 2 m x 0.5 m. The motor is turned off and is at a temperature of 300 K. Assume the motor has an emissivity of 0.8. Assume the motor is raised with an open platform. The motor is located in a room that is at a temperature of 300 K. What is the heat loss from the motor due to radiation?

For this question use the radiative heat transfer equation.

$$Q = \varepsilon\sigma AT^4$$

$$Q = radiation\ heat\ (Btuh\ or\ W); A = area\ (ft^2\ or\ m^2);$$

$$\sigma = 0.1713\ x\ 10^{-8}\left(\frac{Btu}{h * ft^2 * R^4}\right)\ or\ \ 5.67\ x\ 10^{-8}\left(\frac{W}{m^2 * K^4}\right);$$

$$T = \ surface\ temperature\ (°R\ or\ °K\ )$$

$$Q = 0.8 * \ 5.67\ x\ 10^{-8}\left(\frac{W}{m^2 * K^4}\right) * (2 * (1 * 2 + 2 * .5 + 1 * .5) * 300^4$$

$$Q = 2{,}572\ W$$

The correct answer is most nearly, (D) 2,600 W.

17.12 PRACTICE PROBLEM 12 – NET POSITIVE SUCTION HEAD

A cooling tower is located such that the fluid level in the basin is 10 ft above the centerline for the suction of the condenser water pump. The water is at an average temperature of 86 F. The friction loss from the cooling tower basin to the suction of the pump is approximately 15 ft of head. What is the net positive suction head available at the suction side of the pump with a flow rate of 400 GPM?

$$h_{vapor\ pressure} = 1.4\ ft\ of\ head$$

(a) 12.6 ft of head

(b) 17.6 ft of head

(c) 27.6 ft of head

(d) 30.1 ft of head

17.13 PRACTICE PROBLEM 13 – HYDRAULIC COMPONENTS

A centrifugal pump, pumps 50 GPM at 25 feet of an unknown fluid of density 45 lbm/ft^3. What is the mechanical work produced by the pump? Assume 100% efficient motor and pump.

The answer is most nearly,

(a) 1/10 HP

(b) 1/5 HP

(c) 1/4 HP

(d) 1/2 HP

$$Mechanical\ work\ (W) = \frac{p(\frac{g}{g_c})HQ}{n_{pump} * n_{motor}}$$

First convert 50 GPM to cubic feet per second.

$$50\frac{gal}{min} * \left(\frac{ft^3}{7.48\ gal}\right) * \left(\frac{min}{60\ sec}\right) = 0.11\frac{ft^3}{s}$$

Now plug in the new volumetric flow rate into the equation from the NCEES handbook.

$$Mechanical\ work\ (W) = \frac{45\frac{lbm}{ft^3} * \frac{32.2\frac{ft}{s^2}}{32.2\frac{lbm-ft}{lbf-s^2}} * 25\ ft * 0.11\frac{ft^3}{s}}{n_{pump} * n_{motor}}$$

$$W = 123.75\frac{ft-lbf}{s}$$

Finally convert using the NCEES FE Handbook to horsepower.

$$W = 123.75\frac{ft-lbf}{s} * \left(\frac{hp}{550\ \frac{ft-lbf}{s}}\right) = 0.22\ HP$$

The answer is most nearly, (B), 1/4 HP.

18.14 SOLUTION 14 – HYDRAULIC COMPONENTS

A pump is sized for 200 GPM at 150 ft of head. If the speed is decreased by 10%, what is the new design pressure of the pump? Assume the diameter remains the same.

Use the affinity laws.

$$\frac{Q_1}{Q_2} = \left(\frac{N_1}{N_2}\right)^2 ;if\ diameter\ is\ held\ constant$$

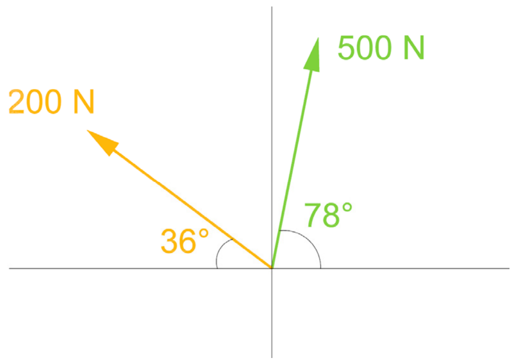
$$\frac{150}{Q_2} = \left(\frac{x}{0.9x}\right)^2$$

$$150 * 0.9^2 * x = Q_2 * x$$

$$Q_2 = 121.5\ ft\ head$$

1.28 Problem 28 – Statics

Given the two force vectors shown in the vector below, find the x and y components of the combined force vector.



(a) F_x = -58 N; F_y = 607 N;

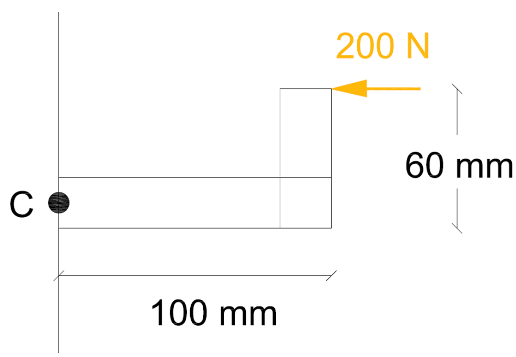
(b) F_x = -158 N; F_y = 75 N;

(c) F_x = -256 N; F_y = 444 N;

(d) F_x = -781 N; F_y = 856 N;

1.29 Problem 29 – Statics

What is the moment about point C, due to the force shown? Neglect the weight of the member.



(a) 12 N-m

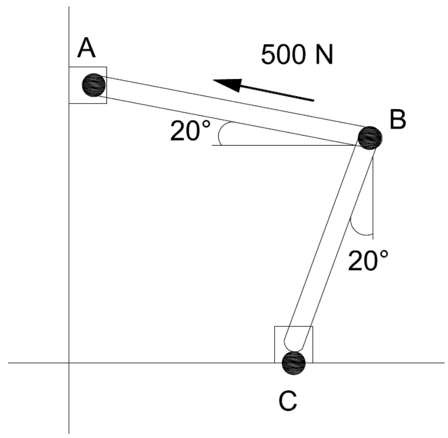
(b) 18 N-m

(c) 24 N-m

(d) 32 N-m

1.30 Problem 30 – Statics

Member BC = 23 mm. What is the moment about point C? Assume the two members are static.



(a) 1.9 N-m

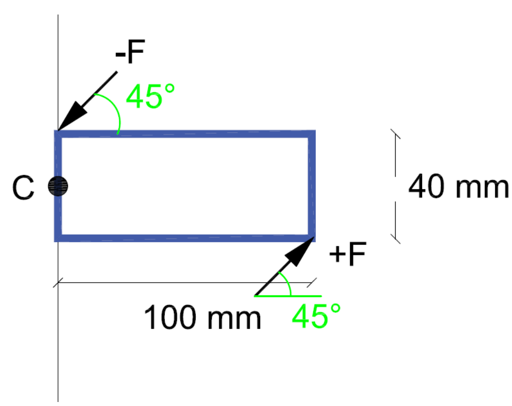
(b) 11.5 N-m

(c) 21.3 N-m

(d) 45.1 N-m

1.31 Problem 31 – Statics

One couple acts on the beam below. Assume F = 100 N, what is the couple moment about the center of the beam?



(a) 9.9 N-m

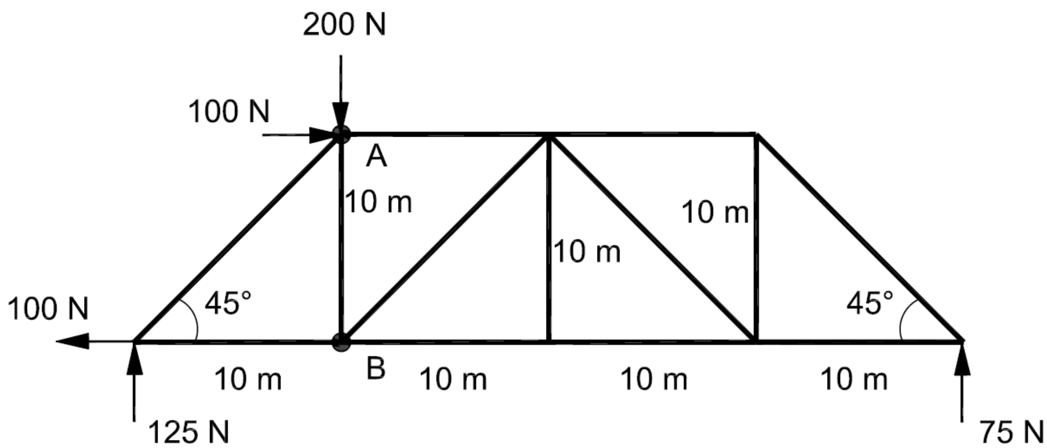
(b) 17.3 N-m

(c) 25.5 N-m

(d) 41.9 N=m

1.34 Problem 34 – Statics

What is the force in member A-B?



(a) Unable to determine

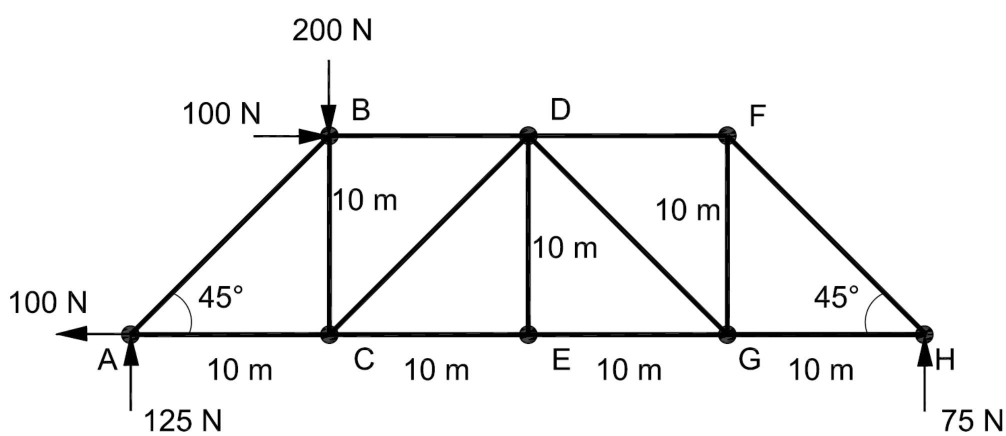
(b) 25 N

(c) 50 N

(d) 75 N

1.35 Problem 35 – Statics

What is the force in member A-C?



(a) Unable to determine

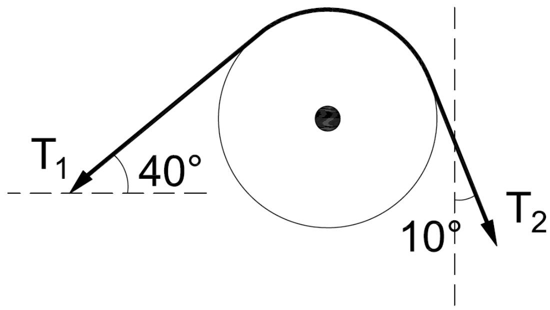
(b) 50 N

(c) 175 N

(d) 225 N

1.36 PROBLEM 36 – STATICS

The coefficient of static friction for the pulley is 0.2. The tension T1 is 100 N. What is the required tension T2 to overcome the static friction? Assume a weightless pulley.



(a) 115 N

(b) 123 N

(c) 135 N

(d) 152 N

1.37 PROBLEM 37 – DYNAMICS, KINEMATICS AND VIBRATIONS

The location of a particle as a function of time is described by the equation below. What is the location of the particle when the velocity is equal to zero? Time is units of seconds and distance is in units of meters.

$$x(t) = \frac{1}{3}t^3 - 4t^2 + 16t$$

(a) 21.3 m

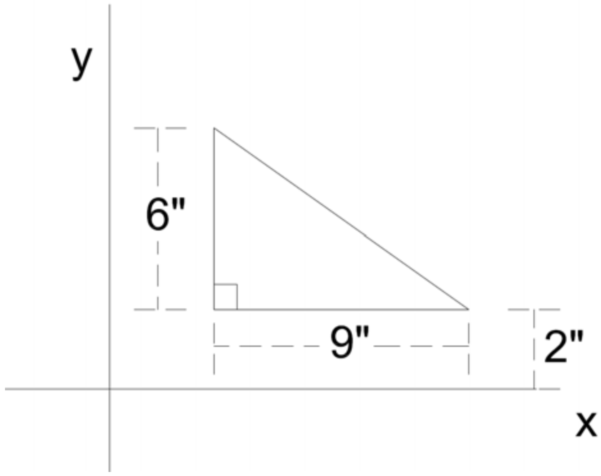
(b) 43.1 m

(c) 88.2 m

(d) 105 m

1.44 Problem 44 – Dynamics, Kinematics and Vibrations

Find the area moment of inertia of the figure below about the x-axis.



(a) 88 in^4

(b) 162 in^4

(c) 270 in^4

(d) 486 in^4

1.45 Problem 45 – Dynamics, Kinematics and Vibrations

A 6” diameter steel shaft has a length of 24”. What is the mass moment of inertia about the centerline along the length of the shaft?

(a) 900 $lb\text{-}in^2$

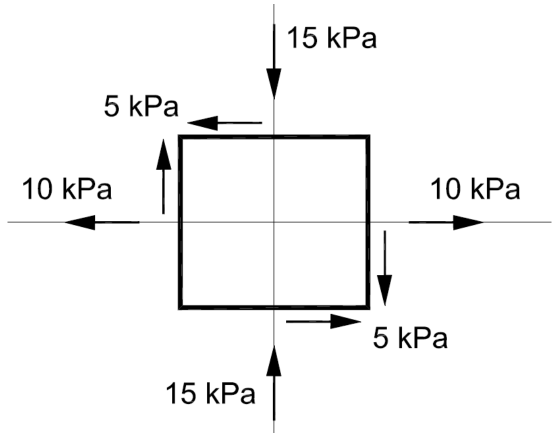
(b) 3,440 $lb\text{-}in^2$

(c) 4,100 $lb\text{-}in^2$

(d) 6,270 $lb\text{-}in^2$

1.47 PROBLEM 47 – MECHANICS OF MATERIALS

What are the principal stresses?



(a) -2.5 & 2.5 kPa

(b) 6.5 & -11.5 kPa

(c) 10.5 & -15.5 kPa

(d) 2.5 & -11.5 kPa

1.48 PROBLEM 48 – MECHANICS OF MATERIALS

A steel rod has a diameter of 150mm and a length of 10m. The rod is secured and locked in place at both ends. The temperature varies by 50 °C. What is the maximum stress developed in the rod?

(a) 117 MPa

(b) 230 MPa

(c) 429 MPa

(d) 1,020 MPa

1.51 Problem 51 – Mechanics of Materials

A steel pipe has an inner diameter of 50 mm and an outer diameter of 63 mm. The pipe is subject to a torque of 5,000 N-m. The pipe is 10 m long. One end is fixed. The other end is free. What is the shear stress?

(a) 150 MPa

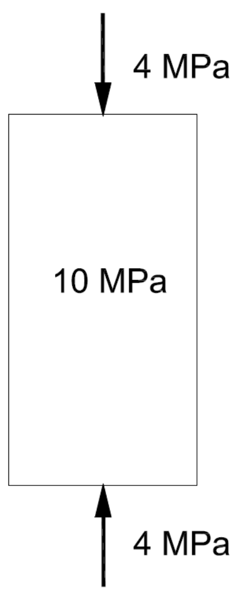
(b) 277 MPa

(c) 301 MPa

(d) 499 MPa

1.52 Problem 52 – Mechanics of Materials

A cylindrical pressure vessel has an internal pressure of 10 MPa. It is also subject to a compressive stress of 4 MPa. The pressure vessel has an inner diameter of 250 mm and a thickness of 5 mm. What is the stress in the up-down direction?



(a) 14 MPa

(b) 34 MPa

(c) 121 MPa

(d) 125 MPa

1.74 PROBLEM 74 – FLUID MECHANICS

At extremely turbulent flow (Reynolds greater than 4 x 10^7), the pressure drop due to friction is independent of which term?

(a) Pipe roughness

(b) Pipe diameter

(c) Velocity

(d) Reynolds number

1.75 PROBLEM 75 – THERMODYNAMICS

A boiler & superheater is used to provide 100 kg/s of steam to a turbine. The condenser temperature is 50 C. The outlet of the superheater is at 500 C and 1 MPa. The isentropic efficiency of the turbine is 80%. The temperature entering the condenser is 50 C. What is the power generated by the turbine? Hint: This problem follows the Rankine Cycle.

(a) 80 MW

(b) 300 MW

(c) 350 MW

(d) 500 MW

1.84 PROBLEM 84 – THERMODYNAMICS

One cubic meter of helium (45 °C & 450 kPa) is expanded to 2 cubic meters. Assume an ideal gas and no change in mass. Also no work is done and there is no change in heat. What is the new temperature when the helium is expanded?

(a) 200 K

(b) 300 K

(c) 400 K

(d) 500 K

1.85 PROBLEM 85 – THERMODYNAMICS

1 kW of heat is added to 45 kg of air for 1 hour. Air is initially at a temperature of 30 °C. What is the final temperature after 1 hour?

(a) 75 °C

(b) 92 °C

(c) 101 °C

(d) 110 °C

1.92 Problem 92 – Heat Transfer

Two parallel flat plates of equal area are separated by 50 mm. One flat plate has an emissivity of 0.2 and is at a temperature of 400 K. The other flat plate has an emissivity of 0.03 and is at a temperature of 1,000 K. The shape factor is equal to 1. What is the radiative heat transfer between the two plates? The plates are assumed to form an enclosure.

(a) 1,500 W/m^2

(b) 2,900 W/m^2

(c) 4,200 W/m^2

(d) 10,700 W/m^2

1.93 Problem 93 – Heat Transfer

Two surfaces of equal area are separated by 100 mm. One surface is at a temperature of 750 K and the other surface is at 250 K. Assume the surfaces are black bodies. The shape factor between the two surfaces is 0.3. Assume the surfaces are part of an enclosure, then what is the radiative heat transfer between the two surfaces?

(a) 800 W/m^2

(b) 5,300 W/m^2

(c) 17,720 W/m^2

(d) 20,640 W/m^2

1.98 Problem 98 – Measurement, Instrumentation and Controls

Which of the following statements is true about a thermistor with a negative temperature coefficient?

(a) A thermistor reacts to an increase in temperature with an increase in voltage.

(b) A thermistor reacts to an increase in temperature with an increase in resistance.

(c) A thermistor reacts to an increase in temperature with a decrease in voltage.

(d) A thermistor reacts to an increase in temperature with a decrease in resistance.

1.99 Problem 99 – Measurement, Instrumentation and Controls

Which of the following sensors most likely uses the piezoelectric effect?

(a) Temperature

(b) Humidity

(c) Vibration

(d) Enthalpy

1.106 PROBLEM 106 – MECHANICAL DESIGN AND ANALYSIS

An open air tank at sea level feeds a centrifugal pump. The pump's centerline is located 25 feet below the water level of the tank. There is a friction loss of 10 feet head from the tank to the pump suction. The vapor pressure is 0.7 psia. What is the net positive suction head available at the pump suction?

(a) 8 psi

(b) 12 psi

(c) 17 psi

(d) 21 psi

1.107 PROBLEM 107 – MECHANICAL DESIGN AND ANALYSIS

Which of the following terms is used to characterize compressibility?

(a) Young's Modulus

(b) Shear Modulus

(c) Bulk Modulus

(d) Rupture Modulus

1.108 Problem 108 – Mechanical Design and Analysis

Which of the following best describes the point at which a material will experience permanent deformation?

(a) Ultimate tensile strength

(b) Yield strength

(c) Proportional stress limit

(d) Poisson's Ratio

1.109 Problem 109 – Mechanical Design and Analysis

A square-threaded power screw is used to raise a load of 10,000 pounds. The mean thread diameter is equal to 2 inches. The screw has 4 threads per inch, which makes its pitch equal to 0.25 inches. The coefficient of friction is equal to 0.05. Hint: pitch is equal to lead for single start, screw threads. Assume no collar. What is the torque required to raise the load?

(a) 800 W/m^2

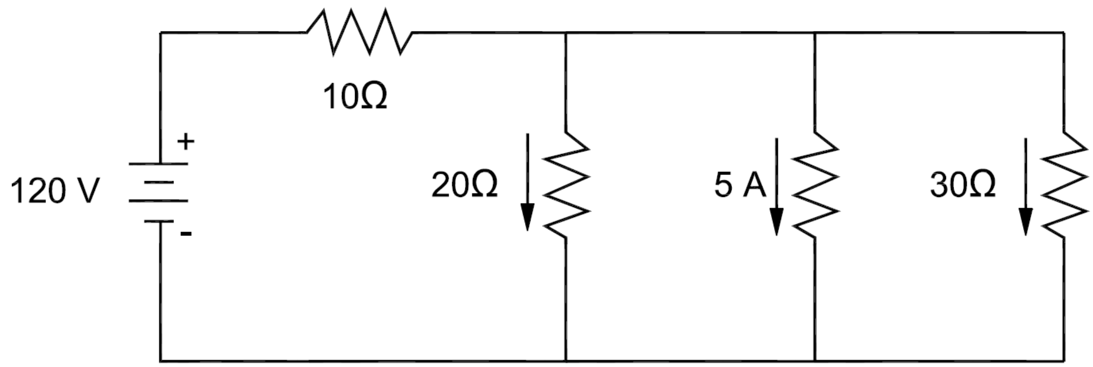
(b) 5,300 W/m^2

(c) 17,720 W/m^2

(d) 20,640 W/m^2

2.23 Solution 23 – Electricity & Magnetism

What is the current through the 10 ohm resistor?



First, create a KVL around 120 V, 10 ohm resistor and the voltage across the remaining resistors in parallel. Call this voltage V_2.

$$KVL \rightarrow 120V = I_{10} * 10 + V_2$$

$$I_{10} = \frac{120 - V_2}{10}$$

Next, create a KCL node at the intersection of the 20 ohm and 10 ohm resistor. The current into the node is equal to I_{10} (current through 10 ohm resistor). The current out of the node is equal to the current through the remaining resistors.

$$KCL \rightarrow I_{10} = \frac{V_2}{20} + 5A + \frac{V_2}{30}$$

You have two equations and two unknowns. Solve for V_2 first.

$$\frac{120 - V_2}{10} = \frac{V_2}{20} + 5A + \frac{V_2}{30}$$

$$120 - V_2 = 0.5V_2 + \frac{1}{3}V_2 + 50A$$

$$70 = 1.833V_2$$

$$V_2 = 38.19\ V$$

Now solve for I10, the current through the 10 ohm resistor.

$$I_{10} = \frac{120 - V_2}{10} = \frac{120 - 38.19\ V}{10} = 8.181\ A$$

The correct answer is most nearly, (c) 8.2A.

(a) 4.1 A

(b) 5.5 A

(c) 8.2 A

(d) 10.9 A

2.24 Solution 24 – Electricity & Magnetism

What is the combined impedance due to a resistor and capacitor in series? Assume a 120 V, 60 Hz system. The resistor has a resistance of 20 ohms and the capacitor has a capacitance of 200 μf.

First, convert the capacitance to impedance, which has units of ohms.

$$Z_c = \frac{1}{j2\pi fC} = \frac{1}{j2\pi(60\ Hz) * 200\ x\ 10^{-6}\ F} = -13.3j\ \Omega$$

Now, add up the impedances in series.

$$Z_{combined} = 20\Omega - 13.3\text{j}\Omega$$

The correct answer is most nearly, (b) 20 – 13.3j Ω.

(a) 7.3 Ω

(b) 20 - 13.3j Ω

(c) 20 + 13.3j Ω

(d) 33.3 Ω

2.25 Solution 25 – Electricity & Magnetism

An inductor has an inductance of 100 mH at a frequency of 60 Hz. What is the impedance of the inductor?

$$Z = 2\pi fL = 2\pi(60)100x10^{-3} = 38\ ohms$$

The correct answer is most nearly, (b) 38 ohms.

(a) 4 ohms

(b) 38 ohms

(c) 47 ohms

(d) 107 ohms

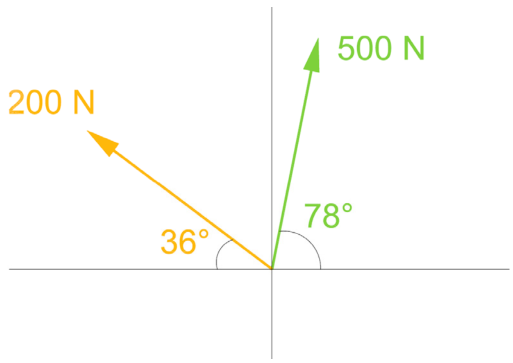
2.26 Solution 26 – Electricity & Magnetism

(c) The resistance of wire B is four times the resistance of wire A.

(d) The resistance of wire B is eight times the resistance of wire A.

2.28 Solution 28 – Statics

Given the two force vectors shown in the vector below, find the x and y components of the combined force vector.



First, find the x and y components of each force vector.

$$F_x = 200\cos(36) = -161.8\ N; F_y = 200\sin(36) = 117.6\ N$$

$$F_x = 500\cos(78) = 104\ N; F_y = 500\sin(78) = 489.1\ N$$

Combine the x-components together and the y-components together.

$$F_x = -161.8 + 104 = -57.8\ N\ ; F_y = 117.6 + 489.1 = 606.7\ N$$

The correct answer is most nearly, (a) F_x = -58 N; F_y = 607 N;

(a) F_x = -58 N; F_y = 607 N;

(b) F_x = -158 N; F_y = 75 N;

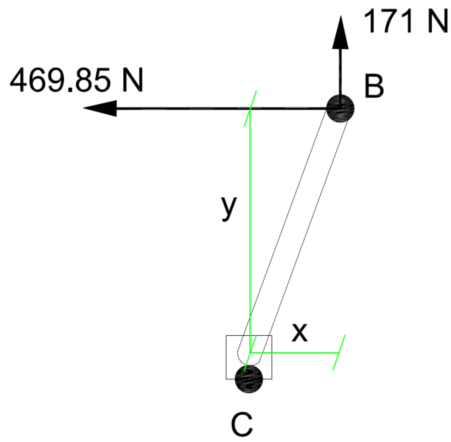
(c) F_x = -256 N; F_y = 444 N;

(d) F_x = -781 N; F_y = 856 N;

2.29 Solution 29 – Statics

What is the moment about point C, due to the force shown? Neglect the weight of the member.

$$F_x = 500N * \cos(20) = 469.85\ N; F_y = 500N * \sin(20) = 171\ N;$$



Now, solve for the distances x and y. These are the perpendicular distances to the forces that you previously calculated.

$$x = 23mm * \sin(20) = 7.87\ mm; y = 23mm * \cos(20) = 21.61\ mm$$

Finally, solve for the moment, add up the forces that cause the member to rotate counterclockwise. Both forces cause a rotation counterclockwise.

$$Moment = 469.85\ N * \frac{21.61}{1000} m + 171N * \frac{7.87}{1000} m = 11.5\ N - m$$

The correct answer is most nearly, (b) 11.5 N-m.

(a) 1.9 N-m

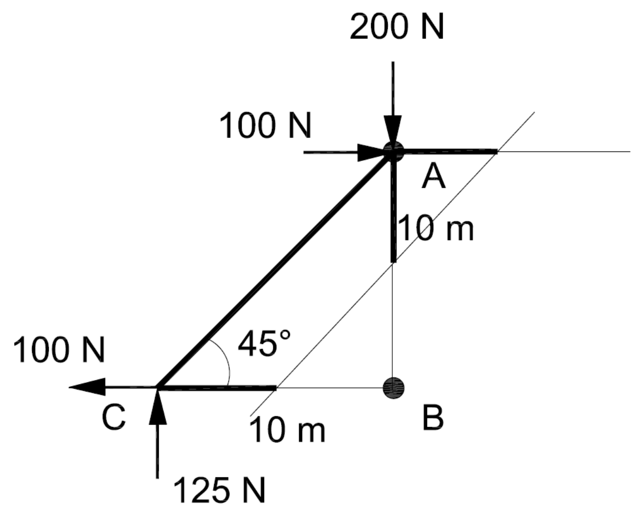
(b) 11.5 N-m

(c) 21.3 N-m

(d) 45.1 N-m

2.31 Solution 31 – Statics

One couple acts on the beam below. Assume F = 100 N, what is the couple moment about the center of the beam?



You can make the assumption that the truss is not moving. So now you can choose to balance forces or moment. The easiest is to balance out the forces in the y-direction, since member A-B is the only unknown member that has a force in the y-direction.

$$\sum F_y = 0 = 125N - 200N + F_{AB}$$

$$F_{AB} = 75\ N$$

The correct answer is most nearly, (d) 75 N.

(a) Unable to determine

(b) 25 N

(c) 50 N

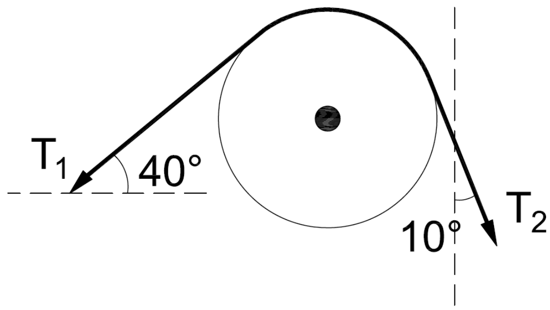
(d) 75 N

2.35 Solution 35 – Statics

What is the force in member A-C?

2.36 SOLUTION 36 – STATICS

The coefficient of static friction for the pulley is 0.2. The tension T1 is 100 N. What is the required tension T2 to overcome the static friction? Assume a weightless pulley.



Find the pulley equation in your FE Reference Handbook.

$$\frac{T_2}{T_1} = e^{\mu_s \theta_{wrap}}$$

$$\theta_{wrap} = 40° + 80° = 120° \rightarrow 120 * \frac{\pi}{180} = 2.09;\ \mu_s = 0.2$$

$$\frac{T_2}{T_1} = e^{0.2*2.09}$$

$$T_2 = 100N * 1.52 = 152\ N$$

The correct answer is most nearly, (d) 152 N.

(a) 115 N

(b) 123 N

(c) 135 N

(d) 152 N

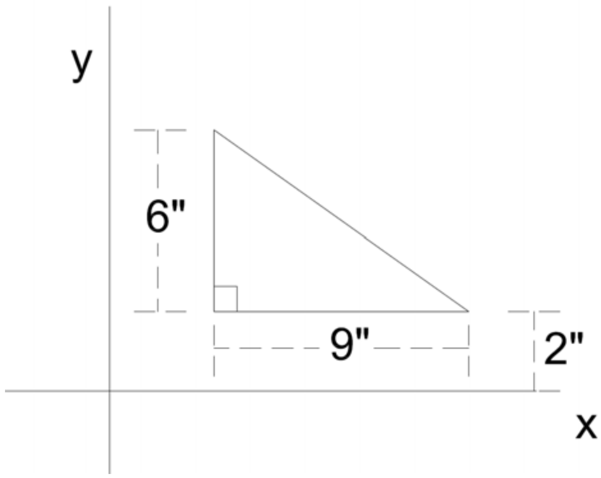
2.37 SOLUTION 37 – DYNAMICS, KINEMATICS AND VIBRATIONS

The location of a particle as a function of time is described by the equation below. What is the location of the particle when the velocity is equal to zero? Time is units of seconds and distance is in units of meters.

$$x(t) = \frac{1}{3}t^3 - 4t^2 + 16t$$

First, find the derivative. The derivative is equal to the velocity.

$$v(t) = t^2 - 8t + 16$$



The area moment of inertia about the centroid x-axis can be found with the statics table for area moment of inertias.

$$I_{x,c} = \frac{h^3 b}{36} = \frac{(6)^3(9)}{36} = 54\ in^4$$

Next, you need to use the parallel axis theorem to move the axis from the centroid x-axis to the x-axis. This equation is in the dynamics section of the handbook, but the handbook version uses mass as opposed to area. The handbook's version of parallel axis theorem is for the mass moment of inertia, but you can derive the area moment of inertia version as shown below.

$$I_x = 54\ in^4 + Ad^2$$

$$I_x = 54\ in^4 + \frac{1}{2} 6 * 9 * 4^2 = 486\ in^4$$

The correct answer is most nearly, (d) 486 in^4.

(a) 88 in^4

(b) 162 in^4

(c) 270 in^4

(d) 486 in^4

2.45 Solution 45 – Dynamics, Kinematics and Vibrations

A 6" diameter steel shaft has a length of 24". What is the mass moment of inertia about the centerline along the length of the shaft?

First, you need to find the mass of the shaft. The density for steel is found in the Mechanics of Materials section.

$$M = \rho AL = \left(0.282 \frac{lb}{in^3}\right)\left(\frac{\pi 6\ in^2}{4}\right)(24\ in) = 191\ lbs$$

Next, use the mass moment of inertia equation from the table in the Dynamics section of the FE Reference Handbook.

$$I_c = \frac{1}{2}Mr^2 = \frac{1}{2} * 191 * (3\ in)^2 = 859\ lb - in^2$$

The correct answer is most nearly, (a) 900 lb-in^2.

(a) 900 lb-in^2

(b) 3,440 lb-in^2

(c) 4,100 lb-in^2

(d) 6,270 lb-in^2

2.46 Solution 46 – Dynamics, Kinematics and Vibrations

A projectile is at an initial velocity of 10 m/s at an angle of 30 degrees above the horizontal. If the projectile is initially at an elevation of 45 m, then at what time will the projectile be at an elevation of 0 m?

The y-component of the initial velocity is found through the sine of 30 degrees. Sine is equal to opposite over hypotenuse. Gravity is acting downward at constant acceleration. The position will be a function of the following equation.

$$y(t) = \left(10 \frac{m}{s}\right)\sin(30)\,t - \frac{1}{2}\left(9.81 \frac{m}{s^2}\right)t + C$$

You need to assign an initial y-value of 45 m, for the initial elevation. Then solve for when the location will equal 0 m.

$$y(t) = \left(10 \frac{m}{s}\right)\sin(30)\,t - \frac{1}{2}\left(9.81 \frac{m}{s^2}\right)t + 45\ m$$

$$0\ m = \left(10 \frac{m}{s}\right)\sin(30)\,t - \frac{1}{2}\left(9.81 \frac{m}{s^2}\right)t + 45\ m$$

$$R = \sqrt{\frac{(\sigma_x - \sigma_y)^2}{2^2} + \tau_{xy}^2} = \sqrt{\frac{(10-(-15))^2}{2^2} + (-5)^2} = 13\ kPa$$

The principal stresses are solved with the following equation.

$$\sigma_1 = C + R; \;\; \sigma_2 = C - R;$$

$$\sigma_1 = -2.5 + 13 = 10.5\ kPa; \;\; \sigma_2 = -2.5 - 13 = -15.5\ kPa;$$

The correct answer is most nearly, (c) 10.5 & -15.5 kPa.

(a) -2.5 & 2.5 kPa

(b) 6.5 & -11.5 kPa

(c) 10.5 & -15.5 kPa

(d) 2.5 & -11.5 kPa

2.48 Solution 48 – Mechanics of Materials

A steel rod has a diameter of 150mm and a length of 10m. The rod is secured and locked in place at both ends. The temperature varies by 50 °C. What is the maximum stress developed in the rod?

You will need the steel thermal expansion coefficient from the Mechanics of Materials section in the FE Reference Handbook.

$$\alpha = 11.7\ x\ 10^{-6}/C$$

Next, solve for the change in length of the rod, if the rod was unconstrained.

$$\Delta L = \alpha L(\Delta T) = \left(11.7\ x10^{-6}\frac{}{C}\right) * (10m) * (50\ C) = 5.85\ mm$$

Next, calculate the force acting on the pipe due to the expansion. This is the force experienced within the constrained rod.

$$5.85\ mm = \frac{FL}{AE} = \frac{F(10{,}000\ mm)}{\left(\frac{1}{4}\pi(150mm)^2\right) * 200\ GPa}$$

You need to convert GPa, so that instead of meters squared on the denominator there are millimeters squared.

$$200\ GPa = 200 * 10^9 \frac{N}{m^2} * \frac{m^2}{10^6\ mm^2}$$

(d) 50 mm diameter, 1 m long bronze rod, undergoing a 40 C change in temperature.

$$\alpha_{bronze} = (18\ x\ 10^{-6}) * (40) * (1) = 0.000720$$

The correct answer is most nearly, (b) 50 mm diameter, 1 m long aluminum rod, undergoing a 40 C change in temperature.

2.51 Solution 51 – Mechanics of Materials

A steel pipe has an inner diameter of 50 mm and an outer diameter of 63 mm. The pipe is subject to a torque of 5,000 N-m. The pipe is 10 m long. One end is fixed. The other end is free. What is the shear stress?

$$\tau = \frac{Tr}{J}$$

You need the polar moment of inertia for a pipe, from the Statics section.

$$J = \frac{\pi}{2} * \left(\left(\frac{1}{2} * \frac{63}{1000}\right)^4 - \left(\frac{1}{2} * \frac{50}{1000}\right)^4\right)$$

$$J = \frac{\pi}{2} * ((0.0315)^4 - (0.025)^4) = 9.33\ x\ 10^{-6}\ m^4$$

$$\tau = \frac{(5{,}000\ N - m) * (r_{avg})}{9.33\ x\ 10^{-6}\ m^4} = \frac{(5{,}000\ N - m) * (0.0565/2\ m)}{9.33\ x\ 10^{-6}\ m^4} = 150\ MPa$$

The correct answer is most nearly, (a) 150 MPa.

(a) 150 MPa

(b) 277 MPa

(c) 301 MPa

(d) 499 MPa

The pressure determined by the manometer is the differential pressure, which corresponds to the velocity pressure. The velocity pressure equation does not have the gravity constant, because you are in SI units.

$$Velocity\ Pressure = 353.16\ Pa = \frac{v^2}{2}$$

But first, we need to convert the density of air to SI units.

$$Density = 0.075\ \frac{lb}{ft^3} * \frac{0.453592\ kg}{1\ lb} * \frac{35.3147\ ft^3}{m^3} = 1.2\frac{kg}{m^3}$$

$$v = \sqrt{2 * 353.16\frac{kg}{m-s^2} * \frac{m^3}{1.2\ kg}} = 24.3\frac{m}{s}$$

The correct answer is most nearly, (a) 27 m/s.

(a) 27 m/s

(b) 41 m/s

(c) 57 m/s

(d) 81 m/s

2.66 Solution 66 – Fluid Mechanics

A Venturi meter has the following diameters, D_1 = 200 mm and D_2 = 100 mm. A manometer is connected between the two locations. The manometer has a delta reading of 100 mm. The density of the manometer liquid is 5,000 kg/m³. What is the volumetric flow rate of water (density = 1,000 kg/m³) through the meter? C_v = 1.

$$Pressure = \rho g h$$

$$Pressure = 5{,}000\frac{kg}{m^3} * 9.81\frac{m}{s^2} * \frac{100}{1000}m = 4{,}905\frac{kg}{m-s^2} = 4{,}905\ Pa$$

Since, you are using SI units, you don't need the gravity term, but you should do dimensional analysis to confirm.

$$Q = C_v A_2 \sqrt{2\frac{\frac{-4{,}905\frac{kg}{m-s^2}}{1{,}000\ kg/m^3}}{\left(\left(\frac{A_2}{A_1}\right)^2 - 1\right)}}$$

A boiler & superheater is used to provide 100 kg/s of steam to a turbine. The condenser temperature is 50 C. The outlet of the superheater is at 500 C and 1 MPa. The isentropic efficiency of the turbine is 80%. The temperature entering the condenser is 50 C. What is the power generated by the turbine? Hint: This problem follows the Rankine Cycle.

This problem uses the Rankine Cycle and in order to complete this problem you need to do an energy balance across the turbine.

Turbine Inlet (outlet of superheater): 500 C & 1 MPa. From the superheat steam tables in the FE Reference Handbook, you will find the following values for enthalpy and entropy.

$$h_{in} = 3{,}478.5 \frac{kJ}{kg}; s_{in} = 7.7622 \frac{kJ}{kg-K}$$

Turbine Outlet (inlet of condenser): 50 C, but unknown pressure. You don't know the pressure, but you do know that an ideal turbine outlet will have the same entropy as the inlet. Unfortunately, there is a turbine efficiency, which means the outlet entropy will be slightly higher than the inlet entropy.

First, find the ideal values for entropy and enthalpy. The entropy value must have a temperature of 50 C. Luckily, the 50 C value has an entropy value that is in the mixed region. Next, solve for the quality.

$$s_{out} = 7.7622 = s_f + x s_{fg}$$

$$s_{out} = 7.7622 = 0.7038 + x(7.3725)$$

$$x = 0.957$$

With the quality value, solve for the ideal outgoing enthalpy value.

$$h_{out} = h_f + (0.957) * h_{fg}$$

$$h_{out} = 209.33 + (0.957) * 2382.7$$

$$h_{out} = 2{,}489.57 \frac{kJ}{kg}$$

Now, use the turbine isentropic efficiency equation from your FE Reference Handbook to find the actual leaving enthalpy.

$$Efficiency = 80\% = \frac{Actual}{Ideal} = \frac{h_{in} - h_{out,actual}}{h_{in} - h_{out,ideal}} = \frac{3{,}478.5 - h_{out,actual}}{3{,}478.5 - 2{,}489.57}$$

$$h_{out,actual} = 2{,}687.5 \frac{kJ}{kg}$$

The work done is found by multiplying the mass flow rate by the change in enthalpy.

$$Work = 100\frac{kg}{s} * (3478.5 - 2{,}687.4)\frac{kJ}{kg} = 79100\frac{kJ}{s} = 79{,}100\ kW = 79\ MW$$

The correct answer is most nearly, (a) 80 MW.

(a) 80 MW

(b) 300 MW

(c) 350 MW

(d) 500 MW

2.76 SOLUTION 76 – THERMODYNAMICS

Water is heated from a saturated liquid at 145 C to a vapor quality of 50%. What is the work done by the water? Assume a constant pressure process and a mass of 1 kg of water.

The equation for constant pressure in the Thermodynamics section of the FE Reference Handbook is shown below. The volume of liquid will expand as it turns into a vapor. If the pressure is constant, then the work done will be due to the change in volume.

$$Work\ (Joule\ aka\ N - m) = (mass\ kg) * \left(Pressure\frac{N}{m^2}\right) * \left(\Delta\ Specific\ Volume\frac{m^3}{kg}\right)$$

First, find the specific volume of the saturated liquid at 145 C in the steam tables of your FE Reference Handbook.

$$v_{liquid} = 0.001085\frac{m^3}{kg};$$

The specific volume of the 50% vapor is found through the mixed equation.

$$v_{50\%} = v_{liquid} + x_{quality} * (v_{vapor} - v_{liquid});$$

$$v_{50\%} = 0.001085 + 0.5 * (.4463 - .001085) = 0.22369\frac{m^3}{kg}$$

Next, you need the pressure. The pressure corresponds to the saturation pressure at 145 C.

$$Pressure = 0.4154\ MPa = 415{,}400\ Pa = 415{,}400\frac{N}{m^2}$$

$$Work\ (Joule\ aka\ N - m) = (1\ kg) * (415{,}400) * (.22369 - .001085) = 92{,}500\ J$$

$$Helium \rightarrow k = 1.67; \quad T_2 = (45 + 273) * \left(\frac{1}{2}\right)^{1.67-1} = 200\ K$$

(a) 200 K

(b) 300 K

(c) 400 K

(d) 500 K

2.85 SOLUTION 85 – THERMODYNAMICS

1 kW of heat is added to 45 kg of air for 1 hour. Air is initially at a temperature of 30 °C. What is the final temperature after 1 hour?

The heat added is 1 kW, which is equal to 1000 J/s.

$$Q = 1\frac{kJ}{s} * (1\ hours) * \left(3600\frac{s}{hr}\right) = 45\ kG * \left(1.0\frac{kJ}{kg - C}\right) * (X - 30)$$

$$X = 141\ °C$$

The correct answer is most nearly, (d) 110 C.

(a) 75 °C

(b) 92 °C

(c) 101 °C

(d) 110 °C

2.86 SOLUTION 86 – HEAT TRANSFER

Which term is not applicable to calculating the convection coefficient of a forced convection fluid, regardless of the fluid viscosity and turbulence?

(a) Nusselt Number

(b) Reynold's Number

(c) Grashof Number

(d) Prandtl Number

The rate of heat transfer between plate 1 and plate 2 is shown below.

$$Q_{12} = \frac{\sigma(T_1^4 - T_2^4)}{\frac{(1-\varepsilon_1)}{\varepsilon_1 A_1} + \frac{1}{A_1 F_{12}} + \frac{(1-\varepsilon_2)}{\varepsilon_2 A_2}}$$

$$\sigma = Stefan\ Boltzman\ Constant = 5.67\ x10^{-8} \frac{W}{m^2 - K^4}$$

$$Q_{12} = \frac{(5.67\ x10^{-8} \frac{W}{m^2 - K^4})(1000^4 - 400^4)}{\frac{(1-0.2)}{0.2A_1} + \frac{1}{A_1 1} + \frac{(1-0.03)}{0.03A_2}}$$

$$Q_{12} = \frac{(55{,}326 \frac{W}{m^2})}{(4 + 1 + 32.33)A_{plate}}$$

$$Q_{12} = 1{,}482\ \frac{W}{m^2}$$

The correct answer is most nearly, (a) 1,500 W/m^2.

(a) 1,500 W/m^2

(b) 2,900 W/m^2

(c) 4,200 W/m^2

(d) 10,700 W/m^2

2.93 SOLUTION 93 – HEAT TRANSFER

Two surfaces of equal area are separated by 100 mm. One surface is at a temperature of 750 K and the other surface is at 250 K. Assume the surfaces are black bodies. The shape factor between the two surfaces is 0.3. Assume the surfaces are part of an enclosure, then what is the radiative heat transfer between the two surfaces?

The rate of heat transfer between the two surfaces is given by the equation below.

$$Q_{12} = \sigma A_{12} F_{12} (T_1^4 - T_2^4)$$

$$\sigma = Stefan\ Boltzman\ Constant = 5.67\ x10^{-8} \frac{W}{m^2 - K^4}$$

$$Q_{12} = 5.67\ x10^{-8} \frac{W}{m^2 - K^4} A_{12} 0.3(750^4 - 250^4)$$

$$Q_{12} = 5315 \frac{W}{m^2}$$

The correct answer is most nearly, (c) 5,300 W/m².

(a) 800 W/m^2

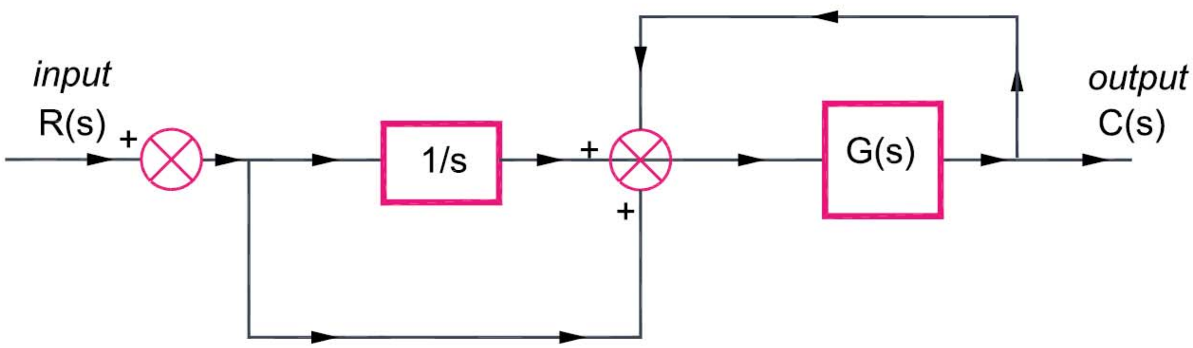
(b) 5,300 W/m^2

(c) 17,720 W/m^2

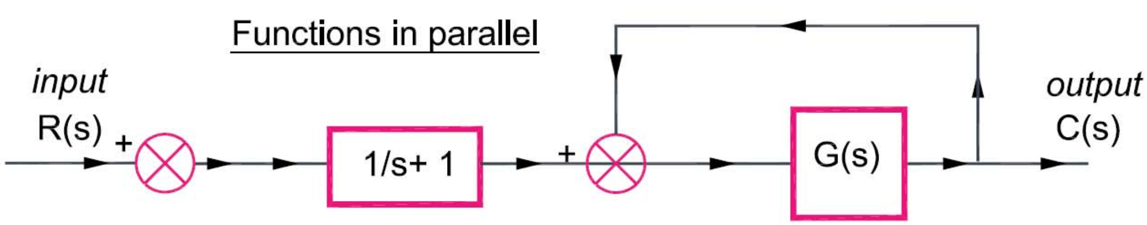
(d) 20,640 W/m^2

2.94 SOLUTION 94 – MEASUREMENTS, INSTRUMENTATION, AND CONTROLS

Simplify the following control diagram and find the governing equation for the output.



First, simplify the paths in parallel.



Next, simplify the feedback loop.

$$\Delta R = (R_T - R_0) = R_0 1.5005 - R_0$$

$$\Delta R = R_0 0.5005$$

$$\frac{\Delta R}{R_0} = \frac{R_0 0.5005}{R_0} = 50\%$$

(a) 50%

(b) 75%

(c) 125%

(d) 150%

2.98 Solution 98 – Measurements, Instrumentation, and Controls

Which of the following statements is true about a thermistor with a negative temperature coefficient?

The FE Reference Handbook shows the following equation in the Measurements, Instrumentation and Controls section.

$$R_T = R_0 e^{\beta\left(\frac{1}{T}-\frac{1}{T_0}\right)}$$

As you can see the change in temperature results in a change in resistance. An increase in temperature causes a negative value in the exponent. That negative value causes a fractional value of the original resistance less than 1, which means the original resistance decreases.

The correct answer is most nearly, (d) A thermistor reacts to an increase in temperature with a decrease in resistance.

(a) A thermistor reacts to an increase in temperature with an increase in voltage.

(b) A thermistor reacts to an increase in temperature with an increase in resistance.

(c) A thermistor reacts to an increase in temperature with a decrease in voltage.

(d) A thermistor reacts to an increase in temperature with a decrease in resistance.

2.99 Solution 99 – Measurements, Instrumentation, and Controls

Which of the following sensors most likely uses the piezoelectric effect?

2.109 SOLUTION 109 – MECHANICAL DESIGN & ANALYSIS

A square-threaded power screw is used to raise a load of 10,000 pounds. The mean thread diameter is equal to 2 inches. The screw has 4 threads per inch, which makes its pitch equal to 0.25 inches. The coefficient of friction is equal to 0.05. Hint: pitch is equal to lead for single start, screw threads. Assume no collar.

The pitch is the distance between screw threads. Since there are four threads per inches, then the distance between the threads is 0.25 inches. The lead is the axial movement per one revolution. For a single start, square thread, the lead is equal to the pitch.

$$T_{raise} = \frac{F * d_m}{2} * \left(\frac{l + \pi \mu d_m}{\pi d_m - \mu l}\right) + \frac{F * \mu_c d_c}{2}$$

$$T_{raise} = \frac{10{,}000\ lb * 2\ in}{2} * \left(\frac{(0.25\ in) + \pi(0.05)(2\ in)}{\pi(2\ in) - (0.05)(0.25\ in)}\right) + 0$$

$$T_{raise} = 899.1\ lb - in$$

The correct answer is most nearly, (a) 900 lb-in.

(a) 900 lb-in

(b) 1,200 lb-in

(c) 2,960 lb-in

(d) 5,990 lb-in

2.110 SOLUTION 110 – MECHANICAL DESIGN & ANALYSIS

A bolt will be subject to a shear force of 5,000 N. If the bolt material has a shear strength of 100 MPa, then what is the required bolt diameter?

The shear force equation is shown below.

$$\sigma = \frac{F}{A} = 100\ x\ 10^6\ Pa = \frac{5{,}000\ N}{\frac{\pi D^2}{4}}$$

$$D = 7.98\ mm$$

The correct answer is most nearly, (b) 8 mm.

(a) .25 mm

(b) 8 mm