Solution

The equation of a sphere with center at $(0, 1, -2)$ and a radius of 9 is:

- A. $x^2 + (y - 1)^2 + (z + 2)^2 = 81$
- B. $x^2 + (y + 1)^2 + (z - 2)^2 = 81$
- C. $(x + 1)^2 + (y + 1)^2 + (z + 2)^2 = 81$
- D. $(x)^2 + (y - 1)^2 + (z + 2)^2 = 9$

Solution

The equation of a sphere with center at (0, 1, −2) and a radius of 9 is:

- A. $x^2 + (y - 1)^2 + (z + 2)^2 = 81$
- B. $x^2 + (y + 1)^2 + (z - 2)^2 = 81$
- C. $(x + 1)^2 + (y + 1)^2 + (z + 2)^2 = 8$
- D. $(x)^2 + (y - 1)^2 + (z + 2)^2 = 9$

Solution

Refer to the Mathematics section of the *FE Reference Handbook*.

$(x - h)^2 + (y - k)^2 + (z - m)^2 = r^2$ with center at (h, k, m)

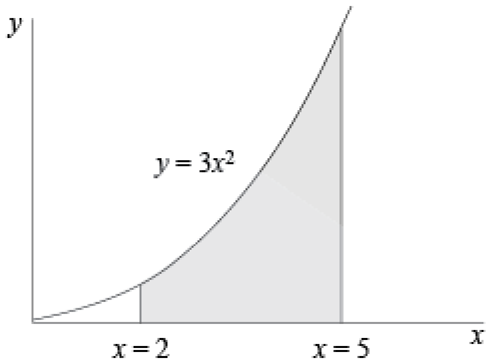
$(x - 0)^2 + (y - 1)^2 + (z - (-2))^2 = r^2$

$x^2 + (y - 1)^2 + (z + 2)^2 = 81$

THE CORRECT ANSWER IS: A

Solution

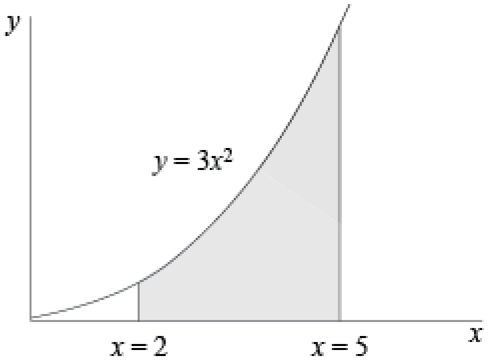
The area of the shaded portion of the figure shown below is most nearly:



- A. 18
- B. 39
- C. 117
- D. 133

Solution

The area of the shaded portion of the figure shown below is most nearly:



A. 18

B. 39

C. 117

D. 133

Solution

Refer to the Mathematics section of the *FE Reference Handbook*.

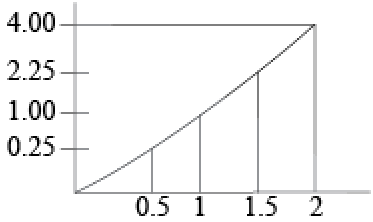
$$A = \int_2^5 3x^2 dx = x^3 \Big|_2^5 = 5^3 - 2^3$$

$$= 117$$

THE CORRECT ANSWER IS: C

Solution

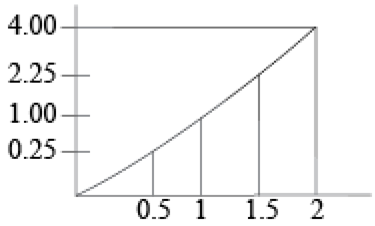
Suppose $f(t) = t^2$. The area under the curve for $0 \leq t \leq 2$, estimated by using the trapezoidal rule with $\Delta t = 0.5$, is most nearly:



- A. 4.00
- B. 2.75
- C. 2.67
- D. 1.33

Solution

Suppose $f(t) = t^2$. The area under the curve for $0 \leq t \leq 2$, estimated by using the trapezoidal rule with $\Delta t = 0.5$, is most nearly:



- A. 4.00
- B. 2.75
- C. 2.67
- D. 1.33

Solution

Refer to the Mathematics section of the *FE Reference Handbook*.

$$\text{Area} = \frac{0.5}{2}\left[0^2 + 2(0.5)^2 + 2(1.0)^2 + 2(1.5)^2 + (2)^2\right] = 2.75$$

THE CORRECT ANSWER IS: B

Solution

A series of measurements gave values of 11, 11, 11, 11, 12, 13, 13, 14, for which the arithmetic mean is 12. The population standard deviation is most nearly:

- A. 1.42
- B. 1.25
- C. 1.19
- D. 1.12

Solution

A series of measurements gave values of 11, 11, 11, 11, 12, 13, 13, 14, for which the arithmetic mean is 12. The population standard deviation is most nearly:

A. 1.42

B. 1.25

C. 1.19

D. 1.12

Solution

From Dispersion, Mean, Median, and Mode Values in the Mathematics section of the *FE Reference Handbook*:

$$\sigma = \sqrt{\frac{1}{N}\sum(x_1 - \mu)^2}$$

$$\sigma = \sqrt{\frac{4(11-12)^2 + 1(12-12)^2 + (13-12)^2 + 1(14-12)^2}{8}}$$

$$\sigma = 1.118$$

THE CORRECT ANSWER IS: D

Solution

Suppose the lengths of telephone calls form a normal distribution with a mean length of 8.0 min and a standard deviation of 2.5 min. The probability that a telephone call selected at random will last more than 15.5 min is most nearly:

- A. 0.0013
- B. 0.0026
- C. 0.2600
- D. 0.9987

Solution

Suppose the lengths of telephone calls form a normal distribution with a mean length of 8.0 min and a standard deviation of 2.5 min. The probability that a telephone call selected at random will last more than 15.5 min is most nearly:

- A. 0.0013
- B. 0.0026
- C. 0.2600
- D. 0.9987

Solution

$$8 - 15.5 = 7.5$$

$$\frac{7.5}{2.5} = 3 \text{ standard deviations}$$

From the Unit Normal Distribution table in the Engineering Probability and Statistics section of the *FE Reference Handbook*.

For $x = 3$, $R(x) = 0.0013$

THE CORRECT ANSWER IS: (A)

Solution

A spreadsheet display shows the following values in Column A:

Row	A
1	–2
2	–1
3	0
4	1
5	2

Cell B1 contains the formula $A1∧3 + A$l∧2 – 3. The formula in Cell B1 is copied down in Column B. The formula in Cell B5 will be:

- (selected) A. $A1∧3 + A$5∧2 – 3
- B. A5∧3 + B$1∧2 – 3
- C. $A5∧3 + A$1∧2 – 3
- D. A5∧3 + A5∧2 – 3

Solution

A spreadsheet display shows the following values in Column A:

Row	A
1	–2
2	–1
3	0
4	1
5	2

Cell B1 contains the formula \$A1∧3 + A\$1∧2 – 3. The formula in Cell B1 is copied down in Column B. The formula in Cell B5 will be:

A. \$A1∧3 + A\$5∧2 – 3

B. A5∧3 + B\$1∧2 – 3

C. \$A5∧3 + A\$1∧2 – 3

D. A5∧3 + A5∧2 – 3

Solution

The following formulas are in the first five rows of Column B

1. \$A1∧3 + A\$1∧2 – 3
2. \$A2∧3 + A\$1∧2 – 3
3. \$A3∧3 + A\$1∧2 – 3
4. \$A4∧3 + A\$1∧2 – 3
5. \$A5∧3 + A\$1∧2 – 3

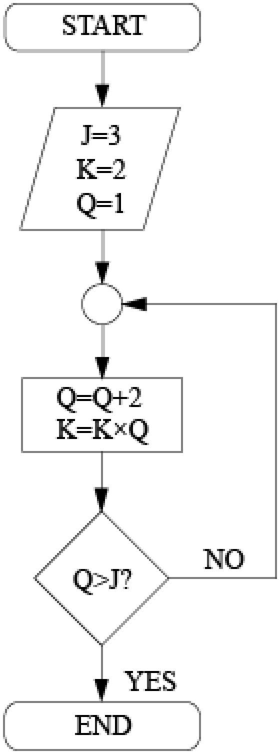
In spreadsheet equation format, the formula in Cell B5 is

\$A5∧3 + A\$1∧2 – 3

THE CORRECT ANSWER IS: (C)

Solution

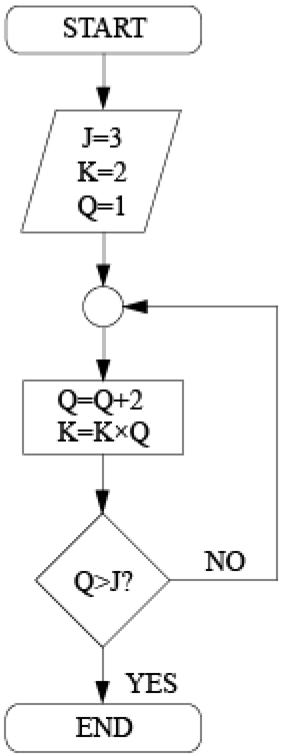
The final value of Q in the following flowchart is most nearly:



- A. 0
- B. 1
- C. 3
- D. 5

Solution

The final value of Q in the following flowchart is most nearly:



Solution

First Round	Second Round
$Q = 1 + 2 = 3$	$Q = 3 + 2 = 5$
$K = 2 \times 3 = 6$	$K = 6 \times 5 = 30$
$3 > 3$ NO!	$5 > 3$ YES!
	$\therefore Q = 5$

THE CORRECT ANSWER IS: D

- A. 0
- B. 1
- C. 3
- D. 5

Solution

According to the *Model Rules*, Section 240.15, Rules of Professional Conduct, licensed professional engineers are obligated to:

- A. ensure that design documents and surveys are reviewed by a panel of licensed engineers prior to affixing a seal of approval
- B. express public opinions under the direction of an employer or client regardless of knowledge of subject matter
- C. practice by performing services only in the areas of their competence and in accordance with the current standards of technical competence
- D. offer, give, or solicit services directly or indirectly in order to secure work or other valuable or political considerations

Solution

According to the *Model Rules*, Section 240.15, Rules of Professional Conduct, licensed professional engineers are obligated to:

- A. ensure that design documents and surveys are reviewed by a panel of licensed engineers prior to affixing a seal of approval
- B. express public opinions under the direction of an employer or client regardless of knowledge of subject matter
- C. practice by performing services only in the areas of their competence and in accordance with the current standards of technical competence
- D. offer, give, or solicit services directly or indirectly in order to secure work or other valuable or political considerations

Solution

Refer to the Ethics section of the *FE Reference Handbook*. Section B.1 in the Rules of Professional Conduct states:

> Licensees shall undertake assignments only when qualified by education or experience in the specific technical fields of engineering or surveying involved.

THE CORRECT ANSWER IS: C

Solution

A company borrows $100,000 today at 12% nominal annual interest. The monthly payment of a 5-year loan is most nearly:

- A. $1,667
- B. $2,200
- C. $3,100
- D. $12,000

Solution

A company borrows $100,000 today at 12% nominal annual interest. The monthly payment of a 5-year loan is most nearly:

- A. $1,667
- B. $2,200
- C. $3,100
- D. $12,000

Solution

Refer to the Engineering Economics section of the *FE Reference Handbook*.

$$A = P\,(A/P,\ i\%,\ n)$$

$$= 100{,}000\,(A/P,\ 1\%,\ 60)$$

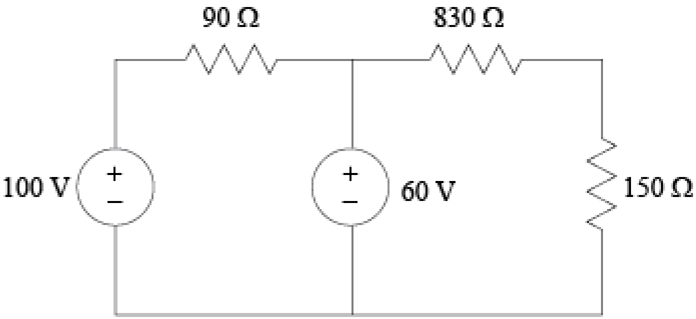
$$= 100{,}000\,(0.0222)$$

$$= \$2{,}220/\text{month}$$

THE CORRECT ANSWER IS: B

Solution

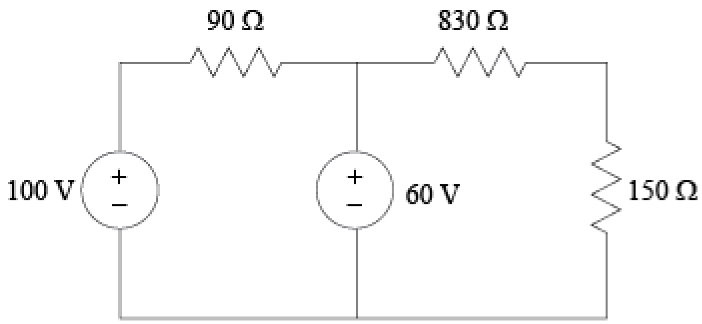
The power (W) dissipated in the 90-Ω resistor of the circuit shown below is most nearly:



- A. 8
- B. 18
- C. 40
- D. 71

Solution

The power (W) dissipated in the 90-Ω resistor of the circuit shown below is most nearly:



- A. 8
- B. 18
- C. 40
- D. 71

Solution

The power dissipated in a resistor can be found by applying the equation $P = \frac{V^2}{R}$.

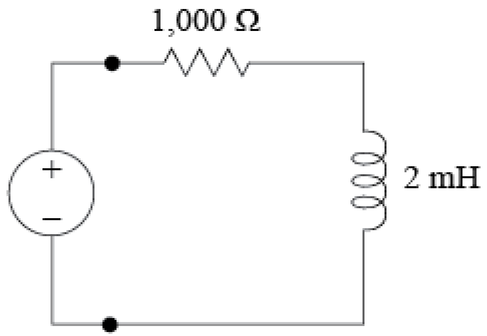
The voltage across the 90-Ω resistor is $100 - 60 = 40$ V. Therefore,

$$P = \frac{40^2}{90\ \Omega} = 17.78\ \text{W}$$

THE CORRECT ANSWER IS: B

Solution

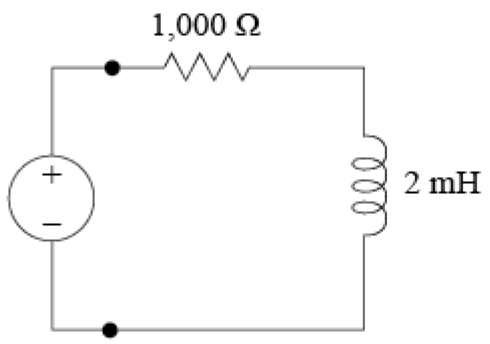
A 1,000-Ω resistor is in series with a 2-mH inductor. An ac voltage source operating at a frequency of 100,000 rad/s is attached as shown in the figure. The impedance (Ω) of the *RL* combination is most nearly:



- A. $200 + j1{,}000$
- B. $1{,}000 + j200$
- C. $38.4 + j192$
- D. $1{,}000 - j200$

Solution

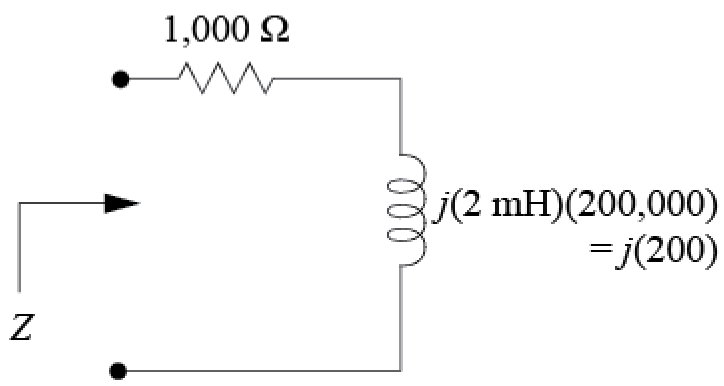
A 1,000-Ω resistor is in series with a 2-mH inductor. An ac voltage source operating at a frequency of 100,000 rad/s is attached as shown in the figure. The impedance (Ω) of the *RL* combination is most nearly:



- A. $200 + j1{,}000$
- B. $1{,}000 + j200$
- C. $38.4 + j192$
- D. $1{,}000 - j200$

Solution

Refer to the Electrical and Computer section of the *FE Reference Handbook.*



The impedance of the resistor is $Z_R = R = 1{,}000\ \Omega$.

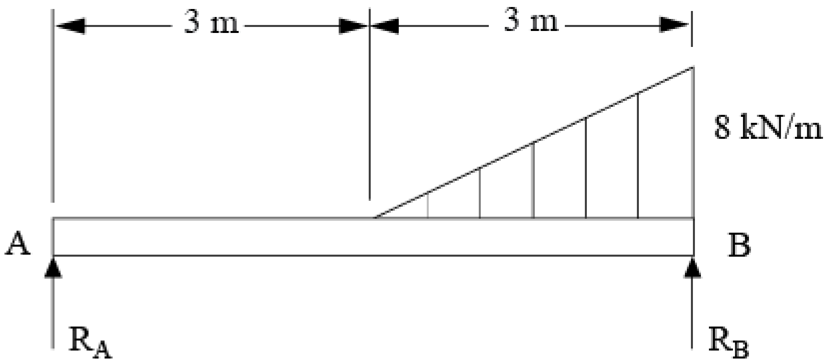
The impedance of the inductor is $Z_L = j\omega L = j(100{,}000)(0.002) = j200\ \Omega$

Since they are in series, $Z = 1{,}000 + j200\ \Omega$

THE CORRECT ANSWER IS: B

Solution

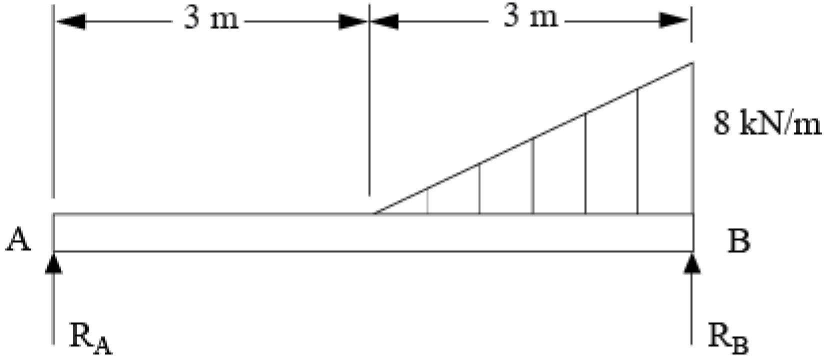
Beam AB has a distributed load as shown and supports at A and B. If the weight of the beam is negligible, the force R_B (kN) is most nearly:



- A. 24
- B. 12
- C. 10
- D. 8

Solution

Beam AB has a distributed load as shown and supports at A and B. If the weight of the beam is negligible, the force R_B (kN) is most nearly:



- A. 24
- B. 12
- C. 10
- D. 8

Solution

Refer to Systems of Forces in the Statics section of the *FE Reference Handbook*.

The triangular force distribution can be replaced with a concentrated force F acting through the centroid of the triangle. The magnitude of F is numerically equal to the area of the triangle.

$F = 1/2\ (\text{base})(\text{height}) = 1/2\ (3\ \text{m})(8\ \text{kN/m})$

$F = 12\ \text{kN}$

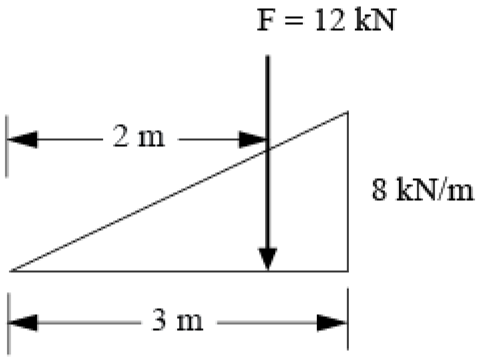
Sum the moments about Point A so that the only unknown is R_B.

$\sum M_A = 0$

$6R_B - 5F = 0$

$6R_B - 5(12\ \text{kN}) = 0$

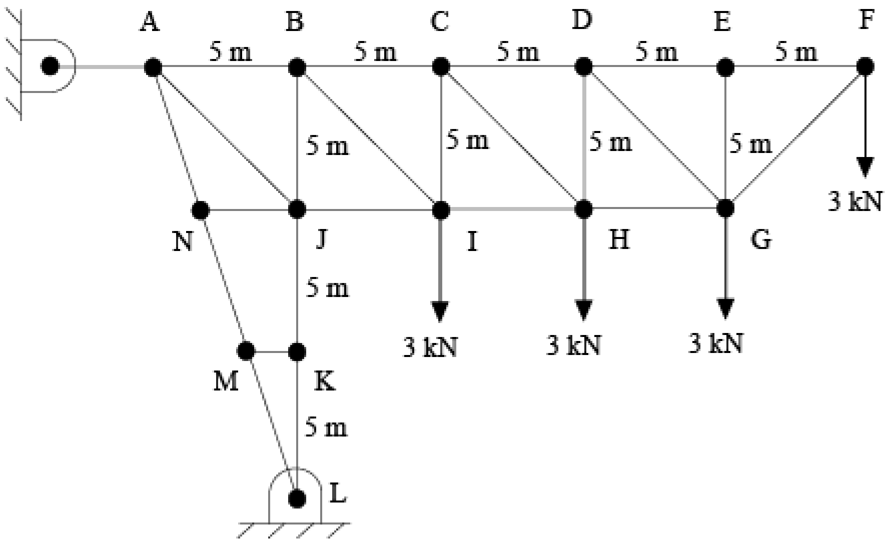
$R_B = 10\ \text{kN}$



THE CORRECT ANSWER IS: C

Solution

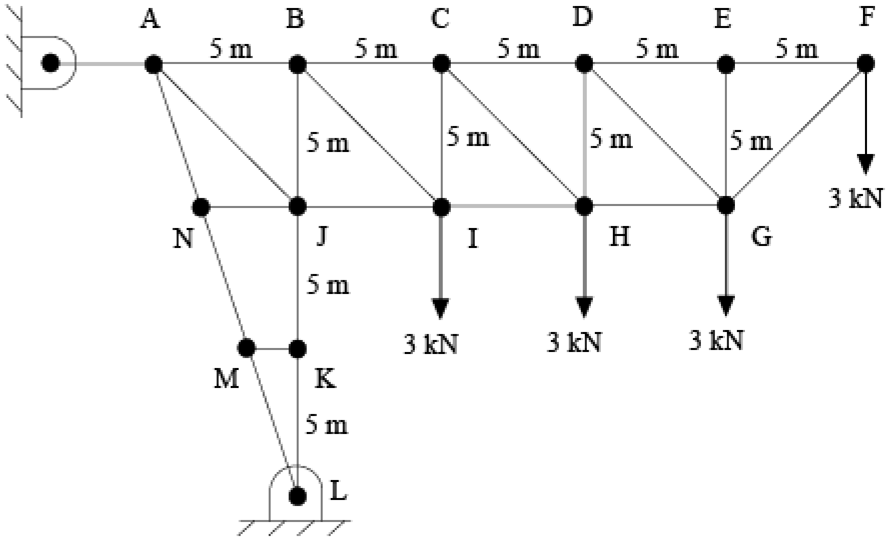
In the figure below, the force (kN) in Member BC is most nearly:



- A. 6
- B. 9
- C. 15
- D. 18

Solution

In the figure below, the force (kN) in Member BC is most nearly:



- A. 6
- B. 9
- C. 15
- D. 18

Solution

Refer to Plane Truss: Method of Sections in the Statics section of the *FE Reference Handbook*.

Place a hypothetical cut as shown below, exposing Member BC as an external force. Then sum the moments about the point so the F_{BC} provides the only unknown moment.

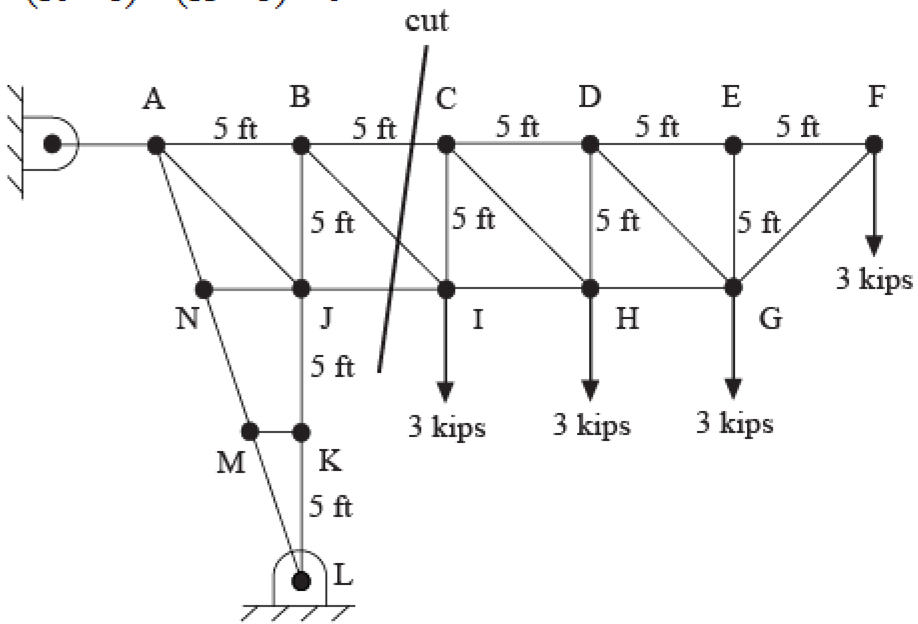
$$\sum M_I = 0$$

$$\sum M_I = (5F_{BC}) - (5 \times 3) - (10 \times 3) - (15 \times 3) = 0$$

$$0 = 5F_{BC} - 15 - 30 - 45$$

$$F_{BC} = 3 + 6 + 9$$

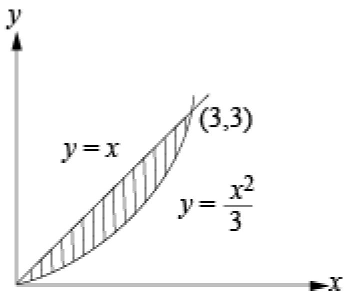
$$F_{BC} = 18 \text{ kN}$$



THE CORRECT ANSWER IS: D

Solution

Consider the following graph:



Which of the following expressions gives the distance from the y-axis to the centroid of the shaded area?

A. $$\frac{\int_0^3 \frac{1}{3} x^3 dx}{\int_0^3 \left(x + \frac{1}{3} x^2\right) dx}$$

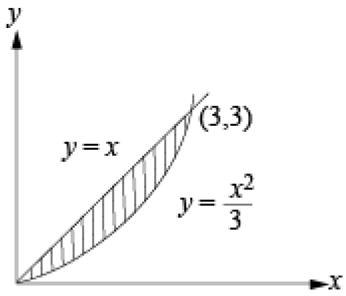
B. $$\frac{\int_0^3 \left(x^2 - \frac{1}{3} x^3\right) dx}{\int_0^3 \left(x - \frac{1}{3} x^2\right) dx}$$

C. $$\frac{\int_0^3 \left(x - \frac{1}{3} x^2\right) dx}{\int_0^3 \left(x - \frac{1}{3} x^2\right) dx}$$

D. $$\frac{\int_0^3 \left(\frac{1}{2} x^2 + \frac{1}{3} x^3\right) dx}{\int_0^3 \left(x - \frac{1}{3} x^2\right) dx}$$

Solution

Consider the following graph:



Which of the following expressions gives the distance from the y-axis to the centroid of the shaded area?

A. $$\frac{\int_0^3 \frac{1}{3}x^3 dx}{\int_0^3 \left(x + \frac{1}{3}x^2\right) dx}$$

B. $$\frac{\int_0^3 \left(x^2 - \frac{1}{3}x^3\right) dx}{\int_0^3 \left(x - \frac{1}{3}x^2\right) dx}$$

C. $$\frac{\int_0^3 \left(x - \frac{1}{3}x^2\right) dx}{\int_0^3 \left(x - \frac{1}{3}x^2\right) dx}$$

D. $$\frac{\int_0^3 \left(\frac{1}{2}x^2 + \frac{1}{3}x^3\right) dx}{\int_0^3 \left(x - \frac{1}{3}x^2\right) dx}$$

Solution

The location of the centroid from the y-axis in the direction parallel to the x-axis is given by:

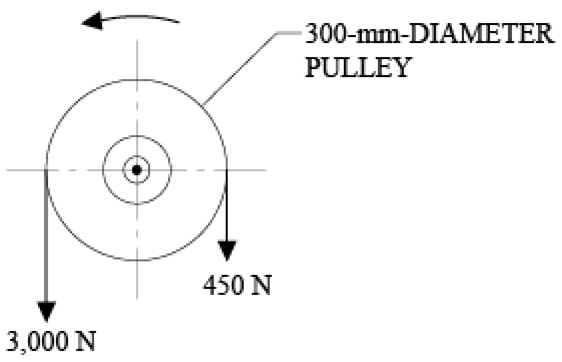
$$\bar{x} = \frac{1}{A}\int_A x\,dA \qquad \text{where } dA = (y_2 - y_1)\,dx$$

$$\bar{x} = \frac{\int_0^3 x\left(x - \frac{x^2}{3}\right)dx}{\int_0^3 \left(x - \frac{x^2}{3}\right)dx} \quad \text{or} \quad \bar{x} = \frac{\int_0^3 \left(x^2 - \frac{1}{3}x^3\right)dx}{\int_0^3 \left(x - \frac{1}{3}x^2\right)dx}$$

THE CORRECT ANSWER IS: B

Solution

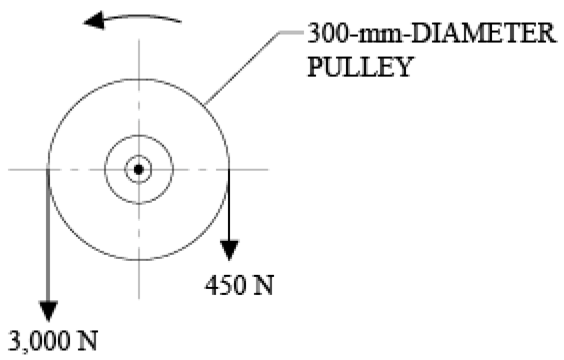
A pulley is driven by a belt as shown in the figure below. Neglecting centrifugal effects, the minimum coefficient of friction that will prevent slipping between the belt and the pulley is most nearly:



- A. 0.60
- B. 0.56
- C. 0.31
- D. 0.20

Solution

A pulley is driven by a belt as shown in the figure below. Neglecting centrifugal effects, the minimum coefficient of friction that will prevent slipping between the belt and the pulley is most nearly:



- A. 0.60
- B. 0.56
- C. 0.31
- D. 0.20

Solution

Refer to the Belt Friction section in the Statics chapter of the *FE Reference Handbook*.

$F_1 = F_2\, e^{\mu\theta}$

$3{,}000 = 450 e^{\mu\pi}$

Set μ equal to μ_s, the static coefficient; and $\theta = \pi$, the angle of wrap.

$\therefore \mu_s\pi = \ln \frac{3{,}000}{450},\ \mu = \frac{1}{\pi}\ln\left(\frac{3{,}000}{450}\right)$

$\mu_s = 0.60$

THE CORRECT ANSWER IS: A

Solution

A 2-kg block slides along a rough horizontal surface and slows to 10 m/s after traveling 20 m. If the kinetic coefficient of friction between the block and surface is 0.2, the initial speed (m/s) of the block was most nearly:

- A. 10.0
- B. 10.4
- C. 13.4
- D. 20.0

Solution

A 2-kg block slides along a rough horizontal surface and slows to 10 m/s after traveling 20 m. If the kinetic coefficient of friction between the block and surface is 0.2, the initial speed (m/s) of the block was most nearly:

- A. 10.0
- B. 10.4
- C. 13.4
- D. 20.0

Solution

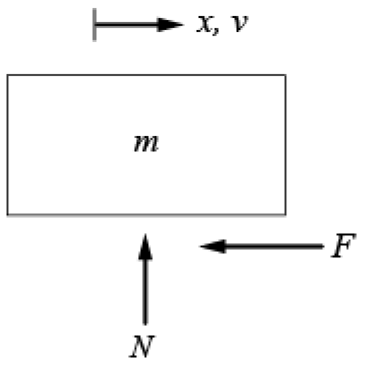
Refer to the Work and Energy section in the Dynamics chapter of the *FE Reference Handbook.*

$$T_2 + U_2 = T_1 + U_1 + W_{1\to 2}, \qquad W_{1\to 2} = -Fx$$

$$\frac{1}{2}mv_2^2 = \frac{1}{2}mv_1^2 - \mu_k mgx$$

Cancel m to obtain $\rightarrow \frac{1}{2}(10)^2 = \frac{1}{2}v_1^2 - 0.2(9.81)(20)$

$v_1 = 13.4 \text{ m/s}$

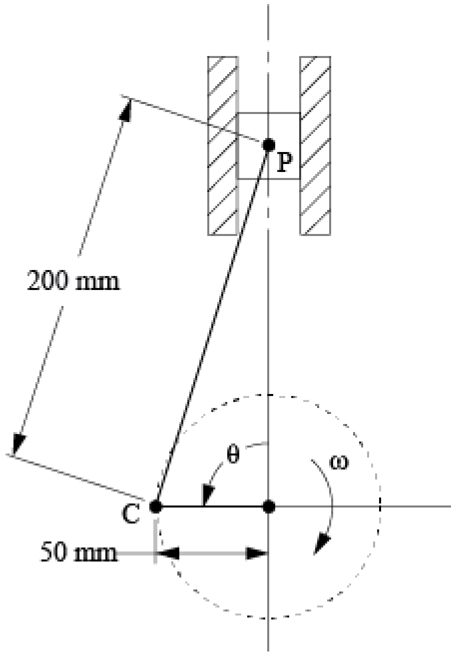


$F = \mu_k \text{mg}$

THE CORRECT ANSWER IS: C

Solution

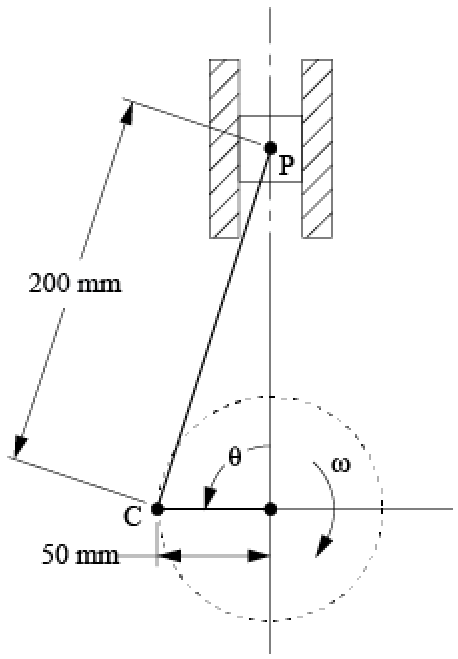
The piston and cylinder of an internal combustion engine are shown in the following figure. If ω = 377 rad/s, the piston speed (mm/s) when θ = 90° is most nearly:



- A. 0
- B. 10,500
- C. 18,850
- D. 24,300

Solution

The piston and cylinder of an internal combustion engine are shown in the following figure. If $\omega = 377$ rad/s, the piston speed (mm/s) when $\theta = 90°$ is most nearly:



A. 0

B. 10,500

C. 18,850

D. 24,300

Solution

Refer to the section Plane Motion of a Rigid Body—Kinematics (Instantaneous Center of Rotation) in the Dynamics chapter of the *FE Reference Handbook*.

The crank and rod are two rigid bodies. At the moment when $\theta = 90°$, v_P is desired (piston speed).

$v_C = 50 \text{ mm} \times 377 \text{ rad/s} = 18{,}850 \text{ mm/s}$

Both points are on the rod. By the method of instantaneous centers, the center of rotation is located where the line at P, $\perp$ to v_P, intersects the line at C, $\perp$ to v_C.

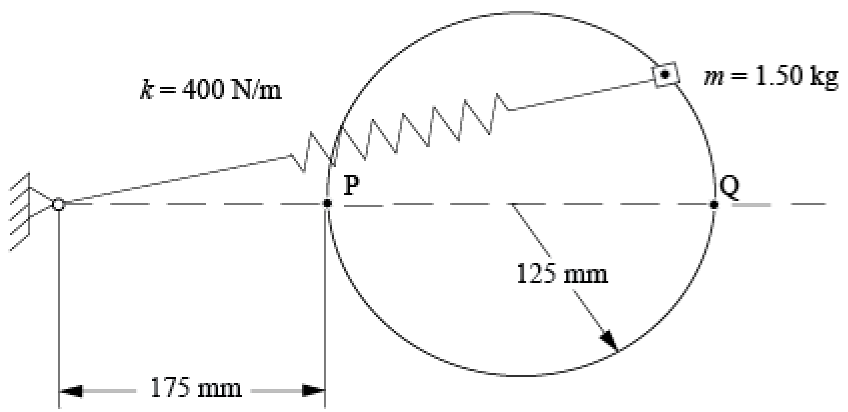
v_C is parallel to v_P so these meet at infinity. Thus the rotation of rod PC is 0, or $\omega_{PC} = 0$.

Since there is no rotation at this instant, *all* points of the rod move with the same velocity and

$v_P = v_C = 18{,}850$ mm/s because $\overline{v}_P = \overline{v}_C + \overline{\omega}_{PC} \times \overline{r}_{P/C}$ and $\omega_{PC} = 0$.

THE CORRECT ANSWER IS: C

An object with a mass m of 1.50 kg moves without friction in a circular path as shown below. Attached to the object is a spring with a spring constant k of 400 N/m. The spring is undeformed when the object is at Point P, and the speed of the object at Point Q is 2.00 m/s.



NOT TO SCALE

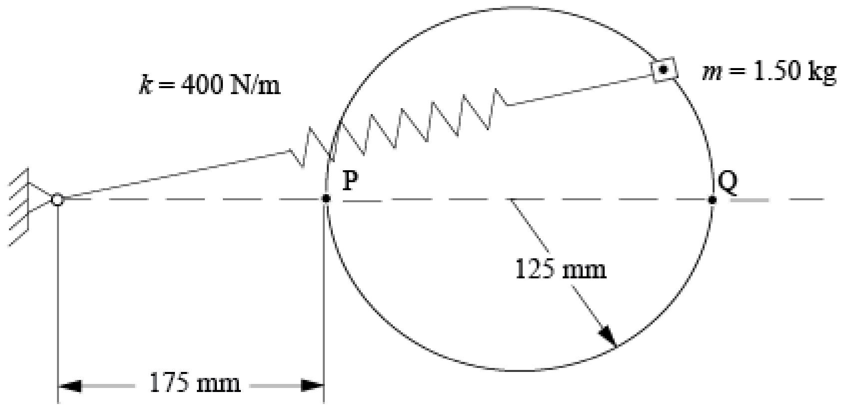
The translational kinetic energy (J) of the object at Point Q is most nearly:

- A. 1.50
- B. 3.00
- C. 6.00
- D. 29.40

Solution

Flag for Re

An object with a mass m of 1.50 kg moves without friction in a circular path as shown below. Attached to the object is a spring with a spring constant k of 400 N/m. The spring is undeformed when the object is at Point P, and the speed of the object at Point Q is 2.00 m/s.



Solution

The kinetic energy T, when the object is at Q, is:

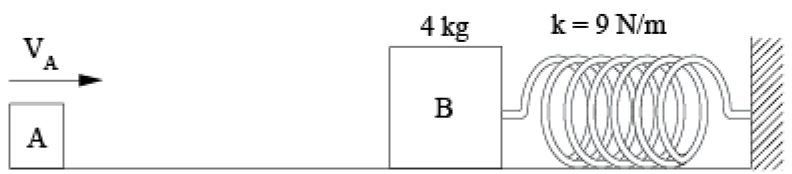
$$T = 1/2\, mv^2 = 1/2\,(1.5\text{ kg})\,(2\text{ m}/\text{s})^2 = 3\text{ J}$$

THE CORRECT ANSWER IS: B

The translational kinetic energy (J) of the object at Point Q is most nearly:

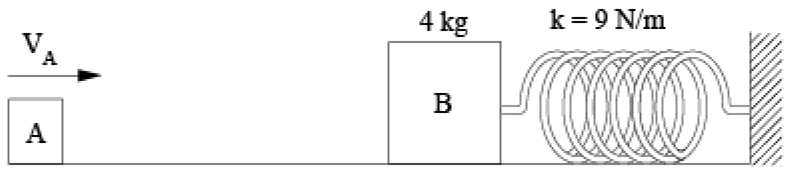
- A. 1.50
- B. 3.00
- C. 6.00
- D. 29.40

In the figure below, Block B is initially at rest and is attached to an unstretched spring. Block A travels to the right and hits Block B. Immediately after impact, the velocity of Block B is 6 m/s to the right. The maximum acceleration (m/s^2) of Block B after impact is most nearly:



- A. 1.5
- B. 2.25
- C. 6.0
- D. 9.0

In the figure below, Block B is initially at rest and is attached to an unstretched spring. Block A travels to the right and hits Block B. Immediately after impact, the velocity of Block B is 6 m/s to the right. The maximum acceleration (m/s^2) of Block B after impact is most nearly:



- A. 1.5
- B. 2.25
- C. 6.0
- D. 9.0

Solution

Refer to the Free Vibration section in the Dynamics chapter of the *FE Reference Handbook*.

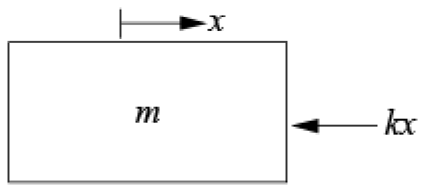
$$m\ddot{x} + kx = 0$$

$$\therefore x = C_1 \cos(\omega_n t) + C_2 \sin(\omega_n t) \quad \text{where } \omega_n = \sqrt{\frac{k}{m}}$$

$x(0) = 0 \therefore C_1 = 0$, and

$$x = C_2 \sin(\omega_n t)$$

$$\dot{x} = C_2 \omega_n \cos(\omega_n t)$$



$\dot{x}(0) = 6 = C_2 \omega_n$, solving for C_2

$$C_2 = \frac{6}{\omega_n}$$

$$\ddot{x} = -C_2 \omega_n^2 \sin(\omega_n t)$$

$$\ddot{x} = -6\omega_n \sin(\omega_n t)$$

$$\ddot{x} = -6\sqrt{\frac{9}{4}} \sin(\omega_n t)$$

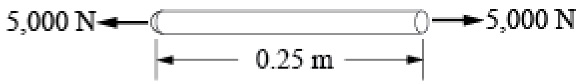
$$\ddot{x} = -9 \text{ m/s}^2 \sin(\omega_n t)$$

$$\therefore \ddot{x}_{max} = 9 \text{ m/s}^2$$

THE CORRECT ANSWER IS: D

Solution

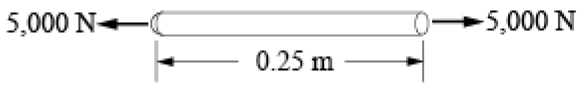
A 0.25-m steel rod with a cross-sectional area of 1,250 mm^2 and a modulus of elasticity E of 200 GPa is subjected to a 5,000-N force as shown below. The elongation of the rod (μm) is most nearly:



- A. 2.4
- B. 4.4
- C. 5.0
- D. 9.6

Solution

A 0.25-m steel rod with a cross-sectional area of 1,250 mm^2 and a modulus of elasticity E of 200 GPa is subjected to a 5,000-N force as shown below. The elongation of the rod (μm) is most nearly:



- A. 2.4
- B. 4.4
- C. 5.0
- D. 9.6

Solution

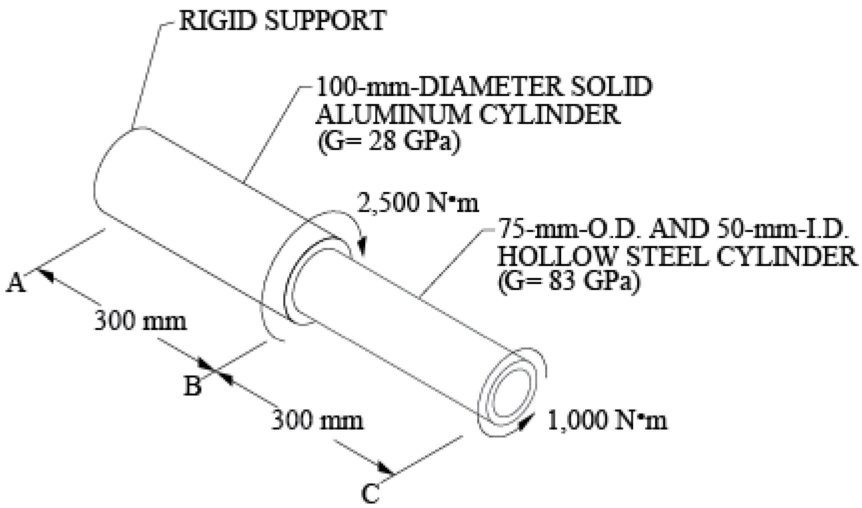
From Uniaxial Loading and Deformation in the Mechanics of Materials section of the *FE Reference Handbook*, the uniaxial deformation is:

$$\text{Deformation} = \delta = \frac{PL}{AE} = \frac{(5{,}000)(0.25)}{\left(1{,}250 \times 10^{-6}\right)\left(200 \times 10^{9}\right)} = 5.0 \times 10^{-6}\ \text{m} = 5.0\ \mu\text{m}$$

THE CORRECT ANSWER IS: C

Solution

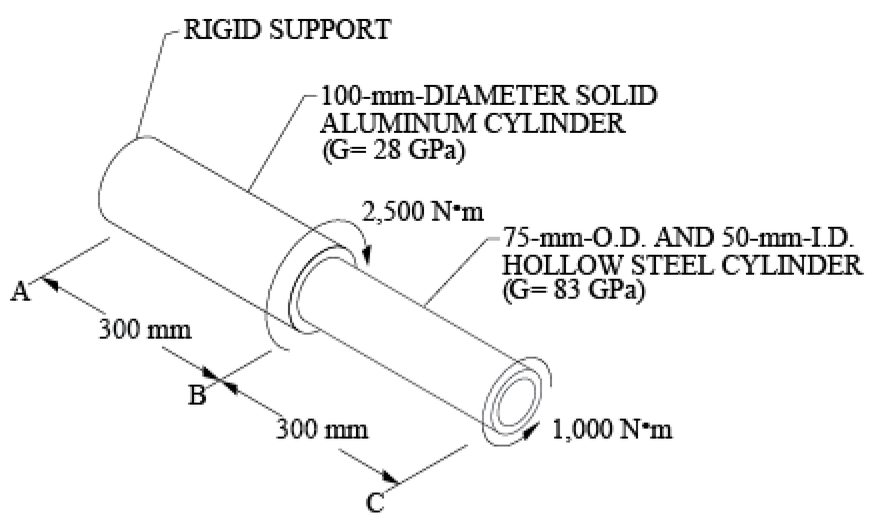
In the figure below, the value of the maximum shear stress (MPa) in Segment BC is most nearly:



- A. 15.0
- B. 30.0
- C. 37.7
- D. 52.7

Solution

In the figure below, the value of the maximum shear stress (MPa) in Segment BC is most nearly:



- A. 15.0
- B. 30.0
- C. 37.7
- D. 52.7

Solution

Refer to the Torsion section in the Mechanics of Materials chapter of the *FE Reference Handbook*.

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

where T = Torque at section of interest (N•mm)

r = radius to point of interest (mm), $r_{outside}$ for maximum shear

J = section (polar) moment of inertia $\left(\text{mm}^4\right)$

For Section BC

$T = 1{,}000\ \text{N}\cdot\text{m}$

$r = \frac{75}{2}\ \text{mm}$

$$J = \frac{\pi\left(75^4 - 50^4\right)}{32}\ \text{mm}^4$$

Hence the maximum torsional shear stress is given by

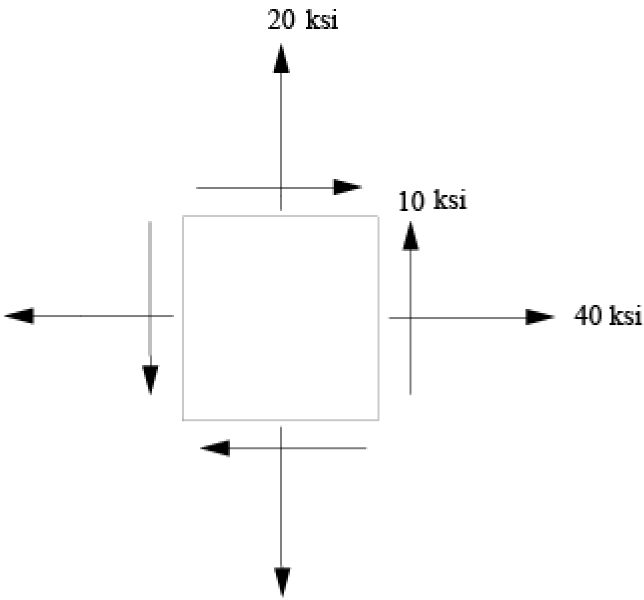
$$\tau = \frac{(1{,}000{,}000\ \text{N}\cdot\text{mm})\left(\frac{75}{2}\ \text{mm}\right)}{\frac{\pi\left(75^4 - 50^4\right)}{32}\ \text{mm}^4}$$

$= 15\ \text{MPa}$

THE CORRECT ANSWER IS: A

Solution

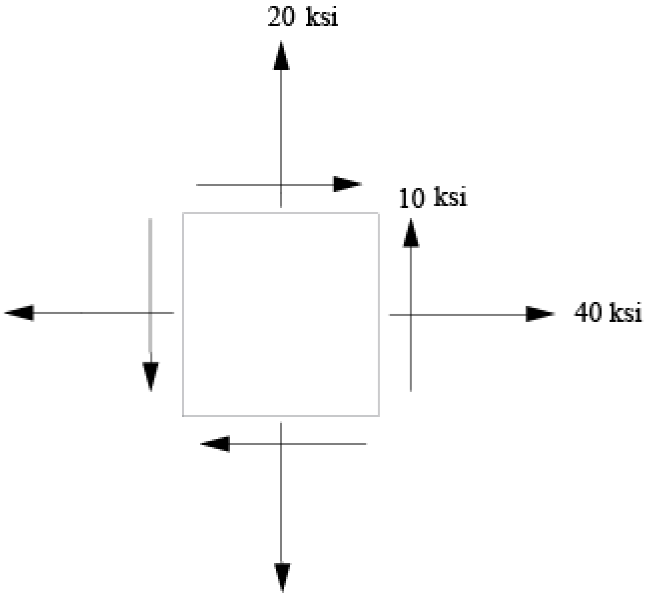
The maximum inplane shear stress (ksi) in the element shown below is most nearly:



- A. 10
- B. 14.1
- C. 44.1
- D. 316

Solution

The maximum inplane shear stress (ksi) in the element shown below is most nearly:



A. 10

B. 14.1

C. 44.1

D. 316

Solution

Refer to Mohr's Circle in the Mechanics of Material section of the *FE Reference Handbook.*

From a constructed Mohr's Circle, the maximum inplane shear stress is $\tau_{max} = R$.

$$R = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}{}^2}$$

$$R = \sqrt{\left(\frac{40 - 20}{2}\right)^2 + 10^2}$$

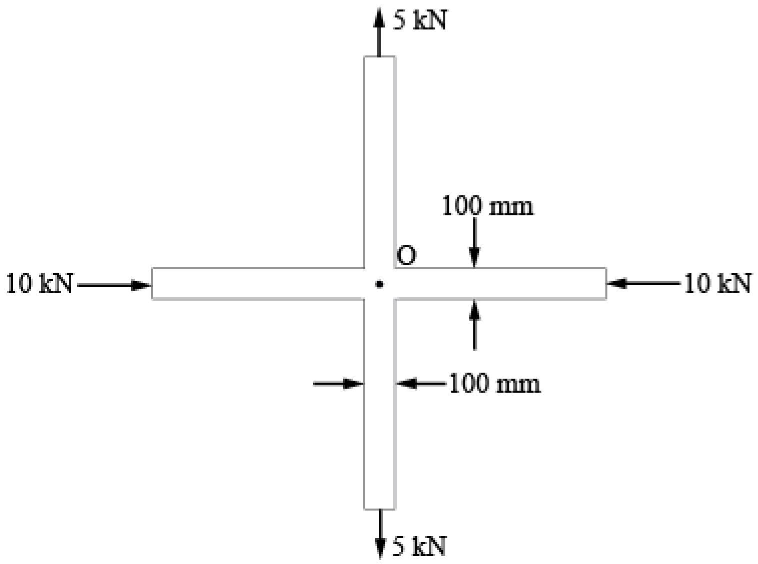
$$R = \sqrt{200}$$

$$R = 14.1 \text{ ksi}$$

THE CORRECT ANSWER IS: B

Solution

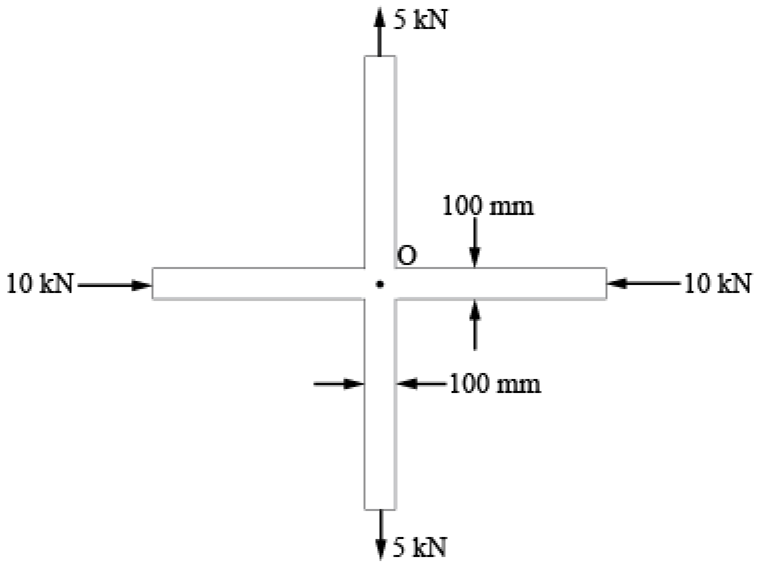
A plane member having a uniform thickness of 10 mm is loaded as shown below. The maximum shear stress (MPa) at Point O is most nearly:



- A. 2.5
- B. 5.0
- C. 7.5
- D. 10.0

Solution

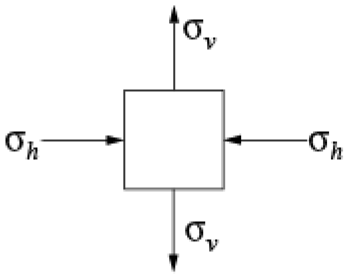
A plane member having a uniform thickness of 10 mm is loaded as shown below. The maximum shear stress (MPa) at Point O is most nearly:



- A. 2.5
- B. 5.0
- C. 7.5
- D. 10.0

Solution

The stress at Point O may be represented as



where $\sigma = \dfrac{\text{Load}}{\text{Area}}$

$$\sigma_h = \frac{10{,}000 \text{ N}}{(100 \text{ mm})(10 \text{ mm})} = -10 \text{ MPa}$$

$$\sigma_v = \frac{5{,}000 \text{ N}}{(100 \text{mm})(10 \text{ mm})} = 5 \text{ MPa}$$

Since σ_h is compressive,

$$\sigma_1 = 5 \text{ MPa}, \sigma_2 = 0 \text{ MPa}, \sigma_3 = -10 \text{ MPa},$$

thus

$$\tau_{\max} = \frac{\sigma_1 - \sigma_3}{2}$$
$$= \frac{5-(-10)}{2}$$
$$= 7.5 \text{ MPa}$$

THE CORRECT ANSWER IS: C

Solution

When a metal is cold-worked, all of the following generally occur **except:**

- A. recrystallization temperature decreases
- B. ductility decreases
- C. grains become equiaxed
- D. slip or twining takes place

Solution

When a metal is cold-worked, all of the following generally occur **except:**

- A. recrystallization temperature decreases
- B. ductility decreases
- C. grains become equiaxed
- D. slip or twining takes place

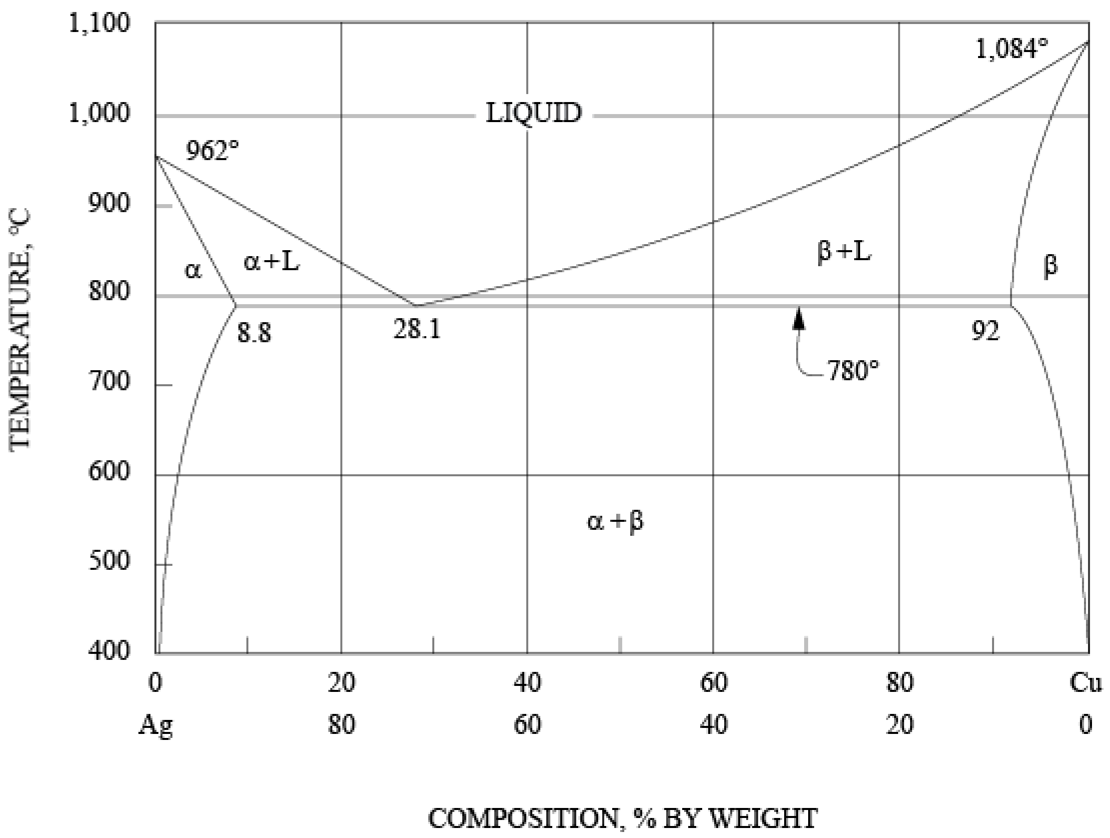
Solution

Cold-working decreases the recrystallization temperature, ductility, and slipping or twining takes place. During cold work, grains become elongated instead of equiaxed.

THE CORRECT ANSWER IS: C

Solution

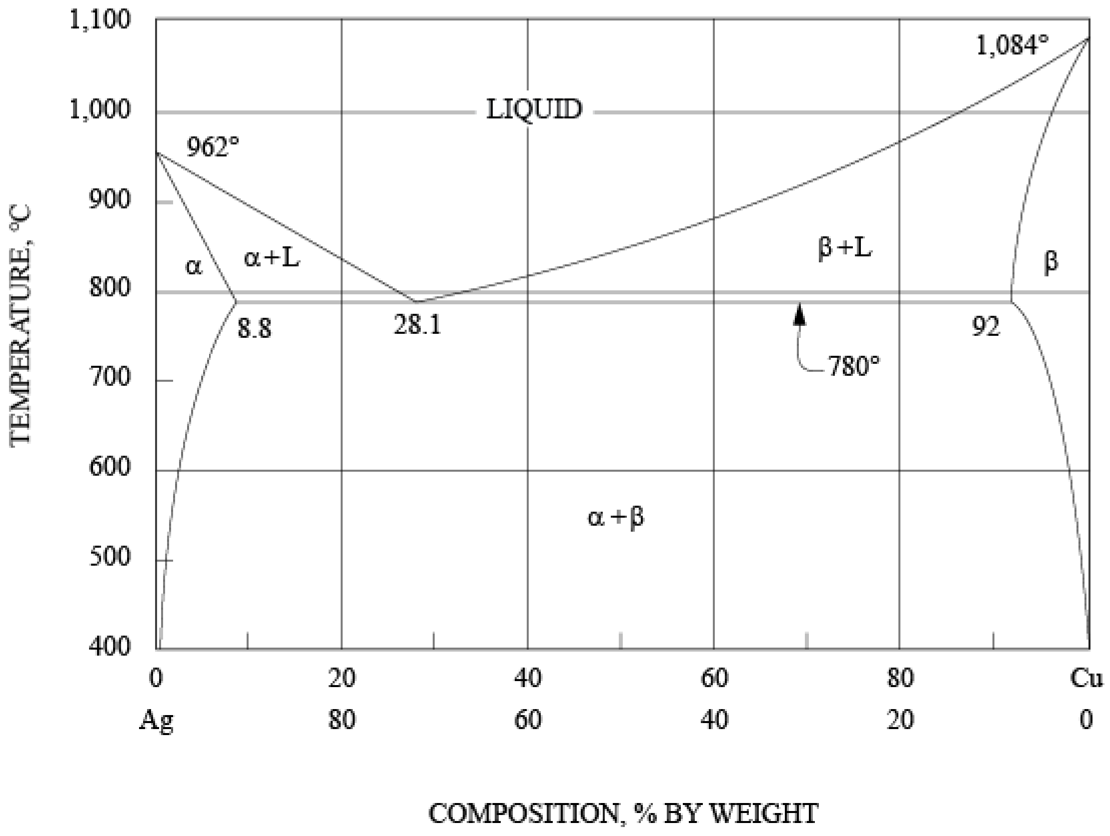
The silver/copper binary phase diagram is shown below. The composition of Ag-Cu alloy that will be completely melted at the lowest temperature is most nearly:



- A. 8.0 wt% Cu
- B. 8.8 wt% Cu
- C. 28.1 wt% Cu
- D. 71.9 wt% Cu

Solution

The silver/copper binary phase diagram is shown below. The composition of Ag-Cu alloy that will be completely melted at the lowest temperature is most nearly:



Solution

Refer to the Binary Phase diagrams in the Material Science/Structure of Matter chapter of the FE Reference Handbook.

The eutectic composition is the point at which the liquid phase transforms directly to two solid phases. For the Ag-Cu phase diagram, the $L \rightarrow \alpha + \beta$ occurs only at 28.1% Cu and 71.9% Ag.

THE CORRECT ANSWER IS: C

- A. 8.0 wt% Cu
- B. 8.8 wt% Cu
- C. 28.1 wt% Cu
- D. 71.9 wt% Cu

Solution

A 40-mm-diameter bar made of 4140 steel is quenched in an agitated oil bath. The expected R_c hardness of the center of the bar is most nearly:

- A. 54
- B. 52
- C. 49
- D. 42

Solution

A 40-mm-diameter bar made of 4140 steel is quenched in an agitated oil bath. The expected R_c hardness of the center of the bar is most nearly:

- A. 54
- B. 52
- C. 49
- D. 42

Solution

Refer to the hardenability curves for agitated oil in the Materials Science/Structure of Matter chapter in the *FE Reference Handbook*.

Find the intersection of 40-mm diameter with the center cooling rate curve (C). Read the distance from the quenched end as 12.5 mm.

Then, go to the Jominy hardenability curves graph for a 4140 steel and a 12.5-mm distance from the quenched end. The R_c hardness is 52. Therefore, 52 is the expected center hardness for a 4140 steel of diameter 40 mm when quenched in an agitated oil bath.

THE CORRECT ANSWER IS: B

Solution

A part is to be formed by bending a thick sheet of Al 2024-T3, which has the following properties:

Fracture toughness = 44 $MPa \cdot m^{1/2}$
Yield strength = 345 MPa

The critical length (mm) of an exterior crack that can be tolerated in the as-received sheet is most nearly:

- A. 2.2
- B. 4.3
- C. 6.9
- D. 13

Solution

A part is to be formed by bending a thick sheet of Al 2024-T3, which has the following properties:

Fracture toughness = 44 MPa·m$^{1/2}$
Yield strength = 345 MPa

The critical length (mm) of an exterior crack that can be tolerated in the as-received sheet is most nearly:

- A. 2.2
- B. 4.3
- C. 6.9
- D. 13

Solution

Refer to Fracture Toughness in the Materials Science/Structure of the Matter chapter in the *FE Reference Handbook*.

Critical crack length: $K_I = y\sigma\sqrt{\pi a}$

Solving for critical a_c yields $a_c = \left(\frac{K_{Ic}}{yS_y}\right)^2 \frac{1}{\pi} = \left(\frac{44}{1.1 \times 345}\right)^2 \frac{1}{\pi}$

$$a_c = 4.3 \text{ mm}$$

THE CORRECT ANSWER IS: B

Solution

A fluid has a specific gravity of 1.263 and an absolute dynamic viscosity of 1.5 kg/(m·s). The standard density of water is 1,000 kg/m^3. The kinematic viscosity (m^2/s) of the fluid is most nearly:

- A. 1.19×10^{-3}
- B. 1.50×10^{-3}
- C. 1.89×10^{-3}
- D. 528

Solution

A fluid has a specific gravity of 1.263 and an absolute dynamic viscosity of 1.5 kg/(m·s). The standard density of water is 1,000 kg/m^3. The kinematic viscosity (m^2/s) of the fluid is most nearly:

- A. 1.19×10^{-3}
- B. 1.50×10^{-3}
- C. 1.89×10^{-3}
- D. 528

Solution

Refer to the Fluid Mechanics section of the *FE Reference Handbook.*

Units of absolute dynamic viscosity (μ) are kg/(m·s).

Units of kinematic viscosity (v) are m^2/s.

$\therefore$ The relationship between the two is:

$v = \mu/\rho$ where ρ is the density in kg/m^3.

$v = 1.5/1.263(1{,}000) = 0.001188 = 1.19 \times 10^{-3}$.

THE CORRECT ANSWER IS: A

Solution

Archimedes' principle states that:

- A. the sum of the pressure, velocity, and elevation heads is constant
- B. flow passing two points in a stream is equal at each point
- C. the buoyant force on a body is equal to the volume displaced by the body
- D. a floating body displaces a weight of fluid equal to its own weight

Solution

Archimedes' principle states that:

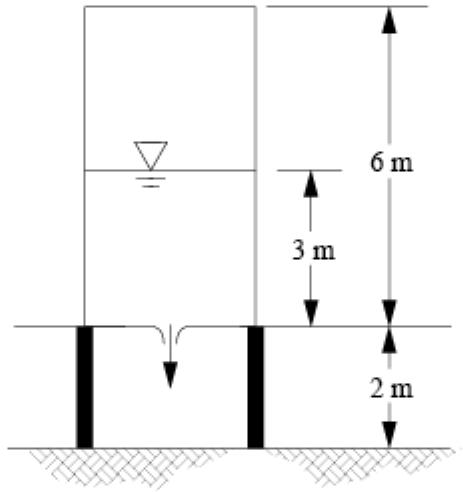
- A. the sum of the pressure, velocity, and elevation heads is constant
- B. flow passing two points in a stream is equal at each point
- C. the buoyant force on a body is equal to the volume displaced by the body
- D. a floating body displaces a weight of fluid equal to its own weight

Solution

Refer to the Fluid Mechanics section of the *FE Reference Handbook*.

THE CORRECT ANSWER IS: D

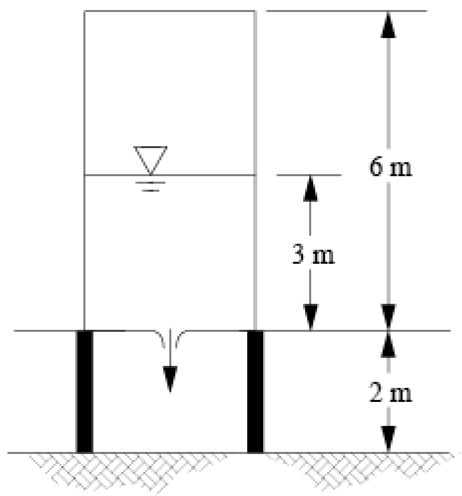
Water is discharged to the atmosphere as a jet from a puncture in the bottom of a ventilated storage tank. The storage tank is a cylinder 6 m high mounted on a level platform 2 m off the ground. Neglecting losses, the jet velocity (m/s) when the tank is half full is most nearly:



- A. 7.7
- B. 9.9
- C. 12.5
- D. 50.8

Solution   Flag for Re

Water is discharged to the atmosphere as a jet from a puncture in the bottom of a ventilated storage tank. The storage tank is a cylinder 6 m high mounted on a level platform 2 m off the ground. Neglecting losses, the jet velocity (m/s) when the tank is half full is most nearly:



Solution

Refer to the Fluid Mechanics section of the *FE Reference Handbook.*

$v = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 3} = 7.67$ m/s

THE CORRECT ANSWER IS: A

- A. 7.7
- B. 9.9
- C. 12.5
- D. 50.8

Solution

Flag for

The mass flow rate of sodium traveling through a pipe with an inside diameter of 0.1023 m is 22.7 kg/s. The mass density of the sodium is 823.3 kg/m^3, and the dynamic viscosity is 2.32×10^{-4} kg/(m·s). The Reynolds number for sodium flow through the pipe is most nearly:

- A. 10,000
- B. 100,000
- C. 1,000,000
- D. 1,200,000

Solution

Flag f

The mass flow rate of sodium traveling through a pipe with an inside diameter of 0.1023 m is 22.7 kg/s. The mass density of the sodium is 823.3 kg/m^3, and the dynamic viscosity is 2.32×10^{-4} kg/(m·s). The Reynolds number for sodium flow through the pipe is most nearly:

- A. 10,000
- B. 100,000
- C. 1,000,000
- D. 1,200,000

Solution

Use the mass flow rate, density, and diameter to determine the flow velocity.

$\dot{m} = \rho A V$ Refer to the One-Dimensional Flows section in the Fluid Mechanics chapter of the *FE Reference Handbook*.

Solve for velocity

$$V = \frac{\dot{m}}{\rho A} \qquad A = \frac{\pi}{4} D^2$$

Substitute:

$$V = \frac{\dot{m}}{\rho \frac{\pi}{4} D^2} = \frac{4\,\dot{m}}{\pi \rho D^2}$$

Use the equation for Reynolds number written in terms of dynamic viscosity:

$$\mathrm{Re} = \frac{VD\rho}{\mu}$$

Refer to the Similitude section in the Fluid Mechanics chapter of the *FE Reference Handbook*.

Substitute the velocity expression and simplify:

$$\mathrm{Re} = \frac{4\dot{m}D\rho}{\pi \rho D^2 \mu} = \frac{4\dot{m}}{\pi D \mu}$$

Substitute the given values and solve:

$$\mathrm{Re} = \frac{(4)(22.7 \text{ kg/s})}{(\pi)(0.1023 \text{ m})\left(2.32 \times 10^{-4} \text{ kg}/(\text{m} \cdot \text{s})\right)}$$

$$\mathrm{Re} = 1{,}217{,}800 \cong 1{,}200{,}000$$

THE CORRECT ANSWER IS: D

Solution

The following data were obtained from a test on a centrifugal fan:

Fluid = Air at 300 K, 101 kPa
Fan wheel diameter = 0.5 m
Speed = 1,000 rpm
Flow rate = 3.0 m^3/s
Pressure rise = 0.90 kPa
Power = 4.0 kW

The efficiency of the fan at the test conditions is most nearly:

- A. 0.38
- B. 0.53
- C. 0.68
- D. 0.82

Solution

The following data were obtained from a test on a centrifugal fan:

Fluid = Air at 300 K, 101 kPa
Fan wheel diameter = 0.5 m
Speed = 1,000 rpm
Flow rate = 3.0 m^3/s
Pressure rise = 0.90 kPa
Power = 4.0 kW

The efficiency of the fan at the test conditions is most nearly:

- A. 0.38
- B. 0.53
- C. 0.68
- D. 0.82

Solution

Refer to the pump power equation in the Fluid Mechanics chapter of the *FE Reference Handbook*.

$$\dot{W} = \frac{Q\gamma h}{\eta} = \frac{\Delta P \cdot Q}{\eta} \quad \text{since } \Delta P = \gamma h$$

$$\eta = \frac{\Delta P \cdot Q}{\dot{W}} = \frac{(0.9 \text{ kPa})(3.0 \text{ m}^3/\text{s})}{4.0 \text{ kW}} \cdot \frac{\text{kN}}{\text{m}^2 \cdot \text{kPa}} \cdot \frac{\text{kW} \cdot \text{s}}{\text{kN} \cdot \text{m}}$$

$$= 0.675$$

THE CORRECT ANSWER IS: C

Solution

The pressure of 100 kg of nitrogen (N_2) at 70°C in a 100-m^3 tank is most nearly:

- A. 2,850 kPa
- B. 102 kPa
- C. 20 kPa
- D. 102 mPa

Solution

The pressure of 100 kg of nitrogen (N_2) at 70°C in a 100-m^3 tank is most nearly:

- A. 2,850 kPa
- B. 102 kPa
- C. 20 kPa
- D. 102 mPa

Solution

Refer to the Thermodynamics section of the *FE Reference Handbook*.

Use the ideal gas formula:

$$PV = mRT$$

$$P = \frac{mRT}{V}$$

$$R = \frac{8{,}314 \text{ J}}{\text{kmole}\bullet\text{K}} \frac{\text{kmol}}{28 \text{ kg}} = 297 \frac{\text{J}}{\text{kg}\bullet\text{K}}$$

$$P = \frac{(100 \text{ kg})\left(297 \frac{\text{J}}{\text{kg}\bullet\text{K}}\right)(343 \text{ K})}{100 \text{ m}^3}$$

$$= 102{,}000 \frac{\text{J}}{\text{m}^3}$$

$$= 102{,}000 \frac{\text{N}\bullet\text{m}}{\text{m}^3}$$

$$= 102{,}000 \frac{\text{N}}{\text{m}^2}$$

$$= 102 \text{ kPa}$$

THE CORRECT ANSWER IS: B

Solution

An insulated tank contains half liquid and half vapor by volume in equilibrium. The release of a small quantity of the vapor without the addition of heat will cause:

- (selected) A. evaporation of some liquid in the tank
- B. superheating of the vapor in the tank
- C. a rise in temperature
- D. an increase in enthalpy

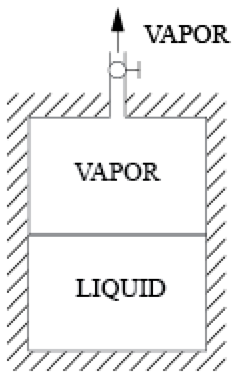
Solution

An insulated tank contains half liquid and half vapor by volume in equilibrium. The release of a small quantity of the vapor without the addition of heat will cause:

- A. evaporation of some liquid in the tank
- B. superheating of the vapor in the tank
- C. a rise in temperature
- D. an increase in enthalpy

Solution

As vapor escapes, the mass within the tank is reduced. With constant volume, the specific volume within the tank must increase. This can happen only if liquid evaporates.

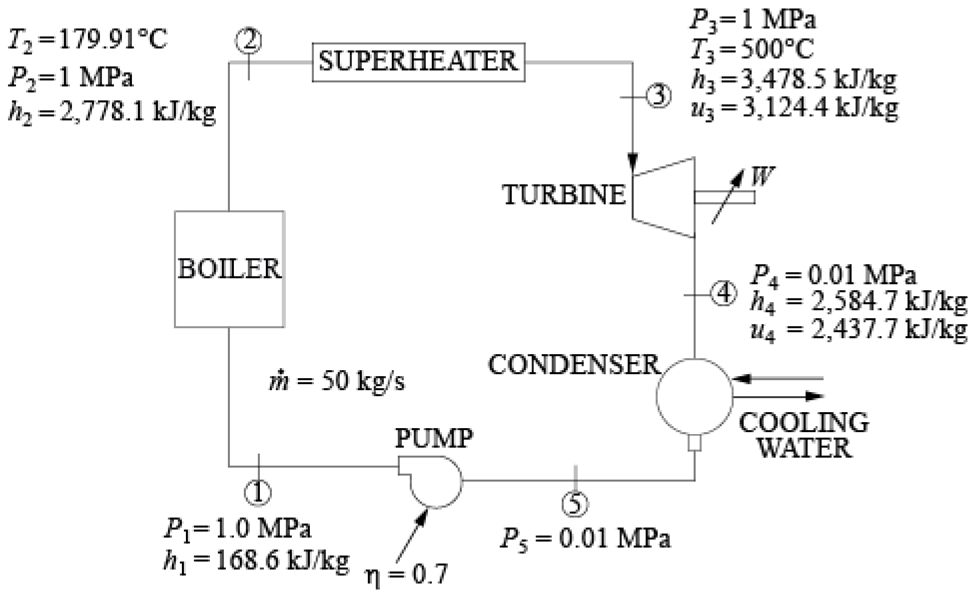


THE CORRECT ANSWER IS: A

Solution

Flag for

A power plant operates on the following simple Rankine cycle. Water is the working fluid. Disregard pressure losses in the piping, steam boiler, and superheater, and neglect kinetic and potential energy effects. Assume steady-state, steady-flow conditions.



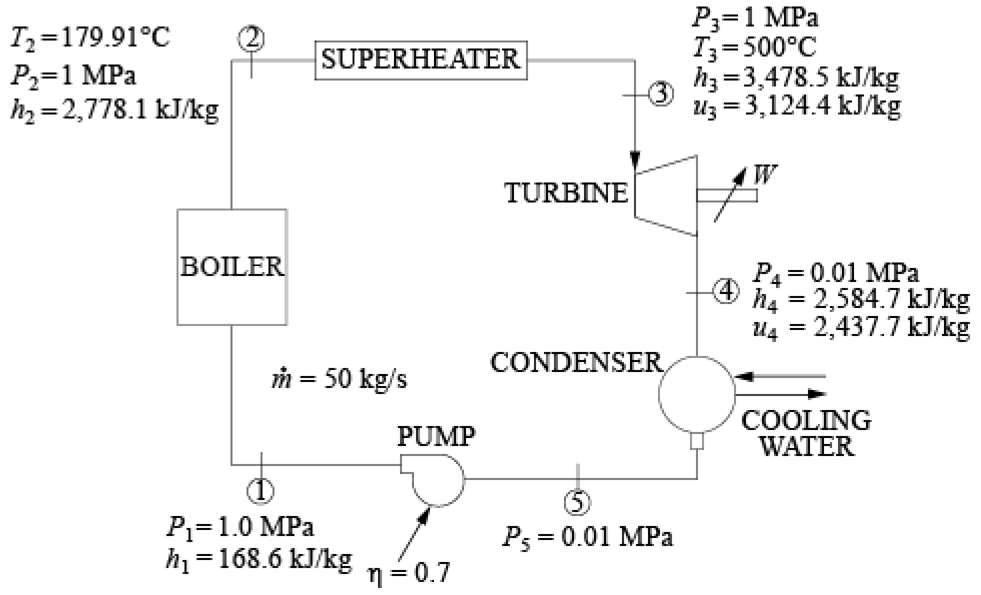
For the thermodynamic conditions shown, the turbine power (MW) is most nearly:

- A. 34.3
- B. 44.7
- C. 52.0
- D. 161,000

Solution

Flag fo

A power plant operates on the following simple Rankine cycle. Water is the working fluid. Disregard pressure losses in the piping, steam boiler, and superheater, and neglect kinetic and potential energy effects. Assume steady-state, steady-flow conditions.



For the thermodynamic conditions shown, the turbine power (MW) is most nearly:

A. 34.3

B. 44.7

C. 52.0

D. 161,000

Solution

Assuming steady-state, steady-flow conditions, a first law analysis of the turbine yields,

$$w_t = h_4 - h_3$$

and with the enthalpy values provided for States 3 and 4, the turbine work per unit mass is

$$w_t = 3,478.5 - 2,584.7 = 893.8 \text{ kJ/kg}$$

The power produced by the turbine is given by

$$\dot{W} = \dot{m}w_t = (50 \text{ kg/s})(893.8 \text{ kJ/kg}) = 44,690 \text{ kW} = 44.7 \text{ MW}$$

THE CORRECT ANSWER IS: B

Solution

The work (kJ) required to compress 1,000 L of an ideal gas to 500 L at a constant pressure of 100 kPa in a closed system is most nearly:

- A. 0.2
- B. 5
- C. 50
- D. 600

Solution

The work (kJ) required to compress 1,000 L of an ideal gas to 500 L at a constant pressure of 100 kPa in a closed system is most nearly:

- A. 0.2
- B. 5
- C. 50
- D. 600

Solution

Refer to the Thermodynamics section of the *FE Reference Handbook*.

Constant Pressure

$$w_b = P\Delta v$$

$$w_b = P\Delta V = P(V_2 - V_1)$$

$$w_b = (100 \text{ kPa})(500 \text{ L} - 1{,}000 \text{ L})\left(\frac{1 \text{ m}^3}{1{,}000 \text{ L}}\right)$$

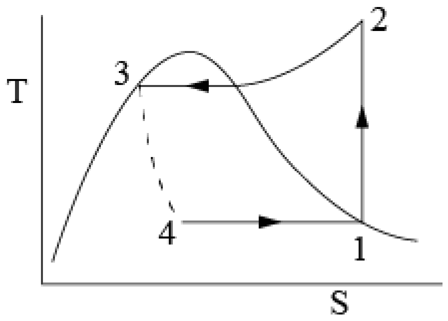
$$w_b = 50 \text{ kJ}$$

THE CORRECT ANSWER IS: C

Solution

The enthalpies provided in the figure below apply to the refrigeration cycle using refrigerant HFC-134a. The coefficient of performance (COP) for this cycle is most nearly:

$h_1 = 394$ kJ/kg
$h_2 = 438$ kJ/kg
$h_3 = 270$ kJ/kg

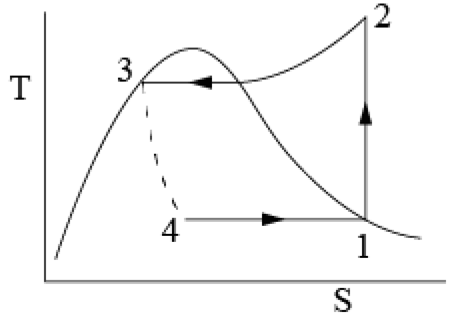


- A. 0.35
- B. 2.82
- C. 3.82
- D. Cannot be determined from data given

Solution

The enthalpies provided in the figure below apply to the refrigeration cycle using refrigerant HFC-134a. The coefficient of performance (COP) for this cycle is most nearly:

$h_1 = 394$ kJ/kg
$h_2 = 438$ kJ/kg
$h_3 = 270$ kJ/kg



- A. 0.35
- B. 2.82
- C. 3.82
- D. Cannot be determined from data given

Solution

Refer to the First Law of Thermodynamics section, the Common Thermodynamic Cycles section, and the P-h diagram for Refrigerant HFC-134a in the Thermodynamics chapter of the *FE Reference Handbook.*

The coefficient of performance of a refrigeration cycle (COP) is defined as the heat added to the refrigerant in the evaporator divided by the work put into the compressor. The heat added, per unit mass of refrigerant, is given by the First Law of Thermodynamics.

$$\dot{m}\left(h_i + \cancel{\frac{V_i^2}{2}}^{0} + \cancel{gZ_i}^{0}\right) - \dot{m}\left(h_e + \cancel{\frac{V_e^2}{2}}^{0} \cancel{gZ_e}^{0}\right) + \dot{Q}_{net} - \cancel{\dot{W}_{net}}^{0} = 0$$

thus $\dot{Q}_{net} = \dot{m}(h_e - h_i) = \dot{m}(h_1 - h_4)$

The work is found similarly, with $\dot{Q}_{net} = 0$, giving $W_{net} = \dot{m}(h_i - h_e) = \dot{m}(h_1 - h_2)$.

This gives $\text{COP} = \dfrac{\dot{Q}_{in}}{-\dot{W}_{net}} = \dfrac{\dot{m}(h_1 - h_4)}{\dot{m}(h_1 - h_2)}$

From the P-h diagram

$h_1 = 394\,\dfrac{\text{kJ}}{\text{kg}},\ h_2 = 438\,\dfrac{\text{kJ}}{\text{kg}}$, and $h_4 = 270\,\dfrac{\text{kJ}}{\text{kg}}$

$$\text{COP} = \frac{(h_1 - h_4)}{(h_2 - h_1)} = \frac{394 - 270}{438 - 394} = 2.82$$

Note that the expansion from h_3 to h_4 is assumed to be constant enthalpy. Therefore, $h_3 = h_4$.

THE CORRECT ANSWER IS: B

Solution

Conditioned air enters a room at 13°C and 70% relative humidity. The dew-point temperature of the air is most nearly:

- A. 5°C
- B. 8°C
- C. 10°C
- D. 13°C

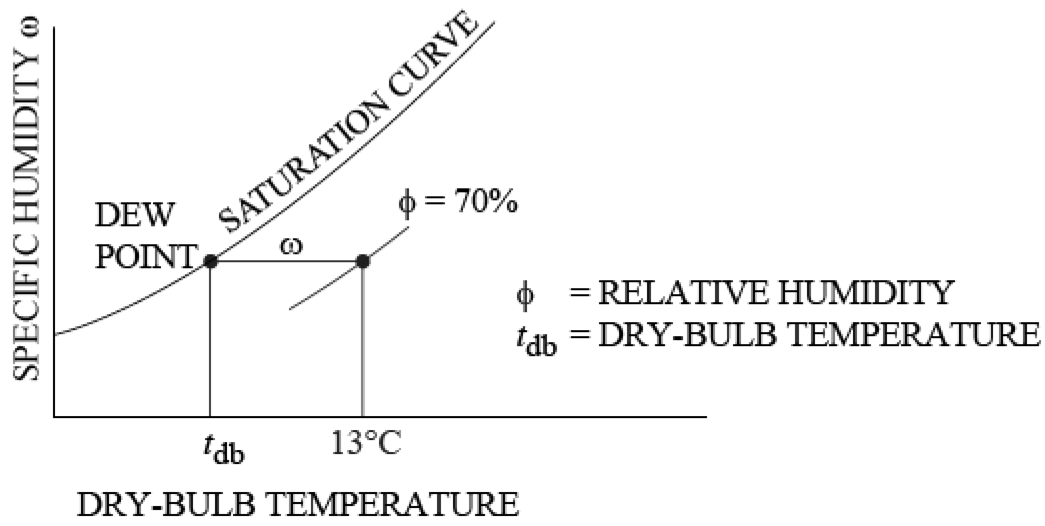
Solution

Conditioned air enters a room at 13°C and 70% relative humidity. The dew-point temperature of the air is most nearly:

- A. 5°C
- B. 8°C
- C. 10°C
- D. 13°C

Solution

Refer to the psychrometric chart in the Thermodynamics chapter of the *FE Reference Handbook.*



At the given state, $t_{db} = 13°C$, $\phi = 70\%$, $\omega = 6.5 \frac{g}{kg\ da}$, da = dry air.

Follow the $\omega = 6.5$ line to the left until the saturation curve is reached. This point is the dew point. Read down to find the dew-point temperature of 7.6°C.

THE CORRECT ANSWER IS: B

Solution

Hot air at 200°C flows across a 50°C surface. If the heat transfer coefficient is 72 $W/(m^2 \cdot °C)$, the heat transfer rate (W) over 2 m^2 of the surface is most nearly:

- A. 300
- B. 5,625
- C. 11,250
- D. 21,600

Solution

Hot air at 200°C flows across a 50°C surface. If the heat transfer coefficient is 72 W/(m^2·°C), the heat transfer rate (W) over 2 m^2 of the surface is most nearly:

- A. 300
- B. 5,625
- C. 11,250
- D. 21,600

Solution

Refer to the Heat Transfer section of the *FE Reference Handbook*.

$$\dot{Q} = hA\Delta T$$

$$\dot{Q} = 72(2)(150)$$

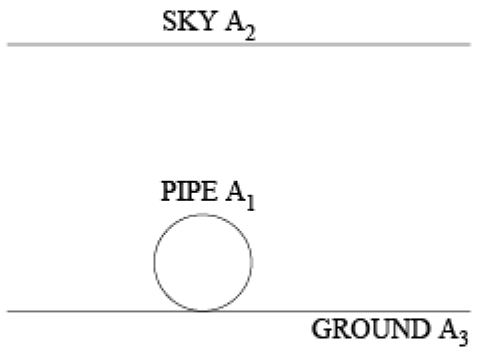
$$\dot{Q} = 21{,}600 \text{ W}$$

THE CORRECT ANSWER IS: D

Solution

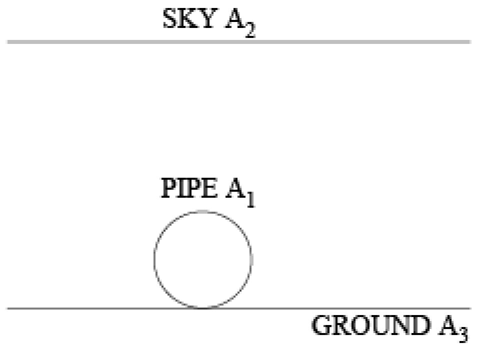
Flag fo

An infinitely long 3-cm water pipe is laid on the ground surface A_3 as shown below. In order to calculate the radiative heat transfer between pairs of surfaces, you must know the shape factor (or view factor) F_{ij} between these surfaces. Assume infinitely large sky and ground surfaces. If the shape factor F_{13} between A_1 and A_3 is 1/2, the shape factor F_{12} between A_1 and A_2 is most nearly:



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

An infinitely long 3-cm water pipe is laid on the ground surface A_3 as shown below. In order to calculate the radiative heat transfer between pairs of surfaces, you must know the shape factor (or view factor) F_{ij} between these surfaces. Assume infinitely large sky and ground surfaces. If the shape factor F_{13} between A_1 and A_3 is 1/2, the shape factor F_{12} between A_1 and A_2 is most nearly:

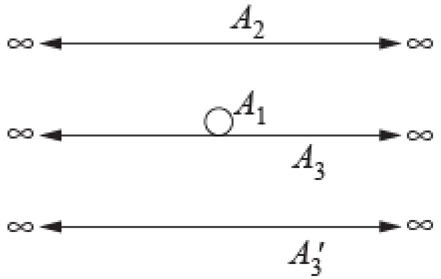


- A. 1/4
- B. 1/2
- C. 3/4
- D. 1

Solution

Refer to the Shape Factor Relations section in the Heat Transfer chapter of the *FE Reference Handbook.*

Consider the figure shown. The ground plane A_3 is moved downward to location A_3' so that A_1 is halfway between A_2 and A_3'. The shape factor F_{12} is the fraction of all the rays leaving A_1 that arrive at A_2. By symmetry, half the rays leaving A_1 strike A_2 and half strike A_3'.



Now the shape factor F_{13} is the same as F_{13}' because each ray that leaves A_1 and strikes A_3' must cross A_3, and each ray that leaves A_1 and strikes A_3 will, if extended, also strike A_3'.

Then by the equations in the Shape Factor Relations section:

$F_{11} + F_{12} + F_{13} = 1$ but $F_{11} = 0$ since Surface A_1 cannot "see" itself

$F_{12} = F_{13}$

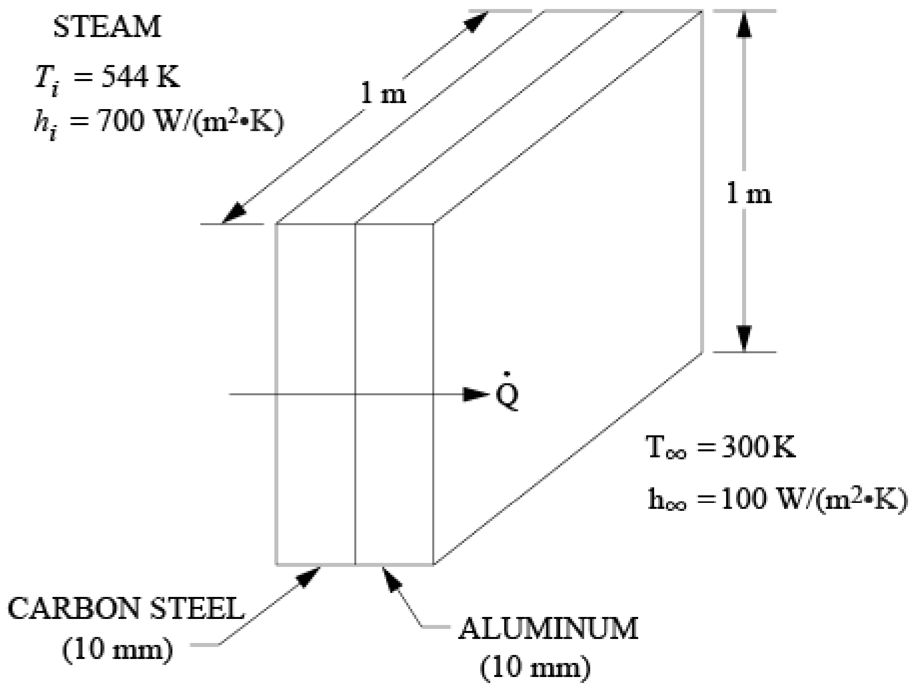
Thus $F_{12} + F_{12} = 1$

$$F_{12} = \frac{1}{2}$$

THE CORRECT ANSWER IS: B

Solution

The heat flux (W/m^2) through 1 m^2 of the steel/aluminum plate system shown is most nearly:



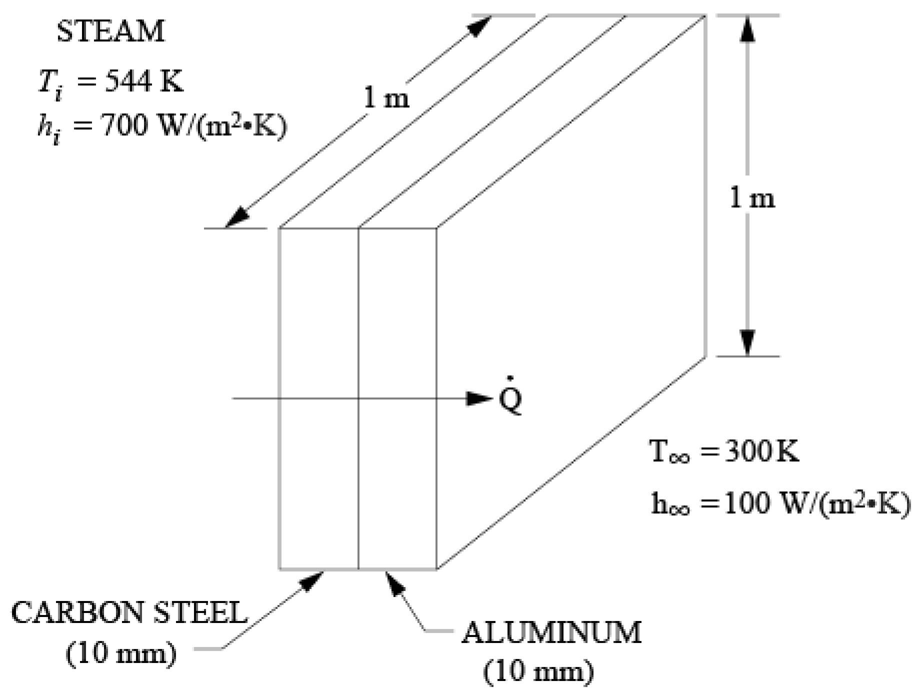
k_S = 60 W/(m•K)
k_A = 240 W/(m•K)

(Ignore radiation losses and contact resistance between the carbon steel and aluminum plates.)

- A. 17,800
- B. 19,800
- C. 21,000
- D. 153,000

Solution

The heat flux (W/m^2) through 1 m^2 of the steel/aluminum plate system shown is most nearly:



k_S = 60 W/(m•K)
k_A = 240 W/(m•K)

(Ignore radiation losses and contact resistance between the carbon steel and aluminum plates.)

- A. 17,800
- B. 19,800
- C. 21,000
- D. 153,000

Solution

Refer to the Thermal Resistance and Heat Exchangers sections in the Heat Transfer chapter of the *FE Reference Handbook*.

$$R'' = \frac{1}{h_i} + \frac{L_{cs}}{k_{cs}} + \frac{L_{AL}}{k_{AL}} + \frac{1}{h_\infty}$$

$$R'' = \frac{1}{700\ \text{W/m}^2\bullet\text{K}} + \frac{0.01\ \text{m}}{60\ \text{W/m}\bullet\text{K}} + \frac{0.01\ \text{m}}{240\ \text{W/m}\bullet\text{K}} + \frac{1}{100\ \text{W/m}^2\bullet\text{K}}$$

$$R'' = 0.01164\ \frac{\text{m}^2\bullet\text{K}}{\text{W}}$$

$$U = \frac{1}{R''} = \frac{1}{0.01164\ \frac{\text{m}^2\bullet\text{K}}{\text{W}}} = 85.93\ \frac{\text{W}}{\text{m}^2\bullet\text{K}}$$

$$\dot{Q} = UA(T_i - T_o)$$

$$\frac{\dot{Q}}{A} = U(T_i - T_o)$$

$$\frac{\dot{Q}}{A} = \left(85.93\frac{\text{W}}{\text{m}^2\bullet\text{K}}\right)(544\ \text{K} - 300\ \text{K})$$

$$\frac{\dot{Q}}{A} = 20{,}968\ \text{W}/\text{m}^2$$

THE CORRECT ANSWER IS: C

Solution

A heat exchanger is designed to heat liquid water from 150°C to 190°C inside tubes using steam condensing at 230°C on the outer surface of the tubes. For a constant flow rate, the effect of fouling of the heat transfer surfaces is to:

- ○ A. increase the temperature rise of the water
- ◉ B. decrease the temperature rise of the water
- ○ C. increase heat exchanger effectiveness
- ○ D. make no change in heat exchanger effectiveness

Solution

A heat exchanger is designed to heat liquid water from 150°C to 190°C inside tubes using steam condensing at 230°C on the outer surface of the tubes. For a constant flow rate, the effect of fouling of the heat transfer surfaces is to:

- A. increase the temperature rise of the water
- B. decrease the temperature rise of the water
- C. increase heat exchanger effectiveness
- D. make no change in heat exchanger effectiveness

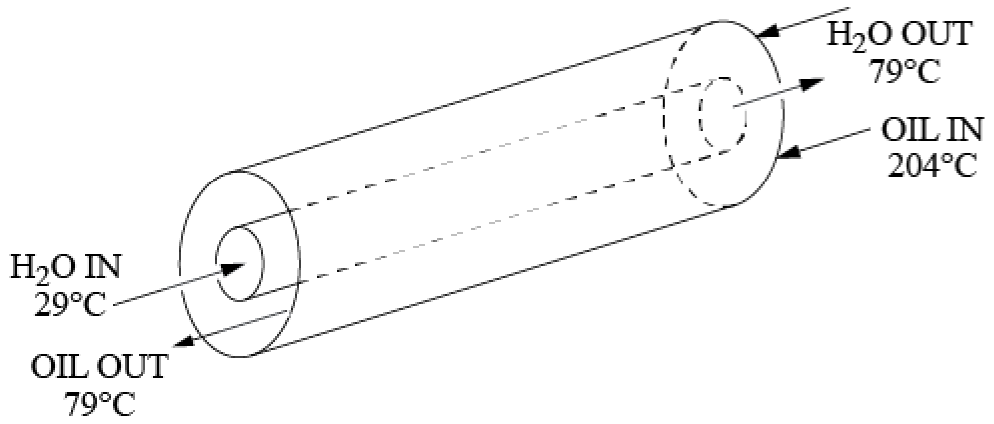
Solution

The effect of fouling on the heat-transfer surfaces is to reduce the heat-transfer rate by increasing the surface resistance. The results on the water being heated would be to reduce the outlet temperature of the water.

THE CORRECT ANSWER IS: B

Water at 29°C flows through the inner pipe of a counterflow double-pipe heat exchanger, as shown in the figure. Hot oil at 204°C enters the annular space between the inner and outer pipes at a flow rate of 2.25 kg/s. The following physical data are known:

Property	Water	Oil
Specific heat, kJ/(kg•K)	4.186	3.5
Viscosity, kg/(m•s)	5.06×10^{-4}	6.3×10^{-3}
Density, kg/m^3	986.7	815.3



The mass flow rate of the water (kg/s) is most nearly:

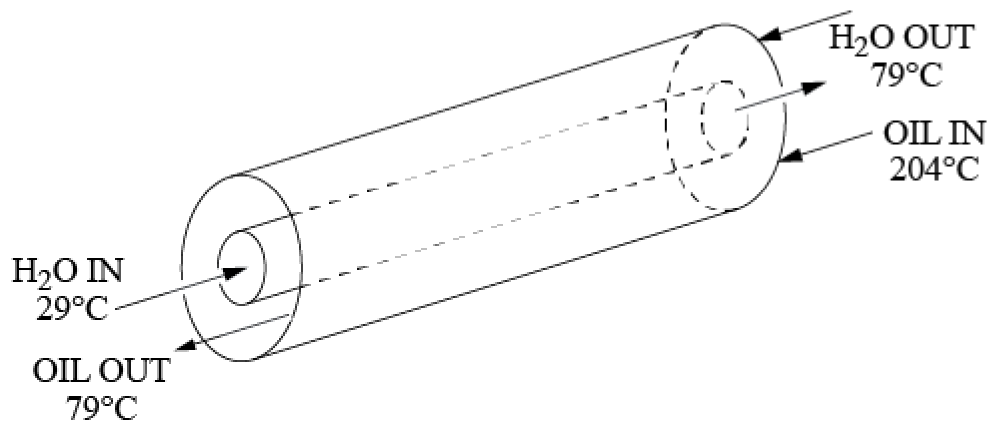
- A. 2.25
- B. 4.70
- C. 6.58
- D. 19.7

Solution

Flag for Rev

Water at 29°C flows through the inner pipe of a counterflow double-pipe heat exchanger, as shown in the figure. Hot oil at 204°C enters the annular space between the inner and outer pipes at a flow rate of 2.25 kg/s. The following physical data are known:

Property	Water	Oil
Specific heat, kJ/(kg•K)	4.186	3.5
Viscosity, kg/(m•s)	5.06×10^{-4}	6.3×10^{-3}
Density, kg/m^3	986.7	815.3



Solution

THE CORRECT ANSWER IS: B

The mass flow rate of the water (kg/s) is most nearly:

- A. 2.25
- B. 4.70
- C. 6.58
- D. 19.7

Solution

A temperature probe has a time constant $\tau = 3.0$ s. The temperature indicated by the probe is given by the equation:

$$T(t) = T_o - (T_o - T_i)e^{-t/\tau}$$

where T_o and T_i are 140°C and 40°C, respectively.

The time (s) required before the probe indicates a temperature within ±1°C of the actual oil temperature is most nearly:

- A. 3.0
- B. 4.6
- C. 9.0
- D. 13.8

Solution

A temperature probe has a time constant $\tau = 3.0$ s. The temperature indicated by the probe is given by the equation:

$$T(t) = T_o - (T_o - T_i)e^{-t/\tau}$$

where T_o and T_i are 140°C and 40°C, respectively.

The time (s) required before the probe indicates a temperature within ±1°C of the actual oil temperature is most nearly:

- A. 3.0
- B. 4.6
- C. 9.0
- D. 13.8

Solution

Rewriting the temperature equation

$$\frac{T(t) - T_o}{T_i - T_o} = e^{-t/\tau}$$

For $T(t) = 139°\mathrm{C}$,

$$\frac{139 - 140}{40 - 140} = e^{-t/3}$$

or $t = 3 \ln 100 = 13.8$ sec

THE CORRECT ANSWER IS: D

Solution

The characteristic equation of a system is $s^3 + 54s^2 + 200s + 200\,K = 0$. From the Routh test, the largest value of K for which the system is stable is most nearly:

- A. 5.2
- B. 8.3
- C. 12
- D. 54

Solution

The characteristic equation of a system is $s^3 + 54s^2 + 200s + 200\,K = 0$. From the Routh test, the largest value of K for which the system is stable is most nearly:

- A. 5.2
- B. 8.3
- C. 12
- D. 54

Solution

Refer to the Control Systems section in the Measurement and Controls chapter of the *FE Reference Handbook* to complete the Routh Array shown.

Routh Array

1	200
54	200 K
b_1	0
c_1	

$$b_1 = \frac{(54)(200) - (1)(200\text{ K})}{54}$$

$$= \frac{10{,}800 - 200\text{ K}}{54}$$

$$c_1 = 200\,K$$

For stability:

$$c_1 \geq 0 \quad \Rightarrow \quad K \geq 0$$

$$b_1 \geq 0 \quad \Rightarrow \quad K \leq 54$$

Hence, $K_{max} = 54$

THE CORRECT ANSWER IS: D

Solution

A resistance temperature detector (RTD) provides a resistance output, R, that is related to temperature by:

$$R = R_0[1 + \alpha(T - T_0)]$$

where:

R = Resistance, Ω
R_0 = Reference resistance, 100 Ω
α = Linear coefficient of resistance, 0.3925×10^{-3}/°C
T = Temperature, °C
T_0 = Reference temperature, 0°C

The uncertainty, U_R, may be calculated from the simplified Klein-McClintock equation:

$$U_R^2 = \left(\frac{\partial R}{\partial T} U_T\right)^2$$

where U_R and U_T are the uncertainties in variables R and T, respectively.

The resistance of the RTD, R, is 110 Ω, and this measured value has an uncertainty $U_R = \pm 0.1$ Ω . The uncertainty in T is most nearly:

- A. ±0.0026°C
- B. ±0.0040°C
- C. ±0.1°C
- D. ±2.5°C

Solution

A resistance temperature detector (RTD) provides a resistance output, R, that is related to temperature by:

$$R = R_0[1 + \alpha(T - T_0)]$$

where:

R = Resistance, Ω
R_0 = Reference resistance, 100 Ω
α = Linear coefficient of resistance, 0.3925×10^{-3}/°C
T = Temperature, °C
T_0 = Reference temperature, 0°C

The uncertainty, U_R, may be calculated from the simplified Klein-McClintock equation:

$$U_R^2 = \left(\frac{\partial R}{\partial T} U_T\right)^2$$

where U_R and U_T are the uncertainties in variables R and T, respectively.

The resistance of the RTD, R, is 110 Ω, and this measured value has an uncertainty $U_R = \pm 0.1$ Ω . The uncertainty in T is most nearly:

- A. ±0.0026°C
- B. ±0.0040°C
- C. ±0.1°C
- D. ±2.5°C

Solution

Since $U_{To} = U_\alpha = U_{Ro} \equiv 0$

$$U_R^2 = \left[\left(\frac{\partial R}{\partial T}\right)U_T\right]^2$$

Also, $\dfrac{\partial R}{\partial T} = R_o\alpha$

so $U_R = 0.1 = (R_o\alpha)U_T$

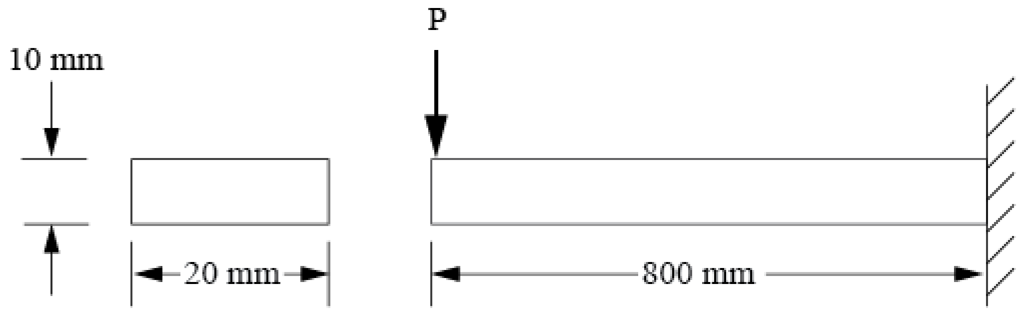
$$= [100 \times (0.3925 \times 10^{-3})]U_T$$

and $U_T = 2.55$°C

THE CORRECT ANSWER IS: D

Solution

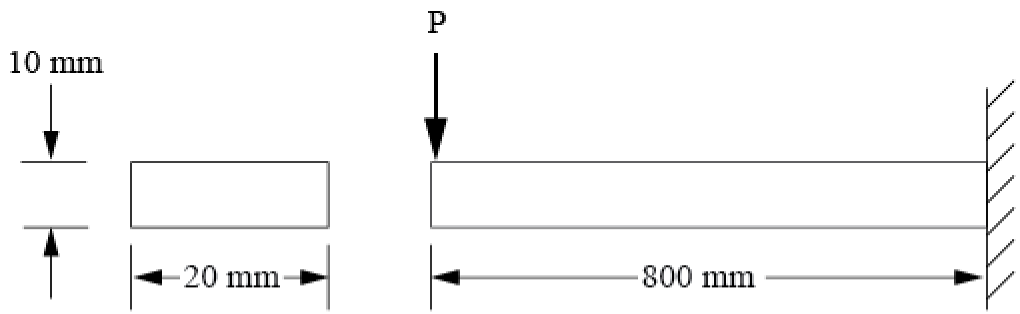
The load P varies between 0 and 40 N. The fatigue strength is $S_e = 200$ MPa, and the ultimate strength is $S_{ut} = 300$ MPa. The factor of safety using the modified Goodman theory is most nearly:



- A. 1.00
- B. 1.25
- C. 2.00
- D. 2.50

Solution

The load P varies between 0 and 40 N. The fatigue strength is $S_e = 200$ MPa, and the ultimate strength is $S_{ut} = 300$ MPa. The factor of safety using the modified Goodman theory is most nearly:



- A. 1.00
- B. 1.25
- C. 2.00
- D. 2.50

Solution

$$\sigma_{max} = \frac{Mc}{I} = \frac{PL\left(\frac{h}{2}\right)}{\frac{1}{12}bh^3}$$

where P = 40 N

h = 10 mm

b = 20 mm

and L = 800 mm

This gives $\sigma_{max} = 96$ MPa

Since the min stress = 0 (no load)

$\sigma_{min} = 0$

$$\therefore \sigma_a = \frac{96-0}{2} = 48 \text{ MPa}$$

$$\sigma_m = \frac{96+0}{2} = 48 \text{ MPa}$$

and $\frac{48}{200} + \frac{48}{300} = \frac{1}{n} = 0.4$

$\therefore n = 2.50$

THE CORRECT ANSWER IS: D

Solution

A helical compression spring has a wire diameter of 2.34 mm and an outside diameter of 15 mm. For a spring load of 150 N, the shear stress (MPa) in the spring is most nearly:

- ○ A. 342
- ○ B. 377
- ○ C. 412
- ◉ D. 577

Solution

A helical compression spring has a wire diameter of 2.34 mm and an outside diameter of 15 mm. For a spring load of 150 N, the shear stress (MPa) in the spring is most nearly:

- A. 342
- B. 377
- C. 412
- D. 577

Solution

Refer to the Mechanical Springs section in the Mechanical Engineering chapter of the *FE Reference Handbook*.

$$\tau = K_s \frac{8FD}{\pi d^3}$$

where

$d = 2.34$ mm

$d_o = 15$ mm

$D = d_o - d = 15 - 2.34 = 12.66$ mm

$$C = \frac{D}{d} = \frac{12.66}{2.34} = 5.410$$

$$K_s = \frac{2C+1}{2C} = \frac{2(5.410)+1}{2(5.410)} = 1.0924$$

$$\tau = 1.0924 \frac{(8)(150 \text{ N})(12.66 \text{ mm})}{\pi(2.34)^3} = 412.3 \text{ MPa}$$

THE CORRECT ANSWER IS: C

Solution

The pressure gage in an air cylinder reads 1,680 kPa. The cylinder is constructed of a 12-mm rolled-steel plate with an internal diameter of 700 mm. The tangential stress (MPa) inside the tank is most nearly:

- A. 25
- B. 50
- C. 77
- D. 100

Solution

The pressure gage in an air cylinder reads 1,680 kPa. The cylinder is constructed of a 12-mm rolled-steel plate with an internal diameter of 700 mm. The tangential stress (MPa) inside the tank is most nearly:

- A. 25
- B. 50
- C. 77
- D. 100

Solution

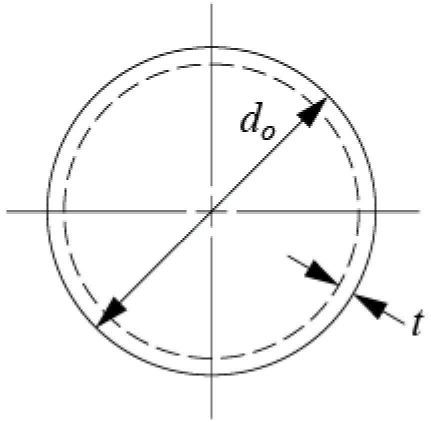
Refer to Cylindrical Pressure Vessel in the Mechanics of Materials section of the *FE Reference Handbook*.

The cylinder can be considered thin-walled if $t \le d_o/20$. In this case, $t = 12$ mm and $r_o = d_o/2 = 362$ mm. Thus

$$\sigma_t = \frac{P_i r}{t}$$

where $r = \dfrac{r_i + r_o}{2} = \dfrac{350 + 362}{2} = 356$ mm

$$\sigma_t = \frac{(1.680\ \text{MPa})(356\ \text{mm})}{12\ \text{mm}} = 49.8\ \text{MPa}$$



THE CORRECT ANSWER IS: B

Solution

A steel pulley with a minimum room-temperature bore diameter of 100.00 mm is to be shrunk onto a steel shaft with a maximum room-temperature diameter of 100.15 mm.

Assume the following:

Room temperature = 20°C

Coefficient of linear expansion of steel = 11×10^{-6}/°C

Required diametral clearance for assembly = 0.05 mm

To shrink the pulley onto the room-temperature shaft with the desired diametral clearance, the pulley must be heated to a minimum temperature of most nearly:

- A. 65°C
- B. 136°C
- C. 182°C
- D. 202°C

Solution

A steel pulley with a minimum room-temperature bore diameter of 100.00 mm is to be shrunk onto a steel shaft with a maximum room-temperature diameter of 100.15 mm.

Assume the following:

Room temperature = 20°C

Coefficient of linear expansion of steel = 11×10^{-6}/°C

Required diametral clearance for assembly = 0.05 mm

To shrink the pulley onto the room-temperature shaft with the desired diametral clearance, the pulley must be heated to a minimum temperature of most nearly:

- A. 65°C
- B. 136°C
- C. 182°C
- D. 202°C

Solution

Refer to the Manufacturability section in the Mechanical Engineering chapter and the Thermal Deformations section of the Mechanics of Materials chapter of the *FE Reference Handbook*.

Required diameter change:

$$\delta_{\text{diameter}} = d_{\text{shaft}} - d_{\text{pulley}} + \text{required assembly clearance}$$
$$= 100.15 - 100.00 + 0.05 = 0.20 \text{ mm}$$

Required temperature change of pulley diameter:

$$\delta_{\text{diameter}} = \alpha d(\Delta T)$$

$$\Delta T = \frac{\delta_{\text{diameter}}}{\alpha d} = \frac{0.20}{(11 \times 10^{-6})(100)} = 181.8°\text{C}$$

Temperature to which pulley must be heated:

$$T = T_{\text{room}} + \Delta T = 20 + 182 = 202°\text{C}$$

THE CORRECT ANSWER IS: D