NCEES
advancing licensure for engineers and surveyors

FE

mechanical

practice exam

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About NCEES

NCEES is a nonprofit organization made up of the U.S. engineering and surveying licensing boards in all 50 states, U.S. territories, and the District of Columbia. We develop and score the exams used for engineering and surveying licensure in the United States. NCEES also promotes professional mobility through its services for licensees and its member boards.

Engineering licensure in the United States is regulated by licensing boards in each state and territory. These boards set and maintain the standards that protect the public they serve. As a result, licensing requirements and procedures vary by jurisdiction, so stay in touch with your board (ncees.org/licensing-boards).

Exam format

The FE exam contains 110 questions and is administered year-round via computer at approved Pearson VUE test centers. A 6-hour appointment time includes a tutorial, the exam, and a break. You'll have 5 hours and 20 minutes to complete the actual exam.

In addition to traditional multiple-choice questions with one correct answer, the FE exam uses common alternative item types such as

- Multiple correct options—allows multiple choices to be correct
- Point and click—requires examinees to click on part of a graphic to answer
- Drag and drop—requires examinees to click on and drag items to match, sort, rank, or label
- Fill in the blank—provides a space for examinees to enter a response to the question

To familiarize yourself with the format, style, and navigation of a computer-based exam, view the demo on ncees.org/ExamPrep.

Examinee Guide

The *NCEES Examinee Guide* is the official guide to policies and procedures for all NCEES exams. During exam registration and again on exam day, examinees must agree to abide by the conditions in the *Examinee Guide*, which includes the CBT Examinee Rules and Agreement. You can download the *Examinee Guide* at ncees.org/exams. It is your responsibility to make sure you have the current version.

Scoring and reporting

Exam results for computer-based exams are typically available 7–10 days after you take the exam. You will receive an email notification from NCEES with instructions to view your results in your MyNCEES account. All results are reported as pass or fail.

Updates on exam content and procedures

Visit us at **ncees.org/exams** for updates on everything exam-related, including specifications, exam-day policies, scoring, and corrections to published exam preparation materials. This is also where you will register for the exam and find additional steps you should follow in your state to be approved for the exam.

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EXAM SPECIFICATIONS

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Fundamentals of Engineering (FE)
MECHANICAL CBT Exam Specifications

Effective Beginning with the July 2020 Examinations

- The FE exam is a computer-based test (CBT). It is closed book with an electronic reference.
- Examinees have 6 hours to complete the exam, which contains 110 questions. The 6-hour time also includes a tutorial and an optional scheduled break.
- The FE exam uses both the International System of Units (SI) and the U.S. Customary System (USCS).

Knowledge	Number of Questions
1. Mathematics	**6–9**
A. Analytic geometry	
B. Calculus (e.g., differential, integral, single-variable, multivariable)	
C. Ordinary differential equations (e.g., homogeneous, nonhomogeneous, Laplace transforms)	
D. Linear algebra (e.g., matrix operations, vector analysis)	
E. Numerical methods (e.g., approximations, precision limits, error propagation, Taylor's series, Newton's method)	
F. Algorithm and logic development (e.g., flowcharts, pseudocode)	
2. Probability and Statistics	**4–6**
A. Probability distributions (e.g., normal, binomial, empirical, discrete, continuous)	
B. Measures of central tendencies and dispersions (e.g., mean, mode, standard deviation, confidence intervals)	
C. Expected value (weighted average) in decision making	
D. Regression (linear, multiple), curve fitting, and goodness of fit (e.g., correlation coefficient, least squares)	
3. Ethics and Professional Practice	**4–6**
A. Codes of ethics (e.g., NCEES *Model Law*, professional and technical societies, ethical and legal considerations)	
B. Public health, safety, and welfare	
C. Intellectual property (e.g., copyright, trade secrets, patents, trademarks)	
D. Societal considerations (e.g., economic, sustainability, life-cycle analysis, environmental)	
4. Engineering Economics	**4–6**
A. Time value of money (e.g., equivalence, present worth, equivalent annual worth, future worth, rate of return, annuities)	
B. Cost types and breakdowns (e.g., fixed, variable, incremental, average, sunk)	
C. Economic analyses (e.g., cost-benefit, break-even, minimum cost, overhead, life cycle)	

5. Electricity and Magnetism **5–8**

A. Electrical fundamentals (e.g., charge, current, voltage, resistance, power, energy, magnetic flux)
B. DC circuit analysis (e.g., Kirchhoff's laws, Ohm's law, series, parallel)
C. AC circuit analysis (e.g., resistors, capacitors, inductors)
D. Motors and generators

6. Statics **9–14**

A. Resultants of force systems
B. Concurrent force systems
C. Equilibrium of rigid bodies
D. Frames and trusses
E. Centroids and moments of inertia
F. Static friction

7. Dynamics, Kinematics, and Vibrations **10–15**

A. Kinematics of particles
B. Kinetic friction
C. Newton’s second law for particles
D. Work-energy of particles
E. Impulse-momentum of particles
F. Kinematics of rigid bodies
G. Kinematics of mechanisms
H. Newton’s second law for rigid bodies
I. Work-energy of rigid bodies
J. Impulse-momentum of rigid bodies
K. Free and forced vibrations

8. Mechanics of Materials **9–14**

A. Shear and moment diagrams
B. Stress transformations and Mohr's circle
C. Stress and strain caused by axial loads
D. Stress and strain caused by bending loads
E. Stress and strain caused by torsional loads
F. Stress and strain caused by shear
G. Stress and strain caused by temperature changes
H. Combined loading
I. Deformations
J. Column buckling
K. Statically indeterminate systems

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9. Material Properties and Processing **7–11**

A. Properties (e.g., chemical, electrical, mechanical, physical, thermal)
B. Stress-strain diagrams
C. Ferrous metals
D. Nonferrous metals
E. Engineered materials (e.g., composites, polymers)
F. Manufacturing processes
G. Phase diagrams, phase transformation, and heat treating
H. Materials selection
I. Corrosion mechanisms and control
J. Failure mechanisms (e.g., thermal failure, fatigue, fracture, creep)

10. Fluid Mechanics **10–15**

A. Fluid properties
B. Fluid statics
C. Energy, impulse, and momentum
D. Internal flow
E. External flow
F. Compressible flow (e.g., Mach number, isentropic flow relationships, normal shock)
G. Power and efficiency
H. Performance curves
I. Scaling laws for fans, pumps, and compressors

11. Thermodynamics **10–15**

A. Properties of ideal gases and pure substances
B Energy transfers
C. Laws of thermodynamics
D. Processes
E. Performance of components
F. Power cycles
G. Refrigeration and heat pump cycles
H. Nonreacting mixtures of gases
I. Psychrometrics
J. Heating, ventilation, and air-conditioning (HVAC) processes
K. Combustion and combustion products

12. Heat Transfer **7–11**

A. Conduction
B. Convection
C. Radiation
D. Transient processes
E. Heat exchangers

13. Measurements, Instrumentation, and Controls **5–8**

A. Sensors and transducers
B. Control systems (e.g., feedback, block diagrams)
C. Dynamic system response
D. Measurement uncertainty (e.g., error propagation, accuracy, precision, significant figures)

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14. Mechanical Design and Analysis **10–15**

A. Stress analysis of machine elements
B. Failure theories and analysis
C. Deformation and stiffness
D. Springs
E. Pressure vessels and piping
F. Bearings
G. Power screws
H. Power transmission
I. Joining methods (e.g., welding, adhesives, mechanical fasteners)
J. Manufacturability (e.g., limits, fits)
K. Quality and reliability
L. Components (e.g., hydraulic, pneumatic, electromechanical)
M. Engineering drawing interpretations and geometric dimensioning and tolerancing (GD&T)

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PRACTICE EXAM

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FE MECHANICAL PRACTICE EXAM

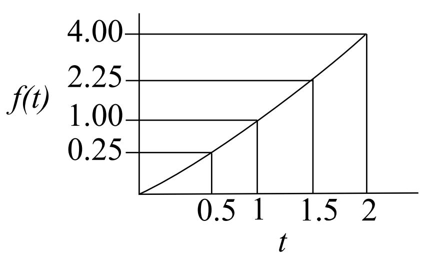
1. The equation of a sphere with center at (0, 1, –2) and a radius of 9 is:

- ○ 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. $(x)^2 + (y - 1)^2 + (z + 2)^2 = 9$

2. What is the area of the region in the first quadrant that is bounded by the line $y = 1$, the curve $x = y^{3/2}$, and the y-axis?

- ○ A. 2/5
- ○ B. 3/5
- ○ C. 2/3
- ○ D. 1

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



NOT TO SCALE

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

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4. Which of the following is the general solution to the differential equation and boundary condition shown below?

$$\frac{dy}{dt} + 5y = 0; y(0) = 1$$

- ○ A. e^{5t}
- ○ B. e^{-5t}
- ○ C. $e^{\sqrt{-5t}}$
- ○ D. $5e^{-5t}$

5. Which of the following is a unit vector perpendicular to the plane determined by the vectors **A** = 2**i** + 4**j** and **B = i + j – k?**

- ○ A. $-2\mathbf{i} + \mathbf{j} - \mathbf{k}$
- ○ B. $\frac{1}{\sqrt{5}}(\mathbf{i} + 2\mathbf{j})$
- ○ C. $\frac{1}{\sqrt{6}}(-2\mathbf{i} + \mathbf{j} - \mathbf{k})$
- ○ D. $\frac{1}{\sqrt{6}}(-2\mathbf{i} - \mathbf{j} - \mathbf{k})$

6. The flowchart for a computer program contains the following segment:

```
VAR = 0
IF VAR < 5 THEN VAR = VAR + 2
ELSE EXIT LOOP
LOOP
```

What is the value of VAR at the conclusion of this routine?

- ○ A. 0
- ○ B. 2
- ○ C. 4
- ○ D. 6

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7. 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

8. 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

9. Consider a set of three values: 4, 4, and 7.

Match each of the statistical quantities with the correct value.

Statistical Quantities

Mean _____	2	3
Variance _____	4	5
Median _____	6	7

10. You wish to estimate the mean M of a population from a sample of size n drawn from the population. For the sample, the mean is x and the standard deviation is s. The probable accuracy of the estimate improves with an increase in:

- ○ A. M
- ○ B. n
- ○ C. s
- ○ D. $M + s$

11. 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

12. As the designer of a distinctively shaped automobile body style, you may protect your intellectual property with a:

- ○ A. trademark
- ○ B. patent
- ○ C. copyright
- ○ D. industrial design right

13. A professional engineer was originally licensed 30 years ago and is still currently licensed. The engineer's employer asks the engineer to evaluate a newly developed computerized control system for public transportation. The employer requires that a currently licensed engineer evaluate the system. The engineer may accept the assignment under which conditions?

- ○ A. The engineer is competent in modern control systems.
- ○ B. The engineer supervises two recent graduates who have passed the FE exam.
- ○ C. The engineer studied transportation systems in college.
- ○ D. The engineer has regularly attended meetings of a professional engineering society.

14. An engineering firm has overall design responsibility for a large multifaceted construction project. The state in which the work is being conducted requires civil, structural, environmental, electrical, and mechanical engineering plans to be prepared and stamped by a professional engineer. Which of the following statements are true?

Select **all** that apply.

- ☐ A. Responsibility for the coordination of the entire project can be accepted by the firm's senior engineer, who is responsible for signing and sealing all the submitted plans.
- ☐ B. Responsibility for coordination of the entire project can be accepted by the firm's senior engineer if each technical submittal is signed and sealed by the qualified engineer assigned to that segment.
- ☐ C. The foremost responsibility of the professional engineer is to safeguard the health, safety, and welfare of the public when performing services for clients and employers.
- ☐ D. The technical competence of the professional engineers on the project is not as important as their responsibility to disclose to their employers or clients all known or potential conflicts of interest or other circumstances that could influence or appear to influence their judgment or the quality of their professional service or engagement.
- ☐ E. Licensing laws and rules governing engineering professional practice may vary in each of the jurisdictions in which a licensee practices.

15. A printer costs $900. Its salvage value after 5 years is $300. Annual maintenance is $50. If the interest rate is 8%, the equivalent uniform annual cost is ____________.

Enter your response in the blank. Answer to the nearest integer.

16. Economic analysis will be used to compute an equivalent value today for an estimated constant monthly expense that is projected to occur each month over the next three years.

Select the column in the factor table that contains the value that could be used for the analysis.

Factor Table –*i* = 2.00%

n	*P/F*	*P/A*	*P/G*	*F/P*	*F/A*	*A/P*	*A/F*	*A/G*
1	0.9804	0.9804	0.0000	1.0200	1.0000	1.0200	1.0000	0.0000
2	0.9612	1.9416	0.9612	1.0404	2.0200	0.5150	0.4950	0.4950
3	0.9423	2.8839	2.8458	1.0612	3.0604	0.3468	0.3268	0.9868
4	0.9238	3.8077	5.6173	1.0824	4.1216	0.2626	0.2426	1.4752
5	**0.9057**	**4.7135**	**9.2403**	**1.1041**	**5.2040**	**0.2122**	**0.1922**	**1.9604**
6	0.8880	5.6014	13.6801	1.1262	6.3081	0.1785	0.1585	2.4423
7	0.8706	6.4720	18.9035	1.1487	7.4343	0.1545	0.1345	2.9208
8	0.8535	7.3255	24.8779	1.1717	8.5830	0.1365	0.1165	3.3961
9	0.8368	8.1622	31.5720	1.1951	9.7546	0.1225	0.1025	3.8681
10	**0.8203**	**8.9826**	**38.9551**	**1.2190**	**10.9497**	**0.1113**	**0.0913**	**4.3367**
11	0.8043	9.7868	46.9977	1.2434	12.1687	0.1022	0.0822	4.8021
12	0.7885	10.5753	55.6712	1.2682	13.4121	0.0946	0.0746	5.2642
13	0.7730	11.3484	64.9475	1.2936	14.6803	0.0881	0.0681	5.7231
14	0.7579	12.1062	74.7999	1.3195	15.9739	0.0826	0.0626	6.1786
15	**0.7430**	**12.8493**	**85.2021**	**1.3459**	**17.2934**	**0.0778**	**0.0578**	**6.6309**
16	0.7284	13.5777	96.1288	1.3728	18.6393	0.0737	0.0537	7.0799
17	0.7142	14.2919	107.5554	1.4002	20.0121	0.0700	0.0500	7.5256
18	0.7002	14.9920	119.4581	1.4282	21.4123	0.0677	0.0467	7.9681
19	0.6864	15.6785	131.8139	1.4568	22.8406	0.0638	0.0438	8.4073
20	**0.6730**	**16.3514**	**144.6003**	**1.4859**	**24.2974**	**0.0612**	**0.0412**	**8.8433**
21	0.6598	17.0112	157.7959	1.5157	25.7833	0.0588	0.0388	9.2760
22	0.6468	17.6580	171.3795	1.5460	27.2990	0.0566	0.0366	9.7055
23	0.6342	18.2922	185.3309	1.5769	28.8450	0.0547	0.0347	10.1317
24	0.6217	18.9139	199.6305	1.6084	30.4219	0.0529	0.0329	10.5547
25	**0.6095**	**19.5235**	**214.2592**	**1.6406**	**32.0303**	**0.0512**	**0.0312**	**10.9745**
30	0.5521	22.3965	291.7164	1.8114	40.5681	0.0446	0.0246	13.0251
40	0.4529	27.3555	461.9931	2.2080	60.4020	0.0366	0.0166	16.8885
50	0.3715	31.4236	642.3606	2.6916	84.5794	0.0318	0.0118	20.4420
60	0.3048	34.7609	823.6975	3.2810	114.0515	0.0288	0.0088	23.6961
100	**0.1380**	**43.0984**	**1,464.7527**	**7.2446**	**312.2323**	**0.0232**	**0.0032**	**33.9863**

17. A business owner wants to build a reserve fund. To have $50,000 in the fund at the end of 10 years, the amount the owner will need to invest annually, assuming an annual return of 5%, is most nearly:

- ○ A. $951
- ○ B. $1,535
- ○ C. $2,500
- ○ D. $3,975

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18. Consider the information below about a company's project. Ignore any time-dependent factors such as interest, inflation, and depreciation.

Initial capital investment: $50,000
Cost to produce each item: $25
Selling price for each item: $40
Production volume (equal distribution through the year):
    Year 1: 1,000 units
    Years 2–3: 750 units
    Years 4 and above: 500 units

The year of production in which the company reaches the end of the payback period for the project is_____________.

Enter your response in the blank.

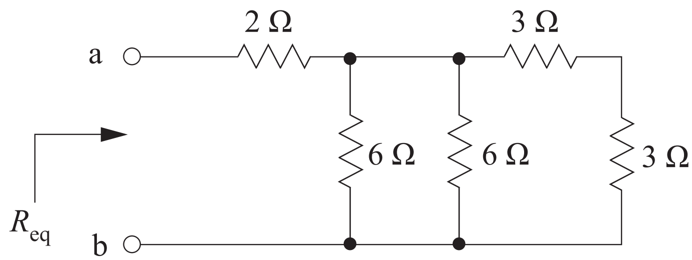
19. An ammeter, a voltmeter, and a wattmeter were installed in an ac circuit and read 15 A_{rms}, 115 V_{rms}, and 1,500 W, respectively. The power factor of the circuit is most nearly:

- A. –0.87
- B. –0.5
- C. 0.5
- D. 0.87

20. A 120-V heater is designed to use a 20-Ω resistor. The power (W) consumed by the heater when in use is_____________ .

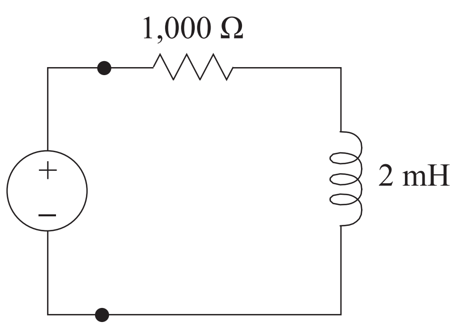
Enter your response in the blank.

21. In the resistor circuit shown below, the equivalent resistance R_{eq} (Ω) at Terminals a-b is most nearly:



- A. 22
- B. 20
- C. 4
- D. 2

22. 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:

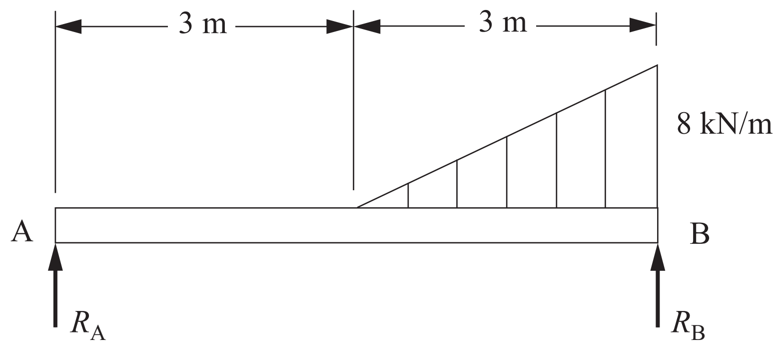


- A. $200 + j1{,}000$
- B. $1{,}000 + j200$
- C. $38.4 + j192$
- D. $1{,}000 - j200$

23. A 4-pole induction motor operates with a line voltage frequency of 60 Hz and 0.09 slip. The rotational speed (rpm) of the motor shaft is ____________.

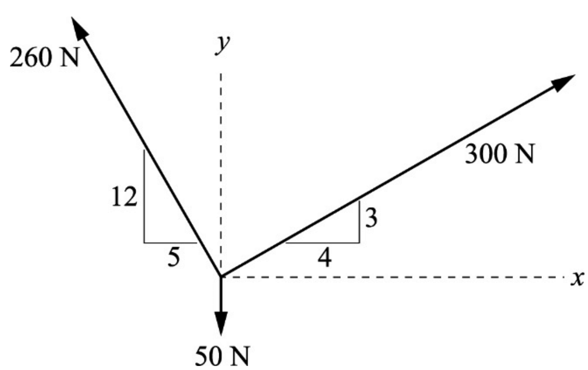
Enter your response in the blank.

24. 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:



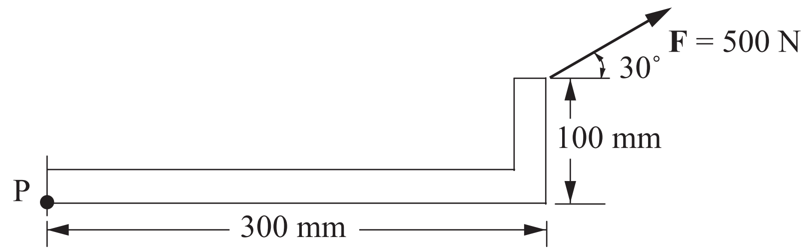
- A. 24
- B. 12
- C. 10
- D. 8

25. Three forces act as shown below. The magnitude (N) of the resultant of the three forces is most nearly:



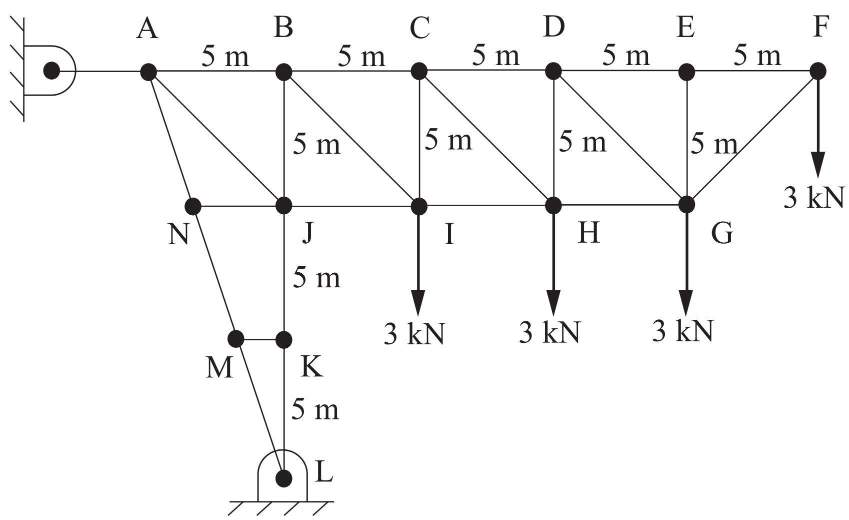
- A. 140
- B. 191
- C. 370
- D. 396

26. The moment (N·m) of force **F** shown below with respect to Point P is most nearly:



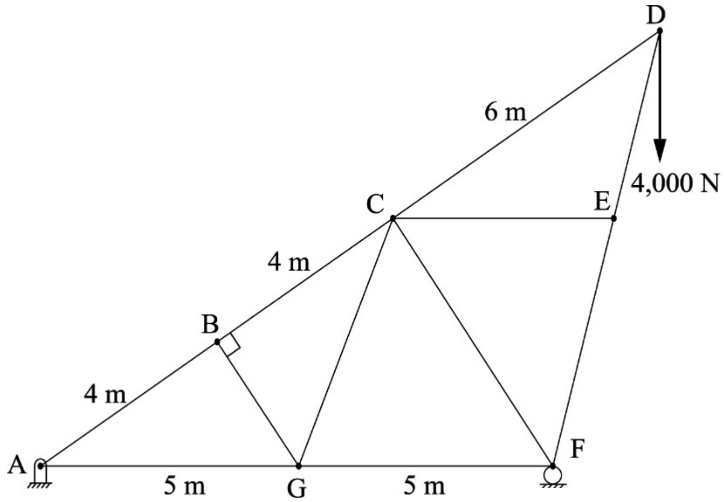
- A. 31.7 ccw
- B. 31.7 cw
- C. 43.3 cw
- D. 43.3 ccw

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



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

28. Mark all of the zero-force members of the simple truss below.



FE MECHANICAL PRACTICE EXAM

29. Evaluate the center of gravity in each figure below. Arrange the figures in increasing order of y-axis center of gravity. All bars are 1 unit wide.

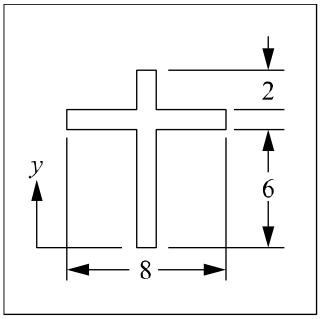


FIGURE A

____________ Lowest

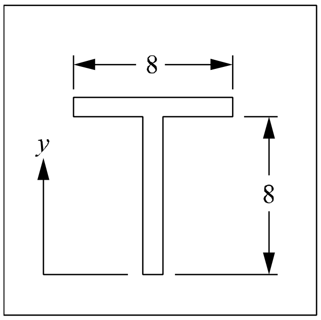


FIGURE B

____

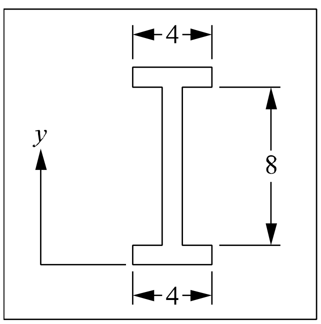


FIGURE C

____

____

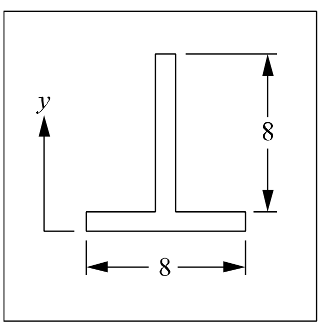


FIGURE D

____________ Highest

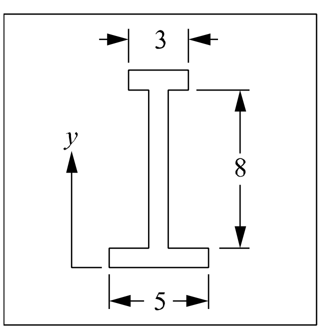


FIGURE E

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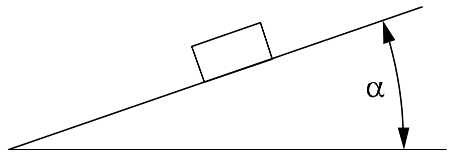
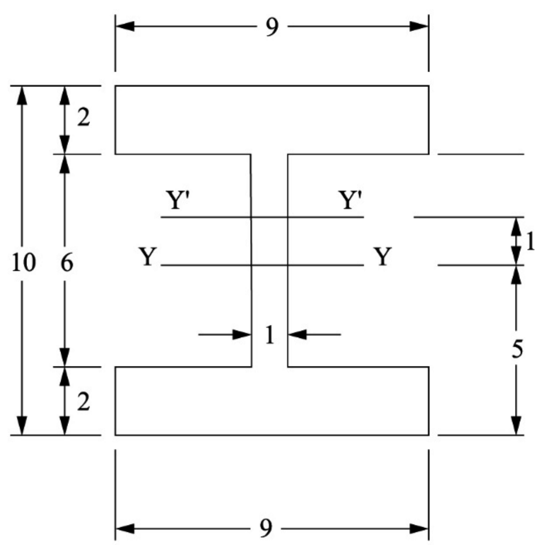
30. The ramp in the figure is rotated until the angle (α) is at 37 degrees, and then the block begins to slide. The coefficient of static friction is most nearly:



- A. 0.602
- B. 0.625
- C. 0.754
- D. 0.798

31. The moment of inertia about the centroid axis (Y-Y) of the figure below is 606 in^4. The moment of inertia (in^4) about a parallel axis (Y'-Y') that is 1 in. higher is____________.

Enter your response in the blank.



All dimensions are in inches.

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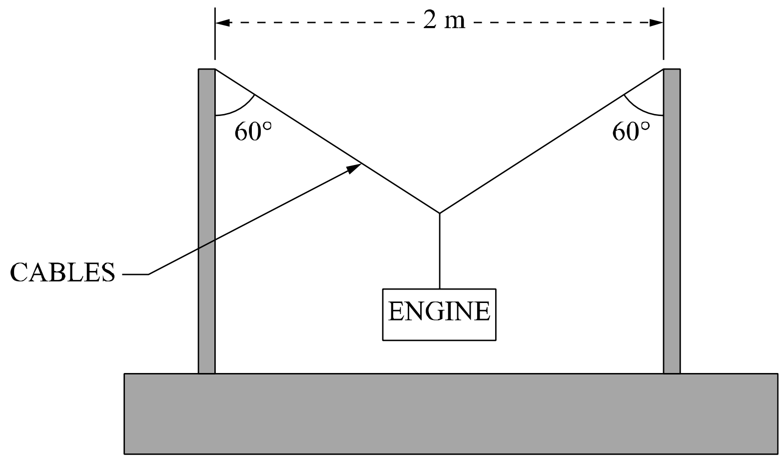
32. The hoist shown is holding an engine with a mass of 100 kg. The tension in the left cable (N) is most nearly:



- ○ A. 490
- ○ B. 566
- ○ C. 849
- ○ D. 981

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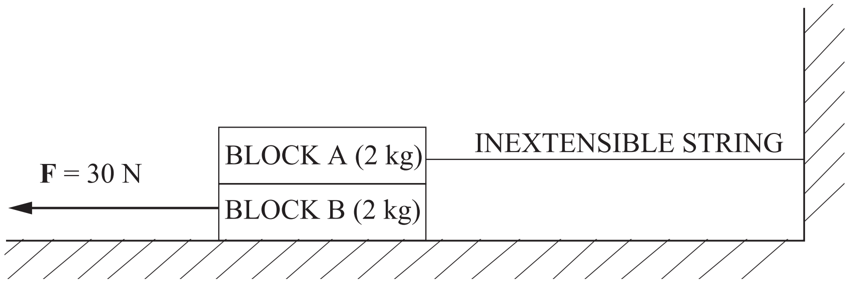
33. Two blocks, A and B, are arranged so that A rests on top of B and is attached to a vertical wall by an inextensible string. A force of 30 N is applied to Block B, which is sufficient to make it slide to the left. If $\mu_K = 0.2$ between A and B, and if $\mu_K = 0.4$ between B and the bottom surface, the acceleration of B (m/s^2) is most nearly:



- A. 5.2
- B. 7.2
- C. 9.1
- D. 15.0

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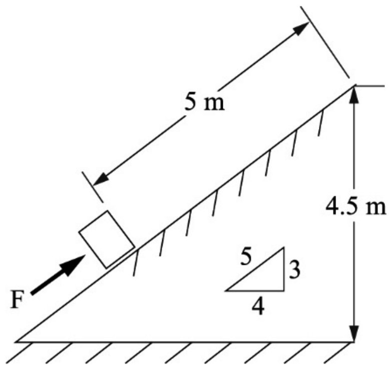
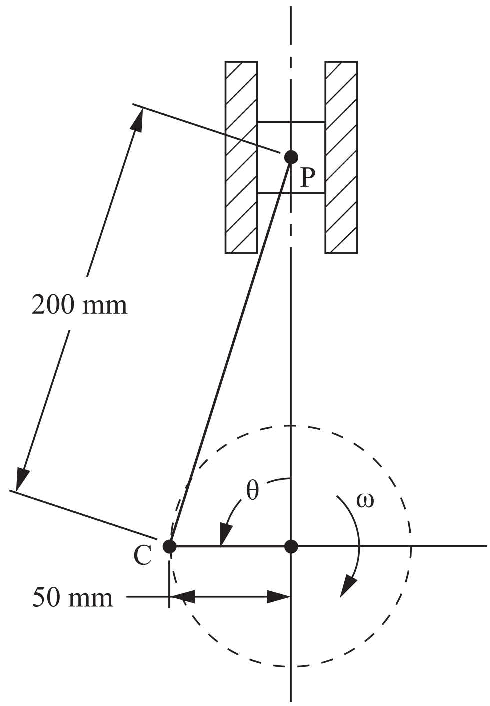
34. The 2-kg block shown in the figure is accelerated from rest by force **F** along the smooth incline for 5 m until it clears the top of the ramp at a speed of 8 m/s. The value of **F** (N) is most nearly:



- A. 11.8
- B. 19.6
- C. 24.6
- D. 69.4

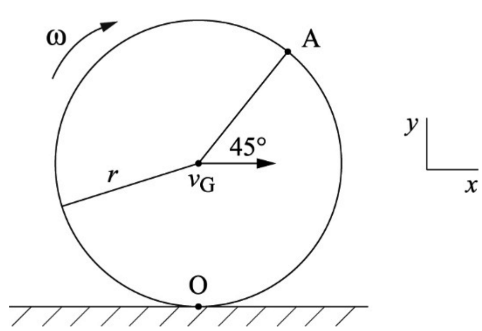
35. The piston and cylinder of an internal combustion engine are shown in the following figure. If ω = 377 rad/s, the piston speed (mm/s) when θ = 90° is most nearly:



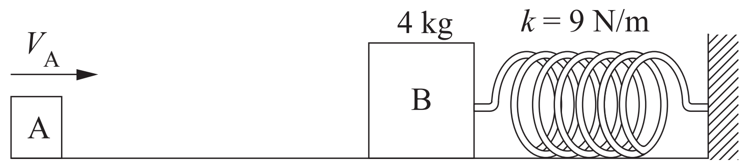
- O A. 0
- O B. 10,500
- O C. 18,850
- O D. 24,300

36. A rigid wheel with radius r = 0.25 m rolls without slip along a horizontal surface, as shown in the figure. The velocity of the center of gravity is v_G = 5.0 m/s. The magnitude of the total velocity (m/s) of Point A is most nearly:

- O A. 3.5
- O B. 5.0
- O C. 8.5
- O D. 9.2



37. 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:



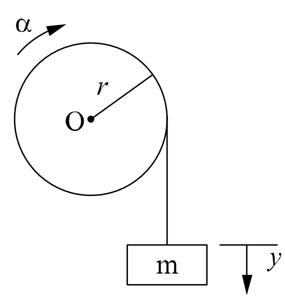
- O A. 1.5
- O B. 2.25
- O C. 6.0
- O D. 9.0

38. A 4-kg mass with a velocity of 10 m/s travels across a horizontal surface with negligible friction and impacts a stationary 2-kg mass. Assuming that the impact is perfectly elastic, the velocity (m/s) of the 2-kg mass after impact is most nearly:

- O A. 6.7
- O B. 8.3
- O C. 10.0
- O D. 13.3

39. A cylinder has a radius $r = 0.1$ m and mass moment of inertia about Point O of $I_O = 0.0428$ k·gm^2 and rotates about a frictionless axle. A mass m = 1 kg is connected by a massless cord wrapped around the cylinder without slip. The angular acceleration, α, of the cylinder (s^{-2}) is most nearly:

- O A. 4.7
- O B. 9.4
- O C. 18.6
- O D. 23.2



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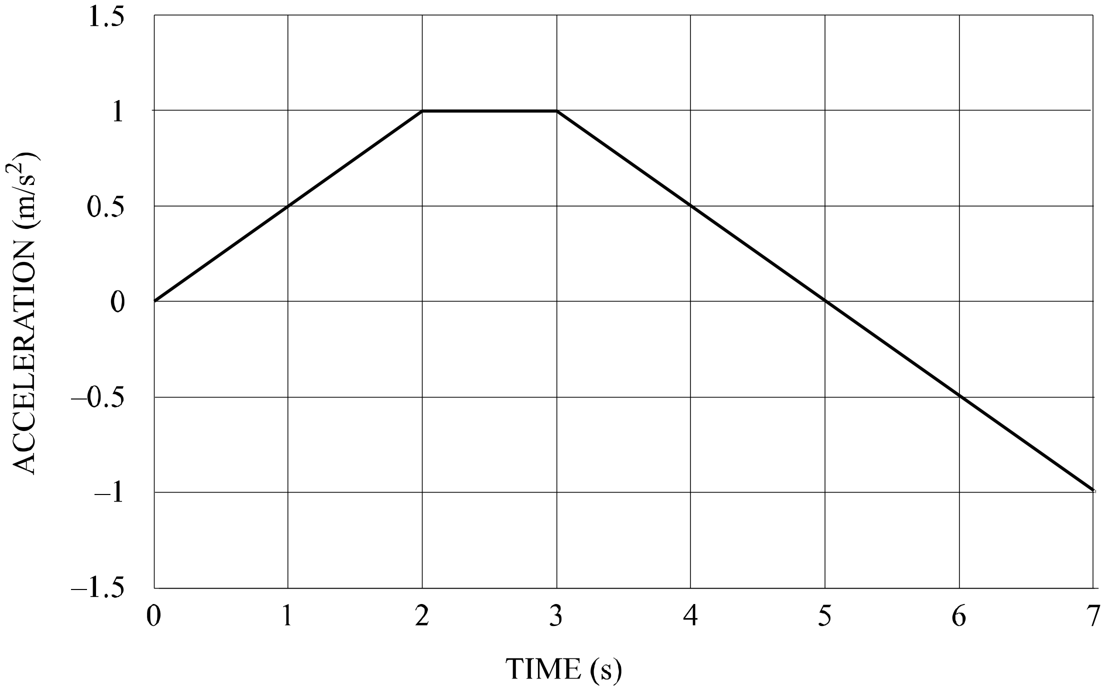
40. An automobile starts from rest on a test track. Its acceleration is plotted in the figure. The speed (m/s) at time $t = 5$ s is____________.

Enter your response in the blank.



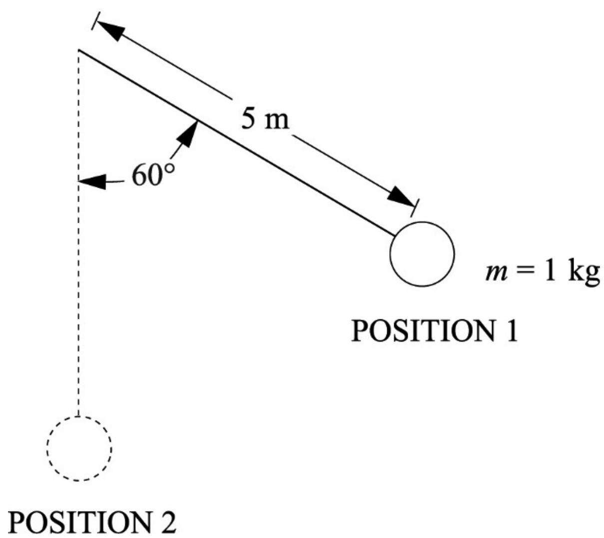
41. An automobile with a mass of 1,020 kg is traveling at 10 m/s. At time $t = 0$, the driver activates the emergency brake and the automobile begins to skid. The properties of the relevant materials are shown.

Material 1	**Material 2**	**Static Friction**	**Kinetic Friction**
Rubber	Asphalt	0.9	0.4

At $t = 1$ s, the speed (m/s) of the automobile is most nearly:

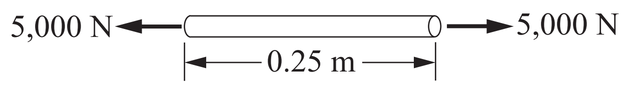
- A. 8.8
- B. 6.1
- C. 3.9
- D. 1.2

42. If a pendulum is released from rest at Position 1, the velocity (m/s) of the mass at Position 2 is most nearly:



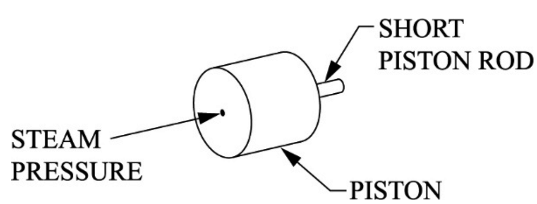
- A. 5.0
- B. 7.0
- C. 9.8
- D. 12.7

43. 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

44. The piston of a steam engine shown is 50 cm in diameter, and the maximum steam gauge pressure is 1.4 MPa. If the design stress for the piston rod is 68 MPa, its cross-sectional area (m^2) should be most nearly:



- A. 40.4×10^{-4}
- B. 98.8×10^{-4}
- C. 228.0×10^{-4}
- D. 323.0×10^{-4}

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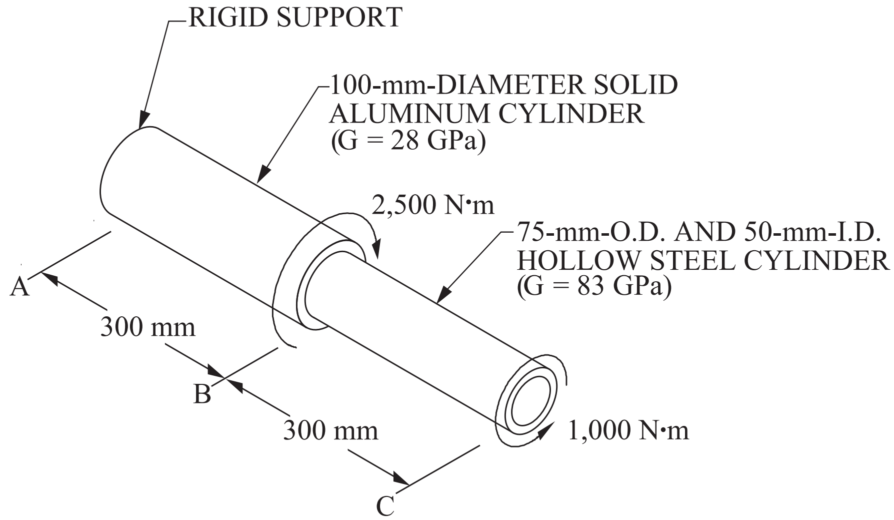
45. In the figure below, the value of the maximum shear stress (MPa) in Segment BC is most nearly:

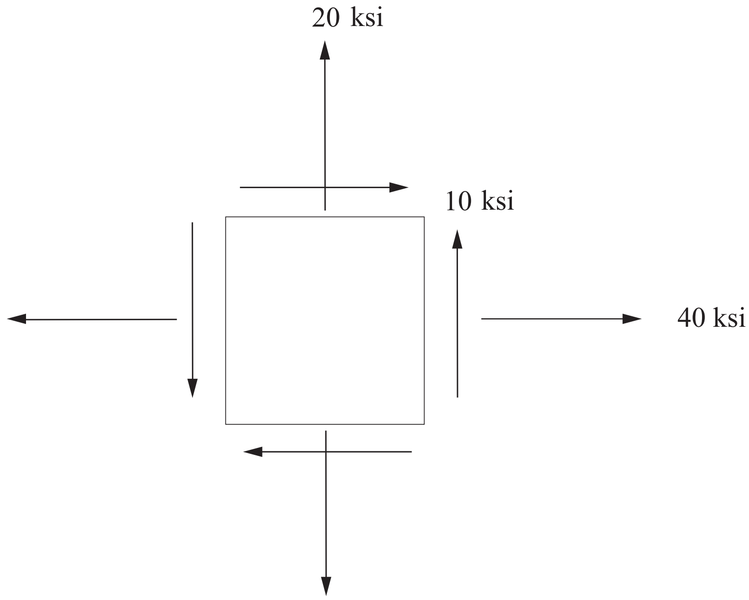


- A. 15.0
- B. 30.0
- C. 37.7
- D. 52.7

46. A shaft of wood is to be used in a certain process. If the allowable shearing stress parallel to the grain of the wood is 840 kN/m^2, the torque (N·m) transmitted by a 200-mm-diameter shaft with the grain parallel to the neutral axis is most nearly:

- A. 500
- B. 1,200
- C. 1,320
- D. 1,500

47. The maximum in-plane shear stress (ksi) in the element shown below is most nearly:



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

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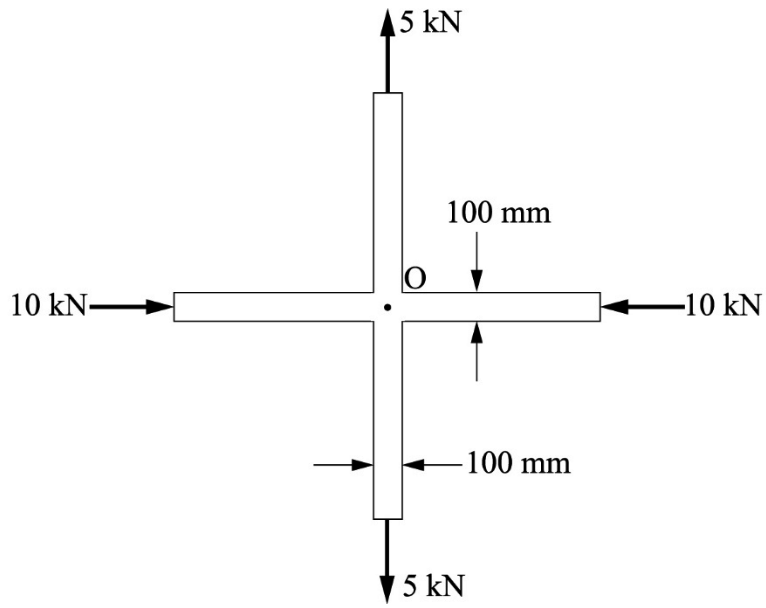
48. A plane member having a uniform thickness of 10 mm is loaded as shown below. The maximum shear stress (MPa) at Point O is most nearly:



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

49. The Euler formula for columns deals with:

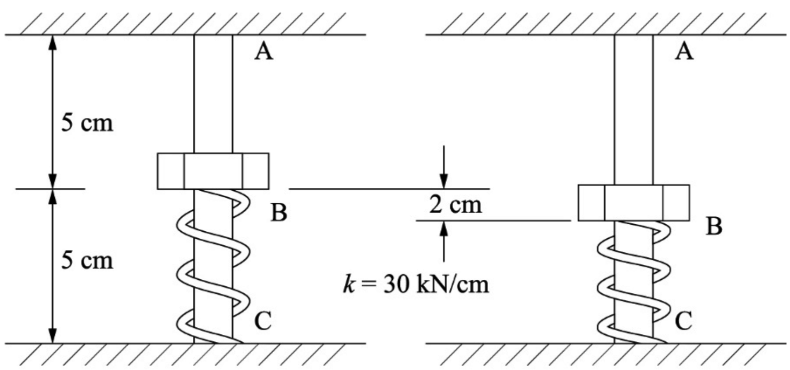
- A. relatively short columns
- B. shear stress
- C. tensile stress
- D. elastic buckling

50. A 50-m length of rail is installed in a railroad switching station during summer. It is rigidly attached at each end while the ambient temperature is 30°C. During winter, the ambient temperature at this section of track drops to –10°C. Based on the properties listed in the following table, the axial stress (MPa) in the section of track is most nearly:

Density (mg/m^3)	Young's Modulus (GPa)	Rigidity (GPa)	Yield Strength (MPa)	Ultimate Stress (MPa)	Sample Elongation %	Poisson's Ratio	Coefficient of Thermal Expansion (10^{-6}/°C)
7.85	200	75	250	400	30%	0.32	12

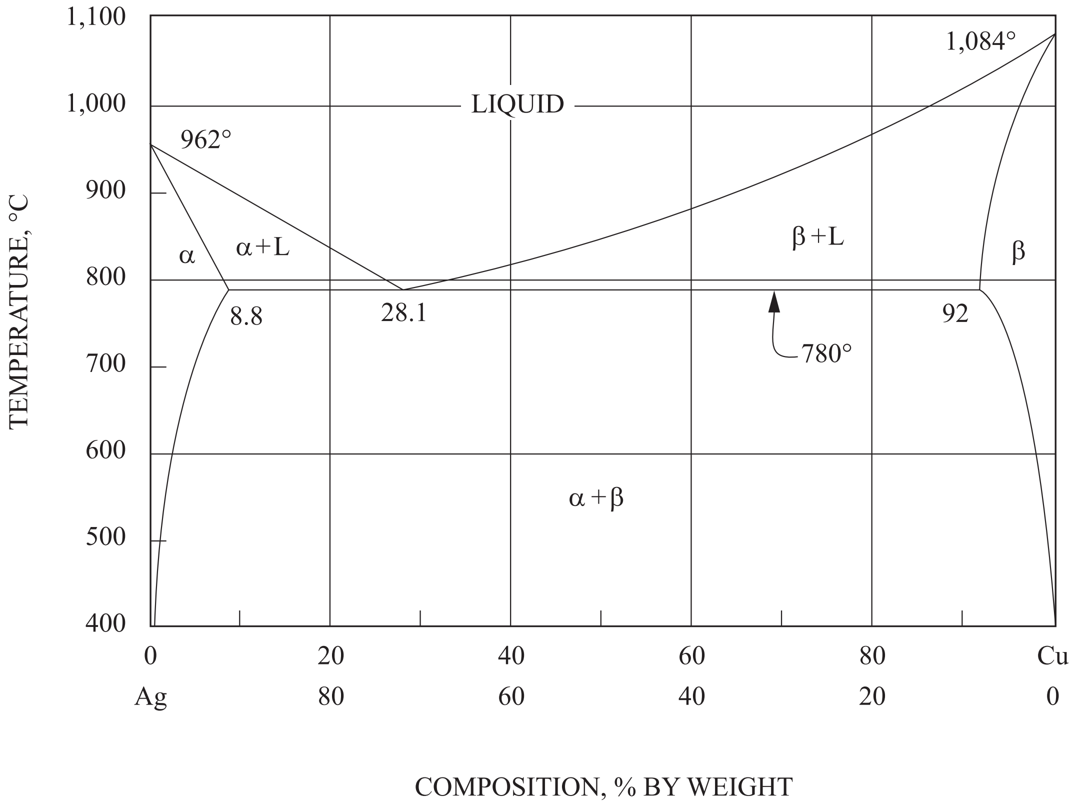
- A. 96
- B. 72
- C. 36
- D. 29

51. A screw rod is fixed at its two ends, A and C, as shown in the figure. A nut initially in the center of the rod is supported by a spring. The spring constant k = 30 kN/cm and is initially in a neutral position. When the nut is screwed down 2 cm, the support force (kN) at the top point of A is most nearly:



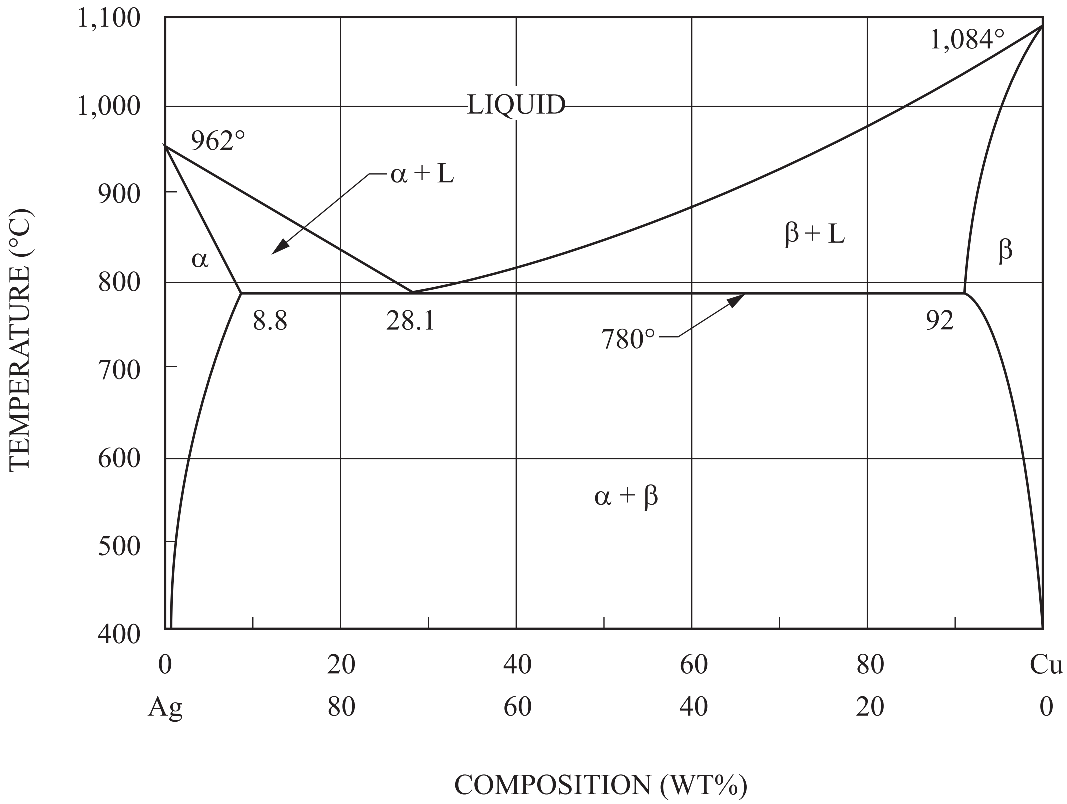
- A. 0
- B. 18
- C. 42
- D. 60

52. 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

53. An alloy that is 70% copper by weight is fully melted and allowed to cool slowly. What phases are present at 850°C?



- A. Liquid only
- B. α + β
- C. α + L
- D. β + L

54. 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

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55. If an aluminum crimp connector were used to connect a copper wire to a battery, what would you expect to happen?

- A. Only the copper wire will corrode.
- B. Only the aluminum connector will corrode.
- C. Both will corrode.
- D. Nothing

56. 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

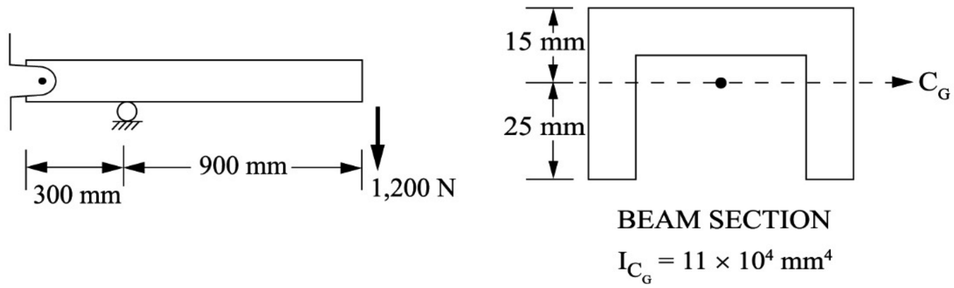
The critical length (mm) of an exterior crack that can be tolerated in the as-received sheet is most nearly:

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

57. 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 twinning takes place

58. The beam is loaded as shown by a hanging 1,200-N force. The tensile stress (MPa) due to bending is most nearly:



- A. 49
- B. 147
- C. 196
- D. 245

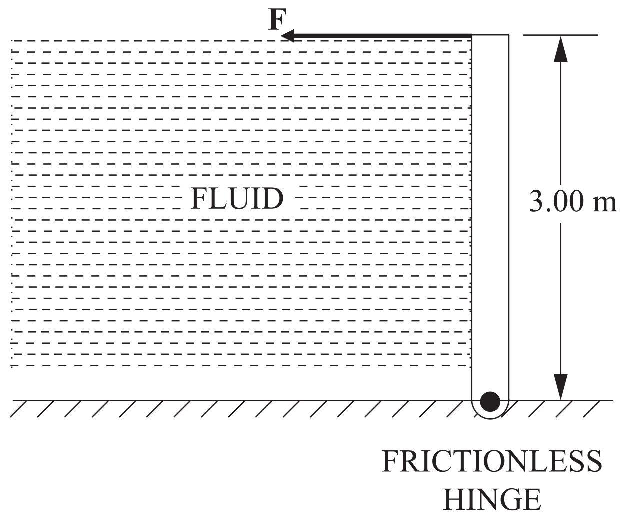
59. A fluid has a specific gravity of 1.263 and an absolute dynamic viscosity of 1.5 kg/(m·s). The standard density of water is 1,000 kg/m^3. The kinematic viscosity (m^2/s) of the fluid is most nearly:

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

60. Archimedes' principle states that:

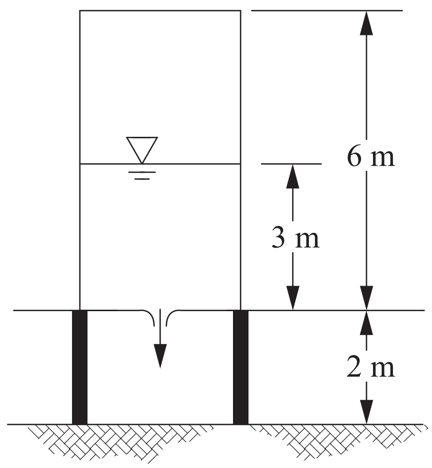
- A. the sum of the pressure, velocity, and elevation heads is constant
- B. flow passing two points in a stream is equal at each point
- C. the buoyant force on a body is equal to the volume displaced by the body
- D. a floating body displaces a weight of fluid equal to its own weight

61. The rectangular, homogeneous gate shown below is 3.00 m high × 1.00 m wide and has a frictionless hinge at the bottom. If the fluid on the left side of the gate has a density of 1,600 kg/m^3, the magnitude of the force **F** (kN) required to keep the gate closed is most nearly:



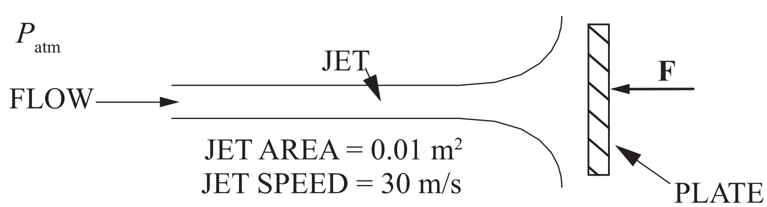
- A. 0
- B. 22
- C. 24
- D. 220

62. 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. If losses are neglected, 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

63. A horizontal jet of water (density = 1,000 kg/m^3) is deflected perpendicularly to the original jet stream by a plate as shown below. The magnitude of force **F** (kN) required to hold the plate in place is most nearly:



- A. 4.5
- B. 9.0
- C. 45.0
- D. 90.0

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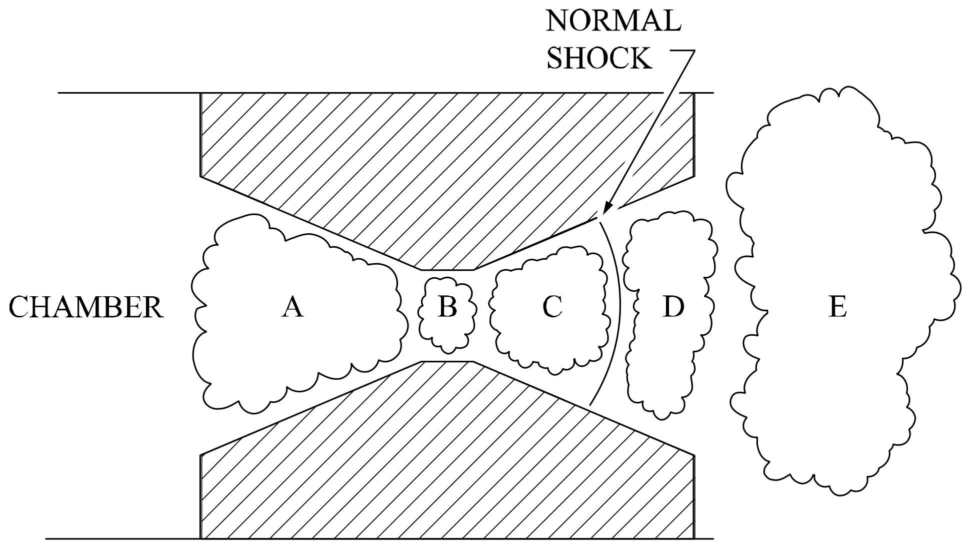
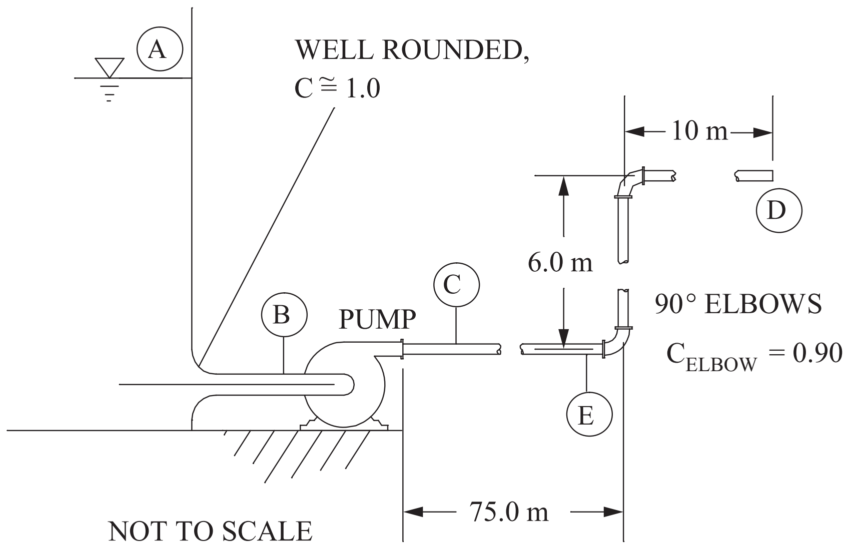
64. A gas mixture (c = 600 mph) accelerated from 450 mph in a chamber through a converging/diverging nozzle experiences a normal shock wave as shown. Select the region where the Mach number is equal to 1.



65. For the system shown, the pipe is steel with an internal diameter of 100 mm. Water is pumped through the system; its velocity at Point C is 2.5 m/s. The pressure at Point A is atmospheric, the gauge pressure at Point B is 125 kPa, and the gauge pressure at Point C is 175 kPa. The discharge at Point D is to the atmosphere. The pumping rate (m^3/min) is most nearly:

Viscosity	$\mu = 1.0 \times 10^{-3}$ N·s/m^2
Kinematic viscosity	$\upsilon = 1.0 \times 10^{-6}$ m^2/s
Density	$\rho = 1{,}000$ kg/m^3



- ○ A. 1.02
- ○ B. 1.18
- ○ C. 1.50
- ○ D. 4.71

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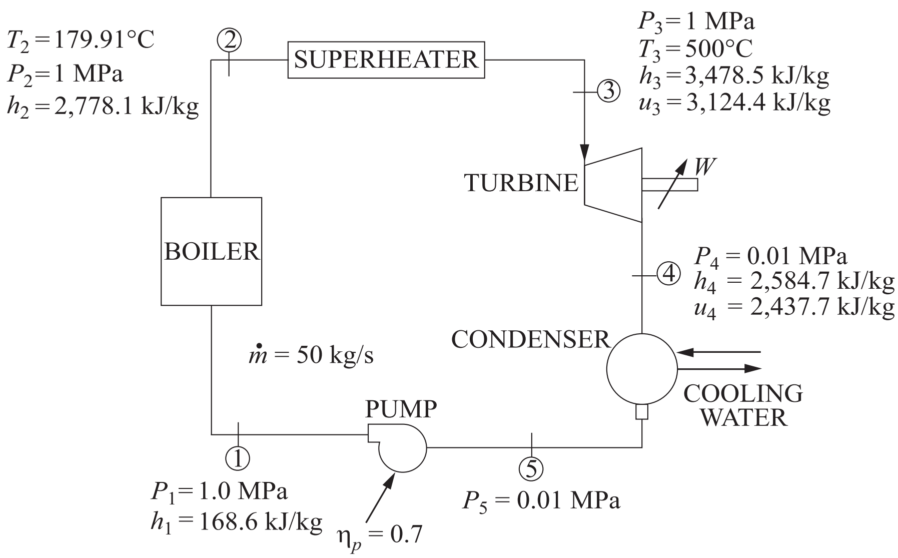
66. The following data were obtained from a test on a centrifugal fan:

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

67. 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.



If the pump isentropic efficiency is 70%, the power (kW) required to drive the pump is most nearly:

- A. 0.70
- B. 1.43
- C. 35.0
- D. 71.0

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68. A pump moves a fluid at a rate of 12 L/s at 1,000 rpm. If the pump volumetric flow rate (L/s) is increased to 18 L/s and the impeller diameter remains constant, the new speed (rpm) is most nearly:

- A. 667
- B. 1,000
- C. 1,500
- D. 2,250

69. 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

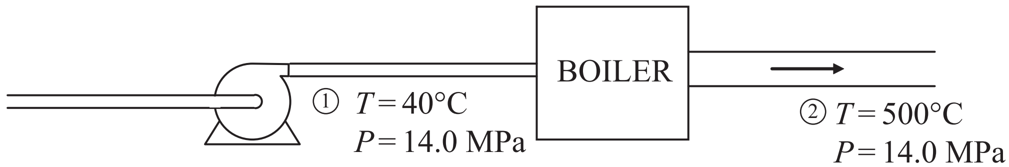
70. An insulated tank contains half liquid and half vapor by volume in equilibrium. The release of a small quantity of the vapor without the addition of heat will cause:

- 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

71. Saturated water at 250°C is introduced into a throttling valve and exits the valve at 0.2321 MPa. The quality of the water at the exit is most nearly:

- A. 1.00
- B. 0.26
- C. 0.21
- D. 0.0

72. The pump shown in the figure is used to pump 50,000 kg of water per hour into a boiler. Pump discharge conditions are 40°C and 14.0 MPa. Boiler outlet conditions are 500°C and 14.0 MPa.

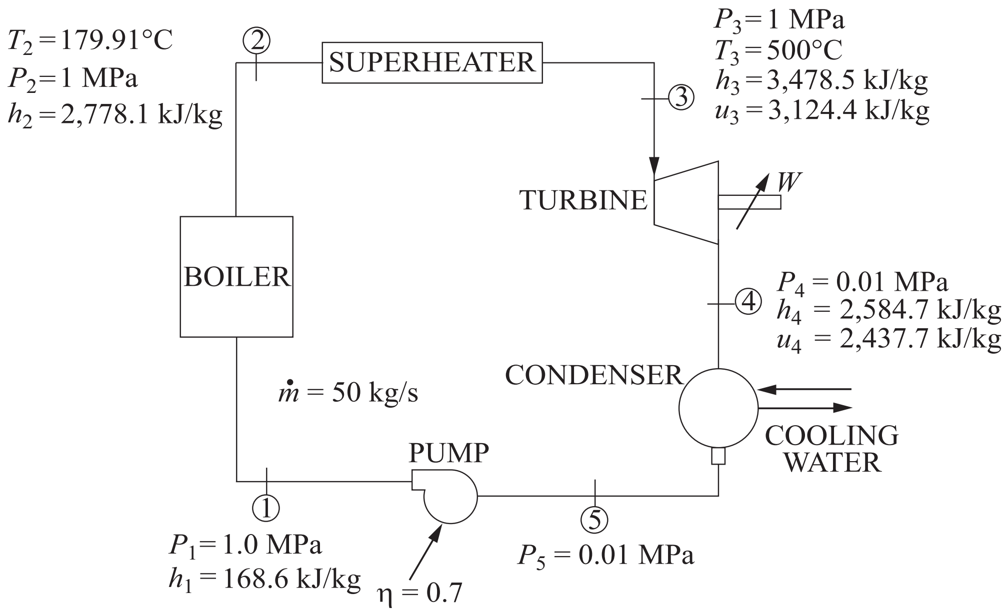


P **(MPa)**	***T*** **(°C)**	**Condition**	***h*** **(kJ/kg)**
14.0	40	Compressed liquid	167.6
14.0	500	Superheated vapor	3,322

The rate of heat transfer (MW) to the working fluid that occurs in the boiler is most nearly:

- A. 10
- B. 15
- C. 29
- D. 44

73. 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.

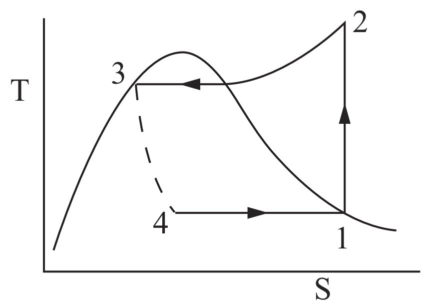


For the thermodynamic conditions shown, the turbine power (MW) is most nearly:

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

74. 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. 0.74
- C. 2.82
- D. 3.82

75. A machine uses nozzles that can produce only 50 kg/s of an ideal gas mixture with an average molecular weight of 30. If the volumetric flow rate is 30 m^3/s at 350 K and 420 kPa, the required number of nozzles is ____________.

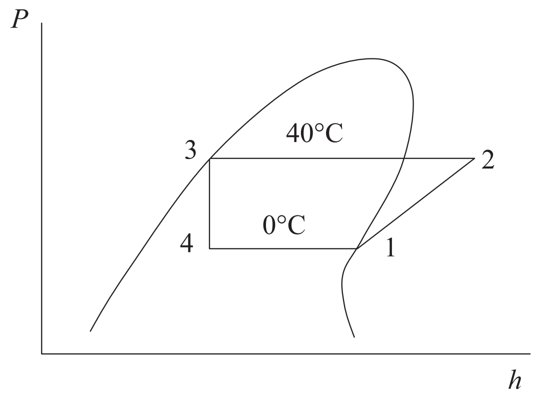
Enter your response in the blank.

76. 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

FE MECHANICAL PRACTICE EXAM

77. A vapor-compression refrigeration cycle using HFC-134a as the refrigerant has the pressure-enthalpy diagram shown below. The evaporator temperature is 0°C, and the condenser temperature is 40°C.



The cooling achieved by the evaporator (kJ/kg) is most nearly:

- A. 28
- B. 143
- C. 169
- D. 210

78. Methanol (CH_3OH) burns in 20% excess air. What is the combustion equation?

- A. $CH_3OH + 1.2\ O_2 + 1.2\ (3.76)\ N_2 \rightarrow CO_2 + 1.2\ H_2O + 1.2\ (3.76)\ N_2$
- B. $CH_3OH + 1.5\ O_2 + 1.5\ (3.76)\ N_2 \rightarrow CO_2 + 2\ H_2O + 1.5\ (3.76)\ N_2$
- C. $CH_3OH + 1.8\ O_2 + 3\ (3.76)\ N_2 \rightarrow CO_2 + 2\ H_2O + 1.8\ (3.76)\ N_2$
- D. $CH_3OH + 1.8\ O_2 + 1.8\ (3.76)\ N_2 \rightarrow CO_2 + 2\ H_2O + 1.8\ (3.76)\ N_2 + 0.3\ O_2$

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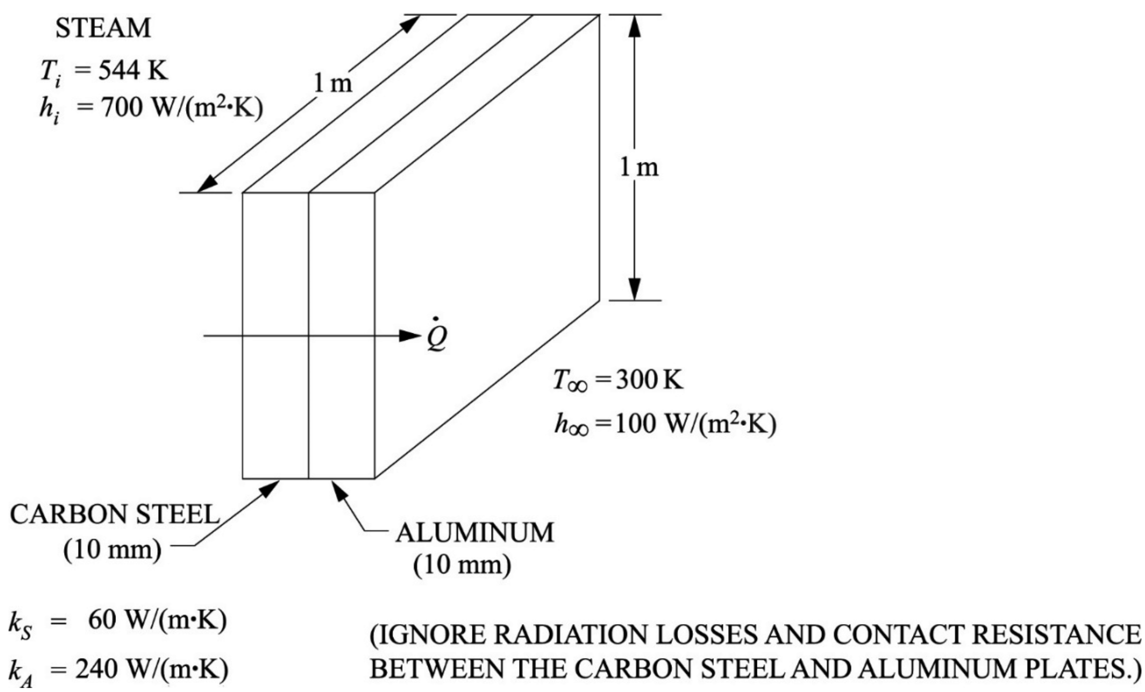
FE MECHANICAL PRACTICE EXAM

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



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

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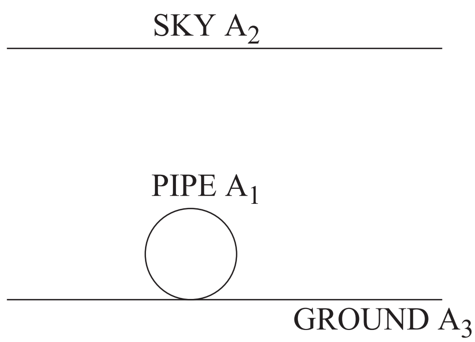
80. Hot air at 200°C flows across a 50°C surface. If the heat-transfer coefficient is 72 W/(m^2·°C), the heat-transfer rate (W) over 2 m^2 of the surface is most nearly:

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

81. 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

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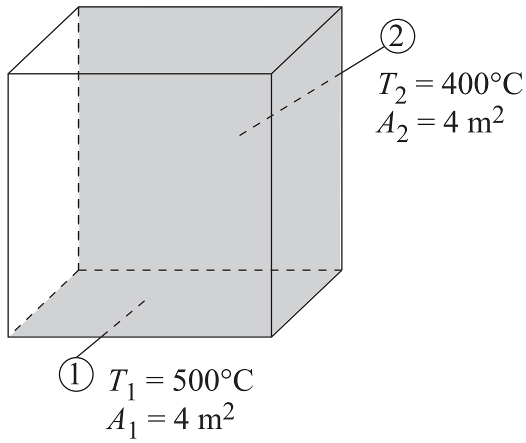
82. An enclosure has Surfaces 1 and 2, each with an area of 4.0 m^2. The shape factor $F_{1\text{–}2}$ is 0.275. Surfaces 1 and 2 are black surfaces with temperatures of 500°C and 400°C, respectively. The net rate of heat transfer (kW) by radiation between Surfaces 1 and 2 is most nearly:



- A. 2.30
- B. 9.47
- C. 22.3
- D. 34.4

83. The lumped capacitance model is valid for which of the following metal cubes?

Select **all** that apply.

☐ A. $h = 10$ (W/m^2·K)
$k = 1{,}000$ (W/m·K)
side = 2 m

☐ B. $h = 500$ (W/m^2·K)
$k = 1{,}000$ (W/m·K)
side = 6 m

☐ C. $h = 2000$ (W/m^2·K)
$k = 400$ (W/m·K)
side = 1 m

☐ D. $h = 100$ (W/m^2·K)
$k = 2{,}000$ (W/m·K)
side = 20 m

☐ E. $h = 30$ (W/m^2·K)
$k = 3{,}000$ (W/m·K)
side = 3 m

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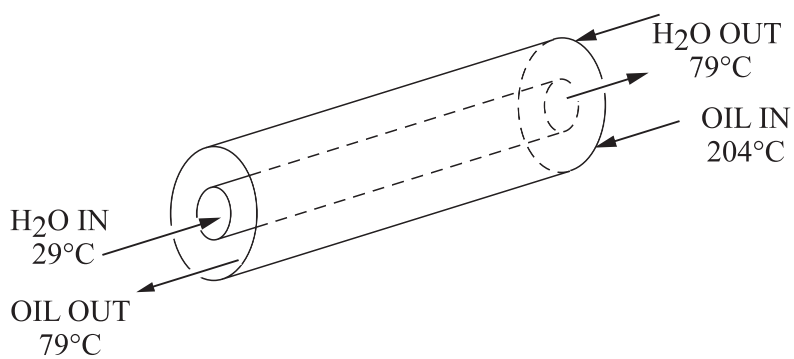
84. Water at 29°C flows through the inner pipe of a counterflow double-pipe heat exchanger, as shown in the figure. Hot oil at 204°C enters the annular space between the inner and outer pipes at a flow rate of 2.25 kg/s. The following physical data are known:

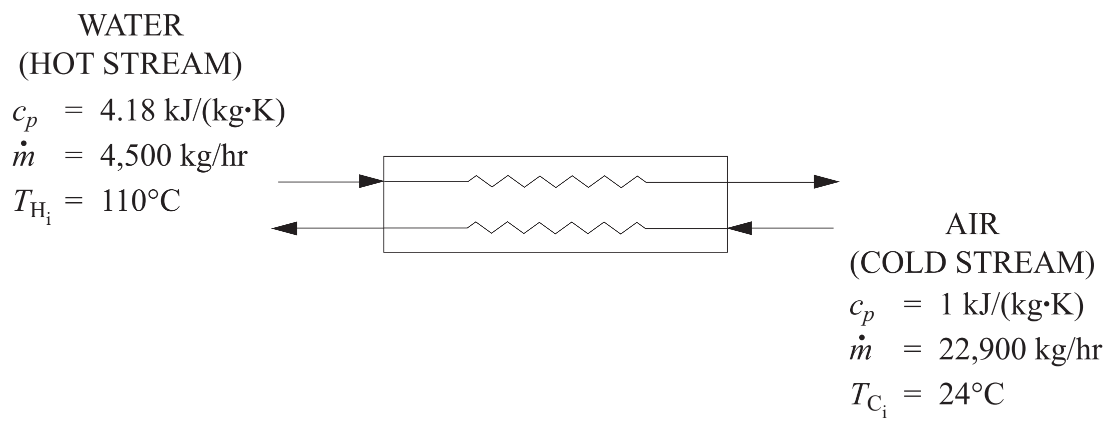
Property	Water	Oil
Specific heat, kJ/(kg•K)	4.186	3.5
Viscosity, kg/(m•s)	5.06×10^{-4}	6.3×10^{-3}
Density, kg/m^3	986.7	815.3



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

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

85. Heat is transferred from a stream of hot water to a stream of cold air in the heat-exchanger arrangement shown in the figure below. The heat exchanger is assumed to be insulated from its surroundings, and the specific heats of the two streams are assumed to be constant. If the exit temperature of the hot stream is 65°C and the exit temperature of the cold stream is 60°C, the logarithmic-mean temperature difference for the heat exchanger is most nearly:



- ○ A. 28.5°C
- ○ B. 41.0°C
- ○ C. 45.4°C
- ○ D. 50.0°C

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

$$R = R_o\,[1 + \alpha(T - T_o)]$$

where

R = resistance, Ω
R_o = reference resistance, Ω
α = coefficient, °C^{-1}
T = temperature, °C
T_o = reference temperature, °C

Consider an RTD with $R_o = 100$ Ω, $\alpha = 0.004$°C^{-1}, and $T_o = 0$°C.

The change in resistance (Ω) of the RTD for a 10°C change in temperature is most nearly:

- A. 0.04
- B. 0.4
- C. 4.0
- D. 100.4

NEXT→

87. 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 Kline-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

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

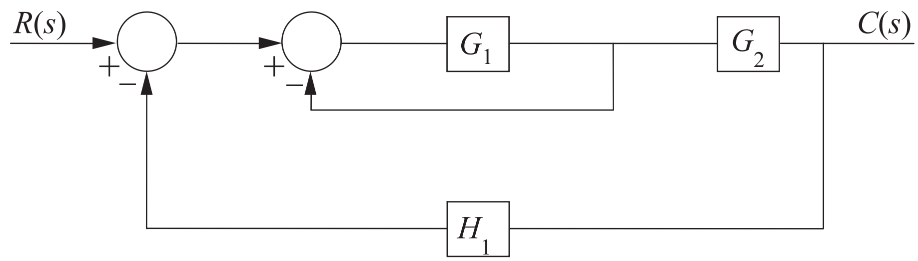
$$T(t) = T_o - (T_o - T_i)e^{-t/\tau}$$

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

89. An automatic controls block diagram is shown below:



The single element relating the input to the output is best represented by:

Option A $R(s)$ — G_1G_2 — $C(s)$

Option B $R(s)$ — $G_1G_2H_1$ — $C(s)$

Option C $R(s)$ — $(G_1G_2)/(1 + H_1)$ — $C(s)$

Option D $R(s)$ — $(G_1G_2)/(1 + G_1 + G_1G_2H_1)$ — $C(s)$

- A. Option A
- B. Option B
- C. Option C
- D. Option D

NEXT→

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FE MECHANICAL PRACTICE EXAM

90. The transfer function relating a step input to the output of a control system is:

$$\frac{16}{s^3 + 0.8s^2 + 16s}$$

The natural frequency ω_n of the system and the damping ratio ς are most nearly:

- A. $\omega_n = 2$ rad/s; $\varsigma = 0.1$
- B. $\omega_n = 2$ rad/s; $\varsigma = 0.2$
- C. $\omega_n = 4$ rad/s; $\varsigma = 0.1$
- D. $\omega_n = 4$ rad/s; $\varsigma = 0.2$

91. Yielding is considered failure for the ductile beam shown. The following data apply:

Yielding first occurs at Point X.
$S_y = 34$ ksi
$\sigma_2 = 0$ ksi

The table below shows various calculated values for σ_1 and σ_3.

Select the columns that show the values at which failures will occur.

Stress	A	B	C	D	E	F
σ_1 (ksi)	35	24	45	60	18	82
σ_3 (ksi)	– 35	0	–35	24	–62	62

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92. 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

93. A helical compression spring has a spring constant of 38.525 N/mm and a free length of 190 mm. The force (N) required to compress the spring to a length of 125 mm is most nearly:

- ○ A. 1,500
- ○ B. 2,500
- ○ C. 4,800
- ○ D. 6,500

94. The pressure gauge 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 (hoop) stress (MPa) inside the tank is most nearly:

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

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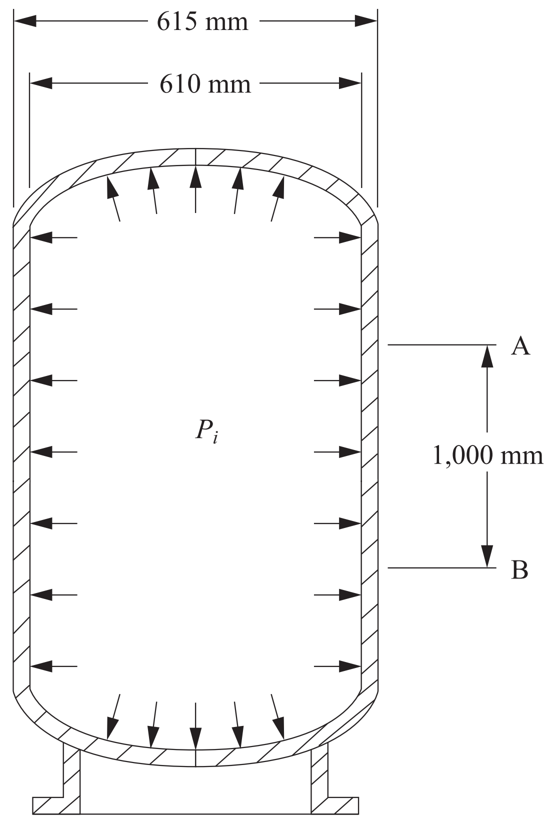
95. The figure below shows an unpressurized vessel. Material properties are given with the figure.

MATERIAL PROPERTIES:

$E = 210 \times 10^3$ MPa
$v = 0.24$
$\alpha = 10.5 \times 10^{-6}/°C$
$S_y = 400$ MPa



VERTICAL-AXIS PRESSURE VESSEL SECTION

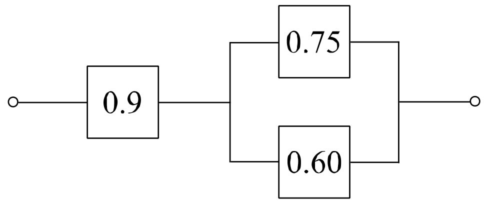
Assume the internal pressure is increased to P_i such that the stresses in the wall between Locations A and B are:

$\sigma_t = 46.2$ MPa
$\sigma_l = 23.1$ MPa
$\sigma_r = 0$

The increase in length (mm), along the outer wall, of the distance between Locations A and B due to the increase in pressure is most nearly:

- A. 0.06
- B. 0.11
- C. 0.19
- D. 0.22

96. A reliability study is conducted for a three-component system which consists of one component connected in series to two additional components that are connected in parallel, as shown in the figure. The results of independent component testing are shown in the boxes and indicate the probability that the individual component is functioning. The reliability of the entire system is most nearly:



- A. 0.09
- B. 0.41
- C. 0.61
- D. 0.81

97. 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.

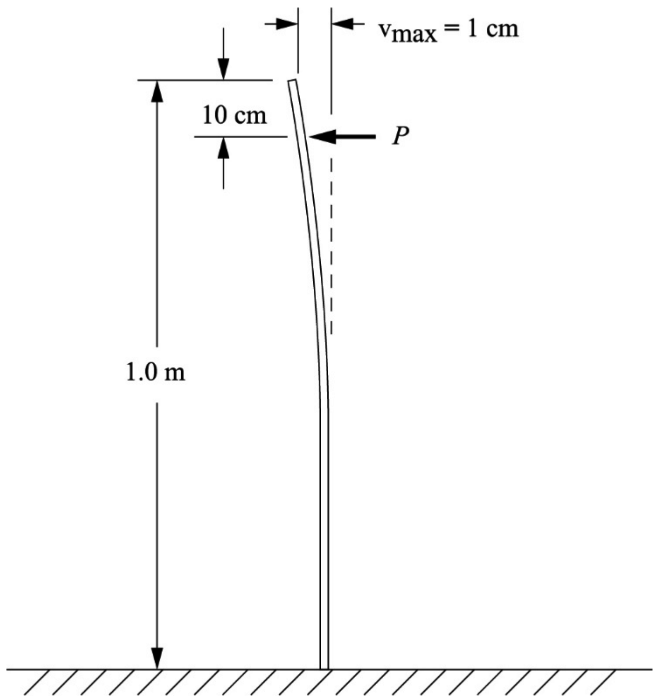
Assume the following:

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

98. A solid steel rod with a round cross section vertically cantilevered in the ground has the following properties:

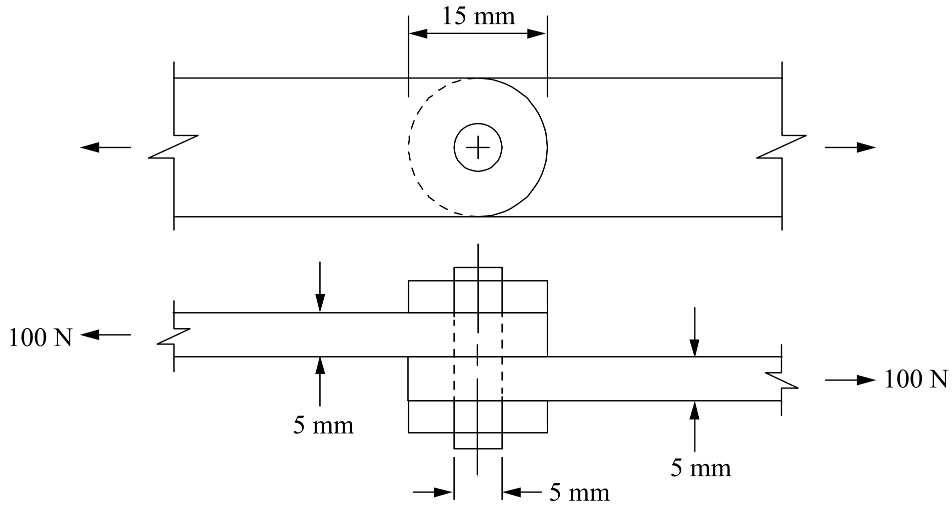


Modulus of elasticity	$E = 200$ GPa
Cross-sectional moment of inertia	$I = 1.60 \times 10^{-8}$ m^4
Length	$L = 1.00$ m

A force P is applied along the horizontal direction, 10 cm below the free end, as shown. To cause a maximum deflection to the end of the rod of 1 cm, the force (N) required is most nearly:

- A. 1.13
- B. 113
- C. 132
- D. 6,620

99. Two aluminum bars with semicircular ends are bolted together in single shear, as shown, using a 5-mm bolt. The tension in the bolt is 8 kN. The tension on the bars is 100 N. The average shear stress (MPa) at the interface of the overlapping bars is most nearly:



- A. 0.56
- B. 0.63
- C. 5.1
- D. 51

100. The positional tolerance of the hole documented below is most nearly:

$\varnothing 50 \begin{array}{l} +0.5 \\ -0.3 \end{array}$

⌖	Ø0.2Ⓜ	A	B	C

- A. –0.3
- B. –0.1
- C. 0.2
- D. 0.5

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SOLUTIONS

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FE MECHANICAL SOLUTIONS

Detailed solutions for each question begin on the next page.

1	A	**26**	A	**51**	B	**76**	B
2	A	**27**	D	**52**	C	**77**	B
3	B	**28**	see solution	**53**	D	**78**	D
4	B	**29**	see solution	**54**	B	**79**	C
5	C	**30**	C	**55**	B	**80**	D
6	D	**31**	648	**56**	B	**81**	B
7	A	**32**	D	**57**	C	**82**	B
8	D	**33**	A	**58**	B	**83**	A, E
9	see solution	**34**	C	**59**	A	**84**	B
10	B	**35**	C	**60**	D	**85**	C
11	C	**36**	D	**61**	C	**86**	C
12	D	**37**	D	**62**	A	**87**	D
13	A	**38**	D	**63**	B	**88**	D
14	B, C, E	**39**	C	**64**	Region B	**89**	D
15	224 or 225	**40**	3	**65**	B	**90**	C
16	see solution	**41**	B	**66**	C	**91**	A, C, D, E
17	D	**42**	B	**67**	D	**92**	C
18	5	**43**	C	**68**	C	**93**	B
19	D	**44**	A	**69**	B	**94**	B
20	720	**45**	A	**70**	A	**95**	A
21	C	**46**	C	**71**	B	**96**	D
22	B	**47**	B	**72**	D	**97**	D
23	1,638	**48**	C	**73**	B	**98**	B
24	C	**49**	D	**74**	C	**99**	B
25	D	**50**	A	**75**	3	**100**	C

FE MECHANICAL SOLUTIONS

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

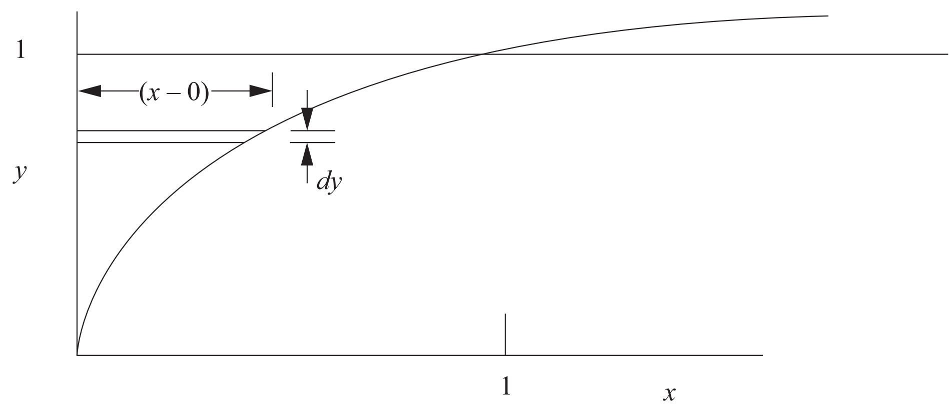
$(x - h)^2 + (y - k)^2 + (z - m)^2 = r^2$ with center at (h,k,m)

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

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

THE CORRECT ANSWER IS: A

2. Define a differential strip with length $(x - 0)$ and height dy.



$$\int dA = \int_0^1 x\,dy = \int_0^1 y^{3/2}\,dy = \left.\frac{y^{5/2}}{5/2}\right|_0^1 = \frac{2}{5}$$

THE CORRECT ANSWER IS: A

3. Refer to the Numerical Integration section in the Mathematics chapter 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

4. Refer to Differential Equations in the Mathematics chapter of the *FE Reference Handbook*.

The characteristic equation for a first-order, linear, homogeneous differential equation is:

$$r + 5 = 0$$

which has a root at $r = -5$.

The form of the solution is then:

$$y = Ce^{-\alpha t}$$

where $\alpha = a$ and

$a = 5$ for this problem

C is determined from the boundary condition.

$$1 = Ce^{-5(0)}$$
$$C = 1$$

Then, $y = e^{-5t}$

THE CORRECT ANSWER IS: B

5. Refer to the Vectors section in the Mathematics chapter of the *FE Reference Handbook*.

The cross product of vectors **A** and **B** is a vector perpendicular to **A** and **B**.

$$\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 2 & 4 & 0 \\ 1 & 1 & -1 \end{vmatrix} = \mathbf{i}(-4) - \mathbf{j}(-2-0) + \mathbf{k}(2-4) = -4\mathbf{i} + 2\mathbf{j} - 2\mathbf{k}$$

To obtain a unit vector, divide by the magnitude.

$$\text{Magnitude} = \sqrt{(-4)^2 + 2^2 + (-2)^2} = \sqrt{24} = 2\sqrt{6}$$

$$\frac{-4\mathbf{i} + 2\mathbf{j} - 2\mathbf{k}}{2\sqrt{6}} = \frac{-2\mathbf{i} + \mathbf{j} - \mathbf{k}}{\sqrt{6}}$$

THE CORRECT ANSWER IS: C

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6. Refer to the Software Syntax Guidelines section in the Electrical and Computer chapter of the *FE Reference Handbook*.

Step	VAR
1	0
2	2
3	4
4	6
EXIT	LOOP

At the conclusion of the routine, VAR = 6.

THE CORRECT ANSWER IS: D

7. Refer to the Normal Distribution section in the Engineering Probability and Statistics chapter of the *FE Reference Handbook*.

Mean $\mu = 8$
Standard deviation $\sigma = 2.5$
$x = 15.5$

Calculate $Z = \dfrac{x-\mu}{\sigma} = 3$.

Refer to the Unit Normal Distribution table. Use 3 for x in the table (3 standard deviations away).

$R(x) = 0.0013$

THE CORRECT ANSWER IS: A

8. Refer to the Dispersion, Mean, Median, and Mode Values section in the Engineering Probability and Statistics chapter of the *FE Reference Handbook*.

$$\sigma = \sqrt{\frac{1}{\mathrm{N}}\Sigma\left(x_1-\mu\right)^2}$$

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

$$\sigma = 1.118$$

THE CORRECT ANSWER IS: D

9. Refer to the Dispersion, Mean, Median, and Mode Values section in the Engineering Probability and Statistics chapter of the *FE Reference Handbook*:

x	$x-\bar{x}$	$(x-\bar{x})^2$
4	−1	1
4	−1	1
7	2	4
Σ = 15		Σ = 6

$\bar{x}$ = 15/3 = 5 = mean

Median is the value of $\left(\dfrac{n+1}{2}\right)^{\text{th}}$ item. $\left(\dfrac{3+1}{2}\right)$ = 2 items

Median = 4

$\sigma^2 = (1/N)\displaystyle\sum_{i=1}^{N}(X_1-\mu)^2 = (1/3)\,(6) = 2$ = variance

Statistical Quantities

Mean	5
Variance	2
Median	4

THE CORRECT ANSWERS ARE SHOWN ABOVE.

10. Accuracy increases with increasing sample size.

THE CORRECT ANSWER IS: B

11. Refer to the Ethics chapter of the *FE Reference Handbook*. Section B 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

12. Refer to the Intellectual Property section in the Ethics chapter of the *FE Reference Handbook*.

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THE CORRECT ANSWER IS: D

13. Refer to the Ethics chapter of the *FE Reference Handbook*.

The Rules of Professional Conduct, Section B.1, states that licensees may undertake assignments only in the fields in which they are qualified by education or experience.

THE CORRECT ANSWER IS: A

14. Refer to the Rules of Professional Conduct, Section B.1, in the Ethics chapter of the *FE Reference Handbook*.

Option A: Not true. Licensees may accept assignments and assume responsibility for coordination of an entire project, provided that each technical segment is signed and sealed by the licensee responsible for preparation of that technical segment.

Option B: True: See above.

Option C: True. The first and foremost responsibility of licensees is to safeguard the health, safety, and welfare of the public when performing services for clients and employers.

Option D: Not true. Licensees must disclose to their employers or clients all known or potential conflicts of interest or other circumstances that could influence or appear to influence their judgment or the quality of their professional service or engagement.

Option E: True. Licensees must comply with the licensing laws and rules governing their professional practice in each of the jurisdictions in which they practice.

THE CORRECT ANSWERS ARE: B, C, E

15. Refer to the Engineering Economics chapter of the FE Reference Handbook.

Annual cost: = cost + maintenance – salvage

Annual cost: $= \$900(A/P, 8\%, 5) + \$50 - \$300(A/F, 8\%, 5)$

$= \$900(0.2505) + \$50 - \$300(0.1705)$

$= \$225.45 + \$50 - \$51.15$

$= \$224.30$

THE CORRECT ANSWER IS: 224 OR 225

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16. Compute *P* (present value) given *A* (the periodic value) for *P*/*A*. Uniform series present worth factors are described in the Engineering Economics chapter of the *FE Reference Handbook*.

Factor Table –*i* = 2.00%

n	*P/F*	*P/A*	*P/G*	*F/P*	*F/A*	*A/P*	*A/F*	*A/G*
1	0.9804	0.9804	0.0000	1.0200	1.0000	1.0200	1.0000	0.0000
2	0.9612	1.9416	0.9612	1.0404	2.0200	0.5150	0.4950	0.4950
3	0.9423	2.8839	2.8458	1.0612	3.0604	0.3468	0.3268	0.9868
4	0.9238	3.8077	5.6173	1.0824	4.1216	0.2626	0.2426	1.4752
5	**0.9057**	**4.7135**	**9.2403**	**1.1041**	**5.2040**	**0.2122**	**0.1922**	**1.9604**
6	0.8880	5.6014	13.6801	1.1262	6.3081	0.1785	0.1585	2.4423
7	0.8706	6.4720	18.9035	1.1487	7.4343	0.1545	0.1345	2.9208
8	0.8535	7.3255	24.8779	1.1717	8.5830	0.1365	0.1165	3.3961
9	0.8368	8.1622	31.5720	1.1951	9.7546	0.1225	0.1025	3.8681
10	**0.8203**	**8.9826**	**38.9551**	**1.2190**	**10.9497**	**0.1113**	**0.0913**	**4.3367**
11	0.8043	9.7868	46.9977	1.2434	12.1687	0.1022	0.0822	4.8021
12	0.7885	10.5753	55.6712	1.2682	13.4121	0.0946	0.0746	5.2642
13	0.7730	11.3484	64.9475	1.2936	14.6803	0.0881	0.0681	5.7231
14	0.7579	12.1062	74.7999	1.3195	15.9739	0.0826	0.0626	6.1786
15	**0.7430**	**12.8493**	**85.2021**	**1.3459**	**17.2934**	**0.0778**	**0.0578**	**6.6309**
16	0.7284	13.5777	96.1288	1.3728	18.6393	0.0737	0.0537	7.0799
17	0.7142	14.2919	107.5554	1.4002	20.0121	0.0700	0.0500	7.5256
18	0.7002	14.9920	119.4581	1.4282	21.4123	0.0677	0.0467	7.9681
19	0.6864	15.6785	131.8139	1.4568	22.8406	0.0638	0.0438	8.4073
20	**0.6730**	**16.3514**	**144.6003**	**1.4859**	**24.2974**	**0.0612**	**0.0412**	**8.8433**
21	0.6598	17.0112	157.7959	1.5157	25.7833	0.0588	0.0388	9.2760
22	0.6468	17.6580	171.3795	1.5460	27.2990	0.0566	0.0366	9.7055
23	0.6342	18.2922	185.3309	1.5769	28.8450	0.0547	0.0347	10.1317
24	0.6217	18.9139	199.6305	1.6084	30.4219	0.0529	0.0329	10.5547
25	**0.6095**	**19.5235**	**214.2592**	**1.6406**	**32.0303**	**0.0512**	**0.0312**	**10.9745**
30	0.5521	22.3965	291.7164	1.8114	40.5681	0.0446	0.0246	13.0251
40	0.4529	27.3555	461.9931	2.2080	60.4020	0.0366	0.0166	16.8885
50	0.3715	31.4236	642.3606	2.6916	84.5794	0.0318	0.0118	20.4420
60	0.3048	34.7609	823.6975	3.2810	114.0515	0.0288	0.0088	23.6961
100	**0.1380**	**43.0984**	**1,464.7527**	**7.2446**	**312.2323**	**0.0232**	**0.0032**	**33.9863**

THE CORRECT ANSWER IS SHADED ABOVE.

17. Refer to the Uniform Series Sinking Fund equation in the Engineering Economics chapter of the *FE Reference Handbook*.

$n = 10$

$i = 0.058$

$$A = F \bullet \frac{A}{F} = \$50,000 \bullet \frac{i}{(1+i)^n - 1}$$

$$A = \$50,000 \bullet \frac{0.05}{(1+0.05)^{10} - 1}$$

$A = \$3,975$

THE CORRECT ANSWER IS: D

18. Ignore depreciation, interest, etc. The initial cost was \$50,000. Net profit from each unit sale is \$40 – \$25 = \$15.

In Year 1: 1,000 units × \$15 = \$15,000 (cumulative \$15,000 at end of Year 1)

In Year 2: 750 units × \$15 = \$11,250 (cumulative \$26,250)

In Year 3: 750 units × \$15 = \$11,250 (cumulative \$37,500)

In Year 4: 500 units × \$15 = \$7,500 (cumulative \$45,000)

In Year 5: 500 units × \$15 = \$7,500 (cumulative \$52,500)

Sometime during Year 5 the project is paid back.

THE CORRECT ANSWER IS: 5

19. Refer to Complex Power in the Electrical and Computer Engineering chapter of the *FE Reference Handbook* for the equation.

$$P = V_{\text{rms}}\, I_{\text{rms}} \cos\theta$$

$$pf = \cos\theta = \frac{P}{V_{\text{rms}}\, I_{\text{rms}}}$$

$$= \frac{1,500}{(115)(15)}$$

$$= 0.87$$

THE CORRECT ANSWER IS: D

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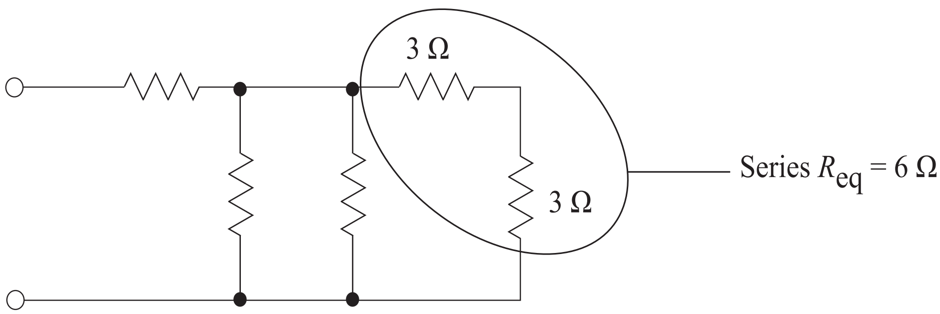
20. Refer to the Power Absorbed by a Resistive Element section in the Electrical and Computer chapter of the *FE Reference Handbook*.

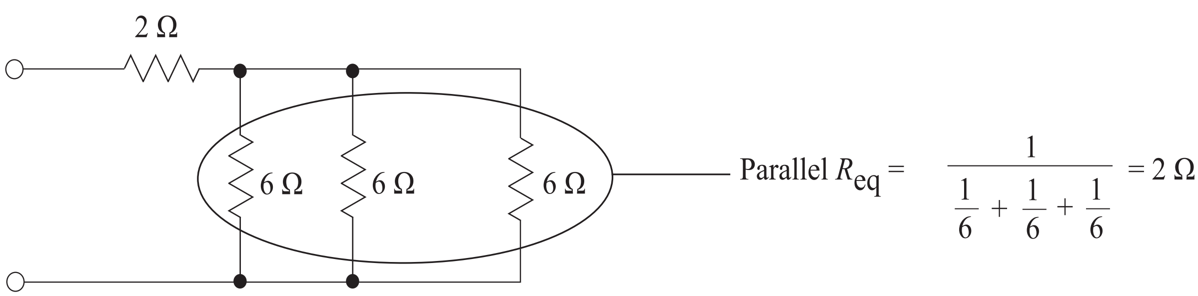
$P = V^2/R$

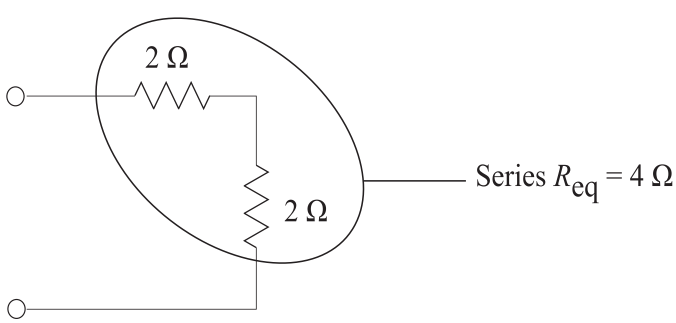
$= (120^2)/20 = 720$

THE CORRECT ANSWER IS: 720

21. Refer to the Resistors in Series and Parallel section in the Electrical and Computer chapter of the *FE Reference Handbook*.

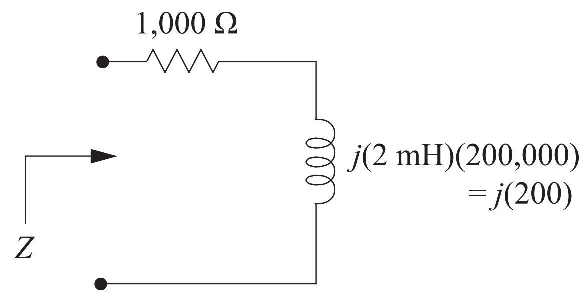






THE CORRECT ANSWER IS: C

22. Refer to the Phasor Transforms of Sinusoids section in the Electrical and Computer chapter 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

23. Refer to the AC Machines section in the Electrical and Computer chapter of the *FE Reference Handbook.*

Synchronous speed

$$ns = 120\ f/p$$

where f = line voltage frequency
p = number of poles

For a 4-pole motor operating on 60-Hz voltage,

$ns = 120 \times 60/4 = 1{,}800$ rpm

For an induction motor,

slip = $(ns - n)/ns$

$0.09 = (1{,}800 - n)/1{,}800 \Longrightarrow n = 1{,}638$

THE CORRECT ANSWER IS: 1,638

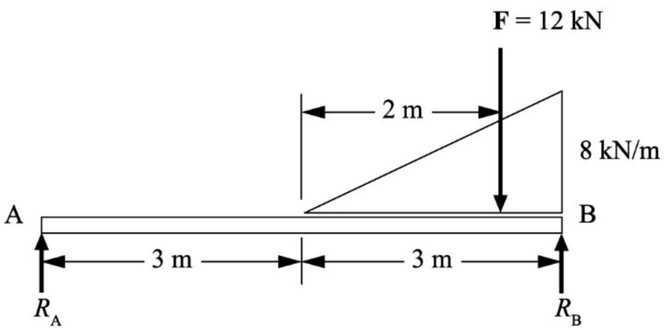
24. Refer to the Systems of Forces section in the Statics chapter of the *FE Reference Handbook*.

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 (base)(height) = 1/2 (3 m)(8 kN/m)
F = 12 kN

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

$\Sigma M_A = 0$
$6R_B - 5\mathbf{F} = 0$
$6R_B - 5(12 \text{ kN}) = 0$
$R_B = 10$ kN



THE CORRECT ANSWER IS: C

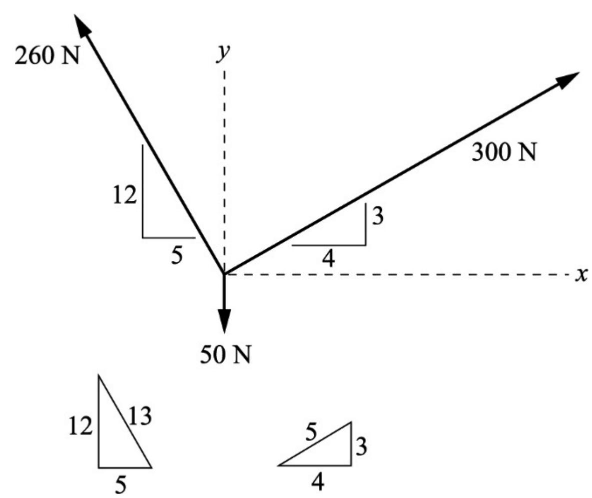
25. Refer to the Resultant (Two Dimensions) section in the Statics chapter of the *FE Reference Handbook.*

$$R_y = \Sigma F_y = \frac{12}{13}(260) + \frac{3}{5}(300) - 50 = 370$$

$$R_x = \Sigma F_x = -\frac{5}{13}(260) + \frac{4}{5}(300) = 140$$

$$R = \sqrt{R_x^2 + R_y^2} = \sqrt{370^2 + 140^2}$$

$R = 396$ N



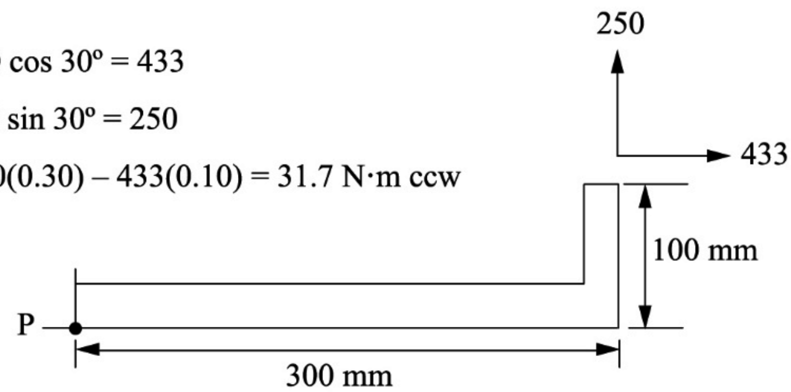
THE CORRECT ANSWER IS: D

26. Refer to the Moments (Couples) section in the Statics chapter of the *FE Reference Handbook*.

$F_H = 500 \cos 30° = 433$

$F_V = 500 \sin 30° = 250$

$M_P = 250(0.30) - 433(0.10) = 31.7 \text{ N·m ccw}$



THE CORRECT ANSWER IS: A

27. Refer to Plane Truss: Method of Sections in the Statics chapter 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.

$$\sum M_I = 0$$

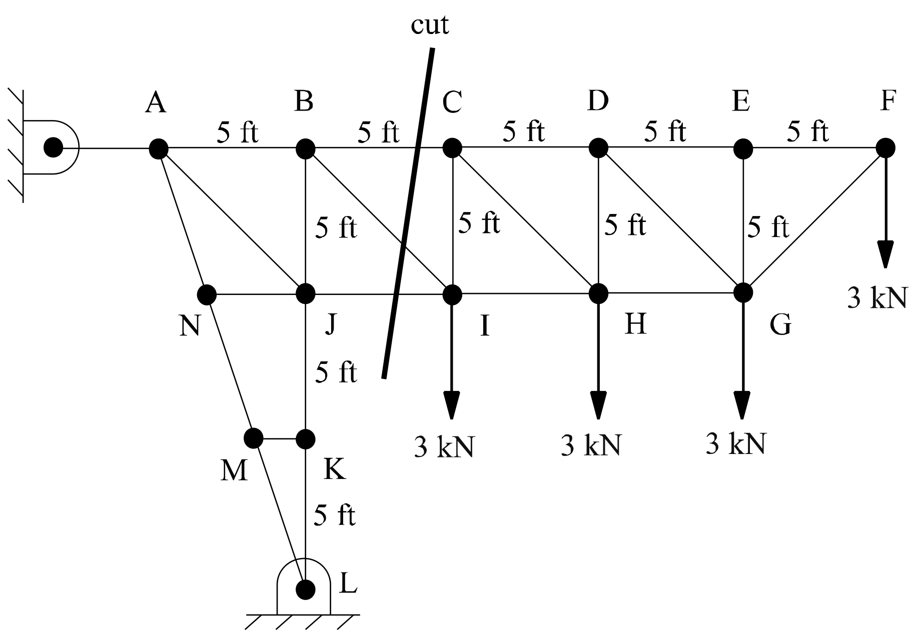
$$= M_C - M_H - M_G - M_F$$

$$\sum M_I = (5F_{BC}) - (5\times3) - (10\times3) - (15\times3) = 0$$

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

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

$F_{BC} = 18$ kN



THE CORRECT ANSWER IS: D

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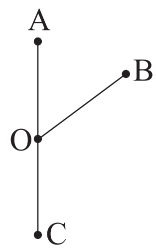
28. Refer to the Statically Determinate Truss section in the Statics chapter of the *FE Reference Handbook*.

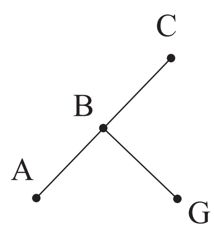
Where members are aligned as follows with no external loads, zero force members occur.



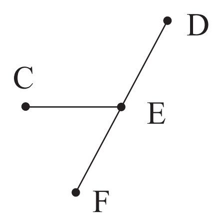
That is, joints where two members are along the same line (OA and OC) and the third member is at some arbitrary angle create zero-force members. That member (OB) is a zero-force member because the forces in OA and OC must be equal and opposite.

For this specific problem, we immediately examine Joints B and E:

B:



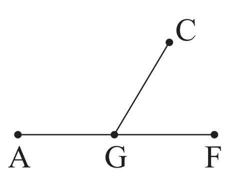
E:



BG is a zero-force member

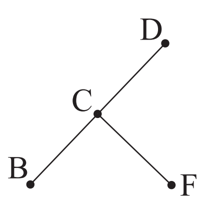
CE is a zero-force member

Now, examine Joint G. Since BG is zero-force member, the joint effectively looks like:



and, therefore, CG is another zero-force member.

Finally, examine Joint C. Since both CG and CE are zero-force members, the joint effectively looks like:



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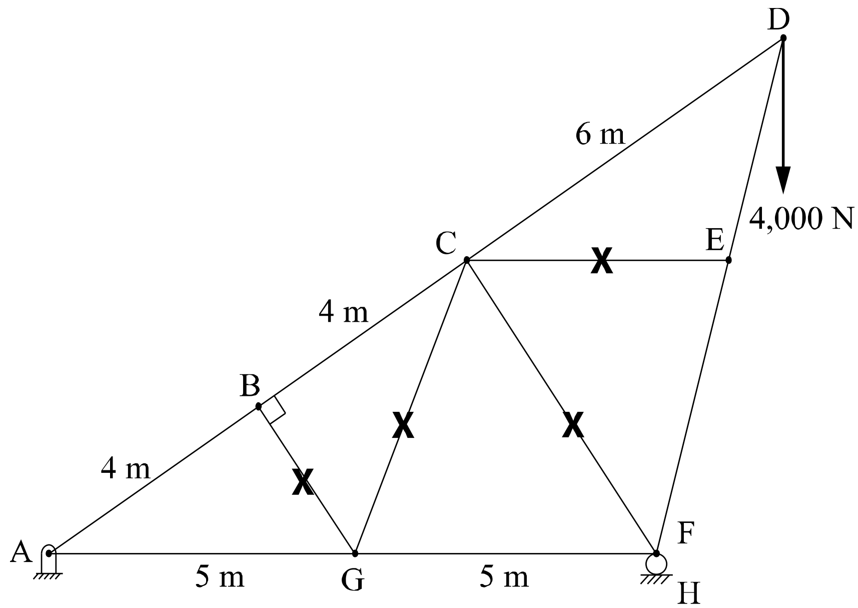
28. **(Continued)**
and, therefore, CF is another zero-force member. Thus, BG, CE, CG, and CF are the zero-force members.



THE CORRECT ANSWERS ARE MARKED ABOVE.

29. Refer to the Centroids of Masses, Areas, Lengths, and Volumes section in the Statics chapter of the *FE Reference Handbook*.

A. Determination of Y = 5.38
$[(6 \times 1)(3) + (8 \times 1)(6.5) + (2 \times 1)(8)]/16$

B. Determination of Y = 6.25
$[(8 \times 1)(4) + (8 \times 1)(8.5)]/16$

C. Determination of Y = 5.00
$[(4 \times 1)(0.5) + (8 \times 1)(5) + (4 \times 1)(9.5)]/16$

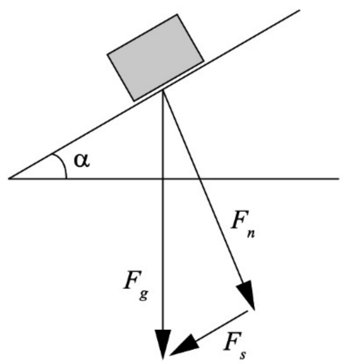
D. Determination of Y = 2.75
$[(8 \times 1)(0.5) + (8 \times 1)(5)]/16$

E. Determination of Y = 4.44
$[(5 \times 1)(0.50) + (8 \times 1)(5.0) + (3 \times 1)(9.5)]/16$

THE CORRECT ORDER IS: D, E, C, A, B

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

The maximum friction force developed before the block slides is $F_s \le \mu F_n$. Formulate a free-body diagram of the block and ramp. Decompose the gravity force into a normal component and a friction component, and then $\mu = \tan \alpha = 0.754$.



THE CORRECT ANSWER IS: C

31. Refer to the Moment of Inertia Parallel Axis Theorem section in the Statics chapter of the *FE Reference Handbook*.

$$\text{Check } I_c = I_{y\text{-}y} = \frac{b\left(d^3 - d_1^3\right)}{12} + \frac{b_0 d_0^3}{12}$$

$$= \frac{9\left(10^3 - 6^3\right)}{12} + \frac{(1)(6)^3}{12}$$

$$= 588 + 18 = 606$$

$d = 10$
$d_1 = 6$
$b = 9$
$b_0 = 1$
$d_0 = 6$

Parallel axis theorem:
$I_{y\text{-}y} = 606 \text{ in}^4$
$d_y = 1 \text{ in.}$
$A = (2)(9) + (1)(6) + (2)(9)$
$A = 42 \text{ in}^2$

$I_{y'\text{-}y'} = I_{y\text{-}y} + d_y^2 A$
$I_{y'\text{-}y'} = (606 + 42) \text{ in}^4$
$= 648 \text{ in}^4$

THE CORRECT ANSWER IS: 648

32. Refer to the Resolution of a Force section in the Statics chapter of the *FE Reference Handbook*.

Sum of forces at $E = 0$

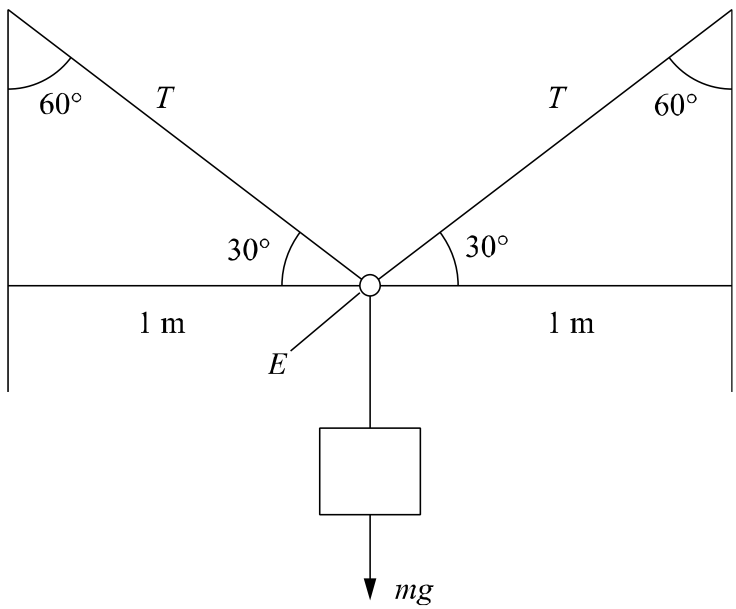
Using symmetry, $T_{\text{left}} = T_{\text{right}}$

Vertical components: $mg = 2\ T \sin 30°$

$$T = \frac{mg}{2\sin 30°} = \frac{100 \times 9.81}{2 \times 0.5}$$

$$= 100 \times 9.81$$

$$= 981\,\text{N}$$



THE CORRECT ANSWER IS: D

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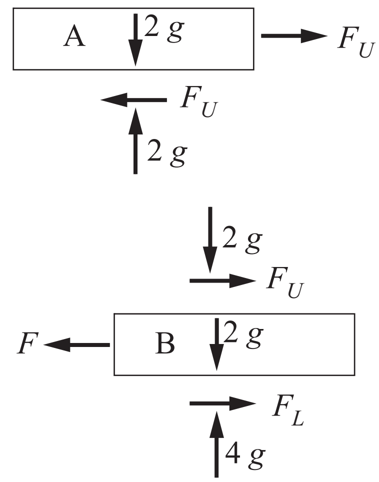
33. Refer to the Friction section in the Dynamics chapter of the *FE Reference Handbook*.

The upper frictional force due to Block A on Block B is

$$F_U = 0.2\ m_A g$$
$$= 0.2(2)(9.81) = 3.924\ \text{N}$$



The lower frictional force on Block B at the bottom surface is

$$F_L = 0.4(m_A + m_B)g$$
$$= 0.4(2+2)9.81 = 15.696\ \text{N}$$

Then from the Kinetics section,

$$\sum F = ma$$
$$F - F_L - F_U = ma$$
$$30 - 15.696 - 3.924 = 2a$$
$$a = 5.19 \approx 5.2\ \text{m/s}^2$$

THE CORRECT ANSWER IS: A

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

$$T_1 + U_1 + W_{1\rightarrow 2} = T_2 + U_2$$
$$0 + 0 + Fs = 1/2\ mv^2 + mgh$$
$$5F = 1/2\ (2)(8)^2 + (2)(9.81)(3)$$
$$F = 24.6\ \text{N}$$

THE CORRECT ANSWER IS: C

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35. Refer to 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 θ = 90°, v_P is desired (piston speed).

v_C = 50 mm × 377 rad/s = 18,850 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, ⊥ to v_P, intersects the line at C, ⊥ 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 $\bar{v}_P = \bar{v}_C + \bar{\omega}_{PC} \times \bar{r}_{P/C}$ and $\omega_{PC} = 0$.

THE CORRECT ANSWER IS: C

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FE MECHANICAL SOLUTIONS

36. Refer to the Relative Motion section in the Dynamics chapter of the *FE Reference Handbook*.

$$v_A = v_G + \omega \times r_{GA}$$

$$v_G = 5.0\hat{i} \text{ m/s}$$

$$\omega = \frac{-5.0 \text{ m/s}}{0.25 \text{ m}}\hat{k}\, s^{-1} = -20\hat{k}\, s^{-1}$$

$$r_{GA} = 0.25\left[\cos 45°\,\hat{i} + \sin 45°\,\hat{j}\right]\text{m}$$

Then

$$v_A = 5.0\hat{i} + \left(-20\hat{k} \times r_{GA}\right)$$

$$= 5.0\hat{i} + 3.54\hat{i} - 3.54\hat{j} \text{ m/s}$$

$$v_A = 8.54\hat{i} - 3.54\hat{j} \text{ m/s}$$

Then

$$|v_A| = \sqrt{8.54^2 + 3.54^2} = 9.24 \text{ m/s}$$

$$|v_A| \simeq 9.2 \text{ m/s}$$

This problem could also be solved by vectorially adding the translational motion and the rotational motion or by using Point O as the reference. In that case,

$$|v_A| = |\omega| \times |r_{OA}| = 20 \text{ s}^{-1} \times 0.462 \text{ m} \simeq 9.2 \text{ m/s}$$

THE CORRECT ANSWER IS: D

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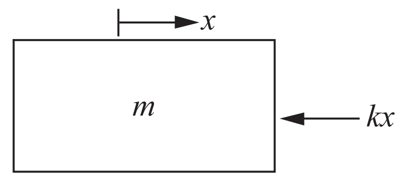
37. Refer to the Free Vibration section in the Dynamics chapter of the *FE Reference Handbook*.

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

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



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

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

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

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

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

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

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

Alternate solution:

Use kinetic energy of Block B to compress the spring a distance of $x = 4$.

$F = Ma$ at maximum compression, and force gives

$36 = 4a$

$a = 9 \text{ m/s}^2$

THE CORRECT ANSWER IS: D

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FE MECHANICAL SOLUTIONS

38. Refer to the Impact section in the Dynamics chapter of the *FE Reference Handbook*.

Use conservation of momentum during impact.

$$4v_1 + 0 = 4v_1' + 2v_2'$$

where ( )′ indicates *after impact*.

$$4(10) = 40 = 4v_1' + 2v_2' \qquad (1)$$

Use the coefficient of restitution

$$e = 1 = \frac{v_2' - v_1'}{v_1 - 0}$$

$$(1)(10) = 10 = -v_1' + v_2' \qquad (2)$$

Solve (1) and (2) to find

$$v_2' = 13.3 \text{ m/s}$$

THE CORRECT ANSWER IS: D

39. Refer to the Kinetics of a Rigid Body section in the Dynamics chapter of the *FE Reference Handbook.*

$\Sigma M_0 = I_0\alpha$

$T(0.1) = 0.0428\ \alpha \qquad (1)$

$\Sigma F_y = ma_y$

$mg - T = ma \qquad (2)$

No slip

$a = \alpha r \qquad (3)$

$(3) \rightarrow (2)$

$mg - T = m\alpha r$

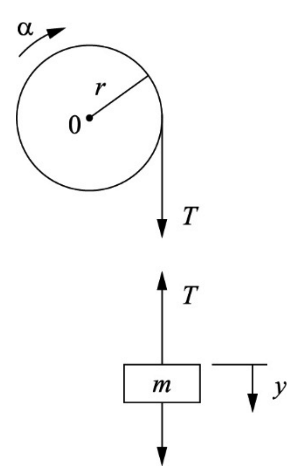
$(1\text{ kg})(9.81\text{ m/s}^2) - T = (1\text{ kg})(0.1\text{ m})\ \alpha$

$T = 9.81 - 0.1\ \alpha \qquad (4)$

$(4) \rightarrow (1)$

$[9.81 - 0.1\ \alpha]\ 0.1 = 0.0428\ \alpha$

$\alpha = 18.6\text{ s}^{-2}$



THE CORRECT ANSWER IS: C

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40. Refer to the Non-constant Acceleration section in the Dynamics chapter of the *FE Reference Handbook.*

The speed is the integral of velocity with respect to time:

Speed = initial speed + $\int_0^t a\,dt = 0 + \int_0^2 a\,dt + \int_2^3 a\,dt + \int_3^5 a\,dt$

By inspecting the graph:

- First segment is a triangle, with area = (1/2) × 1 × 2 = 1
- Second segment is a rectangle, with area = 1 × 1 = 1
- Third segment is a triangle, with area = (1/2) × 1 × 2 =1

The speed will be 1+1+1=3 m/s.

THE CORRECT ANSWER IS: 3

41. Refer to the Particle Kinematics section in the Dynamics chapter of the *FE Reference Handbook.*

From the question, the automobile is sliding, so use kinetic friction. The friction force is:

$F_N \times \mu_k$

F_N = 1,020 kg × 9.807 m/s^2 = 10,003 N, so F_f = 4,001 N.

The deceleration is calculated from $F = ma$, so a = (4,001)/(1,020) = 3.92 m/s^2.

After 1 second, the speed will be 10 – 3.92 = 6.08 m/s.

THE CORRECT ANSWER IS: B

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

$T_2 + U_2 = T_1 + U_1 + W_{1\to2}$

$W_{1\to2} = 0$

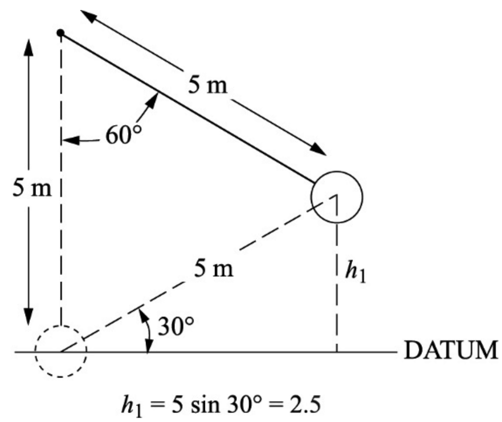
$T_1 = 0$

$T_2 = \dfrac{1}{2}mv_2^2$

$U_1 = mgh_1$

$U_2 = 0$

$$\frac{1}{2}mv_2^2 = mg(2.5) \Rightarrow v_2 = \sqrt{5g} = \sqrt{5(9.81)} = 7\,\text{m/s}$$



THE CORRECT ANSWER IS: B

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

$$\text{Deformation} = \delta = \frac{\text{PL}}{\text{AE}} = \frac{(5{,}000)(0.25)}{\left(1{,}250\times10^{-6}\right)\left(200\times10^{9}\right)} = 5.0\times10^{-6}\ \text{m} = 5.0\ \mu\text{m}$$

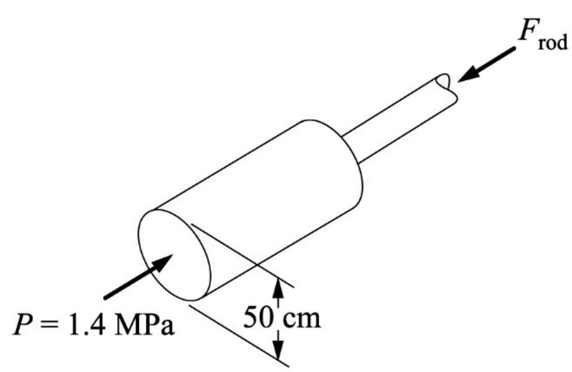
THE CORRECT ANSWER IS: C

44. Refer to the Uniaxial Loading and Deformation section in the Mechanics of Materials chapter of the *FE Reference Handbook*.

$$\Sigma F = PA = \left(1.4\times10^{6}\right)\left(\frac{\pi(0.5)^2}{4}\right) = F_{\text{rod}}$$

$$F_{\text{rod}} = 275\ \text{kN} = \sigma A = 68\times10^{6} A$$

$$A = 40.4\times10^{-4}\,\text{m}^2$$



THE CORRECT ANSWER IS: A

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

$$\tau = \frac{T\,r}{J}$$

where T = torque at section of interest $(\mathrm{N \cdot mm})$

r = radius to point of interest (mm), r_{outside} for maximum shear, and $r = \dfrac{d}{2}$

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

For Section BC

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

$$r = \frac{75}{2}\,\mathrm{mm}$$

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

Hence the maximum torsional shear stress is given by

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

$$= 15\ \mathrm{MPa}$$

THE CORRECT ANSWER IS: A

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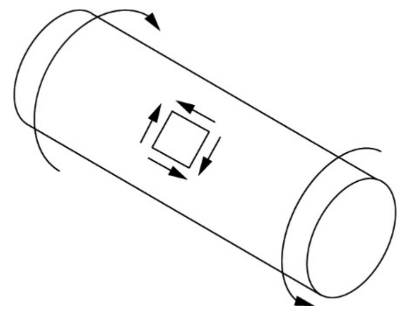
46. Refer to the Torsion section in the Mechanics of Materials chapter of the *FE Reference Handbook.*

$$\tau = \frac{Tr}{J} = \frac{T\frac{d}{2}}{\frac{\pi d^4}{32}} = \frac{16T}{\pi d^3}$$



$$T = \frac{\pi d^3 \tau}{16} = \frac{\pi (0.2)^3 (840 \times 10^3)}{16}$$

$$T = 1{,}319 \text{ N·m}$$

THE CORRECT ANSWER IS: C

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

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

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

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

$$R = \sqrt{200}$$

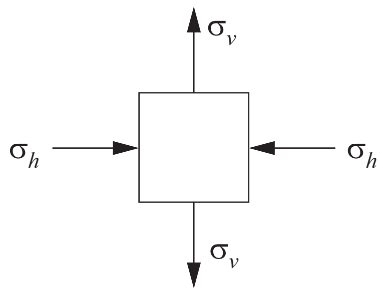
$$R = 14.1 \text{ ksi}$$

THE CORRECT ANSWER IS: B

FE MECHANICAL SOLUTIONS

48. Refer to the Mohr's Circle–Stress, 2D section in the Mechanics of Materials chapter of the *FE Reference Handbook.*

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,

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

Thus

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

THE CORRECT ANSWER IS: C

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

The Euler formula is used for elastic stability of relatively long columns, subjected to concentric axial loads in compression.

THE CORRECT ANSWER IS: D

50. Refer to the Thermal Deformation and Engineering Strain sections in the Mechanics of Materials chapter of the *FE Reference Handbook.*

$$\Delta T = 30 - (-10) = 40°\text{C}$$

$$\delta = \alpha\, \Delta T\, L = \left(12 \times 10^{-6}\right)(40)(50) = 24 \times 10^{-3}\,\text{m}$$

$$\varepsilon = \frac{\delta}{L} = \frac{24}{50} \times 10^{-3} = 0.48 \times 10^{-3}$$

$$\sigma = E\,\varepsilon = \left(200 \times 10^{9}\right) \times \left(0.48 \times 10^{-3}\right) = 96\ \text{MPa}$$

THE CORRECT ANSWER IS: A

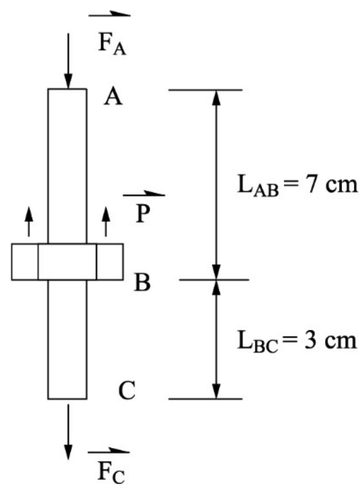
51. Refer to the Mechanical Springs section in the Mechanical Engineering chapter of the *FE Reference Handbook.*

This is an indeterminate axial load question.

$$P = k(\Delta L) = 30\,\frac{\text{kN}}{\text{cm}} \times 2\ \text{cm} = 60\ \text{kN}$$

$$\because |\delta_{AB}| = |\delta_{BC}| \Rightarrow F_A L_{AB} = F_C L_{BC}$$

$$\therefore F_C = \frac{L_{AB}}{L_{BC}} F_A$$



Force equilibrium equation in the Statics chapter

$$F_A + F_C = P = 60\ \text{kN}$$

$$F_A + \left(\frac{L_{AB}}{L_{BC}}\right) F_A = F_A\left(\frac{L_{AC}}{L_{BC}}\right) = 60\ \text{kN}$$

$$F_A = \left(\frac{3}{10}\right) 60 = 18\ \text{kN}$$

THE CORRECT ANSWER IS: B

FE MECHANICAL SOLUTIONS

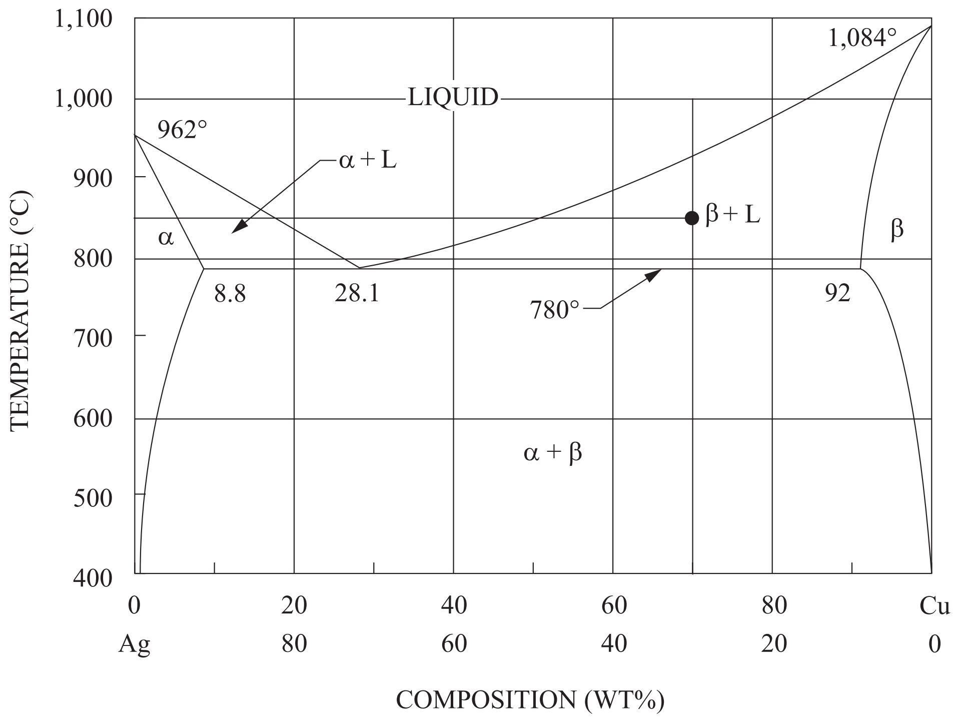
52. Refer to the Binary Phase diagrams in the Material Science/Structure of Matter chapter of the *FE Reference Handbook*.

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

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

At 850°C, β + L phases are present.



THE CORRECT ANSWER IS: D

54. 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

55. Refer to the Electrochemistry section in the Chemistry and Biology chapter and to the Corrosion section in the Materials Science/Structure of Matter chapter of the *FE Reference Handbook*.

Aluminum is anodic relative to copper and, therefore, will corrode to protect the copper.

THE CORRECT ANSWER IS: B

56. Refer to Stress Concentration in the Brittle Materials section of the Materials Science/Structure of Matter chapter of the *FE Reference Handbook.*

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

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

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

THE CORRECT ANSWER IS: B

57. Refer to the Thermal and Mechanical Processing section in the Materials Science/Structure of Matter chapter of the *FE Reference Handbook*.

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

58. Refer to the Stresses in Beams section of the Mechanics of Materials chapter of the *FE Reference Handbook.*

Maximum bending moment $= 900 \text{ mm} \times 1{,}200 \text{ N} = 1.08 \times 10^6 \text{ N·mm}$

$$\sigma_{\text{tension}} = \frac{\left(1.08 \times 10^6 \text{ N·mm}\right)(15 \text{ mm})}{11 \times 10^4 \text{ mm}^4} = 147 \text{ MPa}$$

THE CORRECT ANSWER IS: B

59. Refer to the Stress, Pressure, and Viscosity section and the Density, Specific Volume, Specific Weight, and Specific Gravity section in the Fluid Mechanics section of the *FE Reference Handbook*.

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

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

$\therefore$ the relationship between the two is:

$\upsilon = \mu/\rho$

where ρ is the density in kg/m^3

Use the definition of specific gravity to compute the fluid density.

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

THE CORRECT ANSWER IS: A

60. Refer to the Archimedes Principle and Buoyancy section in the Fluid Mechanics chapter of the *FE Reference Handbook*.

THE CORRECT ANSWER IS: D

61. Refer to the Characteristics of a Static Liquid section in the Fluid Mechanics chapter of the *FE Reference Handbook.*

Since atmospheric pressure acts above the liquid surface and on the non-wetted side of the submerged gate, the resultant force acting on the gate is:

$$F_{R_{\text{net}}} = \left(\rho g y_C \sin\theta\right) A$$

where $y_C = 1.5\,\text{m}$ and $\theta = 90°$

$$F_{R_{\text{net}}} = \left[\left(1,600\,\frac{\text{kg}}{\text{m}^3}\right)\left(9.807\,\frac{\text{m}}{\text{s}^2}\right)(1.5\,\text{m})(\sin 90°)\right](3.00\,\text{m} \times 1.00\,\text{m})\left[\frac{1\,\text{N}}{1\,\frac{\text{kg}\bullet\text{m}}{\text{s}^2}}\right]$$

$$F_{R_{\text{net}}} = 70,610\ \text{N}$$

The point of application of the resultant force is the center of pressure.

$$y_{CP} = y_C + \frac{I_{xC}}{y_C A}$$

The moment of inertia about the centroidal *x*-axis for a rectangle (from the table in the Statics chapter) is

$$I_{xC} = \frac{bh^3}{12} = \frac{(1\,\text{m})(3\,\text{m})^3}{12} = 2.25\,\text{m}^4$$

Thus,

$$y_{CP} = 1.5\,\text{m} + \frac{2.25\,\text{m}^4}{(1.5\,\text{m})(3.00\,\text{m} \times 1.00\,\text{m})} = 2.0\text{ m from fluid surface or 1.0 m above the hinge}$$

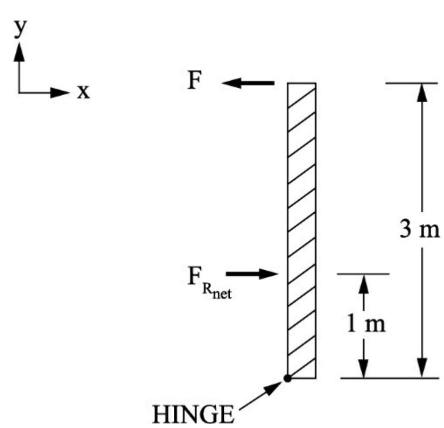
A moment balance about the hinge gives

$$\circlearrowright{+}\ \Sigma M_{\text{hinge}} = 0$$

$$(1\,\text{m})F_{R_{\text{net}}} - (3\,\text{m})F = 0$$

$$F = \frac{(1\,\text{m})(70,610\ \text{N})}{3\,\text{m}}$$

$$F = 23,537\ \text{N} = 24\ \text{kN}$$



THE CORRECT ANSWER IS: C

62. Refer to the Energy Equation section in the Fluid Mechanics chapter of the *FE Reference Handbook*.

$$\cancel{\frac{P_1}{\rho g}} + z_1 + \cancel{\frac{v_1^2}{2g}} = \cancel{\frac{P_2}{\rho g}} + \cancel{z_2} + \frac{v_2^2}{2g} + \cancel{h_f}$$

$$v_2^2 = 2gz_1$$

$$v_2 = \sqrt{2gz_1} = \sqrt{2 \times 9.81 \times 3} = 7.67 \text{ m/s}$$

THE CORRECT ANSWER IS: A

63. Refer to the Impulse-Momentum Principle section in the Fluid Mechanics chapter of the *FE Reference Handbook*.

$Q = A_1 v_1 = (0.01 \text{ m}^2)(30 \text{ m/s})$
$= 0.3 \text{ m}^3/\text{s}$

Since the water jet is deflected perpendicularly, the force **F** must deflect the total horizontal momentum of the water.

$\mathbf{F} = \rho Q v = (1{,}000 \text{ kg/m}^3)\ (0.3 \text{ m}^3/\text{s})\ (30 \text{ m/s}) = 9{,}000 \text{ N} = 9.0 \text{ kN}$

THE CORRECT ANSWER IS: B

64. Refer to the Normal Shock Relationships section in the Fluid Mechanics chapter of the *FE Reference Handbook*.

Flow in a converging/diverging nozzle transitioning from subsonic to supersonic will have Mach = 1 at the throat. Region B is the correct answer.

The flow is subsonic in the chamber, with Ma = V/c = 450/600 = 0.75, so Ma < 1 in Region A.

By definition, in a normal shock the flow slows from supersonic to subsonic. Therefore, Region C has Ma > 1 and Region D has Ma < 1. Region E expands to ambient, so it must still be subsonic Ma < 1.

THE CORRECT ANSWER IS: REGION B

65. Refer to the Continuity Equation in the Principles of One-Dimensional Fluid Flow section in the Fluid Mechanics chapter of the *FE Reference Handbook*.

The cross-sectional area of the pipe is:

$$A_c = \frac{\pi}{4} D^2 = \frac{\pi}{4}(0.10)^2 = 0.007854 \text{ m}^2$$

The flow rate is:

$Q = A_c \, v_c = 0.007854\ (2.5)(60) = 1.178 \text{ m}^3/\text{min}$

THE CORRECT ANSWER IS: B

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

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

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

$$= 0.675$$

THE CORRECT ANSWER IS: C

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67. Refer to Special Cases of Steady-Flow Energy Equation in the Steady-Flow Systems section in the Thermodynamics chapter of the *FE Reference Handbook*.

The isentropic efficiency for a pump is $\eta_p = \dfrac{w_s}{w_{actual}}$

The isentropic pump work for a constant density fluid is

$$w_s = v\Delta P = (0.001010\ \text{m}^3/\text{kg})(1{,}000\ \text{kPa} - 10\ \text{kPa}) = 0.9999\ \text{kJ/kg}$$

and the actual power required at the pump is

$$\dot{W}_a = \dot{m}w_s / \eta_p = (50\ \text{kg/s})(0.9999\ \text{kJ/kg}) / 0.7 = 71\ \text{kW}$$

THE CORRECT ANSWER IS: D

68. Refer to the Affinity Laws section in the Fluid Mechanics chapter of the *FE Reference Handbook*.

$Q_1/N_1 = Q_2/N_2$

$12/1{,}000 = 18/N_2$

$12\ N_2 = 1{,}800$

$N_2 = 1{,}500$ rpm

THE CORRECT ANSWER IS: C

69. Refer to the Thermodynamics chapter of the *FE Reference Handbook*. Use the ideal gas formula:

$$PV = mRT$$

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

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

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

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

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

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

$$= 102\ \text{kPa}$$

THE CORRECT ANSWER IS: B

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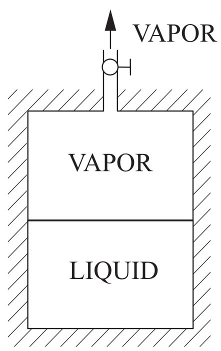
70. Refer to the State Functions and the Properties for Two-Phase (vapor-liquid) Systems sections in the Thermodynamics chapter of the *FE Reference Handbook*.

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

71. Refer to the Throttling Valve section in the Thermodynamics chapter of the *FE Reference Handbook*.

From the steam table at 250°C, the saturation pressure = 3.973 MPa

Enthalpy h_1 at 250°C = 1,085.36 kJ/kg

Through a throttling valve, $h_1 = h_2 = 1{,}085.36$ kJ/kg

At 0.2321 MPa,

$h_f = 524.99$ kJ/kg

$h_{fg} = 2{,}188.5$ kJ/kg

$h_1 = h_f + xh_{fg}$

Substituting:

$1{,}085.36 = 524.99 + x\ 2{,}188.5$

$x = 560/2{,}188.5 = 0.256$, approximately 0.26

THE CORRECT ANSWER IS: B

72. Refer to the Steady-Flow Systems section in the Thermodynamics chapter of the *FE Reference Handbook*.

An energy balance on the boiler gives:

$$\dot{Q} = \dot{m}\left(h_2 - h_1\right) = \left(\frac{50{,}000\ \text{kg}}{3{,}600\ \text{s}}\right)\left[\left(3{,}322 - 167.6\right)\ \text{kJ/kg}\right] = 43{,}811\ \text{kW} = 44\ \text{MW}$$

THE CORRECT ANSWER IS: D

73. Refer to the Steady-Flow Systems section in the Thermodynamics chapter of the *FE Reference Handbook*.

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

74. Refer to the Basic Cycles (Coefficient of Performance) section in the Thermodynamics chapter of the *FE Reference Handbook*.

$$\text{COP} = \frac{h_1 - h_4}{h_2 - h_1} \text{ and } h_4 = h_3$$

$$h_2 - h_1 = 438 - 394 = 44\ \text{kJ/kg}$$

$$\frac{h_1 - h_4}{h_2 - h_1} = \frac{124\ \text{kJ/kg}}{44} = 2.82$$

THE CORRECT ANSWER IS: C

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75. Refer to PVT Behavior section in the Thermodynamics chapter of the *FE Reference Handbook*.

$$Pv = RT \Rightarrow v = \frac{\left(\frac{\overline{R}}{M}\right)T}{P}$$

$\overline{R}$ = universal gas constant = 8.314 kPa·m^3/(kmol·K)

and $\dot{m} = \rho Q = \frac{Q}{v} = \frac{MPQ}{T\left(\overline{R}\right)}$

Solve for mass flow rate:

$$\text{Mass flow rate} = \frac{(30\,\text{kg/kmol})(420\,\text{kPa})(30\,\text{m}^3/\text{s})}{(350\,\text{K})(8.314\,\text{kPa}\cdot\text{m}^3/\text{kmol}\cdot\text{K})} = \frac{378{,}000}{2909.9} = 129.9\,\text{kg/s}$$

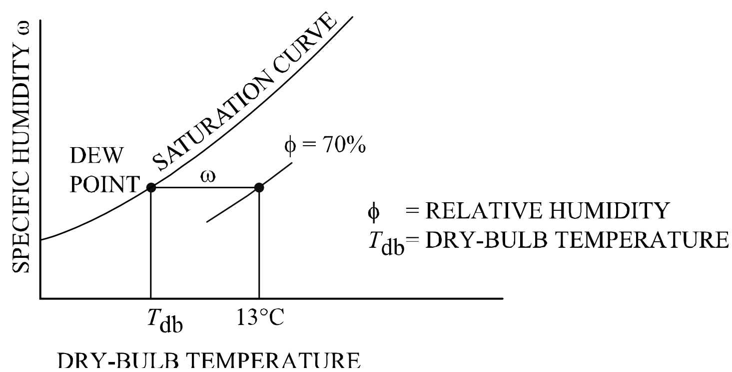
Nozzles max produce 50 kg/s:

$$\frac{129.9\,\text{kg/s}}{50\,\text{kg/s per nozzle}} = 2.6 \text{ nozzles}$$

The machine will require 3 nozzles.

THE CORRECT ANSWER IS: 3

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



At the given state, $T_{db} = 13°\text{C}$, $\phi = 70\%$, $\omega = 6.5\frac{\text{g}}{\text{kg da}}$, 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 $7.6°\text{C}$.

THE CORRECT ANSWER IS: B

77. From the P-h Diagram for Refrigerant HFC-134a given in the Thermodynamics chapter of the *FE Reference Handbook*:

$$h_1 = 400 \text{ kJ/kg}$$
$$h_3 = h_4 = 257 \text{ kJ/kg}$$

Evaporator cooling is $q_{41} = h_1 - h_4 = 400\frac{\text{kJ}}{\text{kg}} - 257\frac{\text{kJ}}{\text{kg}} = 143\frac{\text{kJ}}{\text{kg}}$

THE CORRECT ANSWER IS: B

78. Refer to Combustion in Excess Air in the Combustion Processes section in the Thermodynamics chapter of the *FE Reference Handbook*.

Stoichiometric combustion of methanol is:

$$CH_3OH + 1.5\ O_2 + 1.5\ (3.76)\ N_2 \rightarrow CO_2 + 2\ H_2O + 1.5\ (3.76)\ N_2$$

In 20% excess air, multiply the air components on the reactants side by 1.2. This creates an excess of 0.3 units of air to add in order to balance on the products side.

$$CH_3OH + 1.8\ O_2 + 1.8\ (3.76)\ N_2 \rightarrow CO_2 + 2\ H_2O + 1.8\ (3.76)\ N_2 + 0.3\ O_2$$

THE CORRECT ANSWER IS: D

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79. Refer to the Thermal Resistance section in the Heat Transfer chapter of the *FE Reference Handbook*.

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

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

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

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

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

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

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

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

THE CORRECT ANSWER IS: C

80. Refer to the Conduction section in the Heat Transfer chapter 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

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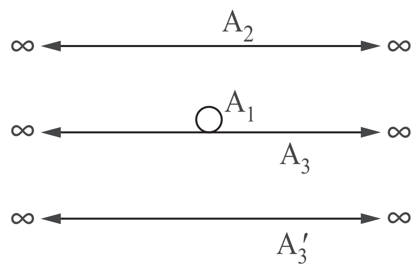
FE MECHANICAL SOLUTIONS

81. 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:

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

$$F_{12} = F_{13}$$

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

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

THE CORRECT ANSWER IS: B

82. Refer to the Radiation section in the Heat Transfer chapter of the *FE Reference Handbook*.

$$\begin{aligned} Q_{1-2} &= \sigma A_1 F_{1-2}\left(T_1^{\,4} - T_2^{\,4}\right) \\ &= 5.67\times10^{-8}(4)(0.275)\left(773^4 - 673^4\right) \\ &= 9474 = 9.47 \text{ kW} \end{aligned}$$

THE CORRECT ANSWER IS: B

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83. Refer to the Transient Conduction Using the Lumped Capacitance Model section in the Heat Transfer chapter of the *FE Reference Handbook*.

Lumped capacitance model is valid if $\frac{hv}{kA_s} \ll 1$

$v = a^3$

$A_s = 6a^2$

$\frac{v}{A_s} = \frac{a}{6}$

Option A: $\frac{h}{k} \times \frac{a}{6} = \frac{10}{1{,}000} \times \frac{2}{6} = 0.0033$

Option E: $\frac{h}{k} \times \frac{a}{6} = \frac{30}{3{,}000} \times \frac{3}{6} = 0.005$

THE CORRECT ANSWERS ARE: A, E

84. Refer to the Heat Exchangers section in the Heat Transfer chapter of the *FE Reference Handbook*.

Subscript H indicates hot fluid.
Subscript C indicates cold fluid.

$$\dot{Q} = \dot{m}_{\mathrm{H}} c_{P,\mathrm{H}} (\mathrm{T}_{\mathrm{H_{in}}} - \mathrm{T}_{\mathrm{H_{out}}})$$
$$= \dot{m}_{\mathrm{C}} c_{P,\mathrm{C}} (\mathrm{T}_{\mathrm{C_{out}}} - \mathrm{T}_{\mathrm{C_{in}}})$$

Water is the cold fluid, so:

$$\dot{m}_{\mathrm{C}} = \dot{m}_{\mathrm{H}} \frac{c_{P,\mathrm{H}}}{c_{P,\mathrm{C}}} \left(\frac{\Delta \mathrm{T_H}}{\Delta \mathrm{T_C}} \right)$$
$$= (2.25 \text{ kg/s}) \left(\frac{3.5}{4.186} \right) \left(\frac{204-79}{79-29} \right)$$
$$= (2.25)(0.836) \left(\frac{125}{50} \right) = 4.70$$

THE CORRECT ANSWER IS: B

85. Refer to the Heat Exchangers section in the Heat Transfer chapter of the *FE Reference Handbook*.

$$\Delta T_{lm} = \frac{\left(T_{\mathrm{H_o}} - T_{\mathrm{C_i}}\right) - \left(T_{\mathrm{H_i}} - T_{\mathrm{C_o}}\right)}{\ln\left(\dfrac{T_{\mathrm{H_o}} - T_{\mathrm{C_i}}}{T_{\mathrm{H_i}} - T_{\mathrm{C_o}}}\right)} \text{ for counterflow HE}$$

$$\Delta T_{lm} = \frac{(65°\mathrm{C} - 24°\mathrm{C}) - (110°\mathrm{C} - 60°\mathrm{C})}{\ln\left(\dfrac{65°\mathrm{C} - 24°\mathrm{C}}{110°\mathrm{C} - 60°\mathrm{C}}\right)}$$

$$\Delta T_{lm} = 45.4°\mathrm{C}$$

THE CORRECT ANSWER IS: C

86. Refer to the Resistance Temperature Detector (RTD) section in the Instrumentation, Measurement, and Controls chapter of the *FE Reference Handbook*.

$$R = R_o\,[1 + \alpha(T - T_o)]$$

$$\Delta R = \frac{dR}{dT}\Delta T$$

$$= R_o \alpha \Delta T$$

$$= (100\ \Omega)\ (0.004°\mathrm{C}^{-1})\ (10°\mathrm{C})$$

$$= 4.0\ \Omega$$

THE CORRECT ANSWER IS: C

87. Refer to the Resistance Temperature Detector (RTD) section in the Instrumentation, Measurement, and Controls chapter of the *FE Reference Handbook*.

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 $U_T = 2.55°\mathrm{C}$

THE CORRECT ANSWER IS: D

88. Refer to the Resistance Temperature Detector (RTD) section in the Instrumentation, Measurement, and Controls chapter of the *FE Reference Handbook*.

Rewriting the temperature equation,

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

For $T(t) = 139°C$,

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

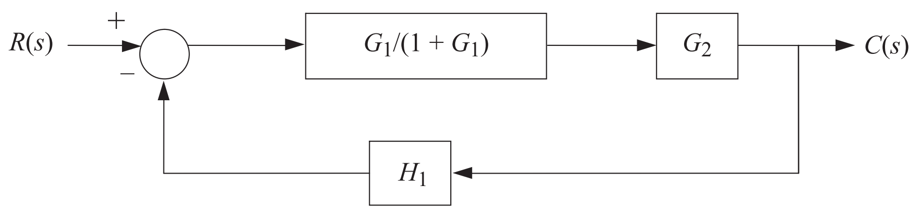
or $t = 3 \ln 100 = 13.8$ s

THE CORRECT ANSWER IS: D

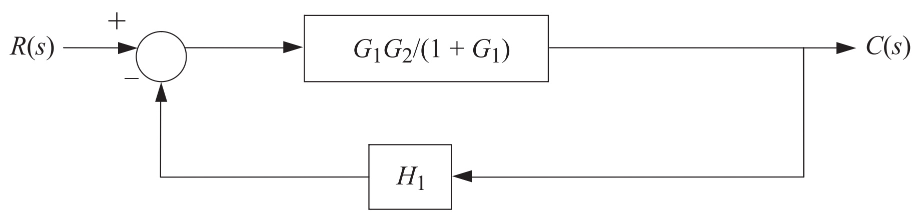
89. Refer to the Control Systems section in the Instrumentation, Measurement, and Controls chapter of the *FE Reference Handbook.*

The solution requires a step-by-step reduction of the system loops.

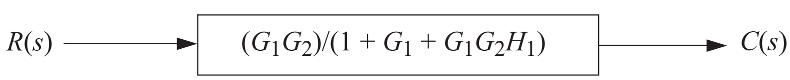
First, reduce the inner loop.



Next, combine the forward blocks.



Finally, reduce the outer loop.



THE CORRECT ANSWER IS: D

90. Refer to the Second-Order Control System Models section in the Instrumentation, Measurement, and Controls chapter of the *FE Reference Handbook*.

The equation of the system can be written as $\dfrac{16}{s\left(s^2+0.8s+16\right)}$ which is in the form

$$\frac{16}{s\left(s^2+2\zeta\omega_n\ s+\omega_n{}^2\right)}$$

thus $\omega_n{}^2=16$ or $\omega_n=4$

and $2\zeta\,\omega_n=0.8$ or $\zeta=\dfrac{0.8}{2\omega_n}=0.1$

THE CORRECT ANSWER IS: C

91. Refer to the Static Loading Failure Theories section in the Mechanical Engineering chapter of the *FE Reference Handbook*.

Maximum shear stress theory is used for the ductile material.

Calculate $\tau_{max}=(\sigma_1-\sigma_3)/2$ and compare with $S_y/2$.

Stress	A	B	C	D	E	F
Calculated τ_{max}	35	12	40	18	40	10
$\tau_{max}>17$?	fails	12–ok	fails	fails	fails	10–ok

THE CORRECT ANSWERS ARE: A, C, D, E

92. 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

$d = 2.34 \text{ mm}$

$d_o = 15 \text{ mm}$

$D = d_o - d = 15 - 2.34 = 12.66 \text{ mm}$

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

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

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

THE CORRECT ANSWER IS: C

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

The force required to displace a spring an amount δ from its free length is $F = k\delta$, where k is the spring constant or rate. In this case:

δ = free length – compressed length

= 190 mm – 125 mm

= 65 mm

The force required to deflect the spring this amount is:

$F = k\delta = (38.525 \text{ N/mm})(65 \text{ mm}) = 2{,}504 \text{ N}$

THE CORRECT ANSWER IS: B

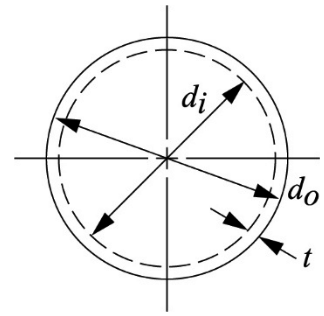
94. Refer to the Cylindrical Pressure Vessel section in the Mechanics of Materials chapter of the *FE Reference Handbook.*

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

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

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

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



THE CORRECT ANSWER IS: B

95. Refer to the Hooke's Law section in the Mechanics of Materials chapter of the *FE Reference Handbook*.

The formula for the total longitudinal strain without a temperature rise is:

$$\varepsilon_{\text{axial}} = \frac{1}{E}\left(\sigma_l - v\left(\sigma_t + \sigma_r\right)\right) = \frac{1}{210\times10^3 \text{ MPa}}\left(23.1 \text{ MPa} - 0.24\left(46.2 \text{ MPa} + 0\right)\right) = 5.72\times10^{-6}$$

This must be converted to displacement using the following formula:

$\varepsilon_{\text{axial}} = \frac{\delta l}{l}$, where l is the length of the section under consideration

$\delta l = \varepsilon_{\text{axial}} \times l$

$= 5.72 \times 10^{-6} \times 1{,}000$ mm

$= 0.0572$ mm

THE CORRECT ANSWER IS: A

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96. Refer to the Reliability section in the Industrial and Systems Engineering chapter of the *FE Reference Handbook.*

For the figure given,

$R \text{ total} = R \text{ series} \times R \text{ parallel}$

$R = 0.9 \times \left[1 - (1 - 0.75)(1 - 0.60)\right]$

$R = 0.81$

THE CORRECT ANSWER IS: D

97. 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

98. Refer to the Cantilevered Beam Slopes and Deflection section in the Mechanics of Material chapter of the *FE Reference Handbook*.

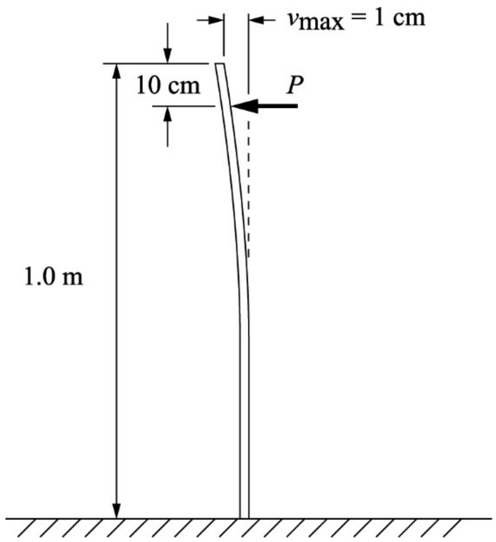
$$v_{\max} = \frac{Pa^2}{6EI}(3L-a)$$

Solve for P

$$P = \frac{6EIv_{\max}}{a^2(3L-a)}$$

$$P = \frac{(6)\left(200\times10^9\ \frac{\mathrm{N}}{\mathrm{m}^2}\right)\left(1.60\times10^{-8}\ \mathrm{m}^4\right)(0.01\ \mathrm{m})}{\left(0.81\ \mathrm{m}^2\right)(2.1\ \mathrm{m})}$$

$$P = 112.9\ \mathrm{N}$$



THE CORRECT ANSWER IS: B

99. Use the shear stress equation from the Uniaxial Loading and Deformation section in the Mechanics of Materials chapter of the *FE Reference Handbook*.

$\tau = T/A$

where

τ = shear stress
T = load = 100 N
A = area = $\pi[(15\text{ mm}/2)^2 - (5\text{ mm}/2)^2] = 157.1\text{ mm}^2$

τ = 0.63 MPa

THE CORRECT ANSWER IS: B

100. Refer to the Geometric Dimensioning and Tolerancing (GD&T) section of the Mechanical Engineering chapter of the *FE Reference Handbook*.

The 0.2 number refers to the positional tolerance of the hole.

THE CORRECT ANSWER IS: C

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