FE Other Disciplines

Free practice problems and worked solutions

This sample contains 14 original problems, one from each knowledge area, already available free on EngineerProof. The original Form A problem numbers are retained. This is a sample, not a complete 110-question exam or a predictor of your NCEES result.

Work the questions before consulting the solutions. Each solution includes the calculation and an explanation of the other choices. The full forms, contents, and purchase conditions are at:

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Included knowledge areas

Practice questions

Mathematics

2. Water drains from an inverted right circular cone, apex down, having a top radius of 3.0 m and a height of 6.0 m. The discharge is steady at 0.25 m^3/s. When the water depth is 4.0 m, the rate of fall of the free surface is most nearly:

(A) 0.0050 m/s

(B) 0.0088 m/s

(C) 0.0199 m/s

(D) 0.0597 m/s

Probability and Statistics

10. A conduit plant fills orders from three extrusion lines. Line 1 supplies 50% of output at a 2% defect rate, Line 2 supplies 30% at a 4% defect rate, and Line 3 supplies 20% at a 5% defect rate. A unit drawn at random from finished stock is found to be defective. The probability that it was produced on Line 2 is most nearly:

(A) 0.040

(B) 0.300

(C) 0.313

(D) 0.375

Chemistry

20. A groundwater supply contains 96 mg/L of magnesium ion (Mg^{2+}). Molar masses are $Mg = 24.31$ g/mol and $CaCO_3 = 100.09$ g/mol. The magnesium hardness expressed as mg/L as $CaCO_3$ is most nearly:

(A) 46.6 mg/L as $CaCO_3$

(B) 198 mg/L as $CaCO_3$

(C) 240 mg/L as $CaCO_3$

(D) 395 mg/L as $CaCO_3$

Instrumentation and Controls

23. A single active foil strain gauge occupies one arm of a Wheatstone bridge; the other three arms are fixed resistors of the same nominal resistance. Bridge excitation is 10.0 V DC, the gauge factor is 2.10, and the bridge output drives an instrumentation amplifier of gain 250. For a surface strain of 850×10^{-6} m/m, the amplifier output voltage is most nearly:

(A) 0.253 V

(B) 1.12 V

(C) 2.23 V

(D) 4.46 V

Engineering Ethics and Societal Impacts

29. An engineer resigns from a consulting firm and joins a competitor, retaining a personal copy of a pump-selection spreadsheet that the engineer wrote while employed at the former firm, using the firm's test data and firm work hours. Under the NCEES Model Rules of Professional Conduct, use of that spreadsheet on the new employer's projects is:

(A) Not permitted without the former firm's consent

(B) Permitted, the engineer being the author of the file

(C) Permitted if the former firm is credited in the deliverable

(D) Permitted once any noncompete period has expired

Safety, Health, and Environment

33. Personal sampling over a single 8-hour shift records a solvent vapor concentration of 180 ppm for 2.0 h, 95 ppm for 3.5 h, and 40 ppm for the remaining 2.5 h. The 8-hour time-weighted average exposure is most nearly:

(A) 87 ppm

(B) 99 ppm

(C) 105 ppm

(D) 126 ppm

Engineering Economics

39. A municipal wastewater pumping station incurs a maintenance cost of USD 8{,}000 at the end of year 1. The cost increases by USD 1{,}200 in each following year through the end of year 8. At an interest rate of 7% per year, the present worth of the 8-year maintenance stream is most nearly:

(A) USD 47{,}800

(B) USD 54{,}900

(C) USD 65{,}400

(D) USD 70{,}300

Statics

47. A 900 lb load hangs from a ring at joint A. The ring is held by cable AB, which runs upward to the left at 35° above the horizontal, and by cable AC, which runs upward to the right at 55° above the horizontal. The tension in cable AB is most nearly:

(A) 516 lb

(B) 630 lb

(C) 737 lb

(D) 785 lb

Dynamics

56. Gravel leaves the head pulley of a conveyor horizontally at 4.2 m/s and falls freely 3.6 m to the surface of a stockpile. Air resistance is negligible. The horizontal distance from the discharge point to the point of impact is most nearly:

(A) 2.54 m

(B) 3.08 m

(C) 3.60 m

(D) 5.09 m

Strength of Materials

66. A stepped steel anchor rod consists of a 1.2 m length of 40 mm diameter bar butt-welded to a 0.8 m length of 25 mm diameter bar. The rod carries an axial tensile load of 90 kN, and $E = 200$ GPa. The total elongation of the rod is most nearly:

(A) 0.43 mm

(B) 0.73 mm

(C) 1.16 mm

(D) 1.83 mm

Materials

77. A binary alloy of overall composition 40 wt% B is held at a temperature at which solid α and liquid coexist. At that temperature the α solidus boundary lies at 12 wt% B and the liquidus lies at 62 wt% B. The mass fraction of liquid present is most nearly:

(A) 0.30

(B) 0.44

(C) 0.45

(D) 0.56

Fluid Mechanics

84. A vertical rectangular sluice gate 4 ft wide and 6 ft high is set in the side wall of a reservoir. The top edge of the gate lies 8 ft below the free water surface, which is open to the atmosphere. Water has a specific weight of 62.4 lbf/ft^3. The resultant hydrostatic force on the gate is most nearly:

(A) 12,000 lbf

(B) 16,500 lbf

(C) 16,900 lbf

(D) 21,000 lbf

Basic Electrical Engineering

96. A 24 V DC source drives a 150 Ω resistor in series with a parallel combination of a 470 Ω resistor and a 330 Ω resistor. The voltage across the 150 Ω resistor is most nearly:

(A) 3.79 V

(B) 5.81 V

(C) 6.55 V

(D) 10.5 V

Thermodynamics and Heat Transfer

104. A binary-cycle geothermal plant produces 450 kW of net power while receiving 3.60 MW from a brine stream at 165 °C and rejecting heat to a condenser loop at 30 °C. The ratio of the plant thermal efficiency to the maximum efficiency attainable between these two temperatures is most nearly:

(A) 0.13

(B) 0.15

(C) 0.31

(D) 0.41

Worked solutions

Mathematics

Problem 2

Answer: (C)

Water drains from an inverted right circular cone, apex down, having a top radius of 3.0 m and a height of 6.0 m. The discharge is steady at 0.25 m^3/s. When the water depth is 4.0 m, the rate of fall of the free surface is most nearly:

The free surface falls about 0.0199 m/s, since at a depth of 4.0 m its area is only 4π m^2.

Geometric similarity ties the surface radius to the depth, reducing the volume to a single variable.

$$r = \frac{h}{2}$$

$$V = \frac{1}{3}\pi r^2 h = \frac{\pi h^3}{12}$$

Differentiating volume with respect to depth produces the instantaneous free-surface area, the only geometry the drain rate responds to.

$$\frac{dV}{dt} = \frac{\pi h^2}{4} \cdot \frac{dh}{dt}$$

At 4.0 m depth the surface radius is 2.0 m and the surface area is 4π m^2, so the level drops at

$$\frac{dh}{dt} = \frac{0.25}{4\pi} = 0.0199 \text{ m/s}$$

FE REFERENCE HANDBOOK — MATHEMATICS: MENSURATION OF AREAS AND VOLUMES, RIGHT CIRCULAR CONE; DIFFERENTIAL CALCULUS, THE CHAIN RULE

WHY THE OTHER CHOICES APPEAR

(A) Sets the surface radius equal to the depth, $r = h = 4.0$ m, giving $0.25/(16\pi) = 0.0050$ m/s.

(B) Uses the fixed 3.0 m top radius as the surface radius, giving $0.25/(9\pi) = 0.0088$ m/s.

(D) Divides the volume by the depth instead of differentiating, taking $dV/dh = \pi h^2/12 = 4.19$ m^2 and giving 0.0597 m/s.

Probability and Statistics

Problem 10

Answer: (D)

A conduit plant fills orders from three extrusion lines. Line 1 supplies 50% of output at a 2% defect rate, Line 2 supplies 30% at a 4% defect rate, and Line 3 supplies 20% at a 5% defect rate. A unit drawn at random from finished stock is found to be defective. The probability that it was produced on Line 2 is most nearly:

Line 2 accounts for 0.375 of all defective units, more than its 30% share of production because its defect rate runs above the plant average.

Total probability applies because the three lines partition the finished stock, so the plant-wide defect rate is the share-weighted sum of the line rates.

$$P(D) = 0.50(0.02) + 0.30(0.04) + 0.20(0.05) = 0.032$$

Bayes' theorem then rescales the 30% prior share of Line 2 by how readily that line generates the observed defect.

$$P(L_2 \mid D) = \frac{0.30(0.04)}{0.032} = \frac{0.012}{0.032} = 0.375$$

FE REFERENCE HANDBOOK — ENGINEERING PROBABILITY AND STATISTICS: BAYES' THEOREM

WHY THE OTHER CHOICES APPEAR

(A) Reports the conditional defect rate of Line 2 itself, $P(D \mid L_2) = 0.04$, rather than the reverse conditional probability.

(B) Reports the prior output share $P(L_2) = 0.30$, ignoring the defect evidence entirely.

(C) Uses the Line 1 (or Line 3) numerator by mistake, $0.010/0.032 = 0.313$.

Chemistry

Problem 20

Answer: (D)

A groundwater supply contains 96 mg/L of magnesium ion (Mg^{2+}). Molar masses are Mg = 24.31 g/mol and $CaCO_3$ = 100.09 g/mol. The magnesium hardness expressed as mg/L as $CaCO_3$ is most nearly:

Reporting the divalent magnesium on an equivalent basis yields about 395 mg/L as calcium carbonate.

Hardness reporting restates every polyvalent ion as the chemically equivalent amount of calcium carbonate, so the ion concentration must first be expressed in equivalents using its charge of 2.

$$EW_{Mg} = \frac{24.31}{2} = 12.16 \text{ g/eq}$$

$$\frac{96}{12.16} = 7.90 \text{ meq/L}$$

That same equivalent count is then priced at the equivalent weight of calcium carbonate, itself a divalent salt.

$$EW_{\text{CaCO}_3} = \frac{100.09}{2} = 50.05 \text{ g/eq}$$

$$C = 7.90(50.05) = 395 \text{ mg/L as CaCO}_3$$

FE REFERENCE HANDBOOK — CHEMISTRY: EQUIVALENT WEIGHT AND NORMALITY (HARDNESS AS CACO3)

WHY THE OTHER CHOICES APPEAR

(A) Inverts the conversion factor, multiplying the ion concentration by $24.31/50.05$ to obtain 46.6 mg/L.

(B) Mismatches the weights by dividing by the magnesium molar mass while multiplying by the carbonate equivalent weight: $(96/24.31)(50.05) = 198$ mg/L.

(C) Uses the equivalent weight of calcium (20.04 g/eq) in place of magnesium's: $(96/20.04)(50.05) = 240$ mg/L.

Instrumentation and Controls

Problem 23

Answer: (B)

A single active foil strain gauge occupies one arm of a Wheatstone bridge; the other three arms are fixed resistors of the same nominal resistance. Bridge excitation is 10.0 V DC, the gauge factor is 2.10, and the bridge output drives an instrumentation amplifier of gain 250. For a surface strain of 850×10^{-6} m/m, the amplifier output voltage is most nearly:

Only one bridge arm is active, so the bridge delivers 4.46 mV and the gain-250 stage raises it to about 1.12 V.

A quarter bridge converts the fractional resistance change of its one active arm into a differential output equal to a quarter of the excitation times that fraction.

$$\frac{\Delta R}{R} = GF \cdot \varepsilon = 2.10(850 \times 10^{-6}) = 1.785 \times 10^{-3}$$

$$V_o = \frac{V_{ex}}{4} \cdot \frac{\Delta R}{R} = \frac{10.0}{4}(1.785 \times 10^{-3}) = 4.4625 \times 10^{-3} \text{ V}$$

Gain of the signal-conditioning stage lifts this millivolt-level difference to a range a data acquisition input can resolve.

$$V_{out} = 250(4.4625 \times 10^{-3}) = 1.12 \text{ V}$$

FE REFERENCE HANDBOOK — INSTRUMENTATION, MEASUREMENT, AND CONTROLS: WHEATSTONE BRIDGE AND STRAIN GAUGE RELATIONS

WHY THE OTHER CHOICES APPEAR

(A) Dividing the strain by the gauge factor instead of multiplying: $(10.0/4)(850 \times 10^{-6}/2.10)(250) = 0.253$ V.

(C) Using the half-bridge sensitivity $V_{ex}/2$ in place of $V_{ex}/4$, which doubles the result to 2.23 V.

(D) Omitting the factor of 4 altogether: $(10.0)(1.785 \times 10^{-3})(250) = 4.46$ V.

Engineering Ethics and Societal Impacts

Problem 29

Answer: (A)

An engineer resigns from a consulting firm and joins a competitor, retaining a personal copy of a pump-selection spreadsheet that the engineer wrote while employed at the former firm, using the firm's test data and firm work hours. Under the NCEES Model Rules of Professional Conduct, use of that spreadsheet on the new employer's projects is:

The spreadsheet belongs to the former firm, and having written it gives the engineer no right to carry it to a competitor.

Ownership of designs, data, and tools created within the scope of employment rests with the employer, so authorship by itself confers no right to carry the product to a competitor.

Attribution and the expiry of a noncompete answer different obligations, since credit is not a license to copy and a noncompete restrains employment rather than the use of proprietary material, which stays protected indefinitely.

Consent from the former firm is the only condition under which the file may be used, and absent that consent the engineer must rebuild the selection method from published data and public correlations.

FE REFERENCE HANDBOOK — ETHICS AND PROFESSIONAL PRACTICE: INTELLECTUAL PROPERTY

WHY THE OTHER CHOICES APPEAR

(B) Equates authorship with ownership, an error that ignores the work-for-hire principle governing material produced on firm time with firm resources.

(C) Treats attribution as a substitute for permission, confusing the duty to credit others' work with the separate requirement of a license to use it.

(D) Applies the expiry of an employment restraint to a property right, which does not lapse on the noncompete schedule.

Safety, Health, and Environment

Problem 33

Answer: (B)

Personal sampling over a single 8-hour shift records a solvent vapor concentration of 180 ppm for 2.0 h, 95 ppm for 3.5 h, and 40 ppm for the remaining 2.5 h. The 8-hour time-weighted average exposure is most nearly:

Weighted by duration over the full 8 h shift, the three intervals average about 99 ppm.

A time-weighted average charges each measured concentration for the fraction of the shift over which it persisted, so the three intervals enter as a duration-weighted sum, not as a plain average of concentrations.

$$\text{TWA} = \frac{\sum C_i T_i}{\sum T_i}$$

Every interval belongs in the numerator, including the low-concentration period, since the denominator is the full 8 h shift.

$$\text{TWA} = \frac{(2.0)(180) + (3.5)(95) + (2.5)(40)}{8.0} = \frac{792.5}{8.0}$$

$$\text{TWA} = 99.1 \text{ ppm}$$

FE REFERENCE HANDBOOK — SAFETY, HEALTH, AND ENVIRONMENT: INDUSTRIAL HYGIENE, TIME-WEIGHTED AVERAGE EXPOSURE

WHY THE OTHER CHOICES APPEAR

(A) Drops the 2.5 h at 40 ppm from the numerator while retaining 8.0 h in the denominator: 692.5/8.0 = 86.6 ppm.

(C) Averages the three concentrations without duration weighting: (180+95+40)/3 = 105 ppm.

(D) Treats the 40 ppm period as non-exposure and divides the remaining 692.5 ppm-h by only 5.5 h of exposure: 126 ppm.

Engineering Economics

Problem 39

Answer: (D)

A municipal wastewater pumping station incurs a maintenance cost of USD 8{,}000 at the end of year 1. The cost increases by USD 1{,}200 in each following year through the end of year 8. At an interest rate of 7% per year, the present worth of the 8-year maintenance stream is most nearly:

Base series and gradient together discount to a present worth of about USD 70{,}300.

Costs that grow by a constant amount each year separate into a uniform base series of USD 8{,}000 and an arithmetic gradient of USD 1{,}200 whose first increment falls at the end of year 2.

$$P = A\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right] + G\left(\frac{1}{i}\right)\left[\frac{(1+i)^n - 1}{i(1+i)^n} - \frac{n}{(1+i)^n}\right]$$

At 7% over eight years the two factors take the values below, with $1.07^8 = 1.71819$.

$$(P/A, 7\%, 8) = \frac{1.71819 - 1}{0.07(1.71819)} = 5.9713$$

$$(P/G, 7\%, 8) = \frac{1}{0.07}\left[5.9713 - \frac{8}{1.71819}\right] = 18.789$$

Gradient growth supplies almost a third of the obligation, so a reserve sized on the first-year cost alone falls badly short.

$$P = 8,000(5.9713) + 1,200(18.789) = 47,770 + 22,547 = 70,317$$

FE REFERENCE HANDBOOK — ENGINEERING ECONOMICS: UNIFORM SERIES PRESENT WORTH FACTOR AND UNIFORM GRADIENT PRESENT WORTH FACTOR

WHY THE OTHER CHOICES APPEAR

(A) Discounting only the uniform USD 8,000 base, 8,000(5.9713) = 47,770, discards the gradient entirely.

(B) Treating the whole stream as a uniform USD 9,200 (the year-2 amount) gives 9,200(5.9713) = 54,936.

(C) Using (P/G, 7%, 7) = 14.7149, from counting the seven gradient steps as the factor's period count, gives 47,770 + 17,658 = 65,428.

Statics

Problem 47

Answer: (A)

A 900 lb load hangs from a ring at joint A. The ring is held by cable AB, which runs upward to the left at 35° above the horizontal, and by cable AC, which runs upward to the right at 55° above the horizontal. The tension in cable AB is most nearly:

Cable AB carries 516 lb, the projection of the 900 lb weight onto its own line.

Cable inclinations that sum to 90° make the two cables mutually perpendicular, so the vertical load resolves along each cable line without solving simultaneous equations.

$$35^\circ + 55^\circ = 90^\circ$$

Projecting the 900 lb weight onto the AB direction gives that cable's share of the load.

$$T_{AB} = W \sin 35^\circ = 900(0.5736) = 516 \text{ lb}$$

FE REFERENCE HANDBOOK — STATICS: EQUILIBRIUM REQUIREMENTS, CONCURRENT FORCE SYSTEMS

WHY THE OTHER CHOICES APPEAR

(B) Uses $900 \tan 35^\circ = 630$ lb, treating the weight as the adjacent side of the angle.

(C) Uses $900 \cos 35^\circ = 737$ lb, which is the tension in cable AC, not AB.

(D) Assumes both cables are inclined at 35°, giving $900/(2 \sin 35^\circ) = 785$ lb.

Dynamics

Problem 56

Answer: (C)

Gravel leaves the head pulley of a conveyor horizontally at 4.2 m/s and falls freely 3.6 m to the surface of a stockpile. Air resistance is negligible. The horizontal distance from the discharge point to the point of impact is most nearly:

A 0.857 s fall paired with an unchanged 4.2 m/s horizontal velocity puts the impact point 3.60 m from the discharge point.

Vertical motion is free fall from rest, so the drop height alone fixes the flight time.

$$t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2(3.6\ \text{m})}{9.81\ \text{m/s}^2}} = 0.857\ \text{s}$$

Horizontal velocity is constant because no horizontal force acts during flight.

$$x = v_0 t = (4.2\ \text{m/s})(0.857\ \text{s}) = 3.60\ \text{m}$$

FE REFERENCE HANDBOOK — DYNAMICS: PARTICLE KINEMATICS, PROJECTILE MOTION

WHY THE OTHER CHOICES APPEAR

(A) Omits the factor 2 inside the radical, using t = sqrt(h/g) = 0.606 s, which gives 4.2(0.606) = 2.54 m.

(B) Solves h = gt^2/2 incorrectly as t = 2h/g = 0.734 s, giving 4.2(0.734) = 3.08 m.

(D) Reports the straight-line distance from discharge point to impact point, sqrt(3.60^2 + 3.60^2) = 5.09 m, instead of the horizontal distance.

Strength of Materials

Problem 66

Answer: (C)

A stepped steel anchor rod consists of a 1.2 m length of 40 mm diameter bar butt-welded to a 0.8 m length of 25 mm diameter bar. The rod carries an axial tensile load of 90 kN, and $E = 200$ GPa. The total elongation of the rod is most nearly:

The slender 25 mm portion supplies most of the movement, and the two series stretches add to about 1.16 mm at the loaded end.

Series segments transmit the identical 90 kN, so each one deforms according to its own area.

$$A_1 = \frac{\pi(40)^2}{4} = 1257\text{mm}^2$$

$$A_2 = \frac{\pi(25)^2}{4} = 490.9\text{mm}^2$$

The 40 mm portion is more than two and a half times as stiff per unit length, so its share stays small despite being the longer piece.

$$\delta_1 = \frac{90,000(1200)}{1257(200,000)} = 0.430 \text{ mm}$$

$$\delta_2 = \frac{90,000(800)}{490.9(200,000)} = 0.733 \text{ mm}$$

Compatibility places the free-end movement at the sum of the two segment stretches.

$$\delta = 0.430 + 0.733 = 1.16 \text{ mm}$$

FE REFERENCE HANDBOOK — MECHANICS OF MATERIALS: UNIAXIAL LOADING AND DEFORMATION

WHY THE OTHER CHOICES APPEAR

(A) Counts only the 40 mm segment, 90,000(1200)/[1257(200,000)] = 0.430 mm, ignoring the smaller bar.

(B) Counts only the 25 mm segment, 90,000(800)/[490.9(200,000)] = 0.733 mm.

(D) Applies the full 2.0 m length to the 25 mm area, 90,000(2000)/[490.9(200,000)] = 1.83 mm.

Materials

Problem 77

Answer: (D)

A binary alloy of overall composition 40 wt% B is held at a temperature at which solid α and liquid coexist. At that temperature the α solidus boundary lies at 12 wt% B and the liquidus lies at 62 wt% B. The mass fraction of liquid present is most nearly:

Slightly more than half the alloy is molten, because the lever arm opposite the liquid spans 28 of the 50 wt% tie line.

Tie-line geometry sets the phase amounts: the fraction of one phase uses the arm on the far side of the overall composition.

$$W_L = \frac{C_0 - C_\alpha}{C_L - C_\alpha}$$

With the tie line running from 12 to 62 wt% B, the full length is 50 wt% and the arm opposite the liquid measures 28 wt%.

$$W_L = \frac{40 - 12}{62 - 12} = 0.56$$

FE REFERENCE HANDBOOK — MATERIALS SCIENCE/STRUCTURE OF MATTER: BINARY PHASE DIAGRAMS, LEVER RULE

WHY THE OTHER CHOICES APPEAR

(A) Forms the ratio of the α boundary composition to the overall composition, $12/40 = 0.30$, instead of using a lever arm.

(B) Inverts the lever and reports the arm adjacent to the liquidus, $(62 - 40)/50 = 0.44$, which is the α fraction.

(C) Divides the correct arm by the liquidus composition rather than the tie-line length, $28/62 = 0.45$.

Fluid Mechanics

Problem 84

Answer: (B)

A vertical rectangular sluice gate 4 ft wide and 6 ft high is set in the side wall of a reservoir. The top edge of the gate lies 8 ft below the free water surface, which is open to the atmosphere. Water has a specific weight of 62.4 lbf/ft^3. The resultant hydrostatic force on the gate is most nearly:

The gate's centroid lies 11 ft below the surface, and pressure at that depth acting over the whole gate gives a resultant near 16,500 lbf.

Hydrostatic pressure grows linearly with depth, so the resultant on a plane area is the centroidal pressure acting over the whole area.

$$h_c = 8 + \frac{6}{2} = 11 \text{ ft}$$

$$A = 4(6) = 24 \text{ft}^2$$

The second moment of area shifts the line of action below the centroid but leaves the magnitude untouched.

$$F = \gamma h_c A = 62.4(11)(24) = 16,474 \text{ lbf}$$

FE REFERENCE HANDBOOK — FLUID MECHANICS: FORCES ON SUBMERGED SURFACES, RESULTANT FORCE ON A PLANE SURFACE

WHY THE OTHER CHOICES APPEAR

(A) Takes the top-edge depth of 8 ft as the centroidal depth: $62.4(8)(24) = 11,980$ lbf.

(C) Uses the center-of-pressure depth 11.27 ft in the force equation: $62.4(11.27)(24) = 16,880$ lbf.

(D) Takes the bottom-edge depth of 14 ft as the centroidal depth: $62.4(14)(24) = 20,970$ lbf.

Basic Electrical Engineering

Problem 96

Answer: (D)

A 24 V DC source drives a 150 Ω resistor in series with a parallel combination of a 470 Ω resistor and a 330 Ω resistor. The voltage across the 150 Ω resistor is most nearly:

Because the parallel pair reduces to 194 Ω, the 150 Ω series element claims about 10.5 V of the 24 V supply.

Parallel branches reduce first, since only their equivalent shares the loop with the 150 Ω element.

$$R_p = \frac{470 \times 330}{470 + 330} = 193.9\ \Omega$$

Loop current is fixed by the total series resistance seen by the source.

$$R_T = 150 + 193.9 = 343.9\ \Omega$$

$$I = \frac{24}{343.9} = 0.0698\ \text{A}$$

Series element voltage follows from that shared current, with the balance appearing across the parallel pair.

$$V_{150} = 0.0698 \times 150 = 10.5\ \text{V}$$

$$V_p = 24 - 10.5 = 13.5\ \text{V}$$

FE REFERENCE HANDBOOK — ELECTRICAL AND COMPUTER ENGINEERING: RESISTORS IN SERIES AND PARALLEL, VOLTAGE DIVISION

WHY THE OTHER CHOICES APPEAR

(A) Adds the two branch resistors as if in series, 470 + 330 = 800 ohm, giving 24(150)/950 = 3.79 V.

(B) Ignores the 330 ohm branch entirely, giving 24(150)/(150 + 470) = 5.81 V.

(C) Uses the arithmetic mean of the branch resistors, 400 ohm, giving 24(150)/550 = 6.55 V.

Thermodynamics and Heat Transfer

Problem 104

Answer: (D)

A binary-cycle geothermal plant produces 450 kW of net power while receiving 3.60 MW from a brine stream at 165 °C and rejecting heat to a condenser loop at 30 °C. The ratio of the plant thermal efficiency to the maximum efficiency attainable between these two temperatures is most nearly:

An actual efficiency of 12.5 percent sits at about 41 percent of the 30.8 percent reversible ceiling set by the 438 K and 303 K reservoirs.

The reversible limit between the same two reservoirs fixes the benchmark, and both temperatures enter on the absolute scale.

$$\eta_{Carnot} = 1 - \frac{T_L}{T_H} = 1 - \frac{303}{438} = 0.308$$

Plant performance follows from the metered energy streams once the net power and the brine heat input carry the same units.

$$\eta_{th} = \frac{W_{net}}{Q_H} = \frac{450}{3600} = 0.125$$

Their quotient is the second-law efficiency, which the Kelvin-Planck statement holds below unity for any real engine and which lands near two-fifths for low-temperature organic Rankine hardware.

$$\eta_{II} = \frac{0.125}{0.308} = 0.41$$

FE REFERENCE HANDBOOK — THERMODYNAMICS: CARNOT CYCLE EFFICIENCY AND POWER CYCLE THERMAL EFFICIENCY

WHY THE OTHER CHOICES APPEAR

(A) Reports the plant thermal efficiency itself, 450/3600 = 0.125.

(B) Builds the ceiling from Celsius readings, 1 - 30/165 = 0.818, giving 0.125/0.818 = 0.153.

(C) Stops at the Carnot ceiling, 1 - 303/438 = 0.308, and offers it as the requested ratio.