PROBLEM 1 [MATHEMATICS]

5. Which of the following equations describes a circle with center at $(2,3)$ and passing through the point $(-3,-4)$?

(A) $(x+3)^2+(y+4)^2=85$

(B) $(x+3)^2+(y+2)^2=\sqrt{74}$

(C) $(x-3)^2+(y-2)^2=74$

(D) $(x-2)^2+(y-3)^2=74$

5. Substitute the known points into the center-radius form of the equation of a circle.

$$\begin{aligned} r^2 &= (x-h)^2+(y-k)^2 \\ &= (-3-2)^2+(-4-3)^2 \\ &= 74 \end{aligned}$$

The equation of the circle is

$$(x-2)^2+(y-3)^2=74$$

($r^2=74$. The radius is $\sqrt{74}$.)

The answer is (D).

PROBLEM 2 [MATHEMATICS]

Problem 21: Mathematics [E0212030006]

Evaluate the following integral.

$$\int \frac{x^2}{4+x^2}dx$$

(A) $x + 2\tan^{-1}\frac{x}{2} + C$

(B) $x - 4\tan^{-1}\frac{x}{2} + C$

(C) $x - 2\tan^{-1}\frac{x}{2} + C$

(D) $x - \tan^{-1}\frac{x}{4} + C$

Solution:

Change the integrand into two parts and then use the following formula from the integral table.

$$\int \frac{1}{a^2+x^2}dx = \frac{1}{a}\tan^{-1}\frac{x}{a} + C$$

(Note: As stated in the *NCEES Handbook*, $\frac{1}{a}\tan^{-1}\frac{x}{a} = \frac{1}{a}\arctan\frac{x}{a}$.)

$$\begin{aligned}\int \frac{x^2}{4+x^2}dx &= \int \frac{4+x^2-4}{4+x^2}dx \\ &= \int \left(1 - \frac{4}{2^2+x^2}\right)dx \\ &= x - \frac{4}{2}\tan^{-1}\frac{x}{2} + C \\ &= x - 2\tan^{-1}\frac{x}{2} + C\end{aligned}$$

Note: $a = 2$ for the second part of the integral.

The answer is C.

PROBLEM 3 [MATHEMATICS]

3. The roots of $F = \dfrac{x^3 + 6x^2 + 11x + 6}{x+1}$ are most nearly:

- ○ A. $-1, -2, -3$
- ○ B. $2, -3$
- ○ C. $-2, -3$
- ○ D. $2, 3$

3. The roots of a function are defined as points where $F = 0$.

In this case, divide the polynomials:

$$
\begin{array}{r}
x^2 + 5x + 6 \\
x+1 \overline{\big) x^3 + 6x^2 + 11x + 6} \\
\underline{x^3 + x^2} \\
5x^2 + 11x \\
\underline{5x^2 + 5x} \\
6x + 6 \\
\underline{6x + 6} \\
0
\end{array}
$$

$x^2 + 5x + 6$ factors to $(x + 2)(x + 3)$. Therefore, the roots of F are $x = -2$ and $x = -3$

THE CORRECT ANSWER IS: C

PROBLEM 4 [MATHEMATICS]

12. Force vectors **A**, **B**, and **C** are applied at a single point.

$$\mathbf{A} = \mathbf{i} + 3\mathbf{j} + 4\mathbf{k}$$
$$\mathbf{B} = 2\mathbf{i} + 7\mathbf{j} - \mathbf{k}$$
$$\mathbf{C} = -\mathbf{i} + 4\mathbf{j} + 2\mathbf{k}$$

What is most nearly the magnitude of the resultant force vector, **R**?

(A) 13

(B) 14

(C) 15

(D) 16

12. The magnitude of **R** is

$$\begin{aligned} |\mathbf{R}| &= \sqrt{(1+2-1)^2 + (3+7+4)^2 + (4-1+2)^2} \\ &= \sqrt{4+196+25} \\ &= \sqrt{225} \\ &= 15 \end{aligned}$$

The answer is (C).

PROBLEM 5 [PROBABILITY AND STATISTICS]

5. A study has a sample size of 5, a standard deviation of 10.4, and a sample standard deviation of 11.6. What is most nearly the variance?

(A) 46

(B) 52

(C) 110

(D) 130

5. The variance is

$$\sigma^2 = (10.4)^2 = 108 \quad (110)$$

The answer is (C).

PROBLEM 6 [PROBABILITY AND STATISTICS]

12. A simulation model for a transportation system is run for 30 replications, and the mean percentage utilization of the transporter used by the system is recorded for each replication. Those 30 data points are then used to form a confidence interval on mean transporter utilization for the system. At a 95% confidence level, the confidence interval is found to be 37.2% ± 3.4%.

Given this information, which of the following facts can be definitively stated about the system?

(A) At 95% confidence, the sample mean of transporter utilization lies in the range 37.2% ± 3.4%.

(B) At 95% confidence, the population mean of transporter utilization lies in the range 37.2% ± 3.4%.

(C) At 95% confidence, the population mean of transporter utilization lies outside of the range of 37.2% ± 3.4%.

(D) At 5% confidence, the population mean of transporter utilization lies inside of the range of 37.2% ± 3.4%.

12. A 95% confidence interval on mean transporter utilization means there is a 95% chance the population (or true) mean transporter utilization lies within the given interval.

The answer is (B).

PROBLEM 7 [PROBABILITY AND STATISTICS]

Problem 5: Eng Probability and Statistics [P0208160431]

You would like to test the null hypothesis at a 5% level of significance that the mean shear strength of spot welds is at least 450 psi. You randomly select 15 welds, measure the shear strength, and determine the following results.

sample mean ($\bar{x}$): 445 psi

sample standard deviation (s): 10 psi

Based upon the data,

(A) the null hypothesis is true
(B) the null hypothesis is false
(C) there is not enough information to say the hypothesis is true
(D) there is not enough information to say the hypothesis is false

Solution:

$$H_0: \mu \geq 450$$
$$H_1: \mu < 450$$

Accept hypothesis H_0 if

$$\frac{\bar{x}-450}{\frac{s}{\sqrt{15}}} \geq -t_{0.05,14} = -1.761$$

$$t = \frac{445-450}{\frac{10}{\sqrt{15}}} = -1.936$$

$$-1.936 < -1.761$$

Reject H_0.

The answer is B.

PROBLEM 8 [COMPUTATIONAL TOOLS]

15. A typical spreadsheet for economic evaluation of alternatives uses cell F4 to store the percentage value of inflation rate. The percentage rate is assumed to be constant throughout the lifetime of the study. What variable should be used to access that value throughout the model?

(A) F4

(B) $F4

(C) %F4

(D) F4

15. The dollar sign symbol, "$", is used in spreadsheets to "fix" the column and/or row designator following it when other columns or rows are permitted to vary.

The answer is (D).

PROBLEM 9 [COMPUTATIONAL TOOLS]

11. A spreadsheet display shows the following values in Column A:

	A	B
1	−2	
2	−1	
3	0	
4	1	
5	2	

Cell B1 contains the formula $A1^3 + A$1^2 − 3. The formula in Cell B1 is copied down in Column B with automatic cell referencing. The formula in Cell B5 will be:

- ○ A. $A1^3 + A$5^2 – 3
- ○ B. A5^3 + B$1^2 – 3
- ○ C. $A5^3 + A$1^2 – 3
- ○ D. A5^3 + A5^2 – 3

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

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

In spreadsheet equation format, the formula in Cell B5 is

$A5^3 + A$1^2 – 3

THE CORRECT ANSWER IS: C

PROBLEM 10 [COMPUTATIONAL TOOLS]

13. The following segment of pseudocode describes a segment of a computer program:

```
Set A = 17
Set K = 2
While K ≤ 4
   A = A/K
   K = K + 1
End While
Print A
```

The value of A that is printed is most nearly:

- A. 0.71
- B. 2.83
- C. 4.25
- D. 408

13. K = 2 gives A = 17/2 = 8.5
K = 3 gives A = 8.5/3 = 2.83
K = 4 gives A = 2.83/4 = 0.71

THE CORRECT ANSWER IS: A

PROBLEM 11 [ETHICS AND PROFESSIONAL PRACTICE]

15. 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

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

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

THE CORRECT ANSWER IS: C

PROBLEM 12 [ETHICS AND PROFESSIONAL PRACTICE]

Problem 15: Ethics and Business Practices [P0302200171]
A civil engineer is contracted to design a parking structure that includes the design of a large power transformer. Which of the following actions should the engineer take?

(A) The engineer should refuse the project.
(B) The engineer may design the structure, but must contract out the design of the power transformer to an electrical engineer.
(C) The engineer may design the parking structure, but must ask the client to find an electrical engineer to design the power transformer.
(D) The engineer may design both the structure and the transformer.

Solution:

Since the engineer lacks the required competency, he cannot design the transformer. He must therefore contract out the design of the transformer, but he can find an electrical engineer himself.

The answer is B.

PROBLEM 13 [ENGINEERING ECONOMICS]

1. Permanent mineral rights on a parcel of land are purchased for an initial lump-sum payment of \$100,000. Profits from mining activities are \$12,000 each year, and these profits are expected to continue indefinitely. The interest rate earned on the initial investment is most nearly

(A) 8.3%

(B) 9.0%

(C) 10%

(D) 12%

1. Use the capitalized cost equation to find the interest rate earned.

$$P = \frac{A}{i}$$

$$i = \frac{A_{\text{profit}}}{P_{\text{cost}}} = \frac{\$12{,}000}{\$100{,}000} = 0.12 \quad (12\%)$$

The answer is (D).

PROBLEM 14 [ENGINEERING ECONOMICS]

20. You must choose between four pieces of comparable equipment based on the costs and salvage values given below. All four pieces have a life of 8 years.

Parameter	Equipment			
	A	**B**	**C**	**D**
First cost	\$25,000	\$35,000	\$20,000	\$40,000
Annual costs	\$8,000	\$6,000	\$9,000	\$5,000
Salvage value	\$2,500	\$3,500	\$2,000	\$4,000

The discount rate is 12%. Ignore taxes. The two most preferable projects and the approximate difference between their present worth values based on least cost are:

- ○ A. A and C, \$170
- ○ B. B and D, \$170
- ○ C. A and C, \$234
- ○ D. B and D, \$234

20. The easiest way to solve this problem is to look at the present worth of each option.

The present worth values are all given by:

$$P = \text{First Cost} + \text{Annual Cost} \times (P/A, 12\%, 8) - \text{Salvage Value} \times (P/F, 12\%, 8)$$
$$= \text{First Cost} + \text{Annual Cost} \times 4.9676 - \text{Salvage Value} \times 0.4039$$

Then $P(\text{A}) = \$63{,}731$
$P(\text{B}) = \$63{,}392$
$\text{P(C)} = \$63{,}901$
$P(\text{D}) = \$63{,}222$

The cash flows are all costs, so the two most preferable projects, those with the lowest present worth costs, are B and D, and the difference between them is \$170.

THE CORRECT ANSWER IS: B

PROBLEM 15 [ENGINEERING ECONOMICS]

13. A computer with a useful life of five years has an initial cost of \$6000. The salvage value is \$2300, and the annual maintenance is \$210/yr. The interest rate is 8%. What is most nearly the present worth of the costs for the computer?

(A) \$5200

(B) \$5300

(C) \$5600

(D) \$5700

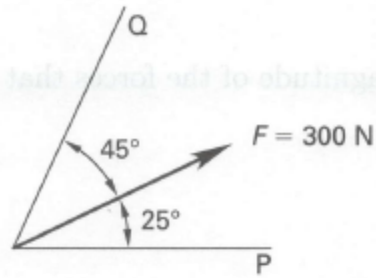
13. Bring all costs and benefits into the present.

$$\begin{aligned} P_{\text{total}} &= P_{\text{initial}} + P_{\text{maintenance}} - P_{\text{salvage}} \\ &= \$6000 + (\$210)(P/A, 8\%, 5) \\ &\quad - (\$2300)(P/F, 8\%, 5) \\ &= \$6000 + (\$210)(3.9927) \\ &\quad - (\$2300)(0.6806) \\ &= \$5273 \quad (\$5300) \end{aligned}$$

The answer is (B).

PROBLEM 16 [STATICS]

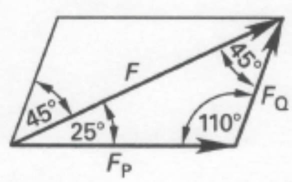
1. In the system shown, force F, line P, and line Q are coplanar.



Resolve the 300 N force into two components, one along line P and the other along line Q.

(A) $F_Q = 272$ N; $F_P = 126$ N
(B) $F_Q = 232$ N; $F_P = 186$ N
(C) $F_Q = 135$ N; $F_P = 226$ N
(D) $F_Q = 212$ N; $F_P = 226$ N

1. One of the characteristics of the components of a force is that they combine as vectors into the total force. Draw the vector addition triangle and determine all of the angles and sides.



Use the law of sines to calculate the components.

$$\frac{F}{\sin 110°} = \frac{F_Q}{\sin 25°} = \frac{F_P}{\sin 45°}$$

$$\frac{300\ \text{N}}{\sin 110°} = \frac{F_Q}{\sin 25°} = \frac{F_P}{\sin 45°}$$

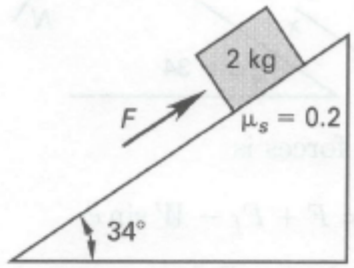
$$F_Q = (300\ \text{N})\frac{\sin 25°}{\sin 110°} = 134.9\ \text{N} \quad (135\ \text{N})$$

$$F_P = (300\ \text{N})\frac{\sin 45°}{\sin 110°} = 225.7\ \text{N} \quad (226\ \text{N})$$

The answer is (C).

PROBLEM 17 [STATICS]

1. A 2 kg block rests on a 34° incline.



If the coefficient of static friction is 0.2, approximately how much additional force, F, must be applied to keep the block from sliding down the incline?

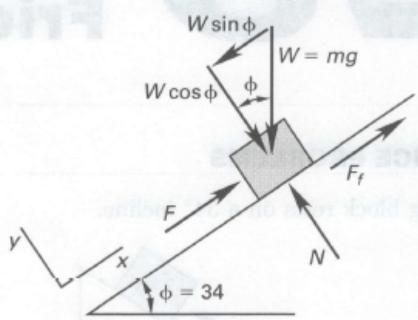
(A) 7.7 N

(B) 8.8 N

(C) 9.1 N

(D) 14 N

1. Choose coordinate axes parallel and perpendicular to the incline.



The sum of the forces is

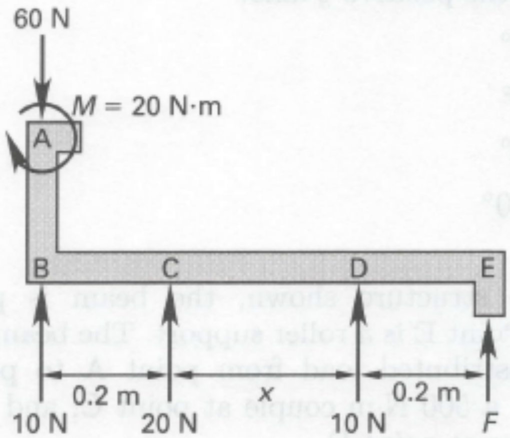
$$\sum F_x = 0 = F + F_f - W\sin\phi$$

$$\begin{aligned} F &= W\sin\phi - F_f \\ &= mg\sin\phi - \mu_s N \\ &= mg\sin\phi - \mu_s mg\cos\phi \\ &= mg(\sin\phi - \mu\cos\phi) \\ &= (2\text{ kg})\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)\left(\sin 34^\circ - 0.2\cos 34^\circ\right) \\ &= 7.7\text{ N} \end{aligned}$$

The answer is (A).

PROBLEM 18 [STATICS]

4. A bent beam is acted upon by a moment and several concentrated forces, as shown.



Approximate the unknown force, F, and distance, x, that will maintain equilibrium on the beam.

(A) $F = 5$ N; $x = 0.8$ m
(B) $F = 10$ N; $x = 0.6$ m
(C) $F = 20$ N; $x = 0.2$ m
(D) $F = 20$ N; $x = 0.4$ m

4. The sum of the forces in the y-direction is

$$\begin{aligned}\sum F_y &= 0\\ &= -60\text{ N} + 10\text{ N} + 20\text{ N} + 10\text{ N} + F\\ F &= 20\text{ N}\end{aligned}$$

Clockwise moments are positive. The sum of the moments around point A is

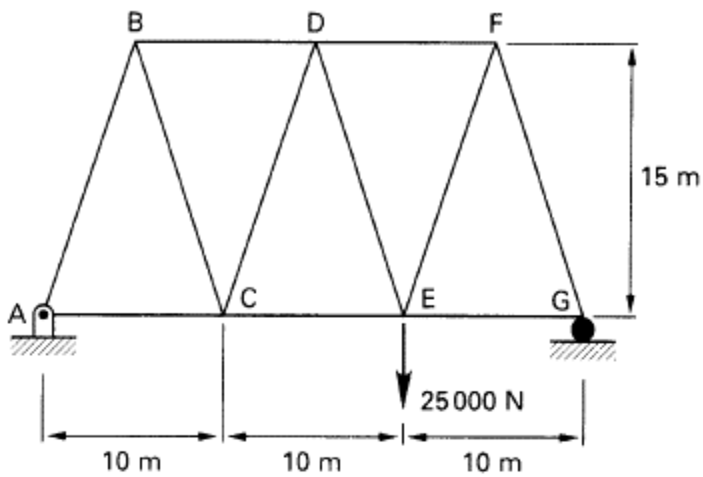
$$\begin{aligned}\sum M_A &= 0\\ &= 20\text{ N·m} - (20\text{ N})(0.2\text{ m})\\ &\quad - (10\text{ N})(0.2\text{ m} + x) - (20\text{ N})(0.4\text{ m} + x)\end{aligned}$$

$$\begin{aligned}4 + 2 + 10x + 8 + 20x &= 20\\ 30x &= 6\\ x &= 0.2\text{ m}\end{aligned}$$

The answer is (C).

PROBLEM 19 [STATICS]

2. Find the approximate force in member DE for the truss shown.



(A) 0 N

(B) 6300 N

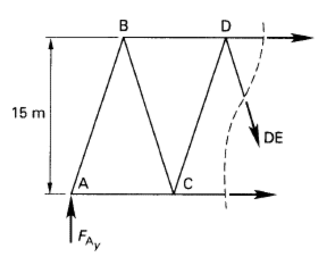
(C) 8800 N

(D) 10 000 N

2. Take moments about point G.

$$\begin{aligned}\sum M_G &= 0 \\ &= (-25\,000 \text{ N})(10 \text{ m}) + F_{A_y}(30 \text{ m}) \\ F_{A_y} &= 8333 \text{ N} \quad \text{[upward]}\end{aligned}$$

Use the method of sections.



$$\begin{aligned}\sum F_y &= 0 \\ &= 8333 \text{ N} - \text{DE}_y \\ \text{DE}_y &= 8333 \text{ N} \\ \text{DE}_x &= (8333 \text{ N})\left(\frac{5 \text{ m}}{15 \text{ m}}\right) \\ &= 2778 \text{ N} \\ \text{DE} &= \sqrt{(8333 \text{ N})^2 + (2778 \text{ N})^2} \\ &= 8784 \text{ N} \quad (8800 \text{ N}) \quad \text{[tension]}\end{aligned}$$

The answer is (C).

PROBLEM 20 [DYNAMICS]

2. A vehicle is traveling at 62 km/h when the driver sees a traffic light in an intersection 530 m ahead turn red. The light's red cycle duration is 25 s. The driver wants to enter the intersection without stopping the vehicle, just as the light turns green. If the vehicle decelerates at a constant rate of 0.35 $\mathrm{m/s^2}$, what will be its approximate speed when the light turns green?

(A) 31 km/h

(B) 43 km/h

(C) 59 km/h

(D) 63 km/h

2. The velocity after 25 s of constant deceleration is

$$\begin{aligned} \mathrm{v}(t) &= a_0(t-t_0)+\mathrm{v}_0 \\ &= \frac{\left(-0.35\ \frac{\mathrm{m}}{\mathrm{s}^2}\right)(25\ \mathrm{s}-0\ \mathrm{s})\left(3600\ \frac{\mathrm{s}}{\mathrm{h}}\right)}{1000\ \frac{\mathrm{m}}{\mathrm{km}}}+62\ \frac{\mathrm{km}}{\mathrm{h}} \\ &= 31\ \mathrm{km/h} \end{aligned}$$

The answer is (A).

PROBLEM 21 [DYNAMICS]

2. Two balls, both of mass 2 kg, collide head on. The velocity of each ball at the time of the collision is 2 m/s. The coefficient of restitution is 0.5. Most nearly, what are the final velocities of the balls?

(A) 1 m/s and −1 m/s

(B) 2 m/s and −2 m/s

(C) 3 m/s and −3 m/s

(D) 4 m/s and −4 m/s

2. Since the two velocities are in opposite directions, let the velocity of one ball, v_1, equal 2 m/s and the velocity of the other ball, v_2, equal −2 m/s.

From the definition of the coefficient of restitution,

$$\begin{aligned} e &= \frac{v_2' - v_1'}{v_1 - v_2} \\ v_2' - v_1' &= e(v_1 - v_2) \\ &= (0.5)\left(2\ \frac{\text{m}}{\text{s}} - \left(-2\ \frac{\text{m}}{\text{s}}\right)\right) \\ &= 2\ \text{m/s} \qquad \text{[Eq. I]} \end{aligned}$$

From the conservation of momentum,

$$m_1 v_1 + m_2 v_2 = m_1 v_1' + m_2 v_2'$$

But, $m_1 = m_2$.

$$v_1 + v_2 = v_1' + v_2'$$

Since $v_1 = 2$ m/s and $v_2 = -2$ m/s,

$$v_1 + v_2 = 2\ \frac{\text{m}}{\text{s}} + \left(-2\ \frac{\text{m}}{\text{s}}\right) = 0$$

So,

$$v_1' + v_2' = 0 \qquad \text{[Eq. II]}$$

Solve Eq. I and Eq. II simultaneously by adding them.

$$\begin{aligned} v_1' &= -1\ \text{m/s} \\ v_2' &= 1\ \text{m/s} \end{aligned}$$

The answer is (A).

PROBLEM 22 [DYNAMICS]

6. A pickup truck is traveling forward at 25 m/s. The bed is loaded with boxes whose coefficient of friction with the bed is 0.40. What is most nearly the shortest time that the truck can be brought to a stop such that the boxes do not shift?

(A) 2.3 s

(B) 4.7 s

(C) 5.9 s

(D) 6.4 s

6. The frictional force is the only force preventing the boxes from shifting. The forces on each box are its weight, the normal force, and the frictional force. The normal force on each box is equal to the box weight.

$$N = W = mg$$

The frictional force is

$$F_f = \mu N = \mu mg$$

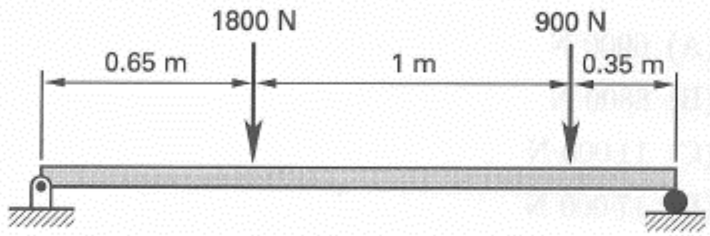
Use the impulse-momentum principle. $\mathrm{v}_2 = 0$. The frictional force is opposite of the direction of motion, so it is negative.

$$\begin{aligned}
\mathrm{Imp} &= \Delta p \\
F_f \Delta t &= m \Delta \mathrm{v} \\
\Delta t &= \frac{m(\mathrm{v}_2 - \mathrm{v}_1)}{F_f} = \frac{-m\mathrm{v}_1}{-\mu mg} = \frac{\mathrm{v}_1}{\mu g} \\
&= \frac{25\ \frac{\mathrm{m}}{\mathrm{s}}}{(0.40)\left(9.81\ \frac{\mathrm{m}}{\mathrm{s}^2}\right)} \\
&= 6.37\ \mathrm{s} \quad (6.4\ \mathrm{s})
\end{aligned}$$

The answer is (D).

PROBLEM 23 [MECHANICS OF MATERIALS]

3. Refer to the simply supported beam shown.



What is most nearly the maximum bending moment?

(A) 340 N·m
(B) 460 N·m
(C) 660 N·m
(D) 890 N·m

3. Determine the reactions by taking moments about each end.

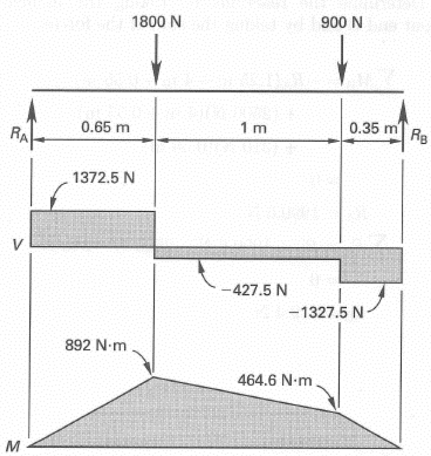
$$\sum M_B = -R_A(0.65\ \text{m} + 1\ \text{m} + 0.35\ \text{m}) + (1800\ \text{N})(1\ \text{m} + 0.35\ \text{m}) + (900\ \text{N})(0.35\ \text{m}) = 0$$

$$R_A = 1372.5\ \text{N}$$

$$\sum F_y = R_B + 1372.5\ \text{N} - 1800\ \text{N} - 900\ \text{N} = 0$$

$$R_B = 1327.5\ \text{N}$$

Draw the shear and moment diagrams.



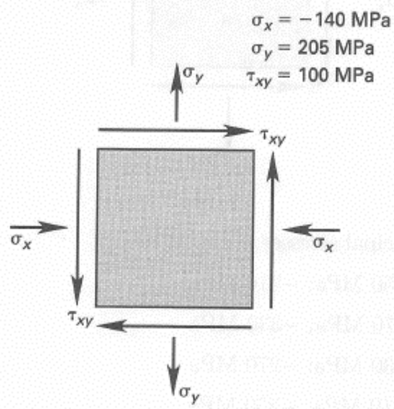
$$M = VR_A = (1372.5\ \text{N})(0.65\ \text{m}) = 892\ \text{N·m}$$

The maximum moment occurs 0.65 m from the left end (where V goes through zero) of the beam and is equal to 892 N·m (890 N·m).

The answer is (D).

PROBLEM 24 [MECHANICS OF MATERIALS]

1. The element is subjected to the plane stress condition shown.



What is the maximum shear stress?

(A) 100 MPa

(B) 160 MPa

(C) 200 MPa

(D) 210 MPa

1. There are two methods for solving the problem. The first method is to use the equation for τ_{max}; the second method is to draw Mohr's circle.

Solving by the equation for τ_{max},

$$\tau_{max} = \pm\sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$
$$= \sqrt{\left(\frac{-140 \text{ MPa} - 205 \text{ MPa}}{2}\right)^2 + (100 \text{ MPa})^2}$$
$$= 199.4 \text{ MPa} \quad (200 \text{ MPa})$$

Solving by Mohr's circle,

step 1:
$$\sigma_x = -140 \text{ MPa}$$
$$\sigma_y = 205 \text{ MPa}$$
$$\tau_{xy} = 100 \text{ MPa}$$

step 2: Draw σ-τ axes.

step 3: The circle center is

$$C = \tfrac{1}{2}(\sigma_x + \sigma_y)$$
$$= \left(\tfrac{1}{2}\right)(-140 \text{ MPa} + 205 \text{ MPa})$$
$$= 32.5 \text{ MPa}$$

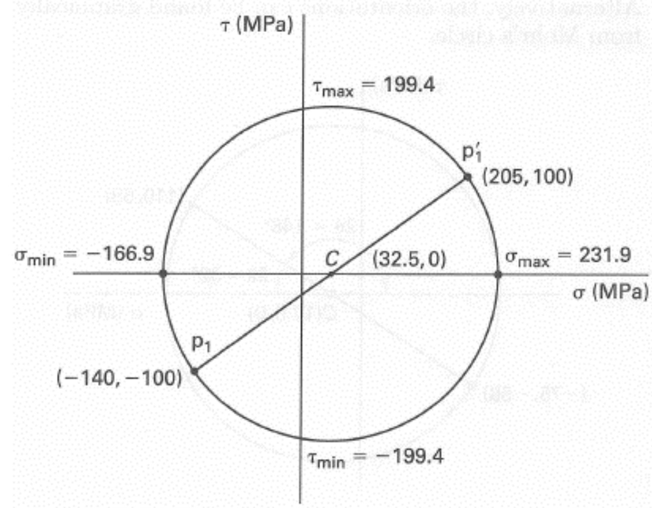
step 4: Plot the points (−140 MPa, −100 MPa) and (205 MPa, 100 MPa).

step 5: Draw the diameter of the circle.

step 6: Draw the circle.

step 7: Find the radius of the circle.

step 8: Maximum shear stress is at the top of the circle, $\tau_{max} = 199.4$ MPa (200 MPa).



The answer is (C).

PROBLEM 25 [MECHANICS OF MATERIALS]

38. A 1-ft rod with a diameter of 0.5 in. is subjected to a tensile force of 1,300 lb and has an elongation of 0.009 in. The modulus of elasticity (ksi) of the material is most nearly:

- ○ A. 740
- ○ B. 884
- ○ C. 8,840
- ○ D. 10,000

38. $P = 1{,}300\text{ lb}$ $\quad A = (0.5)^2\ \dfrac{\pi}{4} = 0.196\text{ in}^2$ $\quad L = 12\text{ in.}$

$\delta = 0.009\text{ in.}$

$\delta = \dfrac{PL}{AE}$ rearranged gives

$$E = \frac{PL}{\delta A} = \frac{(1{,}300)(12)}{(0.009)(0.196)} = 8.84 \times 10^6\text{ psi} = 8{,}840\text{ ksi}$$

THE CORRECT ANSWER IS: C

PROBLEM 26 [MECHANICS OF MATERIALS]

5. A rectangular steel bar 37.5 mm wide and 50 mm thick is pinned at each end and subjected to axial compression. The bar has a length of 1.75 m. The modulus of elasticity is 200 GPa. What is most nearly the critical buckling load?

(A) 60 kN

(B) 93 kN

(C) 110 kN

(D) 140 kN

5. Use Euler's formula. $K = 1$ since both ends are pinned. Use the moment of inertia for the weak direction.

$$P_{cr} = \frac{\pi^2 EI}{(K\ell)^2} = \frac{\pi^2 E\left(\frac{bh^3}{12}\right)}{(K\ell)^2}$$

$$= \frac{\pi^2 (200\ \text{GPa})\left(10^9\ \frac{\text{Pa}}{\text{GPa}}\right)\left(\frac{(50\ \text{mm})(37.5\ \text{mm})^3}{(12)\left(1000\ \frac{\text{mm}}{\text{m}}\right)^4}\right)}{\left((1)(1.75\ \text{m})\right)^2}$$

$$= 141\,624\ \text{N} \quad (140\ \text{kN})$$

The answer is (D).

PROBLEM 27 [MATERIALS]

42. The following preliminary concrete mix has been designed assuming that the aggregates are in oven-dry condition.

Water = 305 lb/yd^3
Cement = 693 lb/yd^3
Coarse aggregate (SSD) = 1,674 lb/yd^3
Fine aggregate (SSD) = 1,100 lb/yd^3

The properties of the aggregates are:

Property	Coarse Aggregate	Fine Aggregate
Absorption (moisture content at SSD)	0.5%	0.7%
Moisture content as used in mix	2.0%	6.0%

The amount of water (lb/yd^3) that would be used in the final mix is most nearly:

- ○ A. 206
- ○ B. 222
- ○ C. 305
- ○ D. 388

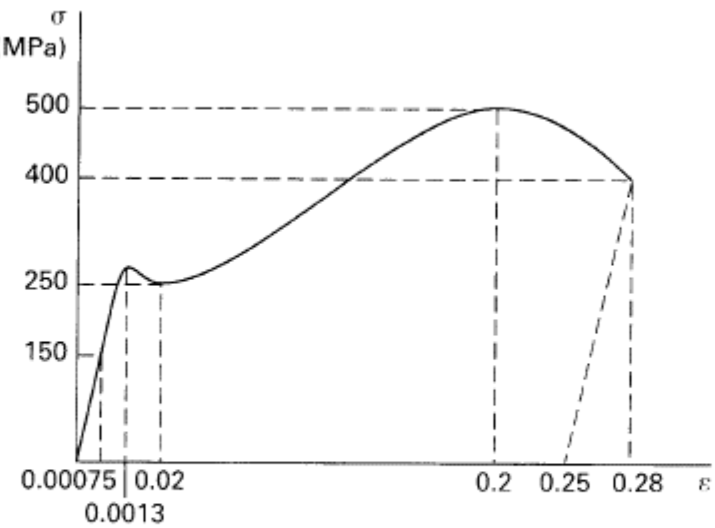
42. The moisture content of each aggregate includes: (1) water that would be needed to bring aggregates to SSD condition (the absorbed water) and (2) the excess water that is free to add to the mix water. Since the as-used moisture content is greater than the absorption for each aggregate, each aggregate contributes the excess water to the mix, thus reducing the water that must be added to mix. The water added to the mix is the water computed for oven-dry aggregates (305 lb/yd^3) plus the excess water in each aggregate.

Final water = $305 - [(2.0\% - 0.5\%)/100] \times 1{,}674 - [(6.0\% - 0.7\%)/100] \times 1{,}100 = 221.6\ lb/yd^3$

THE CORRECT ANSWER IS: B

PROBLEM 28 [MATERIALS]

10. A stress-strain diagram is shown.



What is most nearly the modulus of elasticity of the material?

(A) 20 GPa

(B) 80 GPa

(C) 100 GPa

(D) 200 GPa

10. The modulus of elasticity (Young's modulus) is the slope of the stress-strain line in the proportional region.

$$\sigma = E\varepsilon$$

$$E = \frac{\sigma}{\varepsilon} = \frac{150 \text{ MPa}}{0.00075}$$

$$= 200\,000 \text{ MPa} \quad (20 \times 10^4 \text{ MPa})$$

The answer is (D).

PROBLEM 29 [MATERIALS]

8. If δ is deformation, and L is the original length of the specimen, what is the definition of normal strain, ε?

(A) $\varepsilon = \dfrac{L+\delta}{L}$

(B) $\varepsilon = \dfrac{L+\delta}{\delta}$

(C) $\varepsilon = \dfrac{\delta}{L+\delta}$

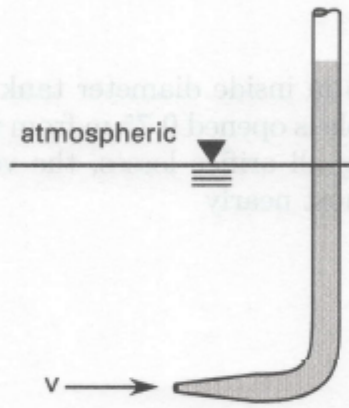
(D) $\varepsilon = \dfrac{\delta}{L}$

8. Strain is defined as elongation, δ, per unit length, L.

The answer is (D).

PROBLEM 30 [FLUID MECHANICS]

3. The velocity of the water in the stream shown is 1.2 m/s.



The height of water in the pitot tube is most nearly

(A) 3.7 cm

(B) 4.6 cm

(C) 7.3 cm

(D) 9.2 cm

3. The difference in height between the pitot tube and the free-water surface is a measure of the difference in static and stagnation pressures. Solve for the height of the water.

$$\mathrm{v} = \sqrt{\left(\frac{2}{\rho}\right)(p_0 - p_s)} = \sqrt{\left(\frac{2}{\rho}\right)\rho g h}$$

$$= \sqrt{2gh}$$

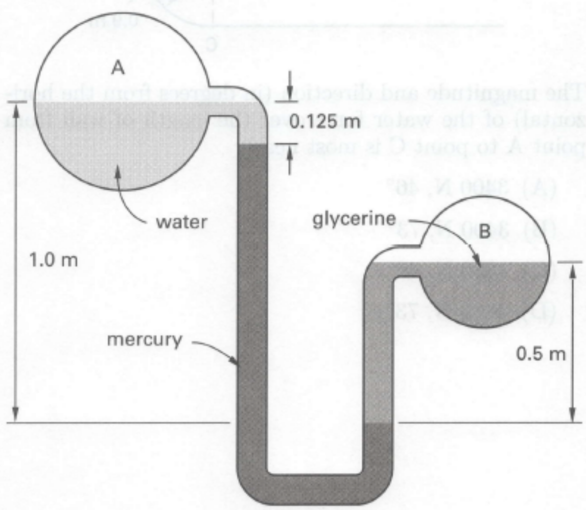
$$h = \frac{\mathrm{v}^2}{2g} = \frac{\left(1.2\ \frac{\mathrm{m}}{\mathrm{s}}\right)^2}{(2)\left(9.81\ \frac{\mathrm{m}}{\mathrm{s}^2}\right)}$$

$$= 0.073\ \mathrm{m} \quad (7.3\ \mathrm{cm})$$

The answer is (C).

PROBLEM 31 [FLUID MECHANICS]

2. The manometer shown contains water, mercury, and glycerine. The specific gravity of mercury is 13.6, and the specific gravity of glycerine is 1.26.



What is most nearly the difference in pressure between points A and B?

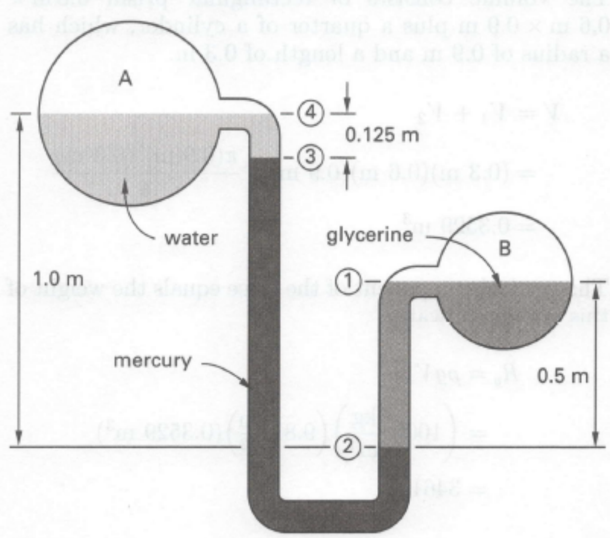
(A) 35 kPa

(B) 42 kPa

(C) 55 kPa

(D) 110 kPa

2. The manometer can be labeled as shown.



The pressure at level 2 is the same in both (left and right) legs of the manometer. For the left leg,

$$p_2 = p_A + \rho_{water} g h_{3\text{-}4} + \rho_{mercury} g h_{2\text{-}3}$$

For the right leg,

$$p_2 = p_B + \rho_{glycerine} g h_{1\text{-}2}$$

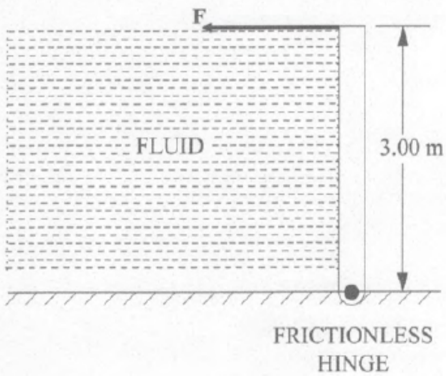
Equating these two equations for p_2 and solving for the pressure difference $p_A - p_B$ gives

$$\begin{aligned} p_A - p_B &= g(\rho_{glycerine} h_{1\text{-}2} - \rho_{water} h_{3\text{-}4} - \rho_{Hg} h_{2\text{-}3}) \\ &= g\rho_{water} \begin{pmatrix} SG_{glycerine} h_{1\text{-}2} - SG_{water} h_{3\text{-}4} \\ - SG_{Hg} h_{2\text{-}3} \end{pmatrix} \\ &= \left(9.81\ \frac{m}{s^2}\right)\left(1000\ \frac{kg}{m^3}\right) \\ &\quad \times \begin{pmatrix} (1.26)(0.5\ m) - (1.00)(0.125\ m) \\ - (13.6)(1.0\ m - 0.125\ m) \end{pmatrix} \\ &= -111\,785\ Pa \quad (110\ kPa) \end{aligned}$$

The answer is (D).

PROBLEM 32 [FLUID MECHANICS]

48. 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

48. The mean pressure of the fluid acting on the gate is evaluated at the mean height, and the center of pressure is 2/3 of the height from the top; thus, the total force of the fluid is:

$$F_f = \rho g \frac{H}{2}(H) = 1{,}600(9.807)\frac{3}{2}(3) = 70{,}610 \text{ N}$$

and its point of application is 1.00 m above the hinge. A moment balance about the hinge gives:

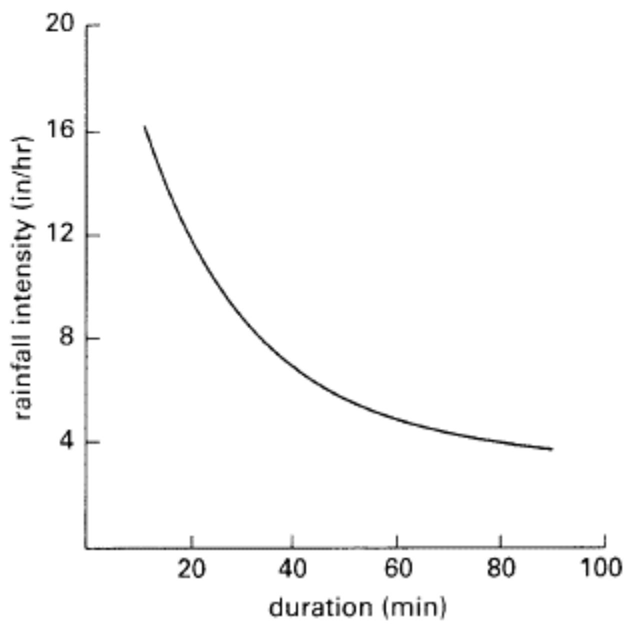
$$F(3) - F_f(1) = 0$$

$$F = \frac{F_f}{3} = \frac{70{,}610}{3} = 23{,}537 \text{ N}$$

THE CORRECT ANSWER IS: C

PROBLEM 33 [HYDRAULICS AND HYDROLOGIC SYSTEMS]

3. A watershed occupies a 70 ac site. 45 ac of the site have been cleared and are used for pasture land with a runoff coefficient of 0.13; 3 ac are occupied by farm buildings, a house, and paved surfaces and have a runoff coefficient of 0.75; the remaining 22 ac are woodland with a runoff coefficient of 0.20. The total time to concentration for the watershed is 30 min. The 20 yr storm is characterized by the intensity duration curve shown.



The peak runoff for the 20 yr storm is most nearly

(A) 50 ft^3/sec

(B) 110 ft^3/sec

(C) 240 ft^3/sec

(D) 530 ft^3/sec

3. The weighted average runoff coefficient for the watershed is

$$C = \frac{(0.13)(45\text{ ac}) + (0.75)(3\text{ ac}) + (0.20)(22\text{ ac})}{70\text{ ac}}$$
$$= 0.179$$

From the graph, at $t_c = 30$ min, $I = 9$ in/hr. Use the rational formula to calculate the peak runoff.

$$Q = CIA = (0.179)\left(9\ \frac{\text{in}}{\text{hr}}\right)(70\text{ ac})$$
$$= 112.5\ \text{ft}^3/\text{sec} \quad (110\ \text{ft}^3/\text{sec})$$

The answer is (B).

PROBLEM 34 [HYDRAULICS AND HYDROLOGIC SYSTEMS]

2. An open channel has a cross-sectional area of flow of 0.5 m^2, a hydraulic radius of 0.15 m, and a roughness coefficient of 0.15. The slope of the hydraulic gradient needed to achieve a flow rate of 10 L/s is most nearly

(A) 1.1×10^{-4}

(B) 6.7×10^{-4}

(C) 1.1×10^{-3}

(D) 6.7×10^{-3}

2. The volumetric flow rate is

$$Q = \frac{10\ \frac{\text{L}}{\text{s}}}{1000\ \frac{\text{L}}{\text{m}^3}} = 0.01\ \text{m}^3/\text{s}$$

The velocity needed is

$$\text{v} = \frac{Q}{A} = \frac{0.01\ \frac{\text{m}^3}{\text{s}}}{0.5\ \text{m}^2} = 0.02\ \text{m/s}$$

Use Manning's equation to find the slope needed to achieve this velocity.

$$\text{v} = (K/n) R_H^{2/3} S^{1/2}$$

$$S = \left(\frac{\text{v}n}{K R_H^{2/3}}\right)^2$$

$$= \left(\frac{\left(0.02\ \frac{\text{m}}{\text{s}}\right)(0.15)}{(1.0)(0.15\ \text{m})^{2/3}}\right)^2$$

$$= 0.0001129 \quad (1.1 \times 10^{-4})$$

The answer is (A).

PROBLEM 35 [HYDRAULICS AND HYDROLOGIC SYSTEMS]

54. The pressure in a water main at ground level is 85 psi. A developer plans to build a six-story building. The height between floors will be 12 ft. Neglecting friction losses, the pressure (psi) on the sixth floor will be most nearly:

- ○ A. 31
- ○ B. 54
- ○ C. 85
- ○ D. 117

54. Pressure difference between the sixth floor and ground level

$$= \left(\frac{62.4 \text{ lb}}{\text{ft}^3}\right)\left(6 \text{ floors} \times \frac{12 \text{ ft}}{\text{floor}}\right)\left(\frac{1 \text{ ft}^2}{144 \text{ in}^2}\right) = 31.2 \text{ psi}$$

Pressure on sixth floor = 85 – 31.2 = 53.8 psi

THE CORRECT ANSWER IS: B

PROBLEM 36 [HYDRAULICS AND HYDROLOGIC SYSTEMS]

51. Waste activated sludge can be described as a Newtonian fluid with a kinematic viscosity of 20×10^{-5} ft²/sec. At the same temperature, the kinematic viscosity, ν, of water is 10^{-5} ft²/sec. The relative roughness of the piping system is 0.001. The pressure drop for flow of water at a Reynolds number of 10^7 in this piping system has been determined to be 1.0 psi. If waste activated sludge flows at the same velocity through the piping system, the pressure drop (psi) is most nearly:

- ○ A. 1.0
- ○ B. 2.0
- ○ C. 3.0
- ○ D. 4.0

51. $H_L = f\left(\frac{L}{D}\right)\left(\frac{V^2}{2g}\right)$

For the same piping system and velocity, H_L is proportional to f. For this case, the Reynolds number is very large, corresponding with fully turbulent flow conditions. Referring to the Moody Stanton Diagram in the Fluid Mechanics section of the *FE Reference Handbook*, it is apparent that f depends on pipe roughness but not Reynolds number for $\varepsilon/D = 0.001$ and Reynolds numbers $>10^6$. Thus, $f \cong 0.02$ for both applications, and pressure drops are equal.

THE CORRECT ANSWER IS: A

PROBLEM 37 [HYDRAULICS AND HYDROLOGIC SYSTEMS]

5. The results of well pumping tests from a homogeneous, unconfined aquifer are shown. At the time of the tests, the pumping had continued long enough for the well discharge to become steady.

parameter	value
pumping rate	20 gal/sec
well diameter	1.5 ft
radius of influence	900 ft
depth of aquifer at radius of influence	135 ft
drawdown in well	11 ft

The hydraulic conductivity of the aquifer is most nearly

(A) 1.2×10^{-3} ft/sec

(B) 2.1×10^{-3} ft/sec

(C) 5.0×10^{-3} ft/sec

(D) 8.7×10^{-3} ft/sec

5. The radius of the well is

$$r_2 = \frac{D}{2} = \frac{1.5\text{ ft}}{2} = 0.75\text{ ft}$$

The thickness of the saturated aquifer at the well is

$$h_2 = D - D_{w,2} = 135\text{ ft} - 11\text{ ft} = 124\text{ ft}$$

Use Dupuit's equation to find the hydraulic conductivity of the aquifer.

$$Q = \frac{\pi k(h_2^2 - h_1^2)}{\ln \frac{r_2}{r_1}}$$

$$k = \frac{Q \ln \frac{r_2}{r_1}}{\pi(h_2^2 - h_1^2)}$$

$$= \frac{\left(\frac{20\ \frac{\text{gal}}{\text{sec}}}{7.48\ \frac{\text{gal}}{\text{ft}^3}}\right) \ln \frac{0.75\text{ ft}}{900\text{ ft}}}{\pi\left((124\text{ ft})^2 - (135\text{ ft})^2\right)}$$

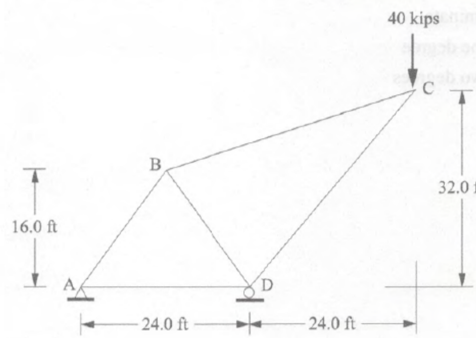
$$= 2.118 \times 10^{-3}\text{ ft/sec} \quad (2.1 \times 10^{-3}\text{ ft/sec})$$

The answer is (B).

PROBLEM 38 [STRUCTURAL ANALYSIS]

57. The 40-kip vertical load at Joint C in the steel truss shown below produces the forces given in the accompanying table. The cross-sectional area of each member is 4.0 in^2, and the length of each member is given in the table. The elastic modulus of steel is 29,000 ksi. The downward vertical displacement (in.) of Joint C is most nearly:

Member	Force, F (kips)	Length, L (in.)	$\frac{FL}{AE}$
AB	50.0	240	0.1034
BC	49.2	473	0.2008
CD	–75.0	480	–0.3103
AD	–30.0	288	–0.0745
BD	–25.0	240	–0.0517



- ○ A. 1.046
- ○ B. 0.294
- ○ C. 0.132
- ○ D. 0.102

57. Apply a downward 1-kip load (unit load) at Joint C and compute forces f in bars. (This can easily be done by dividing each F force by 40).

Multiply each member's change in length $\Delta L = \frac{FL}{AE}$ by its force f in the table below (be sure to use the signed values of $\Delta L = \frac{FL}{AE}$ and f).

Then, sum $f \cdot \frac{FL}{AE}$ to get the displacement at Joint C.

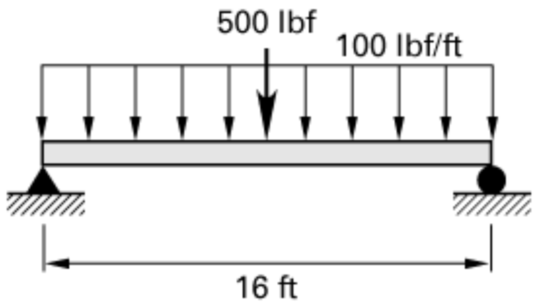
$$\sum f \cdot \frac{FL}{AE} = +\ 1.0464 \text{ in. down}$$

Member	F (kips)	L (in.)	$\frac{FL}{AE}$	f	$f \cdot \frac{FL}{AE}$
AB	50.0	240	0.1034	1.25	0.1292
BC	49.2	473	0.2008	1.231	0.2472
CD	–75.0	480	–0.3103	–1.875	0.5818
AD	–30.0	288	–0.0745	–0.75	0.0559
BD	–25.0	240	–0.0517	–0.625	0.0323
					$\sum = 1.0464$

THE CORRECT ANSWER IS: A

PROBLEM 39 [STRUCTURAL ANALYSIS]

Problem 19: PM - Civil Eng. [E0304070068]
The rectangular steel beam shown is 4 in wide and 2 in deep. The maximum deflection is most nearly



(A) 2.8 in
(B) 3.5 in
(C) 4.2 in
(D) 4.9 in

Solution:

The moment of inertia for a rectangular beam is

$$\begin{aligned} I &= \frac{bh^3}{12} \\ &= \frac{(4\text{ in})(2\text{ in})^3}{12} \\ &= 2.67\text{ in}^4 \end{aligned}$$

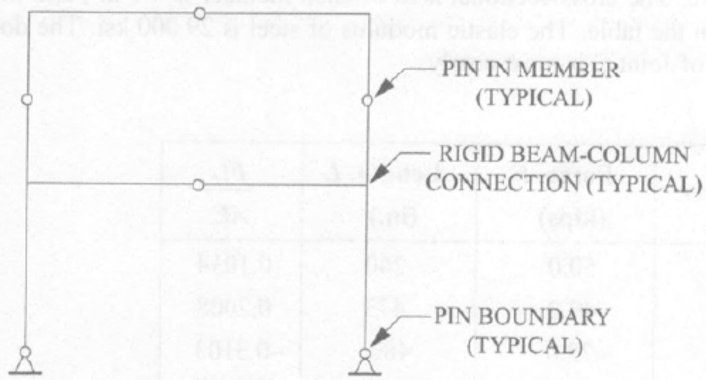
Using superposition, the total deflection of the beam is the sum of the deflection due to the point force and the deflection due to the distributed force.

$$\begin{aligned} \delta &= \delta_{\text{point}} + \delta_{\text{distributed}} \\ &= \frac{PL^3}{48EI} + \frac{5WL^4}{384EI} \\ &= \frac{(500\text{ lbf})(16\text{ ft})^3\left(12\frac{\text{in}}{\text{ft}}\right)^3}{(48)\left(30\times10^6\frac{\text{lbf}}{\text{in}^2}\right)(2.67\text{ in}^4)} + \frac{(5)\left(100\frac{\text{lbf}}{\text{ft}}\right)\left(\frac{1\text{ ft}}{12\text{ in}}\right)(16\text{ ft})^4\left(12\frac{\text{in}}{\text{ft}}\right)^4}{(384)\left(30\times10^6\frac{\text{lbf}}{\text{in}^2}\right)(2.67\text{ in}^4)} \\ &= 0.9204\text{ in} + 1.8409\text{ in} \\ &= 2.7613\text{ in} \quad (2.8\text{ in}) \end{aligned}$$

The answer is A.

PROBLEM 40 [STRUCTURAL ANALYSIS]

58. The frame in the figure below is:



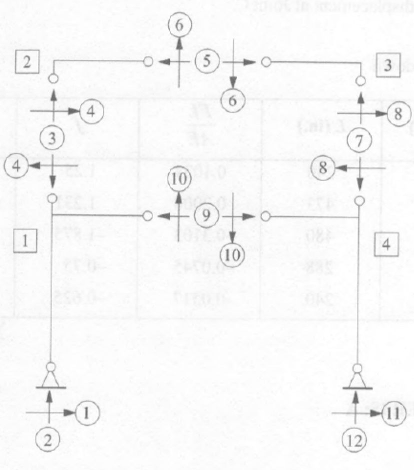
- ○ A. unstable
- ○ B. stable and determinate
- ○ C. indeterminate one degree
- ○ D. indeterminate two degrees

58. Unknown reactions and internal forces at internal pins: $6 \times 2 = 12$

Rigid body components (shown as FBDs) @ 3 equations per component: 4

Number of equations: $4 \times 3 = 12$

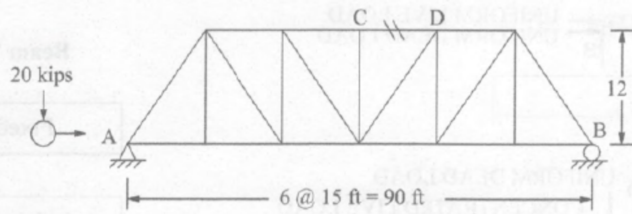
There are 12 equations and 12 unknowns → determinate (stable by member arrangement).



THE CORRECT ANSWER IS: B

PROBLEM 41 [STRUCTURAL ANALYSIS]

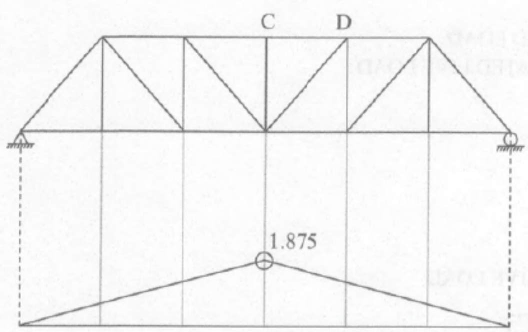
60. A concentrated load of 20 kips moves through the truss shown. Neglecting the weight of the truss, the maximum force (kips) in Member CD due to the moving load is most nearly:



- A. 12.5
- B. 25
- C. 37.5
- D. 50

60. The maximum force in CD occurs when the wheel is placed at the location that corresponds to the peak of the influence line:

Max $F_{CD} = 1.875 \times 20$ kips $= 37.5$ kips

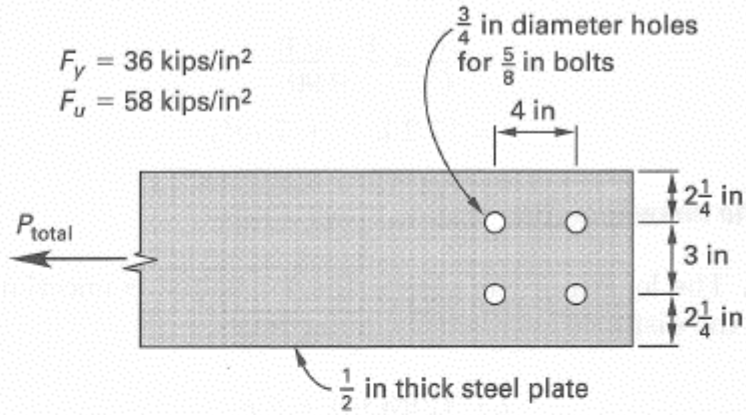


Influence line for CD

THE CORRECT ANSWER IS: C

PROBLEM 42 [STRUCTURAL DESIGN]

1. A bolted steel tension member is shown.



What is most nearly the effective net area in tension for this plate?

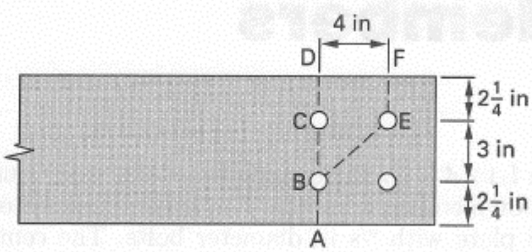
(A) 2.3 in^2

(B) 2.9 in^2

(C) 3.4 in^2

(D) 3.8 in^2

1. For fracture, choose the shortest path, which is along line ABCD, as shown.



The gross member width is

$$b_g = 2.25 \text{ in} + 3 \text{ in} + 2.25 \text{ in} = 7.5 \text{ in}$$

Calculate the net area.

$$\begin{aligned} A_n &= \left(b_g - \sum\left(d_h + \tfrac{1}{16} \text{ in}\right)\right)t \\ &= \left(7.5 \text{ in} - (2)\left(0.75 \text{ in} + \tfrac{1}{16} \text{ in}\right)\right)(0.5 \text{ in}) \\ &= 2.94 \text{ in}^2 \end{aligned}$$

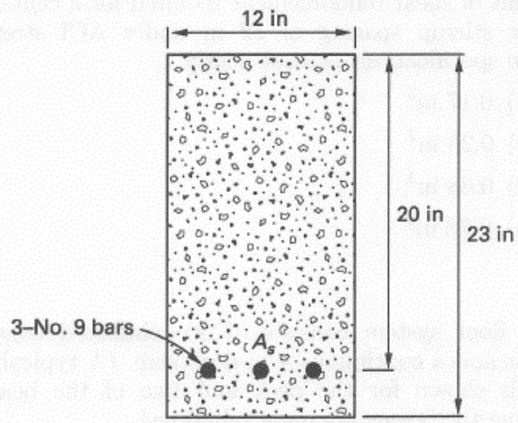
For bolted members with flat bars, the shear lag factor, U, is 1.0. The effective net area is

$$\begin{aligned} A_e &= UA_n = (1.0)(2.94 \text{ in}^2) \\ &= 2.94 \text{ in}^2 \quad (2.9 \text{ in}^2) \end{aligned}$$

The answer is (B).

PROBLEM 43 [STRUCTURAL DESIGN]

3. The cross section of a reinforced concrete beam with tension reinforcement is shown. Assume that the beam is underreinforced.



$$f'_c = 3000\ \text{lbf/in}^2$$
$$f_y = 40{,}000\ \text{lbf/in}^2$$
$$A_s = 3\ \text{in}^2 \quad \text{[three no. 9 bars]}$$
$$A'_s = 1\ \text{in}^2$$

If the dead load shear force in the beam is 5 kips and the live load shear force in the beam is 15 kips, then the minimum amount of shear reinforcement needed for a center-to-center stirrup spacing of 8 in based on ACI strength design is most nearly

(A) 0.10 in^2
(B) 0.12 in^2
(C) 0.14 in^2
(D) 0.18 in^2

3. For shear, the capacity reduction ratio is $\phi = 0.75$. The ultimate shear force in the beam is

$$\begin{aligned} V_u &= 1.2V_D + 1.6V_L \\ &= (1.2)(5\ \text{kips}) + (1.6)(15\ \text{kips}) \\ &= 30\ \text{kips} \end{aligned}$$

The nominal concrete shear strength is

$$\begin{aligned} V_c &= 2b_w d\sqrt{f'_c} \\ &= \frac{(2)(12\ \text{in})(20\ \text{in})\sqrt{3000\ \frac{\text{lbf}}{\text{in}^2}}}{1000\ \frac{\text{kip}}{\text{lbf}}} \\ &= 26.29\ \text{kips} \\ \frac{\phi V_c}{2} &= \frac{(0.75)(26.29\ \text{kips})}{2} \\ &= 9.9\ \text{kips} \end{aligned}$$

Since $V_u > \phi V_c/2$, shear reinforcement is required.

$$\phi V_c = (0.75)(26.29\ \text{kips}) = 19.72\ \text{kips}$$

Since $V_u = 30\ \text{kips} > \phi V_c = 19.72\ \text{kips}$, the required shear strength provided by the steel is

$$V_s = \frac{V_u}{\phi} - V_c = \frac{30\ \text{kips}}{0.75} - 26.29\ \text{kips} = 13.71\ \text{kips}$$

The required steel area is

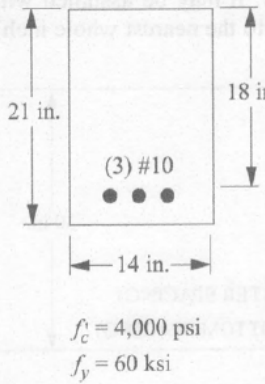
$$\begin{aligned} A_v &= \frac{sV_s}{f_y d} = \frac{(8\ \text{in})(13.71\ \text{kips})\left(1000\ \frac{\text{lbf}}{\text{kip}}\right)}{\left(40{,}000\ \frac{\text{lbf}}{\text{in}^2}\right)(20\ \text{in})} \\ &= 0.1371\ \text{in}^2 \quad (0.14\ \text{in}^2) \end{aligned}$$

Although not required for this problem, in an actual design and analysis situation, a check should be made to ensure that V_s does not exceed the ACI-allowed maximum shear reinforcement given by $V_{s,\max} = 8\sqrt{f'_c}bd$.

The answer is (C).

PROBLEM 44 [STRUCTURAL DESIGN]

67. The flexural design strength (ft-kips) of the reinforced concrete beam section shown is most nearly:



- A. 267
- B. 297
- C. 319
- D. 354

67. $d = 18$ in.

$$A_s = 3(1.27) = 3.81 \text{ in}^2$$

$$a = \frac{A_s f_y}{0.85 f'_c b} = \frac{3.81\ (60)}{0.85\ (4)(14)} = 4.80 \text{ in.}$$

$$M_n = A_s f_y (d - a/2) = 3.81(60)(18 - 4.8/2)/12 = 297 \text{ ft-kips}$$

$$E_s = E_c\left(\frac{d-c}{c}\right) = 0.003\left(\frac{18 - 4.8/0.85}{4.8/0.85}\right) = 0.0066 > 0.005$$

$$\therefore \phi = 0.9$$

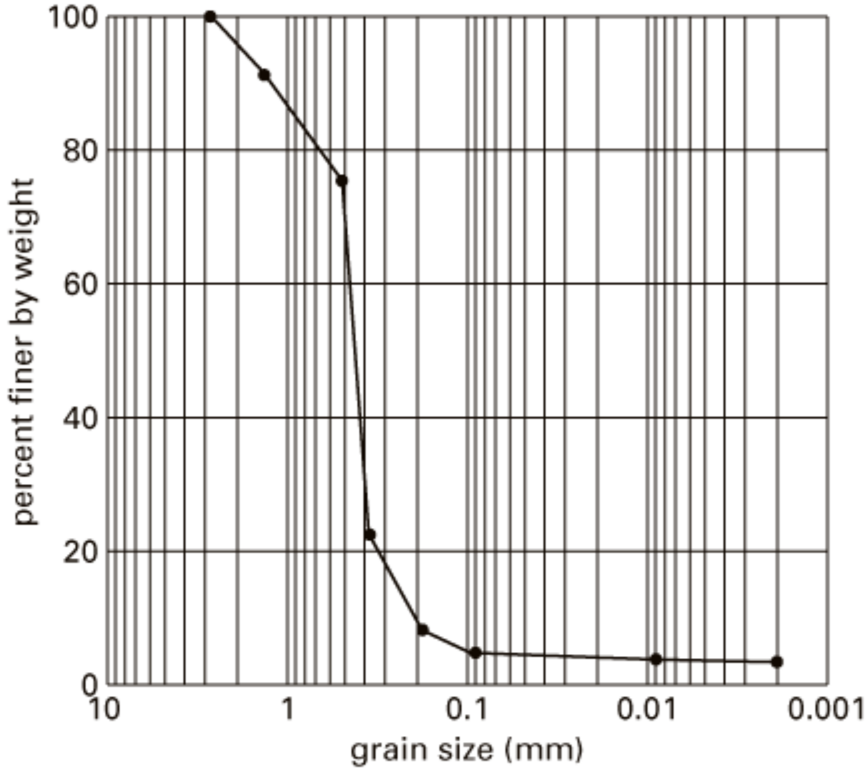
$$\phi M_a = 0.9(297) = 267 \text{ ft-kips}$$

THE CORRECT ANSWER IS: A

PROBLEM 45 [GEOTECHNICAL ENGINEERING]

Problem 17: PM - Civil Eng. [P0208160029]

A soil's grain-size distribution curve is as shown.



The uniformity coefficient is most nearly

(A) 1.6
(B) 2.1
(C) 2.6
(D) 3.2

Solution:

As read from the distribution curve, D_{60} = 0.49 mm, and D_{10} = 0.19 mm.

The uniformity coefficient, c_u, is given by

$$c_u = \frac{D_{60}}{D_{10}} = \frac{0.49\ \text{mm}}{0.19\ \text{mm}} = 258 \quad (26)$$

The answer is C.

PROBLEM 46 [GEOTECHNICAL ENGINEERING]

10. The total moist unit weight of a given soil is 120 lbf/ft^3. The soil has a porosity of 0.26 and is 100% saturated. The dry unit weight of the soil is most nearly

(A) 58 lbf/ft^3

(B) 86 lbf/ft^3

(C) 100 lbf/ft^3

(D) 120 lbf/ft^3

10. The total moist unit weight of the soil is the combined weight of the soil and the water. For a saturated soil, the water completely fills the voids. The weight of the water is the unit weight of water multiplied by the volume of the voids.

$$\begin{aligned}\gamma_{\text{sat}} &= \frac{W}{V} = \frac{W_S + W_W}{V} = \frac{W_S}{V} + \frac{W_W}{V} \\ &= \frac{W_S}{V} + \frac{\gamma_W V_V}{V} \\ &= \gamma_D + \gamma_W n\end{aligned}$$

The dry unit weight of the soil is

$$\begin{aligned}\gamma_D &= \gamma_{\text{sat}} - \gamma_W n \\ &= 120\ \frac{\text{lbf}}{\text{ft}^3} - \left(62.4\ \frac{\text{lbf}}{\text{ft}^3}\right)(0.26) \\ &= 103.8\ \text{lbf/ft}^3 \quad (100\ \text{lbf/ft}^3)\end{aligned}$$

The answer is (C).

PROBLEM 47 [GEOTECHNICAL ENGINEERING]

71. Direct shear test data of a sand are shown below:

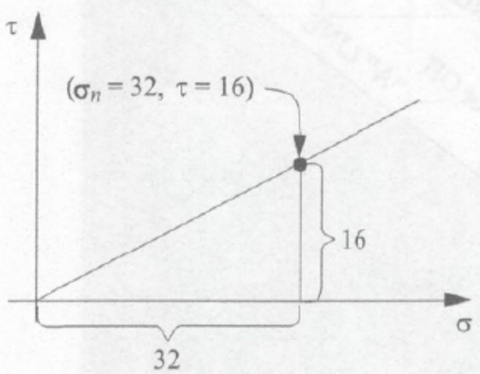
Area of sample = 16 in^2
Normal load at failure = 512 lb
Shear stress at failure = 16 psi

The angle of friction is most nearly:

- ○ A. 0°
- ○ B. 27°
- ○ C. 30°
- ○ D. 63°

71. $\sigma_n = \frac{N}{A} = \frac{512 \text{ lb}}{16 \text{ in}^2} = 32 \text{ psi}$

$\tau = 16$ psi



$\phi = \tan^{-1}\left(\frac{16}{32}\right) \cong 27°$

THE CORRECT ANSWER IS: B

PROBLEM 48 [GEOTECHNICAL ENGINEERING]

72. Subsurface exploration indicates that a level site has a 10-ft upper layer of sand. The groundwater table is at the ground surface. The unit weight of the sand is 135.0 pcf. The effective overburden stress (psf) at a depth of 10 ft is most nearly:

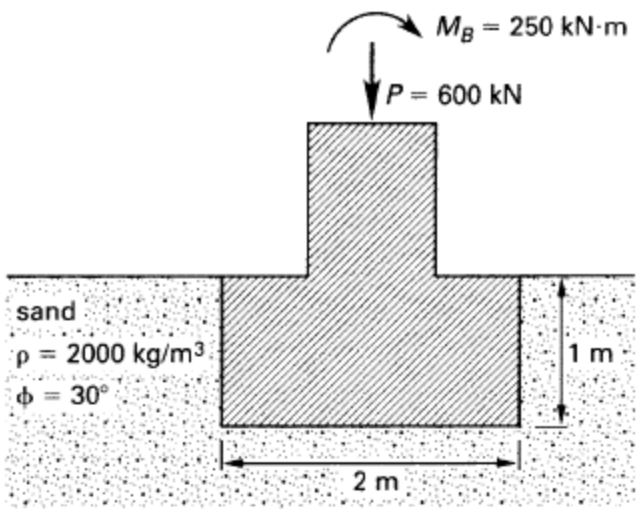
- A. 625
- B. 725
- C. 1,350
- D. 1,975

72. $\sigma' = \sigma - u = (135 \times 10) - 62.4\,(10) = 726$ psf

THE CORRECT ANSWER IS: B

PROBLEM 49 [GEOTECHNICAL ENGINEERING]

4. A 2 m wide continuous wall footing is designed to support an axial column load of 600 kN (per meter of wall length) and a moment of 250 kN·m (per meter of wall length), as shown. The footing is placed 1 m into a sandy soil with a density of 2000 kg/m^3, a cohesion of 0.5 Pa, and an angle of internal friction of 30°.



Most nearly, what is the ultimate bearing capacity per meter of footing length?

(A) 84 kPa

(B) 210 kPa

(C) 430 kPa

(D) 830 kPa

4. From a table of Terzaghi bearing capacity factors, for $\phi = 30°$, $N_c = 37.2$, $N_q = 22.5$, and $N_\gamma = 19.7$.

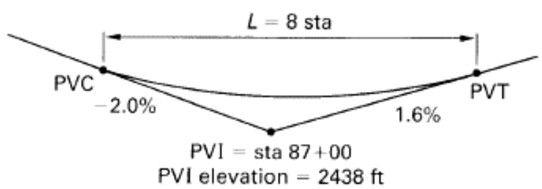
The ultimate bearing capacity is

$$\begin{aligned} q_u &= cN_c + \gamma' D_f N_q + \tfrac{1}{2}\gamma' B N_\gamma \\ &= (0.5\ \text{Pa})(37.2) \\ &\quad + \left(2000\ \frac{\text{kg}}{\text{m}^3}\right)\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(1\ \text{m})(22.5) \\ &\quad + \left(\frac{1}{2}\right)\left(2000\ \frac{\text{kg}}{\text{m}^3}\right)\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(2\ \text{m})(19.7) \\ &= 827\,983\ \text{Pa} \quad (830\ \text{kPa}) \end{aligned}$$

The answer is (D).

PROBLEM 50 [TRANSPORTATION ENGINEERING]

3. A vertical sag curve has a length of 8 sta and connects a −2.0% grade to a 1.6% vertical grade. The PVI is located at sta 87+00 and has an elevation of 2438 ft.



The elevation of the lowest point on the vertical curve is most nearly

(A) 2420 ft

(B) 2430 ft

(C) 2440 ft

(D) 2450 ft

3. The PVI is located at the curve's midpoint. The elevation of the PVC is

$$\begin{aligned} Y_{\text{PVC}} &= Y_{\text{PVI}} + |g_1|\frac{L}{2} \\ &= 2438\ \text{ft} + (0.02)\left(\frac{8\ \text{sta}}{2}\right)\left(100\ \frac{\text{ft}}{\text{sta}}\right) \\ &= 2446\ \text{ft} \end{aligned}$$

The distance from the PVC to the lowest point on the curve is

$$\begin{aligned} x_m &= \frac{g_1 L}{g_1 - g_2} \\ &= \frac{(-0.02)(8\ \text{sta})\left(100\ \frac{\text{ft}}{\text{sta}}\right)}{-0.02 - 0.016} \\ &= 444.44\ \text{ft} \end{aligned}$$

Determine the elevation at the lowest point.

$$\begin{aligned} Y &= Y_{\text{PVC}} + g_1 x + \left(\frac{g_2 - g_1}{2L}\right)x^2 \\ &= 2446\ \text{ft} + (-0.02)(444.44\ \text{ft}) \\ &\quad + \left(\frac{0.016 - (-0.02)}{(2)(8\ \text{sta})\left(100\ \frac{\text{ft}}{\text{sta}}\right)}\right)(444.44\ \text{ft})^2 \\ &= 2441.55\ \text{ft} \quad (2440\ \text{ft}) \end{aligned}$$

The answer is (C).

PROBLEM 51 [TRANSPORTATION ENGINEERING]

4. A highway pavement design has the material specifications shown.

layer	material	layer coefficient	layer thickness
subbase	sandy gravel	$0.11\ \text{in}^{-1}$	12 in
base	crushed stone	$0.14\ \text{in}^{-1}$	15 in
surface	asphalt concrete	$0.44\ \text{in}^{-1}$	6 in

What is most nearly the structural number of the pavement?

(A) 2

(B) 4

(C) 6

(D) 9

4. The structural number is

$$\begin{aligned} SN &= a_1D_1 + a_2D_2 + a_3D_3 \\ &= \left(0.44\ \frac{1}{\text{in}}\right)(6\ \text{in}) + \left(0.14\ \frac{1}{\text{in}}\right)(15\ \text{in}) \\ &\quad + \left(0.11\ \frac{1}{\text{in}}\right)(12\ \text{in}) \\ &= 6.06 \quad (6) \end{aligned}$$

The answer is (C).

PROBLEM 52 [TRANSPORTATION ENGINEERING]

83. An urban intersection is being reconstructed to address safety problems, and it is estimated that the two mutually exclusive countermeasures have a crash reduction factor of 0.25 and 0.15, respectively. If the expected number of crashes per year is 10 and no significant growth in traffic is anticipated, the expected number of average crashes per year after reconstruction is most nearly:

- ○ A. 3.6
- ○ B. 4
- ○ C. 6
- ○ D. 6.4

83. Crash factors are not additive, so combined CR

$$\begin{aligned} CR &= CR_1 + (1 - CR_1)\,CR_2 \\ &= 0.25 + (1 - 0.25)0.15 \\ &= 0.36 \end{aligned}$$

(order CRs from highest to lowest)

1 since no change in ADT

$$\text{Crashes prevented} = N \times CR \cancel{\left(\frac{\text{ADT after}}{\text{ADT before}}\right)}$$

$3.6 = 10 \times 0.36$

$10 - 3.6 = 6.4$

THE CORRECT ANSWER IS: D

PROBLEM 53 [TRANSPORTATION ENGINEERING]

4. Vehicles arrive at a parking garage at an average rate of 45 vehicles per hour. Vehicles are parked by either of two attendants at an average rate of one vehicle per minute for each attendant. The queue discipline is first come, first served. The arrival of vehicles is modeled as a Poisson's distribution and attendant parking time is modeled as an exponential distribution. What is most nearly the probability that at least one attendant will be idle?

(A) 0.34

(B) 0.45

(C) 0.52

(D) 0.80

4. The mean arrival rate of vehicles per minute is

$$\lambda = \frac{45}{(1\ \text{hr})\left(60\ \frac{\text{min}}{\text{hr}}\right)} = 0.75\ 1/\text{min}$$

The service rate per server is $\mu = 1\ 1/\text{min}$.

For two servers ($s = 2$),

$$\rho = \frac{\lambda}{s\mu} = \frac{0.75\ \frac{1}{\text{min}}}{(2)\left(1\ \frac{1}{\text{min}}\right)} = 0.375$$

Next, calculate the probability, P_0, of both attendants being idle (i.e., no units in the system).

$$P_0 = \frac{1-\rho}{1+\rho} = \frac{1-0.375}{1+0.375} = 0.4545$$

Calculate the probability, P_1, of one attendant being idle.

$$P_1 = P_0\left(\frac{\left(\frac{\lambda}{\mu}\right)^n}{n!}\right) = (0.4545)\left(\frac{\left(\frac{0.75\ \frac{1}{\text{min}}}{1\ \frac{1}{\text{min}}}\right)^1}{1!}\right)$$

$$= 0.3409$$

Finally, add P_0 and P_1 to calculate the probability of at least one idle attendant.

$$P = P_0 + P_1 = 0.4545 + 0.3409$$
$$= 0.7954 \quad (0.80)$$

The answer is (D).

PROBLEM 54 [ENVIRONMENTAL ENGINEERING]

4. A water analysis of lake water has the results shown, with all values reported as $CaCO_3$.

alkalinity	151.5 mg/L
sodium	120.0 mg/L
calcium	127.5 mg/L
iron (III)	0.107 mg/L
magnesium	43.5 mg/L
potassium	8.24 mg/L
chloride	39.5 mg/L
fluoride	1.05 mg/L
nitrate	1.06 mg/L
sulfate	106 mg/L

The water's hardness is most nearly

(A) 150 mg/L

(B) 170 mg/L

(C) 290 mg/L

(D) 300 mg/L

4. Water hardness is determined from the polyvalent metallic cations, which are calcium (Ca^{++}), iron (Fe^{+++}), and magnesium (Mg^{++}). Sodium and potassium are singly charged and do not contribute to hardness.

$$\begin{aligned} \text{hardness} &= C_{\text{Ca}^{++}} + C_{\text{Fe}^{+++}} + C_{\text{Mg}^{++}} \\ &= 127.5\ \frac{\text{mg}}{\text{L}} + 0.107\ \frac{\text{mg}}{\text{L}} + 43.5\ \frac{\text{mg}}{\text{L}} \\ &= 171.107\ \text{mg/L} \quad (170\ \text{mg/L}) \end{aligned}$$

The answer is (B).

PROBLEM 55 [ENVIRONMENTAL ENGINEERING]

4. Which of the following equations represents the formation of acid rain?

(A) $S + O_3 + H_2O \rightarrow H_2SO_4$

(B) $SO + O_2 + H_2O \rightarrow H_2SO_4$

(C) $SO_2 + H_2O \rightarrow H_2SO_3$

(D) $SO_3 + H_2O \rightarrow H_2SO_4$

4. $SO_3 + H_2O \rightarrow H_2SO_4$ represents the formation of acid rain.

The answer is (D).

PROBLEM 56 [ENVIRONMENTAL ENGINEERING]

10. Which of the following are generally true for water treatment relative to the adsorption of a contaminate by activated carbon?

I. The adsorption is a chemical reaction and typically irreversible.

II. The adsorption is a physical reaction (van der Waals forces) and generally reversible.

III. Water soluble, inorganic contaminants with low molecular weights are best adsorbed by activated carbon.

IV. The contaminant sticks to the surface of the activated carbon particles.

(A) II and IV

(B) III and IV

(C) I, II, and III

(D) I, II, III, and IV

10. Adsorption is a physical process wherein the contaminant adheres to the surface of an adsorbent such as granular activated charcoal. Following saturation, the adsorbent can be reactivated in a number of ways and reused. Adsorbents are particularly effective at removing large organic molecules from the processing stream.

The answer is (A).

PROBLEM 57 [ENVIRONMENTAL ENGINEERING]

91. A municipal wastewater treatment plant is processing a waste flow with a 5-day BOD of 200 mg/L at 20°C. If the BOD rate constant k_1 (base e) at 20°C is 0.23 day^{-1}, the ultimate BOD (mg/L) of the raw wastewater at 20°C is most nearly:

- ○ A. 133
- ○ B. 233
- ○ C. 292
- ○ D. 420

91. $BOD_5 = 200$ mg/L

$\therefore t = 5$ days

$k_1 = 0.23$ day^{-1}

$$BOD_t = BOD_{ult}\left(1 - e^{-k_1 t}\right)$$

$$200 \text{ mg/L} = BOD_{ult}\left(1 - e^{-0.23 \times 5}\right)$$

$$BOD_{ult} = 200 / \left(1 - e^{-1.15}\right)$$

$$BOD_{ult} = 292.7 \text{ mg/L}$$

THE CORRECT ANSWER IS: C

PROBLEM 58 [CONSTRUCTION]

1. An activity is coded as 0793–31 62 13.16 using the Construction Specifications Institute's MasterFormat 2012. This coding represents

(A) clearing and grubbing land

(B) demolition of an existing structure

(C) shoring an excavation

(D) driving a deep foundation pile

1. The activity designation is translated as follows.

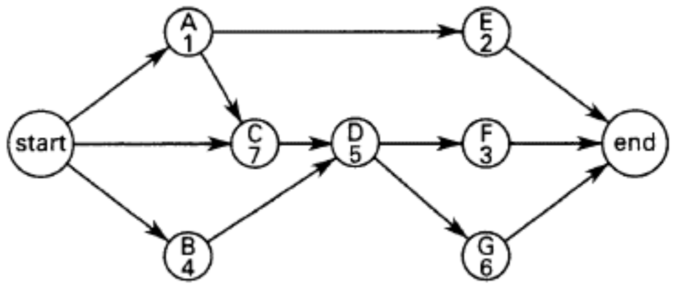
project 793
level 1 activity category 31
level 2 activity category 62
level 3 activity category 13

In the MasterFormat specifications, level 1 category 31 is earthwork, level 2 category 62 is driven piles, and level 3 category 13 is concrete piles.

The answer is (D).

PROBLEM 59 [CONSTRUCTION]

1. An activity-on-node diagram for a construction project is given. (Activity letters and durations are shown in each node circle.)



What is most nearly the float time for activity G?

(A) 0 days

(B) 1 day

(C) 6 days

(D) 25 days

1. Solve this problem using the critical path method (CPM). There are several paths from the start to the end of this project. Identify the paths and calculate their durations.

start-A-E-end:

$$d = 1 \text{ day} + 2 \text{ days} = 3 \text{ days}$$

start-A-C-D-F-end:

$$d = 1 \text{ day} + 7 \text{ days} + 5 \text{ days} + 3 \text{ days} = 16 \text{ days}$$

start-A-C-D-G-end:

$$d = 1 \text{ day} + 7 \text{ days} + 5 \text{ days} + 6 \text{ days} = 19 \text{ days}$$

start-B-D-F-end:

$$d = 4 \text{ days} + 5 \text{ days} + 3 \text{ days} = 12 \text{ days}$$

start-B-D-G-end:

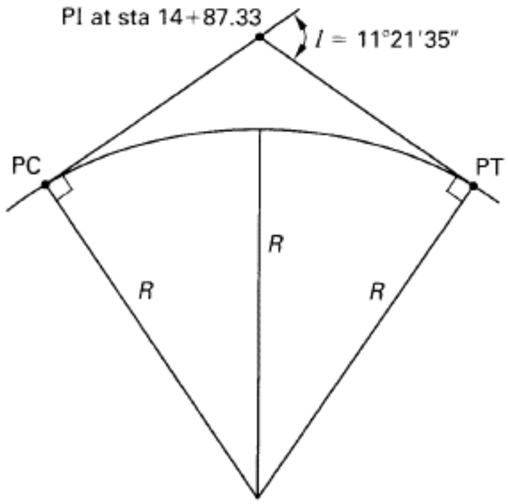
$$d = 4 \text{ days} + 5 \text{ days} + 6 \text{ days} = 15 \text{ days}$$

The longest path is start-A-C-D-G-end, so this is the critical path. Because activity G is along the critical path, the float time for this activity is 0 days.

The answer is (A).

PROBLEM 60 [SURVEYING]

4. A 6° curve has forward and back tangents that intersect at sta 14+87.33.



The station of the point of curve, PC, is most nearly

(A) sta 5+32

(B) sta 9+93

(C) sta 11+28

(D) sta 13+92

4. The radius of the curve is

$$R = \frac{5729.58}{D} = \frac{5729.58 \text{ ft-deg}}{6^\circ} = 954.93 \text{ ft}$$

Convert the intersection angle to a decimal value.

$$I = 11^\circ + \frac{21 \text{ min}}{60 \ \frac{\text{min}}{\text{deg}}} + \frac{35 \text{ sec}}{\left(60 \ \frac{\text{sec}}{\text{min}}\right)\left(60 \ \frac{\text{min}}{\text{deg}}\right)} = 11.36^\circ$$

The tangent length is

$$T = R \tan \frac{I}{2} = (954.93 \text{ ft}) \tan\left(\frac{11.36^\circ}{2}\right) = 94.98 \text{ ft}$$

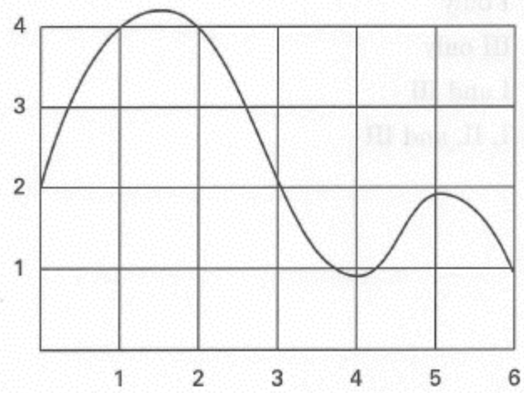
The station of the point of curve, PC, is

$$\begin{aligned} \text{sta PC} &= \text{sta PI} - T \\ &= 1487.33 \text{ ft} - 94.98 \text{ ft} \\ &= 1392 \text{ ft} \quad (\text{sta } 13+92) \end{aligned}$$

The answer is (D).

PROBLEM 61 [SURVEYING]

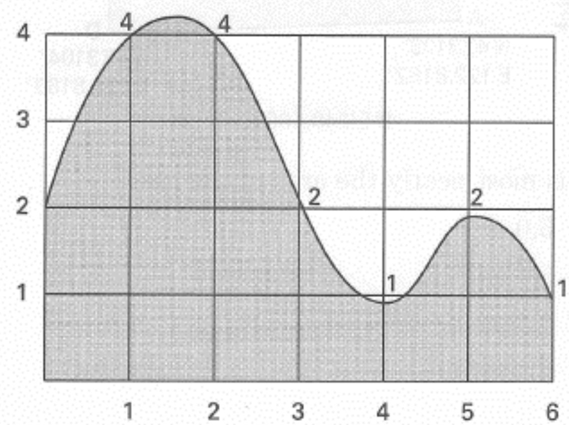
3. The illustration shows a curve from $x = 0$ to $x = 6$.



Using intervals of 1, what is most nearly the area under the curve predicted by Simpson's $1/3$ rule?

(A) 14
(B) 15
(C) 16
(D) 17

3. There is an even number of intervals, so Simpson's $1/3$ rule can be used. Use the graph to determine the measurement at each value of x. The starting measurement is at $x = 0$. That is, $h_1 = 2$.



The area under the curve using Simpson's $1/3$ rule is

$$\text{area} = \frac{w\left(h_1 + 2\left(\sum_{k=3,5,\ldots}^{n-2} h_k\right) + 4\left(\sum_{k=2,4,\ldots}^{n-1} h_k\right) + h_n\right)}{3}$$

$$= \frac{(1)\left(2 + (2)(4+1) + (4)(4+2+2) + 1\right)}{3}$$

$$= 15$$

The answer is (B).

PROBLEM 62 [SURVEYING]

98. The cross-sectional areas to be excavated (cut) at certain sections of a road project are as follows:

Station	Area (ft^2)
3+00	247
4+00	269
4+35	322
5+00	395
5+65	418
6+00	293
7+00	168

Using the prismoidal method, the earth to be excavated (yd^3) between Sections 4+35 and 5+65 is most nearly:

- ○ A. 1,460
- ○ B. 1,840
- ○ C. 1,860
- ○ D. 1,900

98. Refer to Earthwork Formulas in the Civil Engineering section of the *FE Reference Handbook*.

Volume to be excavated = $130[322 + (4)(395) + 418]/[(6)(27)] = 1,862\ yd^3$

THE CORRECT ANSWER IS: C