



5. Which of the following is the solution set of  $1 - 2|x+2| = 6$ ? (1)
- A. ☒  $\emptyset$  B.  $\{1/2, 9/2\}$   
C.  $\{5, 9\}$  D.  $\{-4\}$

**Answer: A**

Isolating the absolute value gives  $|x+2| = -2.5$ , which has no solution because the absolute value of a real number is always non-negative.

6. The solution set of  $|5 - 3x| + 9 > 17$  is: (1)
- A.  $(-\infty, -1] \cup [13/3, \infty)$  B.  $(-\infty, 13/3) \cup (-1, \infty)$   
C.  $(-1, \infty)$  D. ☒  $(-\infty, -1) \cup (13/3, \infty)$

**Answer: D**

The inequality  $|5 - 3x| > 8$  simplifies to  $5 - 3x > 8$  or  $5 - 3x < -8$ , which yields  $x < -1$  or  $x > 13/3$ , corresponding to the interval  $(-\infty, -1) \cup (13/3, \infty)$ .

7. If  $(5^x)^3 \cdot 8^x = 10\sqrt{10}$ , then  $x$  is: (1)
- A.  $1/4$  B. ☒  $1/2$   
C.  $\sqrt{6}/6$  D.  $1/6$

**Answer: B**

Simplifying the equation gives  $(5^{\{3x\}}) \cdot (2^3)^x = 10\sqrt{10}$ , which becomes  $10^{\{3x\}} = 10^{\{1.5\}}$ . Thus,  $3x = 1.5$ , which gives  $x = 1/2$ .

8. The solution set of the equation  $(3^x)^2 \cdot 4^x = 6\sqrt{6}$  is: (1)
- A.  $x=1$  B. ☒  $x=0.75$   
C.  $x=2$  D.  $x=\sqrt{2}$

**Answer: B**

The equation simplifies to  $(3^{\{2x\}}) \cdot (2^2)^x = 6^{\{1.5\}}$ , which is  $36^x = 36^{\{0.75\}}$ , giving  $x = 0.75$ .

9. If  $(16)^x = 1/8$ , then  $x$  is: (1)
- A.  $-4/3$  B.  $4/3$   
C.  $3/4$  D. ☒  $-3/4$

**Answer: D**

Rewriting both sides with base 2 gives  $(2^4)^x = 2^{\{-3\}}$ , which simplifies to  $4x = -3$ , so  $x = -3/4$ .

10. Which of the following interval may not contain a zero of  $f(x)=x^4-7x^2+10$ ? (1)
- A.  $(-2,-1)$  B.  $(1,2)$   
C. ☒  $(-1,0)$  D.  $(2,3)$

**Answer: C**

The zeros of  $f(x) = (x^2 - 2)(x^2 - 5)$  are  $\pm\sqrt{2} \approx \pm 1.414$  and  $\pm\sqrt{5} \approx \pm 2.236$ , none of which lie in the interval  $(-1,0)$ .

11. The solution set of the equation  $(3)(2^{\{4x\}})(5^{\{2x\}}) = 1200$  is: (1)
- A. 2 B. 4  
C. ☒ 1 D. 10

**Answer: C**

Dividing both sides by 3 yields  $(2^{\{4x\}})(5^{\{2x\}}) = 400$ , which can be written as  $(16^x)(25^x) = 400^x = 400$ , so  $x = 1$ .

12. The solution set of the inequality  $2x^2 - 5x - 7 > 0$  is: (1)

- A.  $(1, 7/2)$  B.  $(-\infty, 7) \cup (2, \infty)$   
C. ✓  $(-\infty, -1) \cup (7/2, \infty)$  D.  $(-7, 2)$

**Answer: C**

Factoring the quadratic gives  $(2x-7)(x+1) > 0$ , which holds true when  $x$  is outside the interval  $[-1, 7/2]$ , resulting in  $(-\infty, -1) \cup (7/2, \infty)$ .

13. The solution set of the inequality  $-x^2 + 7x - 12 \leq 0$  is: (1)

- A.  $(-\infty, \infty)$  B.  $[3, 4]$   
C. ✓  $(-\infty, 3] \cup [4, \infty)$  D.  $\emptyset$

**Answer: C**

Multiplying by  $-1$  gives  $x^2 - 7x + 12 \geq 0$ , which factors to  $(x-3)(x-4) \geq 0$ . The solution set is  $x \leq 3$  or  $x \geq 4$ , or  $(-\infty, 3] \cup [4, \infty)$ .

14. The solution set of the inequality  $x^2 - 9 \leq 0$  is: (1)

- A.  $(-\infty, -3] \cup [3, \infty)$  B. ✓  $[-3, 3]$   
C.  $(-\infty, -9] \cup [9, \infty)$  D.  $[-9, 9]$

**Answer: B**

The inequality  $x^2 - 9 \leq 0$  can be factored as  $(x-3)(x+3) \leq 0$ , which is satisfied when  $x$  lies in the interval  $[-3, 3]$ .

15. In the quadratic equation  $(k-1)x^2 - 4x + 2k = 0$ , if the sum of its roots is 2, then  $k = ?$  (1)

- A.  $-4$  B. ✓  $3$   
C.  $-3$  D.  $4$

**Answer: B**

The sum of the roots of  $(k-1)x^2 - 4x + 2k = 0$  is  $-(-4)/(k-1) = 4/(k-1)$ . Setting this equal to 2 yields  $k = 3$ .

16. If 'a' and 'b' are the roots of  $x^2 + 3x + 2 = 0$ , then  $a^2 + b^2 = ?$  (1)

- A. 13 B. 10  
C. ✓ 5 D. -13

**Answer: C**

The roots of the equation are  $-1$  and  $-2$ . Summing their squares gives  $(-1)^2 + (-2)^2 = 1 + 4 = 5$ .

17. What is the range of the inverse of  $R = \{(x, y): y = \sqrt{1 - |x+2|}\}$ ? (1)

- A.  $\{y: y \geq -2\}$  B. ✓  $\{y: -3 \leq y \leq -1\}$   
C.  $\{y: y \leq -2\}$  D.  $\{y: 1 \leq y \leq 3\}$

**Answer: B**

The range of the inverse of  $R$  is equal to the domain of  $R$ . For  $y = \sqrt{1 - |x+2|}$  to be defined, we need  $1 - |x+2| \geq 0$ , which simplifies to  $-3 \leq x \leq -1$ .

18. Which one of the following is true about Signum, absolute value and greatest integer functions? (1)

- A.  $\text{sgn}(x) = \pm|x|, \forall x \in \mathbb{R}$  B.  $\text{sgn}(x) \leq |x|, \forall x \geq 0$   
C.  $\text{sgn}(x) \leq |x|, \forall x \in \mathbb{R}$  D. ✓  $|x| = x \cdot \text{sgn}(x), \forall x \in \mathbb{R}$

**Answer: D**

By definition, the absolute value function can be represented as  $|x| = x \cdot \text{sgn}(x)$  for all real numbers  $x$ , which correctly handles positive, negative, and zero values.

19. Let  $f(x)=3x-4$  and  $g(x)=mx+b$ . For what  $m,b$  is  $(f \circ g)(x)=x=(g \circ f)(x)$ ? (1)

- A. ✓  $m=1/3, b=4/3$                       B.  $m=-3, b=4$   
C.  $m=1/3, b=4$                       D.  $m=1/3, b=3/4$

**Answer: A**

For  $(f \circ g)(x) = x = (g \circ f)(x)$  to hold,  $g$  must be the inverse of  $f$ . Finding the inverse of  $f(x) = 3x - 4$  gives  $f^{-1}(x) = (1/3)x + 4/3$ , so  $m = 1/3$  and  $b = 4/3$ .

20. What is the partial fraction form of  $(3x^2-2x-4)/(x^3+2x)$ ? (1)

- A.  $2/x + (5x+2)/(x^2+2)$                       B.  $-2/x + (5x+3)/(x^2+2)$   
C. ✓  $-2/x + (5x-2)/(x^2+2)$                       D.  $2/x + (5x-2)/(x^2+2)$

**Answer: C**

Decomposing into partial fractions as  $A/x + (Bx+C)/(x^2+2)$  and solving the system of equations gives  $A = -2$ ,  $B = 5$ , and  $C = -2$ .

21. Which one of the following is not true about  $f(x)=(x-x^3)/[x^3(x-1)]$ ? (1)

- A. Vertical asymptotes:  $x=0$   
B. Horizontal asymptote:  $y=0$   
C. Graph intersects horizontal asymptote at  $(-1,0)$   
D. ✓ **Graph intersects vertical line  $x=0$**

**Answer: D**

The domain of  $f(x)$  excludes  $x = 0$ , so the graph of  $f$  can never intersect the vertical line  $x = 0$ , making D the false statement.

22. Equation of line through intersection of  $x-2y+1=0$  and  $2x+y-3=0$  and parallel to  $3x-4y+2=0$ ? (1)

- A.  $4x-3y-1=0$                       B. ✓  **$3x-4y+1=0$**   
C.  $3x+4y+1=0$                       D.  $3x-4y-1=0$

**Answer: B**

The intersection of the two given lines is  $(1,1)$ . A line parallel to  $3x-4y+2=0$  has the form  $3x-4y+C=0$ ; substituting  $(1,1)$  into this equation yields  $C = 1$ .

23. A circle radius 1 is internally tangent to circle  $x^2+y^2-2y=8$  at  $(3,1)$ . Equation of smaller circle? (1)

- A.  $x^2+(y-1)^2=1$                       B.  $(x-1)^2+(y-2)^2=1$   
C. ✓  **$(x-2)^2+(y-1)^2=1$**                       D.  $(x-4)^2+(y-1)^2=1$

**Answer: C**

The larger circle has center  $(0,1)$  and radius 3. The smaller circle of radius 1 is internally tangent at  $(3,1)$ , meaning its center lies at  $(2,1)$ , yielding the equation  $(x-2)^2 + (y-1)^2 = 1$ .

24. Class groups: A:15 students avg16; B:14 students avg17; C:11 students avg14. Overall average? (1)

- A. 15.3                      B. 16.2  
C. ✓ **15.8**                      D. 15.4

**Answer: C**

The overall average is calculated by dividing the total sum of values of all groups, which is  $(15 * 16) + (14 * 17) + (11 * 14) = 632$ , by the total number of students, which is  $15 + 14 + 11 = 40$ . This gives  $632 / 40 = 15.8$ .

The (2,3) entry of C is  $3(\text{BA})_{\{2,3\}} - 2(\text{A}^T)_{\{2,3\}}$ . Computing the dot product of the second row of B and the third column of A gives  $(\text{BA})_{\{2,3\}} = 5$ , and the transpose entry is  $(\text{A}^T)_{\{2,3\}} = \text{A}_{\{3,2\}} = 2$ , so  $\text{C}_{\{2,3\}} = 3(5) - 2(2) = 11$ .

31. If  $A = \begin{bmatrix} 1 & 2 \\ 2 & 3 \end{bmatrix}$ ,  $B = \begin{bmatrix} -3 & 2 \\ 2 & -1 \end{bmatrix}$ , then which is not true? (1)

- A.  $AB = BA$  B.  $A+B$  is symmetric  
C.  $B-A$  is a scalar matrix D. ✓  $A+B = A-B$

**Answer: D**

If  $A+B = A-B$ , then  $2B = 0$ , which implies  $B$  must be the zero matrix. Since  $B$  is non-zero, this statement is false. The other options are easily verified to be true.

32. Which one is false about the sequence  $\{1, -1/3, -5/3, -3, -13/3, -17/3, -7, \dots\}$ ? (1)

- A. It is AP with  $d = -4/3$  B.  $n$ th term  $a_n = (7-4n)/3$   
C.  $a_n = (1/3)(7-4n)$  D. ✓ It is GP

**Answer: D**

The sequence has a constant difference of  $-4/3$  between consecutive terms, which means it is an arithmetic progression (AP) and not a geometric progression (GP).

33. Which one is the  $n$ th term of the sequence  $\{0.5, 0.55, 0.555, \dots\}$ ? (1)

- A.  $5(1-1/10^n)$  B.  $(1/9)(1-1/10^n)$   
C. ✓  $(5/9)(1-1/10^n)$  D.  $(5/9)(5-1/10^n)$

**Answer: C**

For  $n = 1$ , the first term of the sequence is 0.5. Substituting  $n = 1$  into the expression in option C gives  $(5/9)(1 - 0.1) = 0.5$ , whereas the other options do not yield the correct value.

34. The series  $1 - 3/5 + 9/25 - 27/125 + \dots$  is equal to: (1)

- A. 1 B.  $4/25$   
C. ✓  $5/8$  D.  $5/2$

**Answer: C**

This is an infinite geometric series with first term  $a = 1$  and common ratio  $r = -3/5$ . Its sum converges to  $a / (1 - r) = 1 / (1 + 3/5) = 5/8$ .

35. A boat worth Birr 125,000 loses 15% of its value each year. What worth after 5 years? (1)

- A. 65,250.78 B. ✓ 55,463.164  
C. 218,625.78 D. 251,419.648

**Answer: B**

The value of the boat after 5 years is calculated as  $125,000 * (0.85)^5 = 55,463.164$  Birr, where 0.85 represents the annual value retention factor of 85%.

36. Let  $\{a_n\}$  with  $a_1 = -2$  and  $a_n = 1/a_{n-1}$  for  $n \geq 2$ , then  $a_{98} = ?$  (1)

- A. -2 B. ✓  $-1/2$   
C.  $1/97$  D.  $-1/4$

**Answer: B**

The sequence alternates between  $-2$  for odd indices and  $-1/2$  for even indices. Since 98 is an even number, the term  $a_{98}$  is  $-1/2$ .

**37.** Which one is not true about the sequence  $a_n = \{1+3+5+\dots+(2n-1)\}/(3n^2-1)$ ? (1)

- A.  $1/2 < a_n < 1/3$  B. ✓ **glb = 1/2**  
C. glb = 1/3 D.  $\lim a_n = 1/3$

**Answer: B**

The sum in the numerator simplifies to  $n^2$ , giving  $a_n = n^2 / (3n^2 - 1)$ . Because this sequence strictly decreases from its maximum of  $1/2$  to its limit of  $1/3$ , its greatest lower bound (glb) is  $1/3$ , meaning option B is false.

**38.** Let  $f(x) = (kx+3)/(2x-k)$ . If  $f'(1) = -1$ , then  $k = ?$  (1)

- A. 2  
C.  $1/2$   
B. ✓  $-1/2$   
D. -5

**Answer: B**

Using the quotient rule, the derivative is  $f'(x) = (-k^2 - 6)/(2x - k)^2$ . Setting  $f'(1) = -1$  yields  $k^2 + 6 = (2 - k)^2$ , which simplifies to  $6 = 4 - 4k$ , or  $k = -1/2$ .

**39.** Let  $f(x) = (1/3)x - |x^2 - 4|$ . The set of all critical numbers is: (1)

- A.  $\{-2, 1/6, 2\}$  B.  $\{-2, -1/6, 0, 1/6, 2\}$   
C.  $\{-2, -1/6, 1/6, 2\}$  D. ✓  $\{-2, -1/6, 2\}$

**Answer:** D

The critical numbers include  $x = 2$  and  $x = -2$  where the derivative does not exist. For  $x$  in  $(-2, 2)$ , setting the derivative of  $f(x) = x^2 + x/3 - 4$  to zero gives  $x = -1/6$ , resulting in the critical set  $\{-2, -1/6, 2\}$ .

40. Which one is false about  $f(x)=x^3-3x^2+3x+1$ ? (1)

- A.  $f$  concave upward on  $[1, \infty)$       B.  $f$  strictly increasing on  $(-\infty, \infty)$   
C. ✓  $f$  has local extreme at  $x=1$       D.  $(1, 2)$  is inflection point

**Answer: C**

The derivative  $f'(x) = 3(x-1)^2$  is non-negative for all real numbers  $x$ , meaning the function is strictly increasing on its entire domain and therefore has no local extrema.

41. Maximum possible area of an isosceles triangle with perimeter 6 m? (1)

- A.  $2 \text{ m}^2$                       B.  $\sqrt{3} \text{ m}^2$   
C.  $2\sqrt{3} \text{ m}^2$                 D.  $3 \text{ m}^2$

**Answer: B**

An isosceles triangle with a fixed perimeter has the maximum area when it is equilateral. For a perimeter of 6 m, the side length is 2 m, yielding an area of  $(\sqrt{3}/4) * 2^2 = \sqrt{3} \text{ m}^2$ .

**42.** A ladder 6 m long slides. Bottom moves at  $3/4$  m/s. Find angle between top and wall when angle changes at  $\sqrt{2}/8$  rad/s. (1)

- A.  $\pi/2$  B.  $\pi/3$   
C.  $\pi/6$  D. ☒  $\pi/4$

**Answer:** D

By differentiating  $x = 6 \sin(\theta)$  with respect to time  $t$ , we obtain  $dx/dt = 6 \cos(\theta) * (d_\theta/dt)$ . Substituting the given rates  $3/4 = 6 \cos(\theta) * (\sqrt{2}/8)$  gives  $\cos(\theta) = 1/\sqrt{2}$ , so  $\theta = \pi/4$ .

43. Which point on graph of  $f(x)=2x-1$  is closest to  $(1,2)$ ? (1)

- A.  $(8/5, -4/5)$  B. ✓  $(7/5, 9/5)$   
C.  $(4/5, 3/5)$  D.  $(8/5, 4/5)$

**Answer: B**

Minimizing the squared distance  $(x - 1)^2 + (2x - 3)^2$  yields a parabola  $5x^2 - 14x + 10$  whose vertex occurs at  $x = 7/5$ , corresponding to the closest point  $(7/5, 9/5)$ .

44. Volume generated by revolving region between  $f(x)=x^2$  and  $g(x)=4x-x^2$  about x-axis? (1)

- A.  $224\pi/3$  B.  $22\pi/3$   
C. ✓  $32\pi/3$  D.  $24\pi/3$

**Answer: C**

The curves intersect at  $x = 0$  and  $x = 2$ . The volume of the solid generated is computed using the washer method as  $\pi \int_0^2 ((4x - x^2)^2 - x^4) dx = \pi \int_0^2 (16x^2 - 8x^3) dx = 32\pi/3$ .

45. Angle between vectors  $u = m i + m\sqrt{3} j$  and  $v = m\sqrt{3} i + m j$ ? (1)

- A.  $90^\circ$  B.  $60^\circ$   
C. ✓  $30^\circ$  D.  $53^\circ$

**Answer: C**

Using the dot product formula, we have  $\cos(\theta) = (u \cdot v) / (||u|| \cdot ||v||) = (2 * m^2 * \sqrt{3}) / (4 * m^2) = \sqrt{3}/2$ , which corresponds to an angle of 30 degrees.

46. Image of line  $l: 3x+2y=6$  after rotation of  $90^\circ$  about point  $P(2,3)$  is: (1)

- A.  $2x-3y=6$  B.  $3x-2y=1$   
C.  $3x-2y=-6$  D. ✓  $2x-3y=1$

**Answer: D**

A  $90^\circ$  counterclockwise rotation of a point  $(x,y)$  about  $P(2,3)$  maps it to  $(x', y')$  where  $x = y' - 1$  and  $y = 5 - x'$ . Substituting these into  $3x + 2y = 6$  gives  $3(y' - 1) + 2(5 - x') = 6$ , which simplifies to  $2x - 3y = 1$ .

47. If the image of point  $P(-2,3)$  is  $P'(6,7)$  under a line reflection, then the line of reflection is: (1)

- A.  $2y = x + 9$  B. ✓  $y = -2x + 9$   
C.  $y = 2x - 9$  D.  $y = -x + 9$

**Answer: B**

The line of reflection is the perpendicular bisector of the segment  $PP'$ . The midpoint of  $PP'$  is  $(2,5)$  and the slope of  $PP'$  is  $1/2$ , so the slope of the reflection line is  $-2$ . Its equation is  $y - 5 = -2(x - 2)$ , which simplifies to  $y = -2x + 9$ .

48. In triangle ABC,  $AB=7$ ,  $BC=8$ ,  $m\angle B=120^\circ$ . Find AC and  $\sin\angle A$ ? (1)

- A.  $\sqrt{57}$  and  $4\sqrt{3}/13$  B.  $\sqrt{57}$  and  $-4\sqrt{3}/13$   
C. 13 and  $23/26$  D. ✓ 13 and  $4\sqrt{3}/13$

**Answer: D**

By the Law of Cosines,  $AC^2 = 7^2 + 8^2 - 2(7)(8)\cos(120^\circ) = 49 + 64 - 112(-1/2) = 169$ , so  $AC = 13$ . Then, by the Law of Sines,  $\sin A = (8 * \sin(120^\circ)) / 13 = 4\sqrt{3}/13$ .

49. Points P(3,3,2) and Q(2,0,4) on sphere with center on z-axis. Which point is outside? (1)

- A. ✓ (-4,3,0)                      B. (2,-2,1)  
C. (3,1,1)                         D. (0,0,0)

**Answer: A**

The center of the sphere is on the z-axis, C(0,0,z). Since P and Q are on the sphere,  $CP^2 = CQ^2$ , which yields  $18 + (2-z)^2 = 4 + (4-z)^2$ , solving to  $z = -1/2$ . The sphere's equation is  $x^2 + y^2 + (z + 0.5)^2 = 24.25$ , and only point A(-4,3,0) gives a squared distance of  $25.25 > 24.25$ , making it lie outside the sphere.

50. Equation of tangent to circle  $x^2 + y^2 - 2x - 2y - 23 = 0$  at P(-3,4) is: (1)

- A.  $3y + 4x = 24$                       B.  $3x - y = 24$   
C.  $4x - 3y = 0$                          D. ✓  $4x - 3y + 24 = 0$

**Answer: D**

The equation of the tangent to the circle  $x^2 + y^2 - 2x - 2y - 23 = 0$  at P(-3,4) is given by  $xx_1 + yy_1 - (x + x_1) - (y + y_1) - 23 = 0$ . Substituting  $x_1 = -3$  and  $y_1 = 4$  yields  $-3x + 4y - (x - 3) - (y + 4) - 23 = 0$ , which simplifies to  $4x - 3y + 24 = 0$ .

51. Let  $\ell$  be line containing (1,5) with angle of inclination  $\theta = 135^\circ$ . Distance from  $\ell$  to (-1,1) is: (1)

- A.  $2\sqrt{2}$                                   B. ✓  $3\sqrt{2}$   
C.  $4\sqrt{2}$                                   D.  $6\sqrt{2}$

**Answer: B**

The line with inclination  $135^\circ$  has slope  $m = -1$ . Its equation passing through (1,5) is  $y - 5 = -(x - 1)$ , or  $x + y - 6 = 0$ . The perpendicular distance from (-1,1) to this line is  $|-1 + 1 - 6| / \sqrt{1^2 + 1^2} = 6 / \sqrt{2} = 3\sqrt{2}$ .

END OF THE MARKING KEY

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