POLYNOMIALS: FACTOR THEOREM, RATIONAL ROOTS, AND VIETA FOR AMC 12: PRACTICE SET SOLUTIONS

ANDY JO

Contents

1. Solutions 2
2. Answer Key 10

1. Solutions

Beginner.

1. (1982 AHSME, Problem #1) When the polynomial $x^3 - 2$ is divided by the polynomial $x^2 - 2$, the remainder is

(A) 2 **(B)** -2 **(C)** $-2x - 2$ **(D)** $2x + 2$ **(E)** $2x - 2$

Strategy. Divide the leading term x^3 by the leading term x^2 of the divisor and subtract that multiple of the divisor. What is left already has degree less than 2.

Solution. The first step of long division divides x^3 by x^2, which gives x, and subtracts $x(x^2 - 2) = x^3 - 2x$:

$$(x^3 - 2) - x(x^2 - 2) = 2x - 2.$$

What is left has degree 1, which is less than the degree 2 of the divisor, so the division stops here. Hence

$$x^3 - 2 = x(x^2 - 2) + (2x - 2),$$

and by the Division Algorithm the quotient is x and the remainder is $2x - 2$. As a check, at $x = \sqrt{2}$ the divisor is 0, and both $x^3 - 2$ and $2x - 2$ equal $2\sqrt{2} - 2$.

Answer: (E) $2x - 2$. □

2. (2018 AMC 12A, Problem #5) What is the sum of all possible values of k for which the polynomials $x^2 - 3x + 2$ and $x^2 - 5x + k$ have a root in common?

(A) 3 **(B)** 4 **(C)** 5 **(D)** 6 **(E)** 10

Strategy. A root in common is also a root of $(x - 1)(x - 2) = x^2 - 3x + 2$, so it is 1 or 2. A number r is a root of $x^2 - 5x + k$ exactly when $k = 5r - r^2$.

Solution. By the factorization $x^2 - 3x + 2 = (x - 1)(x - 2)$, a root of both polynomials can only be 1 or 2. The number 1 is a root of $x^2 - 5x + k$ exactly when $1 - 5 + k = 0$, that is, $k = 4$. The number 2 is a root exactly when $4 - 10 + k = 0$, that is, $k = 6$. By the Factor Theorem, these values of k make $x - 1$ and $x - 2$ factors:

$$x^2 - 5x + 4 = (x - 1)(x - 4), \qquad x^2 - 5x + 6 = (x - 2)(x - 3).$$

So the possible values of k are 4 and 6, and their sum is 10.

Answer: (E) 10. □

3. (1954 AHSME, Problem #20) The equation $x^3 + 6x^2 + 11x + 6 = 0$ has:

(A) no negative real roots **(B)** no positive real roots **(C)** no real roots
(D) 1 positive and 2 negative roots **(E)** 2 positive and 1 negative root

Strategy. The polynomial is monic with integer coefficients, so each rational root is an integer that divides 6. Find one root, divide it out, and factor the quadratic quotient.

Solution. Let $P(x) = x^3 + 6x^2 + 11x + 6$. By the Integer Roots corollary, every rational root of P is an integer that divides 6, so the candidates are ± 1, ± 2, ± 3 and ± 6. Testing $x = -1$ gives $P(-1) = -1 + 6 - 11 + 6 = 0$, so $x + 1$ is a factor by the Factor Theorem. Dividing,

$$x^3 + 6x^2 + 11x + 6 = (x + 1)(x^2 + 5x + 6) = (x + 1)(x + 2)(x + 3).$$

So the roots are -1, -2 and -3, and by the Roots and Degree theorem the cubic has no others. All three are negative, so the equation has no positive real roots, and of the five

statements only (B) is true. As a check, for $x > 0$ every term of $P(x)$ is positive, so P has no positive root.

Answer: (B) no positive real roots. □

4. (1965 AHSME, Problem #27) When $y^2 + my + 2$ is divided by $y - 1$ the quotient is $f(y)$ and the remainder is R_1. When $y^2 + my + 2$ is divided by $y + 1$ the quotient is $g(y)$ and the remainder is R_2. If $R_1 = R_2$, then m is:

(A) 0 **(B)** 1 **(C)** 2 **(D)** -1 **(E)** an undetermined constant

Strategy. The quotients are not needed. By the Remainder Theorem, each remainder is a value of the polynomial, at $y = 1$ and at $y = -1$.

Solution. Let $P(y) = y^2 + my + 2$. By the Remainder Theorem, the remainder upon division by $y - 1$ is

$$R_1 = P(1) = 1 + m + 2 = 3 + m.$$

Since $y + 1 = y - (-1)$, the remainder upon division by $y + 1$ is

$$R_2 = P(-1) = 1 - m + 2 = 3 - m.$$

The condition $R_1 = R_2$ becomes $3 + m = 3 - m$, so $m = 0$.

Answer: (A) 0. □

5. (1956 AHSME, Problem #17) The fraction $\dfrac{5x - 11}{2x^2 + x - 6}$ was obtained by adding the two fractions $\dfrac{A}{x + 2}$ and $\dfrac{B}{2x - 3}$. The values of A and B must be, respectively:

(A) $5x$, -11 **(B)** -11, $5x$ **(C)** -1, 3 **(D)** 3, -1 **(E)** 5, -11

Strategy. Factor the denominator as $(x+2)(2x-3)$ and clear denominators. The resulting equation holds for all but two values of x, so it is an identity between polynomials, and their coefficients can be compared.

Solution. The denominator factors as $2x^2 + x - 6 = (x + 2)(2x - 3)$, so

$$\frac{A}{x + 2} + \frac{B}{2x - 3} = \frac{A(2x - 3) + B(x + 2)}{2x^2 + x - 6}.$$

If one of A and B were $5x$ and the other -11, as in choices (A) and (B), the numerator $A(2x - 3) + B(x + 2)$ would have an x^2 term and could not equal $5x - 11$. In the other three choices, A and B are numbers, and the sum is the given fraction exactly when

$$5x - 11 = A(2x - 3) + B(x + 2) = (2A + B)x + (2B - 3A)$$

for every x other than -2 and $\frac{3}{2}$. Both sides are polynomials of degree at most 1 that agree at more than two numbers, so by the Identity corollary their coefficients agree:

$$2A + B = 5, \qquad 2B - 3A = -11.$$

By the first equation, $B = 5 - 2A$. Then the second equation becomes $10 - 7A = -11$, so $A = 3$ and $B = -1$. As a check, setting $x = -2$ in the identity gives $-21 = -7A$, and setting $x = \frac{3}{2}$ gives $-\frac{7}{2} = \frac{7}{2}B$.

Answer: (D) 3, -1. □

Intermediate.

6. (2020 AMC 10A, Problem #17) Define

$$P(x) = (x - 1^2)(x - 2^2) \cdots (x - 100^2).$$

How many integers n are there such that $P(n) \leq 0$?

(A) 4900 **(B)** 4950 **(C)** 5000 **(D)** 5050 **(E)** 5100

Strategy. The 100 roots are all simple, so P changes sign at each of them. Find the sign of P between consecutive squares, count the integers where it is negative, and add the roots.

Solution. The roots of P are the 100 squares $1^2, 2^2, \ldots, 100^2$, and each of them is a simple root. For $x > 100^2$ all 100 factors $x - j^2$ are positive, so $P(x) > 0$. By the Sign near a Root theorem, P changes sign at each simple root, and a polynomial changes sign only at its roots. So the sign alternates from one interval between consecutive squares to the next: for $1 \leq k \leq 99$, the polynomial is negative on the interval $k^2 < x < (k+1)^2$ exactly when $100 - k$ is odd, that is, when k is odd, and $P(x) > 0$ for $x < 1$. This agrees with a direct count: for $k^2 < x < (k+1)^2$, exactly the $100 - k$ factors $x - j^2$ with $j > k$ are negative.

There are $(k+1)^2 - k^2 - 1 = 2k$ integers strictly between k^2 and $(k+1)^2$. So the number of integers n with $P(n) < 0$ is

$$2(1 + 3 + 5 + \cdots + 99) = 2 \cdot 50^2 = 5000.$$

The 100 roots give $P(n) = 0$, so $P(n) \leq 0$ for $5000 + 100 = 5100$ integers.

Answer: (E) 5100. □

7. (2022 AIME I, Problem #1) Quadratic polynomials $P(x)$ and $Q(x)$ have leading coefficients of 2 and -2, respectively. The graphs of both polynomials pass through the two points $(16, 54)$ and $(20, 53)$. Find $P(0) + Q(0)$.

Strategy. Both graphs pass through the same two points, so P and Q agree with the linear polynomial L through those points at $x = 16$ and $x = 20$. Then $P - L$ and $Q - L$ are quadratics with the roots 16 and 20 and known leading coefficients.

Solution. The line through $(16, 54)$ and $(20, 53)$ has slope $\frac{53-54}{20-16} = -\frac{1}{4}$, so it is the graph of

$$L(x) = 54 - \frac{x - 16}{4}.$$

The polynomial $P(x) - L(x)$ is 0 at $x = 16$ and at $x = 20$. Subtracting the linear polynomial L does not change the leading term $2x^2$, so $P - L$ is a quadratic with leading coefficient 2 and roots 16 and 20. By the Roots and Degree theorem,

$$P(x) - L(x) = 2(x - 16)(x - 20).$$

In the same way, $Q(x) - L(x) = -2(x - 16)(x - 20)$. Adding the two equations gives $P(x) + Q(x) = 2L(x)$ for every x, so

$$P(0) + Q(0) = 2L(0) = 2(54 + 4) = 116.$$

As a check, $P(0) = 58 + 640 = 698$ and $Q(0) = 58 - 640 = -582$.

Answer: 116. □

8. (1983 AHSME, Problem #18) Let f be a polynomial function such that, for all real x,

$$f(x^2+1) = x^4 + 5x^2 + 3.$$

For all real x, $f(x^2-1)$ is

(A) x^4+5x^2+1 **(B)** x^4+x^2-3 **(C)** x^4-5x^2+1 **(D)** x^4+x^2+3
(E) none of these

Strategy. The degree of $f(x^2+1)$ is twice the degree of f, so f is quadratic. Write $f(t) = pt^2+qt+r$, expand $f(x^2+1)$, and compare coefficients.

Solution. If f has degree n and leading coefficient p, then the leading term of $f(x^2+1)$ is px^{2n}. So $2n = 4$ and $n = 2$. Write $f(t) = pt^2+qt+r$. Then

$$f(x^2+1) = p(x^2+1)^2 + q(x^2+1) + r = px^4 + (2p+q)x^2 + (p+q+r).$$

This equals x^4+5x^2+3 for all real x, so by the Identity corollary the coefficients agree: $p = 1$, $2p+q = 5$ and $p+q+r = 3$. Hence $p = 1$, $q = 3$ and $r = -1$, so

$$f(t) = t^2 + 3t - 1$$

for every real t, including the numbers less than 1, which x^2+1 never reaches. Therefore

$$f(x^2-1) = (x^2-1)^2 + 3(x^2-1) - 1 = x^4 - 2x^2 + 1 + 3x^2 - 3 - 1 = x^4 + x^2 - 3.$$

Answer: (B) x^4+x^2-3. □

9. (2003 AMC 12A, Problem #21) The graph of the polynomial

$$P(x) = x^5 + ax^4 + bx^3 + cx^2 + dx + e$$

has five distinct x-intercepts, one of which is at $(0,0)$. Which of the following coefficients cannot be zero?

(A) a **(B)** b **(C)** c **(D)** d **(E)** e

Strategy. Write P as a product of linear factors, one of which is x. By Vieta's formulas, d is the sum of the products of the roots taken four at a time, and every such product that contains the root 0 vanishes.

Solution. Let the roots be 0, p, q, r, s, where p, q, r, s are distinct and nonzero. Since P is monic of degree 5, the Roots and Degree theorem gives

$$P(x) = x(x-p)(x-q)(x-r)(x-s).$$

By Vieta's formulas, the coefficient d of x is $(-1)^4 = 1$ times the sum of the five products of four of the roots. Four of these products contain the root 0 and are 0, so $d = pqrs$, which is not 0. Hence d cannot be zero.

The other coefficients can be zero. The constant term is $e = P(0) = 0$ for every such polynomial. The roots 0, ± 1, ± 2 give

$$P(x) = x(x^2-1)(x^2-4) = x^5 - 5x^3 + 4x,$$

in which $a = c = 0$, and the roots 0, 1, 4, ± 2 give

$$P(x) = x(x-1)(x-4)(x^2-4) = x^5 - 5x^4 + 20x^2 - 16x,$$

in which $b = 0$.

Answer: (D) d. □

10. The polynomial $x^4 + ax^3 + bx^2 + cx + d$, where a, b, c, and d are rational numbers, has $1 + \sqrt{2}$ as a double root. What is $a + b + c + d$?

(A) -4 **(B)** -1 **(C)** 1 **(D)** 3 **(E)** 4

Strategy. By the Conjugate Roots theorem, $(x-1)^2 - 2 = x^2 - 2x - 1$ is a factor. The other quadratic factor still has the root $1 + \sqrt{2}$, because that root is double, so it is the same quadratic.

Solution. Let $P(x) = x^4 + ax^3 + bx^2 + cx + d$ and $M(x) = (x-1)^2 - 2 = x^2 - 2x - 1$. Let $u = 1 + \sqrt{2}$ and $v = 1 - \sqrt{2}$, so that $M(x) = (x-u)(x-v)$. By the Conjugate Roots theorem, v is also a root of P and M divides P, so $P = MQ$, where Q is monic of degree 2. Long division of P by M involves only rational numbers, so Q has rational coefficients.

The root u of P has multiplicity 2 and v is another root, so by the Factorization with Multiplicities theorem

$$P(x) = (x-u)^2(x-v)T(x) = M(x) \cdot (x-u)T(x)$$

for some polynomial T. The quotient upon division by M is unique, so $Q(x) = (x-u)T(x)$, and in particular $Q(u) = 0$. Then Q has rational coefficients and the root $1 + \sqrt{2}$, so M divides Q by the Conjugate Roots theorem. Both are monic of degree 2, so $Q = M$ and

$$P(x) = (x^2 - 2x - 1)^2 = x^4 - 4x^3 + 2x^2 + 4x + 1.$$

The sum of all the coefficients is $P(1) = (1 - 2 - 1)^2 = 4$, so $a + b + c + d = 4 - 1 = 3$. Conversely, this P has rational coefficients, and $1 + \sqrt{2}$ is a double root, because $P(x) = (x-u)^2(x-v)^2$ and $(u-v)^2 \neq 0$.

Answer: (D) 3. □

Advanced.

11. (2010 AIME I, Problem #6) Let $P(x)$ be a quadratic polynomial with real coefficients satisfying

$$x^2 - 2x + 2 \leq P(x) \leq 2x^2 - 4x + 3$$

for all real numbers x, and suppose $P(11) = 181$. Find $P(16)$.

Strategy. Complete the square in both bounds: they are $(x-1)^2 + 1$ and $2(x-1)^2 + 1$, which are equal at $x = 1$. Then $P(x) - (x-1)^2 - 1$ is never negative and has the root 1, which must have even multiplicity.

Solution. Completing the square,

$$x^2 - 2x + 2 = (x-1)^2 + 1, \qquad 2x^2 - 4x + 3 = 2(x-1)^2 + 1.$$

Both bounds equal 1 at $x = 1$, so $P(1) = 1$. Let $D(x) = P(x) - (x-1)^2 - 1$. Then $D(x) \geq 0$ for every real x, $D(1) = 0$, and D is the zero polynomial or has degree at most 2. If D is not the zero polynomial, then 1 is a root of D, and by the Sign near a Root theorem its multiplicity is even, since a root of odd multiplicity would make D change sign. Then $(x-1)^2$ divides D, and the quotient has degree 0. In either case $D(x) = c(x-1)^2$ for a constant c, so

$$P(x) = (1 + c)(x-1)^2 + 1.$$

From $P(11) = 100(1+c) + 1 = 181$ it follows that $1 + c = \frac{9}{5}$. This P satisfies both bounds, because $1 \leq \frac{9}{5} \leq 2$. Therefore

$$P(16) = \frac{9}{5} \cdot 15^2 + 1 = 405 + 1 = 406.$$

Answer: 406. □

12. (2005 AIME I, Problem #8) The equation

$$2^{333x-2} + 2^{111x+2} = 2^{222x+1} + 1$$

has three real roots. Given that their sum is $\frac{m}{n}$, where m and n are relatively prime positive integers, find $m + n$.

Strategy. With $y = 2^{111x}$, the terms 2^{333x-2}, 2^{111x+2} and 2^{222x+1} are constant multiples of y^3, y and y^2, so the equation is a cubic equation in y. Vieta's formulas give the product of its roots, which is 2^{111s}, where s is the sum of the three roots x.

Solution. Let $y = 2^{111x}$, which is positive. By the exponent rules, $2^{333x-2} = \frac{y^3}{4}$, $2^{111x+2} = 4y$ and $2^{222x+1} = 2y^2$. In terms of y, the equation reads $\frac{y^3}{4} + 4y = 2y^2 + 1$, and multiplying it by 4 gives the cubic equation

$$y^3 - 8y^2 + 16y - 4 = 0.$$

Let x_1, x_2, x_3 be the three real roots, and let $y_i = 2^{111x_i}$. Each y_i is a root of the cubic, and different x_i give different y_i, because 2^{111x} takes each positive value only once. By the Roots and Degree theorem the cubic has no other roots, so

$$y^3 - 8y^2 + 16y - 4 = (y - y_1)(y - y_2)(y - y_3),$$

and Vieta's formulas give $y_1y_2y_3 = 4$. On the other hand, $y_1y_2y_3 = 2^{111(x_1+x_2+x_3)}$, so $111(x_1 + x_2 + x_3) = 2$ and

$$x_1 + x_2 + x_3 = \frac{2}{111}.$$

Since $111 = 3 \cdot 37$, this fraction is in lowest terms, and $m + n = 2 + 111 = 113$.

Answer: 113. □

13. (2015 AIME II, Problem #6) Steve says to Jon, "I am thinking of a polynomial whose roots are all positive integers. The polynomial has the form $P(x) = 2x^3 - 2ax^2 + (a^2 - 81)x - c$ for some positive integers a and c. Can you tell me the values of a and c?"
After some calculations, Jon says, "There is more than one such polynomial."
Steve says, "You're right. Here is the value of a." He writes down a positive integer and asks, "Can you tell me the value of c?"
Jon says, "There are still two possible values of c."
Find the sum of the two possible values of c.

Strategy. Vieta's formulas give the sum of the roots and the sum of their products in pairs in terms of a. The sum of the squares of the roots is then 81 whatever a is, which leaves only a few triples of roots.

Solution. The roots are positive integers, so $P(x) = 2(x - r)(x - s)(x - t)$ for positive integers $r \le s \le t$, the roots listed with multiplicity. By Vieta's formulas,

$$r + s + t = \frac{2a}{2} = a, \qquad rs + st + tr = \frac{a^2 - 81}{2}, \qquad rst = \frac{c}{2}.$$

Hence

$$r^2 + s^2 + t^2 = (r + s + t)^2 - 2(rs + st + tr) = a^2 - (a^2 - 81) = 81.$$

Since $3t^2 \ge 81$ and $t^2 \le 81 - 2$, the largest root satisfies $6 \le t \le 8$. If $t = 8$, then $r^2 + s^2 = 17$ and $(r, s) = (1, 4)$. If $t = 7$, then $r^2 + s^2 = 32$ and $(r, s) = (4, 4)$. If $t = 6$, then $r^2 + s^2 = 45$ with $s \le 6$, and $(r, s) = (3, 6)$.

Conversely, each of these triples gives a polynomial of the required form, with $a = r+s+t$ and $c = 2rst$, because $2(rs + st + tr) = (r + s + t)^2 - (r^2 + s^2 + t^2) = a^2 - 81$. The roots

1, 4, 8 give $a = 13$ and $c = 64$; the roots 3, 6, 6 give $a = 15$ and $c = 216$; and the roots 4, 4, 7 give $a = 15$ and $c = 224$. So there is more than one polynomial, as Jon says. Once Jon knows a, two values of c remain, so $a = 15$, and the two possible values of c have sum $216 + 224 = 440$.

Answer: 440. □

14. (2018 AIME II, Problem #6) A real number a is chosen randomly and uniformly from the interval $[-20, 18]$. The probability that the roots of the polynomial

$$x^4 + 2ax^3 + (2a-2)x^2 + (-4a+3)x - 2$$

are all real can be written in the form $\frac{m}{n}$, where m and n are relatively prime positive integers. Find $m + n$.

Strategy. The leading coefficient 1 and the constant term -2 do not depend on a, so test the candidates ± 1 and ± 2 from the Rational Root Theorem. Two of them are roots for every a; after they are divided out, the discriminant of the remaining quadratic decides whether all the roots are real.

Solution. Let $P(x) = x^4 + 2ax^3 + (2a-2)x^2 + (-4a+3)x - 2$. Its coefficients need not be integers, so the Rational Root Theorem does not apply directly. Still, the leading coefficient 1 and the constant term -2 do not depend on a, so the candidates ± 1 and ± 2 that the theorem lists for these two coefficients can be tested for every a. Two of them are roots:

$$P(1) = 1 + 2a + (2a-2) + (-4a+3) - 2 = 0$$

and

$$P(-2) = 16 - 16a + (8a-8) + (8a-6) - 2 = 0.$$

By the Roots and Degree theorem, $P(x) = (x-1)(x+2)Q(x) = (x^2+x-2)Q(x)$, where Q is monic of degree 2. Its constant term is 1, because -2 times it is the constant term -2 of P. Write $Q(x) = x^2 + \beta x + 1$. Then

$$(x^2+x-2)(x^2+\beta x+1) = x^4 + (\beta+1)x^3 + (\beta-1)x^2 + (1-2\beta)x - 2,$$

and comparing the coefficients of x^3 with those of P gives $\beta = 2a - 1$. The coefficients of x^2 and x then agree as well.

Hence the roots of P are 1, -2 and the two roots of $x^2 + (2a-1)x + 1$. They are all real exactly when the discriminant $(2a-1)^2 - 4$ is not negative, that is, when $|2a-1| \geq 2$, or $a \leq -\frac{1}{2}$ or $a \geq \frac{3}{2}$. The values $-\frac{1}{2} < a < \frac{3}{2}$ fail; they fill an interval of length 2, while a ranges over an interval of length $18 - (-20) = 38$. Hence the probability that all the roots are real is

$$\frac{38-2}{38} = \frac{18}{19},$$

and $m + n = 18 + 19 = 37$.

Answer: 37. □

15. (2005 AMC 12A, Problem #24) Let $P(x) = (x-1)(x-2)(x-3)$. For how many polynomials $Q(x)$ does there exist a polynomial $R(x)$ of degree 3 such that $P(Q(x)) = P(x) \cdot R(x)$?

(A) 19 **(B)** 22 **(C)** 24 **(D)** 27 **(E)** 32

Strategy. Comparing degrees shows that Q is quadratic. The product $(x-1)(x-2)(x-3)$ divides $P(Q(x))$ exactly when $Q(1)$, $Q(2)$, $Q(3)$ are roots of P, and a polynomial of degree at most 2 is determined by its values at 1, 2, 3.

Solution. If Q is constant, then $P(Q(x))$ is constant, while $P(x)R(x)$ has degree $3+3=6$. So Q has some degree $q \geq 1$. Then $P(Q(x)) = (Q(x)-1)(Q(x)-2)(Q(x)-3)$ is a product of three polynomials of degree q, so it has degree $3q$, and $3q = 6$ gives $q = 2$.

Now let Q have degree 2, so that $P(Q(x))$ has degree 6. A polynomial R as required exists exactly when $P(x)$ divides $P(Q(x))$, since the quotient then has degree $6-3=3$. By the Factor Theorem and the Roots and Degree theorem, $(x-1)(x-2)(x-3)$ divides $P(Q(x))$ exactly when 1, 2 and 3 are roots of $P(Q(x))$, that is, when $P(Q(1)) = P(Q(2)) = P(Q(3)) = 0$. The roots of P are 1, 2, 3, so the condition is that each of $Q(1)$, $Q(2)$, $Q(3)$ is 1, 2 or 3.

For each of the $3^3 = 27$ triples (u_1, u_2, u_3) of such values, the polynomial

$$Q(x) = u_1 + (u_2 - u_1)(x-1) + \frac{u_3 - 2u_2 + u_1}{2}(x-1)(x-2)$$

has $Q(1) = u_1$, $Q(2) = u_2$ and $Q(3) = u_3$, and by the Identity corollary it is the only polynomial of degree at most 2 with these values. It has degree less than 2 exactly when $u_1 + u_3 = 2u_2$, which happens for the five triples $(1,1,1)$, $(2,2,2)$, $(3,3,3)$, $(1,2,3)$ and $(3,2,1)$. So the number of polynomials Q is $27 - 5 = 22$.

Answer: (B) 22. □

2. Answer Key

Problem	Letter	Value
1	E	$2x - 2$
2	E	10
3	B	no positive real roots
4	A	0
5	D	$3, -1$
6	E	5100
7		116
8	B	$x^4 + x^2 - 3$
9	D	d
10	D	3
11		406
12		113
13		440
14		37
15	B	22