AMC 10

PRACTICE EXAMINATION

SET 10

SOLUTIONS

Answer key • Sources • Step-by-step solutions

All 25 problems are taken from past AMC 10 contests (2000–2025) and appear in their original wording. Advanced level: each problem sits two or three places earlier than it did in its original contest, and problems 21–25 come from original positions 23–25. Problems © Mathematical Association of America.

Answer Key and Sources

No.	Ans.	Source	Topic
1	**B**	2024 AMC 10A #4	Number Theory
2	**C**	2005 AMC 10B #5	Algebra
3	**D**	2003 AMC 10B #6	Geometry
4	**A**	2004 AMC 10B #7	Algebra
5	**E**	2006 AMC 10A #8	Algebra
6	**B**	2015 AMC 10B #9	Geometry
7	**D**	2017 AMC 10B #9	Counting & Probability
8	**E**	2021 AMC 10A #11	Number Theory
9	**B**	2013 AMC 10B #11	Algebra
10	**C**	2008 AMC 10A #12	Algebra
11	**C**	2025 AMC 10B #14	Counting & Probability
12	**D**	2021 Fall AMC 10A #14	Geometry
13	**D**	2020 AMC 10B #15	Algebra
14	**A**	2008 AMC 10B #16	Counting & Probability
15	**D**	2009 AMC 10B #18	Geometry
16	**C**	2024 AMC 10B #19	Geometry
17	**A**	2023 AMC 10B #20	Geometry
18	**C**	2013 AMC 10A #20	Geometry
19	**D**	2018 AMC 10A #22	Number Theory
20	**C**	2011 AMC 10A #22	Counting & Probability
21	**D**	2011 AMC 10B #23	Number Theory
22	**E**	2022 AMC 10A #24	Counting & Probability
23	**E**	2012 AMC 10A #24	Algebra
24	**A**	2016 AMC 10A #25	Number Theory
25	**C**	2019 AMC 10B #25	Counting & Probability

1 Number Theory

Source: 2024 AMC 10A #4

> The number 2024 is written as the sum of not necessarily distinct two-digit numbers. What is the least number of two-digit numbers needed to write this sum?
>
> **(A)** 20 **(B)** 21 **(C)** 22 **(D)** 23 **(E)** 24

Key idea. To use as *few* numbers as possible, each number should be as *large* as possible. So compare 2024 with multiples of 99, the largest two-digit number.

Lower bound. Each two-digit number is at most 99, so k of them add up to at most $99k$. With $k = 20$ the most we can reach is $99 \cdot 20 = 1980$, which is less than 2024. So 20 numbers are not enough, and neither is any smaller count.

It can be done with 21. Take twenty 99s and one more number: $2024 - 1980 = 44$, which is a two-digit number. Indeed

$$\underbrace{99 + 99 + \cdots + 99}_{20} + 44 = 1980 + 44 = 2024.$$

So 21 numbers suffice, and 21 is the least.

Watch out. $2024 \div 99 \approx 20.4$, and rounding this *down* gives 20, choice (A). But 20 numbers fall 44 short; the count must be rounded *up*.

Answer: (B) 21

2 Algebra

Source: 2005 AMC 10B #5

> Brianna is using part of the money she earned on her weekend job to buy several equally-priced CDs. She used one fifth of her money to buy one third of the CDs. What fraction of her money will she have left after she buys all the CDs?
>
> **(A)** $\frac{1}{5}$ **(B)** $\frac{1}{3}$ **(C)** $\frac{2}{5}$ **(D)** $\frac{2}{3}$ **(E)** $\frac{4}{5}$

Key idea. All the CDs cost the same, so the cost is proportional to the number of CDs: three times as many CDs cost three times as much money.

One third of the CDs cost $\frac{1}{5}$ of her money. All of the CDs are three of those thirds, so they cost

$$3 \cdot \frac{1}{5} = \frac{3}{5}$$

of her money. The fraction she has left is

$$1 - \frac{3}{5} = \frac{2}{5}.$$

Notice that we never needed to know how much money she had or how many CDs she bought — only the ratios matter.

Watch out. $\frac{4}{5}$ is what she has left after buying only the *first* third of the CDs ($1 - \frac{1}{5} = \frac{4}{5}$). The question asks what is left after she buys *all* of them; stopping early gives (E).

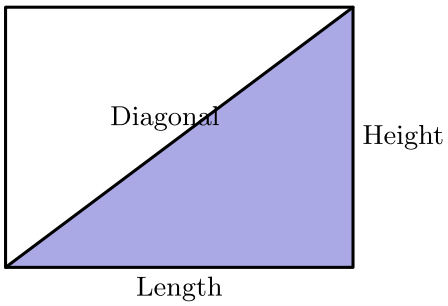
Answer: (C) $\frac{2}{5}$

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3 Geometry

Source: 2003 AMC 10B #6

Many television screens are rectangles that are measured by the length of their diagonals. The ratio of the horizontal length to the height in a standard television screen is $4:3$. The horizontal length of a "27-inch" television screen is closest, in inches, to which of the following?



(A) 20 **(B)** 20.5 **(C)** 21 **(D)** 21.5 **(E)** 22

Key idea. The diagonal, the length and the height form a right triangle. A $4:3$ ratio of legs is the famous 3-4-5 triangle, so the hypotenuse is 5 parts.

Write the horizontal length as $4k$ and the height as $3k$. By the Pythagorean Theorem the diagonal is

$$\sqrt{(4k)^2 + (3k)^2} = \sqrt{16k^2 + 9k^2} = \sqrt{25k^2} = 5k.$$

The screen is a "27-inch" screen, so the diagonal is 27: $5k = 27$, giving $k = 5.4$.

The horizontal length is $4k = 4 \cdot 5.4 = 21.6$ inches.

Among the choices, 21.6 is 0.1 away from 21.5 and 0.4 away from 22, so the closest choice is 21.5.

Watch out. Rounding 21.6 to the nearest whole number gives 22, choice (E). The question asks for the closest *choice*, and 21.5 is closer.

Answer: (D) 21.5

4 Algebra

Source: 2004 AMC 10B #7

> On a trip from the United States to Canada, Isabella took d U.S. dollars. At the border she exchanged them all, receiving 10 Canadian dollars for every 7 U.S. dollars. After spending 60 Canadian dollars, she had d Canadian dollars left. What is the sum of the digits of d?
>
> **(A)** 5 **(B)** 6 **(C)** 7 **(D)** 8 **(E)** 9

Key idea. Translate each sentence into an amount of Canadian dollars and set up one equation in d.

Each U.S. dollar is worth $\frac{10}{7}$ Canadian dollars, so Isabella received $\frac{10}{7}d$ Canadian dollars. After spending 60 she had d left:

$$\frac{10}{7}d - 60 = d.$$

Subtract d from both sides: $\frac{10}{7}d - d = \frac{3}{7}d = 60$. Multiply by $\frac{7}{3}$: $d = 60 \cdot \frac{7}{3} = 140$.

Check: 140 U.S. dollars become $140 \cdot \frac{10}{7} = 200$ Canadian dollars, and $200 - 60 = 140$.

The question asks for the *sum of the digits* of d: $1 + 4 + 0 = 5$.

Watch out. Using the exchange rate upside down, $\frac{7}{10}d - 60 = d$, gives a negative d — a sign the rate is reversed. Also be sure to answer the digit sum, not $d = 140$ itself.

Answer: (A) 5

5 Algebra

Source: 2006 AMC 10A #8

> A parabola with equation $y = x^2 + bx + c$ passes through the points $(2, 3)$ and $(4, 3)$. What is c?
>
> **(A)** 2 **(B)** 5 **(C)** 7 **(D)** 10 **(E)** 11

Key idea. The two points have the same y-value, 3, so they are mirror images of each other across the parabola's axis of symmetry.

Step 1. The axis of symmetry lies halfway between $x = 2$ and $x = 4$, so it is the line $x = 3$. For $y = x^2 + bx + c$ the axis is $x = -\frac{b}{2}$, so $-\frac{b}{2} = 3$ and $b = -6$.

Step 2. Substitute the point $(2, 3)$:

$$3 = 2^2 + (-6)(2) + c = 4 - 12 + c = c - 8,$$

so $c = 11$. Check with $(4, 3)$: $16 - 24 + 11 = 3$. ✓

Another way. Since $y - 3$ equals 0 at $x = 2$ and $x = 4$ and has leading coefficient 1,

$$y - 3 = (x - 2)(x - 4) = x^2 - 6x + 8,$$

so $y = x^2 - 6x + 11$ and $c = 11$. (Subtracting the two substituted equations $3 = 4 + 2b + c$ and $3 = 16 + 4b + c$ also gives $b = -6$ directly.)

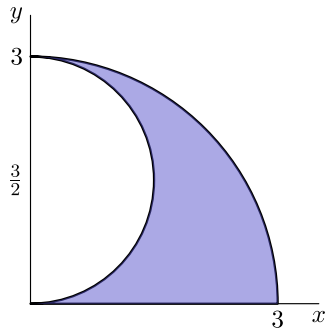
Answer: (E) 11

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6 Geometry

Source: 2015 AMC 10B #9

The shaded region below is called a shark's fin falcata, a figure studied by Leonardo da Vinci. It is bounded by the portion of the circle of radius 3 and center $(0, 0)$ that lies in the first quadrant, the portion of the circle with radius $\frac{3}{2}$ and center $(0, \frac{3}{2})$ that lies in the first quadrant, and the line segment from $(0, 0)$ to $(3, 0)$. What is the area of the shark's fin falcata?



(A) $\frac{4\pi}{5}$ **(B)** $\frac{9\pi}{8}$ **(C)** $\frac{4\pi}{3}$ **(D)** $\frac{7\pi}{5}$ **(E)** $\frac{3\pi}{2}$

Key idea. The fin is a big shape with a smaller shape cut out of it: area of the quarter disk minus area of the half disk.

Step 1. The outer boundary is the part of the circle of radius 3 in the first quadrant, a quarter circle. Together with the axes it encloses a quarter disk of area $\frac{1}{4}\pi \cdot 3^2 = \frac{9\pi}{4}$.

Step 2. The small circle has center $(0, \frac{3}{2})$ on the y-axis and radius $\frac{3}{2}$, so it passes through $(0, 0)$ and $(0, 3)$. Its first-quadrant part is its right half, enclosing a half disk of area $\frac{1}{2}\pi\left(\frac{3}{2}\right)^2 = \frac{9\pi}{8}$. This half disk lies inside the quarter disk (the two circles touch only at $(0, 3)$).

Step 3. The shaded fin is what is left: $\frac{9\pi}{4} - \frac{9\pi}{8} = \frac{18\pi}{8} - \frac{9\pi}{8} = \frac{9\pi}{8}$.

Watch out. The small region is half of the small disk, not a quarter of it. Subtracting $\frac{1}{4}\pi\left(\frac{3}{2}\right)^2$ gives $\frac{27\pi}{16}$, which is not a choice.

Answer: (B) $\frac{9\pi}{8}$

7 Counting & Probability

Source: 2017 AMC 10B #9

A radio program has a quiz consisting of 3 multiple-choice questions, each with 3 choices. A contestant wins if he or she gets 2 or more of the questions right. The contestant answers randomly to each question. What is the probability of winning?

(A) $\frac{1}{27}$ **(B)** $\frac{1}{9}$ **(C)** $\frac{2}{9}$ **(D)** $\frac{7}{27}$ **(E)** $\frac{1}{2}$

Key idea. "2 or more" splits into two separate cases: exactly 2 right, or all 3 right. Each guess is right with probability $\frac{1}{3}$ and wrong with probability $\frac{2}{3}$.

All 3 right. The guesses are independent, so the probability is $\frac{1}{3} \cdot \frac{1}{3} \cdot \frac{1}{3} = \frac{1}{27}$.

Exactly 2 right. One particular pattern, such as right–right–wrong, has probability $\frac{1}{3} \cdot \frac{1}{3} \cdot \frac{2}{3} = \frac{2}{27}$. The wrong answer can be on any of the 3 questions, so there are 3 such patterns, giving $3 \cdot \frac{2}{27} = \frac{6}{27}$.

Total. $\frac{6}{27} + \frac{1}{27} = \frac{7}{27}$.

Watch out. Forgetting that the wrong answer can sit on any of 3 questions gives $\frac{2}{27} + \frac{1}{27} = \frac{1}{9}$, choice (B). Counting only "exactly 2" and dropping the all-correct case gives $\frac{6}{27} = \frac{2}{9}$, choice (C).

Answer: (D) $\frac{7}{27}$

8 Number Theory

Source: 2021 AMC 10A #11

For which of the following integers b is the base-b number $2021_b - 221_b$ not divisible by 3?

(A) 3 **(B)** 4 **(C)** 6 **(D)** 7 **(E)** 8

Key idea. Do not test five bases one by one. Write the difference as a polynomial in b and factor it, because divisibility by the prime 3 can then be read off the factors.

Step 1. By place value,

$$2021_b = 2b^3 + 0 \cdot b^2 + 2b + 1, \qquad 221_b = 2b^2 + 2b + 1.$$

Subtracting, the $2b + 1$ cancels:

$$2021_b - 221_b = 2b^3 - 2b^2 = 2b^2(b - 1).$$

Step 2. Since 3 is prime, it divides $2b^2(b-1)$ exactly when it divides b or $b-1$ (it never divides 2).

Step 3. Check the choices: $b = 3$ and $b = 6$ are multiples of 3; for $b = 4$ and $b = 7$ we get $b - 1 = 3$ and $b - 1 = 6$, multiples of 3. Only $b = 8$ fails both tests: 8 and 7 are not multiples of 3.

Indeed, for $b = 8$ the number is $2 \cdot 64 \cdot 7 = 896$, and $8 + 9 + 6 = 23$ is not a multiple of 3.

Watch out. Looking only at the factor b^2 and forgetting $b - 1$ makes $b = 4$ and $b = 7$ look like answers too; every base except 3 and 6 would then seem to work, which is a sign a factor was missed.

Answer: (E) 8

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9 Algebra

Source: 2013 AMC 10B #11

Real numbers x and y satisfy the equation

$$x^2 + y^2 = 10x - 6y - 34.$$

What is $x + y$?

(A) 1 **(B)** 2 **(C)** 3 **(D)** 6 **(E)** 8

Key idea. One equation with two unknowns usually cannot pin both down — unless it forces a sum of squares to be zero. The terms $x^2 - 10x$ and $y^2 + 6y$ beg to be completed into squares, which is what points you there.

Step 1. Move everything to the left side:

$$x^2 - 10x + y^2 + 6y + 34 = 0.$$

Step 2. Complete each square. Half of -10 is -5 and $(-5)^2 = 25$; half of 6 is 3 and $3^2 = 9$. Since $25 + 9 = 34$, the constant splits exactly:

$$(x^2 - 10x + 25) + (y^2 + 6y + 9) = 0, \qquad \text{that is,} \qquad (x - 5)^2 + (y + 3)^2 = 0.$$

Step 3. A square of a real number is never negative, so two squares can add to 0 only if each one is 0. Hence $x - 5 = 0$ and $y + 3 = 0$, so $x = 5$ and $y = -3$.

Check: $x^2 + y^2 = 25 + 9 = 34$ and $10x - 6y - 34 = 50 + 18 - 34 = 34$. So $x + y = 5 + (-3) = 2$.

Watch out. A sign slip in completing the square, writing $(y - 3)^2$ instead of $(y + 3)^2$, gives $y = 3$ and $x + y = 8$, which is choice (E).

Answer: (B) 2

10 Algebra

Source: 2008 AMC 10A #12

In a collection of red, blue, and green marbles, there are 25% more red marbles than blue marbles, and there are 60% more green marbles than red marbles. Suppose that there are r red marbles. What is the total number of marbles in the collection?

(A) $2.85r$ **(B)** $3r$ **(C)** $3.4r$ **(D)** $3.85r$ **(E)** $4.25r$

Key idea. Write every colour in terms of r, because the answer choices are all multiples of r. The only care needed is that "25% more red marbles than blue marbles" compares red *to* *blue*, so blue is the base of that percentage.

Step 1. Red is 25% more than blue: $r = b + 0.25b = 1.25b$. Dividing by 1.25, $b = \dfrac{r}{1.25} = \dfrac{4}{5}r = 0.8r$.

Step 2. Green is 60% more than red, and here red is the base: $g = r + 0.6r = 1.6r$.

Step 3. The total is $r + 0.8r + 1.6r = 3.4r$.

Quick check with $r = 100$: then $b = 80$ (and indeed 100 is 25% more than 80, since $0.25 \cdot 80 = 20$), $g = 160$, and the total is $340 = 3.4 \cdot 100$.

Watch out. Taking blue to be 25% *less* than red, $b = 0.75r$, gives $r + 0.75r + 1.6r = 3.35r$, which is not a choice. "Red is 25% more than blue" is not the same as "blue is 25% less than red": going up 25% from 80 reaches 100, but going down 25% from 100 reaches only 75.

Answer: (C) $3.4r$

11 Counting & Probability

Source: 2025 AMC 10B #14

Nine athletes, no two of whom are the same height, try out for the basketball team. One at a time, they draw a wristband at random, without replacement, from a bag containing 3 blue bands, 3 red bands, and 3 green bands. They are divided into a blue group, a red group, and a green group. The tallest member of each group is named the group captain. What is the probability that the group captains are the three tallest athletes?

(A) $\dfrac{2}{9}$ **(B)** $\dfrac{2}{7}$ **(C)** $\dfrac{9}{28}$ **(D)** $\dfrac{1}{3}$ **(E)** $\dfrac{3}{8}$

Key idea. Turn the condition into a statement about where the three tallest athletes land: the captains are the three tallest exactly when those three are in three different groups. Then track only those three people.

Step 1: Restate the condition. If the three tallest are in different groups, each of them is taller than everyone else in their own group (the only taller people are the other two, who are elsewhere), so all three are captains. If two of them share a group, only one of those two can be that group's captain, so the three captains cannot be exactly the three tallest.

Step 2: Place them one at a time. Think of 9 slots, 3 per color, and the athletes are randomly assigned to slots. The tallest goes somewhere. The second tallest is in one of the 8 remaining slots, equally likely; 6 of them are outside the tallest's group, so the chance is $\frac{6}{8}$.

The third tallest is in one of the 7 remaining slots; only the 3 slots of the untouched color work, so the chance is $\frac{3}{7}$.

Step 3. Multiply: $\frac{6}{8} \cdot \frac{3}{7} = \frac{18}{56} = \frac{9}{28}$.

Watch out. Treating each athlete's color as an independent $\frac{1}{3}$ chance gives $\frac{2}{3} \cdot \frac{1}{3} = \frac{2}{9}$, choice (A). The draws are *without replacement*: once a band is taken, that color has fewer bands left, so the second and third tallest are less likely to repeat a color.

Answer: (C) $\frac{9}{28}$

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12 Geometry

Source: 2021 Fall AMC 10A #14

How many ordered pairs (x, y) of real numbers satisfy the following system of equations?

$$x^2 + 3y = 9,$$
$$(|x| + |y| - 4)^2 = 1.$$

(A) 1 **(B)** 2 **(C)** 3 **(D)** 5 **(E)** 7

Key idea. The square equals 1, so $|x| + |y| - 4 = \pm 1$: either $|x| + |y| = 3$ or $|x| + |y| = 5$. Absolute values call for splitting into the cases $y \geq 0$ and $y < 0$; and since only $|x|$ and x^2 appear, work with $t = |x| \geq 0$ and double each $t > 0$ at the end.

From the first equation, $y = 3 - \frac{t^2}{3}$. So $y \geq 0$ exactly when $t \leq 3$, and $y < 0$ exactly when $t > 3$.

Case 1: $y \geq 0$ ($0 \leq t \leq 3$). Here $|y| = y$. For $t + y = 3$: $t + 3 - \frac{t^2}{3} = 3$ gives $t\left(1 - \frac{t}{3}\right) = 0$, so $t = 0$ or $t = 3$. These give $(0, 3)$, $(3, 0)$, $(-3, 0)$ — three points.

For $t + y = 5$: $t + 3 - \frac{t^2}{3} = 5$ gives $t^2 - 3t + 6 = 0$, whose discriminant $9 - 24 < 0$; no solutions.

Case 2: $y < 0$ ($t > 3$). Here $|y| = -y = \frac{t^2}{3} - 3$. For $t - y = 3$: $t + \frac{t^2}{3} - 3 = 3$ gives $t^2 + 3t - 18 = 0$, i.e. $(t + 6)(t - 3) = 0$. But $t = 3$ is not > 3, so nothing new.

For $t - y = 5$: $t^2 + 3t - 24 = 0$ gives $t = \frac{-3 + \sqrt{105}}{2} \approx 3.62 > 3$ (the other root is negative). Since $t > 0$, $x = \pm t$ gives two points.

Total. $3 + 2 = 5$ ordered pairs.

Watch out. Stopping after the case $y \geq 0$ gives 3, choice C. The parabola $y = 3 - \frac{x^2}{3}$ dips below the x-axis and meets the outer diamond $|x| + |y| = 5$ there too.

Answer: (D) 5

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13 Algebra

Source: 2020 AMC 10B #15

> Steve wrote the digits 1, 2, 3, 4, and 5 in order repeatedly from left to right, forming a list of 10,000 digits, beginning 123451234512... He then erased every third digit from his list (that is, the 3rd, 6th, 9th, ... digits from the left), then erased every fourth digit from the resulting list (that is, the 4th, 8th, 12th, ... digits from the left in what remained), and then erased every fifth digit from what remained at that point. What is the sum of the three digits that were then in positions 2019, 2020, and 2021?
>
> **(A)** 7 **(B)** 9 **(C)** 10 **(D)** 11 **(E)** 12

Key idea. Each list is periodic, and erasing every mth digit from a list with period p gives a new periodic list: the pattern repeats once both the digits and the erasing rhythm line up, after $\operatorname{lcm}(m, p)$ digits. So track one period through the three erasures instead of 10,000 digits.

Step 1: erase every third digit. The list 12345 12345... has period 5. Every third digit is erased, so the pattern of survivors repeats every $\operatorname{lcm}(3, 5) = 15$ digits. In the first 15 digits 123451234512345, cross out positions $3, 6, 9, 12, 15$ (the digits $3, 1, 4, 2, 5$). What remains is the 10-digit block

$$1245235134.$$

Step 2: erase every fourth digit. Now the period is 10, so the new pattern repeats every $\operatorname{lcm}(4, 10) = 20$ digits. Write the block twice, 12452351341245235134, and cross out positions $4, 8, 12, 16, 20$. The survivors form the 15-digit block

$$124235341452513.$$

Step 3: erase every fifth digit. The period is 15 and $\operatorname{lcm}(5, 15) = 15$. Cross out positions $5, 10, 15$ of 124235341452513 to get the 12-digit block

$$124253415251.$$

Step 4: find the positions. The final list repeats 124253415251. Since $2016 = 12 \cdot 168$, positions 2017–2028 hold one complete copy of the block. So positions 2019, 2020, 2021 are the 3rd, 4th and 5th digits of the block: 4, 2, 5. (The final list has 4001 digits, so these positions exist.)

Their sum is $4 + 2 + 5 = 11$.

Answer: (D) 11

14 Counting & Probability

Source: 2008 AMC 10B #16

Two fair coins are to be tossed once. For each head that results, one fair die is to be rolled. What is the probability that the sum of the die rolls is odd? (Note that if no die is rolled, the sum is 0.)

(A) $\frac{3}{8}$ **(B)** $\frac{1}{2}$ **(C)** $\frac{43}{72}$ **(D)** $\frac{5}{8}$ **(E)** $\frac{2}{3}$

Key idea. Split on the number of heads. Once at least one die is rolled, the last die alone decides odd or even, so the chance of an odd sum is exactly $\frac{1}{2}$.

Step 1. The number of heads is 0, 1 or 2 with probabilities $\frac{1}{4}$, $\frac{1}{2}$, $\frac{1}{4}$.

Step 2. No heads: no die is rolled, the sum is 0, which is even. Probability of odd: 0.

Step 3. One or two heads: whatever the other dice show, the last die is odd for 3 of its 6 faces and even for the other 3, and switching its parity switches the parity of the total. So the sum is odd with probability $\frac{1}{2}$.

Step 4. Combine:

$$P(\text{odd}) = \tfrac{1}{4}\cdot 0 + \tfrac{1}{2}\cdot\tfrac{1}{2} + \tfrac{1}{4}\cdot\tfrac{1}{2} = \tfrac{1}{4} + \tfrac{1}{8} = \tfrac{3}{8}.$$

Watch out. Forgetting the no-dice case and saying "dice sums are odd half the time" gives $\frac{1}{2}$, choice (B). The $\frac{1}{4}$ chance of two tails always gives the even sum 0.

Answer: (A) $\frac{3}{8}$

15 Geometry

Source: 2009 AMC 10B #18

Rectangle $ABCD$ has $AB = 8$ and $BC = 6$. Point M is the midpoint of diagonal $\overline{AC}$, and E is on $\overline{AB}$ with $\overline{ME} \perp \overline{AC}$. What is the area of $\triangle AME$?

(A) $\frac{65}{8}$ **(B)** $\frac{25}{3}$ **(C)** 9 **(D)** $\frac{75}{8}$ **(E)** $\frac{85}{8}$

Key idea. $\triangle AME$ has a right angle at M and shares the angle at A with right triangle ABC. Two right triangles sharing an acute angle are similar, so ME comes straight from the known sides AB and BC.

Step 1. By the Pythagorean Theorem, $AC = \sqrt{8^2 + 6^2} = \sqrt{100} = 10$, so $AM = \frac{10}{2} = 5$.

Step 2. Triangle AME has its right angle at M; triangle ABC has its right angle at B. Both contain $\angle A$ (the angle between $\overline{AB}$ and $\overline{AC}$), so $\triangle AME \sim \triangle ABC$, with AM matching AB and ME matching BC:

$$\frac{ME}{AM} = \frac{BC}{AB} = \frac{6}{8} = \frac{3}{4}, \qquad ME = \frac{3}{4}\cdot 5 = \frac{15}{4}.$$

(Then $AE = \sqrt{5^2 + \left(\frac{15}{4}\right)^2} = \frac{25}{4} < 8$, so E really lies on side $\overline{AB}$.)

Step 3. The legs of right triangle AME are AM and ME, so

$$[\triangle AME] = \frac{1}{2} \cdot 5 \cdot \frac{15}{4} = \frac{75}{8}.$$

Watch out. Matching the wrong sides — writing $\frac{ME}{AM} = \frac{AB}{BC} = \frac{8}{6}$ — gives $ME = \frac{20}{3}$ and area $\frac{50}{3}$, which is not a choice. In $\triangle AME$ the side opposite $\angle A$ is ME; in $\triangle ABC$ it is BC.

Answer: (D) $\frac{75}{8}$

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16 Geometry

Source: 2024 AMC 10B #19

In the following table, each question mark is to be replaced by "Possible" or "Not Possible" to indicate whether a nonvertical line with the given slope can contain the given number of lattice points (points both of whose coordinates are integers). How many of the 12 entries will be "Possible"?

	zero	exactly one	exactly two	more than two
zero slope	?	?	?	?
nonzero rational slope	?	?	?	?
irrational slope	?	?	?	?

(A) 4 **(B)** 5 **(C)** 6 **(D)** 7 **(E)** 9

Key idea. Ask what *two* lattice points on a line force. The slope between two lattice points is a ratio of integers, so it is rational — that one fact splits the table into "rational" rows and the "irrational" row.

Step 1. Irrational slope. If such a line contained two lattice points (x_1, y_1) and (x_2, y_2), its slope would be $\frac{y_2 - y_1}{x_2 - x_1}$, a rational number. So it holds *at most one* lattice point, and "exactly two" and "more than two" are Not Possible. Both remaining entries happen:

- $y = \sqrt{2}\,x$ contains $(0, 0)$, and no other lattice point (for $x \neq 0$, an integer y would make $\sqrt{2} = \frac{y}{x}$ rational) — exactly one.
- $y = \sqrt{2}\,x + \frac{1}{2}$ contains none: $x = 0$ gives $y = \frac{1}{2}$, and $x \neq 0$ would make $\sqrt{2} = \frac{y - 1/2}{x}$ rational — zero.

Step 2. Rational slope (zero or nonzero). Write the slope as $\frac{p}{q}$ with integers p, q and $q > 0$ (for zero slope, $p = 0,\ q = 1$). If the line passes through one lattice point (x_0, y_0), then moving q right and p up keeps you on the line, so it also contains $(x_0 + kq,\ y_0 + kp)$ for every integer k — infinitely many. So "exactly one" and "exactly two" are Not Possible.

Both other entries happen in each row: $y = 0$ and $y = x$ contain infinitely many lattice points, while $y = \frac{1}{2}$ and $y = x + \frac{1}{2}$ contain none (the y-coordinate would be an integer plus $\frac{1}{2}$).

Step 3. Each of the three rows has exactly two "Possible" entries, for a total of $2 + 2 + 2 = 6$.

Watch out. Do not assume every rational-slope line hits a lattice point. Missing the "zero" entries in the two rational rows (lines like $y = \frac{1}{2}$) leaves $1 + 1 + 2 = 4$, choice (A).

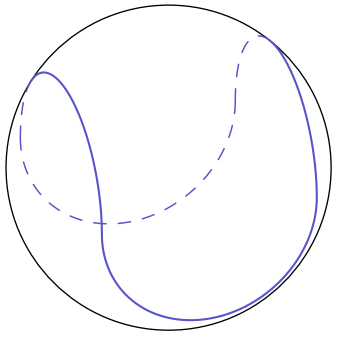
Answer: (C) 6

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17 Geometry

Source: 2023 AMC 10B #20

Four congruent semicircles are drawn on the surface of a sphere with radius 2, as shown, creating a closed curve that divides the surface into two congruent regions. The length of the curve is $\pi\sqrt{n}$. What is n?



(A) 32 **(B)** 12 **(C)** 48 **(D)** 36 **(E)** 27

Key idea. The curve looks like the seam of a tennis ball. Each piece is half of a small circle on the sphere, so its length is $\pi \times$ (its radius). The radius comes from the straight-line distance between the two ends of the semicircle, which is that circle's diameter.

Step 1. The four semicircles meet at four points. Because the four arcs are congruent and the two regions are congruent, these junction points are evenly spaced around a great circle (an "equator" of radius 2), as in the picture. Four evenly spaced points on a circle form a square, and adjacent points are $90°$ apart as seen from the center O.

Step 2. Each semicircle joins two adjacent junction points, say P and Q. A semicircle's endpoints are the ends of a diameter of its circle, so that circle's diameter is the straight segment PQ. Since $OP = OQ = 2$ and $\angle POQ = 90°$,

$$PQ = \sqrt{2^2 + 2^2} = 2\sqrt{2},$$

so each semicircle has radius $\sqrt{2}$.

Step 3. *Check that such a circle really lies on the sphere.* The midpoint M of $\overline{PQ}$ is at distance $\sqrt{2^2 - (\sqrt{2})^2} = \sqrt{2}$ from O. The plane through $\overline{PQ}$ perpendicular to $\overline{OM}$ meets the sphere in a circle of radius $\sqrt{2^2 - (\sqrt{2})^2} = \sqrt{2}$ centered at M — exactly the circle with diameter $\overline{PQ}$.

Step 4. One semicircle has length $\frac{1}{2} \cdot 2\pi\sqrt{2} = \pi\sqrt{2}$, so the curve has length

$$4\pi\sqrt{2} = \pi\sqrt{16 \cdot 2} = \pi\sqrt{32}.$$

Hence $n = 32$.

Watch out. The semicircles are *not* halves of great circles. Using radius 2 for each gives $4 \cdot 2\pi = 8\pi = \pi\sqrt{64}$, which is not a choice.

Answer: (A) 32

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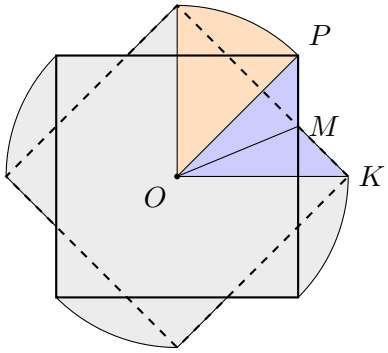
18 Geometry

Source: 2013 AMC 10A #20

A unit square is rotated 45° about its center. What is the area of the region swept out by the interior of the square?

(A) $1 - \frac{\sqrt{2}}{2} + \frac{\pi}{4}$ **(B)** $\frac{1}{2} + \frac{\pi}{4}$ **(C)** $2 - \sqrt{2} + \frac{\pi}{4}$ **(D)** $\frac{\sqrt{2}}{2} + \frac{\pi}{4}$ **(E)** $1 + \frac{\sqrt{2}}{4} + \frac{\pi}{8}$

Key idea. Cut the plane into eight 45° wedges at the center O. In four of them a corner of the square sweeps a circular arc; in the other four no corner passes, so the farthest reach is set by the starting or ending square. Each wedge is then a simple sector or a pair of triangles.



Place O at the origin with the starting square's sides on $x = \pm\frac{1}{2}$, $y = \pm\frac{1}{2}$ (solid), and rotate counterclockwise; the final square is dashed. Each corner is $\frac{\sqrt{2}}{2}$ from O.

Step 1: The four sectors. The corner $P = (\frac{1}{2}, \frac{1}{2})$, at angle 45°, travels to angle 90° along a circle of radius $\frac{\sqrt{2}}{2}$. So the wedge from 45° to 90° is a full 45° sector (orange), of area

$$\frac{1}{8} \cdot \pi \left(\frac{\sqrt{2}}{2}\right)^2 = \frac{\pi}{16}.$$

The same happens for all four corners: total $4 \cdot \frac{\pi}{16} = \frac{\pi}{4}$.

Step 2: The other wedges. In the wedge from 0° to 45° no corner passes. Along a fixed direction, the distance from O to a side grows as the direction moves toward a corner, so the farthest the square

reaches is at the start or at the end of the turn. The region here is therefore the union of the two squares (blue): the triangle OMP from the starting square and the triangle OKM from the final one, where the two squares' sides cross at M on the $22.5°$ bisector.

The final square's side through K lies on the line $x + y = \frac{\sqrt{2}}{2}$, so M, where it meets $x = \frac{1}{2}$, has height $y = \frac{\sqrt{2}}{2} - \frac{1}{2} = \frac{\sqrt{2}-1}{2}$. Triangle OMP has base $MP = \frac{1}{2} - \frac{\sqrt{2}-1}{2} = \frac{2-\sqrt{2}}{2}$ on the line $x = \frac{1}{2}$ and height $\frac{1}{2}$, so its area is $\frac{1}{2} \cdot \frac{2-\sqrt{2}}{2} \cdot \frac{1}{2} = \frac{2-\sqrt{2}}{8}$. By symmetry (reflect in the bisector) OKM has the same area, so this wedge has area $\frac{2-\sqrt{2}}{4}$. Four such wedges: $4 \cdot \frac{2-\sqrt{2}}{4} = 2 - \sqrt{2}$.

Step 3. Total swept area $= 2 - \sqrt{2} + \dfrac{\pi}{4}$.

Watch out. Counting only the starting square's triangle in each non-arc wedge (forgetting that the final square pokes out too) gives $4 \cdot \frac{2-\sqrt{2}}{8} + \frac{\pi}{4} = 1 - \frac{\sqrt{2}}{2} + \frac{\pi}{4}$, choice (A).

Answer: (C) $2 - \sqrt{2} + \dfrac{\pi}{4}$

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19 Number Theory

Source: 2018 AMC 10A #22

Let a, b, c, and d be positive integers such that

$$\gcd(a, b) = 24,$$
$$\gcd(b, c) = 36,$$
$$\gcd(c, d) = 54,$$

and

$$70 < \gcd(d, a) < 100.$$

Which of the following must be a divisor of a?

(A) 5 **(B)** 7 **(C)** 11 **(D)** 13 **(E)** 17

Key idea. A gcd is decided prime by prime: its exponent of each prime is the *smaller* of the two numbers' exponents. The given gcds involve only the primes 2 and 3, so track those exponents around the chain a, b, c, d; whatever is left in $\gcd(d, a)$ must come from a new prime.

Step 1: factor. $24 = 2^3 \cdot 3$, $36 = 2^2 \cdot 3^2$, $54 = 2 \cdot 3^3$.

Step 2: the prime 3 in a. From $\gcd(b, c) = 36$, b has at least two 3s. But $\gcd(a, b) = 24$ has only one 3, so the smaller of the two exponents is 1; since b's is at least 2, a has exactly one 3. Also a has at least three 2s.

Step 3: the prime 2 in d. From $\gcd(b, c) = 36$, c has at least two 2s. But $\gcd(c, d) = 54$ has only one 2, so d has exactly one 2. Also d has at least three 3s.

Step 4: $\gcd(d, a)$. Its power of 2 is $\min(1, \geq 3) = 1$ and its power of 3 is $\min(\geq 3, 1) = 1$. So $\gcd(d, a) = 6n$, where n is divisible by neither 2 nor 3.

Step 5. $70 < 6n < 100$ gives $n \in \{12, 13, 14, 15, 16\}$. Among these only 13 avoids the factors 2 and 3. So $\gcd(d, a) = 78$, and 13 divides a.

The others need not. Take $a = 312 = 2^3 \cdot 3 \cdot 13$, $b = 72$, $c = 108$, $d = 702 = 2 \cdot 3^3 \cdot 13$. Then the four gcds are $24, 36, 54, 78$, and 312 is not divisible by 5, 7, 11, or 17.

Watch out. If you forget that d has *exactly* one factor of 2, then $84 = 2^2 \cdot 3 \cdot 7$ also looks like a possible $\gcd(d, a)$, and you might pick 7, choice (B).

Answer: (D) 13

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20 Counting & Probability

Source: 2011 AMC 10A #22

Each vertex of convex pentagon $ABCDE$ is to be assigned a color. There are 6 colors to choose from, and the ends of each diagonal must have different colors. How many different colorings are possible?

(A) 2520 **(B)** 2880 **(C)** 3120 **(D)** 3250 **(E)** 3750

Key idea. In a pentagon each vertex is joined by diagonals to the two vertices that are not its neighbors. So two vertices may share a color *only if they are neighbors* — that turns the problem into counting how the vertices can be grouped into same-color blocks.

Step 1. What the same-color blocks look like. Group the vertices by color. Any two vertices in one group must be adjacent. Three vertices cannot share a color, since among any three vertices of a pentagon some two are not adjacent. So each group is a single vertex or a pair of neighbors (a side), and different groups get different colors. Conversely, any such grouping with distinct colors is valid, because the ends of a diagonal are never in the same group.

Step 2. Case: five singletons. All colors different: $6 \cdot 5 \cdot 4 \cdot 3 \cdot 2 = 720$.

Step 3. Case: one pair. Choose the side: 5 ways. That leaves 4 groups to color with different colors: $6 \cdot 5 \cdot 4 \cdot 3 = 360$. Total $5 \cdot 360 = 1800$.

Step 4. Case: two pairs. The two sides must not share a vertex. Pick the vertex left alone (5 ways); the other four form a path, which splits into two sides in exactly one way. Then 3 groups get different colors: $6 \cdot 5 \cdot 4 = 120$. Total $5 \cdot 120 = 600$. (Three pairs would need six vertices.)

Step 5. Adding, $720 + 1800 + 600 = 3120$.

Another way. The diagonals form a single closed loop $A-C-E-B-D-A$, and we need neighbors on this loop to differ. Going along the loop A, C, E, B, D and making each vertex differ from the previous one gives $6 \cdot 5^4 = 3750$ colorings, but this ignores the last condition $D \neq A$. The bad ones, with $D = A$, are exactly the colorings of the shorter loop $A-C-E-B-A$ with neighbors different; by the same reasoning those number $6 \cdot 5^3 - 6 \cdot 5 \cdot 4 = 750 - 120 = 630$ (path colorings of A, C, E, B, minus those with $B = A$, which are colorings of A, C, E in three different colors). So the answer is $3750 - 630 = 3120$.

Watch out. Counting $6 \cdot 5 \cdot 5 \cdot 5 \cdot 5 = 3750$ around the loop and forgetting that the last vertex must also differ from the first gives choice (E).

Answer: (C) 3120

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21 Number Theory

Source: 2011 AMC 10B #23

What is the hundreds digit of 2011^{2011}?

(A) 1 **(B)** 4 **(C)** 5 **(D)** 6 **(E)** 9

Key idea. The hundreds digit depends only on the last three digits, so work modulo 1000. Then 2011 behaves like $11 = 10+1$, and a power of $10+1$ is made for the binomial theorem: every term with 10^3 or more vanishes modulo 1000.

Step 1: reduce the base. The last three digits of a product depend only on the last three digits of the factors. Since $2011 \equiv 11 \pmod{1000}$,

$$2011^{2011} \equiv 11^{2011} \pmod{1000}.$$

Step 2: expand. By the binomial theorem,

$$11^{2011} = (1+10)^{2011} = 1 + \binom{2011}{1}10 + \binom{2011}{2}10^2 + \binom{2011}{3}10^3 + \cdots.$$

Every term from $\binom{2011}{3}10^3$ on is a multiple of 1000, so only the first three terms matter.

Step 3: the three terms modulo 1000.

- $\binom{2011}{1} \cdot 10 = 20110 \equiv 110$.
- $\binom{2011}{2} = \dfrac{2011 \cdot 2010}{2} = 2011 \cdot 1005 = 2021055$. Multiplying by 100 keeps only its last digit, 5, in the hundreds place: $2021055 \cdot 100 \equiv 500$.

Adding, $11^{2011} \equiv 1 + 110 + 500 = 611 \pmod{1000}$.

Step 4. The last three digits of 2011^{2011} are 611, so the hundreds digit is 6.

Watch out. Stopping the expansion after two terms gives $1 + 20110 = 20111 \equiv 111$, hundreds digit 1, choice (A). The 10^2 term still affects the hundreds digit; only 10^3 and higher can be dropped.

Answer: (D) 6

22 Counting & Probability

Source: 2022 AMC 10A #24

How many strings of length 5 formed from the digits $0, 1, 2, 3, 4$, are there such that for each $j \in \{1, 2, 3, 4\}$, at least j of the digits are less than j?

(For example, 02214 satisfies this condition because it contains at least 1 digit less than 1, at least 2 digits less than 2, at least 3 digits less than 3, and at least 4 digits less than 4. The string 23404 does not satisfy the condition because it does not contain at least 2 digits less than 2.)

(A) 500 **(B)** 625 **(C)** 1089 **(D)** 1199 **(E)** 1296

Key idea. Conditions of the form "at least j entries are below j" are exactly what it takes for everyone to find a seat in a one-way parking lot. Recasting the strings as parking preferences lets a neat circular symmetry do the counting.

Step 1: the parking model. A one-way street has spaces $0, 1, 2, 3, 4$. Five cars arrive in order; the kth car wants the space given by the kth digit. It parks there if that space is free, otherwise in the first free space to its right; if there is none, it fails. Call a string *good* if every car parks.

Step 2: good strings are exactly the strings we want. If all cars park, spaces $0, \ldots, j-1$ are filled, and cars only move right, so those j spaces were filled by cars wanting a space $< j$: at least j digits are less than j. Conversely, suppose some car fails. Then some space k stays empty. Every car wanting a space $\le k$ would have stopped at k at the latest, so these cars all park in spaces $0, \ldots, k-1$ — at most k of them. If $k = 4$ that says at most 4 of the five digits are ≤ 4, which is false; so $k \le 3$, and at most k digits are less than $k+1$, breaking the condition for $j = k+1$.

Step 3: go around a circle. Add a space 5 and bend the street into a circle $0 \to 1 \to \cdots \to 5 \to 0$. Now let each digit be any of $0, \ldots, 5$: there are 6^5 strings. Six spaces and five cars means every car parks and exactly one space stays empty.

Adding 1 to every digit (with $5 + 1$ read as 0) shifts the whole parking pattern one space around, so the empty space moves one step too. The six strings obtained by repeated shifting therefore have six different empty spaces, one each. So exactly one sixth of the strings leave space 5 empty:

$$\frac{6^5}{6} = 6^4 = 1296.$$

Step 4: back to the street. If space 5 stays empty, no car wanted space 5 and no car ever drove past it, so the digits are in $0, \ldots, 4$ and the cars parked as on the straight street — the string is good. Conversely, a good string never uses or passes space 5. So the good strings number 1296.

Answer: (E) 1296

23 Algebra

Source: 2012 AMC 10A #24

Let a, b, and c be positive integers with $a \geq b \geq c$ such that

$$a^2 - b^2 - c^2 + ab = 2011$$

and

$$a^2 + 3b^2 + 3c^2 - 3ab - 2ac - 2bc = -1997.$$

What is a?

(A) 249 **(B)** 250 **(C)** 251 **(D)** 252 **(E)** 253

Key idea. Two equations, three unknowns, and the answer is an integer: combine the equations into something with very few integer solutions. Adding them leaves only the "mixed" terms $a^2 + b^2 + c^2 - ab - bc - ca$, which is a famous sum of squares in disguise.

Step 1. Add. Adding the two equations:

$$2a^2 + 2b^2 + 2c^2 - 2ab - 2ac - 2bc = 2011 - 1997 = 14.$$

The left side regroups as $(a-b)^2 + (b-c)^2 + (a-c)^2$, so

$$(a-b)^2 + (b-c)^2 + (a-c)^2 = 14.$$

Step 2. Squares. The squares not exceeding 14 are $0, 1, 4, 9$. The only way to write 14 as a sum of three of them is $9+4+1$. Because $a \geq b \geq c$, all three differences are nonnegative and $a-c = (a-b)+(b-c)$ is the largest, so $a - c = 3$ and $\{a-b,\ b-c\} = \{1, 2\}$.

Step 3. Case $a-b=1, b-c=2$. Then $b = a-1$, $c = a-3$, and the first equation becomes

$$a^2 - (a-1)^2 - (a-3)^2 + a(a-1) = 7a - 10 = 2011,$$

so $7a = 2021$. But $2021 = 7 \cdot 288 + 5$, so a is not an integer.

Step 4. Case $a-b=2, b-c=1$. Then $b = a-2$, $c = a-3$:

$$a^2 - (a-2)^2 - (a-3)^2 + a(a-2) = 8a - 13 = 2011,$$

so $8a = 2024$ and $a = 253$, with $b = 251$, $c = 250$.

Check: $253^2 - 251^2 - 250^2 + 253 \cdot 251 = 2011$, and the second equation gives -1997 (it must, since the sum of the two equations holds).

Answer: (E) 253

24 Number Theory

Source: 2016 AMC 10A #25

How many ordered triples (x, y, z) of positive integers satisfy

$$\operatorname{lcm}(x, y) = 72,$$
$$\operatorname{lcm}(x, z) = 600,$$

and

$$\operatorname{lcm}(y, z) = 900?$$

(A) 15 **(B)** 16 **(C)** 24 **(D)** 27 **(E)** 64

Key idea. An lcm takes, prime by prime, the larger exponent. So factor everything and split the problem into one small, independent puzzle for each prime — then multiply the counts.

Step 1: factor.

$$72 = 2^3 \cdot 3^2, \qquad 600 = 2^3 \cdot 3 \cdot 5^2, \qquad 900 = 2^2 \cdot 3^2 \cdot 5^2.$$

No other primes appear, so x, y, z use only 2, 3, 5.

Step 2: the prime 5. $\operatorname{lcm}(x, y) = 72$ has no factor 5, so neither x nor y does. Then $\operatorname{lcm}(x, z)$ has 5^2 only if z has exactly 5^2. One choice.

Step 3: the prime 2. Let the exponents of 2 in x, y, z be a, c, e. We need $\max(a, c) = 3$, $\max(a, e) = 3$, $\max(c, e) = 2$. The last condition gives $c \le 2$ and $e \le 2$, so the first forces $a = 3$ (and then the second holds). It remains to count pairs (c, e) from $\{0, 1, 2\}$ with $\max(c, e) = 2$: all $3^2 = 9$ pairs minus the $2^2 = 4$ with both at most 1, so 5 choices.

Step 4: the prime 3. Let the exponents be b, d, f. We need $\max(b, d) = 2$, $\max(b, f) = 1$, $\max(d, f) = 2$. The middle condition gives $b \le 1$ and $f \le 1$, so the first forces $d = 2$ (and the third then holds). Pairs (b, f) from $\{0, 1\}$ with $\max(b, f) = 1$: $4 - 1 = 3$ choices.

Step 5: multiply. The primes are independent, so the number of triples is $1 \cdot 5 \cdot 3 = 15$.

Watch out. Counting "$\max(c, e) = 2$" as "$c = 2$ (3 ways) or $e = 2$ (3 ways)" gives 6, counting $(2, 2)$ twice; doing the same for the 3s gives 4. The product $6 \cdot 4 = 24$ is choice (C).

Answer: (A) 15

25 Counting & Probability

Source: 2019 AMC 10B #25

> How many sequences of 0s and 1s of length 19 are there that begin with a 0, end with a 0, contain no two consecutive 0s, and contain no three consecutive 1s?
>
> **(A)** 55 **(B)** 60 **(C)** 65 **(D)** 70 **(E)** 75

Key idea. The two "no consecutive" rules say exactly what can sit between two neighbouring 0s: one 1 or two 1s, nothing else. So the sequence is built from a small set of blocks, and counting sequences becomes counting arrangements of blocks.

Step 1. Break into blocks. No two 0s are adjacent, so between consecutive 0s there is at least one 1. No three 1s are adjacent, so there are at most two. The sequence starts and ends with 0, so it looks like

$$0\ \ [1 \text{ or } 11]\ \ 0\ \ [1 \text{ or } 11]\ \ 0\ \cdots\ 0\ \ [1 \text{ or } 11]\ \ 0.$$

Equivalently: a single 0 followed by a string of blocks, each 10 or 110. Conversely, any such string of blocks gives a valid sequence.

Step 2. Count the blocks. Say there are x blocks 110 and y blocks 10. The length is

$$1 + 3x + 2y = 19, \qquad \text{so} \qquad 3x + 2y = 18.$$

Since $3x = 18 - 2y$ is even, x is even, giving

$$(x, y) = (0, 9),\ (2, 6),\ (4, 3),\ (6, 0).$$

Step 3. Arrange the blocks. With $x + y$ blocks in a row, choose which x positions hold a 110: $\binom{x+y}{x}$ ways. Adding over the four cases,

$$\binom{9}{0} + \binom{8}{2} + \binom{7}{4} + \binom{6}{6} = 1 + 28 + 35 + 1 = 65.$$

Another way. Let a_n be the number of valid sequences of length n (starting and ending with 0). The final 0 is preceded by 1 or 11, and before that comes a 0 ending a valid sequence of length $n - 2$ or $n - 3$. So

$$a_n = a_{n-2} + a_{n-3}, \qquad a_1 = 1,\ a_2 = 0,\ a_3 = 1.$$

Then $a_4, a_5, \ldots, a_{19}$ are

$$1, 1, 2, 2, 3, 4, 5, 7, 9, 12, 16, 21, 28, 37, 49, 65.$$

Answer: (C) 65