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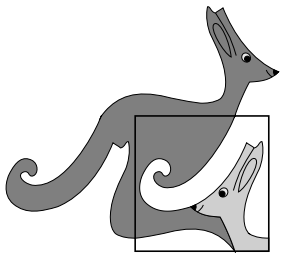

Pink Kangaroo

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Solutions

These are polished solutions and do not illustrate the process of failed ideas and rough work by which candidates may arrive at their own solutions.

It is not intended that these solutions should be thought of as the 'best' possible solutions and the ideas of readers may be equally meritorious.

Enquiries about the Pink Kangaroo should be sent to:

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1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
A	D	C	C	B	B	D	C	C	C	B	E	E	A	D	A	B	D	E	D	E	C	D	B	B

1. Which of these expressions has the smallest value?

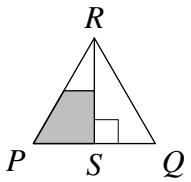
A $202 \div 6$ B 202.6 C $20 + 26$ D $202 - 6$ E 20×26

SOLUTION **A**

Since the question asks for the *smallest* number, options B, D and E can be eliminated, as each gives a three-digit answer and option C clearly results in a two-digit number.

Evaluating C gives 46, and the result of the division in A is $33\frac{2}{3}$. Hence the answer is A.

2. Amber draws an equilateral triangle PQR. The point S is the midpoint of PQ. A line is drawn parallel to the base, PQ, through the midpoint of RS.

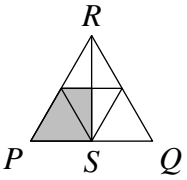


What fraction of the area of triangle PQR is shaded?

A $\frac{1}{8}$ B $\frac{3}{10}$ C $\frac{1}{4}$ D $\frac{3}{8}$ E $\frac{1}{3}$

SOLUTION **D**

The equilateral triangle can be divided into four congruent equilateral triangles, as shown in the figure.



Therefore the fraction of the whole area that is shaded is that of one and a half of these triangles out of four, that is, three-eights of the whole area.

3. Yong writes down a 7-digit number, '193391a'. His number is divisible by 6. What is the value of a?

A 0 B 2 C 4 D 6 E 8

SOLUTION **C**

For Yong's number to be divisible by 6, it must be divisible by both 2 and 3.

Divisibility by 2 requires the number to be even, so a must be even.

Divisibility by 3 requires the sum of the digits to be a multiple of 3.

The digit sum is $1 + 9 + 3 + 3 + 9 + 1 + a = 26 + a$. For this to be divisible by 3, a must be 1, 4 or 7. Of these, only 4 is even.

4. What is the value of the expression $(1-2)-(3-4)-(5-6)-\ldots-(2025-2026)$?

A -1013 B -1011 C 1011 D 1013 E 2024

SOLUTION **C**

Each of the brackets in the expression evaluates to -1. Hence, the expression can be written as $(-1)-(-1)-(-1)-\cdots-(-1)-(-1)$.

Since there are $2026 \div 2 = 1013$ brackets, expanding the brackets will give $-1+\underbrace{1+1+\cdots+1+1}_{1012 \text{ times}}$.

Hence the expression simplifies to $-1+1012$ which is 1011.

5. Sanika wants to write the numbers 1, 2, 3, 4, 5, 6 and 7 in the boxes in the diagram. She has already written two numbers, as shown.



She wants the sum of the numbers in each pair of adjacent boxes to be odd, and to avoid the sum of the numbers in any three consecutive boxes being a multiple of 3.

What is the sum of the numbers she will need to write in the shaded boxes?

A 5 B 7 C 9 D 11 E 13

SOLUTION **B**

For adjacent boxes to sum to an odd number, the digits must alternate between odd and even. Since 2 is placed in the second box, the fourth and sixth boxes must therefore contain the even digits 4 and 6 in some order.

The two digits neighbouring 2 must be chosen from 1, 3 or 7. The only sum which comes from adding two of these digits along with 2 and which is not a multiple of 3 is $10 = 1+2+7$. Hence 3 must be placed in the fifth box.

The final three boxes must be either 3, 4 and 5, which sum to a multiple of 3, or 3, 6 and 5 which do not. Hence, the sixth box must be 6 and fourth box must be 4. Therefore the sum of the shaded boxes is $4+3$ which is 7. The diagram can be completed by placing the digits 1 and 7 in the remaining boxes in either order.

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6. A farmer has dogs, sheep, goats, pigs and chickens on her farm. There are more chickens than pigs, more pigs than goats, more goats than sheep and more sheep than dogs. There are half as many dogs as chickens. The total number of animals is as small as it could be. How many animals are there on her farm?

A 28 B 30 C 32 D 34 E 36

SOLUTION **B**

Let the number of dogs on the farm be n. Since the total number of animals is as small as possible and there are more sheep than dogs, there must be exactly $n + 1$ sheep. Similarly, the smallest possible numbers of the other animals are:

$$\text{goats } = n + 2, \quad \text{pigs } = n + 3, \quad \text{chickens } = n + 4.$$

Thus the number of chickens is at least $n + 4$ but also equals $2n$. Hence, $2n \geq n + 4$, which gives $n \geq 4$. So the least value of n is 4.

Therefore the total number of animals on the farm is $4 + 5 + 6 + 7 + 8$ which is 30.

7. After a day trip through the Scottish Highlands, five hikers are covered in midge bites.

They have 7, 9, 10, 13 and 14 bites. The total number of bites Gabriel and Jesseca have is three times the number of bites Isobel has.

The total number of bites Kyle and Jesseca have is twice the number of bites Henry has.

How many bites does Jesseca have?

A 7 B 9 C 10 D 13 E 14

SOLUTION **D**

Gabriel and Jesseca together can have at most $13 + 14 = 27$ bites. Therefore Isobel has at most $27 \div 3 = 9$ bites.

If Isobel had 7 bites Gabriel and Jesseca would need to have $7 \times 3 = 21$ bites between the two of them. This is impossible, since no pair of the numbers 9, 10, 13 and 14 sum to 21. Hence Isobel must have exactly 9 bites. This means that Gabriel and Jesseca must have 13 and 14 bites in either order.

It follows that Kyle and Henry must have 7 and 10 bites in some order. If Kyle had 10 bites and Henry had 7 bites then Jesseca would have $2 \times 7 - 10 = 4$ bites, which is impossible. Therefore Kyle has 7 bites, Henry has 10 bites and Jesseca has $2 \times 10 - 7 = 13$ bites.

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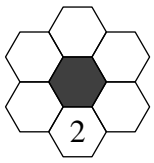
8. The six smallest prime numbers are to be written in the empty hexagons on the right. Numbers in adjacent empty hexagons must **not** add to a prime number. The 2 is already in place. In how many ways can the hexagons be filled in?



A 2 B 6 C 12 D 60 E 120

SOLUTION **C**

When we add 2 to 3, 5 or 11, we get another prime number. However, $2+7=9$ and $2+13=15$, which are not primes. So the neighbours of 2 must be 7 and 13, in some order. The other three primes can be arranged freely in $3\times2\times1=6$ ways. This is because any other pair of neighbouring primes would sum to an even number greater than 2, which cannot be prime. Hence, there are 2×6 which is 12 ways to complete the hexagons.

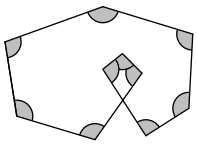
9. Fifteen points are equally spaced around a circle. How many regular polygons can be drawn by selecting the vertices of each polygon from these points?

A 5 B 7 C 9 D 11 E 13

SOLUTION **C**

The divisors of 15 are 1, 3, 5 and 15, so the only regular polygons that can be formed using these vertices are a triangle, a pentagon and a pentadecagon. Taking rotational symmetry into account, there are 5 distinct triangles, 3 distinct pentagons and 1 pentadecagon. Hence there are $5+3+1=9$ possible polygons.

10. The diagram, which is not drawn to scale, shows a shape with ten equal angles marked. What is the size of each of these angles?

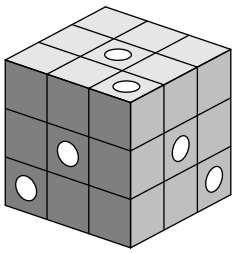


A 96° B 105° C 108° D 115° E 120°

SOLUTION **C**

Let α denote the size of each of the ten equal angles. Tracing once around the whole shape results in two complete turns. Hence the sum of the exterior angles is 720°. Adding the exterior angles gives $10(180^\circ-\alpha)=720^\circ$. Hence $\alpha=108^\circ$.

11. Six woodworms made their home in an old wooden cube made up of identical small cubes. Each one drilled a tunnel all the way through the cube, parallel to one of its edges. The diagram shows the entrances to the six tunnels.



How many small cubes do **not** have a tunnel drilled through them?

A 9 B 12 C 15 D 18 E 21

SOLUTION **B**

Each woodworm drills through 3 small cubes, so altogether at most $6 \times 3 = 18$ cubes are drilled. This leaves at least 9 small cubes without a tunnel.

However, some small cubes are drilled by more than one worm and so have been counted more than once. The small cube at the centre of the cube is drilled by three worms, so it has been counted two more times than it should be. On the lowest level, one small cube is drilled from the right and also from the left, so it has been counted one more time than it should have been. So there are $9 + 2 + 1 = 12$ cubes without a tunnel.

12. Five pupils took part in a one-mile run. One of them didn't finish and the others finished at different times. When asked about the race later, they said:

Priya: "I was second or third."
Qusay: "I didn't make it to the finish line."
Rathursan: "I got to the finish line and wasn't fourth."
Sara: "I was fourth."
Tanisha: "I was first."
One of the pupils lied and all the others told the truth. Which of the pupils lied?

A Priya B Qusay C Rathursan D Sara E Tanisha

SOLUTION **E**

If Qusay were lying, then at least one other person would also have to be lying about their finishing position. This is not possible, so Qusay must be telling the truth and therefore did not finish.

Sara must also be telling the truth, since otherwise no one could be in fourth place. This implies that Rathursan is telling the truth, as he cannot have finished fourth.

If Priya were lying, then she must have finished either first or fourth. This would force either Tanisha or Sara to be lying as well.

Hence, Tanisha must be the liar. The finish order must be either Rathursan, Tanisha, Priya and Sara or Rathursan, Priya, Tanisha and Sara.

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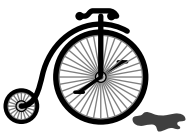
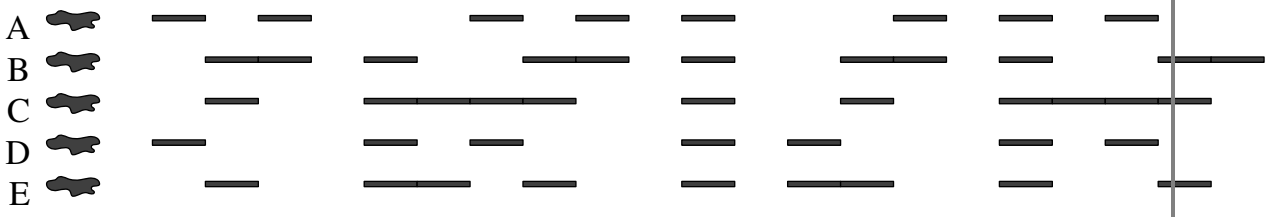
13. Donita rides her penny-farthing through a small puddle, as shown in the picture below.



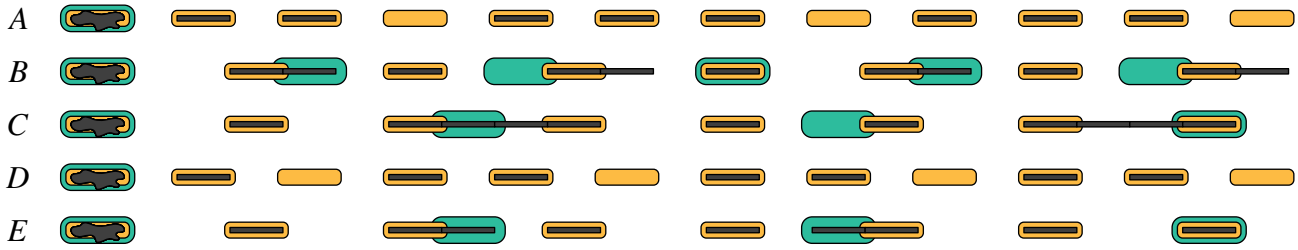
What might the track that she leaves behind look like?



SOLUTION **E**

The marks left by the two weeks will be the same size, with the relative periods depending on the relative sizes of the wheels. The marks must consist of two overlapping regular patterns: one produced by the back wheel and one by the front wheel. The first mark must be from the back wheel, and taking the puddle as the 'zeroth' mark allows us to determine the period of the back wheel. This is illustrated in the diagram by the yellow boxes. This immediately rules out options A and D, as both are would have the back wheel making marks where none are given.

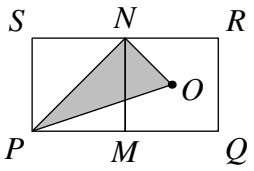
We now take the first unaccounted-for mark to be the first mark made by the front wheel. Applying the same method determines the period of the front wheel; these marks are shown in green boxes.



The only option that accounts for all the marks, with none left uncovered, is option E.

14. Let M and N be the midpoints of PQ and RS respectively in the rectangle $PQRS$. Let O be the centre of the rectangle $MQRN$. What fraction of the rectangle $PQRS$ is shaded?

A $\frac{1}{4}$ B $\frac{1}{2}$ C $\frac{1}{3}$ D $\frac{1}{5}$ E $\frac{2}{9}$



SOLUTION **A**

Point O is the midpoint of NQ. This means that NO is half the length of NQ. Since triangles PNO and PNQ share the common base PN, the area of PNO must be half that PNQ.

Triangle PNQ has the same base and the same height as rectangle $PQRS$, and therefore has half its area.

Hence the required fraction is $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$.

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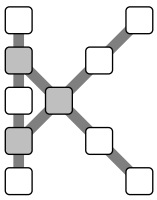
15. Avani wants to place the numbers 1 to 10 in the boxes of the K-shaped grid shown.
She wants the sum of the numbers in each line of boxes - either 5 in a row vertically or 4 in a row diagonally - to be the same.
She also wants this sum to be as large as possible.
What will be the sum of the numbers she places in the three shaded boxes.



A 13 B 18 C 23 D 26 E 27

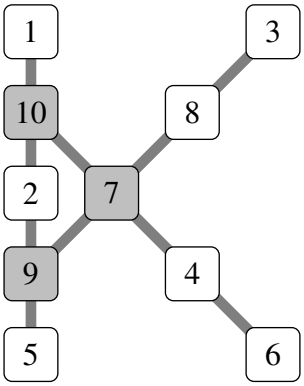
SOLUTION **D**

Let S be the common line sum, and suppose the three shaded boxes contain the numbers a, b and c in some order.

Each number appears in exactly one line, except that the shaded numbers each appear in two lines. Adding the totals of the three lines gives:

$$3S = (1 + 2 + 3 + \cdots + 9 + 10) + a + b + c = 55 + a + b + c.$$

To maximise S, we must maximise $a + b + c$, subject to $55 + a + b + c$ being divisible by 3.



If $a + b + c = 10 + 9 + 8 = 27$, then $55 + 27 = 82$, which is not divisible by 3.

If $a + b + c = 10 + 9 + 7 = 26$, then $55 + 26 = 81$, which is divisible by 3, giving $S = 27$.

The diagram on the right shows that this value of S is achievable.

Therefore, the sum of the numbers she places in the three shaded boxes is 26.

16. In the first round of a chess tournament, each player plays against every other player exactly once. A player gets 3, 1 or -1 points respectively for winning, drawing or losing a match. At the end of the first round, the sum of the scores of all the players is 90. How many players are there in the tournament?

A 10 B 11 C 12 D 13 E 14

SOLUTION **A**

If a match is drawn then both players receive 1 point. However, if a match is not drawn then one player receives 3 points and the other -1 points. So after each match, the total score of all players increases by 2. Since the total increase in score is 90, the tournament must consist of $\frac{90}{2} = 45$ matches.

Let the number of players be n.

Consider how the players for each match may be chosen. The first player may be chosen in n different ways and the second player in $n-1$ different ways. Although this suggests that there are $n(n-1)$ possible matches, each pair has been chosen twice in this calculation. So the total number of matches is $\frac{n(n-1)}{2}$.

Therefore, we get $\frac{n(n-1)}{2} = 45$. Multiplying through by 2 gives $n^2 - n - 90 = 0$. Solving this quadratic gives $n = 10$.

17. Given that, $2026 = a^b - ab$ for two positive integers a and b. What is the value of $a + b$?

A 10 B 13 C 15 D 1013 E 1015

SOLUTION **B**

Factorising the expression gives $a(a^{b-1} - b) = 2026$. Hence a must be a factor of 2026. Since 1013 is a prime, a must be either 1, 2, 1013 or 2026. The values 1013 and 2026 can be rejected, since they would require $a^{b-1} - b$ to equal 2 or 1 respectively, which is impossible for such large values of a.

If a was equal to 1, then $1^b = 1$, and so we would solve the equation $1 - b = 2026$, which implies $b = -2025$. Which is a negative number and not acceptable.

Taking $a = 2$ gives $2^{b-1} - b = 1013$. Since $2^{10} = 1024$, we see that $2^{11-1} - 11 = 1013$, so $b = 11$. Hence $a + b = 2 + 11$, which is 13.

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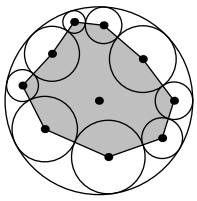
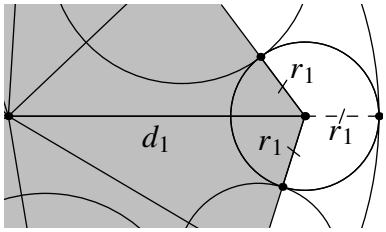
18. The diagram shows a large circle of radius 10 and nine smaller circles, each tangential to two other small circles and also tangential to the large circle. The sum of the distances between the centres of the smaller circles and the centre of the large circle is equal to d. What is the perimeter of the shaded polygon in terms of d?



A $90 - 2d$ B $90 - d$ C $180 - d$ D $180 - 2d$ E $180 + 2d$

SOLUTION **D**

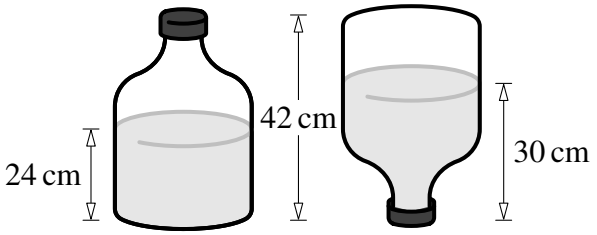
We use the subscript notation r_i for the radius of the ith small circle, where $1 \leq i \leq 9$ and d_i for the distance from its centre to the centre of the large circle. The diagram illustrates a subsection of the figure, with these distances labelled for the first circle, i.e. when $i = 1$.



The radius of the large circle is the sum of the distance from the centre of the large circle to the centre of the small circle and the radius of the small circle. Hence $d_i + r_i = 10$, so $r_i = 10 - d_i$. The perimeter of the shaded shape consists of two radii from each small circle. Therefore the perimeter is $2 \times (r_1 + r_2 + \cdots + r_9)$. Substituting gives $2 \times ((10 - d_1) + (10 - d_2) + \cdots + (10 - d_9))$. Expanding and collecting terms gives $2 \times (\underbrace{10 + 10 + \cdots + 10}_{9 \text{ times}} - (d_1 + d_2 + \cdots + d_9))$.

Since $d_1 + d_2 + \cdots + d_9 = d$, this expression simplifies to $2 \times (90 - d)$, which is $180 - 2d$.

19. Michael has a bottle partially filled with water. The figure on the right shows how the height of water in the bottle changes when it is flipped upside down. The bottle's capacity is $4.5\,\ell$ and the water-filled part in the first diagram is cylindrical.
What is the volume of water in the bottle?

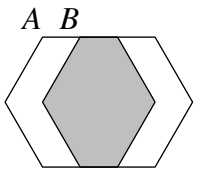


A $2.1\,\ell$ B $2.4\,\ell$ C $2.5\,\ell$ D $2.7\,\ell$ E $3.0\,\ell$

SOLUTION **E**

In the second diagram, the empty part is $(42 - 30)$ cm $= 12$ cm deep, and in the first diagram the water filled region is 24 cm deep. Since both regions are cylindrical, their volumes are proportional to their depths. Hence the ratio of water to empty space is $2 : 1$. Therefore the bottle is $\frac{2}{3}$ full. The volume of water is $\frac{2}{3} \times 4.5\,\ell$, which is $3\,\ell$.

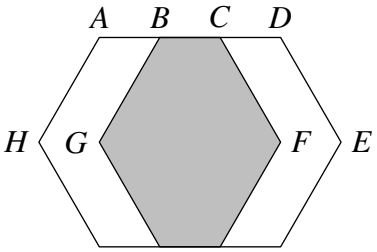
20. Two regular hexagons with side-lengths of 60 are shown in the diagram which is not drawn to scale. The right-hand hexagon was created by shifting the left-hand hexagon horizontally by the length of the segment AB. This creates three regions of equal area. What is the length of AB?



A 30 B 39 C 40 D 45 E 52

SOLUTION **D**

Let the length of AB be x and let the height of each of the regular hexagons be $2h$.



The area of parallelogram $ABGH$ is xh. The length BC must be what remains of the side of the hexagon once AB is removed. This is $60-x$. The length FG is similarly the remainder when the length GH is subtracted from the width FH. The width of the hexagon is twice its side-length so FG is $120-x$. The area of the trapezium $BCFG$ is $\frac{BC+GF}{2} \times h$. This is $\frac{60-x+120-x}{2} \times h$, which is $(90-x) \times h$. We can equate the areas of $ABGH$ and $BCFG$. Therefore $(90-x) \times h = xh$. Hence $90-x = x$, so $x = 45$.

21. Nico has eight sticks with distinct integer lengths, no three of which are able to form a triangle. What is the shortest possible length of the longest stick?

A 30 B 31 C 32 D 33 E 34

SOLUTION **E**

Let the stick lengths be $a_1 < a_2 < \cdots < a_8$, where all are distinct positive integers.

Since no three can form a triangle, for any three lengths $x \le y \le z$, the triangle inequality must fail. That is, $x + y \le z$. Thus, to avoid forming any triangle, it is necessary that

$$a_i \ \ge \ a_{i-1} + a_{i-2}, \quad \text{for all } i \ge 3.$$

To minimise the longest stick, we start with the smallest possible values $a_1 = 1$ and $a_2 = 2$. We then take equality at each step (since any larger choice would only increase subsequent terms):

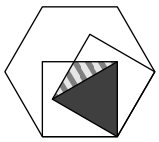
$$a_3 = a_2 + a_1 = 3, \quad a_4 = a_3 + a_2 = 5, \quad a_5 = a_4 + a_3 = 8,$$
$$a_6 = a_5 + a_4 = 13, \quad a_7 = a_6 + a_5 = 21, \quad a_8 = a_7 + a_6 = 34.$$

Thus, the sequence is

$$1,\ 2,\ 3,\ 5,\ 8,\ 13,\ 21,\ 34.$$

Therefore, the smallest possible value of the longest stick is 34.

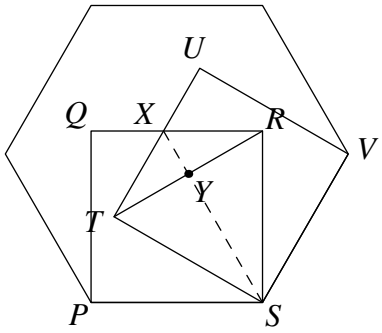
22. Aadi draws a regular hexagon and two squares inside the hexagon, as shown. What is the ratio of the area of the striped triangle to the area of the shaded triangle?



A 1 : 4 B $\sqrt{3} : 6$ C 1 : 3 D 2 : 5 E 1 : 2

SOLUTION **C**

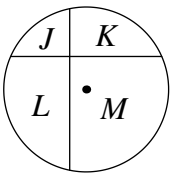
Let us first label the key vertices and intersection points. Then taking the shared side TR as the base of each triangle, the ratio of their areas depends only on their perpendicular heights.



Since $\angle PSV$ is an interior angle of a regular hexagon, it is equal to 120°. Since S is the vertex of a square, $\angle TSV = 90°$. Hence $\angle PST = \angle PSV - \angle TSV = 120° - 90°$, which is 30°. Hence, $\angle TSR = \angle PSR - \angle PST = 90° - 30°$, which is 60°.

Since $\triangle TSR$ shares two equal sides from the squares and has an angle of 60° between them, follows that this triangle is equilateral. Thus $\angle RTS$ is 60° and by using the fact that $\angle STX$ is 90°, it follows that $\angle XTR$ is 30°. Using trigonometry, the perpendicular heights are $XY = TY \times \tan 30° = TY \times \frac{\sqrt{3}}{3}$ and $YS = TY \times \tan 60° = TY \times \sqrt{3}$. Hence the ratio of the heights, and therefore of the areas, is $TY \times \frac{\sqrt{3}}{3} : TY \times \sqrt{3}$ which simplifies to 1 : 3.

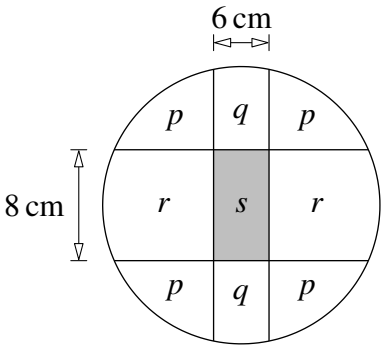
23. Two perpendicular chords are drawn in a circle with radius 12 cm, dividing the circle into four regions, as labelled in the diagram. One chord lies 3 cm from the centre, and the other lies 4 cm from the centre. The sum of the areas of regions J and M is X cm^2 larger than the sum of the areas of regions K and L. What is the value of X?



A 9 B 16 C 36 D 48 E 60

SOLUTION **D**

Take the chord that lies 3 cm from the centre and draw an additional chord that is parallel to the original but is 3 cm the other side. We can do the same to the chord that is 4 cm away. This divides our circle up into nine regions as shown in the diagram on the left. By symmetry, some of the nine regions have the same area. We let p, q, r and s by the areas of the regions, as shown. Each labelled region in the question can then be expressed as a sum of these areas:



Region J: p

Region K: $p+q$

Region L: $r+p$

Region M: $s+r+q+p$

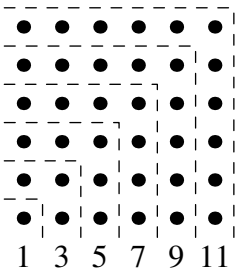
We seek the difference between the combined areas of regions $J+M$ and $K+L$. This difference is $(p)+(s+r+q+p)-(p+q)-(r+p)$, which is s. Since the area of region s is (6×8) cm^2, the required difference is 48 cm^2.

24. Elijah and Mason alternate in taking toffees out of a box: Elijah takes 1, then Mason takes 2, then Elijah takes 3, then Mason takes 4, and so on. When there are not enough toffees to follow this pattern, the boy whose turn it is takes all of the remaining ones. At the end, Elijah has 407 toffees. How many toffees were in the box at the beginning?

A 814 B 827 C 834 D 841 E 851

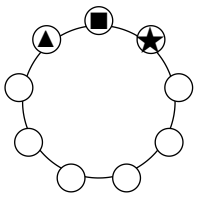
SOLUTION **B**

Elijah takes an odd number of toffees on each turn, in the sequence 1, 3, 5, 7, ... The sum of the first n odd numbers is n^2, as shown in the diagram. Since Elijah has not finished on a square number, he must have taken the final turn. The largest square less than 407 is $400 = 20^2$. Hence, on the final turn, Elijah must have found only 7 toffees remaining in the box; and on the penultimate turn Elijah took 39 toffees and Mason took 40 toffees. Since Mason always takes one more toffee than Elijah, over his 20 turns he has taken a total of 20 more toffees than Elijah.



Thus the total number of toffees is $400 + 400 + 20 + 7$, which is 827.

25. Anni places the digits $1, 2, \ldots, 9$ on a circle in some order. She reads three adjacent digits clockwise to form a three-digit number, such as ▲■★ as in the diagram, and writes down all nine such numbers. One of these numbers is a, which is a factor of the sum of the remaining 8 numbers. How many possible values of a are there?



A 1 B 2 C 3 D 4 E 5

SOLUTION **B**

Note that the three digits of a will be distinct. We also require a to divide the sum of the eight other three-digit numbers around the circle. It will therefore have to divide the sum of all nine of the three-digit numbers since this is a more than the previous sum.

Amongst these nine, three-digit numbers, every digit from 1 to 9 must appear exactly once in the hundreds place, once in the tens place, and once in the units place. Therefore, the sum of the nine three-digit numbers is $(1 + 2 + \cdots + 9) + (10 + 20 + \cdots + 90) + (100 + 200 + \cdots + 900)$.

This sum can be written as $(1 + 2 + \cdots + 9)(1 + 10 + 100)$, which is 45×111. It therefore has the prime factorisation $3^3 \times 5 \times 37$. Using this, one can check that its three-digit factors are 111, 135, 185, 333, 555 and 999. Since a cannot have repeated digits, the only possible values are 135 or 185. So there are 2 possible values for a.