

GCPC 2024 Presentation of Solutions

The GCPC Jury

September 12, 2024

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- **Jannik Olbrich**
Ulm University, CPUIm
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CPUIm
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A: Alien Attack 2

Problem author: Yvonne Kothmeier & Andreas Grigorjew

Problem

- Find the size of the largest connected component in an undirected graph representing friendships.

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- Utilize algorithms like Depth First Search (DFS), Breadth First Search (BFS), or Union-Find with path compression to traverse the graph.

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- Repeat the process until all nodes have been visited.

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- Count the number of nodes visited during each traversal to determine the size of the connected component.
- Repeat the process until all nodes have been visited.
- The size of the largest component found will dictate the size of the smallest necessary ship.
- Pitfalls: Inefficient graph traversal algorithms, e.g. revisiting nodes or Union-Find without path compression, may lead to time limit problems.
- For Python users: default recursion depth is low. Increase using `sys.setrecursionlimit`

B: Bookshelf Bottleneck

Problem author: Jannik Olbrich

Problem

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- If it still does not fit, the task is impossible

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- Put the smallest side length in shelf direction and the second smallest upwards
- If this does not fit with the height H , swap the dimensions
- If it still does not fit, the task is impossible
- Otherwise, do this for every book. The sum of the lengths is the solution

C: Copycat Catcher

Problem author: Jannik Olbrich

Problem

- Determine whether pieces of code can be obtained by renaming variables from substrings of a reference

```
for i in list do print i j  
  k in list do print k a  
    print b c
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Replace each occurrence of a variable V with

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- Do this for all suffixes of the reference:

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for 0 in list do print 5 0
  0 in list do print 5 0
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for 0 in list do print 5 0
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```
list do print 0 0      0 0
do print 0 0          0
  print 0 0
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- Sort these transformed suffixes lexicographically, use binary search to find the transformed query
- Time complexity: $\mathcal{O}(n^2 + q \cdot qlen \cdot \log n)$, where $qlen \leq 2000$ is the max. length of a query

D: Dark Alley

Problem author: Michael Zündorf

Problem

Process the following queries:

- + b x : place a lamp with brightness b at position x .
- b x : remove a lamp with brightness b at position x .
- ? x : calculate the brightness at position x .

Note that the light reduces by a factor of $\tilde{p} = 1 - p$ every metre.

0	0	0	0	0	0
---	---	---	---	---	---

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0.25	0.5	1	0.5	0.25	0.125
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⇒ only consider light to the right for now



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- A light with brightness b at position x contributes $b \cdot \tilde{p}^{y-x}$ at $y \geq x$.



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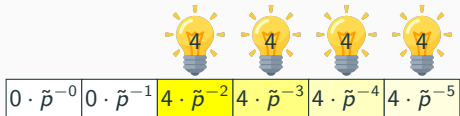
4	2	1	0.5	0.25	0.125
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- Place bulbs at positions $x, x+1, \dots, n$ with constant brightness $b \cdot \tilde{p}^x$.

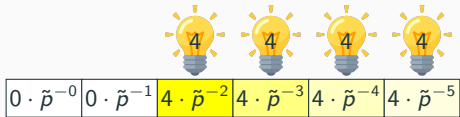


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- The light at position y is now too bright by a constant factor \tilde{p}^y .
- For queries of type ? x , answer with $\ell_x \cdot \tilde{p}^{-x}$.

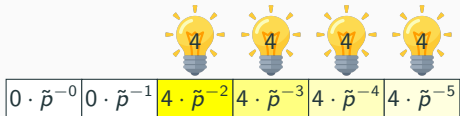


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- Use segment tree or fenwick tree to maintain ℓ in $\mathcal{O}(q \log(n))$.



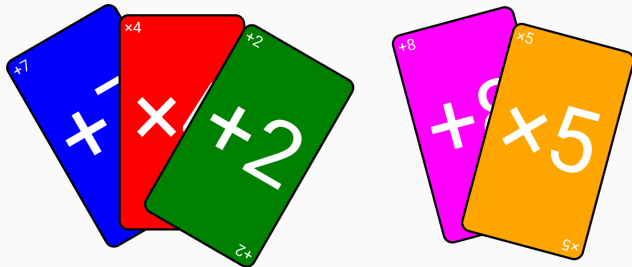
E: Even Odd Game

Problem author: Paul Wild

Problem

Find and interactively execute a winning strategy in the following game:

- There are some cards containing math operations $+n$ and $\times n$.
- Two players alternate picking cards until no cards are left.
- These operations are applied to a given number in the order they are picked.
- One player wins if the final result is even, the other wins if it is odd.



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Solution

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- So there are only three types of cards: $+0$, $+1$, $\times 0$
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- As we only care about parity, reduce all numbers mod 2.
- So there are only three types of cards: $+0$, $+1$, $\times 0$
 - Note that $+0$ is the same as $\times 1$.
- There are at most $n \leq 300$ cards, so we can use $\Theta(n^3)$ dynamic programming:

$\text{dp}[\text{who}][\text{cur}][a][b][c] =$ Does player who win when the current value is cur and there are a, b and c operations of the respective types remaining?

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Challenge

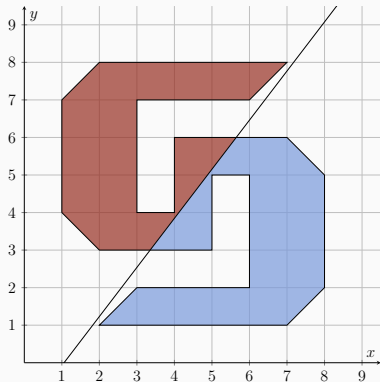
Can you also solve the problem for $n \leq 10^5$?

F: Fair Fruitcake Fragmenting

Problem author: Jannik Olbrich

Problem

Given a point symmetric polygon, check if it can be cut into exactly two pieces of equal size along an infinite line.



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Problem author: Jannik Olbrich

Solution

- Polygon is point symmetric
 - Parts must have equal size
- ⇒ Line has to go through centre of mass = point of symmetry

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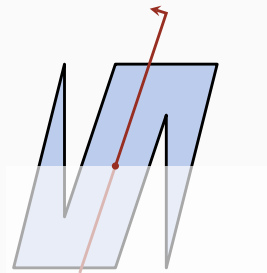
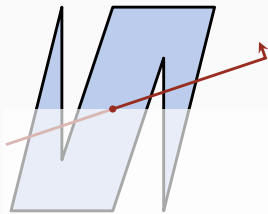
- Polygon is point symmetric
- Parts must have equal size
 - ⇒ Line has to go through centre of mass = point of symmetry
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- Due to symmetry, it is sufficient to keep track of the upper half of the polygon

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- Parts must have equal size
 - ⇒ Line has to go through centre of mass = point of symmetry
 - ⇒ We can do a sweepline around centre of mass
- Due to symmetry, it is sufficient to keep track of the upper half of the polygon
- Sweepline is valid answer \iff sweepline intersects the polygon exactly once

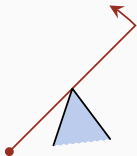


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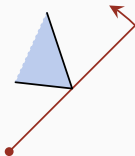
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Sweepline

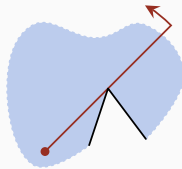
- Number of intersections can only change at corners



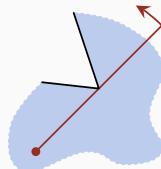
a: -2



b: $+2$



c: -2



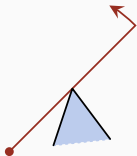
d: $+2$

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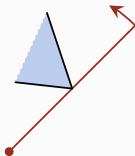
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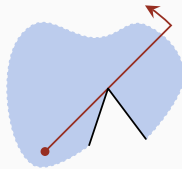
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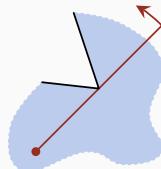
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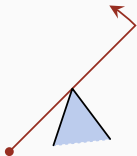
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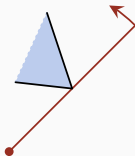
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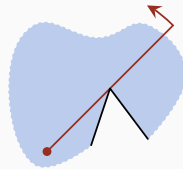
- Number of intersections can only change at corners
- $+$ events come before $-$ events
- If after a type a event the sweepline has size 1, the line is ok
- Type c events are only ok if we can rotate an ε further
(add a dummy event halfway to the next actual event)



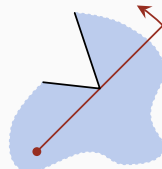
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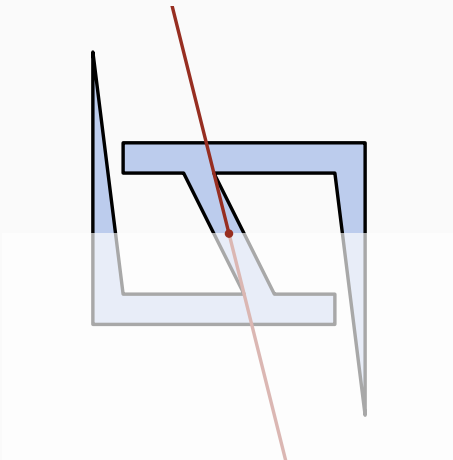
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Edgecase

There might be no valid cut line that goes through any corner

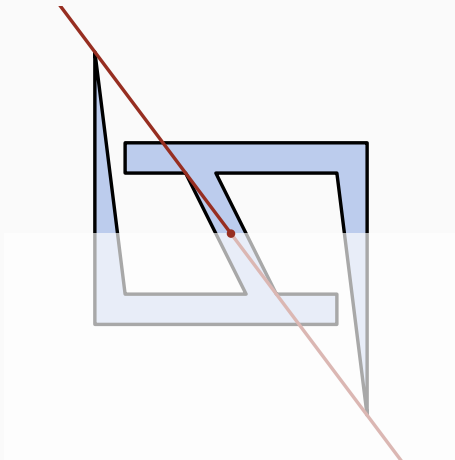


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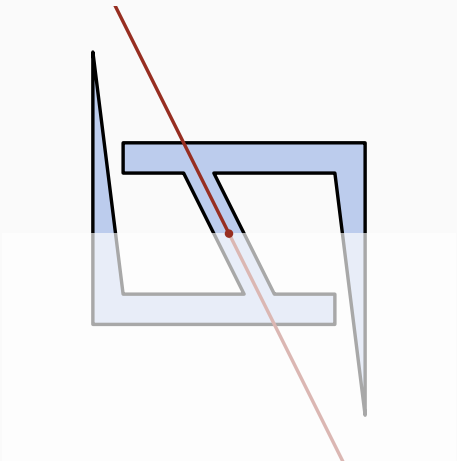


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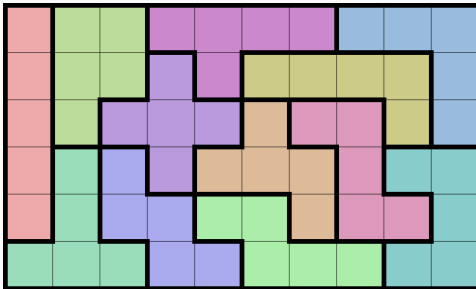
G: Geometric Gridlock

Problem author: Paul Wild

Problem

Construct a valid *Pentominous* grid of a given size:

- Divide an $h \times w$ grid into regions of size 5 (pentominoes). . .
- . . . such that no two adjacent regions have the same shape.



G: Geometric Gridlock

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Insights and corner cases

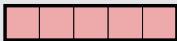
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Insights and corner cases

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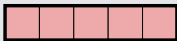


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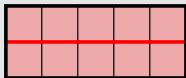
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- 2×5 is not solvable:

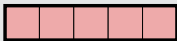


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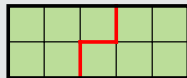
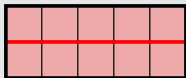
Problem author: Paul Wild

Insights and corner cases

- One of h or w must be a multiple of 5; by symmetry, assume it's w .
- $1 \times w$ is only solvable for $w = 5$:



- 2×5 is not solvable:



- $2 \times w$ is solvable in all other cases:

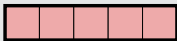


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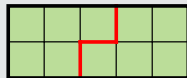
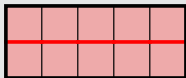
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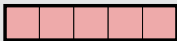


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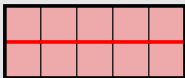
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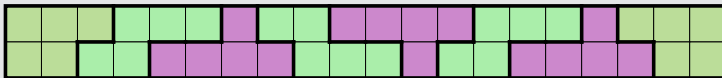
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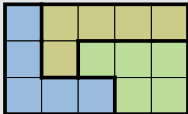


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- For 3×5 we can come up with a solution that can be repeated to achieve any width:

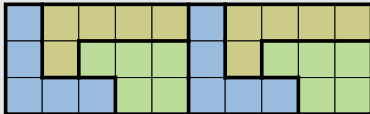


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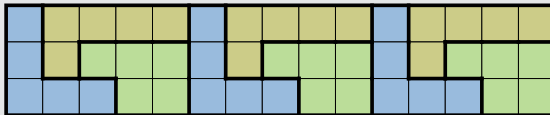


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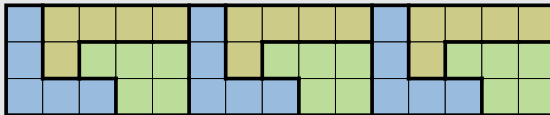
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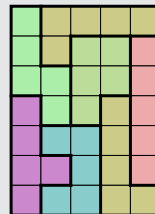
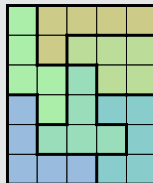
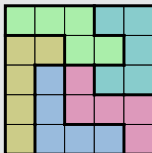


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- Similar repeatable patterns exist for heights 4, 5, 6 and 7:

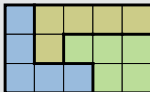


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Solution (continued)

- With some care, these patterns can be chosen so that they tile along both directions:

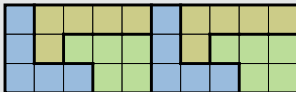


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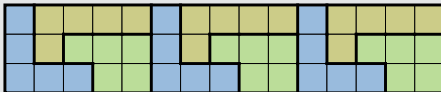


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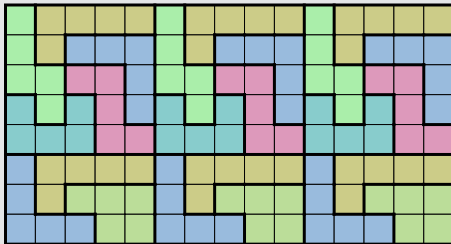


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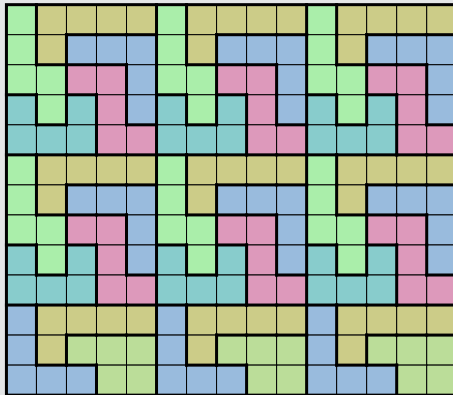


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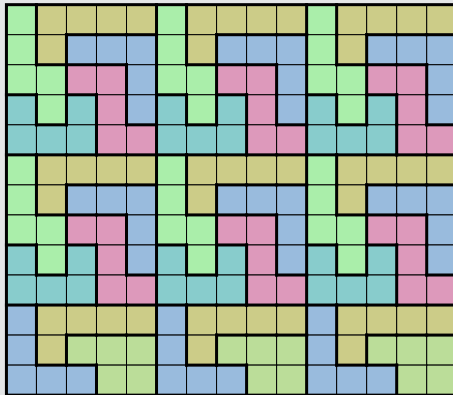


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- This way, we can reduce any height h to one of the base cases 3, 4, 5, 6 or 7.

H: Headline Heat

Problem author: Christopher Weyand

Problem

- Given $n < 10^5$ university names, $m < 10^5$ rivalries between universities, and $k < 10^5$ texts. For each text, answer if there are two rivaling universities with different number of occurrences. The summed length of all names and texts is $W < 10^6$.

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To avoid quadratic time, hash the vectors. **Runtime:** $\mathcal{O}(n + m + k)$

I: Interference

Problem author: Sebastian Angrick

Problem

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- $\mathcal{O}(n^2)$ is sufficient, for each query simulate all former updates.
- Pitfalls: Results can be large (long long may be needed) or negative, correctly deal with alternation

J: Jigsaw Present

Problem author: Erik Sünderhauf

Problem

- Given $n \leq 4\,096$ pairs of numbers (x_i, y_i) , with $1 \leq x_i \leq 4\,096 =: C$ and $|y_i| \leq C$. Find two distinct subsets with the same sum or report that this is not possible.

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and finding a collision.

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- But n is waaay too large for this approach...

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Insights

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- One can prove that for $n \geq 32$ there always is a collision (short sketch on next slide).
- Challenge: Construct test cases without collision and with a large n . The best case we could achieve has $n = 27$. Hint: powers of 2 are not useful.

Proof sketch

Let (X, Y) be the total sum of all pairs. Pick a random subset with sum (\tilde{x}, \tilde{y}) . Using Chebyshev's inequality you can show that the probability that we are “close” to the total sum

$$\left| (\tilde{x}, \tilde{y}) - \frac{1}{2}(X, Y) \right| \lesssim \sqrt{n}C$$

happens with probability $\geq 1/2$. Note that there are $\mathcal{O}(nC^2)$ possible sums that are “close”. If all subset sums that are “close” to the total sum are distinct, then this requires

$$nC^2 \cdot 2^{-n} \gtrsim \frac{1}{2} \Rightarrow C \gtrsim \frac{2^{n/2}}{\sqrt{n}}.$$

Inserting numbers and more details¹ shows that we always have a collision for $n \geq 32$.

¹search for “Probabilistic method”

K: Kitten of Chaos

Problem author: Paul Wild

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Apply a bunch of rotations and reflections to a string consisting of `bdpq`:

- `h`: horizontal flip: `bbq` \leftrightarrow `pdd`
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- Using these, we only need to do at most one `h` and at most one `v` transformation.
- All of this can be done in $\mathcal{O}(n)$ time.

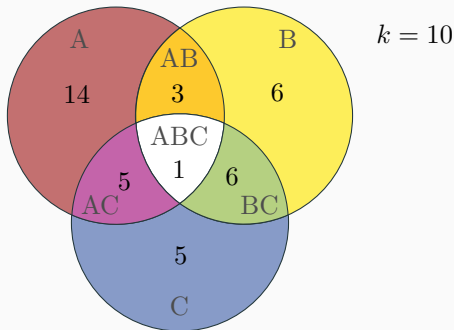
L: Laundry

Problem author: Wendy Yi

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Given the capacity $1 \leq k \leq 10^9$ of a washing machine with three programmes, and how many items can be washed with which programmes.

What is the minimum number of loads needed to wash all items?



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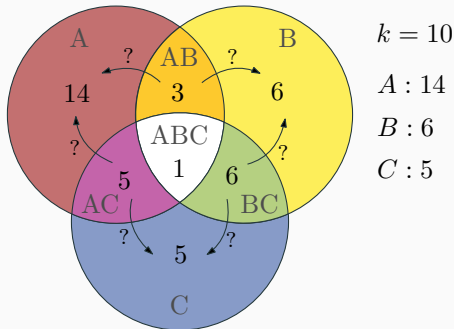
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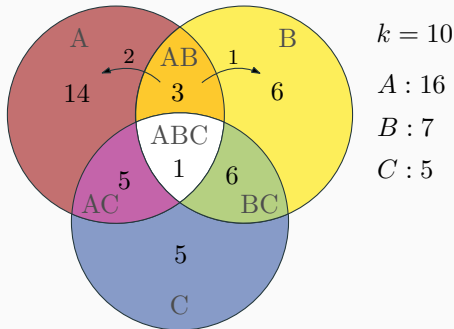
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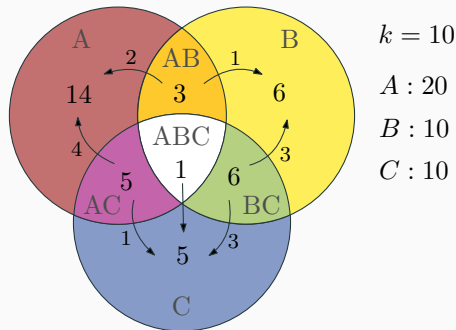
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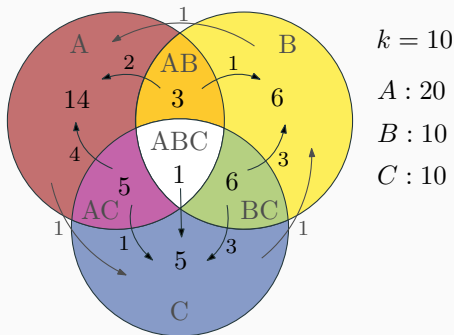
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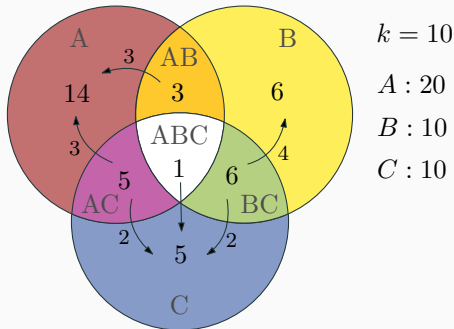
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 - Determine the optimal solution for the other sets with two choices.

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- Process items that can only be washed with one programme first.
- For each set with two choices:
 - Try to assign the whole set to one of the two choices.
 - Determine the optimal solution for the other sets with two choices.
 - Distribute the items with three choices optimally.

L: Laundry

Problem author: Wendy Yi

Problem

Given the capacity $1 \leq k \leq 10^9$ of a washing machine with three programmes, and how many items can be washed with which programmes.

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Running time: $\mathcal{O}(1)$ per test case

M: Musical Mending

Problem author: Brutenis Gliwa, Marian Zuska

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- **Problem:** Find the minimal distance from the input sequence to any sequence $x, x + 1, x + 2, \dots, x + n - 1$.

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- Ternary search the answer over all possible x ! $O(\log(v) \cdot n)$

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Jury work

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On average 24.1 lines per problem

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- The minimum number of characters the jury needed to solve all problems is

$$231 + 196 + 495 + 828 + 674 + 1109 + 818 + 1407 + 393 + 952 + 254 + 615 + 231$$

On average 631 characters per problem