香港電腦奧林匹克競賽
Hong Kong Olympiad in Informatics

G264 - Infinite Whack-a-mole

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Background

- Problem idea by kctung
- Preparation by hywong1
- Presentation by cwong

Problem Restatement

- There are N+1 holes and a mole initial in hole 1
- Each time a mole is whacked, it disappears and two appear in the next hole
- Determine whether it is possible to get exactly M moles in hole N and find the minimum number of whacks needed to do so

Statistics

Task	Attempts	Max	Mean	Std Dev	Subtasks					
G264 - Infinite Whack-A-Mole	101	100	12.772	24.213	13: 31	22: 12	18: 11	13: 11	16: 12	18: 5

First solved by **bstc-21003** at **1h 25m**

Subtask 1: M ≤ 2

- **Case 1**: N = 1
- Initially, we only have 1 mole in hole 1.
- Hence it is only possible if M = 1, and we do not need any whacks

- **Case 2**: N > 1
- We can always get 2 moles in hole N by whacking a mole in hole 1, 2, … N - 1 in order for a total of N - 1 whacks
- If M = 1 then we need to whack away 1 mole in hole N

Subtask 2: N, M ≤ 1000

- We can simulate the process with a greedy algorithm:
- We find the hole with the largest id that has a mole in it (and is not hole N), and we whack once in that hole
- Repeat this until we have at least M moles in hole N (and whack once more if M is odd!)
- Time complexity: O(NM)

Subtask 3: M is a power of 2, Always possible to win

- Assume we need $M = 2^k > 1$ moles in hole N
- Then we need to whack 2^{k-1} moles in hole N-1, 2^{k-2} moles in hole N-2 … and 2 moles in hole N-k+1
- Use the solution in subtask 1 to get 2 moles in hole N-k+1 and whack the moles in hole N-k+1, N-k+2 … N-1
- Handle the M = 1 case using the solution from subtask 1
- Time complexity: O(log M)

Subtask 4: M is a power of 2

- When will the solution from subtask 3 fail?
- It requires that $N-k+1 \geq 2$, otherwise we will not be able to perform the subtask 1 solution
- Add an if-then-else statement to check this condition
  - If the condition holds then do the subtask 3 solution
  - Otherwise report impossible
- Time complexity: $O(\min(N, \log M))$

Subtask 5: $N \le 10^5$

- We can expand the idea from previous subtasks:
- If we want hole i+1 to have k moles, then we will also need hole i to have at least ceil(k/2) moles
- We can compute an array cnt[], where cnt[i] is the minimum number of moles needed such that we can get M moles in hole N
  - cnt[N] = M
  - cnt[i] = ceil(cnt[i+1]/2) for all 1 ≤ i < N
- If cnt[1] > 1, we report impossible
- Otherwise the answer is the sum of cnt[1], cnt[2], ..., cnt[N-1] as we will need to whack all cnt[i] moles in hole i
- Remember to do the +1 whack if M is odd!
- Time complexity: O(N)

Subtask 6: No additional constraints

- We cannot compute the whole cnt[] array anymore, as it would be too large
- Notice that the first N-k elements, where k=ceil(log M), of cnt[] are all 1s
- Therefore we can skip the calculation for all of those entries of cnt[] and only compute the ones that are not equal to 1
- Time complexity: O(min(N, log M))