5 PUZZLES TO START ANY SCIENCE CLASS

curated from Riddler section of FiveThirtyEight.com

How Many Earthlings Would Survive 63 Thanos Snaps?

From Rich Holmes, published on April 26, 2019
https://fivethirtyeight.com/features/how-many-earthlings-would-survive-63-thanos-snaps/

Thanos, the all-powerful supervillain, can snap his fingers and destroy half of all the beings in the universe.

But what if there were 63 Thanoses, each snapping his fingers one after the other? Out of 7.5 billion people on Earth, how many can we expect would survive?

If there were N Thanoses, what would the survival fraction be?

Thanos - Solution
So this was a teeny bit of a trick question. But who said dealing with supervillains wouldn't be tricky.

One way to approach this problem was to assume that each Thanos did indeed snap. In this case, half the population would be destroyed 63 times in a row, leaving a remaining decimal of (0.5)63, or about 0.0000000000000000001. Multiplying that by the population of 7.5 billion gives about 0.0000000008 expected people remaining. In other words, everyone on the planet is dead. (Full credit shall be awarded for this solution, as I am a benevolent leader of Riddler Nation and certainly no pedant.)

But … the puzzle did say that Thanos snaps would destroy half of all the beings in the universe, and that includes other Thanoses. In this case, the problem gets far more interesting. So how do we deal with self-destructing Thanoses?In an act of self-preservation, some of Riddler Nation attacked the problem head on. By this route, the first Thanos snap will leave 31 Thanoses, the second will leave 15, the third will leave seven, the fourth will leave three, the fifth will leave one and the sixth will leave none, for six total snaps. In other words, we figure that six snaps is the most likely number of snaps before all the Thanoses are gone — which is true. Six snaps means (0.5)6 or 1/64 of the population will survive, yielding an answer of about 117.2 million.

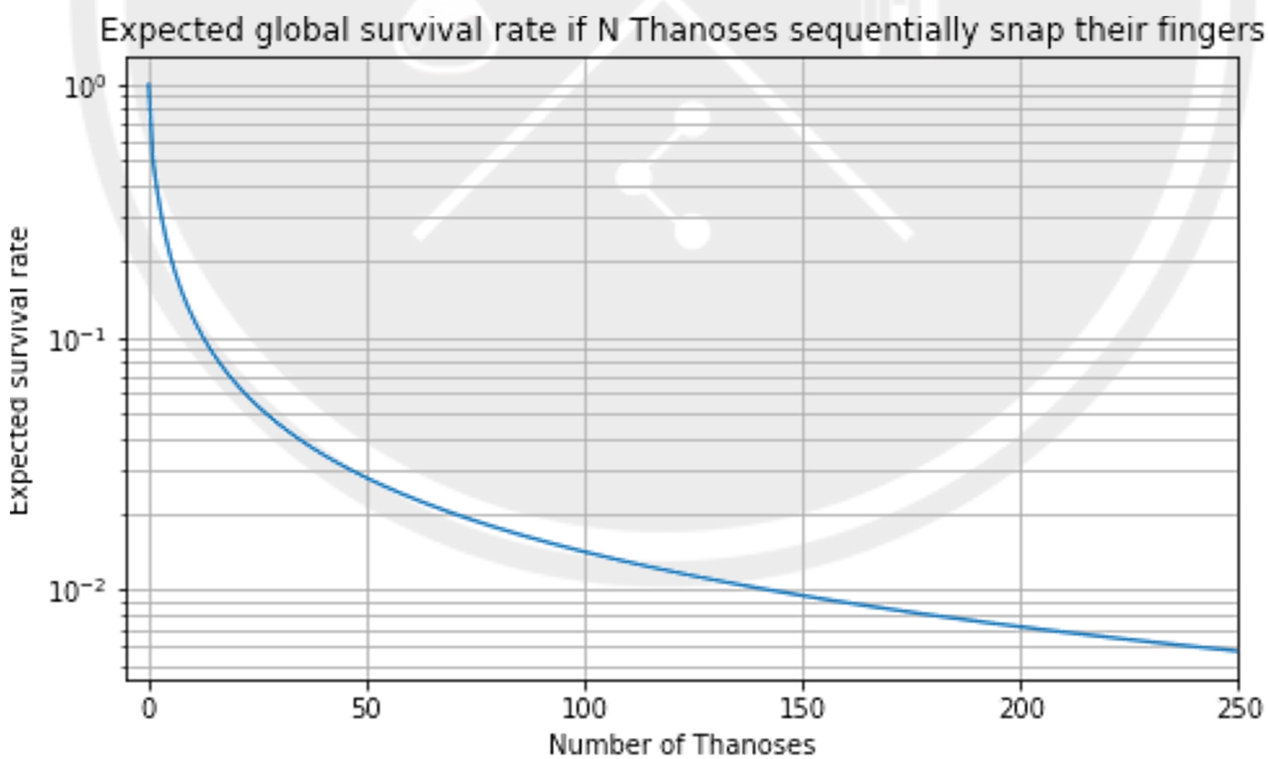
But this answer is wrong. Why? Six snaps is certainly the most likely outcome of this supervillainous digital onslaught, but we don't yet know how many Thanoses are caught up in another Thanos's snap. It will most likely take six snaps, but it could also take just one snap or 10 snaps. What we're really after is the distribution of how many Thanoses are poofed per snap (PPS for you sabermetricians).

As solver Tracy Hall explained, for the case of one Thanos, half of humanity survives. For two Thanoses, though, we don't know whether the first snap takes out the second Thanos. Half the time, one Thanos survives, leaving 1/4 of humanity, and half the time, the second Thanos doesn't survive, leaving 1/2 of humanity, for an overall average expected survival rate of 3/8. For three Thanoses, the probabilities are 1/4, 1/2 and 1/4, respectively, that zero, one or two Thanoses remain after the first snap, from which we can calculate the ensuing probabilities from a possible second snap, and a third snap, which at the end yields a more optimistic survival rate (19/64) than we would've gotten using the (wrong) methodology described above.

All this means that 1) this problem probably should have been a Riddler Express and a Riddler Classic and 2) the survival rates as a function of N can be calculated recursively using the binomial coefficients and the previously calculated values. (As I said, a Riddler Classic.)The right answer, at the end of all this calculation (some of which I have chosen to spare you), is that about 166.5 million people are expected to survive — honestly not bad considering more than five dozen all-powerful beings out to destroy everyone.

Lastly, solver Laurent Lessard illustrated the survival rate as the number of initial Thanoses grew:

https://laurentlessard.com/bookproofs/thanos-snaps/



Which Billiard Ball is Rigged?
From Corey Grodner, published on August 16, 2019
https://fivethirtyeight.com/features/which-billiard-ball-is-rigged/

You have 12 billiard balls. To the naked eye, they all look identical, and in your hand, they all feel identical. One of the balls, however, is slightly heavier or slightly lighter than the others, but you don't know which ball or whether it is heavier or lighter.

You do, however, have a balance scale. You can place any equal number of balls on each side of the scale, and the scale will tilt if one side differs in weight. (Note: There is no use in weighing different numbers of balls against each other — the weight difference is so slight that if the scale has more balls on one side, that side will always be heavier.) However, you can only use the scale three times.

How can you determine which ball is different, and whether it is heavier or lighter?

Billiard Ball - Solution

This puzzle's submitter, Corey Grodner, described how to accomplish that measuring feat. To begin with — and this is the really important bit — separate the balls into three groups. To keep track of them, label them like so: A1, A2, A3, A4, B1, B2, B3, B4, C1, C2, C3 and C4.

Use your scale a first time to weigh the four balls in the A group against the four balls in the B group. There are three possible scenarios that could result. One, the groups weigh the same. Two, the A balls are heavier. Three, the B balls are heavier. (The third scenario, as far as solving this puzzle goes, is essentially identical to the second scenario, so we'll just lay out what to do in Scenarios One and Two below.)

Scenario One: Now you know for sure that the abnormal ball is in group C. You also know that all of the A and B balls are normal, and can therefore be used as controls — a handy trick in this billiard hall. Use your scale a second time to weigh C1, C2 and C3 against A1, A2 and A3. If this weighing is equal, you know C4 must be the abnormal ball and you can weigh it against A1 (your third and final use of the scale) to determine if it's heavier or lighter than normal. If this weighing is unequal, then you know the abnormal ball is C1, C2 or C3. You can weigh C1 against C2 to find out which of the three it is, and you'll know whether its heavier or lighter based on the results of the weighing that came before.

Scenario Two: Now you know for sure that the abnormal ball is in either group A or B — and moreover that a ball in A is heavier or a ball in B is lighter. You also know that the balls in group C are normal, and can therefore be used as controls. Use your scale a second time to weigh A1, A2, A3 and B1 against A4, C1, C2 and C3. If this weighing is equal, you know that an abnormally light ball is one of B2, B3 and B4, and you can weigh B2 against B3 (your final use) to figure out which. If that second weighing shows that the left side is heavier, you know one of A1, A2 and A3 is the culprit and you can weigh A1 against A2 to suss it out. If that second weighing shows that the right side is heavier, you know that either B1 is abnormally light or that A4 is abnormally heavy. Weigh B1 against C1 to figure it out.

Where in the Square?

From Tyler Barron, published on June 19, 2019
https://fivethirtyeight.com/features/can-you-construct-the-optimal-tournament/

You are given an empty 4-by-4 square and one marker. You can color in the individual squares or leave them untouched. After you color as many or as few squares as you'd like, I will secretly cut out a 2-by-2 piece of it and then show it to you without rotating it. You then have to tell me where it was (e.g., "top middle" or "bottom right," etc.) in the original 4-by-4 square.

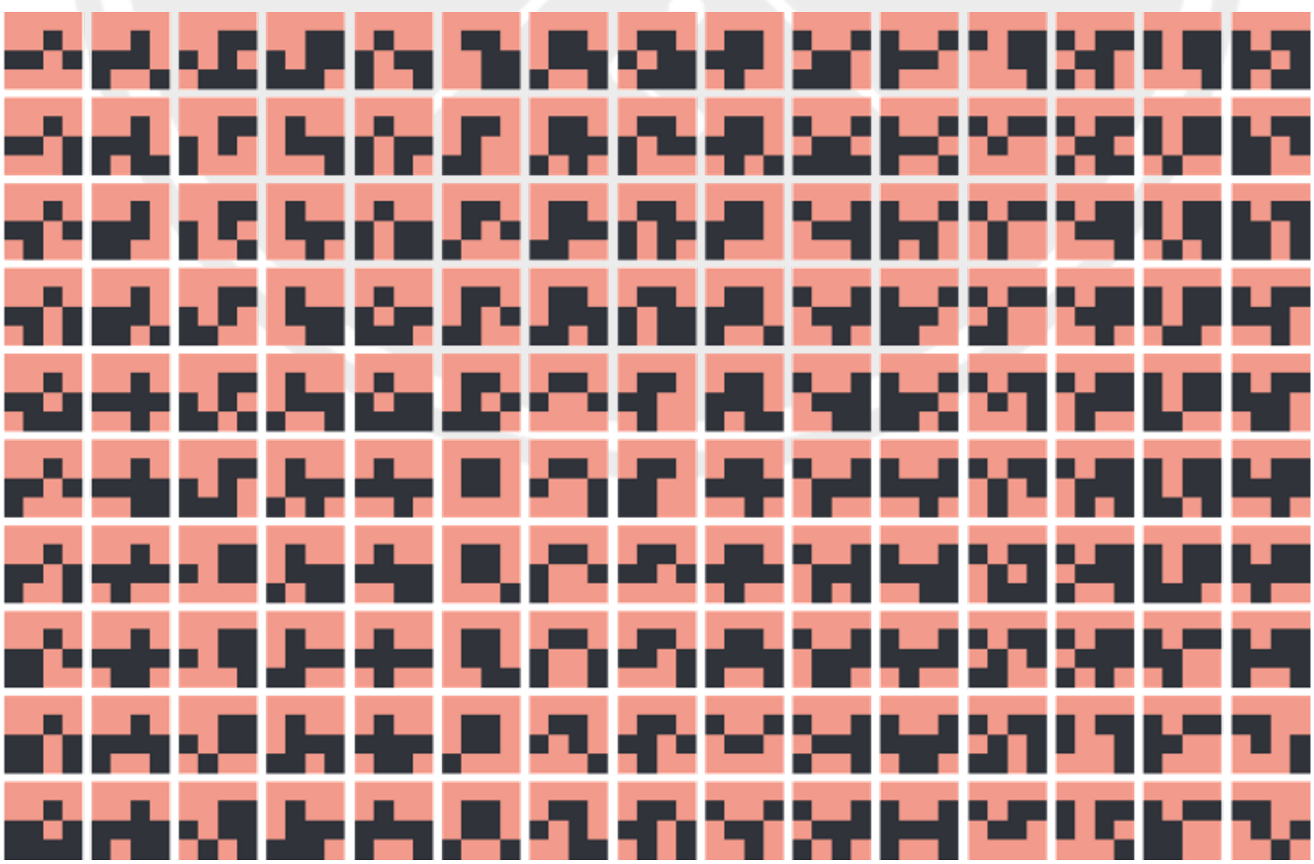
Can you design a square for which you'll always know where the piece came from?

Where in the Square - Solution

There were 6,188 different ways to do so. This puzzle's submitter, Tyler Barron, illustrated 150 of them:

https://barronwasteland.wordpress.com/2019/07/21/where-in-the-square/

Perhaps the most elegant solution is to simply color in a small 2-by-2 square smack in the middle of the big 4-by-4 square. One might call it the donut. It's quick to check whether that one, for example, works as a solution to challenge. No matter what piece I cut, the pattern you've colored will be different — a colored piece in the lower right, or along the bottom, and so on — and so you'll be able to tell me where I cut in the original square.



Can you escape a maze without walls?
From Tom Hanrahan,, published on Feb 1, 2019
https://fivethirtyeight.com/features/can-you-escape-a-maze-without-walls/Riddler Express

Bad news: the enemies of Riddler Nation have forced you into a maze. And this maze is weird. The rules are as follows.

- You move between boxes in a grid: up, down, left or right, but never diagonally.
- Your goal is to arrive in the finish square, designated here by a "☺."
- Your movement is dictated by the symbol inside the square you have just moved to, and each direction is relative to where you'd be facing if you were physically walking the maze. "S" means you continue straight, "R" means you turn right, "L" means you turn left, "U" means you make a U-turn, and "?" gives you the option of any of those four directions.
- An "X" ends your game in failure — think hot lava. (But hey, you can always start over!)
- If you are forced to exit the maze's grid, you lose — more hot lava.

Your maze is below. You may enter the maze anywhere along the perimeter, giving you 32 options. Some of these, however, immediately fail. If you enter at a "U" on the top of the maze, for example, you must immediately U-turn out of the maze, so you lose.

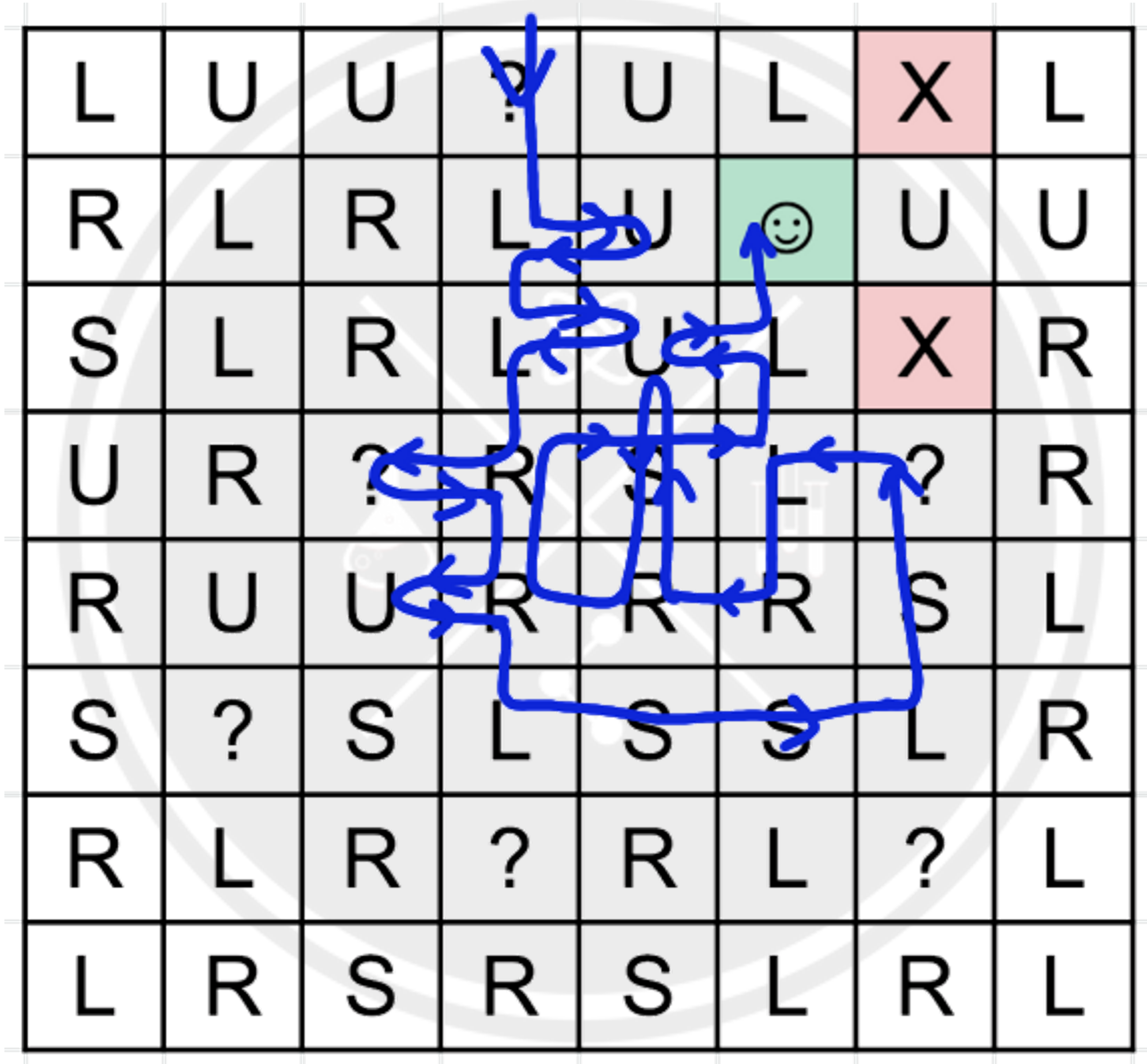
Can you reach the smiley face? If so, how many moves does it take?

L	U	U	?	U	L	X	L
R	L	R	L	U	☺	U	U
S	L	R	L	U	L	X	R
U	R	?	R	S	L	?	R
R	U	U	R	R	R	S	L
S	?	S	L	S	S	L	R
R	L	R	?	R	L	?	L
L	R	S	R	S	L	R	L

Can you Escape a Maze without Walls - Solution

There was more than one way to solve the maze, but the quickest path took 34 moves.

Here’s that path, from this week’s winner, Gwen:



You've been marooned by kidnappers - can you escape at dawn?

From Marcus Farbstein and Mark Baird, published on June 7, 2019

https://fivethirtyeight.com/features/youve-been-marooned-by-kidnappers-can-you-escape-at-dawn/

You're super rich, and you often joke with your cadre of intelligent friends and family about getting kidnapped. You all agree that if you were ever kidnapped, the evildoers would knock you out so stealthily that you'd never feel the blow. Then, one snowy night, you step out of a restaurant and, just as predicted, never feel the blow.

When you stir back into consciousness, it's night, but it's not snowy. You find yourself sitting on a beach. The sky is clear, with no moon. In front of you stands a shadowy figure whose face you can't make out. He throws a blocky rectangular object at your feet. "That's a satellite phone," the figure growls. "It's got one minute of battery left in it. Use that to call your people to let 'em know you're not dead — but not until daylight." He tosses a paper bag next to the sat phone. "That's some sandwiches and water, enough for a few days. That's salt," he explains, waving toward the surf. "If your people pay our ransom," he continues, "We'll come get you. Otherwise, there won't be any more paper bags. Remember, wait until daylight to make that call."

He then turns and climbs into a dinghy in the light surf, starts its outboard motor and zooms away. All this time you've been too groggy to do anything but listen. Now you watch as the dinghy disappears into the gloom, its wake a faint wash of phosphorescence that quickly fades. Later, there's a bare wink of lights at the horizon, presumably the mothership getting underway and leaving.

Even though it's a moonless night, there's sufficient starlight to assess your surroundings. Your grogginess is gone and you walk about. You're on a tiny island, which you estimate is a bit more than a mile by half a mile. There are no trees; it's all flat sand. You taste the water rolled up by the surf, and it is indeed salt. The air is cool, but not cold. Your wallet, expensive chronometer, keys, cell phone, jewelry and small change are all gone; all you have are the clothes on your back — even your shoes and socks have been taken. The bag contains four sandwiches, all liverwurst with peanut butter on cheap rye bread, and four one-pint bottles of water. No napkins. Your knowledge of astronomy is too weak to try to estimate your location by the stars, but you're not stupid. Before daybreak, you've worked out exactly how you'll use that minute of time on the satellite phone so that your people, who are also not stupid, will be able to dispatch rescue.

What will you say?

Escape at dawn - Solution

This puzzle's co-submitter, Mark Baird, has the life-saving answer:

You call your people, knowing that what you say will be communicated to the best person to receive it, at exactly daybreak. You tell them, "I'm OK, it's precisely sunrise. I'll call again at sunset." At exactly sunset, you make the second call, saying, "It's exactly sunset, and I'm still OK." You even have a few seconds left on the battery for contingencies, but none should arise.

Your call at sunrise locates you along the great circle between the poles at the penumbra — the space between shadow and light. You don't know what time it is, but your people do, so the line of penumbra at that moment constitutes a line of longitude between the poles of globe illumination. Your second call provides a crucial piece of information: how long daylight lasted where you are, which fixes your latitude.

Had you been kidnapped at equinox season, when daylight has the same duration the world over, finding your latitude would be more involved, requiring, for example, finding the ratio between a shadow's length and the height of a water bottle at noon, and identifying the hemisphere by which side of the bottle the shadow extends from (north or south).