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~~Settlers of Catan~~ A board game is played on a hexagonal grid of 19 tiles. A 'traveler' token starts on the center tile. Each turn a die is rolled to determine what neighboring tile the traveler moves to (all six directions equally likely). The turn that the traveler leaves the board, the game ends. What is the expected number of turns of the game?

A hexagonal lattice graph with 36 nodes. The central node is labeled 0. Nodes are numbered 1 through 35 in a spiral pattern starting from the center. Each node is represented by a red dot and a black number. The nodes are connected by blue lines forming a hexagonal grid. The outermost nodes are labeled 21 through 36.

We wish to find the expected value of the number of turns in the game, which we denote N .

The dice is truly random, so there is no upper bound on N . We note that this game is really akin to a Markov chain, in that it doesn't matter what the past states are.

$$N^{-1} = \begin{pmatrix} p_{0,0} = 1 & p_{0,1} = \frac{1}{6} & p_{0,2} = \frac{1}{6} & p_{0,3} = \frac{1}{6} & p_{0,4} = \frac{1}{6} & p_{0,5} = \frac{1}{6} & p_{0,6} = \frac{1}{6} & p_{0,7} = 0 & p_{0,8} = 0 & p_{0,9} = 0 & p_{0,10} = 0 & p_{0,11} = 0 & p_{0,12} = 0 & p_{0,13} = 0 & p_{0,14} = 0 & p_{0,15} = 0 & p_{0,16} = 0 & p_{0,17} = 0 & p_{0,18} = 0 & p_{0,19} = 0 \\ p_{1,0} = \frac{1}{6} & p_{1,1} = 1 & p_{1,2} = \frac{1}{6} & p_{1,3} = \frac{1}{6} & p_{1,4} = 0 & p_{1,5} = 0 & p_{1,6} = \frac{1}{6} & p_{1,7} = \frac{1}{6} & p_{1,8} = \frac{1}{6} & p_{1,9} = \frac{1}{6} & p_{1,10} = 0 & p_{1,11} = \frac{1}{6} & p_{1,12} = 0 & p_{1,13} = 0 & p_{1,14} = 0 & p_{1,15} = 0 & p_{1,16} = 0 & p_{1,17} = 0 & p_{1,18} = 0 & p_{1,19} = 0 \\ p_{2,0} = \frac{1}{6} & p_{2,1} = \frac{1}{6} & p_{2,2} = 1 & p_{2,3} = \frac{1}{6} & p_{2,4} = 0 & p_{2,5} = 0 & p_{2,6} = 0 & p_{2,7} = 0 & p_{2,8} = 0 & p_{2,9} = \frac{1}{6} & p_{2,10} = \frac{1}{6} & p_{2,11} = \frac{1}{6} & p_{2,12} = 0 & p_{2,13} = 0 & p_{2,14} = 0 & p_{2,15} = 0 & p_{2,16} = 0 & p_{2,17} = 0 & p_{2,18} = 0 & p_{2,19} = 0 \\ p_{3,0} = \frac{1}{6} & p_{3,1} = \frac{1}{6} & p_{3,2} = \frac{1}{6} & p_{3,3} = 1 & p_{3,4} = \frac{1}{6} & p_{3,5} = \frac{1}{6} & p_{3,6} = \frac{1}{6} & p_{3,7} = 0 & p_{3,8} = 0 & p_{3,9} = 0 & p_{3,10} = 0 & p_{3,11} = \frac{1}{6} & p_{3,12} = \frac{1}{6} & p_{3,13} = \frac{1}{6} & p_{3,14} = 0 & p_{3,15} = 0 & p_{3,16} = 0 & p_{3,17} = 0 & p_{3,18} = 0 & p_{3,19} = 0 \\ p_{4,0} = \frac{1}{6} & p_{4,1} = 0 & p_{4,2} = 0 & p_{4,3} = \frac{1}{6} & p_{4,4} = 1 & p_{4,5} = \frac{1}{6} & p_{4,6} = 0 & p_{4,7} = 0 & p_{4,8} = 0 & p_{4,9} = 0 & p_{4,10} = 0 & p_{4,11} = 0 & p_{4,12} = 0 & p_{4,13} = \frac{1}{6} & p_{4,14} = \frac{1}{6} & p_{4,15} = \frac{1}{6} & p_{4,16} = 0 & p_{4,17} = 0 & p_{4,18} = 0 & p_{4,19} = 0 \\ p_{5,0} = \frac{1}{6} & p_{5,1} = 0 & p_{5,2} = 0 & p_{5,3} = 0 & p_{5,4} = \frac{1}{6} & p_{5,5} = 1 & p_{5,6} = \frac{1}{6} & p_{5,7} = 0 & p_{5,8} = 0 & p_{5,9} = 0 & p_{5,10} = 0 & p_{5,11} = 0 & p_{5,12} = 0 & p_{5,13} = 0 & p_{5,14} = 0 & p_{5,15} = 0 & p_{5,16} = \frac{1}{6} & p_{5,17} = \frac{1}{6} & p_{5,18} = 0 & p_{5,19} = 0 \\ p_{6,0} = \frac{1}{6} & p_{6,1} = \frac{1}{6} & p_{6,2} = \frac{1}{6} & p_{6,3} = 0 & p_{6,4} = 0 & p_{6,5} = \frac{1}{6} & p_{6,6} = 1 & p_{6,7} = \frac{1}{6} & p_{6,8} = \frac{1}{6} & p_{6,9} = 0 & p_{6,10} = 0 & p_{6,11} = 0 & p_{6,12} = 0 & p_{6,13} = 0 & p_{6,14} = 0 & p_{6,15} = 0 & p_{6,16} = 0 & p_{6,17} = \frac{1}{6} & p_{6,18} = \frac{1}{6} & p_{6,19} = 0 \\ p_{7,0} = 0 & p_{7,1} = \frac{1}{6} & p_{7,2} = 0 & p_{7,3} = 0 & p_{7,4} = 0 & p_{7,5} = \frac{1}{6} & p_{7,6} = \frac{1}{6} & p_{7,7} = 1 & p_{7,8} = \frac{1}{6} & p_{7,9} = 0 & p_{7,10} = 0 & p_{7,11} = 0 & p_{7,12} = 0 & p_{7,13} = 0 & p_{7,14} = 0 & p_{7,15} = 0 & p_{7,16} = 0 & p_{7,17} = 0 & p_{7,18} = \frac{1}{6} & p_{7,19} = \frac{1}{6} \\ p_{8,0} = 0 & p_{8,1} = \frac{1}{6} & p_{8,2} = 0 & p_{8,3} = 0 & p_{8,4} = 0 & p_{8,5} = 0 & p_{8,6} = 0 & p_{8,7} = \frac{1}{6} & p_{8,8} = 1 & p_{8,9} = \frac{1}{6} & p_{8,10} = 0 & p_{8,11} = 0 & p_{8,12} = 0 & p_{8,13} = 0 & p_{8,14} = 0 & p_{8,15} = 0 & p_{8,16} = 0 & p_{8,17} = 0 & p_{8,18} = 0 & p_{8,19} = 0 \\ p_{9,0} = 0 & p_{9,1} = \frac{1}{6} & p_{9,2} = \frac{1}{6} & p_{9,3} = 0 & p_{9,4} = 0 & p_{9,5} = 0 & p_{9,6} = 0 & p_{9,7} = \frac{1}{6} & p_{9,8} = \frac{1}{6} & p_{9,9} = 1 & p_{9,10} = \frac{1}{6} & p_{9,11} = 0 & p_{9,12} = 0 & p_{9,13} = 0 & p_{9,14} = 0 & p_{9,15} = 0 & p_{9,16} = 0 & p_{9,17} = 0 & p_{9,18} = 0 & p_{9,19} = 0 \\ p_{10,0} = 0 & p_{10,1} = 0 & p_{10,2} = \frac{1}{6} & p_{10,3} = 0 & p_{10,4} = 0 & p_{10,5} = 0 & p_{10,6} = 0 & p_{10,7} = 0 & p_{10,8} = 0 & p_{10,9} = \frac{1}{6} & p_{10,10} = 1 & p_{10,11} = 0 & p_{10,12} = 0 & p_{10,13} = 0 & p_{10,14} = 0 & p_{10,15} = 0 & p_{10,16} = 0 & p_{10,17} = 0 & p_{10,18} = 0 & p_{10,19} = 0 \\ p_{11,0} = 0 & p_{11,1} = 0 & p_{11,2} = \frac{1}{6} & p_{11,3} = 0 & p_{11,4} = 0 & p_{11,5} = 0 & p_{11,6} = 0 & p_{11,7} = 0 & p_{11,8} = 0 & p_{11,9} = 0 & p_{11,10} = \frac{1}{6} & p_{11,11} = 1 & p_{11,12} = \frac{1}{6} & p_{11,13} = 0 & p_{11,14} = 0 & p_{11,15} = 0 & p_{11,16} = 0 & p_{11,17} = 0 & p_{11,18} = 0 & p_{11,19} = 0 \\ p_{12,0} = 0 & p_{12,1} = 0 & p_{12,2} = 0 & p_{12,3} = \frac{1}{6} & p_{12,4} = 0 & p_{12,5} = 0 & p_{12,6} = 0 & p_{12,7} = 0 & p_{12,8} = 0 & p_{12,9} = 0 & p_{12,10} = 0 & p_{12,11} = \frac{1}{6} & p_{12,12} = 1 & p_{12,13} = \frac{1}{6} & p_{12,14} = 0 & p_{12,15} = 0 & p_{12,16} = 0 & p_{12,17} = 0 & p_{12,18} = 0 & p_{12,19} = 0 \\ p_{13,0} = 0 & p_{13,1} = 0 & p_{13,2} = 0 & p_{13,3} = \frac{1}{6} & p_{13,4} = \frac{1}{6} & p_{13,5} = 0 & p_{13,6} = 0 & p_{13,7} = 0 & p_{13,8} = 0 & p_{13,9} = 0 & p_{13,10} = 0 & p_{13,11} = 0 & p_{13,12} = \frac{1}{6} & p_{13,13} = 1 & p_{13,14} = \frac{1}{6} & p_{13,15} = 0 & p_{13,16} = 0 & p_{13,17} = 0 & p_{13,18} = 0 & p_{13,19} = 0 \\ p_{14,0} = 0 & p_{14,1} = 0 & p_{14,2} = 0 & p_{14,3} = \frac{1}{6} & p_{14,4} = \frac{1}{6} & p_{14,5} = 0 & p_{14,6} = 0 & p_{14,7} = 0 & p_{14,8} = 0 & p_{14,9} = 0 & p_{14,10} = 0 & p_{1$$

$N =$	$P_{0,0} = 45$	$P_{0,1} = 16$	$P_{0,2} = 16$	$P_{0,3} = 16$	$P_{0,4} = 16$	$P_{0,5} = 16$	$P_{0,6} = 16$	$P_{0,7} = 7$	$P_{0,8} = \frac{5}{2}$	$P_{0,9} = 7$	$P_{0,10} = 16$	$P_{0,11} = 7$	$P_{0,12} = 5$	$P_{0,13} = 7$	$P_{0,14} = 5$	$P_{0,15} = 7$	$P_{0,16} = 5$	$P_{0,17} = 7$	$P_{0,18} = 5$
	$P_{1,0} = 16$	$P_{1,1} = 45$	$P_{1,2} = 16$	$P_{1,3} = 16$	$P_{1,4} = 16$	$P_{1,5} = 16$	$P_{1,6} = 16$	$P_{1,7} = 14$	$P_{1,8} = 24$	$P_{1,9} = 14$	$P_{1,10} = 16$	$P_{1,11} = 14$	$P_{1,12} = 12$	$P_{1,13} = 14$	$P_{1,14} = 12$	$P_{1,15} = 14$	$P_{1,16} = 12$	$P_{1,17} = 14$	$P_{1,18} = 12$
	$P_{2,0} = 16$	$P_{2,1} = 16$	$P_{2,2} = 45$	$P_{2,3} = 16$	$P_{2,4} = 16$	$P_{2,5} = 16$	$P_{2,6} = 16$	$P_{2,7} = 14$	$P_{2,8} = 24$	$P_{2,9} = 14$	$P_{2,10} = 16$	$P_{2,11} = 14$	$P_{2,12} = 12$	$P_{2,13} = 14$	$P_{2,14} = 12$	$P_{2,15} = 14$	$P_{2,16} = 12$	$P_{2,17} = 14$	$P_{2,18} = 12$
	$P_{3,0} = 16$	$P_{3,1} = 16$	$P_{3,2} = 16$	$P_{3,3} = 45$	$P_{3,4} = 16$	$P_{3,5} = 16$	$P_{3,6} = 16$	$P_{3,7} = 14$	$P_{3,8} = 24$	$P_{3,9} = 14$	$P_{3,10} = 16$	$P_{3,11} = 14$	$P_{3,12} = 12$	$P_{3,13} = 14$	$P_{3,14} = 12$	$P_{3,15} = 14$	$P_{3,16} = 12$	$P_{3,17} = 14$	$P_{3,18} = 12$
	$P_{4,0} = 16$	$P_{4,1} = 16$	$P_{4,2} = 16$	$P_{4,3} = 16$	$P_{4,4} = 45$	$P_{4,5} = 16$	$P_{4,6} = 16$	$P_{4,7} = 14$	$P_{4,8} = 24$	$P_{4,9} = 14$	$P_{4,10} = 16$	$P_{4,11} = 14$	$P_{4,12} = 12$	$P_{4,13} = 14$	$P_{4,14} = 12$	$P_{4,15} = 14$	$P_{4,16} = 12$	$P_{4,17} = 14$	$P_{4,18} = 12$
	$P_{5,0} = 16$	$P_{5,1} = 16$	$P_{5,2} = 16$	$P_{5,3} = 16$	$P_{5,4} = 16$	$P_{5,5} = 45$	$P_{5,6} = 16$	$P_{5,7} = 14$	$P_{5,8} = 24$	$P_{5,9} = 14$	$P_{5,10} = 16$	$P_{5,11} = 14$	$P_{5,12} = 12$	$P_{5,13} = 14$	$P_{5,14} = 12$	$P_{5,15} = 14$	$P_{5,16} = 12$	$P_{5,17} = 14$	$P_{5,18} = 12$
	$P_{6,0} = 16$	$P_{6,1} = 16$	$P_{6,2} = 16$	$P_{6,3} = 16$	$P_{6,4} = 16$	$P_{6,5} = 16$	$P_{6,6} = 45$	$P_{6,7} = 14$	$P_{6,8} = 24$	$P_{6,9} = 14$	$P_{6,10} = 16$	$P_{6,11} = 14$	$P_{6,12} = 12$	$P_{6,13} = 14$	$P_{6,14} = 12$	$P_{6,15} = 14$	$P_{6,16} = 12$	$P_{6,17} = 14$	$P_{6,18} = 12$
	$P_{7,0} = 7$	$P_{7,1} = 14$	$P_{7,2} = 14$	$P_{7,3} = 14$	$P_{7,4} = 14$	$P_{7,5} = 14$	$P_{7,6} = 14$	$P_{7,7} = 45$	$P_{7,8} = 24$	$P_{7,9} = 14$	$P_{7,10} = 16$	$P_{7,11} = 14$	$P_{7,12} = 12$	$P_{7,13} = 14$	$P_{7,14} = 12$	$P_{7,15} = 14$	$P_{7,16} = 12$	$P_{7,17} = 14$	$P_{7,18} = 12$
	$P_{8,0} = 24$	$P_{8,1} = 24$	$P_{8,2} = 24$	$P_{8,3} = 24$	$P_{8,4} = 24$	$P_{8,5} = 24$	$P_{8,6} = 24$	$P_{8,7} = 24$	$P_{8,8} = 45$	$P_{8,9} = 14$	$P_{8,10} = 16$	$P_{8,11} = 14$	$P_{8,12} = 12$	$P_{8,13} = 14$	$P_{8,14} = 12$	$P_{8,15} = 14$	$P_{8,16} = 12$	$P_{8,17} = 14$	$P_{8,18} = 12$
	$P_{9,0} = 14$	$P_{9,1} = 14$	$P_{9,2} = 14$	$P_{9,3} = 14$	$P_{9,4} = 14$	$P_{9,5} = 14$	$P_{9,6} = 14$	$P_{9,7} = 14$	$P_{9,8} = 14$	$P_{9,9} = 45$	$P_{9,10} = 16$	$P_{9,11} = 14$	$P_{9,12} = 12$	$P_{9,13} = 14$	$P_{9,14} = 12$	$P_{9,15} = 14$	$P_{9,16} = 12$	$P_{9,17} = 14$	$P_{9,18} = 12$

In order to get the expected number of steps, we find t_0 , where

$$t = N\mathbf{1}$$

Here, $\mathbf{1}$ is a vector whose entries are all 1.

[illegible]

Finally, we see that $t_0 = \boxed{\frac{213}{29} \approx 7.345}$