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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?

The diagram shows a hexagonal lattice structure. The internal nodes are numbered 0 through 18, and the external nodes are numbered 19 through 30. The nodes are arranged in a honeycomb pattern, with the central node labeled 0. The external nodes are located at the vertices of the hexagonal lattice, forming a larger hexagonal shape around the internal nodes.

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.



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

$$t = N\mathbf{1}$$
$$t = \begin{pmatrix} 213 \\ \frac{29}{184} \\ \frac{29}{184} \\ \frac{29}{184} \\ \frac{29}{184} \\ \frac{29}{184} \\ \frac{29}{184} \\ \frac{29}{101} \\ \frac{29}{124} \\ \frac{29}{101} \\ \frac{29}{101} \\ \frac{29}{124} \\ \frac{29}{101} \\ \frac{29}{124} \\ \frac{29}{101} \\ \frac{29}{124} \\ \frac{29}{101} \\ \frac{29}{101} \end{pmatrix}$$

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