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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 diagram of a hexagonal lattice with 37 cells. The central cell is labeled 0 and has a red dot. Cells 1 through 14 are labeled with black numbers and have red dots. Cells 15 through 36 are labeled with black numbers and have green dots. The lattice is surrounded by 21 green dots labeled 19 through 36, 38 through 40, and 42 through 44.

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.

Let $X_i \in [0, 36]$ be the current state, or position of the traveler. The traveler always starts at position $X_0 = 0$. The final state must be $X_N \in [19, 36]$.

Now that we've defined some notation, we can write the transition matrix P . Because a 37×37 matrix is cumbersome, we combine the states $[19, 36]$ into a

$$P = \begin{pmatrix} p_{0,0} = 0 & 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} = 0 & p_{1,2} = \frac{1}{6} & p_{1,3} = 0 & p_{1,4} = 0 & p_{1,5} = \frac{1}{6} & 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} = 0 & 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} = 0 & p_{2,1} = \frac{1}{6} & p_{2,2} = 0 & 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 & 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p_{11,9} = 0 & p_{11,10} = \frac{1}{6} & p_{11,11} = 0 & 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} = \frac{1}{6} \\ p_{12,0} = 0 & p_{12,1} = 0 & p_{12,2} = 0 & p_{12,3} = \frac{1}{6} & p_{12,4} = \frac{1}{6} & 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} = 0 & 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} = \frac{1}{6} \\ 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} = 0 & 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} = \frac{1}{6} \\ p_{14,0} = 0 & p_{14,1} = 0 & p_{14,2} = 0 & p_{14,3} = 0 & 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_{14,11} = 0$$

$$Q = \left(\begin{array}{ccccccccc} P_{0,0}=0 & 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_{1,0}=\frac{1}{6} & P_{1,1}=0 & P_{1,2}=0 & P_{1,3}=0 & 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}=0 & 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_{2,0}=0 & P_{2,1}=\frac{1}{6} & P_{2,2}=0 & 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_{3,0}=\frac{1}{6} & P_{3,1}=0 & P_{3,2}=\frac{1}{6} & P_{3,3}=\frac{1}{6} & P_{3,4}=\frac{1}{6} & P_{3,5}=0 & P_{3,6}=0 & 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_{4,0}=0 & P_{4,1}=0 & P_{4,2}=0 & P_{4,3}=\frac{1}{6} & P_{4,4}=0 & 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_{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}=0 & 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}=\frac{1}{6} & P_{5,16}=\frac{1}{6} & P_{5,17}=\frac{1}{6} & P_{5,18}=0 \\ P_{6,0}=0 & P_{6,1}=\frac{1}{6} & P_{6,2}=0 & P_{6,3}=0 & P_{6,4}=0 & P_{6,5}=\frac{1}{6} & P_{6,6}=0 & P_{6,7}=\frac{1}{6} & P_{6,8}=0 & 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}=0 & P_{6,18}=\frac{1}{6} \\ 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}=0 & P_{7,6}=\frac{1}{6} & P_{7,7}=0 & 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_{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}=0 & 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_{9,0}=0 & P_{9,1}=-\frac{1}{6} & P_{9,2}=0 & P_{9,3}=0 & P_{9,4}=0 & P_{9,5}=0 & P_{9,6}=0 & P_{9,7}=0 & P_{9,8}=-\frac{1}{6} & P_{9,9}=0 & 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_{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}=0 & P_{10,11}=\frac{1}{6} & 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_{11,0}=0 & P_{11,1}=0 & P_{11,2}=\frac{1}{6} & P_{11,3}=\frac{1}{6} & 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}=0 & P_{11,11}=\frac{1}{6} & 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_{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}=0 & 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_{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}=0 & P_{13,14}=\frac{1}{6} & P_{13,15}=0 & P_{13,16}=0 & P_{13,17}=0 & P_{13,18}=0 \\ P_{14,0}=0 & P_{14,1}=0 & P_{14,2}=0 & P_{14,3}=0 & P_{14,4}=\frac{1}{6} ><$$

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

$$t = N\mathbf{1}$$
[illegible]

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