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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 central cell is labeled 0. It is surrounded by six cells labeled 1 through 6. These are further surrounded by a ring of cells labeled 7 through 18. The vertices of the lattice are marked with green dots and numbered 1 through 19. The numbering of the vertices follows a similar outward pattern from the center.

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.



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

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

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