$\{\{v, 0\} \leftrightarrow \{Ordering[List@@Abs/@k][v], 1\},$ 

 $\{Ordering[List@@Abs/@k][Mod[v-1, Length@k, 1]], 3\}\},$ 

 $\{v, 2\} \leftrightarrow$ 

{v, Length@k}] // Graph);