Assignment 1

1) Start State — 3 poles, 2 empty, 1 with 64 discs of decreasing diameter

Goal State - 3 poles, 2 empty, 1 with 64 discs of decreasing diameter (Any pole other than the initial one)

Restrictions

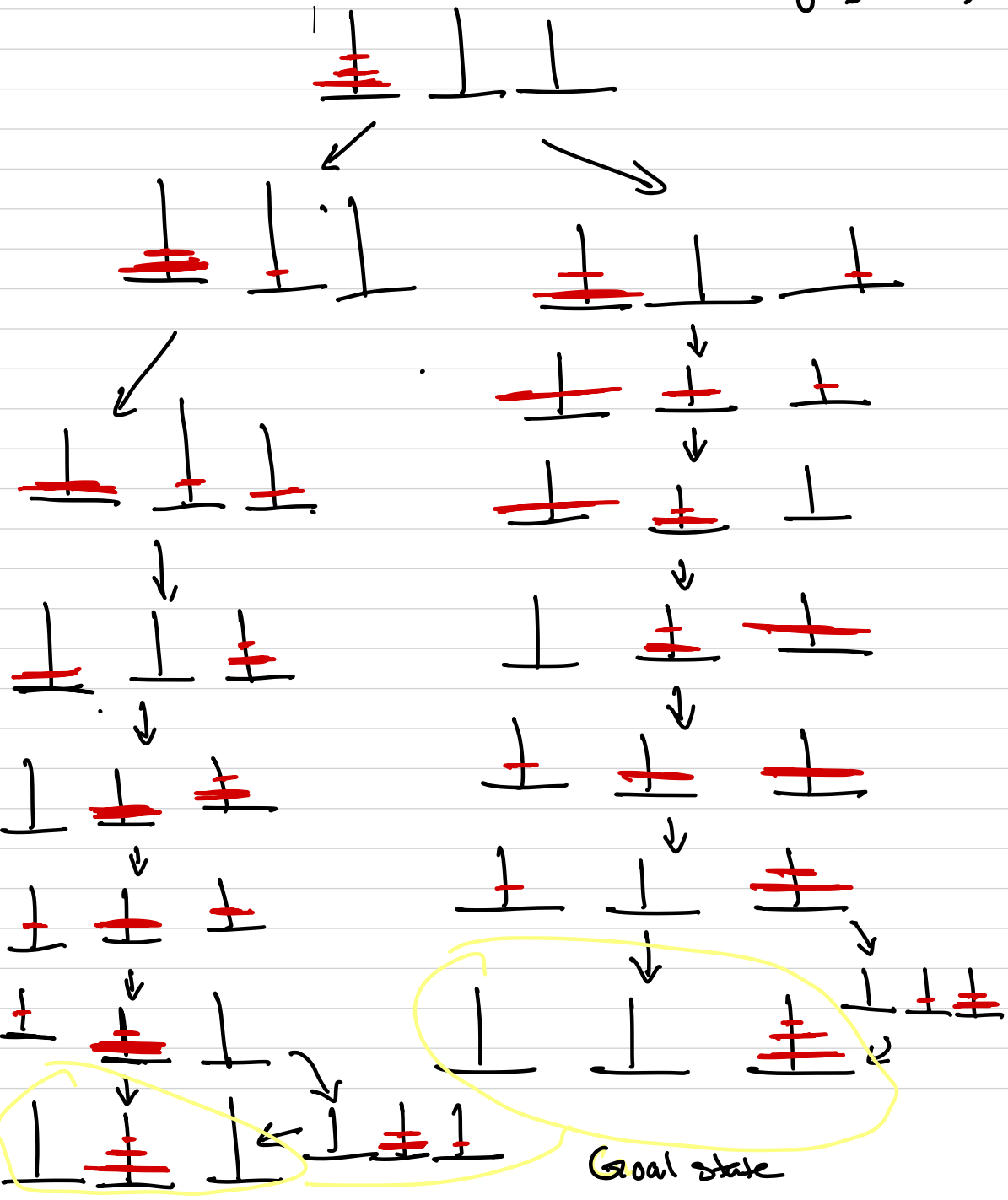
A disc can only be stacked on a disc of higher diameter or an empty pole.

States: A combination of 64 discs on 3 poles with poles with multiple discs in increasing diameter

Possible actions:

possible action is to move a disc to an empty pole or to a pole of a disc with greater diameter at the top

State Space Diagram (sample space of 3 discs)



Problem 2

Initial State – A 4 gallon & 3 gallon that is empty

Goal State – A 3 gallon jug with 2 gallons of water in it.

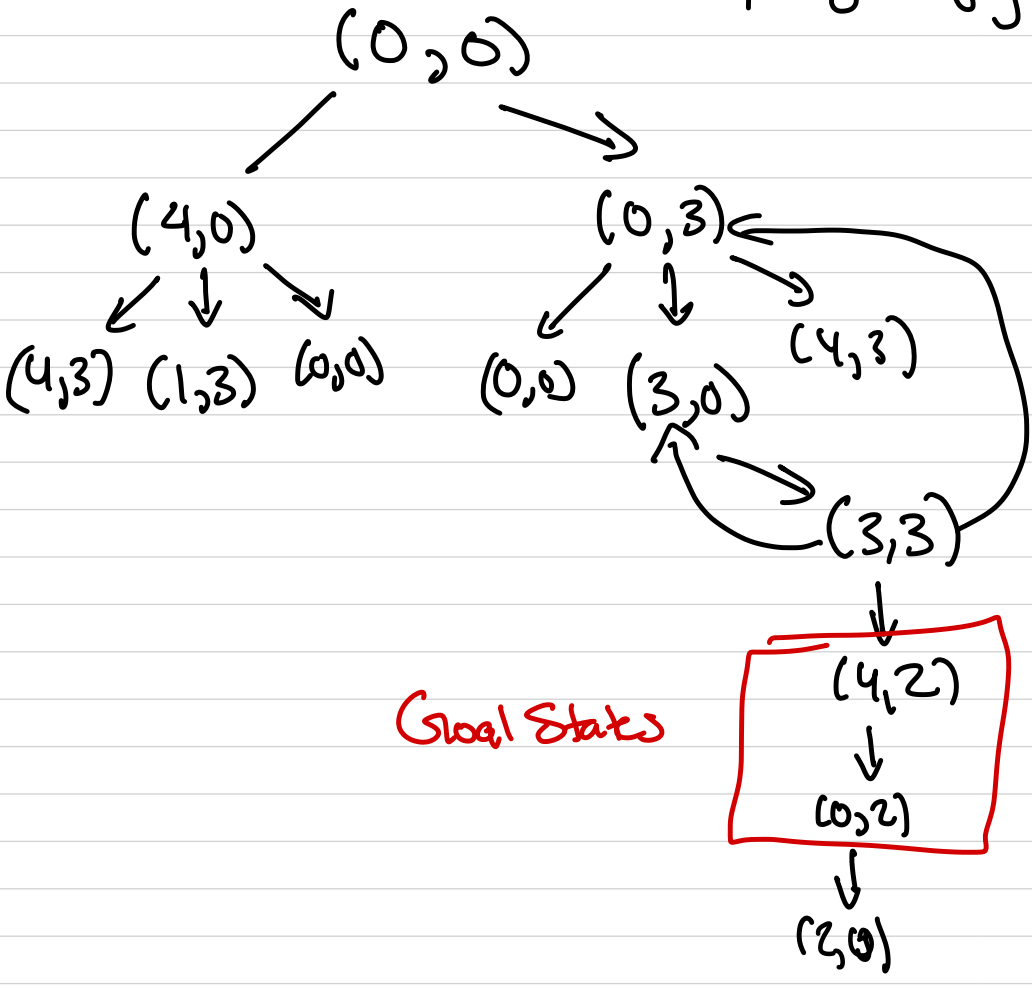
States

The possible states are (x, y) where $x \in \{0, 1, 2, 3, 4\}$ and $y \in \{0, 1, 2, 3\}$

possible actions – You can fill one or both 4 & 3 gallon jugs. You can pour water from one jug into the other or onto the ground

State Space Diagram

x - 4 gallon jug
y - 3 gallon jug



Problem 3

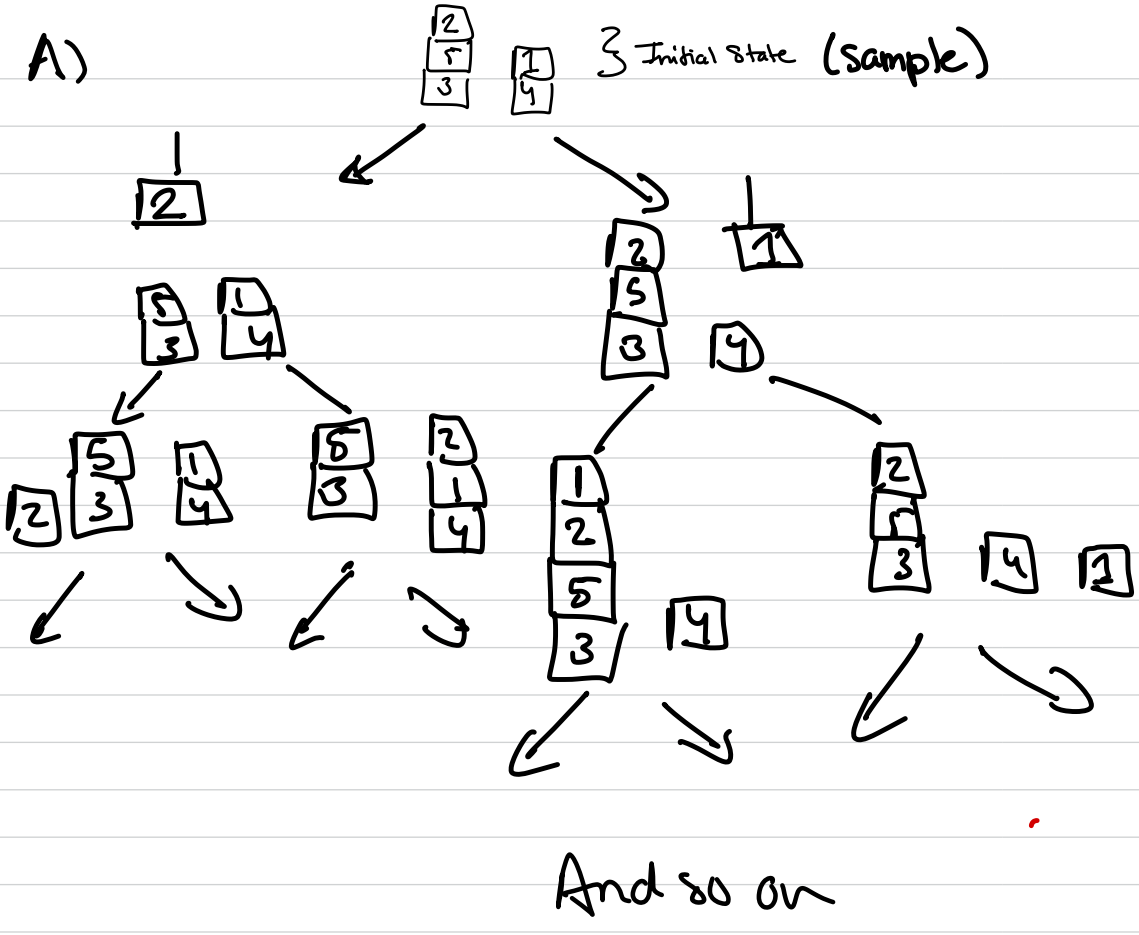
Initial state - 5 blocks distributed randomly into $1 \leq n \leq 5$ piles

Goal state — 5 blocks in one pile in ascending order from top to bottom

Possible states / actions — you can only move the top block of a pile to another pile

The states can be any random order of the 5 blocks distributed into $1 \leq n \leq 5$ piles. Depends on starting state

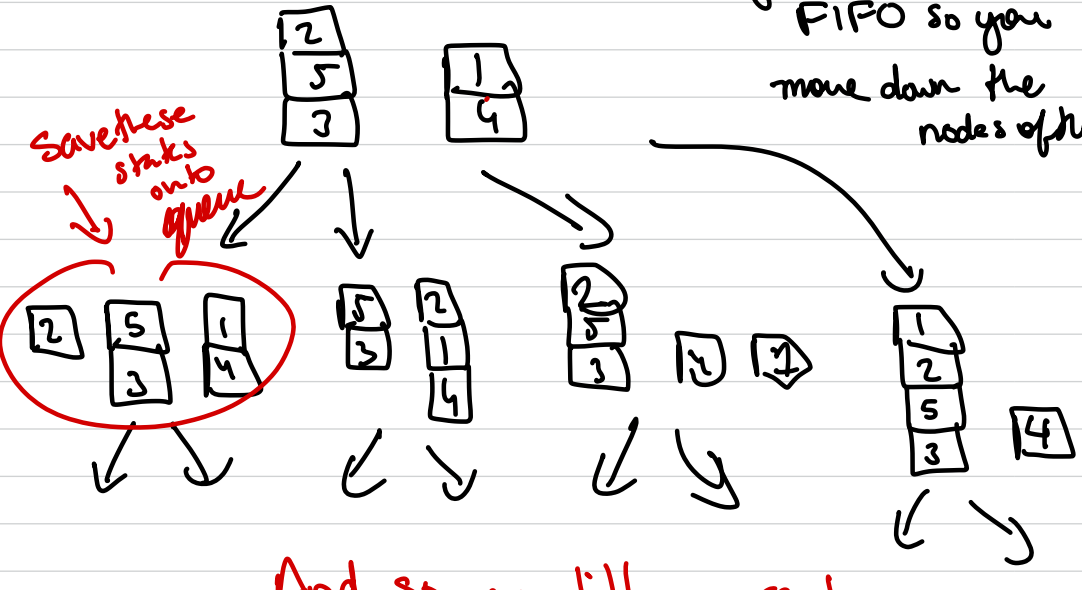
A)



And so on

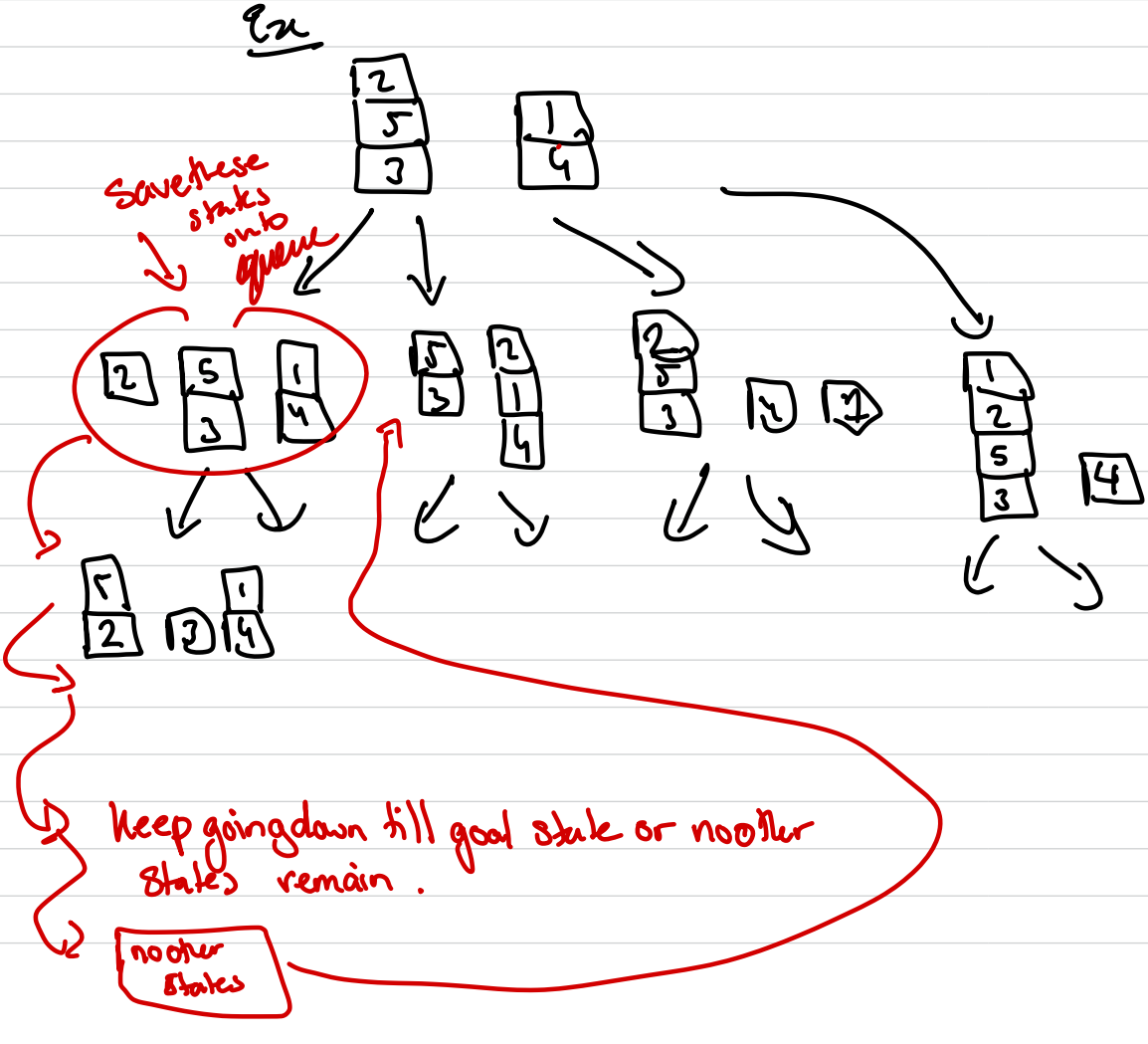
b) A breadth first strategy would include looking at the top of each pile then moving them to another pile. You look at the stacks it produces save that onto a queue. You then pop off the first stack saved onto the queue until you reach the goal stack.

The key for BFS is the FIFO so you move down the nodes of the tree



And so on till you reach

c) A DFS strategy would be to make one change & then continually going down those actions till you cannot do anymore or if you reach the goal state. You save the states & pop off the stack using a LIFO strategy



Problem 4

BFS

open	closed
S	
A D	S
D B	S A
B E	S A D
E C H	S A D B
C H F	S A D B E
H F	S A D B E C
F G	S A D B E C H
G	S A D B E C H F
	S A D B E C H F G

nodes visited in this order

Final path- S A B H G

DFS

FIFO - pop from top of stack

open queue	closed
S	
AD	S
BD	SA
CHD	SAB
HD	SABC
GD	SABCH
D	SABCHG

nodes visited inorder

Final path- S A B H G

UCS

open	closed
S	
A^3 D^4	S
D^4 B^7	SA^3
E^6 B^7	SA^3D^4
B^7 C^{10} F^{10}	$SA^3D^4E^6$
C^{10} F^{10} H^{11}	$SA^3D^4E^6B^7$
F^{10} H^{11}	$SA^3D^4E^6B^7C^{10}$
H^{11}	$SA^3D^4E^6B^7C^{10}F^{10}$
G^{12}	$SA^3D^4E^6B^7C^{10}F^{10}H^{11}$
	$SA^3D^4E^6B^7C^{10}F^{10}H^{11}G^{12}$

sequence of nodes visited

SABHG — final path

Problem 5

UCS

open	closed
1	
5^5 8^{24}	1
8^{24} 6^{40}	$1\ 5^5$
10^{39} 6^{40} 3^{47}	$1\ 5^5\ 8^{24}$
6^{40} 3^{47} 9^{65}	$1\ 5^5\ 8^{24}\ 10^{39}$
3^{47} 9^{65} 2^{78}	$1\ 5^5\ 8^{24}\ 10^{39}\ 6^{40}$
4^{54} 9^{65} 2^{78}	$1\ 5^5\ 8^{24}\ 10^{39}\ 6^{40}\ 3^{47}$
9^{65} 2^{78}	$1\ 5^5\ 8^{24}\ 10^{39}\ 6^{40}\ 3^{47}\ 4^{54}$
2^{78} 7^{100}	$1\ 5^5\ 8^{24}\ 10^{39}\ 6^{40}\ 3^{47}\ 4^{54}\ 9^{65}$
7^{100}	$1\ 5^5\ 8^{24}\ 10^{39}\ 6^{40}\ 3^{47}\ 4^{54}\ 9^{65}\ 2^{78}$
	$1\ 5^5\ 8^{24}\ 10^{39}\ 6^{40}\ 3^{47}\ 4^{54}\ 9^{65}\ 2^{78}\ 7^{100}$

order of nodes visited → 1, 8, 10, 9, 7 – Final path

Greedy Best Search

open	closed
1^{78}	
$g^{60}\,5^{75}$	1^{78}
$5^{75}\,10^{57}\,3^{37}$	$1^{78}\,g^{60}$
$4^{30}\,10^{57}\,5^{75}$	$1^{78}\,g^{60}\,3^{37}$
$9^{35}\,10^{57}\,5^{75}$	$1^{78}\,g^{60}\,3^{37}\,4^{30}$
$7^{0}\,2^{32}\,6^{60}\,10^{57}\,5^{75}$	$1^{78}\,g^{60}\,3^{37}\,4^{30}\,9^{35}$
$2^{32}\,10^{57}\,6^{60}\,5^{75}$	$1^{78}\,g^{60}\,3^{37}\,4^{30}\,9^{35}\,7^{0}$

order of nodes visited & final path

A* search

open	closed
1^{78}	
$5^{80}\ 8^{84}$	1^{78}
$8^{84}\ 6^{100}$	$1^{78}\ 5^{80}$
$3^{84}\ 10^{96}\ 6^{100}$	$1^{78}\ 5^{80}\ 8^{84}$
$4^{84}\ 10^{96}\ 6^{100}$	$1^{78}\ 5^{80}\ 8^{84}\ 3^{84}$
$10^{96}\ 6^{100}\ 9^{107}$	$1^{78}\ 5^{80}\ 8^{84}\ 3^{84}\ 4^{84}$
$6^{100}\ 9^{107}$	$1^{78}\ 5^{80}\ 8^{84}\ 3^{84}\ 4^{84}\ 10^{96}$
$9^{107}\ 2^{110}$	$1^{78}\ 5^{80}\ 8^{84}\ 3^{84}\ 4^{84}\ 10^{96}\ 6^{100}$
$2^{110}\ 7^{110}$	$1^{78}\ 5^{80}\ 8^{84}\ 3^{84}\ 4^{84}\ 10^{96}\ 6^{100}\ 9^{107}$
7^{110}	$1^{78}\ 5^{80}\ 8^{84}\ 3^{84}\ 4^{84}\ 10^{96}\ 6^{100}\ 9^{107}\ 2^{110}$
	$1^{78}\ 5^{80}\ 8^{84}\ 3^{84}\ 4^{84}\ 10^{96}\ 6^{100}\ 9^{107}\ 2^{110}\ 7^{110}$

→ order of nodes visited

1, 8, 10, 9, 7 — Final path

Question 6

The actual code has further comments on the implementation of the BFS, DFS and A* search. The cost for the BFS and DFS is equivalent to the nodes explored value. The 999 view represents the black wall. The path goes from 0 to the end of the path (nodesexplored in BFS, A* search and mindistance in DFS)

1. BFS

The BFS implementation uses a queue for the coordinates to check out. We start from the starting coordinates and add all the neighbors of it to the back of the queue. We then add the starting coordinates to the visited queue (already populated with the black squares in the maze). From there we keep repeating this till we get a coordinate that equals the ending coordinate. Whatever coordinate was added first will be the first ones to be analyzed this replicating the FIFO methodology and mimicking Breadth First Search.

The output of this function is as follows:

S to E1

```
DaivikMac:Assignment 1 daivikgoel$ python3 q6bfs.py
NODES EXPLORED: 371
PATH:  [(2, 11), (2, 12), (3, 11), (1, 11), (2, 10), (2, 13), (3, 12), (1, 12), (3, 10), (0, 11), (1, 10), (2, 9), (2,
14), (3, 13), (1, 13), (4, 12), (0, 12), (4, 10), (3, 9), (0, 10), (1, 9), (2, 15), (3, 14), (1, 14), (4, 13), (0, 13),
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), (9, 11), (10, 10), (9, 9), (8, 8), (4, 6), (5, 5), (7, 16), (8, 15), (10, 11), (11, 10), (10, 9), (9, 8), (8, 7), (3
, 6), (4, 5), (5, 4), (7, 17), (8, 16), (9, 15), (11, 11), (12, 10), (11, 9), (10, 8), (9, 7), (8, 6), (3, 5), (4, 4),
(5, 3), (7, 18), (9, 16), (11, 12), (12, 11), (13, 10), (12, 9), (11, 8), (9, 6), (8, 5), (3, 4), (4, 3), (5, 2), (7, 1
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11), (19, 10), (19, 0), (19, 23), (21, 21), (22, 20), (23, 19)]
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Maze Output

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
24	0.0	0.0	0.0	0.0	999.0	999.0	349.0	337.0	326.0	315.0	303.0	287.0	302.0	314.0	325.0	336.0	348.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0
23	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	289.0	270.0	288.0	304.0	316.0	327.0	338.0	350.0	358.0	367.0	0.0	0.0	0.0	0.0	0.0
22	999.0	999.0	999.0	999.0	999.0	211.0	191.0	171.0	999.0	291.0	272.0	252.0	271.0	290.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	0.0	0.0	0.0	0.0
21	286.0	268.0	249.0	999.0	999.0	999.0	172.0	153.0	999.0	274.0	254.0	234.0	253.0	273.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	368.0	0.0	0.0	0.0
20	269.0	250.0	231.0	999.0	999.0	999.0	154.0	136.0	999.0	999.0	999.0	214.0	235.0	255.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	359.0	369.0	0.0	0.0
19	251.0	232.0	212.0	192.0	173.0	155.0	137.0	121.0	999.0	999.0	999.0	194.0	215.0	236.0	256.0	275.0	292.0	305.0	317.0	328.0	339.0	351.0	360.0	370.0	0.0
18	233.0	213.0	193.0	174.0	156.0	138.0	122.0	109.0	999.0	999.0	999.0	175.0	195.0	216.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	340.0	352.0	361.0	0.0
17	999.0	999.0	999.0	999.0	999.0	999.0	999.0	97.0	999.0	123.0	139.0	157.0	176.0	196.0	217.0	237.0	257.0	276.0	293.0	306.0	318.0	329.0	341.0	353.0	362.0
16	57.0	44.0	31.0	43.0	56.0	68.0	78.0	87.0	98.0	110.0	999.0	177.0	197.0	218.0	238.0	258.0	277.0	294.0	307.0	319.0	330.0	342.0	354.0	363.0	999.0
15	46.0	33.0	21.0	32.0	45.0	58.0	69.0	79.0	88.0	99.0	999.0	198.0	219.0	199.0	220.0	239.0	259.0	278.0	295.0	308.0	320.0	331.0	343.0	999.0	999.0
14	35.0	23.0	12.0	22.0	34.0	47.0	59.0	70.0	999.0	999.0	999.0	999.0	999.0	178.0	200.0	999.0	999.0	296.0	309.0	321.0	332.0	344.0	999.0	999.0	999.0
13	25.0	14.0	5.0	13.0	24.0	36.0	48.0	60.0	71.0	80.0	999.0	124.0	140.0	158.0	179.0	999.0	999.0	279.0	999.0	333.0	345.0	999.0	999.0	999.0	999.0
12	16.0	7.0	1.0	6.0	15.0	26.0	37.0	49.0	61.0	72.0	999.0	111.0	125.0	141.0	159.0	999.0	999.0	260.0	999.0	346.0	355.0	999.0	0.0	0.0	999.0
11	9.0	3.0	0.0	2.0	999.0	38.0	50.0	62.0	73.0	81.0	89.0	100.0	112.0	126.0	142.0	999.0	999.0	240.0	999.0	356.0	364.0	999.0	0.0	0.0	0.0
10	19.0	10.0	4.0	8.0	17.0	27.0	39.0	51.0	63.0	74.0	82.0	90.0	101.0	113.0	127.0	999.0	999.0	221.0	999.0	365.0	0.0	999.0	0.0	0.0	0.0
9	29.0	20.0	11.0	18.0	28.0	40.0	52.0	64.0	75.0	83.0	91.0	102.0	114.0	128.0	143.0	160.0	180.0	201.0	999.0	0.0	0.0	999.0	0.0	0.0	0.0
8	41.0	30.0	999.0	999.0	999.0	53.0	65.0	76.0	84.0	92.0	103.0	115.0	129.0	144.0	161.0	181.0	202.0	222.0	999.0	0.0	0.0	999.0	0.0	0.0	0.0
7	54.0	42.0	999.0	999.0	999.0	66.0	999.0	999.0	93.0	104.0	999.0	999.0	999.0	162.0	182.0	203.0	223.0	241.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0
6	67.0	55.0	999.0	94.0	85.0	77.0	999.0	999.0	105.0	116.0	999.0	999.0	999.0	183.0	204.0	224.0	242.0	261.0	999.0	999.0	999.0	999.0	999.0	999.0	0.0
5	999.0	999.0	999.0	106.0	95.0	86.0	999.0	999.0	117.0	130.0	999.0	999.0	999.0	205.0	225.0	243.0	262.0	280.0	999.0	999.0	999.0	999.0	0.0	0.0	0.0
4	999.0	999.0	999.0	118.0	107.0	96.0	999.0	999.0	131.0	145.0	999.0	999.0	999.0	226.0	244.0	263.0	281.0	297.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0
3	186.0	165.0	147.0	132.0	119.0	108.0	999.0	999.0	146.0	163.0	999.0	999.0	999.0	245.0	264.0	282.0	298.0	310.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0
2	208.0	187.0	166.0	148.0	133.0	120.0	134.0	150.0	164.0	184.0	999.0	999.0	999.0	265.0	283.0	299.0	311.0	322.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0
1	229.0	209.0	188.0	167.0	149.0	135.0	151.0	169.0	185.0	206.0	227.0	246.0	266.0	284.0	300.0	312.0	323.0	334.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0
0	248.0	230.0	210.0	189.0	168.0	152.0	170.0	190.0	207.0	228.0	247.0	267.0	285.0	301.0	313.0	324.0	335.0	347.0	357.0	366.0	0.0	0.0	0.0	0.0	0.0

S to E2

```
DaivikMac:Assignment 1 daivikgoel$ python3 q6bfs.py
NODES EXPLORED: 250
PATH:  [(2, 11), (2, 12), (3, 11), (1, 11), (2, 10), (2, 13), (3, 12), (1, 12), (3, 10), (0, 11), (1, 10), (2, 9), (2, 14), (3, 13
), (1, 13), (4, 12), (0, 12), (4, 10), (3, 9), (0, 10), (1, 9), (2, 15), (3, 14), (1, 14), (4, 13), (0, 13), (5, 12), (5, 10), (4,
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Maze Output

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24	0.0	0.0	0.0	0.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0
23	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	999.0	999.0	999.0	999.0	999.0	211.0	191.0	171.0	999.0	0.0	0.0	0.0	0.0	0.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	0.0	0.0	0.0	0.0
21	0.0	0.0	249.0	999.0	999.0	999.0	172.0	153.0	999.0	0.0	0.0	234.0	0.0	0.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	0.0	0.0	0.0	0.0
20	0.0	0.0	231.0	999.0	999.0	999.0	154.0	136.0	999.0	999.0	999.0	214.0	235.0	0.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	0.0	0.0	0.0	0.0
19	0.0	232.0	212.0	192.0	173.0	155.0	137.0	121.0	999.0	999.0	999.0	194.0	215.0	236.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	233.0	213.0	193.0	174.0	156.0	138.0	122.0	109.0	999.0	999.0	999.0	175.0	195.0	216.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	0.0	0.0	0.0	0.0
17	999.0	999.0	999.0	999.0	999.0	999.0	999.0	97.0	999.0	123.0	139.0	157.0	176.0	196.0	217.0	237.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	57.0	44.0	31.0	43.0	56.0	68.0	78.0	87.0	98.0	110.0	999.0	177.0	197.0	218.0	238.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
15	46.0	33.0	21.0	32.0	45.0	58.0	69.0	79.0	88.0	99.0	999.0	198.0	219.0	199.0	220.0	239.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0	999.0
14	35.0	23.0	12.0	22.0	34.0	47.0	59.0	70.0	999.0	999.0	999.0	999.0	999.0	178.0	200.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0	999.0
13	25.0	14.0	5.0	13.0	24.0	36.0	48.0	60.0	71.0	80.0	999.0	124.0	140.0	158.0	179.0	999.0	999.0	0.0	999.0	0.0	0.0	999.0	999.0	999.0	999.0
12	16.0	7.0	1.0	6.0	15.0	26.0	37.0	49.0	61.0	72.0	999.0	111.0	125.0	141.0	159.0	999.0	999.0	0.0	999.0	0.0	0.0	999.0	0.0	0.0	999.0
11	9.0	3.0	0.0	2.0	999.0	38.0	50.0	62.0	73.0	81.0	89.0	100.0	112.0	126.0	142.0	999.0	999.0	240.0	999.0	0.0	0.0	999.0	0.0	0.0	0.0
10	19.0	10.0	4.0	8.0	17.0	27.0	39.0	51.0	63.0	74.0	82.0	90.0	101.0	113.0	127.0	999.0	999.0	221.0	999.0	0.0	0.0	999.0	0.0	0.0	0.0
9	29.0	20.0	11.0	18.0	28.0	40.0	52.0	64.0	75.0	83.0	91.0	102.0	114.0	128.0	143.0	160.0	180.0	201.0	999.0	0.0	0.0	999.0	0.0	0.0	0.0
8	41.0	30.0	999.0	999.0	999.0	53.0	65.0	76.0	84.0	92.0	103.0	115.0	129.0	144.0	161.0	181.0	202.0	222.0	999.0	0.0	0.0	999.0	0.0	0.0	0.0
7	54.0	42.0	999.0	999.0	999.0	66.0	999.0	999.0	93.0	104.0	999.0	999.0	999.0	162.0	182.0	203.0	223.0	241.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0
6	67.0	55.0	999.0	94.0	85.0	77.0	999.0	999.0	105.0	116.0	999.0	999.0	999.0	183.0	204.0	224.0	242.0	0.0	999.0	999.0	999.0	999.0	999.0	999.0	0.0
5	999.0	999.0	999.0	106.0	95.0	86.0	999.0	999.0	117.0	130.0	999.0	999.0	999.0	205.0	225.0	243.0	0.0	0.0	999.0	999.0	999.0	999.0	0.0	0.0	0.0
4	999.0	999.0	999.0	118.0	107.0	96.0	999.0	999.0	131.0	145.0	999.0	999.0	999.0	226.0	244.0	0.0	0.0	0.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0
3	186.0	165.0	147.0	132.0	119.0	108.0	999.0	999.0	146.0	163.0	999.0	999.0	999.0	245.0	0.0	0.0	0.0	0.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0
2	208.0	187.0	166.0	148.0	133.0	120.0	134.0	150.0	164.0	184.0	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0
1	229.0	209.0	188.0	167.0	149.0	135.0	151.0	169.0	185.0	206.0	227.0	246.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0
0	248.0	230.0	210.0	189.0	168.0	152.0	170.0	190.0	207.0	228.0	247.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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Maze Output

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
24	0.0	0.0	0.0	0.0	999.0	999.0	411.0	404.0	395.0	382.0	369.0	352.0	368.0	381.0	394.0	403.0	410.0	999.0	999.0	426.0	432.0	437.0	441.0	444.0	446.0
23	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	354.0	336.0	353.0	370.0	383.0	396.0	405.0	412.0	416.0	421.0	427.0	433.0	438.0	442.0	445.0
22	999.0	999.0	999.0	999.0	999.0	296.0	284.0	272.0	999.0	356.0	338.0	322.0	337.0	355.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	428.0	434.0	439.0	443.0
21	351.0	334.0	319.0	999.0	999.0	999.0	273.0	262.0	999.0	340.0	324.0	310.0	323.0	339.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	422.0	429.0	435.0	440.0
20	335.0	320.0	307.0	999.0	999.0	999.0	263.0	252.0	999.0	999.0	999.0	299.0	311.0	325.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	417.0	423.0	430.0	436.0
19	321.0	308.0	297.0	285.0	274.0	264.0	253.0	242.0	999.0	999.0	999.0	287.0	300.0	312.0	326.0	341.0	357.0	371.0	384.0	397.0	406.0	413.0	418.0	424.0	431.0
18	309.0	298.0	286.0	275.0	265.0	254.0	243.0	229.0	999.0	999.0	999.0	276.0	288.0	301.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	407.0	414.0	419.0	425.0
17	999.0	999.0	999.0	999.0	999.0	999.0	999.0	211.0	999.0	244.0	255.0	266.0	277.0	289.0	302.0	313.0	327.0	342.0	358.0	372.0	385.0	398.0	408.0	415.0	420.0
16	245.0	231.0	213.0	195.0	176.0	153.0	175.0	194.0	212.0	230.0	999.0	278.0	290.0	279.0	292.0	303.0	314.0	328.0	343.0	359.0	373.0	386.0	399.0	409.0	999.0
15	232.0	215.0	197.0	178.0	155.0	132.0	154.0	177.0	196.0	214.0	999.0	291.0	281.0	267.0	280.0	293.0	304.0	315.0	329.0	344.0	360.0	374.0	387.0	999.0	999.0
14	216.0	198.0	179.0	157.0	134.0	113.0	133.0	156.0	999.0	999.0	999.0	999.0	999.0	256.0	268.0	999.0	999.0	305.0	316.0	330.0	345.0	361.0	999.0	999.0	999.0
13	199.0	181.0	159.0	136.0	115.0	97.0	114.0	135.0	158.0	180.0	999.0	217.0	233.0	246.0	257.0	999.0	999.0	294.0	999.0	346.0	362.0	999.0	999.0	999.0	999.0
12	182.0	161.0	138.0	117.0	99.0	85.0	98.0	116.0	137.0	160.0	999.0	200.0	218.0	234.0	247.0	999.0	999.0	282.0	999.0	363.0	375.0	999.0	402.0	390.0	999.0
11	164.0	141.0	120.0	102.0	999.0	74.0	86.0	100.0	118.0	139.0	162.0	183.0	201.0	219.0	235.0	999.0	999.0	269.0	999.0	376.0	388.0	999.0	391.0	377.0	364.0
10	142.0	121.0	103.0	88.0	76.0	65.0	75.0	87.0	101.0	119.0	140.0	163.0	184.0	202.0	220.0	999.0	999.0	258.0	999.0	389.0	400.0	999.0	378.0	365.0	347.0
9	123.0	105.0	90.0	78.0	67.0	59.0	66.0	77.0	89.0	104.0	122.0	143.0	165.0	185.0	203.0	221.0	236.0	248.0	999.0	401.0	392.0	999.0	366.0	348.0	331.0
8	144.0	124.0	999.0	999.0	999.0	54.0	60.0	68.0	79.0	91.0	106.0	125.0	146.0	168.0	187.0	204.0	222.0	237.0	999.0	393.0	379.0	999.0	349.0	332.0	317.0
7	166.0	145.0	999.0	999.0	999.0	49.0	999.0	999.0	69.0	80.0	999.0	999.0	999.0	147.0	169.0	188.0	205.0	223.0	999.0	380.0	367.0	350.0	333.0	318.0	306.0
6	186.0	167.0	999.0	33.0	39.0	44.0	999.0	999.0	61.0	70.0	999.0	999.0	999.0	126.0	148.0	170.0	189.0	206.0	999.0	999.0	999.0	999.0	999.0	999.0	295.0
5	999.0	999.0	999.0	27.0	34.0	40.0	999.0	999.0	55.0	62.0	999.0	999.0	999.0	107.0	127.0	149.0	171.0	190.0	999.0	999.0	999.0	999.0	259.0	270.0	283.0
4	999.0	999.0	999.0	22.0	28.0	35.0	999.0	999.0	50.0	56.0	999.0	999.0	999.0	92.0	108.0	128.0	150.0	172.0	999.0	999.0	224.0	238.0	249.0	260.0	271.0
3	6.0	10.0	14.0	18.0	23.0	29.0	999.0	999.0	45.0	51.0	999.0	999.0	999.0	81.0	93.0	109.0	129.0	151.0	999.0	999.0	207.0	225.0	239.0	250.0	261.0
2	3.0	7.0	11.0	15.0	19.0	24.0	30.0	36.0	41.0	46.0	999.0	999.0	999.0	71.0	82.0	94.0	110.0	130.0	999.0	999.0	191.0	208.0	226.0	240.0	251.0
1	1.0	4.0	8.0	12.0	16.0	20.0	25.0	31.0	37.0	42.0	47.0	52.0	57.0	63.0	72.0	83.0	95.0	111.0	999.0	999.0	173.0	192.0	209.0	227.0	241.0
0	0.0	2.0	5.0	9.0	13.0	17.0	21.0	26.0	32.0	38.0	43.0	48.0	53.0	58.0	64.0	73.0	84.0	96.0	112.0	131.0	152.0	174.0	193.0	210.0	228.0

2. DFS

The Depth First Search uses a stack in order to store nodes. These nodes contain the nodes coordinates and the parent node. Similar to the BFS implementation we first create a starting

node with the coordinates and populate it onto the stack. We then pop it off the stack and see if it is the ending coordinate. If not, we append to the visited list and add its neighbors to the TOP of the stack. We then repeat till we find the ending node.

Once we find the ending node, we then work backwards to find the path back to the start. Therefore, we get the path generated from the DFS and the min distance.

S to E1

```
DaivikMac:Assignment 1 daivikgoel$ python3 q6dfs.py
NODES EXPLORED: 405
PATH [(2, 11), (2, 10), (2, 9), (1, 9), (1, 8), (1, 7), (1, 6), (0, 6), (0, 7), (0, 8), (0, 9), (0, 10), (1, 10), (1, 11), (0, 11), (0, 12), (1, 12), (2, 12), (3, 12), (3, 11), (3, 10), (3, 9), (4, 9), (5, 9), (5, 8), (5, 7), (5, 6), (5, 5), (5, 4), (5, 3), (5, 2), (5, 1), (5, 0), (6, 0), (7, 0), (8, 0), (9, 0), (10, 0), (11, 0), (12, 0), (13, 0), (14, 0), (15, 0), (16, 0), (17, 0), (18, 0), (19, 0), (20, 0), (21, 0), (22, 0), (23, 0), (24, 0), (24, 1), (23, 1), (22, 1), (21, 1), (20, 1), (20, 2), (21, 2), (22, 2), (23, 2), (24, 2), (24, 3), (23, 3), (22, 3), (21, 3), (20, 3), (20, 4), (21, 4), (22, 4), (23, 4), (24, 4), (24, 5), (24, 6), (24, 7), (23, 7), (22, 7), (21, 7), (20, 7), (19, 7), (19, 8), (20, 8), (20, 9), (19, 9), (19, 10), (20, 10), (20, 11), (19, 11), (19, 12), (20, 12), (20, 13), (19, 13), (19, 14), (18, 14), (17, 14), (17, 13), (17, 12), (17, 11), (17, 10), (17, 9), (17, 8), (17, 7), (17, 6), (17, 5), (17, 4), (17, 3), (17, 2), (17, 1), (16, 1), (15, 1), (14, 1), (13, 1), (12, 1), (11, 1), (10, 1), (9, 1), (8, 1), (7, 1), (6, 1), (6, 2), (7, 2), (8, 2), (9, 2), (9, 3), (8, 3), (8, 4), (9, 4), (9, 5), (8, 5), (8, 6), (9, 6), (9, 7), (8, 7), (8, 8), (7, 8), (6, 8), (6, 9), (7, 9), (8, 9), (9, 9), (9, 8), (10, 8), (11, 8), (12, 8), (13, 8), (13, 7), (13, 6), (13, 5), (13, 4), (13, 3), (13, 2), (14, 2), (15, 2), (16, 2), (16, 3), (15, 3), (14, 3), (14, 4), (15, 4), (16, 4), (16, 5), (15, 5), (14, 5), (14, 6), (15, 6), (16, 6), (16, 7), (15, 7), (14, 7), (14, 8), (15, 8), (16, 8), (16, 9), (15, 9), (14, 9), (13, 9), (12, 9), (11, 9), (10, 9), (10, 10), (9, 10), (8, 10), (7, 10), (6, 10), (5, 10), (5, 11), (6, 11), (7, 11), (8, 11), (9, 11), (10, 11), (11, 11), (11, 10), (12, 10), (13, 10), (14, 10), (14, 11), (13, 11), (12, 11), (12, 12), (11, 12), (11, 13), (12, 13), (13, 13), (13, 12), (14, 12), (14, 13), (14, 14), (13, 14), (13, 15), (12, 15), (11, 15), (11, 16), (12, 16), (13, 16), (14, 16), (14, 15), (15, 15), (16, 15), (17, 15), (18, 15), (19, 15), (20, 15), (20, 14), (21, 14), (21, 15), (22, 15), (22, 16), (21, 16), (20, 16), (19, 16), (18, 16), (17, 16), (16, 16), (15, 16), (15, 17), (14, 17), (13, 17), (12, 17), (11, 17), (11, 18), (12, 18), (13, 18), (13, 19), (12, 19), (11, 19), (11, 20), (12, 20), (13, 20), (13, 21), (12, 21), (11, 21), (10, 21), (9, 21), (9, 22), (10, 22), (11, 22), (12, 22), (13, 22), (13, 23), (12, 23), (11, 23), (10, 23), (10, 24), (11, 24), (12, 24), (13, 24), (14, 24), (14, 23), (15, 23), (16, 23), (17, 23), (18, 23), (19, 23), (20, 23), (21, 23), (21, 22), (21, 21), (21, 20), (21, 19), (21, 18), (21, 17), (22, 17), (23, 17), (24, 17), (24, 18), (23, 18), (22, 18), (22, 19), (23, 19)]
MIN DISTANCE: 290
```

Maze Output

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
24	0.0	0.0	0.0	0.0	999.0	999.0	0.0	0.0	0.0	0.0	263.0	264.0	265.0	266.0	267.0	0.0	0.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0
23	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	262.0	261.0	260.0	259.0	268.0	269.0	270.0	271.0	272.0	273.0	274.0	275.0	0.0	0.0	0.0
22	999.0	999.0	999.0	999.0	999.0	0.0	0.0	0.0	999.0	254.0	255.0	256.0	257.0	258.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	276.0	0.0	0.0	0.0
21	0.0	0.0	0.0	999.0	999.0	999.0	0.0	0.0	999.0	253.0	252.0	251.0	250.0	249.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	277.0	0.0	0.0	0.0
20	0.0	0.0	0.0	999.0	999.0	999.0	0.0	0.0	999.0	999.0	999.0	246.0	247.0	248.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	278.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0	999.0	999.0	245.0	244.0	243.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	279.0	288.0	289.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0	999.0	999.0	240.0	241.0	242.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	280.0	287.0	286.0	285.0
17	999.0	999.0	999.0	999.0	999.0	999.0	999.0	0.0	999.0	0.0	0.0	239.0	238.0	237.0	236.0	235.0	0.0	0.0	0.0	0.0	0.0	281.0	282.0	283.0	284.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0	212.0	213.0	214.0	215.0	234.0	233.0	232.0	231.0	230.0	229.0	228.0	227.0	0.0	999.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0	211.0	210.0	209.0	216.0	217.0	218.0	219.0	220.0	221.0	222.0	225.0	226.0	999.0	999.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0	999.0	999.0	999.0	999.0	208.0	207.0	999.0	999.0	94.0	93.0	92.0	223.0	224.0	999.0	999.0	999.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0	201.0	202.0	203.0	206.0	999.0	999.0	95.0	999.0	91.0	90.0	999.0	999.0	999.0	999.0
12	15.0	16.0	17.0	18.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0	200.0	199.0	204.0	205.0	999.0	999.0	96.0	999.0	88.0	89.0	999.0	0.0	0.0	999.0
11	14.0	13.0	0.0	19.0	999.0	185.0	186.0	187.0	188.0	189.0	190.0	191.0	198.0	197.0	196.0	999.0	999.0	97.0	999.0	87.0	86.0	999.0	0.0	0.0	0.0
10	11.0	12.0	1.0	20.0	0.0	184.0	183.0	182.0	181.0	180.0	179.0	192.0	193.0	194.0	195.0	999.0	999.0	98.0	999.0	84.0	85.0	999.0	0.0	0.0	0.0
9	10.0	3.0	2.0	21.0	22.0	23.0	136.0	137.0	138.0	139.0	178.0	177.0	176.0	175.0	174.0	173.0	172.0	99.0	999.0	83.0	82.0	999.0	0.0	0.0	0.0
8	9.0	4.0	999.0	999.0	999.0	24.0	135.0	134.0	133.0	140.0	141.0	142.0	143.0	144.0	169.0	170.0	171.0	100.0	999.0	80.0	81.0	999.0	0.0	0.0	0.0
7	8.0	5.0	999.0	999.0	999.0	25.0	999.0	999.0	132.0	131.0	999.0	999.0	999.0	145.0	168.0	167.0	166.0	101.0	999.0	79.0	78.0	77.0	76.0	75.0	74.0
6	7.0	6.0	999.0	0.0	0.0	26.0	999.0	999.0	129.0	130.0	999.0	999.0	999.0	146.0	163.0	164.0	165.0	102.0	999.0	999.0	999.0	999.0	999.0	999.0	73.0
5	999.0	999.0	999.0	0.0	0.0	27.0	999.0	999.0	128.0	127.0	999.0	999.0	999.0	147.0	162.0	161.0	160.0	103.0	999.0	999.0	999.0	999.0	0.0	0.0	72.0
4	999.0	999.0	999.0	0.0	0.0	28.0	999.0	999.0	125.0	126.0	999.0	999.0	999.0	148.0	157.0	158.0	159.0	104.0	999.0	999.0	67.0	68.0	69.0	70.0	71.0
3	0.0	0.0	0.0	0.0	0.0	29.0	999.0	999.0	124.0	123.0	999.0	999.0	999.0	149.0	156.0	155.0	154.0	105.0	999.0	999.0	66.0	65.0	64.0	63.0	62.0
2	0.0	0.0	0.0	0.0	0.0	30.0	119.0	120.0	121.0	122.0	999.0	999.0	999.0	150.0	151.0	152.0	153.0	106.0	999.0	999.0	57.0	58.0	59.0	60.0	61.0
1	0.0	0.0	0.0	0.0	0.0	31.0	118.0	117.0	116.0	115.0	114.0	113.0	112.0	111.0	110.0	109.0	108.0	107.0	999.0	999.0	56.0	55.0	54.0	53.0	52.0
0	0.0	0.0	0.0	0.0	0.0	32.0	33.0	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0	44.0	45.0	46.0	47.0	48.0	49.0	50.0	51.0

S to E2

```
DaivikMac:Assignment 1 daivikgoel$ python3 q6dfs.py
NODES EXPLORED: 405
PATH [(2, 11), (2, 10), (2, 9), (1, 9), (1, 8), (1, 7), (1, 6), (0, 6), (0, 7), (0, 8), (0, 9), (0, 10), (1, 10), (1, 11), (0, 11)
, (0, 12), (1, 12), (2, 12), (3, 12), (3, 11), (3, 10), (3, 9), (4, 9), (5, 9), (5, 8), (5, 7), (5, 6), (5, 5), (5, 4), (5, 3), (5
, 2), (5, 1), (5, 0), (6, 0), (7, 0), (8, 0), (9, 0), (10, 0), (11, 0), (12, 0), (13, 0), (14, 0), (15, 0), (16, 0), (17, 0), (18,
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22, 17), (23, 17), (24, 17), (24, 18), (23, 18), (22, 18), (22, 19), (23, 19)]
MIN DISTANCE: 290
```

Maze Output

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
24	0.0	0.0	0.0	0.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0
23	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	999.0	999.0	999.0	999.0	999.0	0.0	0.0	0.0	999.0	0.0	0.0	0.0	0.0	0.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	0.0	0.0	0.0	0.0
21	296.0	297.0	298.0	999.0	999.0	999.0	0.0	0.0	999.0	0.0	0.0	0.0	0.0	0.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	0.0	0.0	0.0	0.0
20	295.0	294.0	293.0	999.0	999.0	999.0	0.0	0.0	999.0	999.0	999.0	0.0	0.0	0.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	0.0	0.0	0.0	0.0
19	290.0	291.0	292.0	0.0	0.0	0.0	0.0	0.0	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	289.0	288.0	287.0	286.0	285.0	284.0	283.0	282.0	999.0	999.0	999.0	0.0	0.0	0.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	0.0	0.0	0.0	0.0
17	999.0	999.0	999.0	999.0	999.0	999.0	999.0	281.0	999.0	241.0	240.0	239.0	238.0	237.0	236.0	235.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	273.0	274.0	275.0	276.0	277.0	278.0	279.0	280.0	0.0	242.0	999.0	212.0	213.0	214.0	215.0	234.0	233.0	232.0	231.0	230.0	229.0	228.0	227.0	0.0	999.0
15	272.0	271.0	270.0	269.0	268.0	267.0	266.0	245.0	244.0	243.0	999.0	211.0	210.0	209.0	216.0	217.0	218.0	219.0	220.0	221.0	222.0	225.0	226.0	999.0	999.0
14	257.0	258.0	259.0	260.0	261.0	262.0	265.0	246.0	999.0	999.0	999.0	999.0	999.0	208.0	207.0	999.0	999.0	94.0	93.0	92.0	223.0	224.0	999.0	999.0	999.0
13	256.0	255.0	254.0	253.0	252.0	263.0	264.0	247.0	0.0	0.0	999.0	201.0	202.0	203.0	206.0	999.0	999.0	95.0	999.0	91.0	90.0	999.0	999.0	999.0	999.0
12	15.0	16.0	17.0	18.0	251.0	250.0	249.0	248.0	0.0	0.0	999.0	200.0	199.0	204.0	205.0	999.0	999.0	96.0	999.0	88.0	89.0	999.0	0.0	0.0	999.0
11	14.0	13.0	0.0	19.0	999.0	185.0	186.0	187.0	188.0	189.0	190.0	191.0	198.0	197.0	196.0	999.0	999.0	97.0	999.0	87.0	86.0	999.0	0.0	0.0	0.0
10	11.0	12.0	1.0	20.0	0.0	184.0	183.0	182.0	181.0	180.0	179.0	192.0	193.0	194.0	195.0	999.0	999.0	98.0	999.0	84.0	85.0	999.0	0.0	0.0	0.0
9	10.0	3.0	2.0	21.0	22.0	23.0	136.0	137.0	138.0	139.0	178.0	177.0	176.0	175.0	174.0	173.0	172.0	99.0	999.0	83.0	82.0	999.0	0.0	0.0	0.0
8	9.0	4.0	999.0	999.0	999.0	24.0	135.0	134.0	133.0	140.0	141.0	142.0	143.0	144.0	169.0	170.0	171.0	100.0	999.0	80.0	81.0	999.0	0.0	0.0	0.0
7	8.0	5.0	999.0	999.0	999.0	25.0	999.0	999.0	132.0	131.0	999.0	999.0	999.0	145.0	168.0	167.0	166.0	101.0	999.0	79.0	78.0	77.0	76.0	75.0	74.0
6	7.0	6.0	999.0	0.0	0.0	26.0	999.0	999.0	129.0	130.0	999.0	999.0	999.0	146.0	163.0	164.0	165.0	102.0	999.0	999.0	999.0	999.0	999.0	999.0	73.0
5	999.0	999.0	999.0	0.0	0.0	27.0	999.0	999.0	128.0	127.0	999.0	999.0	999.0	147.0	162.0	161.0	160.0	103.0	999.0	999.0	999.0	999.0	0.0	0.0	72.0
4	999.0	999.0	999.0	0.0	0.0	28.0	999.0	999.0	125.0	126.0	999.0	999.0	999.0	148.0	157.0	158.0	159.0	104.0	999.0	999.0	67.0	68.0	69.0	70.0	71.0
3	0.0	0.0	0.0	0.0	0.0	29.0	999.0	999.0	124.0	123.0	999.0	999.0	999.0	149.0	156.0	155.0	154.0	105.0	999.0	999.0	66.0	65.0	64.0	63.0	62.0
2	0.0	0.0	0.0	0.0	0.0	30.0	119.0	120.0	121.0	122.0	999.0	999.0	999.0	150.0	151.0	152.0	153.0	106.0	999.0	999.0	57.0	58.0	59.0	60.0	61.0
1	0.0	0.0	0.0	0.0	0.0	31.0	118.0	117.0	116.0	115.0	114.0	113.0	112.0	111.0	110.0	109.0	108.0	107.0	999.0	999.0	56.0	55.0	54.0	53.0	52.0
0	0.0	0.0	0.0	0.0	0.0	32.0	33.0	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0	44.0	45.0	46.0	47.0	48.0	49.0	50.0	51.0

(0,0) to (24,24)

```
DaIVIKMac:Assignment 1 daivikgoel$ python3 qodrs.py
NODES EXPLORED: 419
PATH [(0, 0), (1, 0), (2, 0), (3, 0), (4, 0), (5, 0), (6, 0), (7, 0), (8, 0), (9, 0), (10, 0), (11, 0), (12, 0), (13, 0), (14, 0), (15, 0), (16, 0), (17, 0), (18, 0), (19, 0), (20, 0), (21, 0), (22, 0), (23, 0), (24, 0), (24, 1), (23, 1), (22, 1), (21, 1), (20, 1), (20, 2), (21, 2), (22, 2), (23, 2), (24, 2), (24, 3), (23, 3), (22, 3), (21, 3), (20, 3), (20, 4), (21, 4), (22, 4), (23, 4), (24, 4), (24, 5), (24, 6), (24, 7), (23, 7), (22, 7), (21, 7), (20, 7), (19, 7), (19, 8), (20, 8), (20, 9), (19, 9), (19, 10), (20, 10), (20, 11), (19, 11), (19, 12), (20, 12), (20, 13), (19, 13), (19, 14), (18, 14), (17, 14), (17, 13), (17, 12), (17, 11), (17, 10), (17, 9), (17, 8), (17, 7), (17, 6), (17, 5), (17, 4), (17, 3), (17, 2), (17, 1), (16, 1), (15, 1), (14, 1), (13, 1), (12, 1), (11, 1), (10, 1), (9, 1), (8, 1), (7, 1), (6, 1), (5, 1), (4, 1), (3, 1), (2, 1), (1, 1), (0, 1), (0, 2), (1, 2), (2, 2), (3, 2), (4, 2), (5, 2), (6, 2), (7, 2), (8, 2), (9, 2), (9, 3), (8, 3), (8, 4), (9, 4), (9, 5), (8, 5), (8, 6), (9, 6), (9, 7), (8, 7), (8, 8), (7, 8), (6, 8), (5, 8), (5, 9), (4, 9), (3, 9), (2, 9), (1, 9), (1, 8), (1, 7), (1, 6), (0, 6), (0, 7), (0, 8), (0, 9), (0, 10), (1, 10), (2, 10), (3, 10), (4, 10), (5, 10), (6, 10), (6, 9), (7, 9), (8, 9), (9, 9), (9, 8), (10, 8), (11, 8), (12, 8), (13, 8), (13, 7), (13, 6), (13, 5), (13, 4), (13, 3), (13, 2), (14, 2), (15, 2), (16, 2), (16, 3), (15, 3), (14, 3), (14, 4), (15, 4), (16, 4), (16, 5), (15, 5), (14, 5), (14, 6), (15, 6), (16, 6), (16, 7), (15, 7), (14, 7), (14, 8), (15, 8), (16, 8), (16, 9), (15, 9), (14, 9), (13, 9), (12, 9), (11, 9), (10, 9), (10, 10), (9, 10), (8, 10), (7, 10), (7, 11), (6, 11), (5, 11), (5, 12), (4, 12), (3, 12), (3, 11), (2, 11), (1, 11), (0, 11), (0, 12), (1, 12), (2, 12), (2, 13), (1, 13), (0, 13), (0, 14), (1, 14), (2, 14), (3, 14), (3, 13), (4, 13), (5, 13), (6, 13), (6, 12), (7, 12), (8, 12), (8, 11), (9, 11), (10, 11), (11, 11), (11, 10), (12, 10), (13, 10), (14, 10), (14, 11), (13, 11), (12, 11), (12, 12), (11, 12), (11, 13), (12, 13), (13, 13), (13, 12), (14, 12), (14, 13), (14, 14), (13, 14), (13, 15), (12, 15), (11, 15), (11, 16), (12, 16), (13, 16), (14, 16), (14, 15), (15, 15), (16, 15), (17, 15), (18, 15), (19, 15), (20, 15), (20, 14), (21, 14), (21, 15), (22, 15), (22, 16), (21, 16), (20, 16), (19, 16), (18, 16), (17, 16), (16, 16), (15, 16), (15, 17), (14, 17), (13, 17), (12, 17), (11, 17), (11, 18), (12, 18), (13, 18), (13, 19), (12, 19), (11, 19), (11, 20), (12, 20), (13, 20), (13, 21), (12, 21), (11, 21), (10, 21), (9, 21), (9, 22), (10, 22), (11, 22), (12, 22), (13, 22), (13, 23), (12, 23), (11, 23), (10, 23), (10, 24), (11, 24), (12, 24), (13, 24), (14, 24), (14, 23), (15, 23), (16, 23), (17, 23), (18, 23), (19, 23), (20, 23), (21, 23), (21, 22), (21, 21), (21, 20), (21, 19), (21, 18), (21, 17), (22, 17), (23, 17), (24, 17), (24, 18), (23, 18), (22, 18), (22, 19), (23, 19), (24, 19), (24, 20), (23, 20), (22, 20), (22, 21), (23, 21), (24, 21), (24, 22), (23, 22), (22, 22), (22, 23), (23, 23), (24, 23), (24, 24)]
MIN DISTANCE: 331
```

Maze Output

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
24	0.0	0.0	0.0	0.0	999.0	999.0	0.0	0.0	0.0	0.0	290.0	291.0	292.0	293.0	294.0	0.0	0.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	330.0
23	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	289.0	288.0	287.0	286.0	295.0	296.0	297.0	298.0	299.0	300.0	301.0	302.0	327.0	328.0	329.0
22	999.0	999.0	999.0	999.0	999.0	0.0	0.0	0.0	999.0	281.0	282.0	283.0	284.0	285.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	303.0	326.0	325.0	324.0
21	0.0	0.0	0.0	999.0	999.0	999.0	0.0	0.0	999.0	280.0	279.0	278.0	277.0	276.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	304.0	321.0	322.0	323.0
20	0.0	0.0	0.0	999.0	999.0	999.0	0.0	0.0	999.0	999.0	999.0	273.0	274.0	275.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	305.0	320.0	319.0	318.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0	999.0	999.0	272.0	271.0	270.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	306.0	315.0	316.0	317.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0	999.0	999.0	267.0	268.0	269.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	307.0	314.0	313.0	312.0
17	999.0	999.0	999.0	999.0	999.0	999.0	999.0	0.0	999.0	0.0	0.0	266.0	265.0	264.0	263.0	262.0	0.0	0.0	0.0	0.0	0.0	308.0	309.0	310.0	311.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0	239.0	240.0	241.0	242.0	261.0	260.0	259.0	258.0	257.0	256.0	255.0	254.0	0.0	999.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0	238.0	237.0	236.0	243.0	244.0	245.0	246.0	247.0	248.0	249.0	252.0	253.0	999.0	999.0
14	204.0	205.0	206.0	207.0	0.0	0.0	0.0	0.0	999.0	999.0	999.0	999.0	999.0	235.0	234.0	999.0	999.0	67.0	66.0	65.0	250.0	251.0	999.0	999.0	999.0
13	203.0	202.0	201.0	208.0	209.0	210.0	211.0	0.0	0.0	0.0	999.0	228.0	229.0	230.0	233.0	999.0	999.0	68.0	999.0	64.0	63.0	999.0	999.0	999.0	999.0
12	198.0	199.0	200.0	193.0	192.0	191.0	212.0	213.0	214.0	0.0	999.0	227.0	226.0	231.0	232.0	999.0	999.0	69.0	999.0	61.0	62.0	999.0	0.0	0.0	999.0
11	197.0	196.0	195.0	194.0	999.0	190.0	189.0	188.0	215.0	216.0	217.0	218.0	225.0	224.0	223.0	999.0	999.0	70.0	999.0	60.0	59.0	999.0	0.0	0.0	0.0
10	134.0	135.0	136.0	137.0	138.0	139.0	140.0	187.0	186.0	185.0	184.0	219.0	220.0	221.0	222.0	999.0	999.0	71.0	999.0	57.0	58.0	999.0	0.0	0.0	0.0
9	133.0	126.0	125.0	124.0	123.0	122.0	141.0	142.0	143.0	144.0	183.0	182.0	181.0	180.0	179.0	178.0	177.0	72.0	999.0	56.0	55.0	999.0	0.0	0.0	0.0
8	132.0	127.0	999.0	999.0	999.0	121.0	120.0	119.0	118.0	145.0	146.0	147.0	148.0	149.0	174.0	175.0	176.0	73.0	999.0	53.0	54.0	999.0	0.0	0.0	0.0
7	131.0	128.0	999.0	999.0	999.0	0.0	999.0	999.0	117.0	116.0	999.0	999.0	999.0	150.0	173.0	172.0	171.0	74.0	999.0	52.0	51.0	50.0	49.0	48.0	47.0
6	130.0	129.0	999.0	0.0	0.0	0.0	999.0	999.0	114.0	115.0	999.0	999.0	999.0	151.0	168.0	169.0	170.0	75.0	999.0	999.0	999.0	999.0	999.0	999.0	46.0
5	999.0	999.0	999.0	0.0	0.0	0.0	999.0	999.0	113.0	112.0	999.0	999.0	999.0	152.0	167.0	166.0	165.0	76.0	999.0	999.0	999.0	999.0	0.0	0.0	45.0
4	999.0	999.0	999.0	0.0	0.0	0.0	999.0	999.0	110.0	111.0	999.0	999.0	999.0	153.0	162.0	163.0	164.0	77.0	999.0	999.0	40.0	41.0	42.0	43.0	44.0
3	0.0	0.0	0.0	0.0	0.0	0.0	999.0	999.0	109.0	108.0	999.0	999.0	999.0	154.0	161.0	160.0	159.0	78.0	999.0	999.0	39.0	38.0	37.0	36.0	35.0
2	98.0	99.0	100.0	101.0	102.0	103.0	104.0	105.0	106.0	107.0	999.0	999.0	999.0	155.0	156.0	157.0	158.0	79.0	999.0	999.0	30.0	31.0	32.0	33.0	34.0
1	97.0	96.0	95.0	94.0	93.0	92.0	91.0	90.0	89.0	88.0	87.0	86.0	85.0	84.0	83.0	82.0	81.0	80.0	999.0	999.0	29.0	28.0	27.0	26.0	25.0
0	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0

3. A* Search

The A* search is very similar to BFS except I created a heuristic function to change the cost of analyzing the node. I chose to make my heuristic function add additional cost for values that do not fall in between the ranges of the startingX and the endingY or the startingX and the endingY.

So cost of the node is valuated as follows:
1 + (1 if startingX < nodeX < endX is not true) + (1 if startingY < nodeY < endY is not true)

I then sort the list of nodes to have the list sorted by the cost, so we look at the node with the lower cost first. In our output we got less nodes expanded than our BFS, so it seems to be successful!

S to E1

```
DaivikMac:Assignment 1 daivikgoel$ python3 astarsearch.py
NODES EXPLORED: 195
PATH: [(2, 11), (2, 12), (3, 11), (2, 13), (3, 12), (2, 14), (3, 13), (4, 12), (2, 15), (3, 14), (4, 13), (5, 12), (2, 1
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(7, 20), (12, 9), (6, 20), (13, 9), (14, 9), (11, 20), (2, 20), (1, 19), (0, 18), (12, 20), (13, 20), (14, 19), (17, 9),
 (21, 20), (20, 19), (24, 17), (22, 20)]
TOTAL COST: 263
```

Maze output

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
24	0.0	0.0	0.0	0.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0
23	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	999.0	999.0	999.0	999.0	999.0	0.0	0.0	0.0	999.0	0.0	0.0	0.0	0.0	0.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	999.0	999.0	999.0	0.0	0.0	999.0	0.0	0.0	0.0	0.0	0.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	0.0	0.0	0.0	0.0
20	0.0	0.0	183.0	999.0	999.0	999.0	179.0	177.0	999.0	999.0	999.0	182.0	186.0	187.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	190.0	193.0	0.0	0.0
19	0.0	184.0	148.0	146.0	145.0	143.0	141.0	139.0	999.0	999.0	999.0	147.0	150.0	151.0	188.0	0.0	0.0	0.0	0.0	0.0	191.0	153.0	155.0	0.0	0.0
18	185.0	149.0	71.0	65.0	61.0	56.0	51.0	47.0	999.0	999.0	999.0	66.0	72.0	78.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	112.0	119.0	156.0	0.0
17	999.0	999.0	999.0	999.0	999.0	999.0	999.0	43.0	999.0	52.0	57.0	62.0	67.0	73.0	79.0	83.0	86.0	89.0	92.0	96.0	101.0	106.0	113.0	154.0	192.0
16	169.0	131.0	12.0	18.0	24.0	30.0	36.0	40.0	44.0	48.0	999.0	68.0	74.0	80.0	84.0	87.0	90.0	93.0	97.0	102.0	107.0	114.0	120.0	157.0	999.0
15	168.0	130.0	8.0	13.0	19.0	25.0	31.0	37.0	41.0	45.0	999.0	75.0	81.0	76.0	82.0	85.0	88.0	91.0	94.0	98.0	103.0	108.0	115.0	999.0	999.0
14	167.0	129.0	5.0	9.0	14.0	20.0	26.0	32.0	999.0	999.0	999.0	999.0	999.0	69.0	77.0	999.0	999.0	95.0	99.0	104.0	109.0	116.0	999.0	999.0	999.0
13	166.0	128.0	3.0	6.0	10.0	15.0	21.0	27.0	33.0	38.0	999.0	53.0	58.0	63.0	70.0	999.0	999.0	100.0	999.0	110.0	117.0	999.0	999.0	999.0	999.0
12	163.0	126.0	1.0	4.0	7.0	11.0	16.0	22.0	28.0	34.0	999.0	49.0	54.0	59.0	64.0	999.0	999.0	105.0	999.0	118.0	121.0	999.0	0.0	0.0	999.0
11	160.0	124.0	0.0	2.0	999.0	17.0	23.0	29.0	35.0	39.0	42.0	46.0	50.0	55.0	60.0	999.0	999.0	111.0	999.0	122.0	123.0	999.0	0.0	0.0	0.0
10	0.0	161.0	125.0	127.0	164.0	132.0	133.0	134.0	135.0	136.0	137.0	138.0	140.0	142.0	144.0	999.0	999.0	152.0	999.0	158.0	159.0	999.0	0.0	0.0	0.0
9	0.0	0.0	162.0	165.0	0.0	170.0	171.0	172.0	173.0	174.0	175.0	176.0	178.0	180.0	181.0	0.0	0.0	189.0	999.0	0.0	0.0	999.0	0.0	0.0	0.0
8	0.0	0.0	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0	0.0	0.0	999.0	0.0	0.0	0.0
7	0.0	0.0	999.0	999.0	999.0	0.0	999.0	999.0	0.0	0.0	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	999.0	0.0	0.0	0.0	999.0	999.0	0.0	0.0	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	999.0	999.0	999.0	999.0	999.0	999.0	0.0
5	999.0	999.0	999.0	0.0	0.0	0.0	999.0	999.0	0.0	0.0	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	999.0	999.0	999.0	999.0	0.0	0.0	0.0
4	999.0	999.0	999.0	0.0	0.0	0.0	999.0	999.0	0.0	0.0	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	999.0	999.0	0.0	0.0	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

S to E2

```
DaivikMac:Assignment 1 daivikgoel$ python3 astarsearch.py
NODES EXPLORED: 250
PATH: [(2, 11), (2, 12), (3, 11), (1, 11), (2, 10), (2, 13), (3, 12), (1, 12), (3, 10), (0, 11), (1, 10), (2, 9), (2,
 14), (3, 13), (1, 13), (4, 12), (0, 12), (4, 10), (3, 9), (0, 10), (1, 9), (2, 15), (3, 14), (1, 14), (4, 13), (0, 1
3), (5, 12), (5, 10), (4, 9), (0, 9), (1, 8), (2, 16), (3, 15), (1, 15), (4, 14), (0, 14), (5, 13), (6, 12), (5, 11),
 (6, 10), (5, 9), (0, 8), (1, 7), (3, 16), (1, 16), (4, 15), (0, 15), (5, 14), (6, 13), (7, 12), (6, 11), (7, 10), (6
, 9), (5, 8), (0, 7), (1, 6), (4, 16), (0, 16), (5, 15), (6, 14), (7, 13), (8, 12), (7, 11), (8, 10), (7, 9), (6, 8),
 (5, 7), (0, 6), (5, 16), (6, 15), (7, 14), (8, 13), (9, 12), (8, 11), (9, 10), (8, 9), (7, 8), (5, 6), (6, 16), (7,
15), (9, 13), (9, 11), (10, 10), (9, 9), (8, 8), (4, 6), (5, 5), (7, 16), (8, 15), (10, 11), (11, 10), (10, 9), (9, 8
), (8, 7), (3, 6), (4, 5), (5, 4), (7, 17), (8, 16), (9, 15), (11, 11), (12, 10), (11, 9), (10, 8), (9, 7), (8, 6), (
3, 5), (4, 4), (5, 3), (7, 18), (9, 16), (11, 12), (12, 11), (13, 10), (12, 9), (11, 8), (9, 6), (8, 5), (3, 4), (4,
3), (5, 2), (7, 19), (6, 18), (9, 17), (11, 13), (12, 12), (13, 11), (14, 10), (13, 9), (12, 8), (9, 5), (8, 4), (3,
3), (4, 2), (6, 2), (5, 1), (7, 20), (6, 19), (5, 18), (10, 17), (12, 13), (13, 12), (14, 11), (14, 9), (13, 8), (9,
4), (8, 3), (2, 3), (3, 2), (4, 1), (7, 2), (6, 1), (5, 0), (7, 21), (6, 20), (5, 19), (4, 18), (11, 17), (13, 13), (
14, 12), (15, 9), (14, 8), (13, 7), (9, 3), (8, 2), (1, 3), (2, 2), (3, 1), (4, 0), (7, 1), (6, 0), (7, 22), (6, 21),
 (4, 19), (3, 18), (11, 18), (12, 17), (11, 16), (13, 14), (14, 13), (16, 9), (15, 8), (14, 7), (13, 6), (9, 2), (8,
1), (0, 3), (1, 2), (2, 1), (3, 0), (7, 0), (6, 22), (3, 19), (2, 18), (11, 19), (12, 18), (13, 17), (12, 16), (11, 1
5), (13, 15), (14, 14), (17, 9), (16, 8), (15, 7), (14, 6), (13, 5), (9, 1), (8, 0), (0, 2), (1, 1), (2, 0), (5, 22),
 (2, 19), (1, 18), (11, 20), (12, 19), (13, 18), (14, 17), (13, 16), (12, 15), (14, 15), (17, 10), (17, 8), (16, 7),
(15, 6), (14, 5), (13, 4), (10, 1), (9, 0), (0, 1), (1, 0), (2, 20), (1, 19), (0, 18), (11, 21), (12, 20), (13, 19),
(15, 17), (14, 16), (15, 15), (17, 11), (17, 7), (16, 6), (15, 5), (14, 4), (13, 3), (11, 1), (10, 0), (0, 0)]
TOTAL COST: 496
```

Maze Output

	0	1	2	3	4	5	6	7	...	17	18	19	20	21	22	23	24
24	0.0	0.0	0.0	0.0	999.0	999.0	0.0	0.0	...	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0
23	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	...	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	999.0	999.0	999.0	999.0	999.0	211.0	191.0	171.0	...	999.0	999.0	999.0	999.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	999.0	999.0	999.0	172.0	153.0	...	999.0	999.0	999.0	999.0	0.0	0.0	0.0	0.0
20	0.0	0.0	231.0	999.0	999.0	999.0	154.0	136.0	...	999.0	999.0	999.0	999.0	0.0	0.0	0.0	0.0
19	0.0	232.0	212.0	192.0	173.0	155.0	137.0	121.0	...	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	233.0	213.0	193.0	174.0	156.0	138.0	122.0	109.0	...	999.0	999.0	999.0	999.0	0.0	0.0	0.0	0.0
17	999.0	999.0	999.0	999.0	999.0	999.0	999.0	97.0	...	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	57.0	44.0	31.0	43.0	56.0	68.0	78.0	87.0	...	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
15	46.0	33.0	21.0	32.0	45.0	58.0	69.0	79.0	...	0.0	0.0	0.0	0.0	0.0	0.0	999.0	999.0
14	35.0	23.0	12.0	22.0	34.0	47.0	59.0	70.0	...	0.0	0.0	0.0	0.0	0.0	999.0	999.0	999.0
13	25.0	14.0	5.0	13.0	24.0	36.0	48.0	60.0	...	0.0	999.0	0.0	0.0	999.0	999.0	999.0	999.0
12	16.0	7.0	1.0	6.0	15.0	26.0	37.0	49.0	...	0.0	999.0	0.0	0.0	999.0	0.0	0.0	999.0
11	9.0	3.0	0.0	2.0	999.0	38.0	50.0	62.0	...	240.0	999.0	0.0	0.0	999.0	0.0	0.0	0.0
10	19.0	10.0	4.0	8.0	17.0	27.0	39.0	51.0	...	221.0	999.0	0.0	0.0	999.0	0.0	0.0	0.0
9	29.0	20.0	11.0	18.0	28.0	40.0	52.0	64.0	...	201.0	999.0	0.0	0.0	999.0	0.0	0.0	0.0
8	41.0	30.0	999.0	999.0	999.0	53.0	65.0	76.0	...	222.0	999.0	0.0	0.0	999.0	0.0	0.0	0.0
7	54.0	42.0	999.0	999.0	999.0	66.0	999.0	999.0	...	241.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0
6	67.0	55.0	999.0	94.0	85.0	77.0	999.0	999.0	...	0.0	999.0	999.0	999.0	999.0	999.0	999.0	0.0
5	999.0	999.0	999.0	106.0	95.0	86.0	999.0	999.0	...	0.0	999.0	999.0	999.0	999.0	0.0	0.0	0.0
4	999.0	999.0	999.0	118.0	107.0	96.0	999.0	999.0	...	0.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0
3	186.0	165.0	147.0	132.0	119.0	108.0	999.0	999.0	...	0.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0
2	208.0	187.0	166.0	148.0	133.0	120.0	134.0	150.0	...	0.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0
1	229.0	209.0	188.0	167.0	149.0	135.0	151.0	169.0	...	0.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0
0	248.0	230.0	210.0	189.0	168.0	152.0	170.0	190.0	...	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

(0,0) to (24,24)

```
DaivikMac:Assignment 1 daivikgoel$ python3 astarsearch.py
NODES EXPLORED: 444
PATH: [(0, 0), (0, 1), (1, 0), (0, 2), (1, 1), (2, 0), (0, 3), (1, 2), (2, 1), (3, 0), (1, 3), (2, 2), (3, 1), (4, 0), (2, 3), (3, 2), (4,
1), (5, 0), (3, 3), (4, 2), (5, 1), (6, 0), (3, 4), (4, 3), (5, 2), (6, 1), (7, 0), (3, 5), (4, 4), (5, 3), (6, 2), (7, 1), (8, 0), (3, 6),
 (4, 5), (5, 4), (7, 2), (8, 1), (9, 0), (4, 6), (5, 5), (8, 2), (9, 1), (10, 0), (5, 6), (8, 3), (9, 2), (10, 1), (11, 0), (5, 7), (8, 4),
 (9, 3), (11, 1), (12, 0), (5, 8), (8, 5), (9, 4), (12, 1), (13, 0), (5, 9), (6, 8), (8, 6), (9, 5), (13, 1), (14, 0), (5, 10), (6, 9), (4,
 9), (7, 8), (8, 7), (9, 6), (13, 2), (14, 1), (15, 0), (5, 11), (6, 10), (4, 10), (7, 9), (3, 9), (8, 8), (9, 7), (13, 3), (14, 2), (15, 1
), (16, 0), (5, 12), (6, 11), (7, 10), (3, 10), (8, 9), (2, 9), (9, 8), (13, 4), (14, 3), (15, 2), (16, 1), (17, 0), (5, 13), (6, 12), (4,
12), (7, 11), (8, 10), (3, 11), (2, 10), (9, 9), (1, 9), (10, 8), (13, 5), (14, 4), (15, 3), (16, 2), (17, 1), (18, 0), (5, 14), (6, 13), (
4, 13), (7, 12), (3, 12), (8, 11), (9, 10), (2, 11), (1, 10), (10, 9), (0, 9), (1, 8), (11, 8), (13, 6), (14, 5), (15, 4), (16, 3), (17, 2)
, (19, 0), (5, 15), (6, 14), (4, 14), (7, 13), (3, 13), (8, 12), (2, 12), (9, 11), (10, 10), (1, 11), (0, 10), (11, 9), (0, 8), (1, 7), (12
, 8), (13, 7), (14, 6), (15, 5), (16, 4), (17, 3), (20, 0), (5, 16), (6, 15), (4, 15), (7, 14), (3, 14), (8, 13), (2, 13), (9, 12), (1, 12)
, (10, 11), (11, 10), (0, 11), (12, 9), (0, 7), (1, 6), (13, 8), (14, 7), (15, 6), (16, 5), (17, 4), (20, 1), (21, 0), (6, 16), (4, 16), (7
, 15), (3, 15), (2, 14), (9, 13), (1, 13), (0, 12), (11, 11), (12, 10), (13, 9), (0, 6), (14, 8), (15, 7), (16, 6), (17, 5), (20, 2), (21,
1), (22, 0), (7, 16), (3, 16), (8, 15), (2, 15), (1, 14), (0, 13), (11, 12), (12, 11), (13, 10), (14, 9), (15, 8), (16, 7), (17, 6), (20, 3
), (21, 2), (22, 1), (23, 0), (7, 17), (8, 16), (2, 16), (9, 15), (1, 15), (0, 14), (11, 13), (12, 12), (13, 11), (14, 10), (15, 9), (16, 8
), (17, 7), (20, 4), (21, 3), (22, 2), (23, 1), (7, 18), (9, 16), (1, 16), (0, 15), (12, 13), (13, 12), (14, 11), (16, 9), (17, 8), (21, 4)
, (22, 3), (23, 2), (7, 19), (6, 18), (9, 17), (0, 16), (13, 13), (14, 12), (17, 9), (22, 4), (23, 3), (7, 20), (6, 19), (5, 18), (10, 17),
 (13, 14), (14, 13), (17, 10), (22, 5), (23, 4), (7, 21), (6, 20), (5, 19), (4, 18), (11, 17), (13, 15), (14, 14), (17, 11), (23, 5), (7, 2
2), (6, 21), (4, 19), (3, 18), (11, 18), (12, 17), (11, 16), (13, 16), (14, 15), (12, 15), (17, 12), (6, 22), (3, 19), (2, 18), (11, 19), (
12, 18), (13, 17), (12, 16), (11, 15), (14, 16), (15, 15), (17, 13), (5, 22), (2, 19), (1, 18), (11, 20), (12, 19), (13, 18), (14, 17), (15
, 16), (16, 15), (17, 14), (2, 20), (1, 19), (0, 18), (11, 21), (12, 20), (13, 19), (15, 17), (16, 16), (17, 15), (18, 14), (2, 21), (1, 20
), (0, 19), (11, 22), (12, 21), (10, 21), (13, 20), (14, 19), (16, 17), (17, 16), (18, 15), (19, 14), (1, 21), (0, 20), (11, 23), (12, 22),
 (10, 22), (13, 21), (9, 21), (15, 19), (17, 17), (18, 16), (19, 15), (20, 14), (19, 13), (0, 21), (12, 23), (10, 23), (13, 22), (9, 22), (
16, 19), (18, 17), (19, 16), (20, 15), (21, 14), (20, 13), (19, 12), (13, 23), (17, 19), (19, 17), (20, 16), (21, 15), (20, 12), (19, 11),
(14, 23), (18, 19), (20, 17), (21, 16), (22, 15), (20, 11), (19, 10), (15, 23), (19, 19), (21, 17), (22, 16), (20, 10), (19, 9), (16, 23),
(20, 19), (21, 18), (22, 17), (23, 16), (20, 9), (19, 8), (17, 23), (21, 19), (22, 18), (23, 17), (20, 8), (19, 7), (18, 23), (21, 20), (22
, 19), (23, 18), (20, 7), (19, 23), (21, 21), (22, 20), (23, 19), (21, 7), (20, 23), (21, 22), (22, 21), (23, 20), (22, 7), (21, 23), (22,
22), (23, 21), (22, 8), (23, 7), (22, 23), (23, 22), (22, 9), (23, 8), (23, 23), (22, 10), (23, 9), (22, 11), (23, 10), (22, 12), (23, 11),
 (23, 12), (24, 0), (24, 1), (24, 2), (24, 3), (24, 4), (24, 5), (11, 24), (12, 24), (10, 24), (13, 24), (14, 24), (15, 24), (16, 24), (24,
 17), (24, 18), (19, 24), (24, 19), (20, 24), (24, 20), (21, 24), (24, 21), (24, 7), (22, 24), (24, 22), (24, 8), (23, 24), (24, 23), (24,
9), (24, 10), (24, 11), (24, 6), (9, 24)]
TOTAL COST: 474
```

Maze Output

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
24	0.0	0.0	0.0	0.0	999.0	999.0	0.0	0.0	0.0	442.0	419.0	417.0	418.0	420.0	421.0	422.0	423.0	999.0	999.0	426.0	428.0	430.0	433.0	436.0	0.0
23	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	336.0	323.0	335.0	346.0	353.0	360.0	366.0	373.0	379.0	384.0	389.0	394.0	399.0	403.0	437.0
22	999.0	999.0	999.0	999.0	999.0	289.0	278.0	267.0	999.0	338.0	325.0	312.0	324.0	337.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	390.0	395.0	400.0	434.0
21	334.0	321.0	309.0	999.0	999.0	999.0	268.0	258.0	999.0	327.0	314.0	302.0	313.0	326.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	385.0	391.0	396.0	431.0
20	322.0	310.0	299.0	999.0	999.0	999.0	259.0	249.0	999.0	999.0	999.0	292.0	303.0	315.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	380.0	386.0	392.0	429.0
19	311.0	300.0	290.0	279.0	269.0	260.0	250.0	240.0	999.0	999.0	999.0	281.0	293.0	304.0	316.0	328.0	339.0	347.0	354.0	361.0	367.0	374.0	381.0	387.0	427.0
18	301.0	291.0	280.0	270.0	261.0	251.0	241.0	228.0	999.0	999.0	999.0	271.0	282.0	294.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	368.0	375.0	382.0	425.0
17	999.0	999.0	999.0	999.0	999.0	999.0	999.0	211.0	999.0	242.0	252.0	262.0	272.0	283.0	295.0	305.0	317.0	329.0	340.0	348.0	355.0	362.0	369.0	376.0	424.0
16	243.0	230.0	213.0	195.0	176.0	153.0	175.0	194.0	212.0	229.0	999.0	273.0	284.0	274.0	286.0	296.0	306.0	318.0	330.0	341.0	349.0	356.0	363.0	370.0	999.0
15	231.0	215.0	197.0	178.0	155.0	132.0	154.0	177.0	196.0	214.0	999.0	285.0	276.0	263.0	275.0	287.0	297.0	307.0	319.0	331.0	342.0	350.0	357.0	999.0	999.0
14	216.0	198.0	179.0	157.0	134.0	113.0	133.0	156.0	999.0	999.0	999.0	999.0	999.0	253.0	264.0	999.0	999.0	298.0	308.0	320.0	332.0	343.0	999.0	999.0	999.0
13	199.0	181.0	159.0	136.0	115.0	97.0	114.0	135.0	158.0	180.0	999.0	217.0	232.0	244.0	254.0	999.0	999.0	288.0	999.0	333.0	344.0	999.0	999.0	999.0	999.0
12	182.0	161.0	138.0	117.0	99.0	85.0	98.0	116.0	137.0	160.0	999.0	200.0	218.0	233.0	245.0	999.0	999.0	277.0	999.0	345.0	351.0	999.0	408.0	410.0	999.0
11	164.0	141.0	120.0	102.0	999.0	74.0	86.0	100.0	118.0	139.0	162.0	183.0	201.0	219.0	234.0	999.0	999.0	265.0	999.0	352.0	358.0	999.0	406.0	409.0	440.0
10	142.0	121.0	103.0	88.0	76.0	65.0	75.0	87.0	101.0	119.0	140.0	163.0	184.0	202.0	220.0	999.0	999.0	255.0	999.0	359.0	364.0	999.0	404.0	407.0	439.0
9	123.0	105.0	90.0	78.0	67.0	59.0	66.0	77.0	89.0	104.0	122.0	143.0	165.0	185.0	203.0	221.0	235.0	246.0	999.0	365.0	371.0	999.0	401.0	405.0	438.0
8	144.0	124.0	999.0	999.0	999.0	54.0	60.0	68.0	79.0	91.0	106.0	125.0	146.0	168.0	187.0	204.0	222.0	236.0	999.0	372.0	377.0	999.0	397.0	402.0	435.0
7	166.0	145.0	999.0	999.0	999.0	49.0	999.0	999.0	69.0	80.0	999.0	999.0	999.0	147.0	169.0	188.0	205.0	223.0	999.0	378.0	383.0	388.0	393.0	398.0	432.0
6	186.0	167.0	999.0	33.0	39.0	44.0	999.0	999.0	61.0	70.0	999.0	999.0	999.0	126.0	148.0	170.0	189.0	206.0	999.0	999.0	999.0	999.0	999.0	999.0	441.0
5	999.0	999.0	999.0	27.0	34.0	40.0	999.0	999.0	55.0	62.0	999.0	999.0	999.0	107.0	127.0	149.0	171.0	190.0	999.0	999.0	999.0	999.0	256.0	266.0	416.0
4	999.0	999.0	999.0	22.0	28.0	35.0	999.0	999.0	50.0	56.0	999.0	999.0	999.0	92.0	108.0	128.0	150.0	172.0	999.0	999.0	224.0	237.0	247.0	257.0	415.0
3	6.0	10.0	14.0	18.0	23.0	29.0	999.0	999.0	45.0	51.0	999.0	999.0	999.0	81.0	93.0	109.0	129.0	151.0	999.0	999.0	207.0	225.0	238.0	248.0	414.0
2	3.0	7.0	11.0	15.0	19.0	24.0	30.0	36.0	41.0	46.0	999.0	999.0	999.0	71.0	82.0	94.0	110.0	130.0	999.0	999.0	191.0	208.0	226.0	239.0	413.0
1	1.0	4.0	8.0	12.0	16.0	20.0	25.0	31.0	37.0	42.0	47.0	52.0	57.0	63.0	72.0	83.0	95.0	111.0	999.0	999.0	173.0	192.0	209.0	227.0	412.0
0	0.0	2.0	5.0	9.0	13.0	17.0	21.0	26.0	32.0	38.0	43.0	48.0	53.0	58.0	64.0	73.0	84.0	96.0	112.0	131.0	152.0	174.0	193.0	210.0	411.0