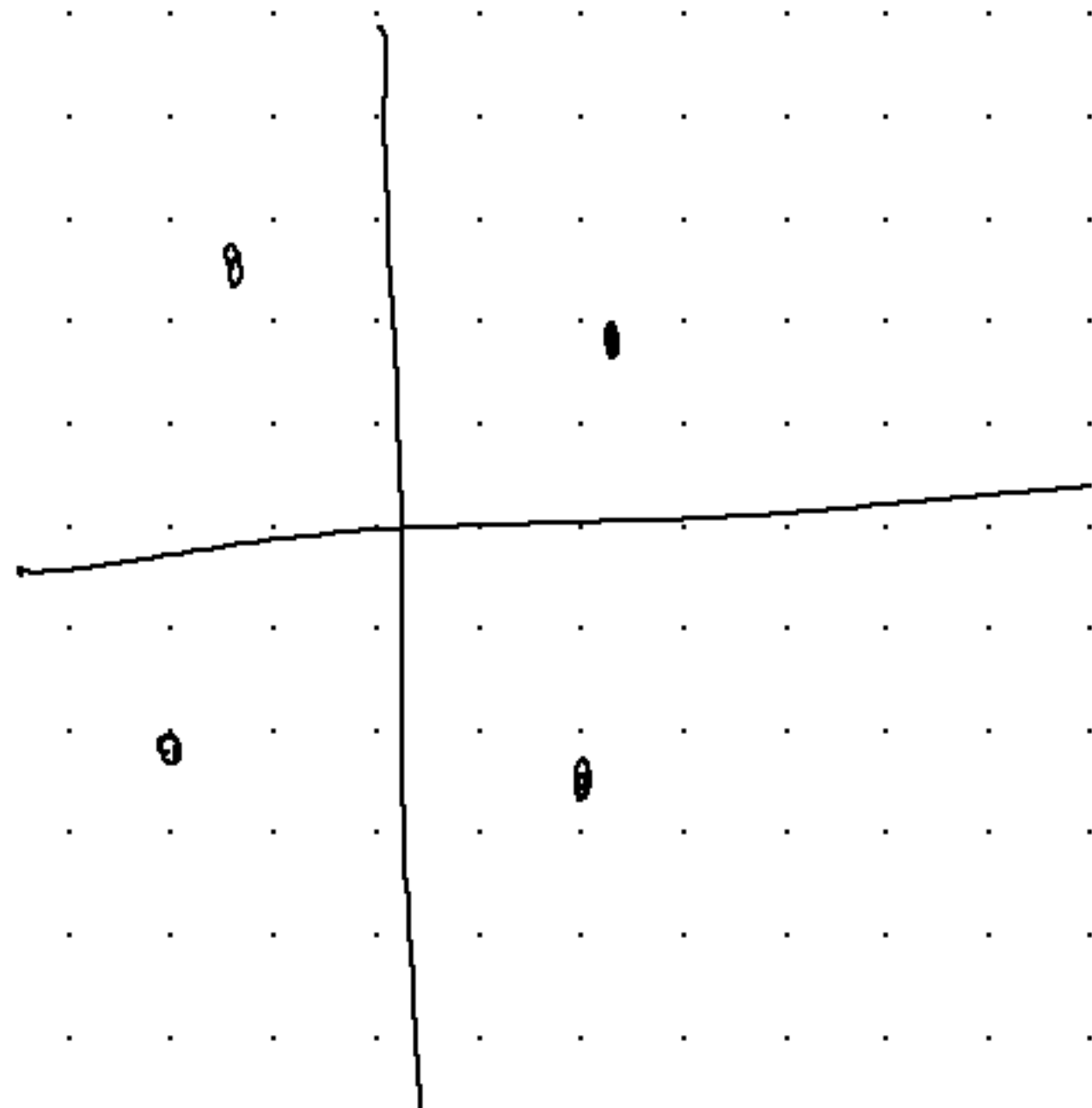


cube attributes only color



$$y = mx + b$$

$$m = \frac{y_2 - y_1}{x_2 - x_1}$$

4: red
0: purple
2: orange
7: pink

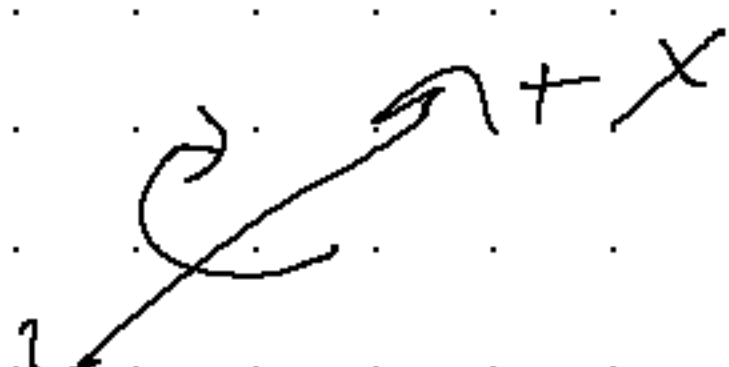
1. Click 4;

Click 6

2. { 0 becomes 4
2 becomes 0
7 becomes 2
4 becomes 7

temp = 4
4 = 7
7 = 2
2 = 0
0 = temp

0 becomes 6 temp = 6
1 becomes 0 6 = 7
7 becomes 1 7 = 1
1 = 0
6 becomes 7 0 = temp

3. 1: 
-x

1-6

3-5

2-4

3:


-y
+y

5:

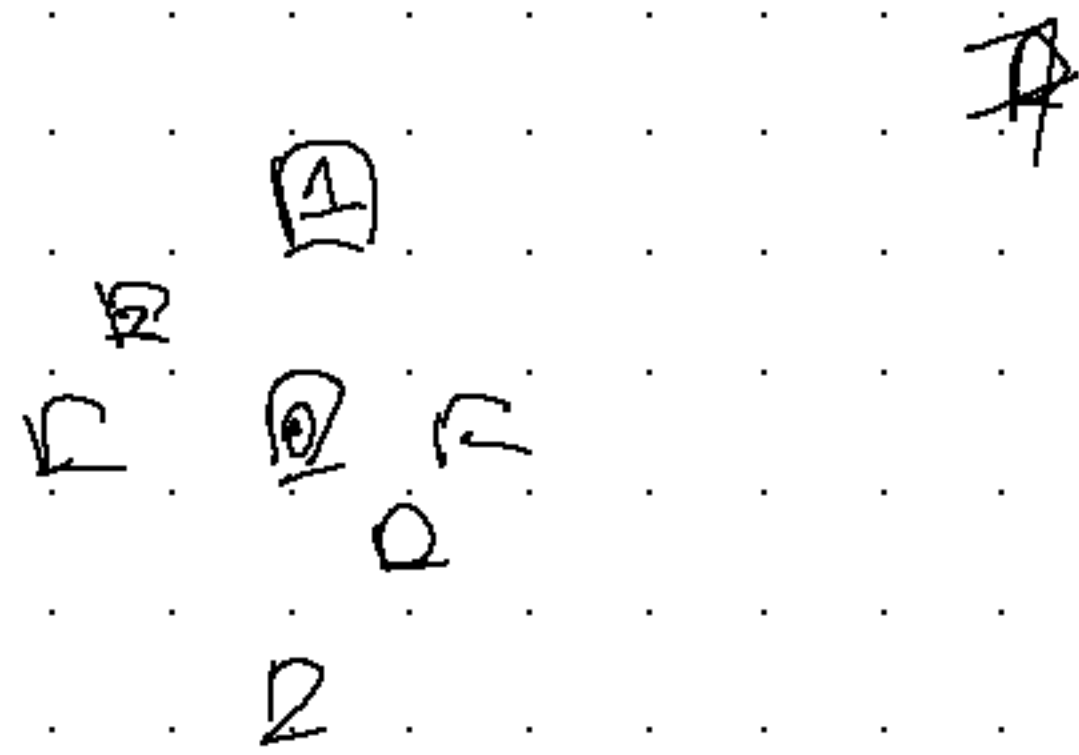

-y
+y

6: 
-x +x

Todo (after base model completed)

1. Write number corresponding w/ cube

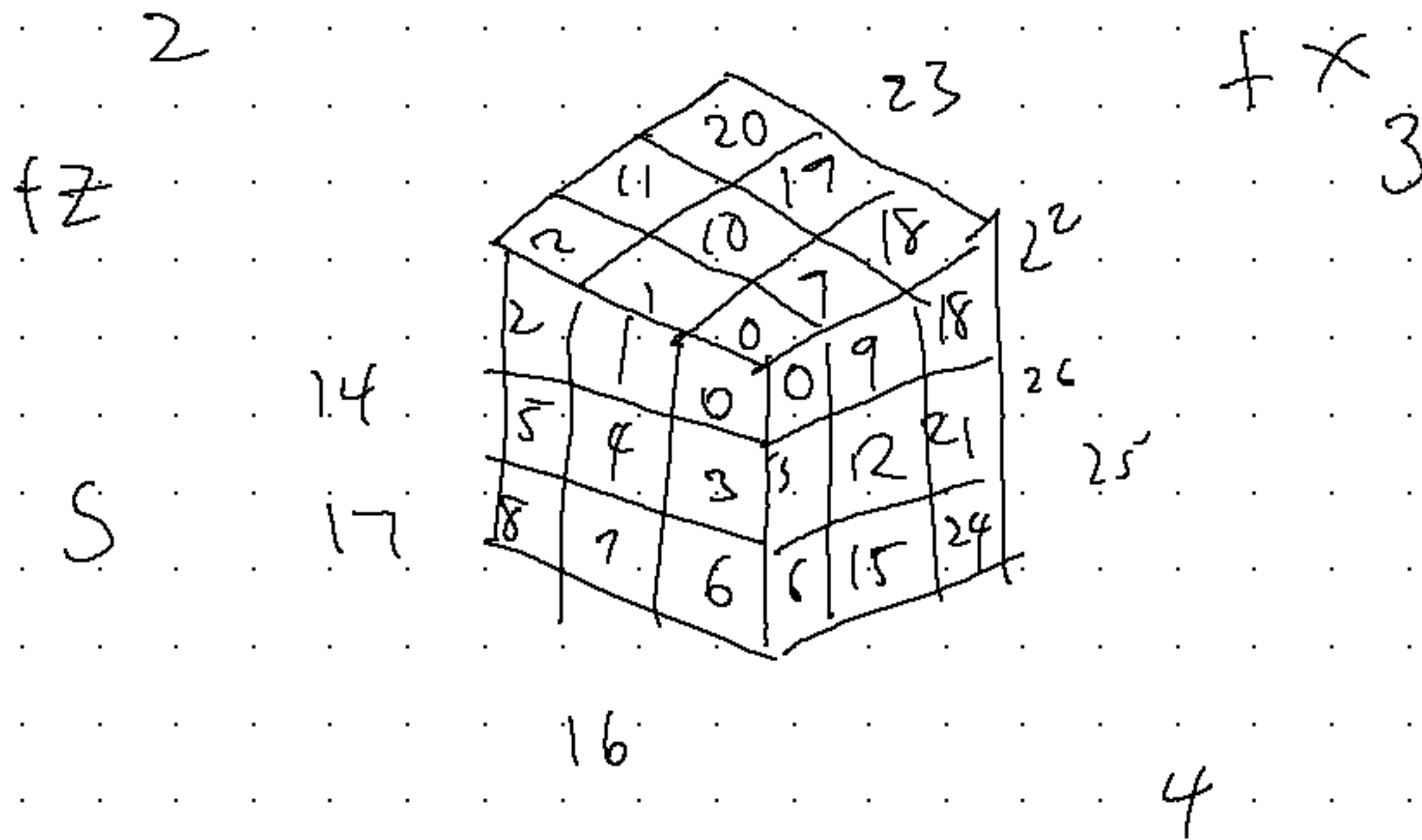
when press key



center on middle middle cube

2. Animation frames

-7 1



Corner: 0, 2, 6, 8, 18, 20, 24, 26

Center: 4, 10, 12, 14, 16, 22

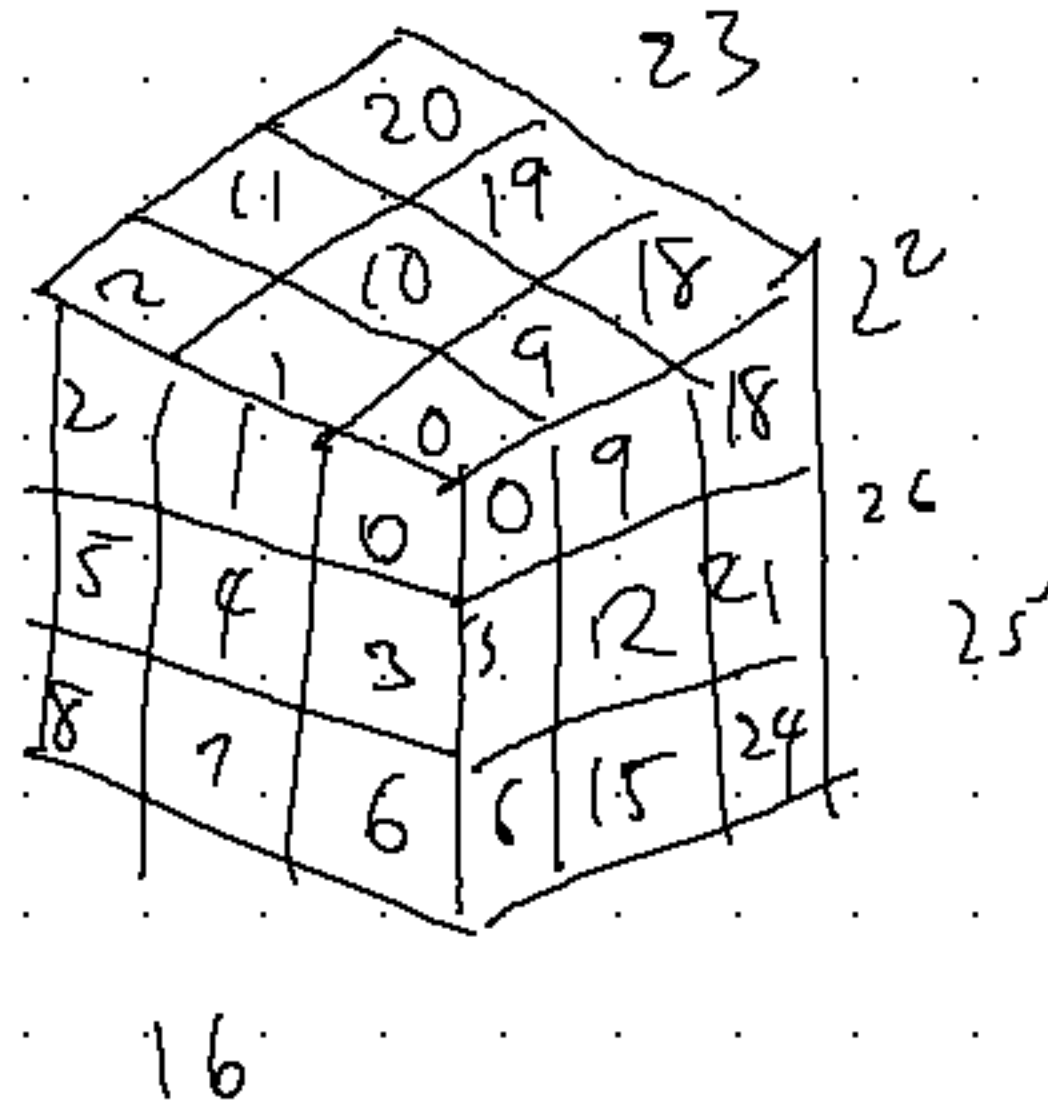
Edge: odd

6

Center

-7 1

2
+z



+x 3

temp = 1

1 = 4

4 = 6

6 = 2

2 = temp

Cube 4:
1 → 4
4 → 6
6 → 2
2 → 1

1. take bottom
8, 17, 26,
7, 16, 25
6, 15, 24

2.
4. left
2, 11, 20
5, 14, 23
8, 17, 26

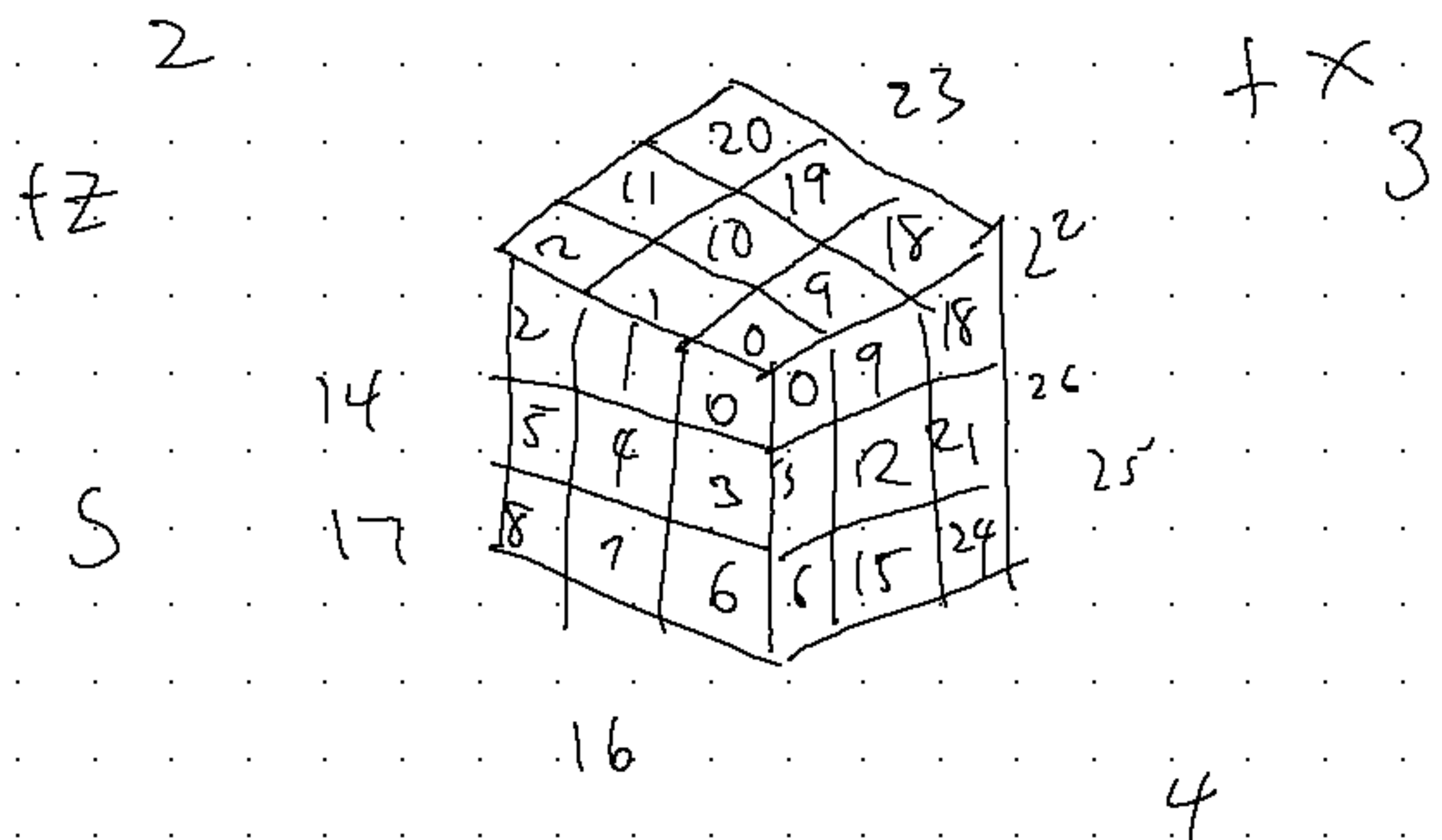
3.
6. Top
0, 9, 18
1, 10, 19
2, 11, 20
4.
2. Right
6, 15, 24,
3, 12, 21
0, 9, 18

all have +9 diff

Le epic plan:

temp * cubes[9]. Load them and replace w/ this order

- 7 1



3: 2, 1, 0
5, 4, 3
8, 7, 6

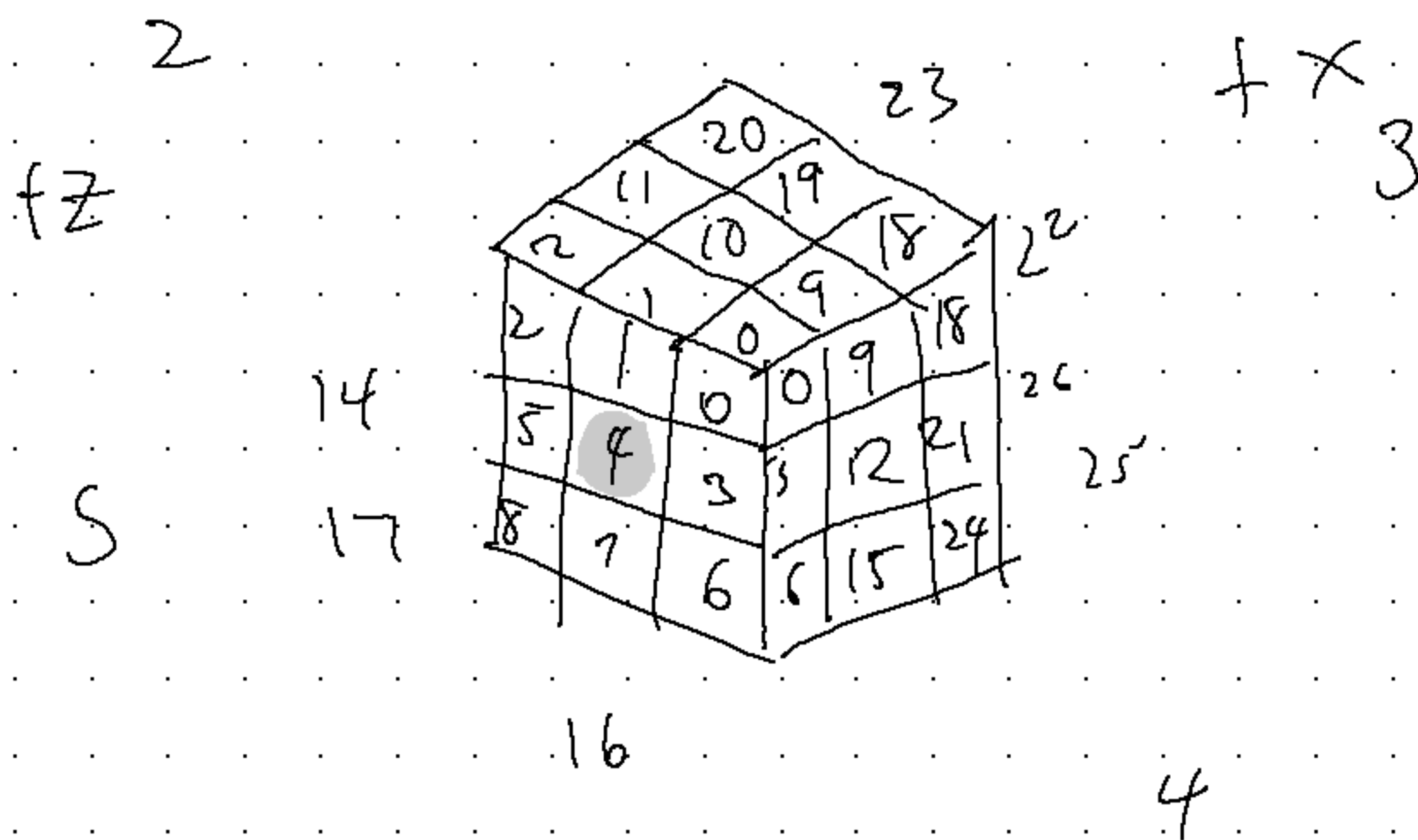
5: 26, 25, 24
23, 22, 21
20, 19, 18

1: 8, 7, 6
17, 16, 15
26, 25, 24

6: 2, 1, 0
11, 10, 9
20, 19, 18

Do they disagree ☹️

About X-axis
-7, 1



1 → 4

4 → 6

6 → 2

2 → 1

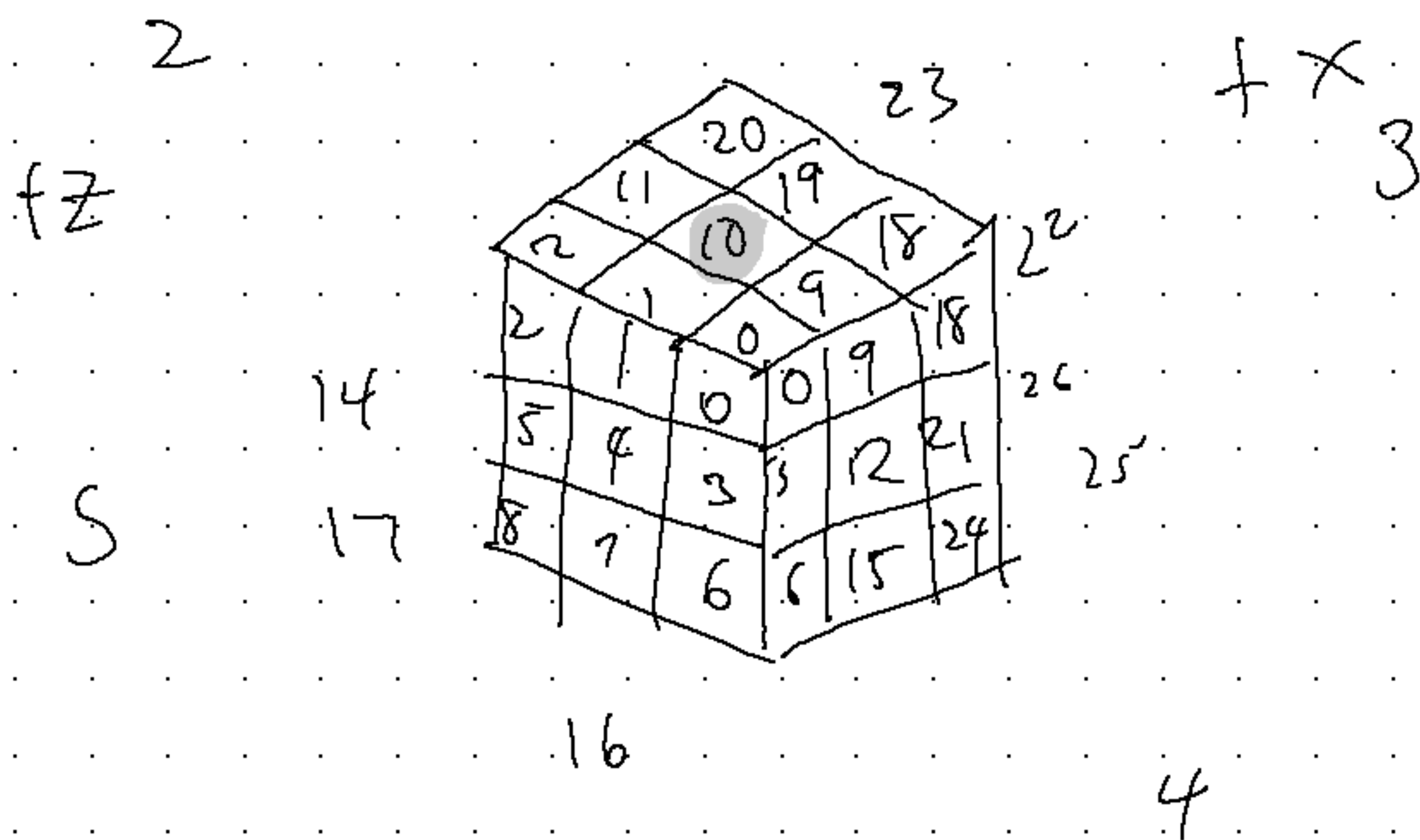
1. take bottom 9
8, 17, 26,
7, 16, 25
6, 15, 24

2. 4. left 9
2, 11, 20
5, 14, 23
8, 17, 26

3. 6. Top 9
0, 9, 18
1, 10, 19
2, 11, 20

4. 2. Right 9
6, 15, 24,
3, 12, 21,
0, 9, 18

About y-axis
-7, 1



From
-y: Clockwise

6

1, 5: 18, 21, 24
19, 22, 25
20, 23, 26

3, 3: 2, 5, 8
1, 4, 7
0, 3, 6

5 → 2

2 → 3

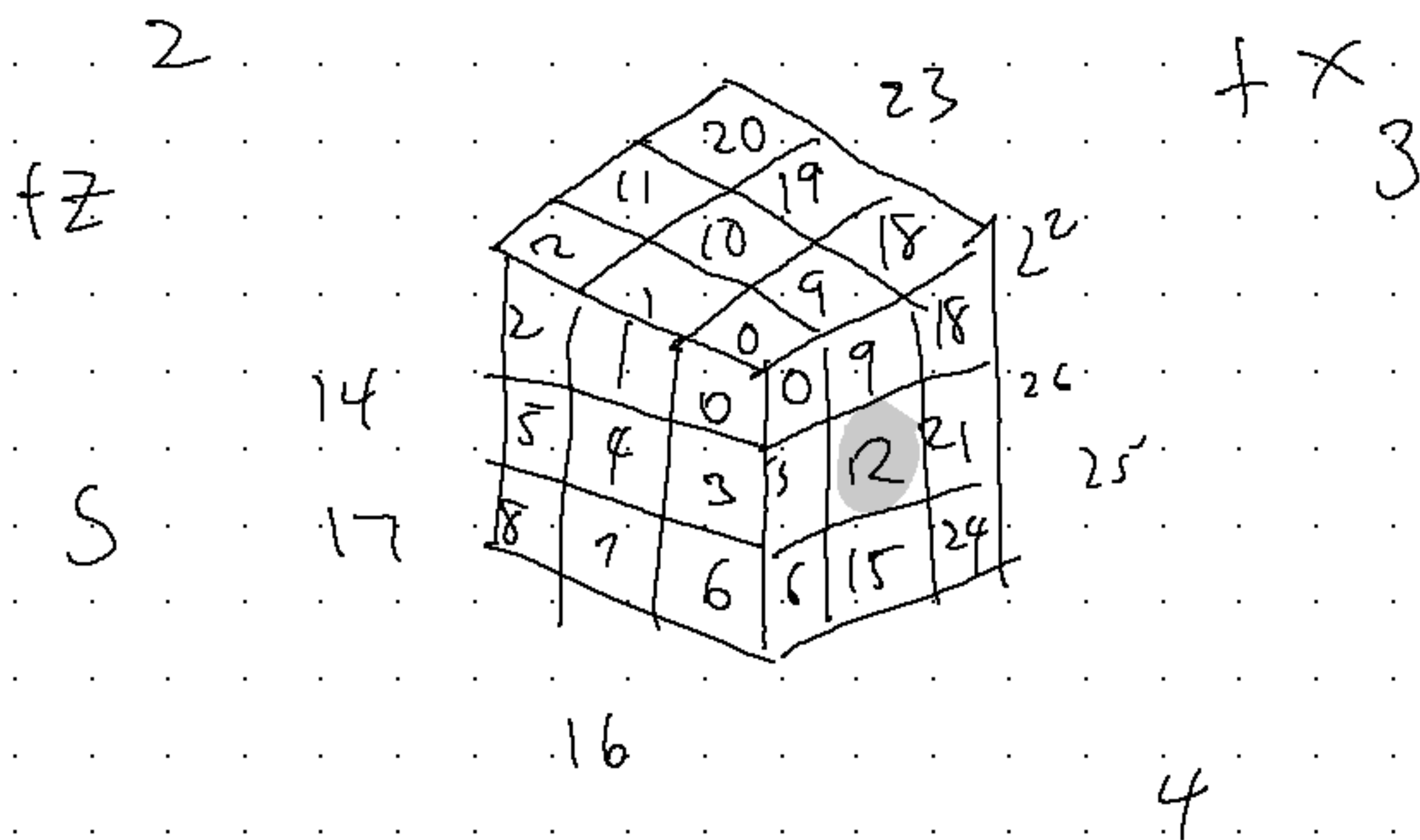
3 → 4

4 → 5

2, 2: 0, 3, 6
9, 12, 15
18, 21, 24

4, 4: 20, 23, 26
11, 14, 17
2, 5, 8

About z-axis
-7 1



From
-z: Clockwise

6

1, 1': 8, 7, 6
17, 16, 15
26, 25, 24

3, 6': 20, 19, 18
11, 10, 9
2, 1, 0

1 → 3

3 → 6

6 → 5

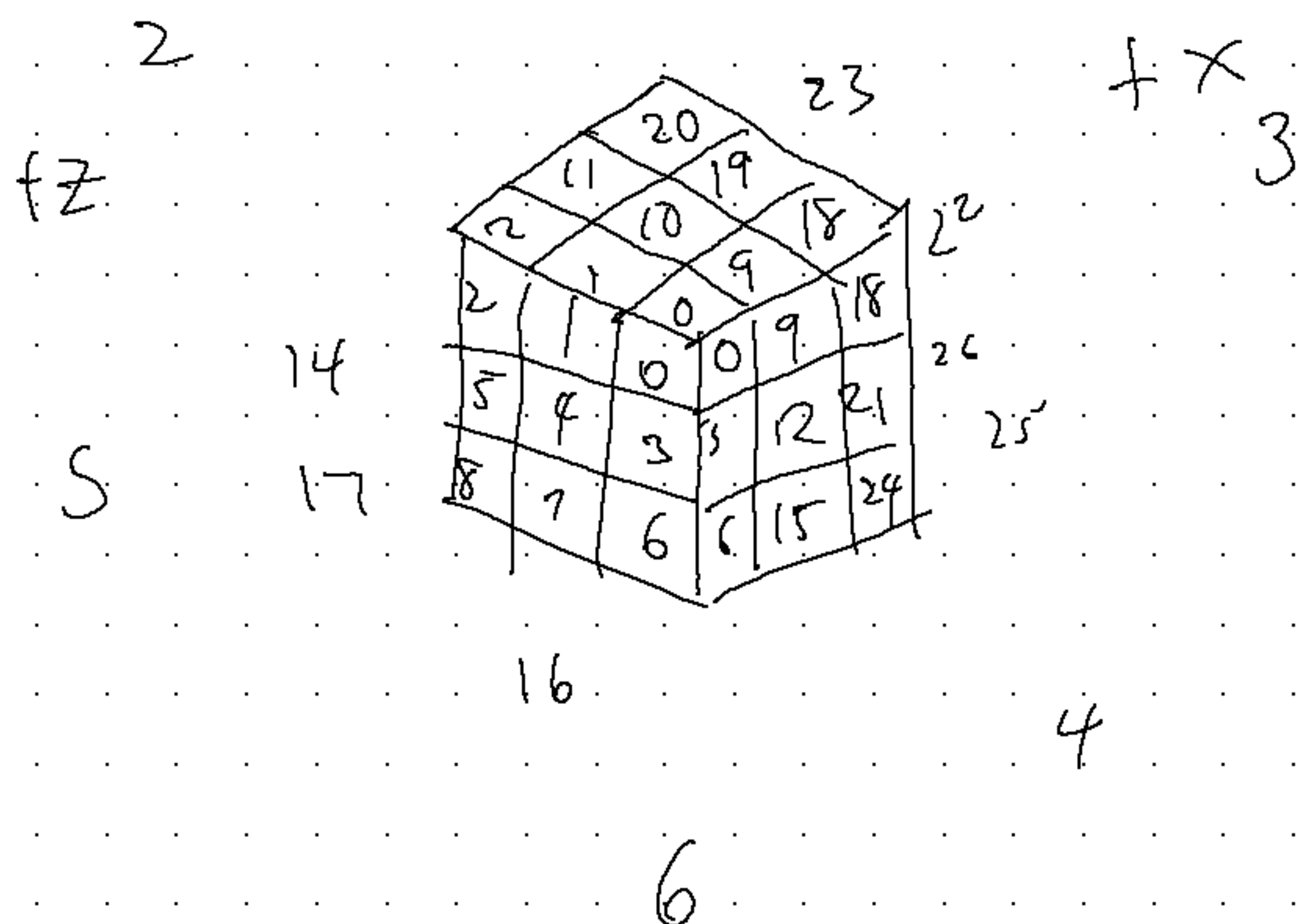
5 → 1

2, 3': 2, 1, 0
5, 4, 3
8, 7, 6

4, 5': 26, 25, 24
23, 22, 21
20, 19, 18

Cube Self Rotation

- 7, 1

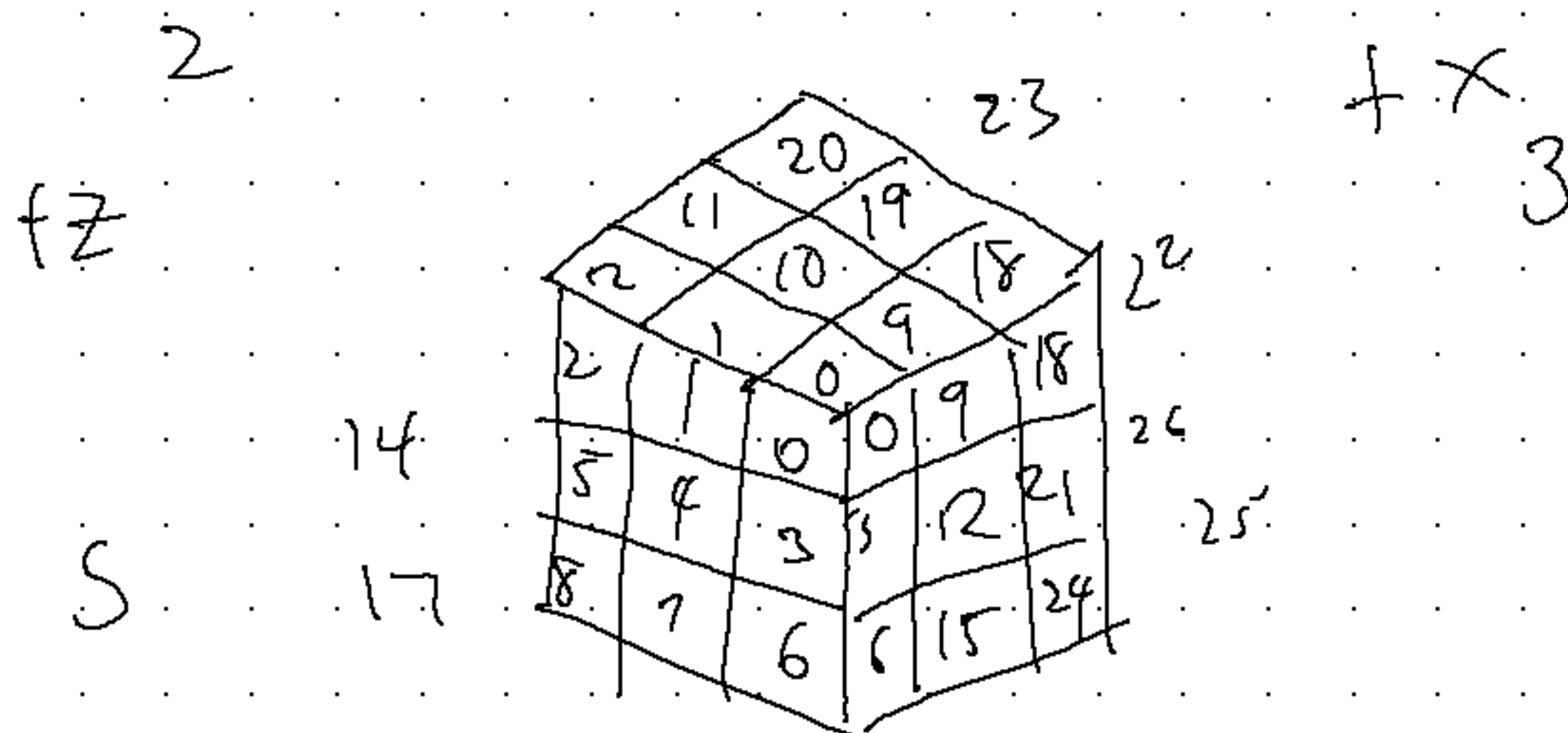


3 axes, 2 directions
6 total

PLAN: 4 sets of swap for corners stacks
4 sets of swap for middle stacks

About Z-axis

-7, 1



w/ respect to -z

CCW:

corner stacks:

0, 1, 2

6, 7, 8

24, 25, 26

18, 19, 20

edge:

3, 4, 5

15, 16, 17

21, 22, 23

9, 10, 11

CW:

18, 19, 20

24, 25, 26

6, 7, 8

0, 1, 2

9, 10, 11

21, 22, 23

15, 16, 17

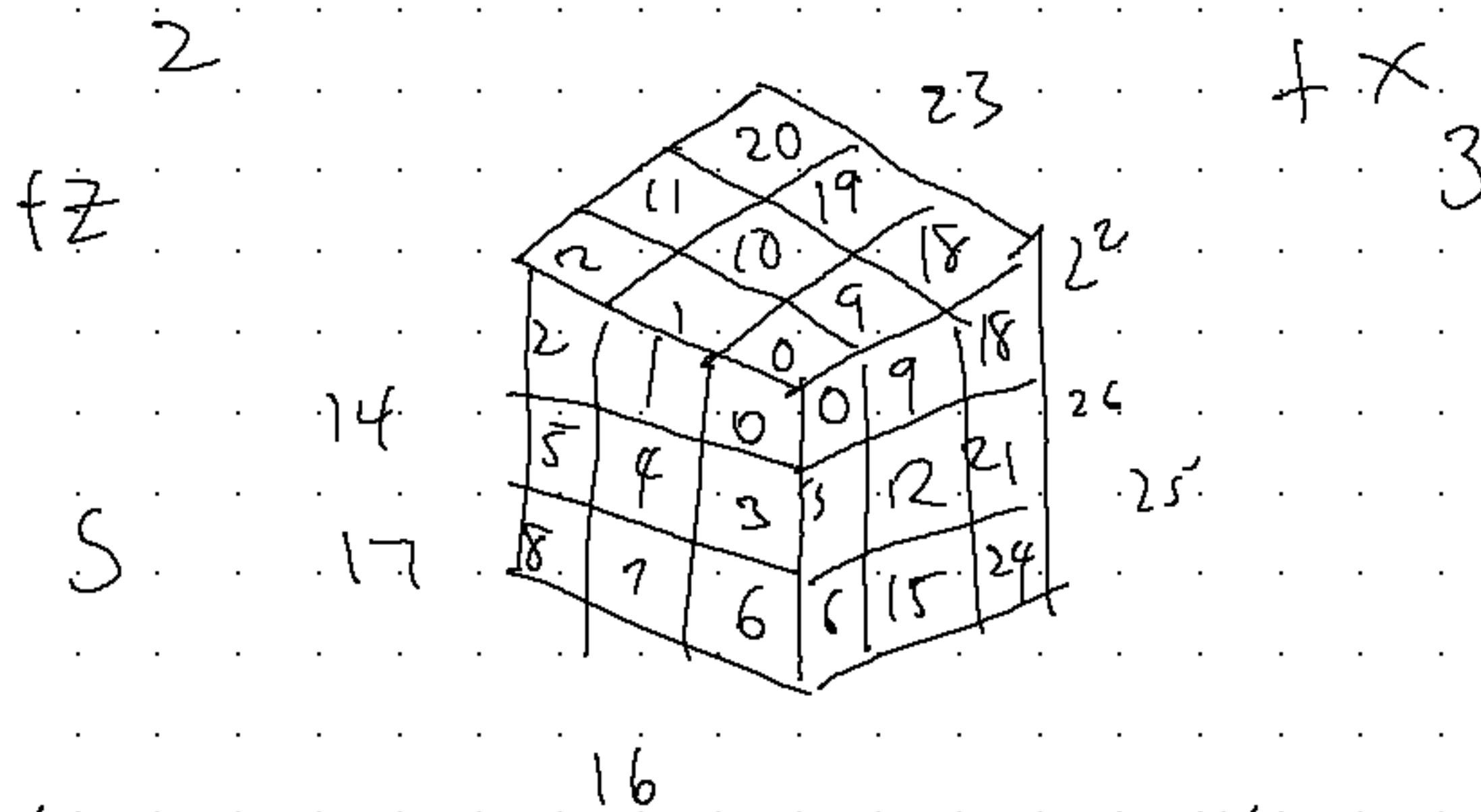
3, 4, 5

Increment:

1

About y -axis

-7, 1



-y
CW

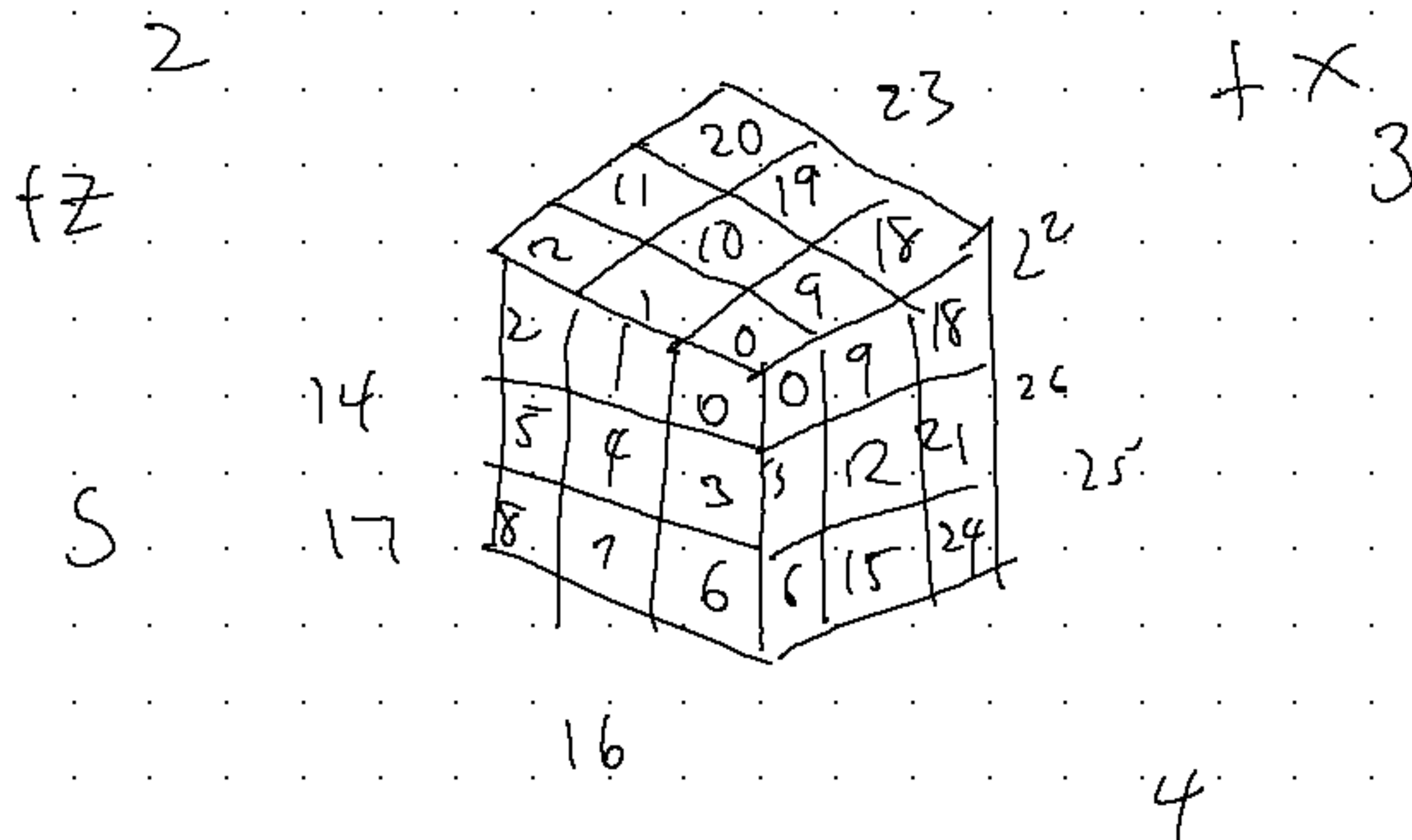
corner stacks: 0, 3, 6
2, 5, 8
20, 23, 26
18, 21, 24

edge: 1, 4, 7
11, 14, 17
19, 22, 25
9, 12, 15

Increment: 3

About x-axis

-7, 1



CW

6

corner stacks:

- 0, 9, 18
- 6, 15, 24
- 8, 17, 26
- 2, 11, 20

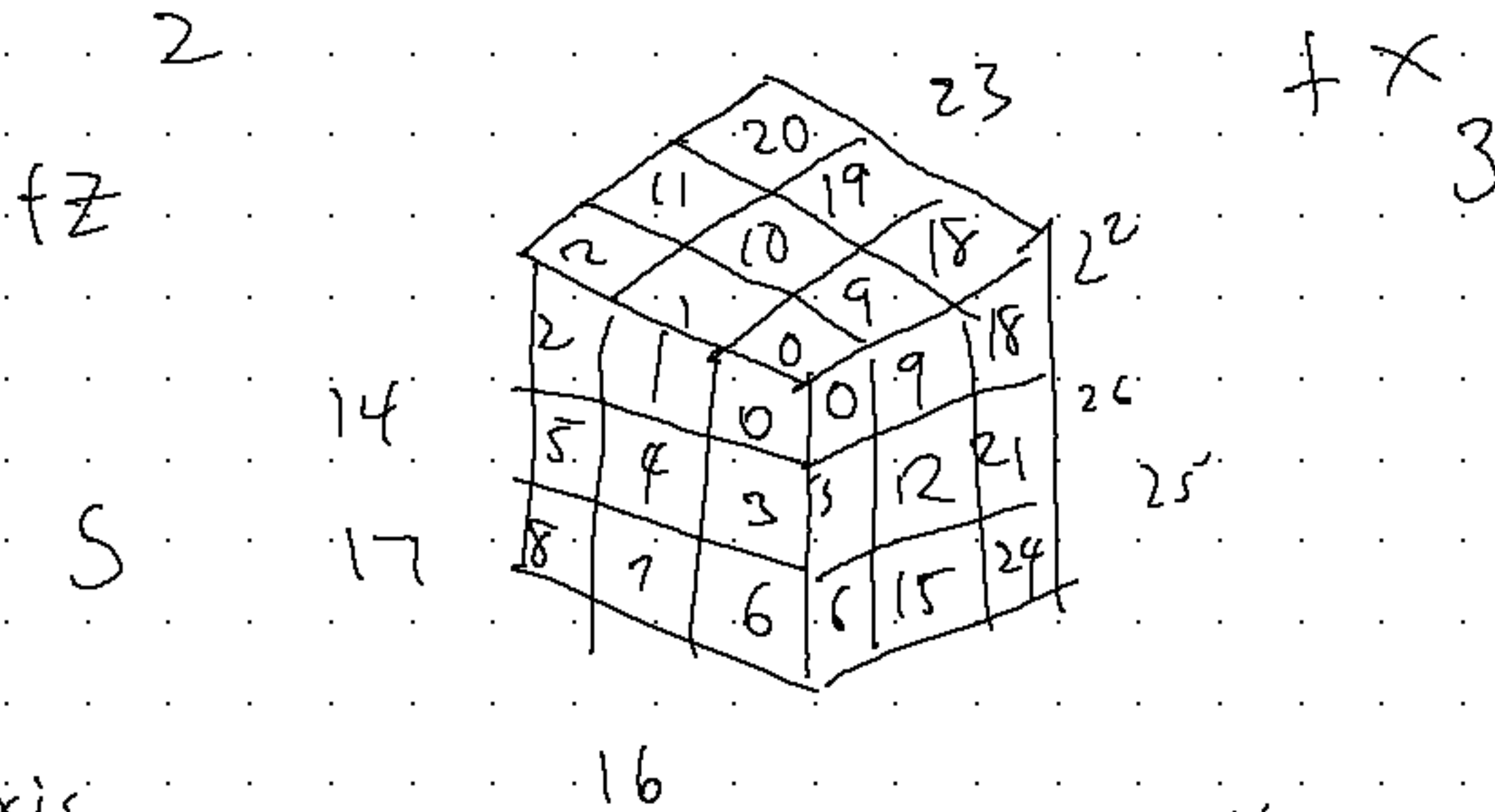
edge:

- 3, 12, 21
- 7, 16, 25
- 5, 14, 23
- 1, 10, 19

Increment: 9

Sandwich rotations all axes

-7 1



z-axis

Rotate 2 2 4 6

0 9 18
3 12 21
6 15 24
side

2 11 20
5 14 23
8 17 26
side

4 y-axis

Rotate 1 2 6

8 17 26
7 16 25
6 15 24
side

2 11 20
1 10 19
0 9 18
side

x-axis

Rotate 3 8 5

2 1 0
5 4 3
8 7 6
side

20 19 18
23 22 21
26 25 24
side

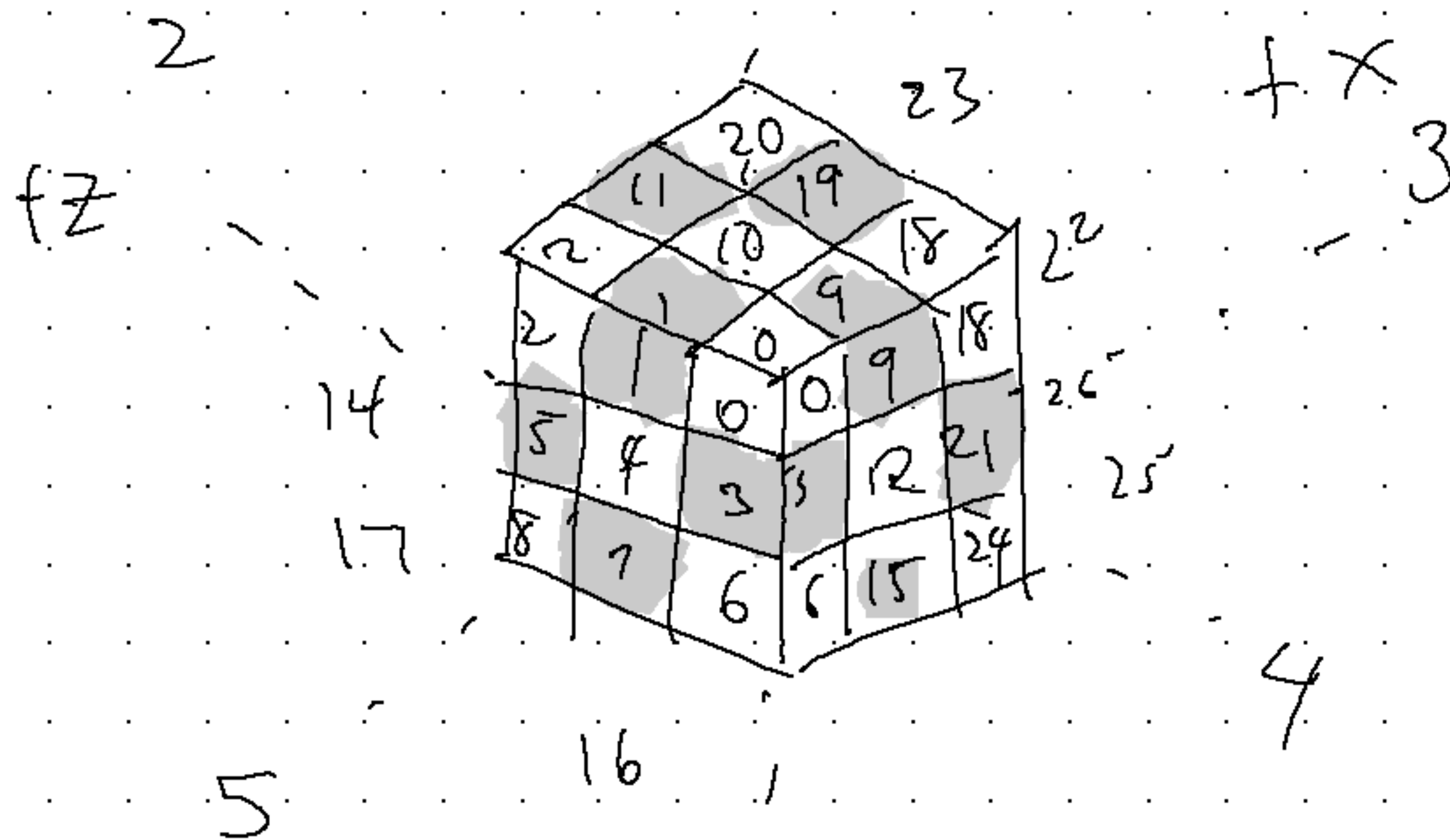
Might have to hard code

~(5)

use seeded technique?
anchor & increment

Edge Turns

-7 1



x-y plane
1 & 25 pairs

2-4

1-5

3-6

7 & 19 pairs

5-6

2-4

1-3

y-z plane

9 & 17 pairs

3-5

2-6

1-4

11 & 15 pairs

1-2

3-5

4-6

x-z plane

3 & 23 pairs

1-6

2-3

4-5

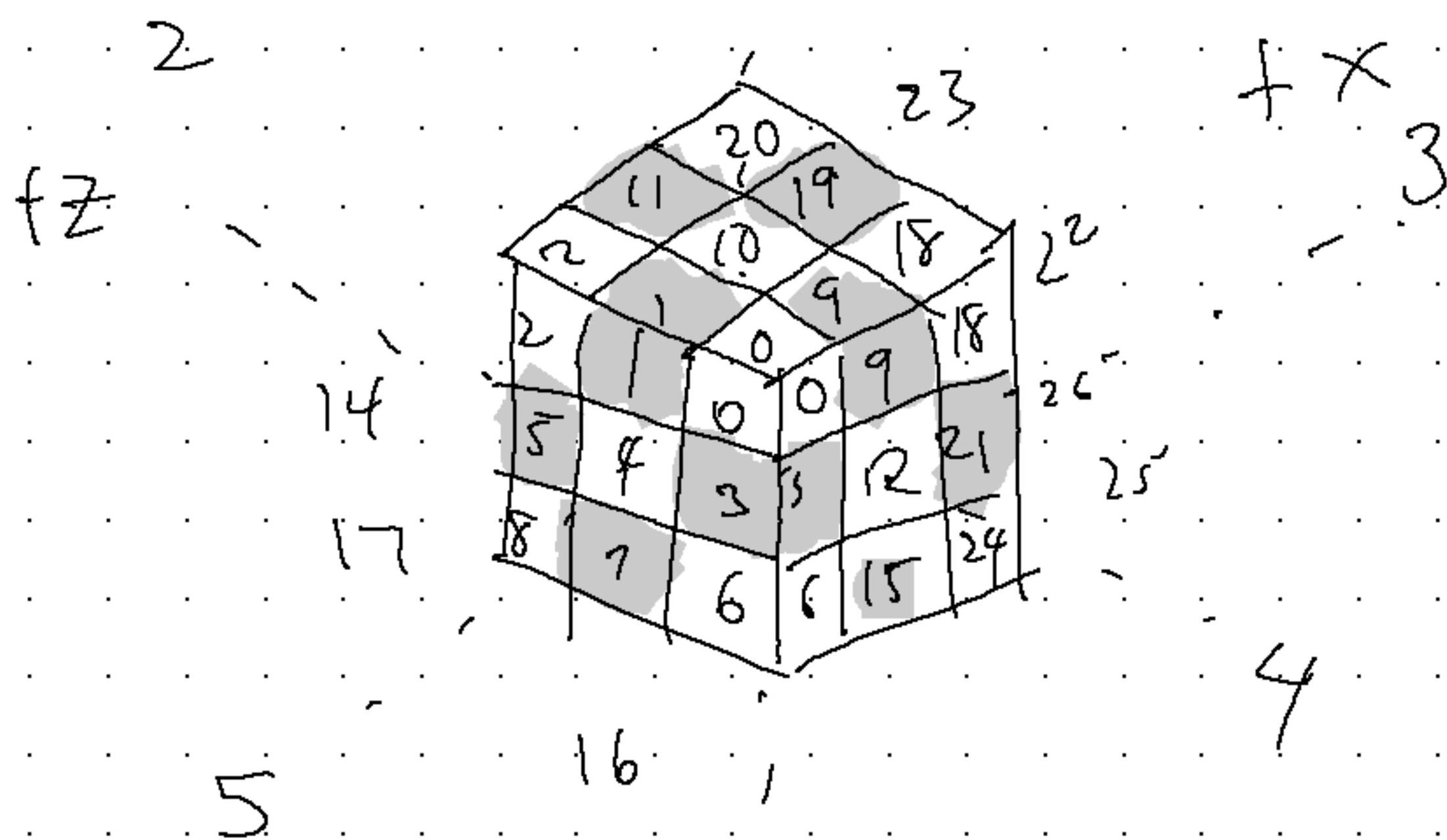
5 & 21 pairs

2-5

1-6

3-4

Edge Turns: Opposites - 7
on y axis



6 [6, 7, 8, 15, 16, 17, 24, 25, 26]

1-6 2-4 3-5

Rotate 1 & 6

8 17 26
7 16 25
6 15 24
side

2 11 20
1 10 19
0 9 18
side

reverse for 5 & 21

+1 [6 → 0
7 → 9
8 → 18
15 → 1
16 → 10
17 → 19
24 → 2
25 → 11
26 → 20] +9

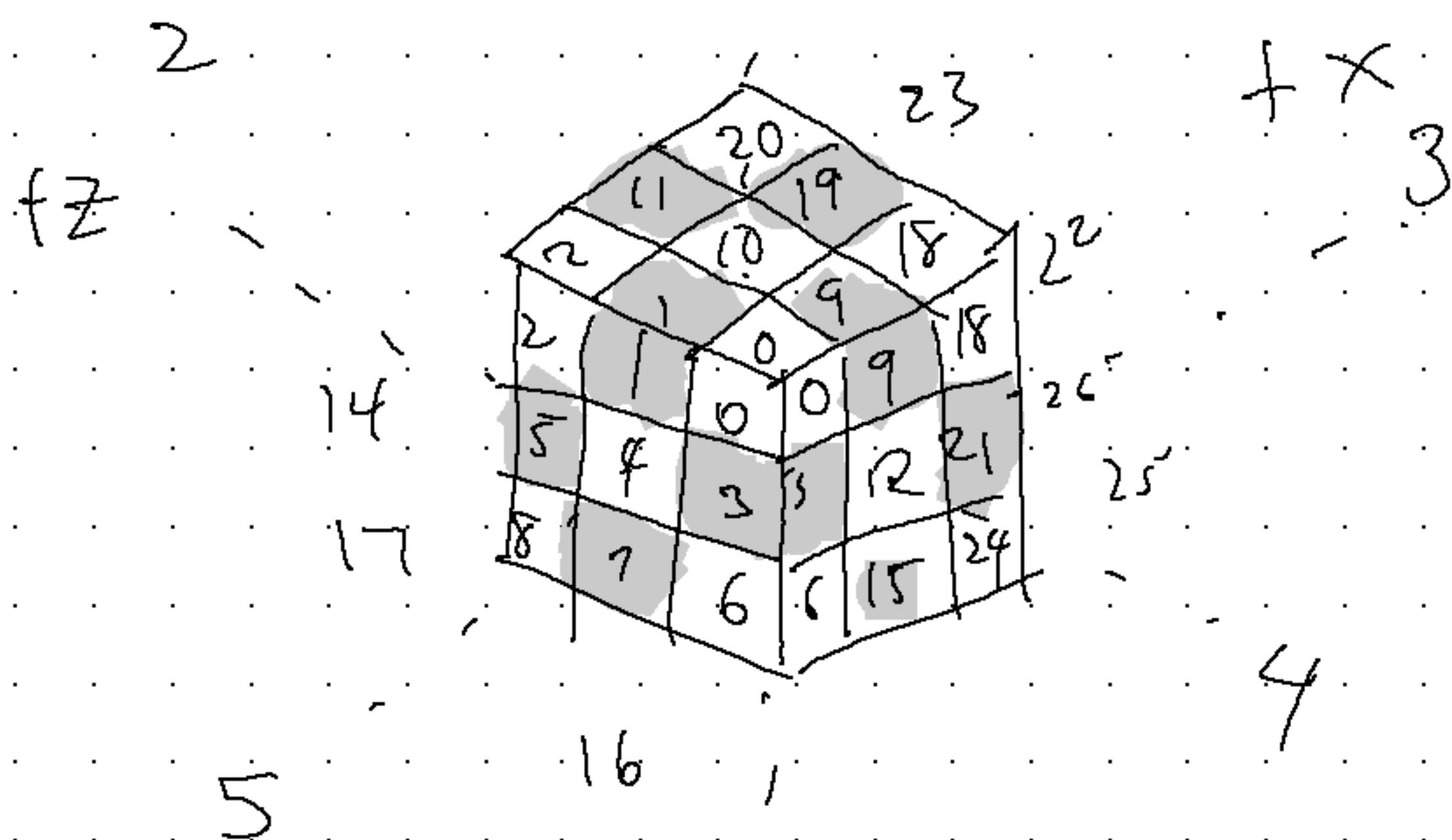
(3 and 23)

(5 and 21) +1 [6 → 20
7 → 11
8 → 2] -9

15 → 19
16 → 10
17 → 1

24 → 18
25 → 9
26 → 0

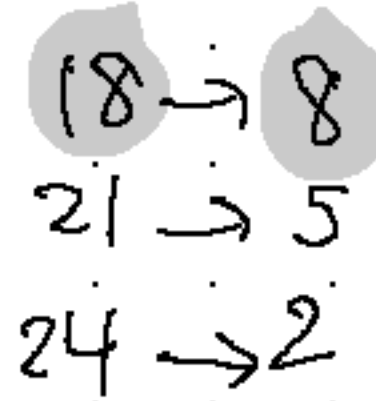
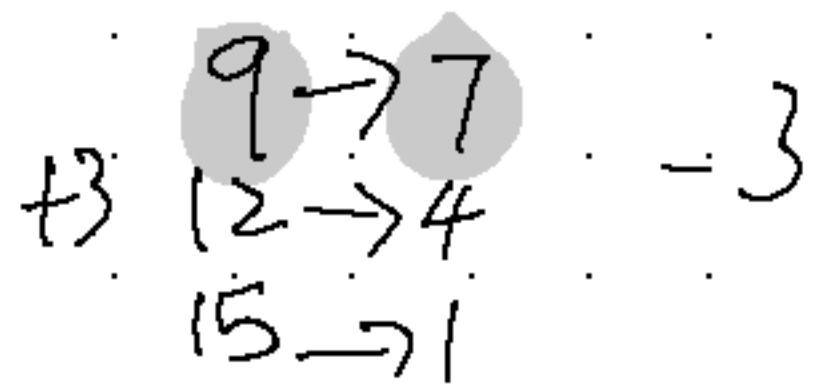
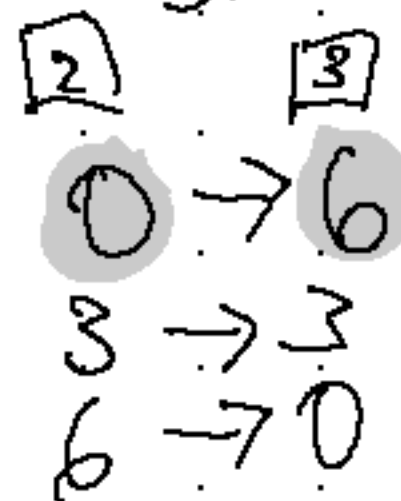
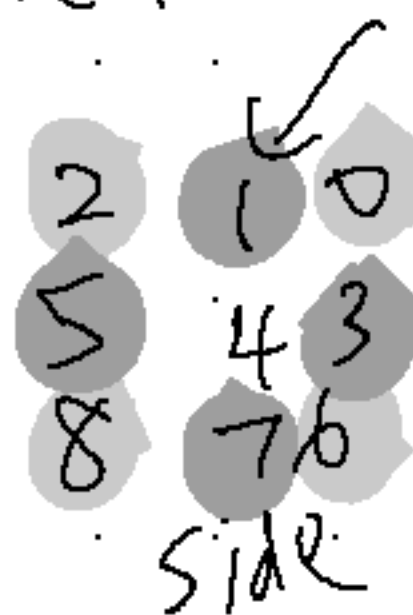
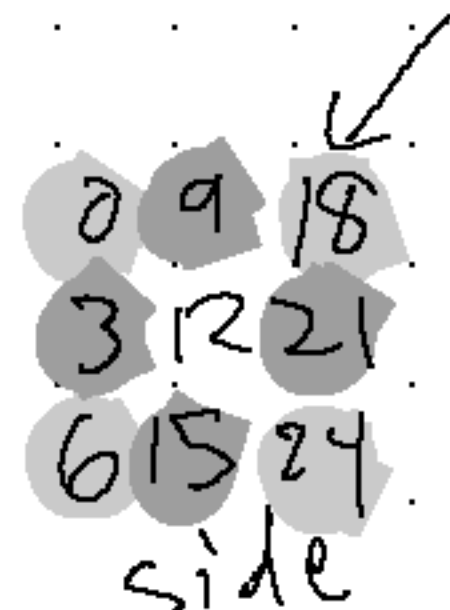
Edge Turn: 3 & 23



for 3 & 23

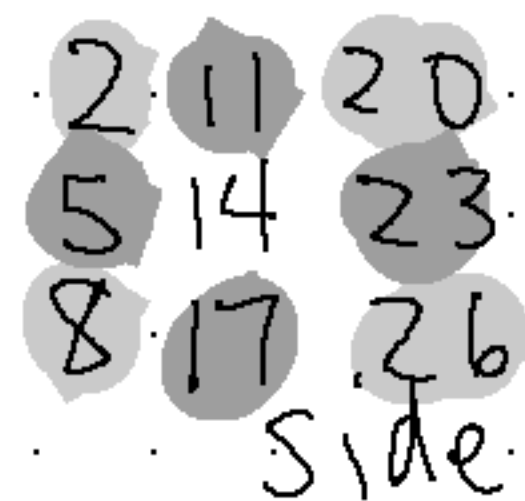
2-3 neighbor

Rotate 2 Rotate 3

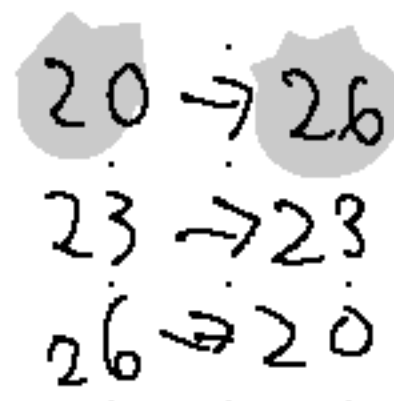
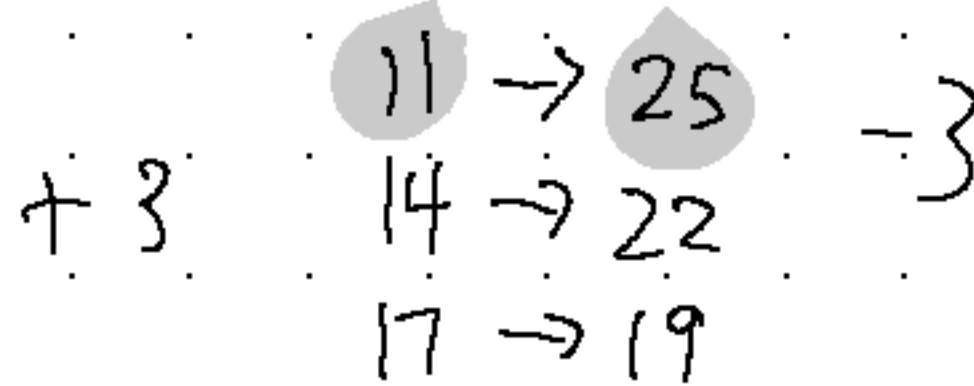
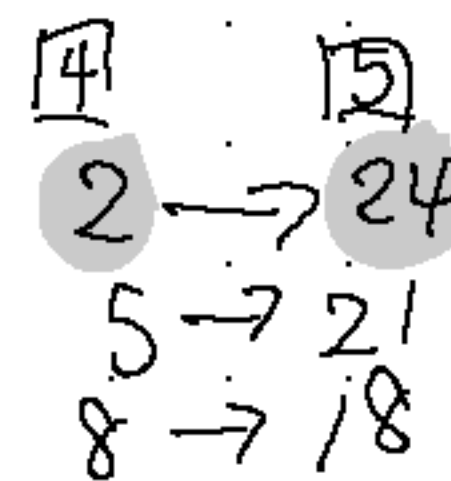
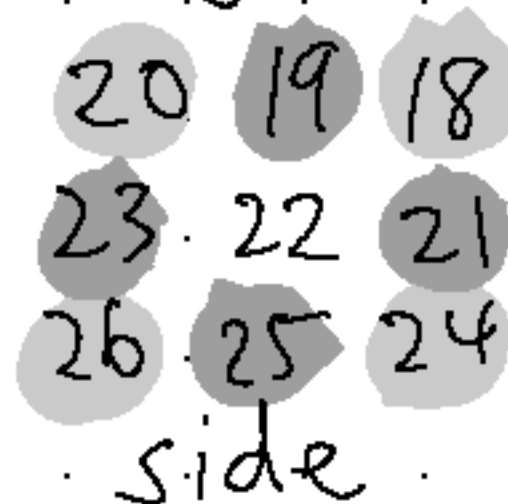


4-5 neighbor

4



5



+X, +Z -X, -Z

self:

2x 4 (x)

(x) 10 (y)

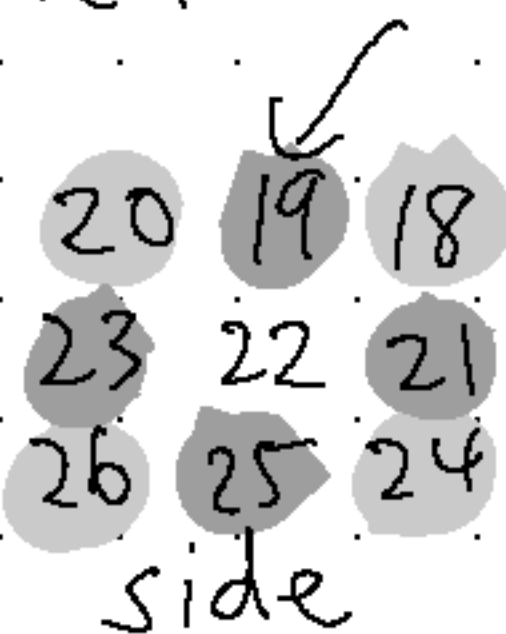
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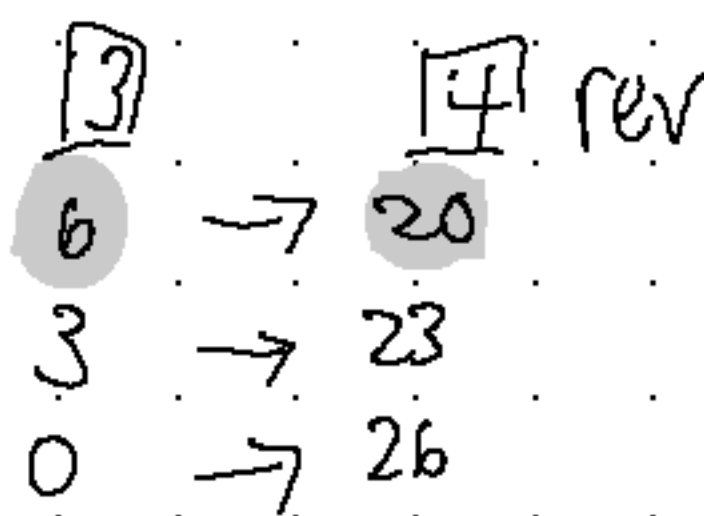
6

3-4 neighbor

Rate 5.



3
2
5
8


$$+z \cdot x, -z + x$$

-3

| | | |
|---|---|----|
| 7 | → | 11 |
| 4 | → | 14 |
| 1 | → | 17 |

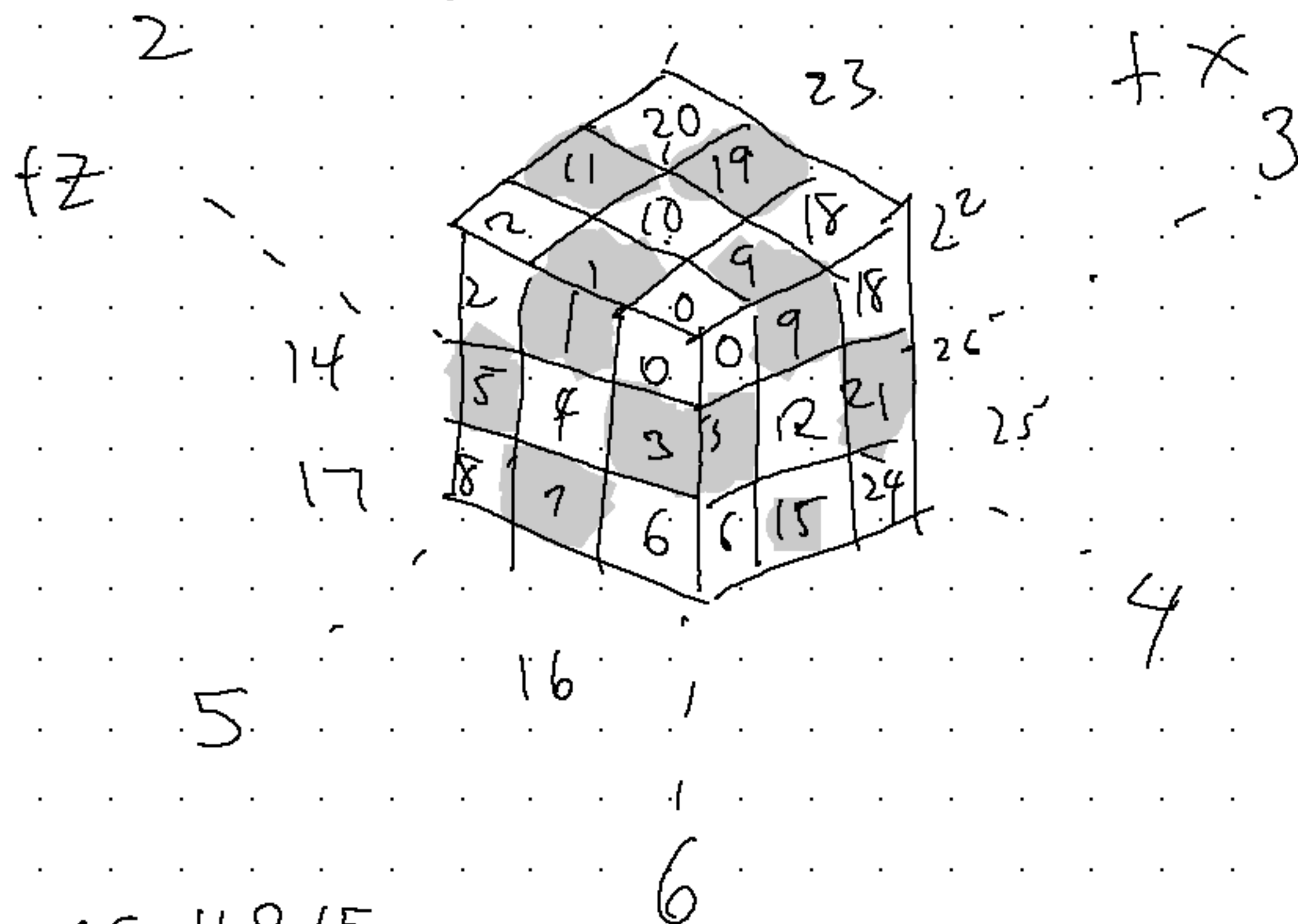
+3

to rotate self:

8 → 2
5 → 5
2 → 8

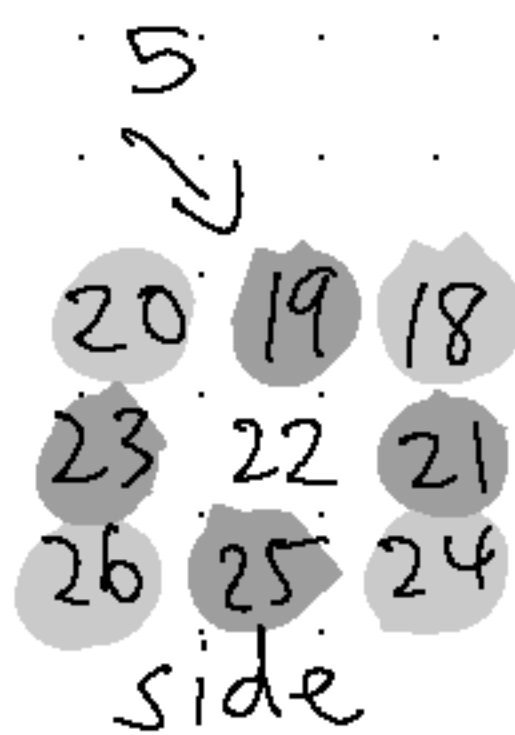
$$2 \times (2 \cdot 2)$$
$$1 \times 10$$

Edge Turn on $-y$!
 X axis
 (Opposites [3 & 5])



9 & 17 or 11 & 15

Rotate 3

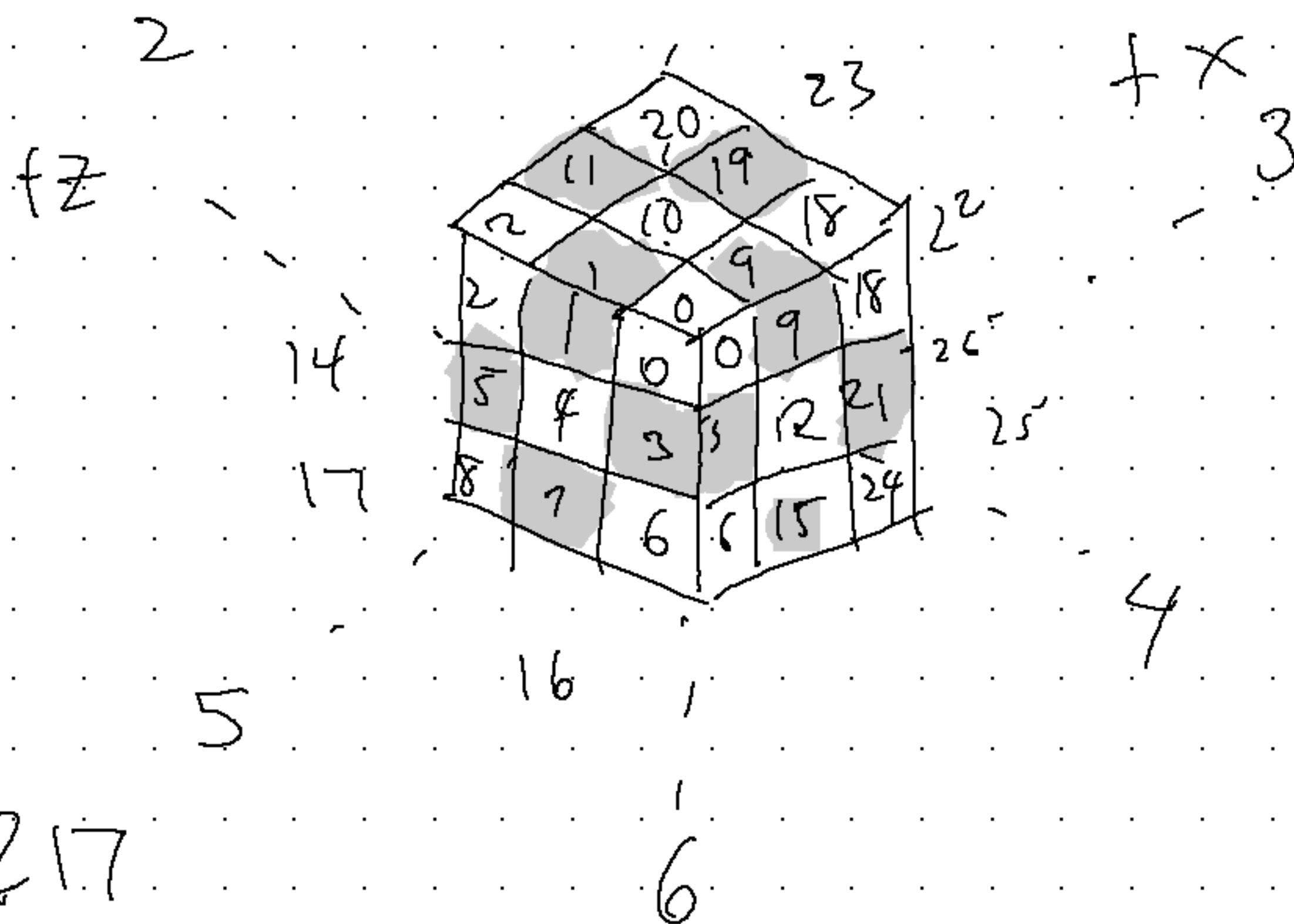


2 5 8

| | |
|-----|------|
| [3] | [5] |
| 6 | → 20 |
| 3 | → 19 |
| 0 | → 18 |
| 7 | → 23 |
| 4 | → 22 |
| 1 | → 21 |
| 8 | → 26 |
| 5 | → 25 |
| 2 | → 24 |

24 25 26
 Reversed [5] rev 1
 24
 25
 26
 21
 22
 23
 18
 19
 20

Edge Turn: 9 & 17 -y !



for 9 & 17

1-4 neighbor

Rotate 1 Rotate 4

8 17 26
7 16 25
6 15 24
side

2 11 20
5 14 23
8 17 26
side

11 14 rev
6 → 20
7 → 23
8 → 26

15 → 11
16 → 14
17 → 17

24 → 2
25 → 5
26 → 8

2-6 neighbor

Rotate 2 Rotate 6

0 9 18
3 12 21
6 15 24
side

2 11 20
1 10 19
0 9 18
side

12 16 add_1
0 → 18
3 → 19
6 → 20

9 → 9
12 → 10
15 → 11

18 → 0
21 → 1
24 → 2

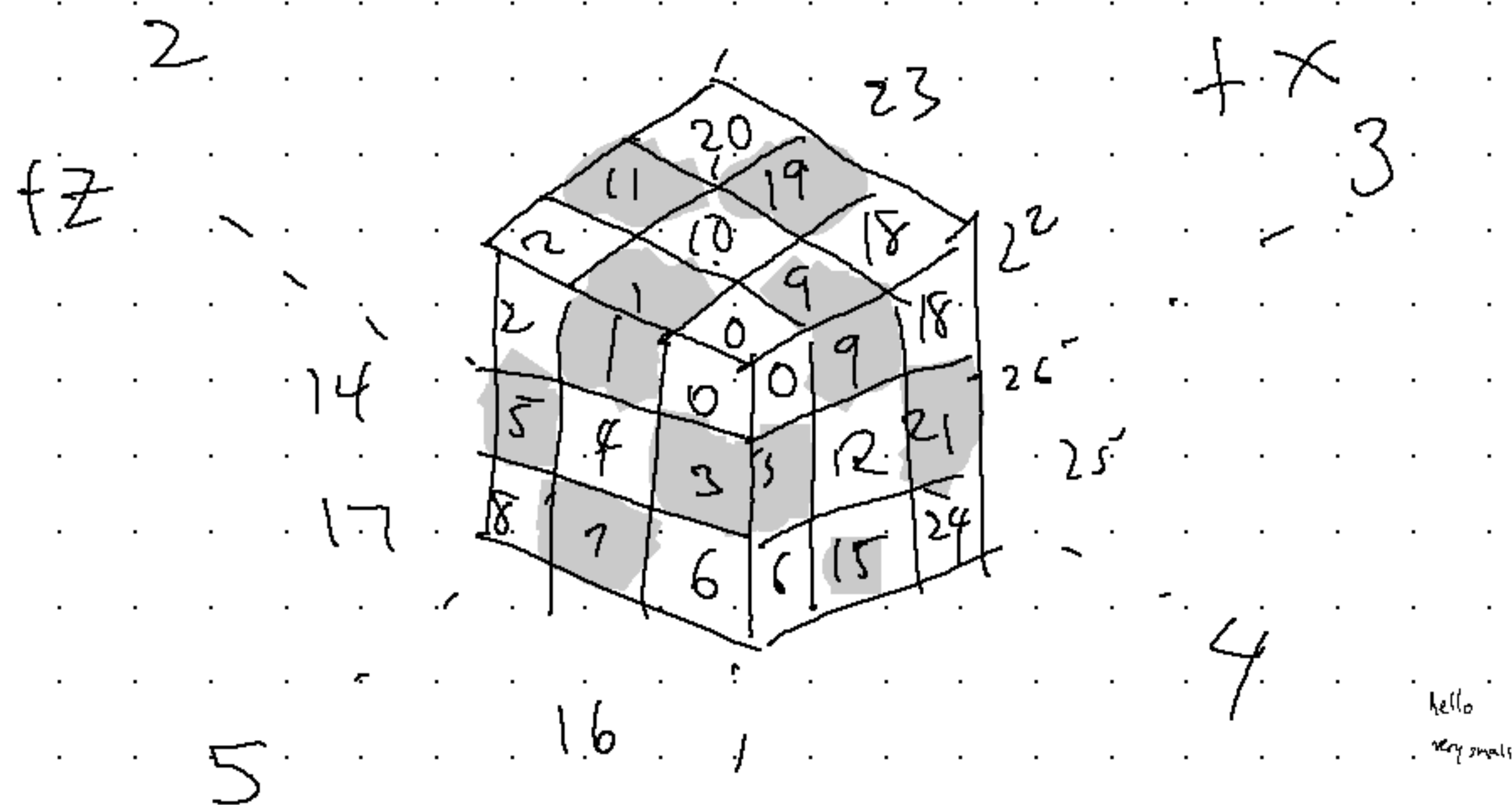
+y+z

+1 self:

2x (0 4)

(x 22 x)

Edge Turn 11 & 15 -y



for 11 & 15

1-2 neighbor

Rotate 1 Rotate 2

| | | |
|---|----|----|
| 8 | 17 | 26 |
| 7 | 16 | 25 |
| 6 | 15 | 24 |

side

| | | |
|---|----|----|
| 0 | 9 | 18 |
| 3 | 12 | 21 |
| 6 | 15 | 24 |

side

1 2 rev dec

| | | |
|---|---|----|
| 6 | → | 24 |
| 7 | → | 21 |
| 8 | → | 18 |

f1 15 → 15 -3

| | | |
|----|---|----|
| 16 | → | 12 |
| 17 | → | 9 |

| | | |
|----|---|---|
| 24 | → | 6 |
| 25 | → | 3 |
| 26 | → | 0 |

4-6 neighbor

Rotate 4 Rotate 6

| | | |
|---|----|----|
| 2 | 11 | 20 |
| 5 | 14 | 23 |
| 8 | 17 | 26 |

side

| | | |
|---|----|----|
| 2 | 11 | 20 |
| 1 | 10 | 19 |
| 0 | 9 | 18 |

side

14 16 rev dec 1

| | | |
|---|---|----|
| 2 | → | 20 |
| 5 | → | 19 |
| 8 | → | 18 |

+3 11 → 11 -1

| | | |
|----|---|----|
| 14 | → | 10 |
| 17 | → | 9 |

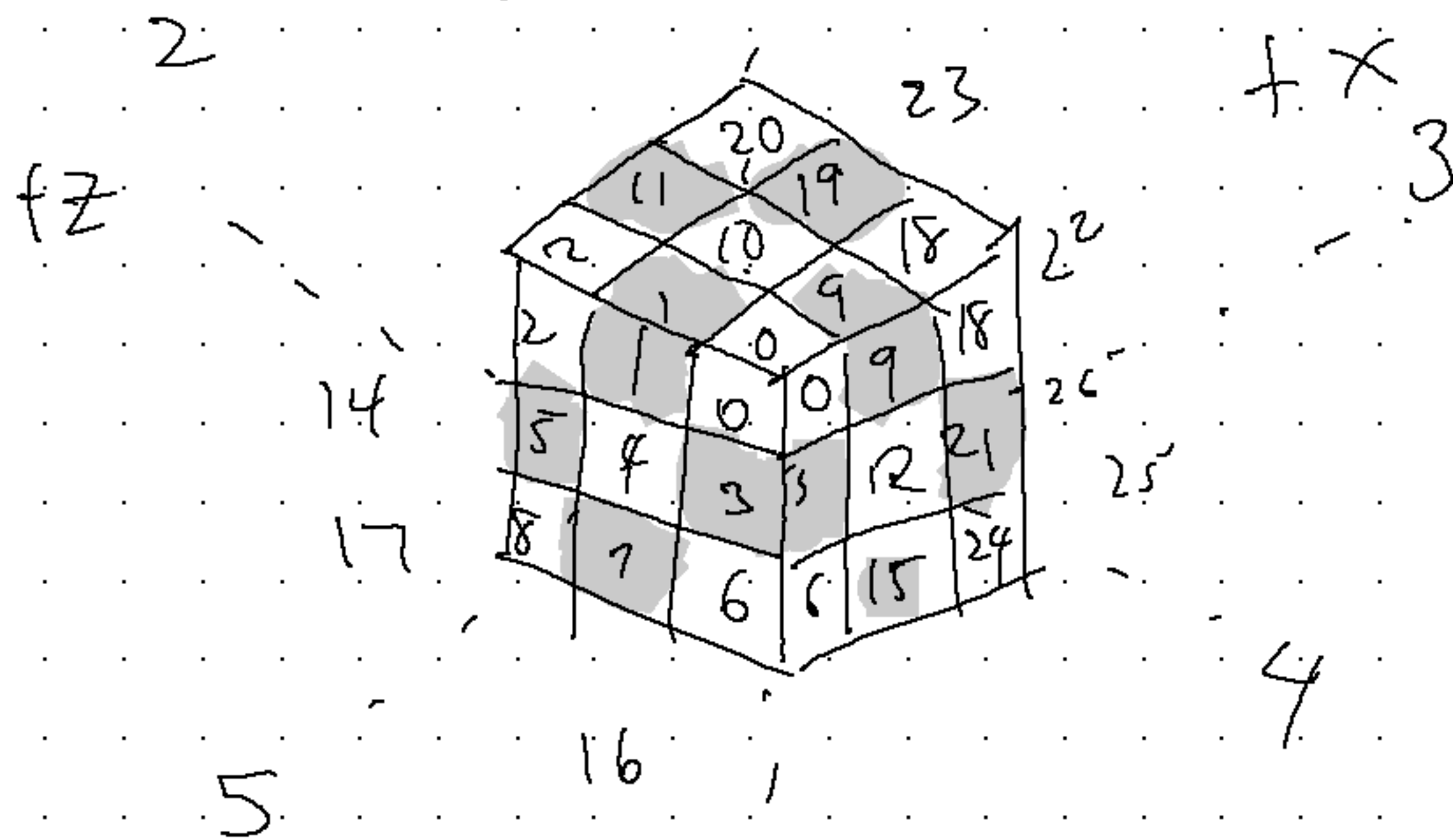
| | | |
|----|---|---|
| 20 | → | 2 |
| 23 | → | 1 |
| 26 | → | 0 |

order matters!

1x22

2x10

Edge Turn on $-y$!
 z axis
 (Opposites [2 & 4])



1 & 25 or 7 & 19

Rotate 2 & 4
 0 9 18
 3 12 21
 6 15 24
 side
 2 11 20
 5 14 23
 8 17 26
 side

2 5 8

[2]
 0 \rightarrow 2
 3 \rightarrow 11
 6 \rightarrow 20

[4] rotated

24 25 26
 [4] rev 1
 26
 17
 8

9 \rightarrow 5
 12 \rightarrow 14
 15 \rightarrow 23
 $+9$

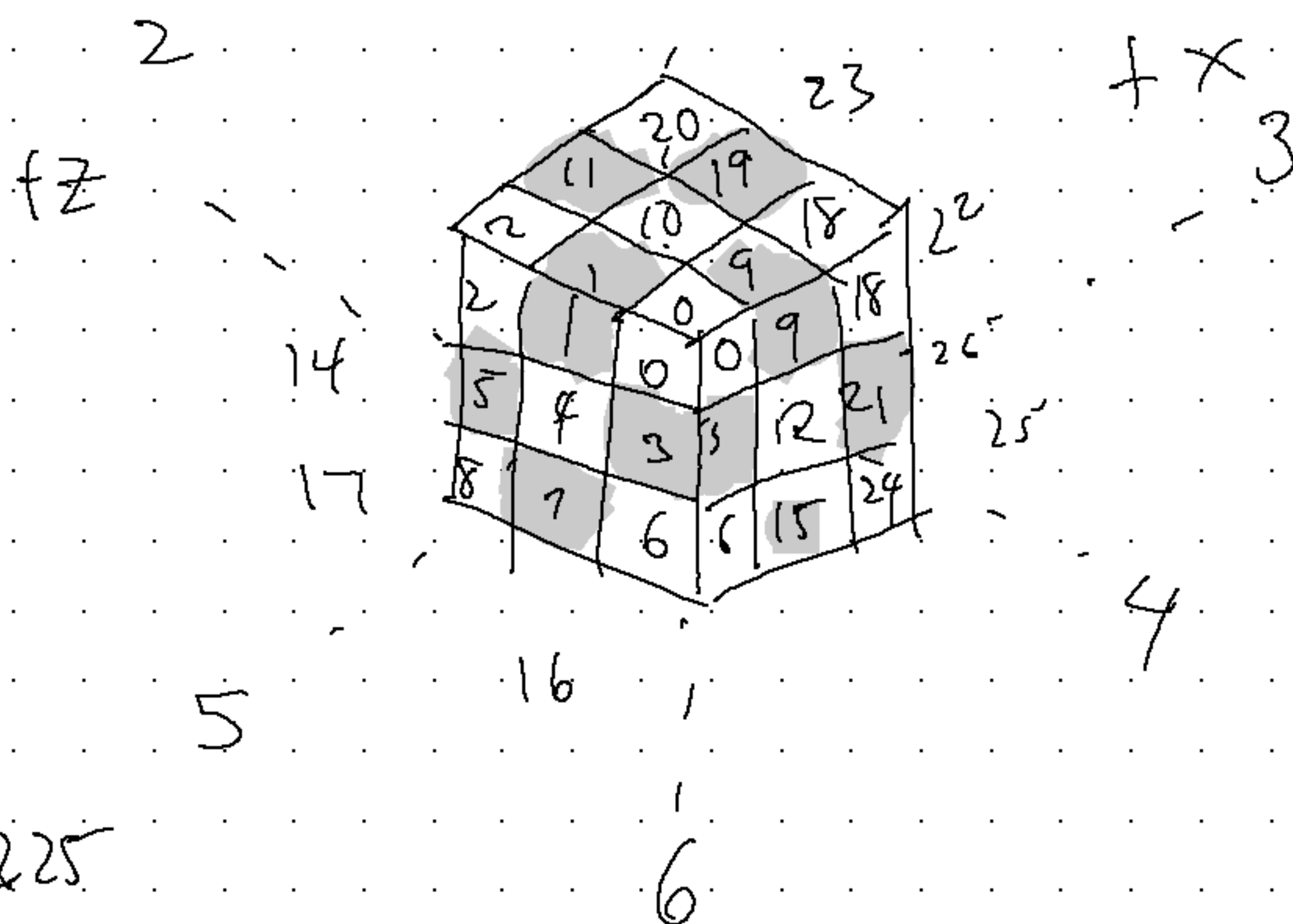
6 15 24
 $\downarrow \downarrow \downarrow$
 20 23 26

23
 14
 5
 -9

18 \rightarrow 8
 21 \rightarrow 17
 24 \rightarrow 26

20
 11
 2

Edge Turn: 1 & 25 -Y



for 1 & 25

1-5 neighbor

Rotate 1 Rotate 5

8 17 26
7 16 25
6 15 24
side

20 19 18
23 22 21
26 25 24
side

6 → 20
7 → 19
8 → 18

15 → 23
16 → 22
17 → 21

24 → 26
25 → 25
26 → 24

3-6 neighbor

Rotate 3 Rotate 6

2 1 0
5 4 3
8 7 6
side

2 11 20
1 10 19
0 9 18
side

3 → 11
6 → 20
0 → 2

7 → 19
4 → 10
1 → 1

8 → 18
5 → 9
2 → 0

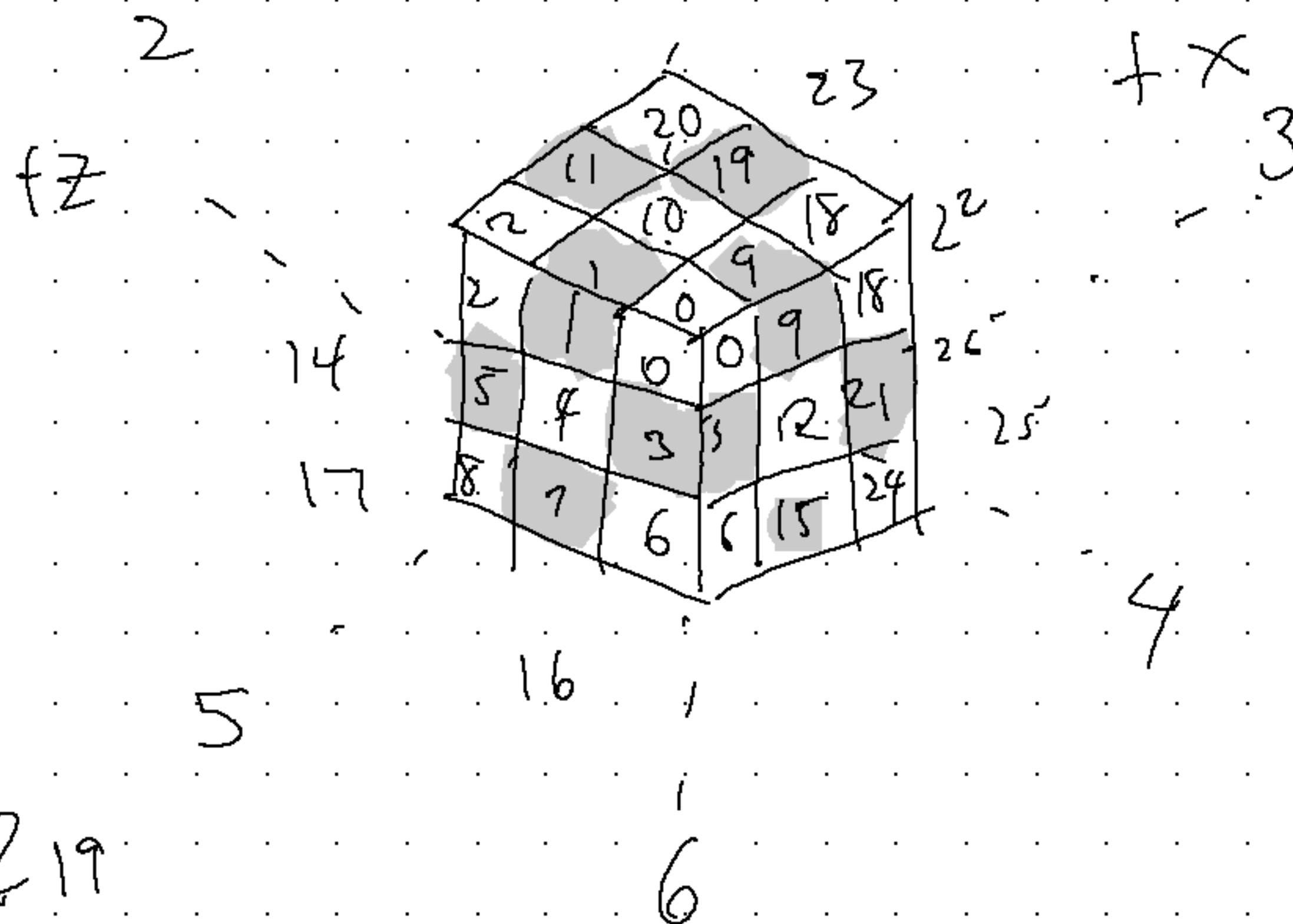
self:

14

10

10

Edge Turn 7 & 19 -Y



for 7 & 19

1-3 neighbor

Rotate 1 Rotate 3

| | | | | | |
|---|----|----|---|---|---|
| 8 | 17 | 26 | 2 | 1 | 0 |
| 7 | 16 | 25 | 5 | 4 | 3 |
| 6 | 15 | 24 | 8 | 7 | 6 |

side side

11 13 rotated

6 → 8

7 → 7

8 → 6

f1

15 → 5

16 → 4

17 → 3

24 → 2

25 → 1

26 → 0

5-6 neighbor

Rotate 5 Rotate 6

| | | | | | |
|----|----|----|---|----|----|
| 20 | 19 | 18 | 2 | 11 | 20 |
| 23 | 22 | 21 | 1 | 10 | 19 |
| 26 | 25 | 24 | 0 | 9 | 18 |

side side

15 16 rev

24 → 2

21 → 11

18 → 20

25 → 1

22 → 10

19 → 19

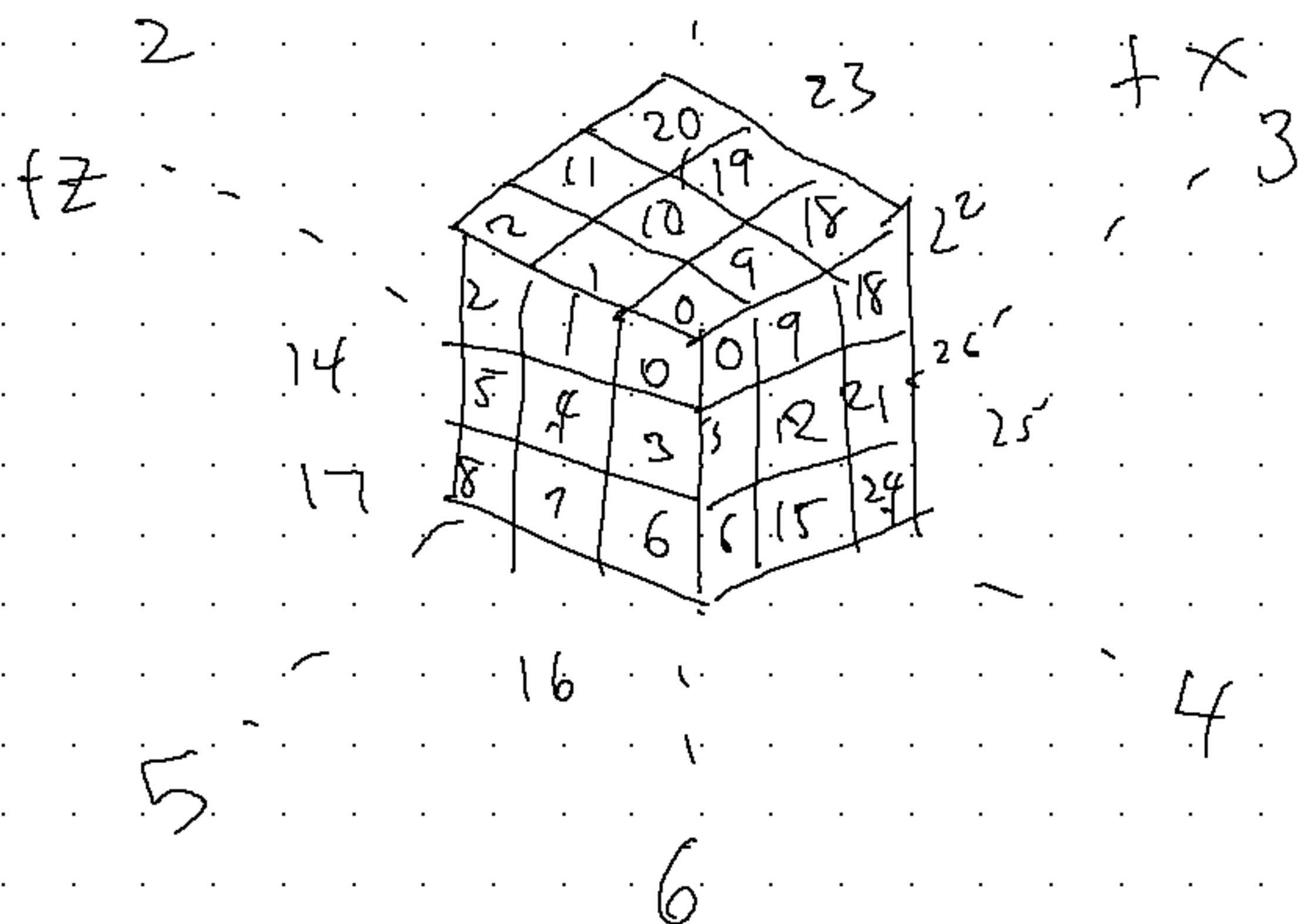
26 → 0

23 → 9

20 → 18

self:

Edge turn



1: 12, 4, 4

9: 4, 10, 10

17: 4, 10, 10

3: 10, 12, 12

11: 4, 12, 12

19: 12, 10, 10

5: 10, 4, 4

13: N/A

21: 10, 4, 4

7: 12, 10, 10

15: 4, 12, 12

23: 10, 12, 12

25: 12, 4, 4

Quaternion Matrix

$$\vec{q} = q_r + q_i \hat{i} + q_j \hat{j} + q_k \hat{k}$$

$$q_r = \cos\left(\frac{\theta}{2}\right)$$

$$q_i = \sin\left(\frac{\theta}{2}\right) \cdot i$$

$$q_j = \sin\left(\frac{\theta}{2}\right) \cdot j$$

$$q_k = \sin\left(\frac{\theta}{2}\right) \cdot k$$

$$s = \|\vec{q}\|^{-2} = \frac{1}{\|\vec{q}\|^2} = \frac{1}{(q_r^2 + q_i^2 + q_j^2 + q_k^2)^2}$$

$$s \text{ should always be } = \frac{1}{q_r^2 + q_i^2 + q_j^2 + q_k^2}$$

$$\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = \begin{bmatrix} a & b & c \\ d & e & f \\ g & h & j \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} ax + by + cz \\ dx + ey + fz \\ gx + hy + jz \end{bmatrix}$$

$$x' = x \cdot (1 - 2s(q_j^2 + q_k^2)) + y \cdot (2s(q_i q_j - q_k q_r)) + z \cdot (2s(q_i q_k + q_j q_r))$$

$$y' = x \cdot (2s(q_i q_j + q_k q_r)) + y \cdot (1 - 2s(q_i^2 + q_k^2)) + z \cdot (2s(q_j q_k - q_i q_r))$$

$$z' = x \cdot (2s(q_i q_k - q_j q_r)) + y \cdot (2s(q_j q_k + q_i q_r)) + z \cdot (1 - 2s(q_i^2 + q_j^2))$$

$$x' = x \cdot (1 - 2s(q_j^2 + q_k^2)) + y \cdot (2s(q_i q_j - q_k q_r)) + z \cdot (2s(q_i q_k + q_j q_r))$$

$$y' = x \cdot (2s(q_i q_j + q_k q_r)) + y \cdot (1 - 2s(q_i^2 + q_k^2)) + z \cdot (2s(q_j q_k - q_i q_r))$$

$$z' = x \cdot (2s(q_i q_k - q_j q_r)) + y \cdot (2s(q_j q_k + q_i q_r)) + z \cdot (1 - 2s(q_i^2 + q_j^2))$$

Replacing s with $|$

$$x' = x \cdot (1 - 2(q_j^2 + q_k^2)) + y \cdot (2(q_i q_j - q_k q_r)) + z \cdot (2(q_i q_k + q_j q_r))$$

$$y' = x \cdot (2(q_i q_j + q_k q_r)) + y \cdot (1 - 2(q_i^2 + q_k^2)) + z \cdot (2(q_j q_k - q_i q_r))$$

$$z' = x \cdot (2(q_i q_k - q_j q_r)) + y \cdot (2(q_j q_k + q_i q_r)) + z \cdot (1 - 2(q_i^2 + q_j^2))$$

$$\vec{q} = q_r \hat{i} + q_i \hat{j} + q_j \hat{k} + q_k \hat{l}$$

$$q_r = q[0]$$

$$q_i = q[1]$$

$$q_j = q[2]$$

$$q_k = q[3]$$

$$q_r = \cos\left(\frac{\theta}{2}\right)$$

$$q_i = \sin\left(\frac{\theta}{2}\right) \cdot i$$

$$q_j = \sin\left(\frac{\theta}{2}\right) \cdot j$$

$$q_k = \sin\left(\frac{\theta}{2}\right) \cdot k$$

Types

$+x$ $+y$ $+z$

$-x$ $-y$ $-z$

1. $+x$ $+y$ $+y$ $+z$ ~~$+z$ $-z$~~

2. $+x$ $+z$ $+y$ $-x$ $-x$ $-y$

~~$+y$ $-y$~~ $-x$ $-z$

3. ~~$+x$ $-x$~~ $+y$ $-z$ is, $-y$ $-z$

4. $+x$ $-y$ $+z$ $-x$

5. $+x$ $-z$ 4. $+z$ $-y$

$$6C2 = 15$$

$$\vec{u} = \begin{matrix} x & y & z \\ \langle a, b, c \rangle \end{matrix} \quad \vec{v} = \begin{matrix} x & y & z \\ \langle d, e, f \rangle \end{matrix}$$

$$\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ a & b & c \\ d & e & f \end{vmatrix} = \begin{vmatrix} \hat{i} & \hat{j} \\ a & b \\ d & e \end{vmatrix}$$

$$\hat{i} \cdot b \cdot f + \hat{j} \cdot c \cdot d + \hat{k} \cdot a \cdot e - d \cdot b \cdot \hat{k} - e \cdot c \cdot \hat{i} - f \cdot a \cdot \hat{j}$$

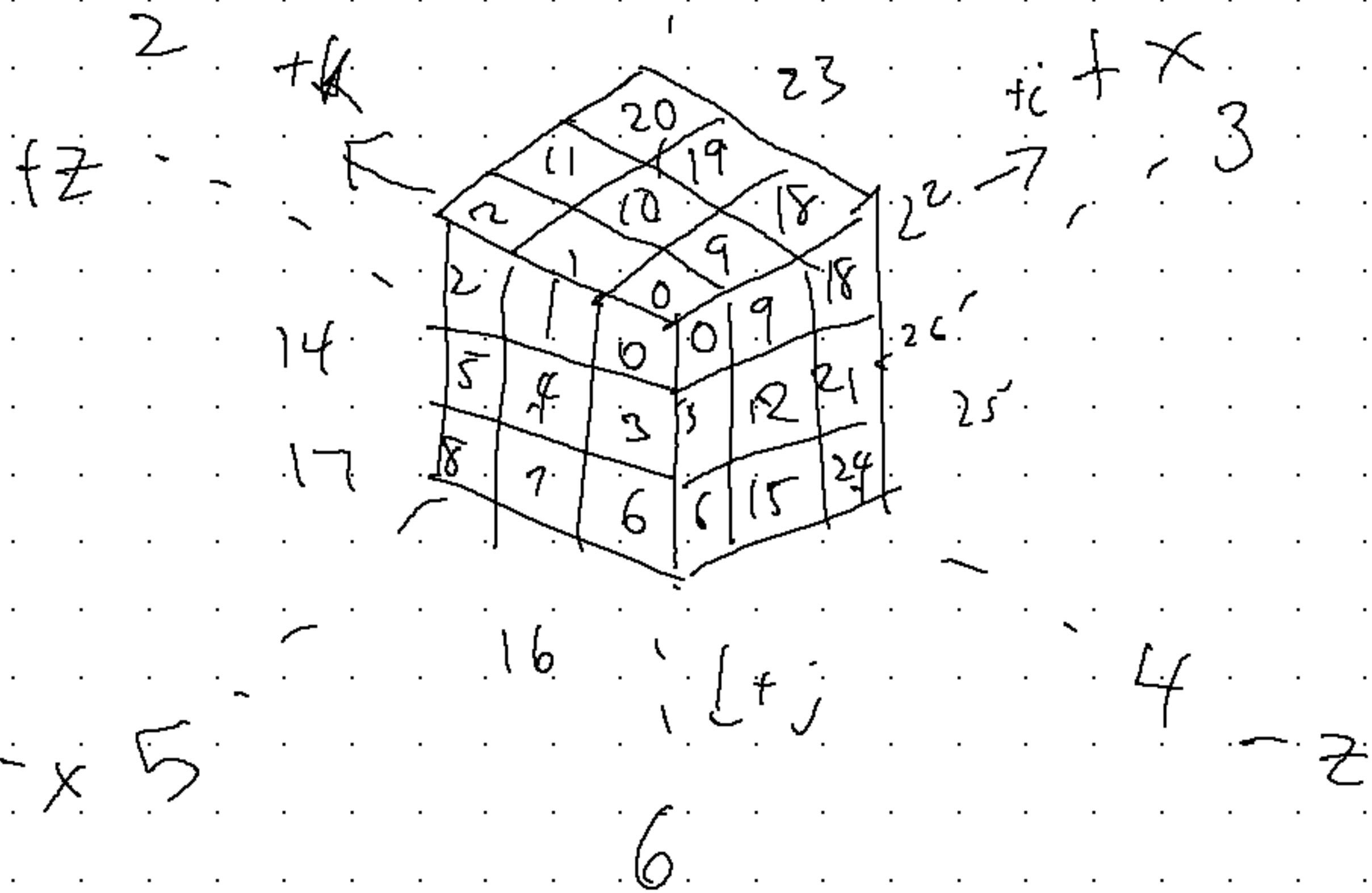
$$i = bf - e \cdot c$$

$$j = c \cdot d - f \cdot a$$

$$k = a \cdot e - d \cdot b$$

Axis of rotation

-y
1
1
1



- 0: -x, -y, -z
- 1: -x, -y
- 2: -x, -y, +z
- 3: -x, -z
- 4: -x
- 5: -x, +z
- 6: -x, +y, -z
- 7: -x, +y
- 8: -x, +y, +z
- 9: -y, -z
- 10: -y
- 11: -y, +z
- 12: -z
- 13: N/A
- 14: +z
- 15: +y, -z
- 16: +y
- 17: +y, +z

- 18: +x, -y, -z
- 19: +x, -y
- 20: +x, -y, +z
- 21: +x, -z
- 22: +x
- 23: +x, +z
- 24: +x, +y, -z
- 25: +x, +y
- 26: +x, +y, +z



