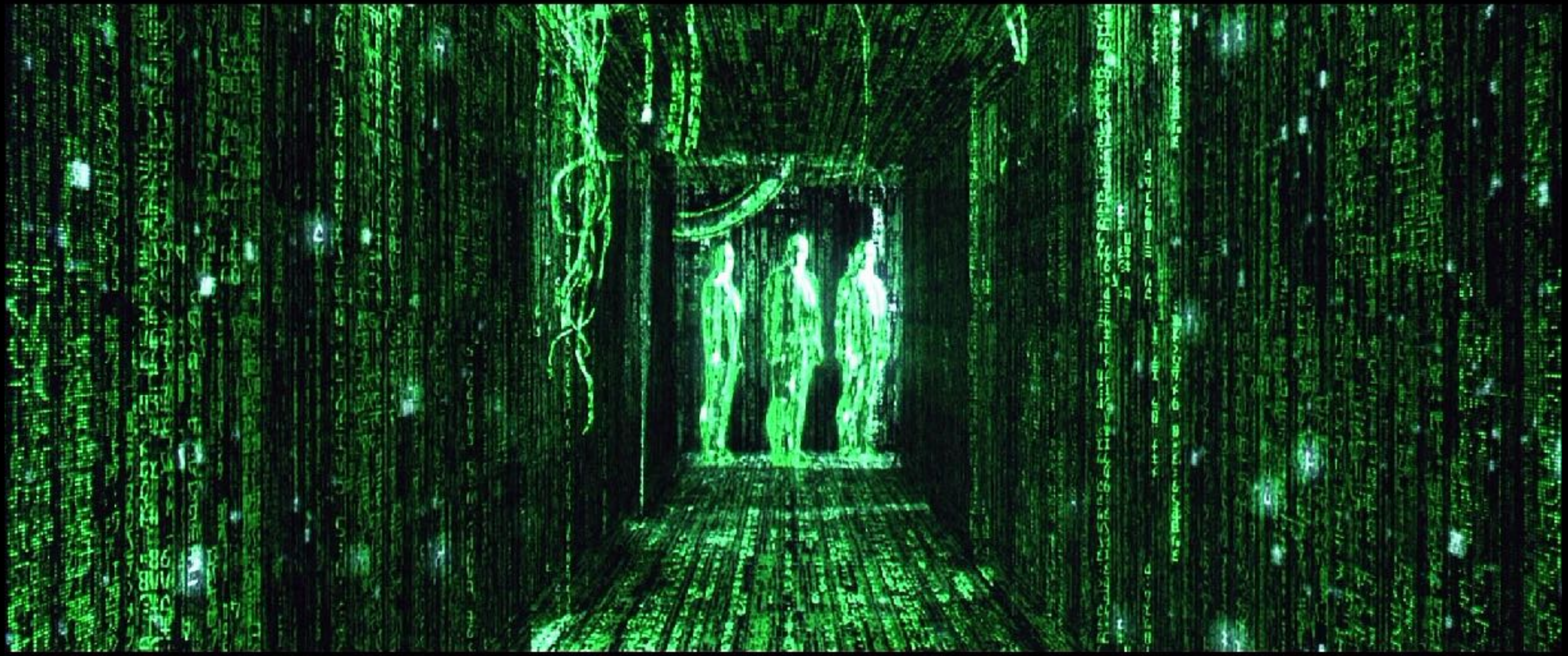
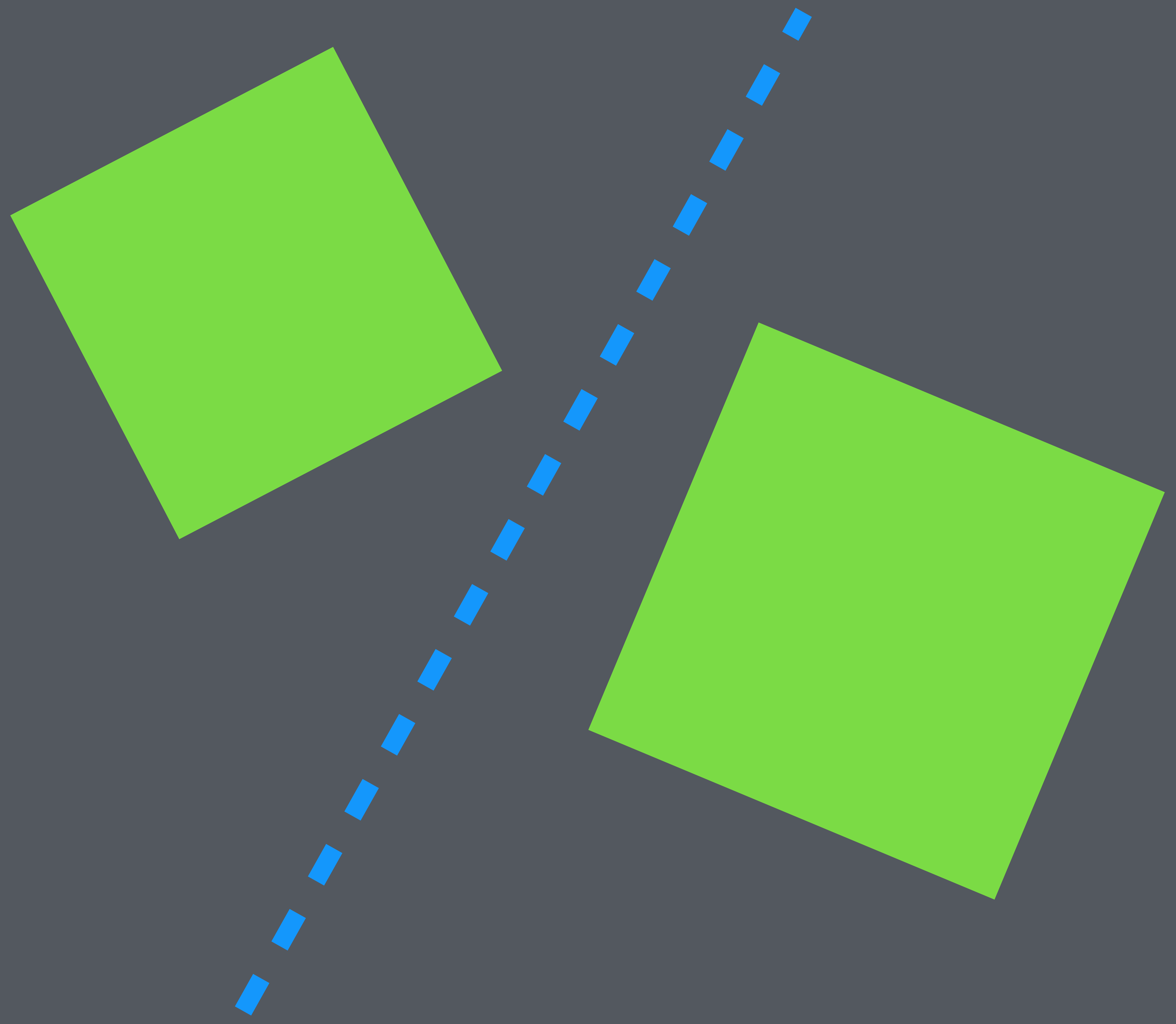
Matrix transformations.

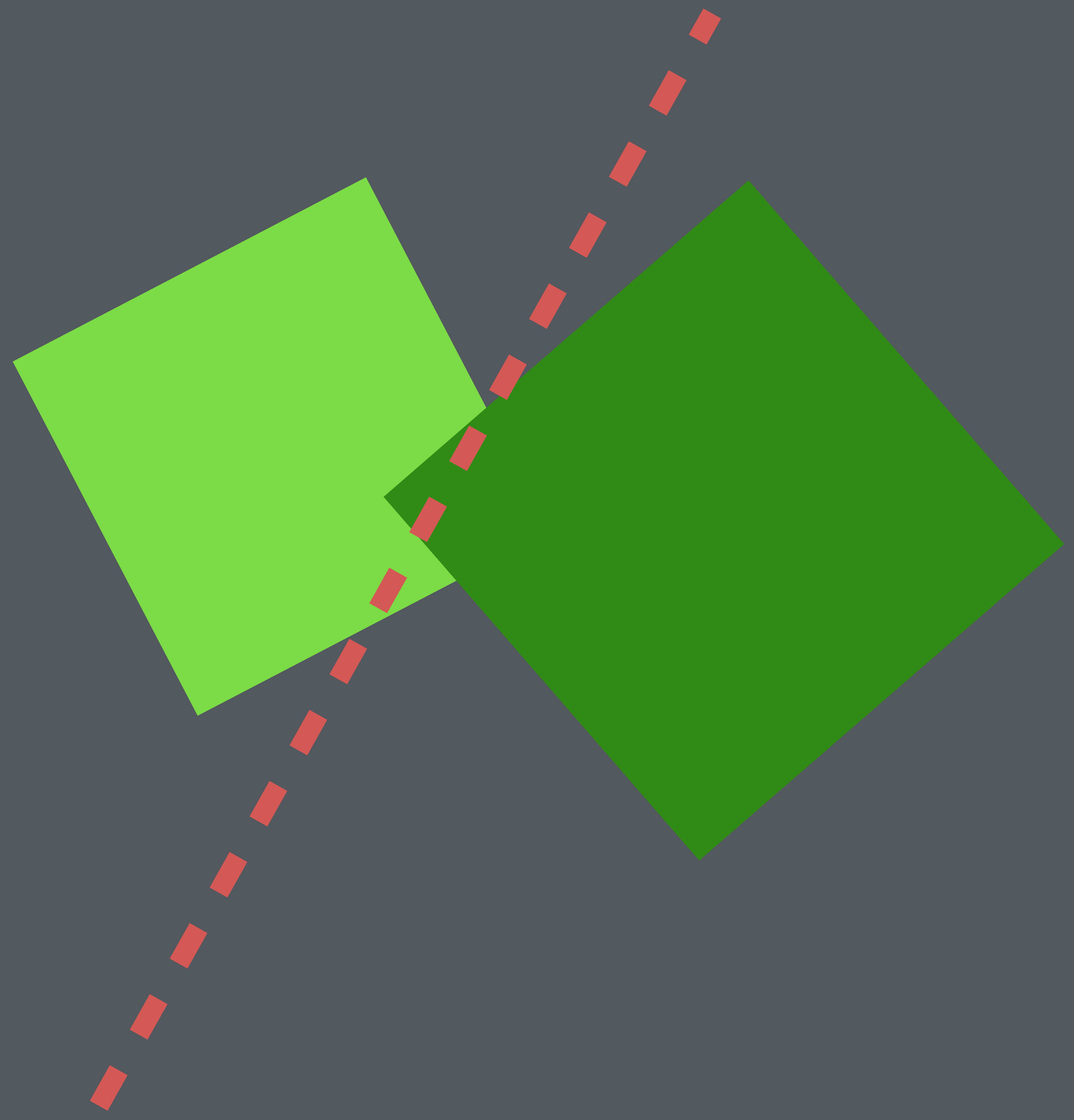
Part 3



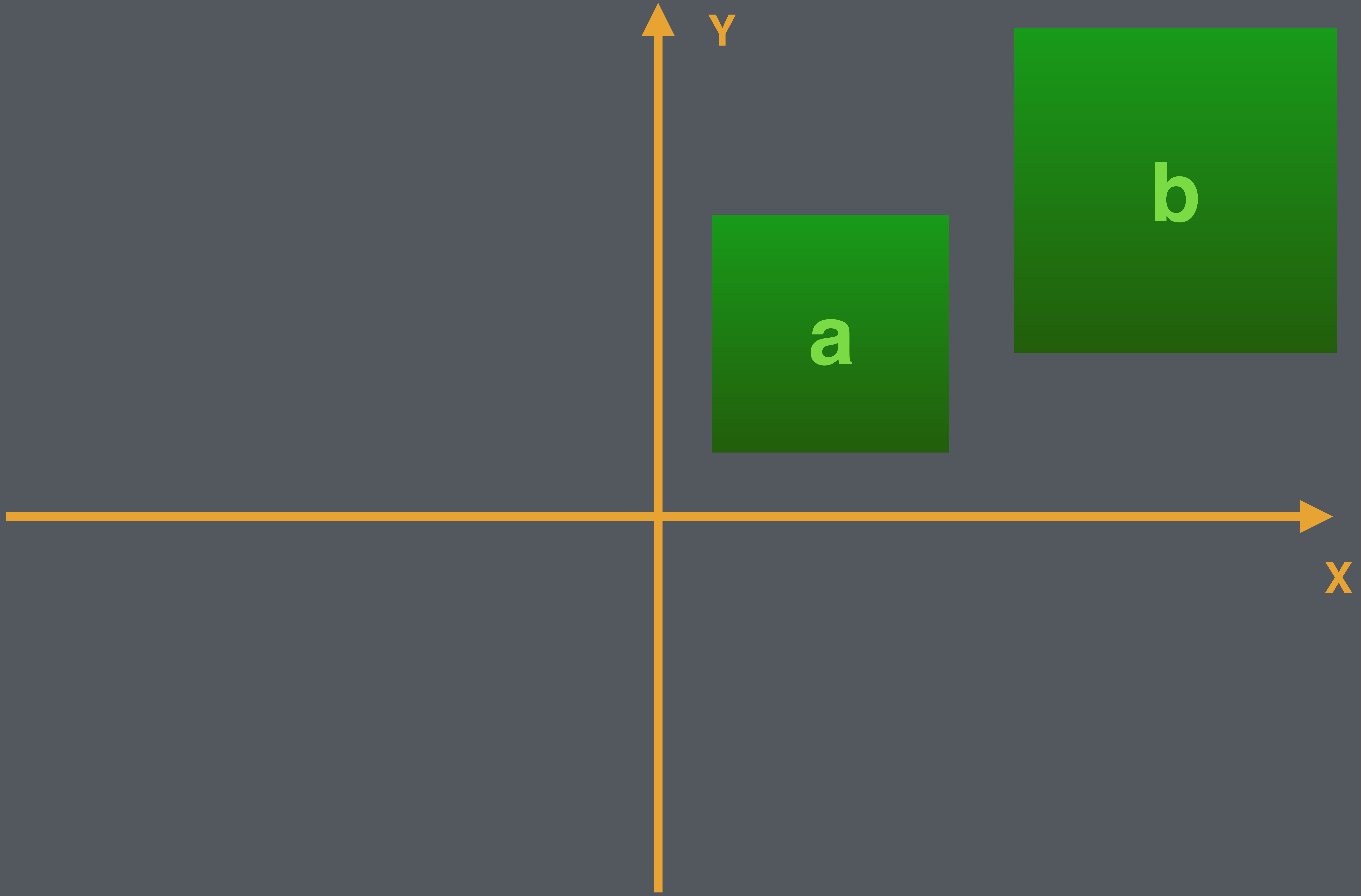
Complex collision

Separating axis theorem.





An axis-aligned example.

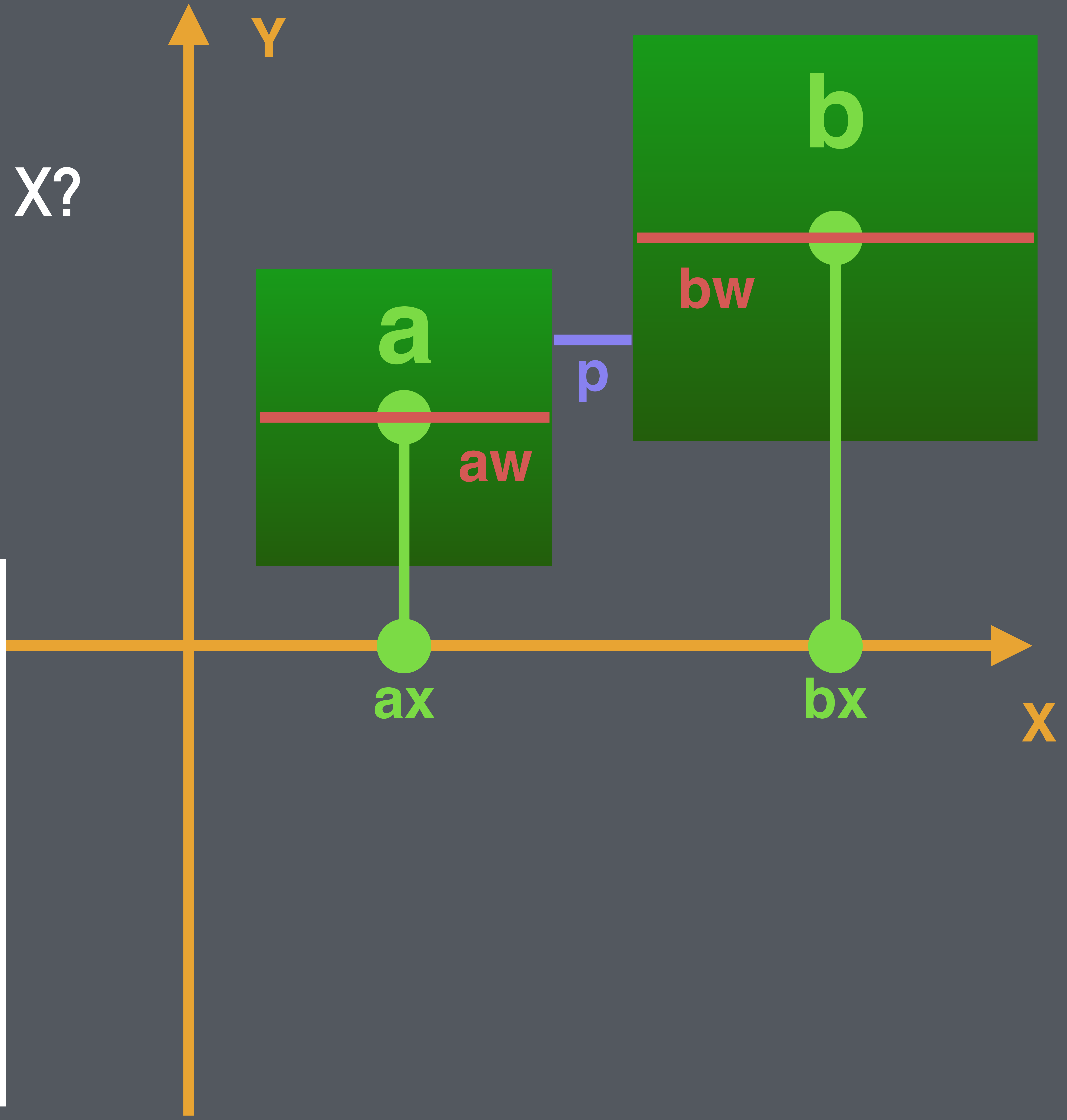


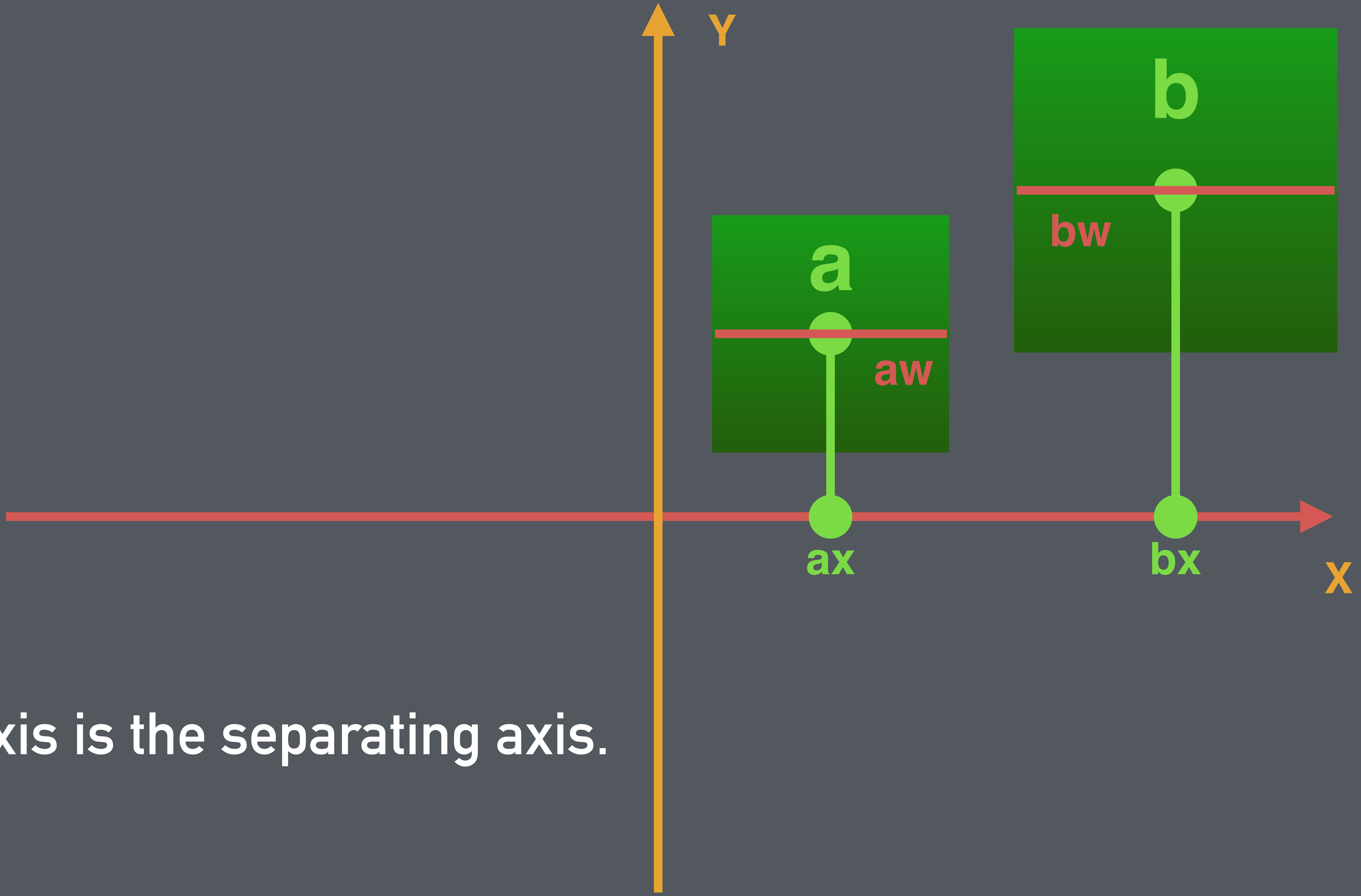
Y
b
a
X

How far away are they on X?

$$p = |x_1 - x_2| - \frac{w_1 + w_2}{2}$$

if p >= 0, we are not colliding!



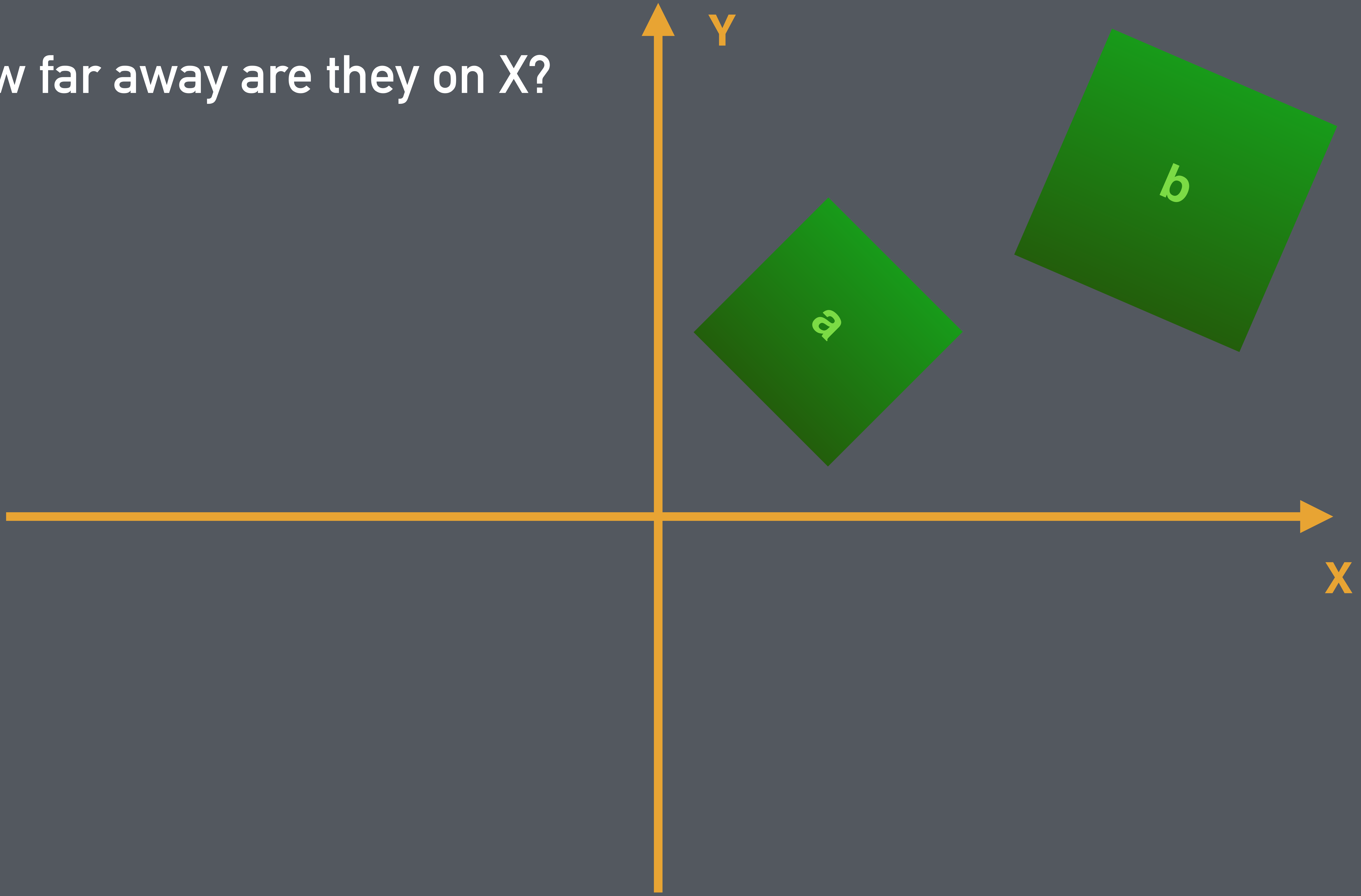


X axis is the separating axis.

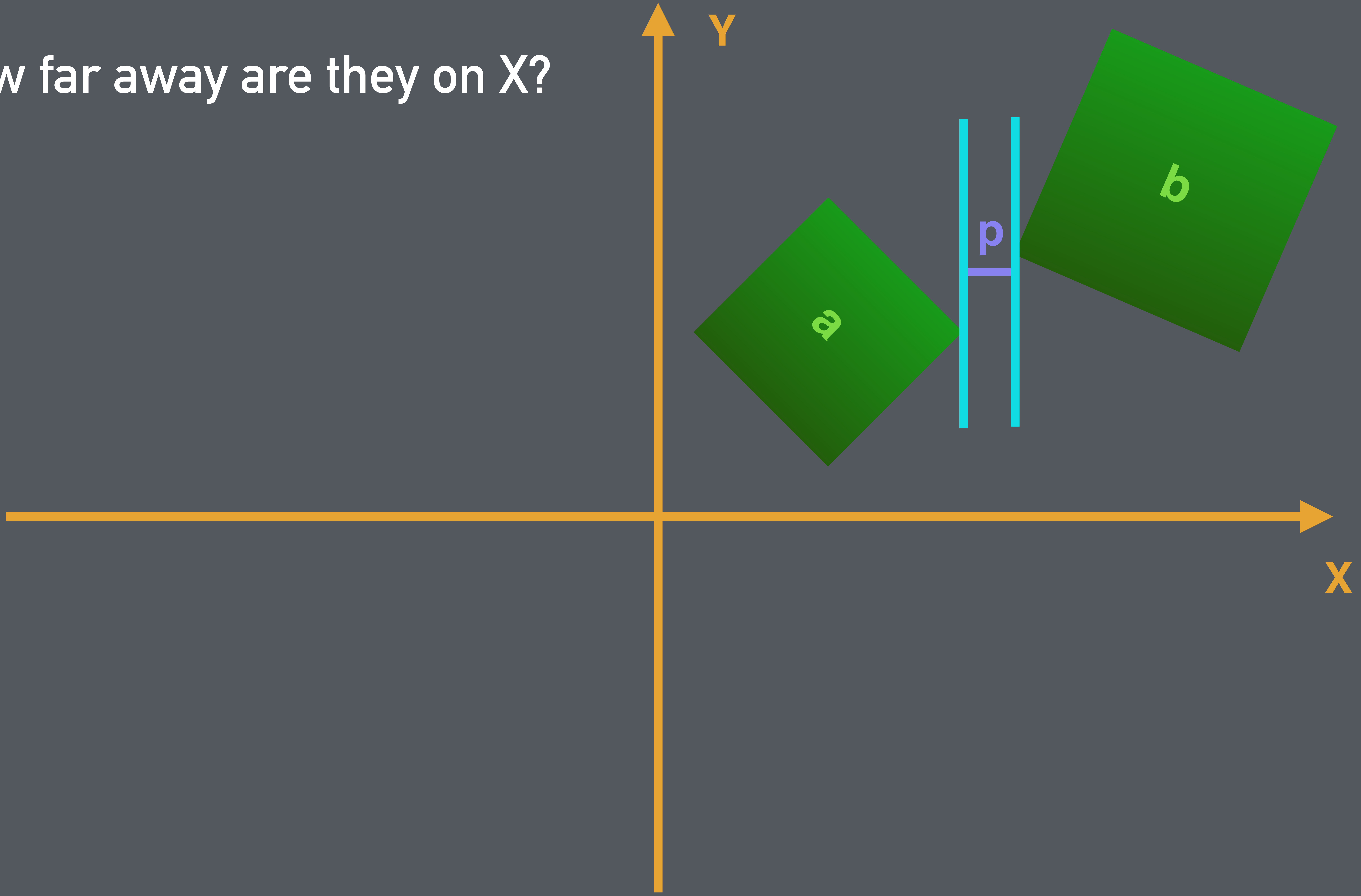
Do the same on the Y-axis with box heights if X is not separating.

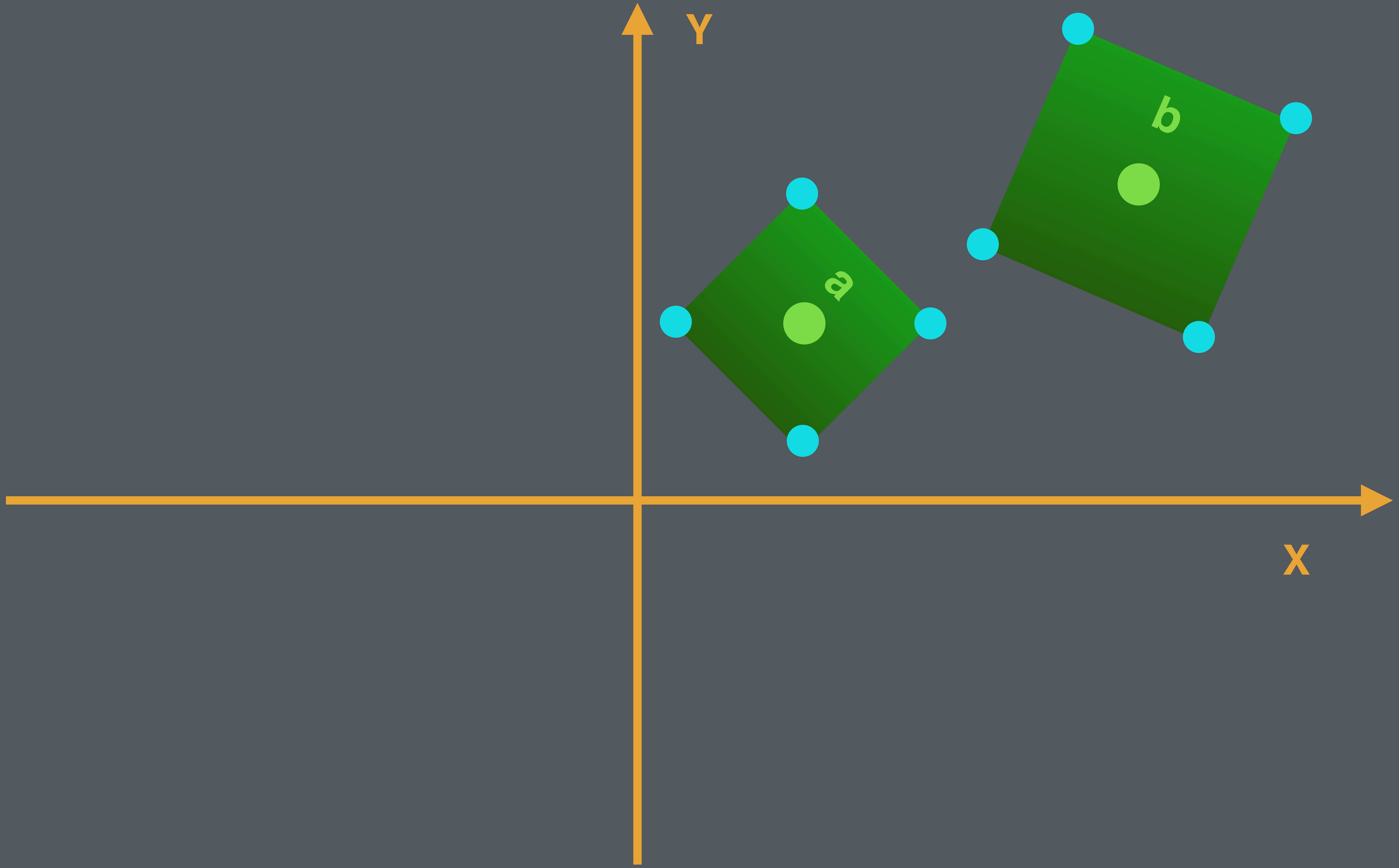
If neither axis is separating, we have a collision!

How far away are they on X?



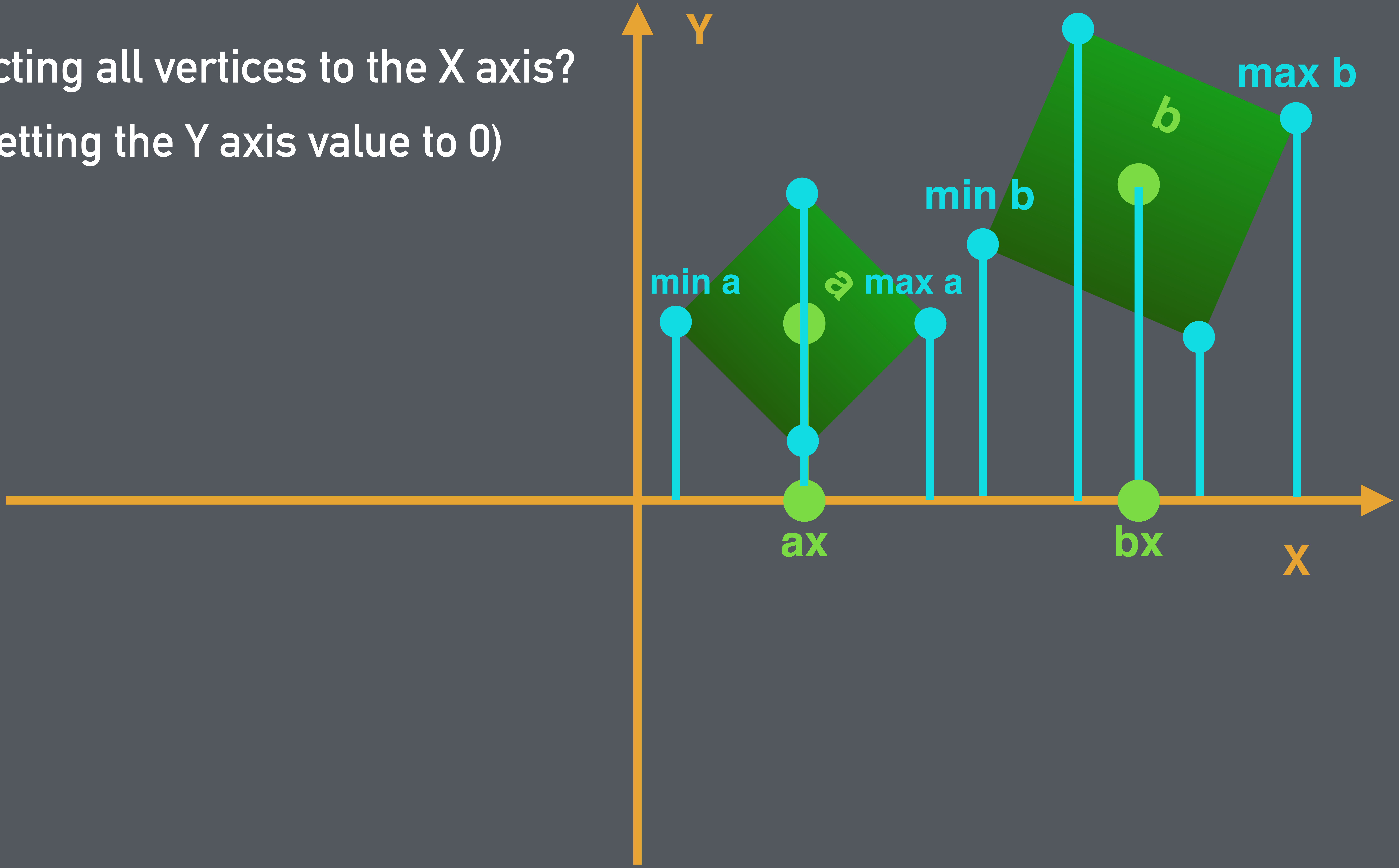
How far away are they on X?



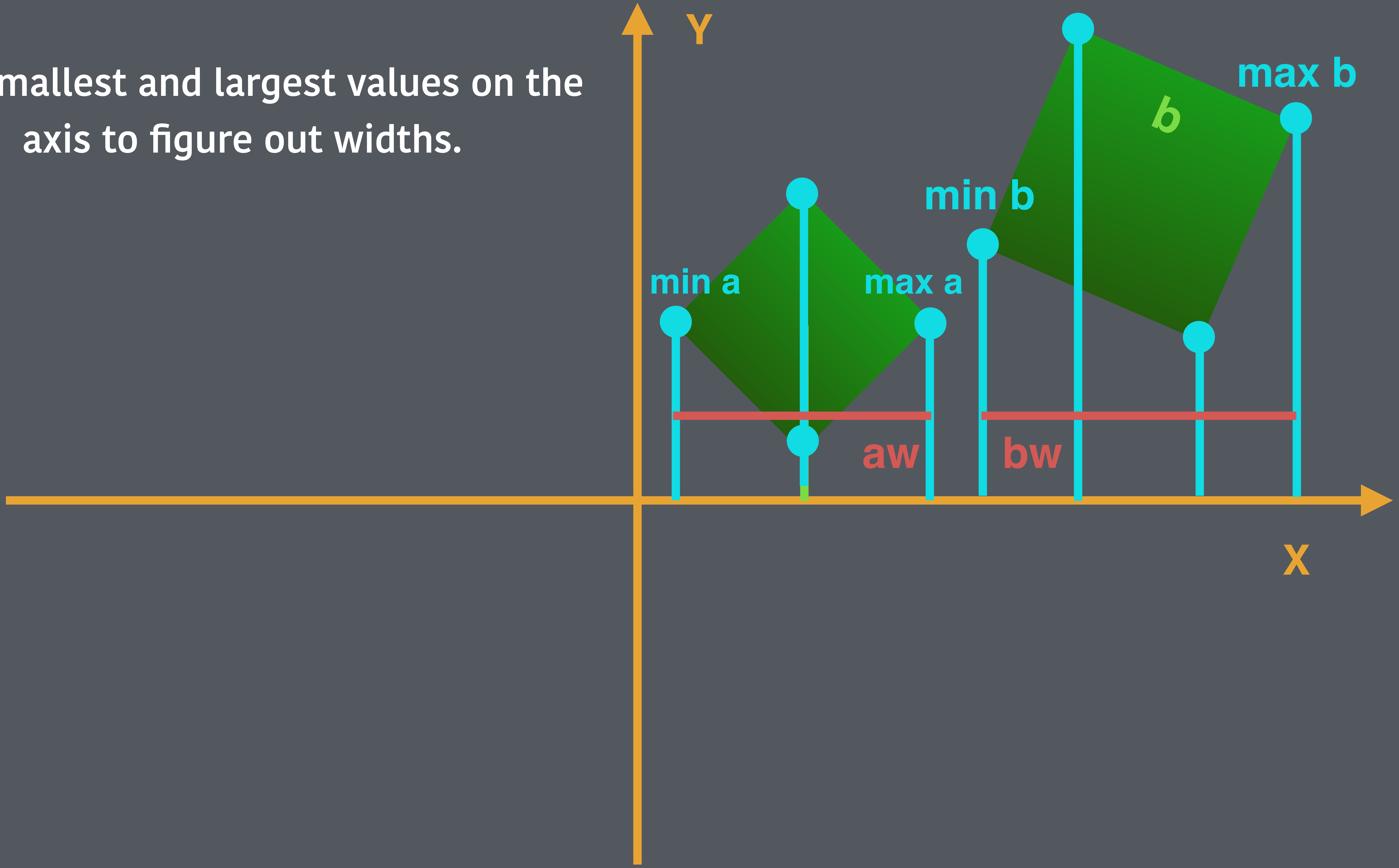

Y
X
a
b

Projecting all vertices to the X axis?

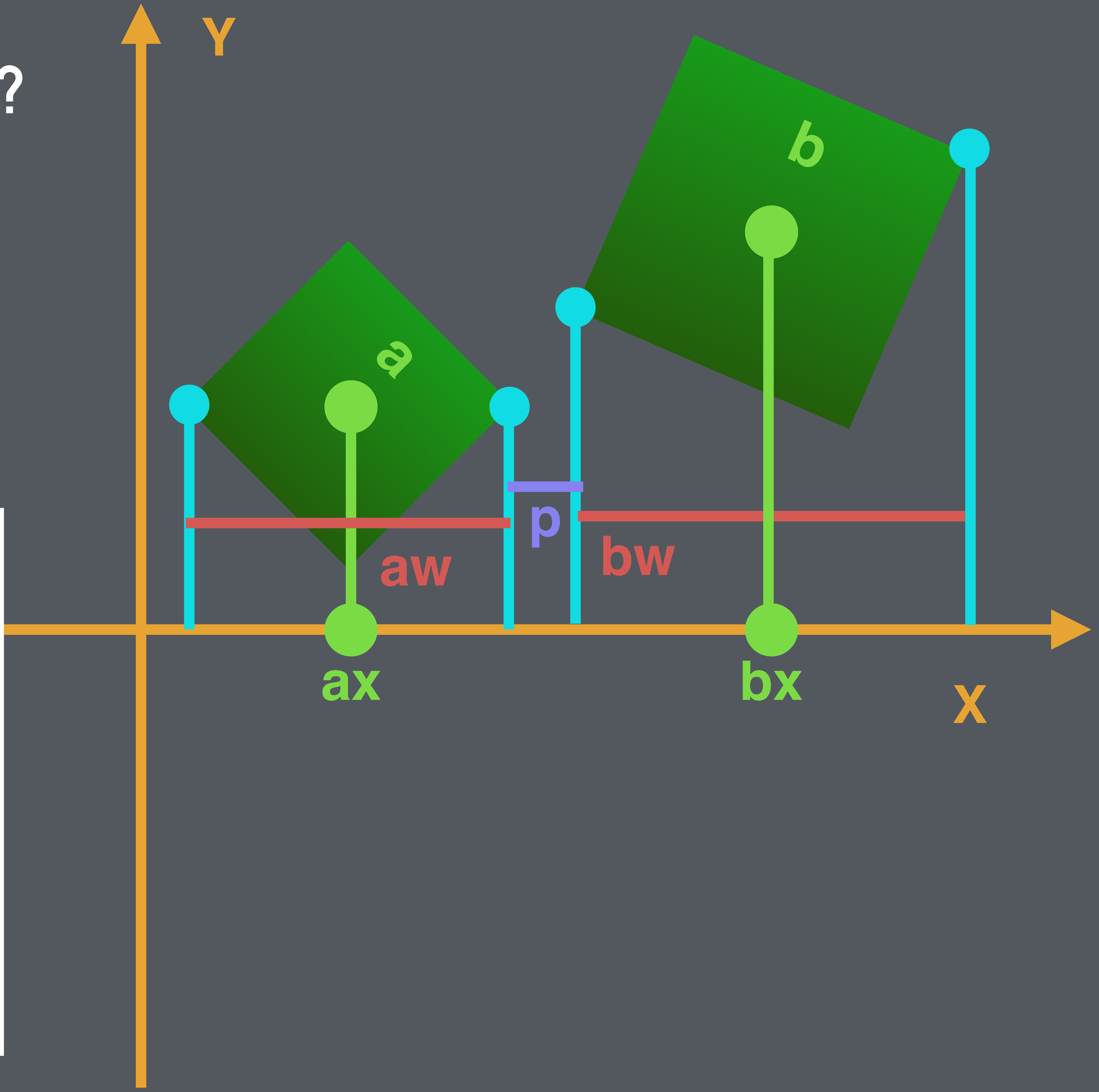
(setting the Y axis value to 0)



Use smallest and largest values on the axis to figure out widths.



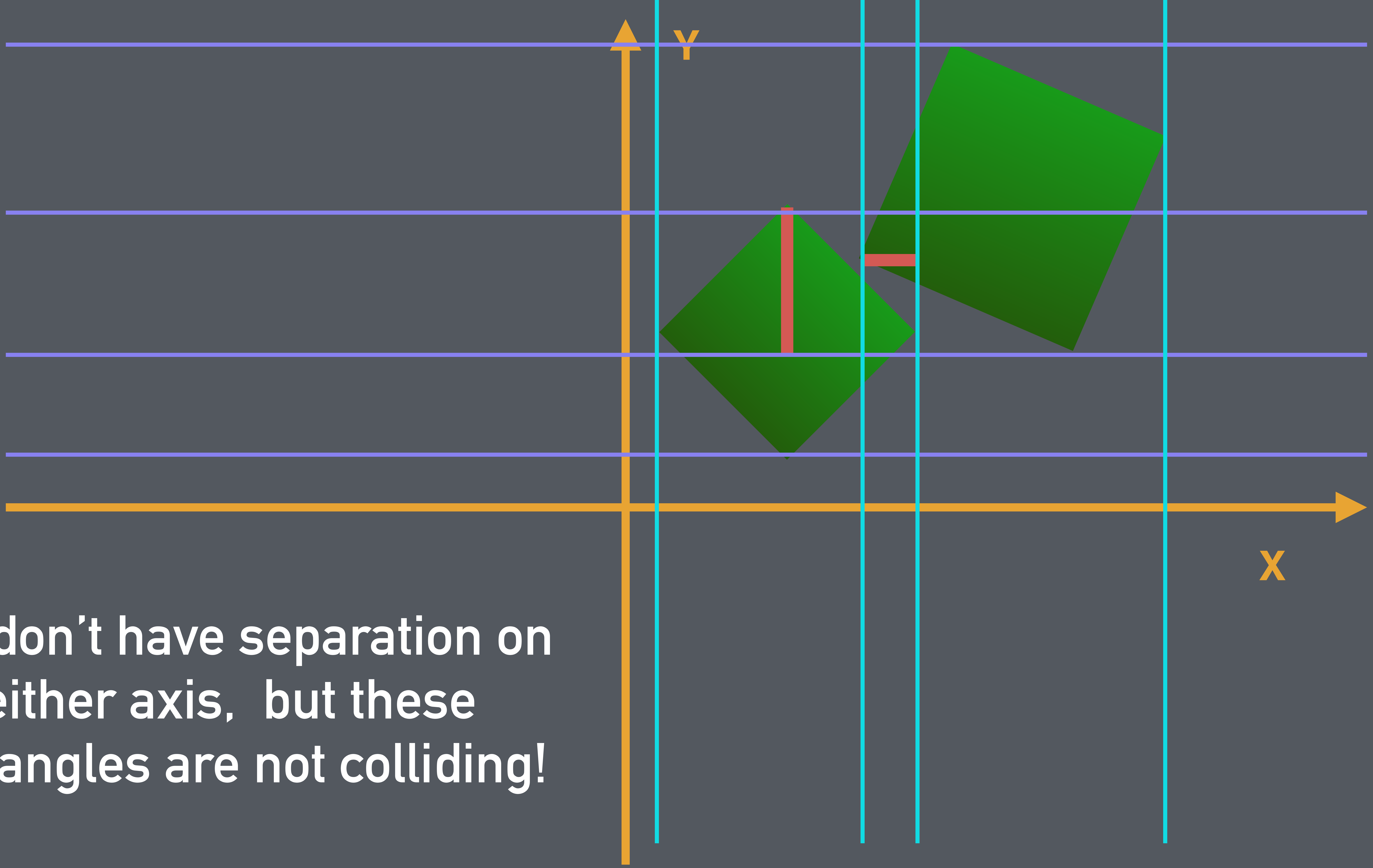
How far away are they on X?



$$p = |x_1 - x_2| - \frac{w_1 + w_2}{2}$$

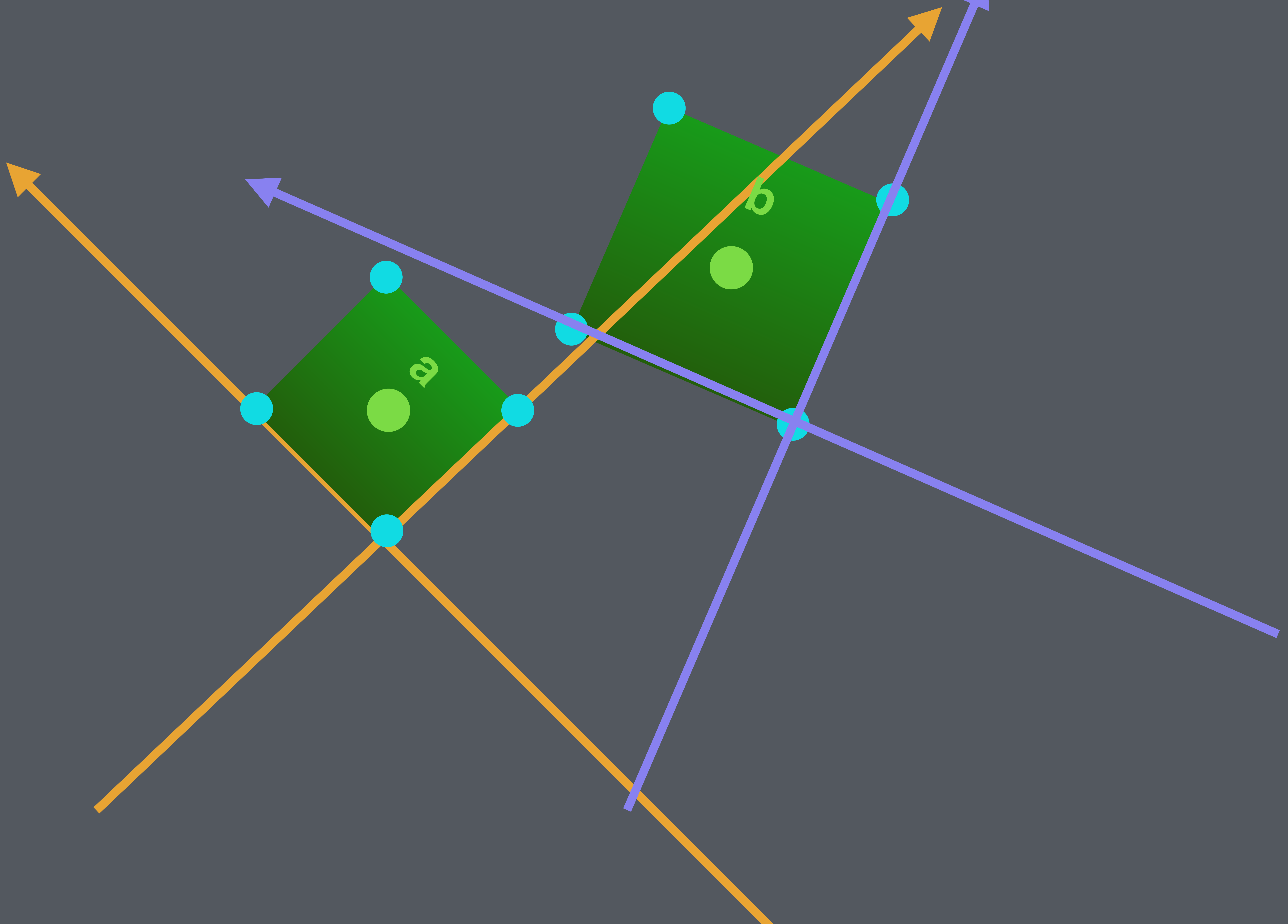
if p >= 0, we are not colliding!

We cannot check rotated separation on X and Y axes!



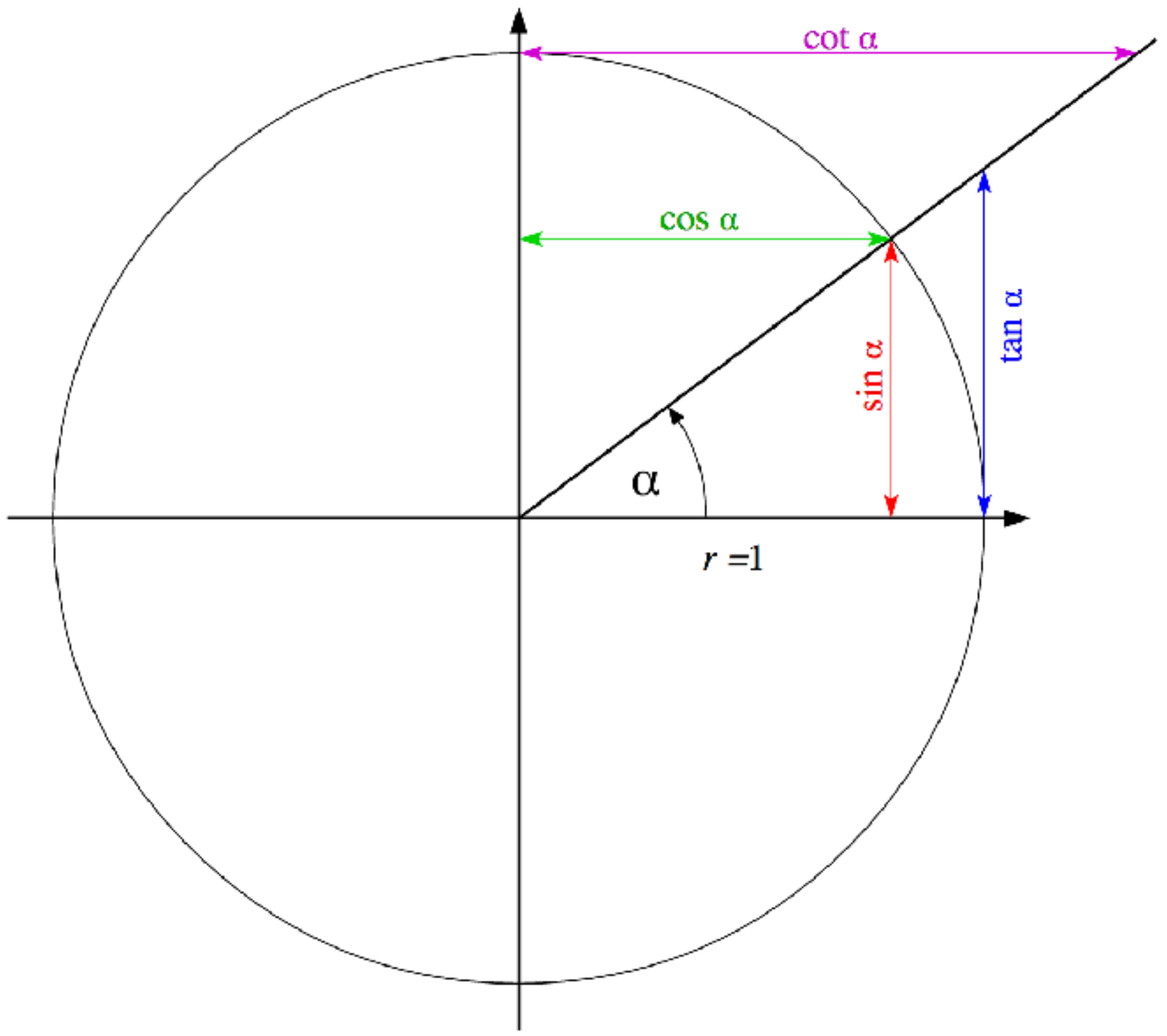
We don't have separation on either axis, but these rectangles are not colliding!

We need to check on both axes
of each rectangle.

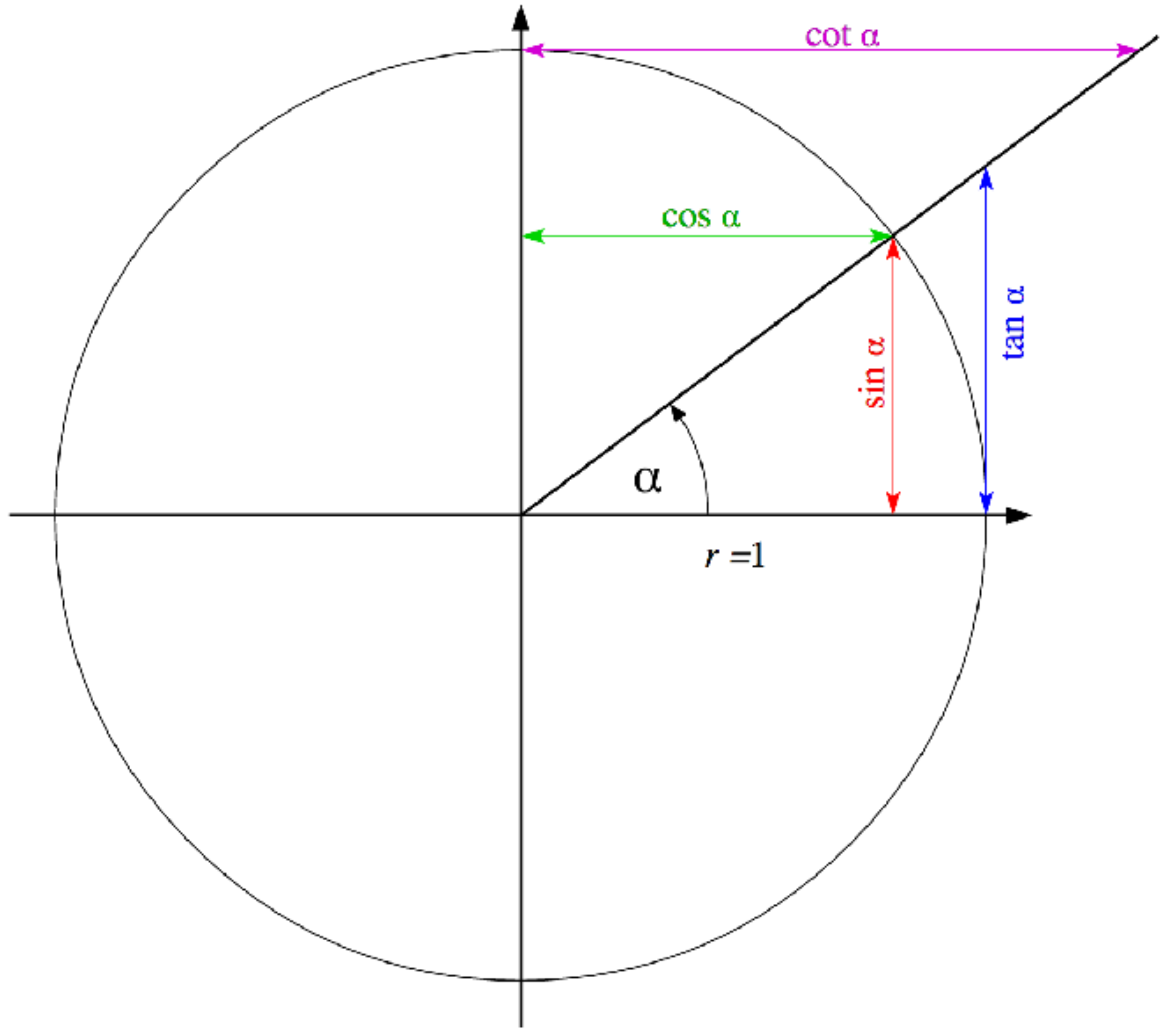

a
b

What is an axis?

An axis is a unit vector representing a direction.



An axis is a unit vector representing a direction.



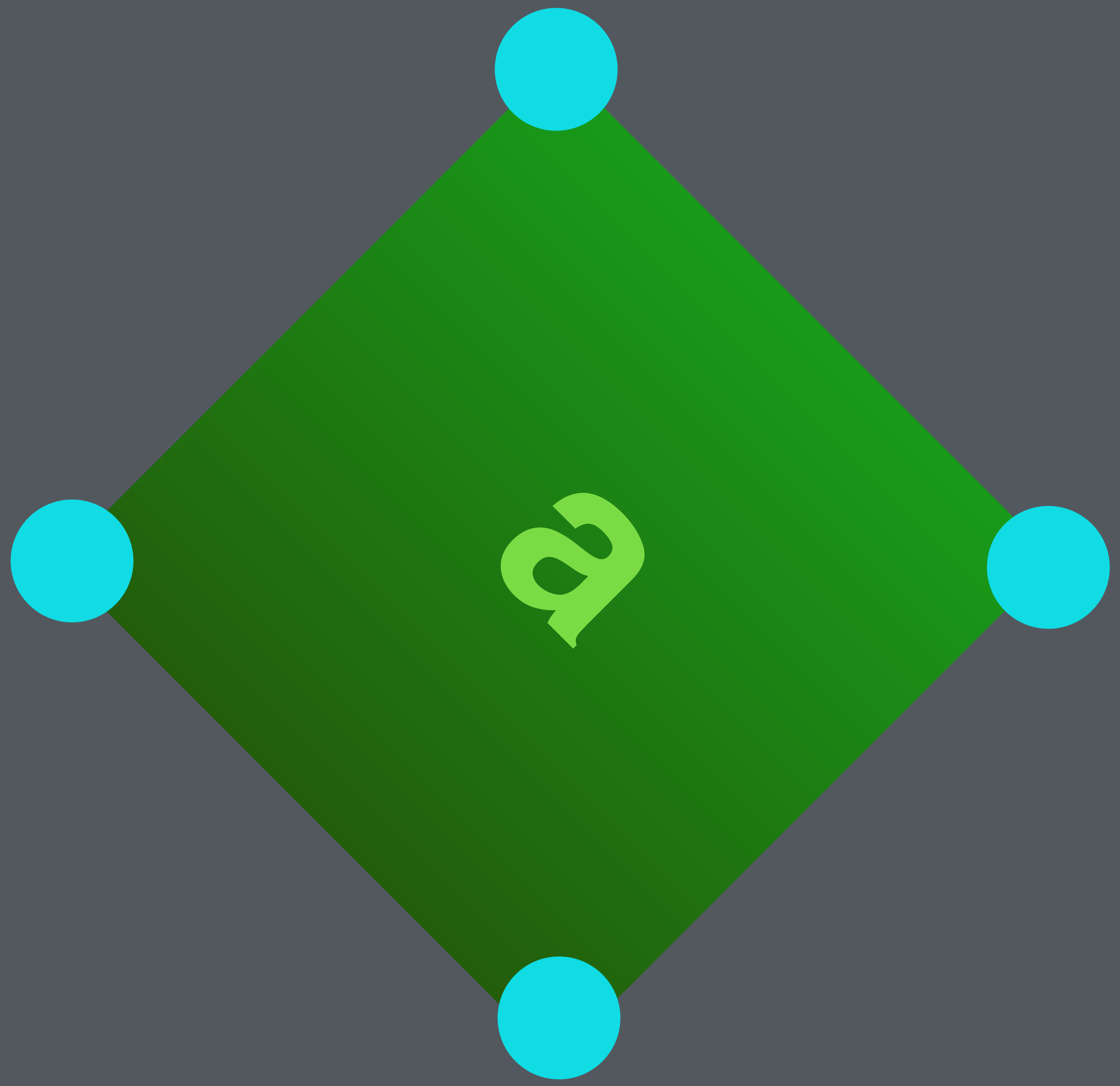
Our standard X axis is (1.0, 0.0) and Y is (0.0, 1.0).

An axis that's at a 45 degree angle (PI/4) can be represented by **(cos(PI/4), sin(PI/4)).**

How do we figure out our rectangle axes?

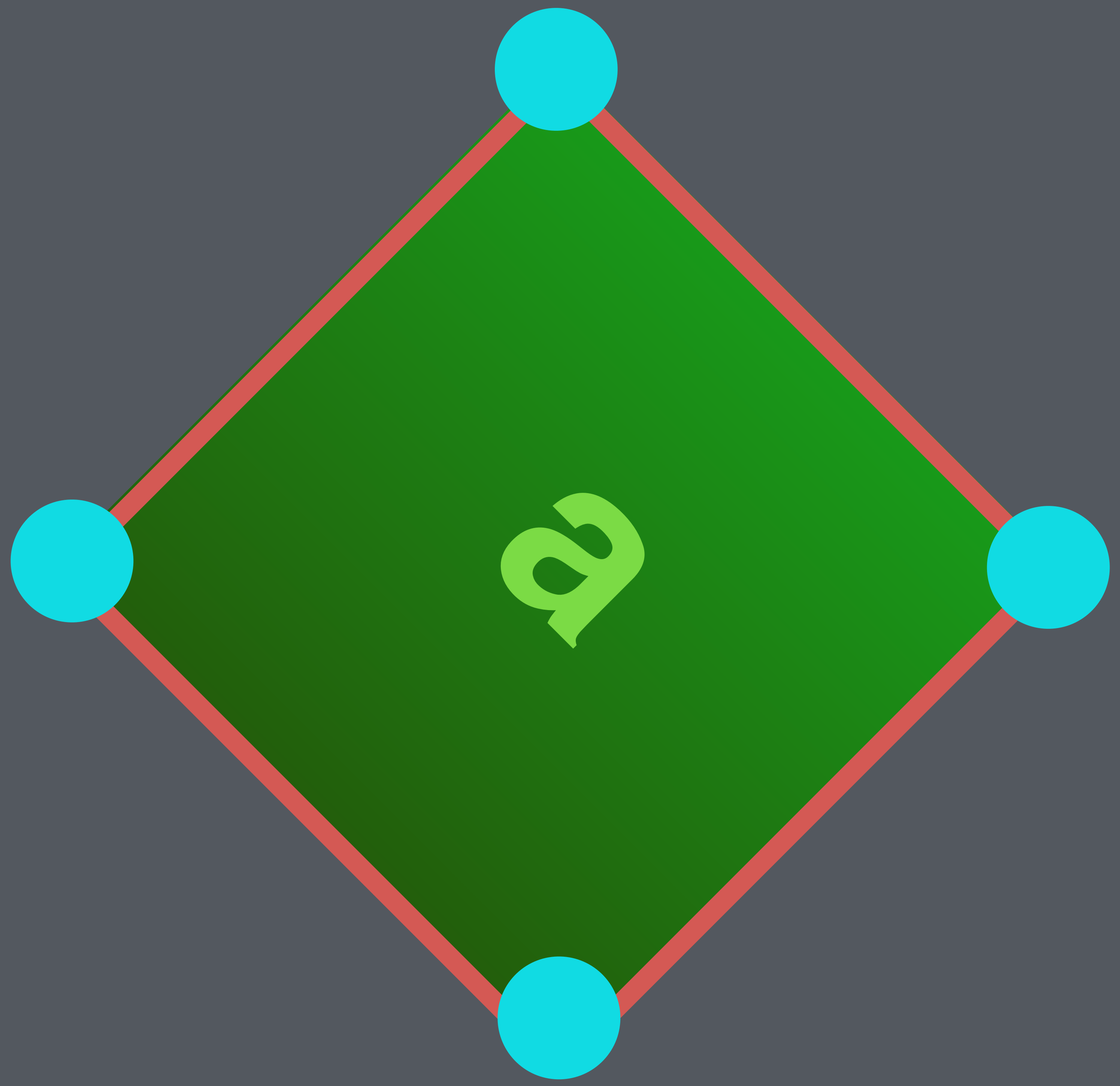
Normals.

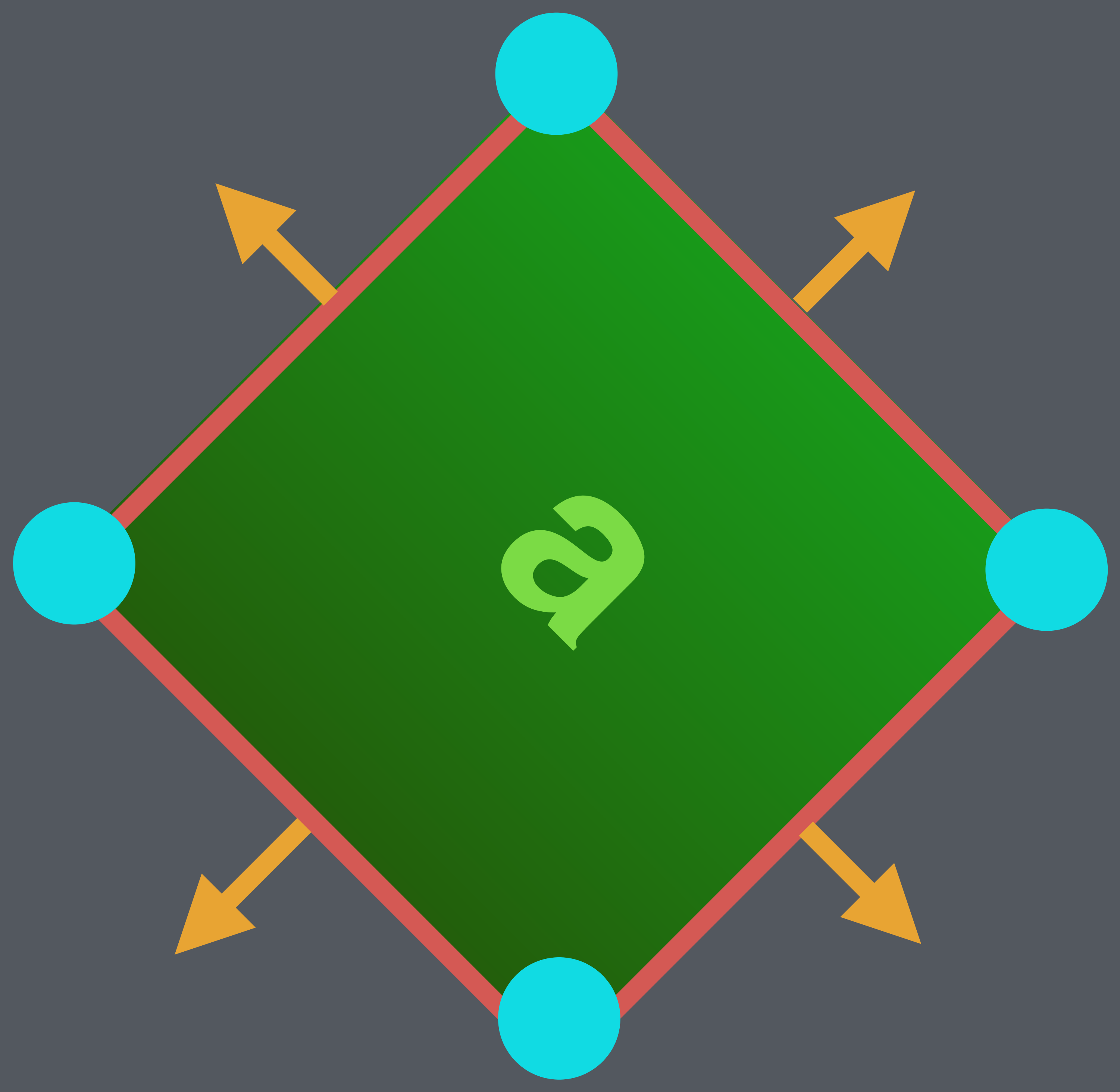
Polygon



To get world space positions of the vertices of a polygon, multiply their object space positions with its model matrix.

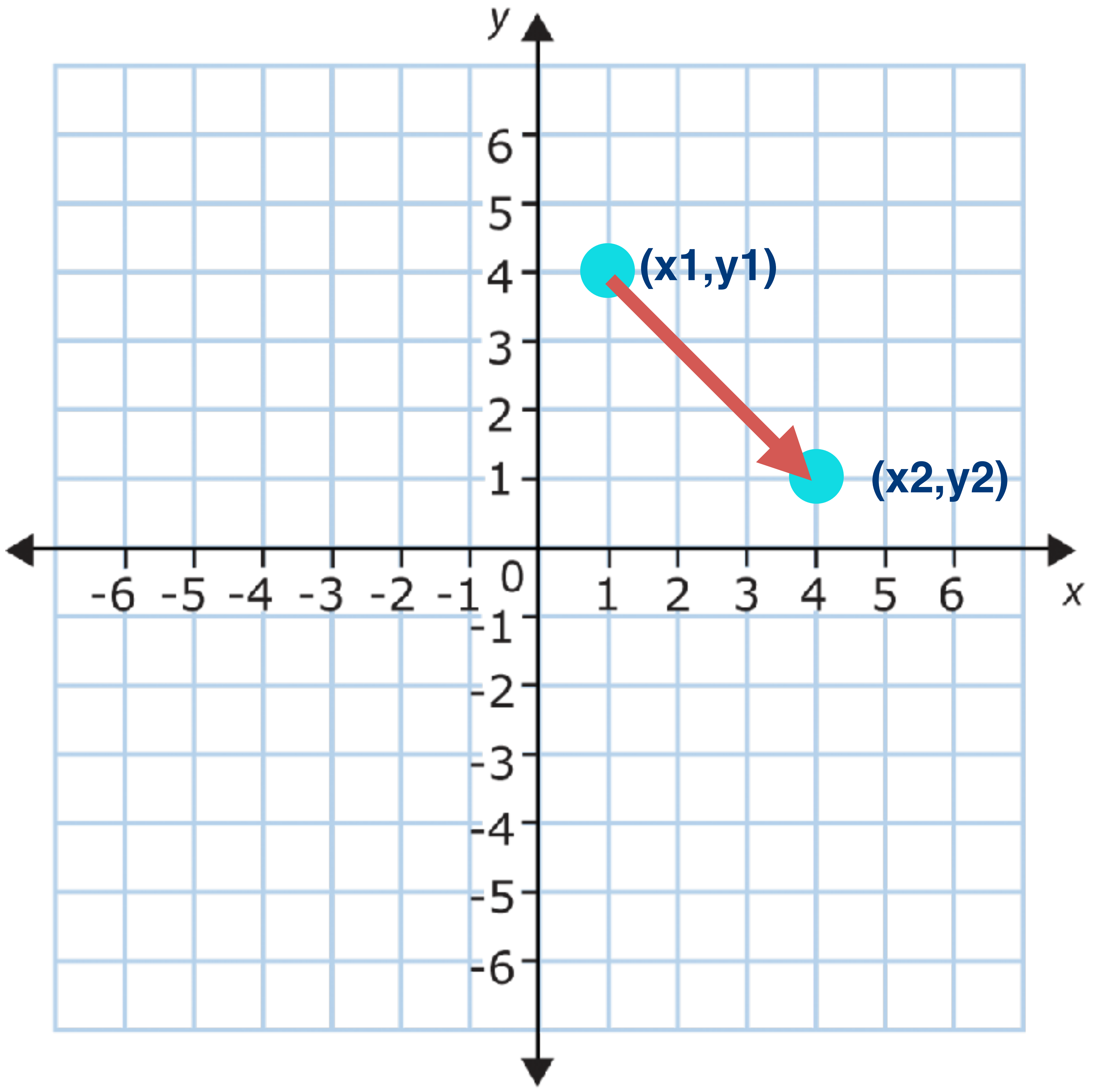
Polygon edges or sides.





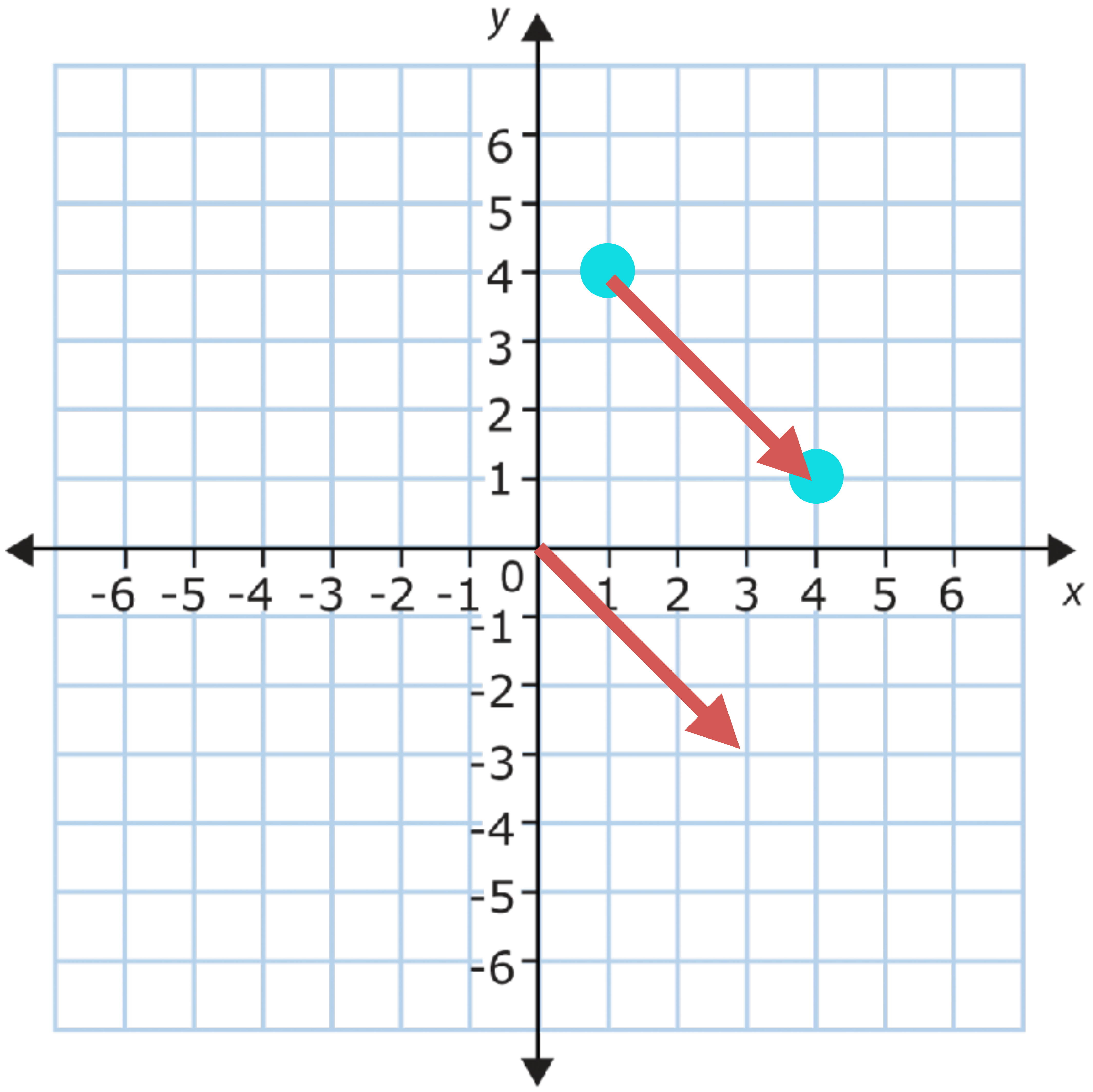
Edge normals.

Unit vectors perpendicular to the edge.



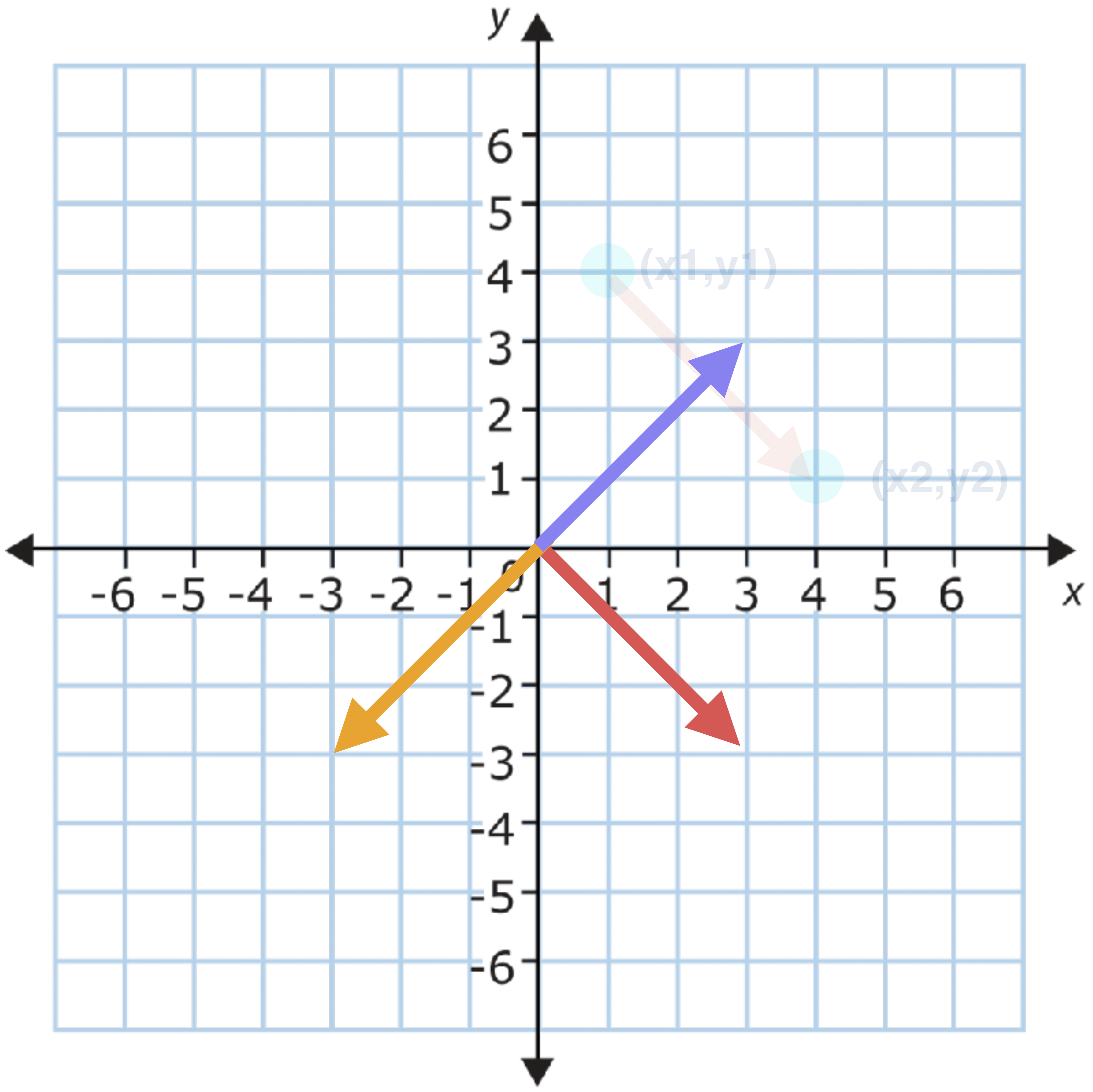
An edge is a vector from one vertex to another.

edge_x = x2-x1
edge_y = y2-y1
edge = (edge_x, edge_y)



An edge is a vector from one vertex to another.

edge_x = x2-x1
edge_y = y2-y1
edge = (edge_x, edge_y)



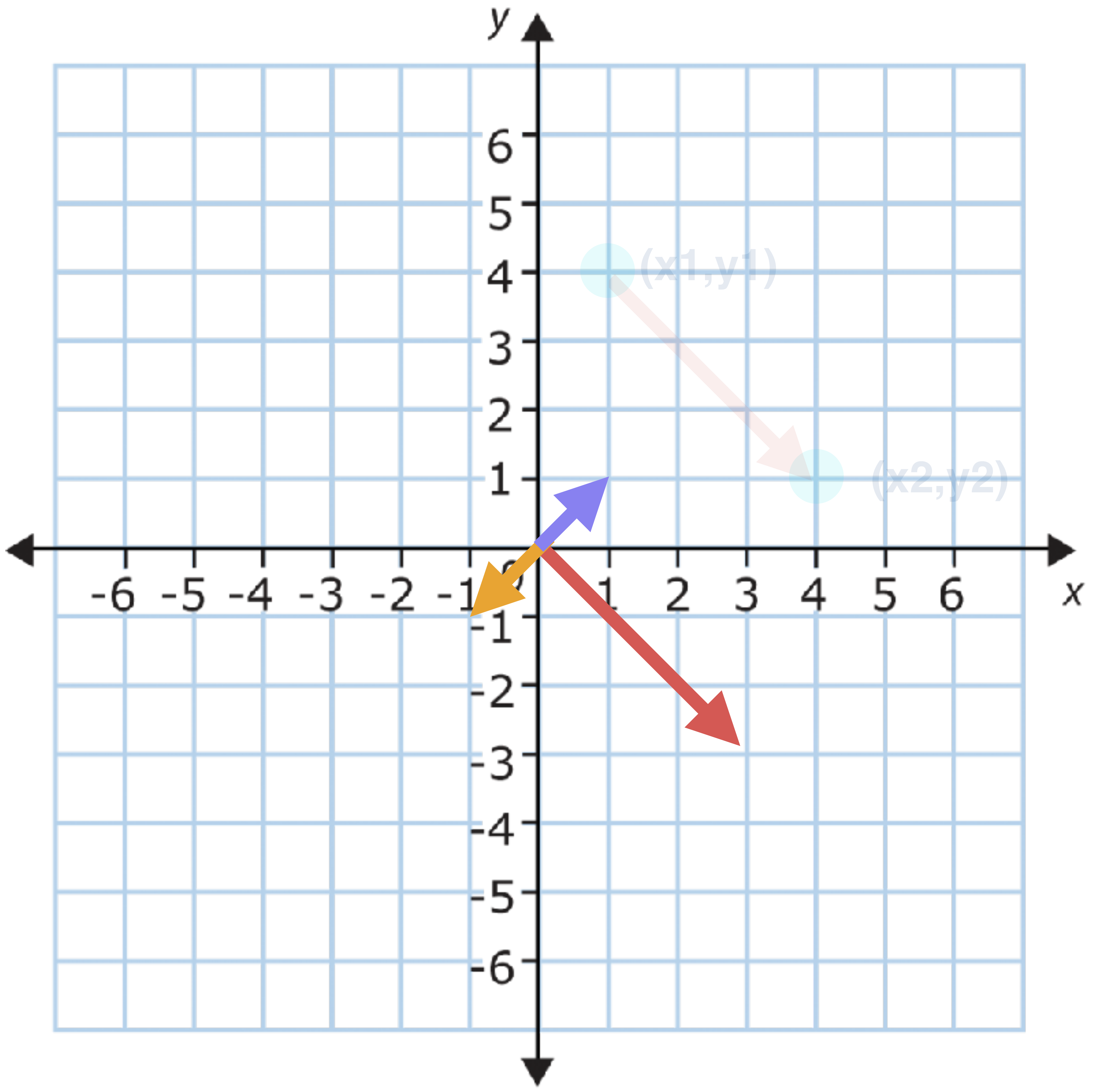
An edge is a vector from one vertex to another.

edge_x = x2-x1
edge_y = y2-y1
edge = (edge_x, edge_y)

Its normals are the vectors perpendicular to that vector.
normal1 = (edge_y, -edge_x)

and

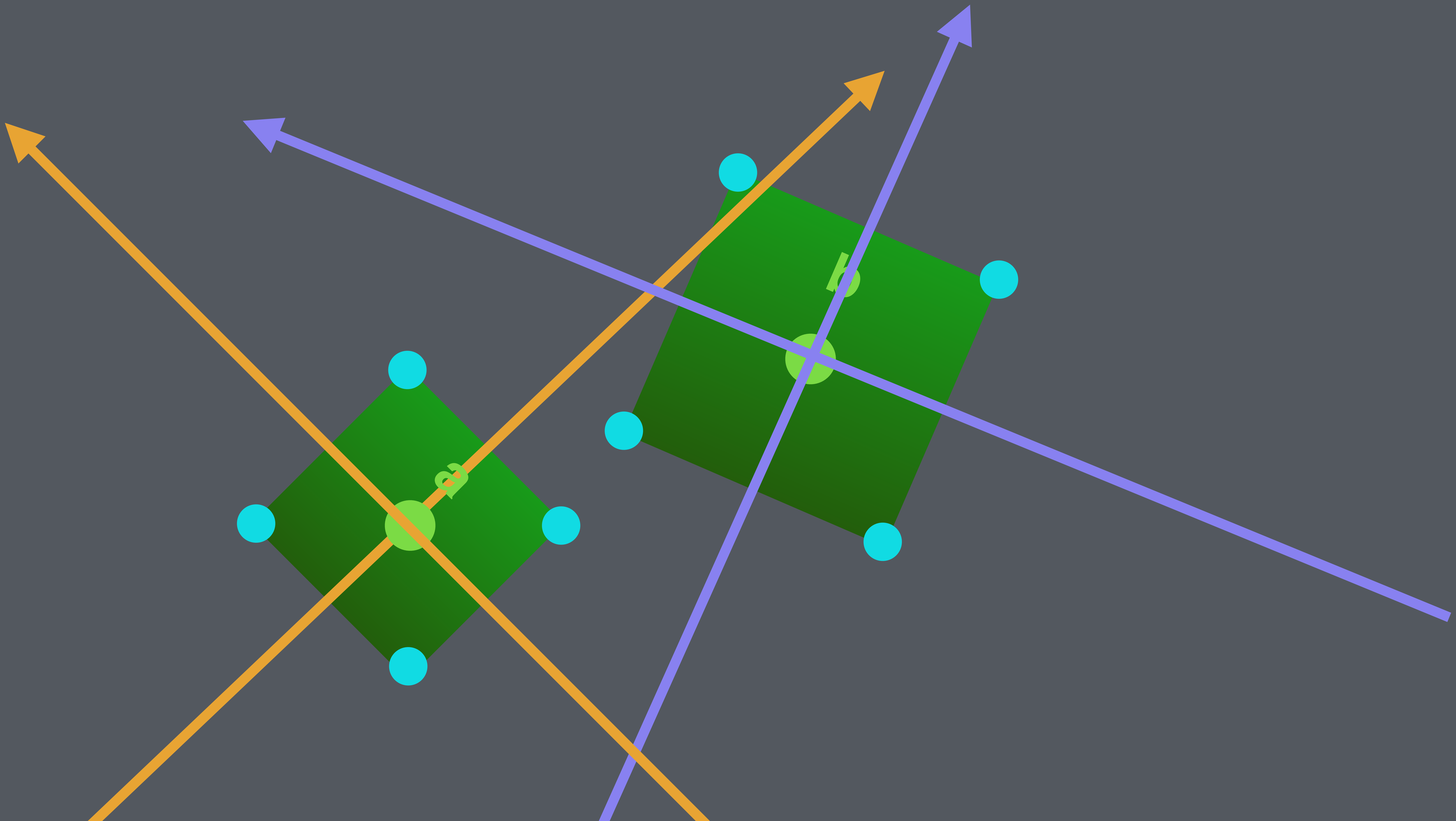
normal2 = (-edge_y, edge_x)



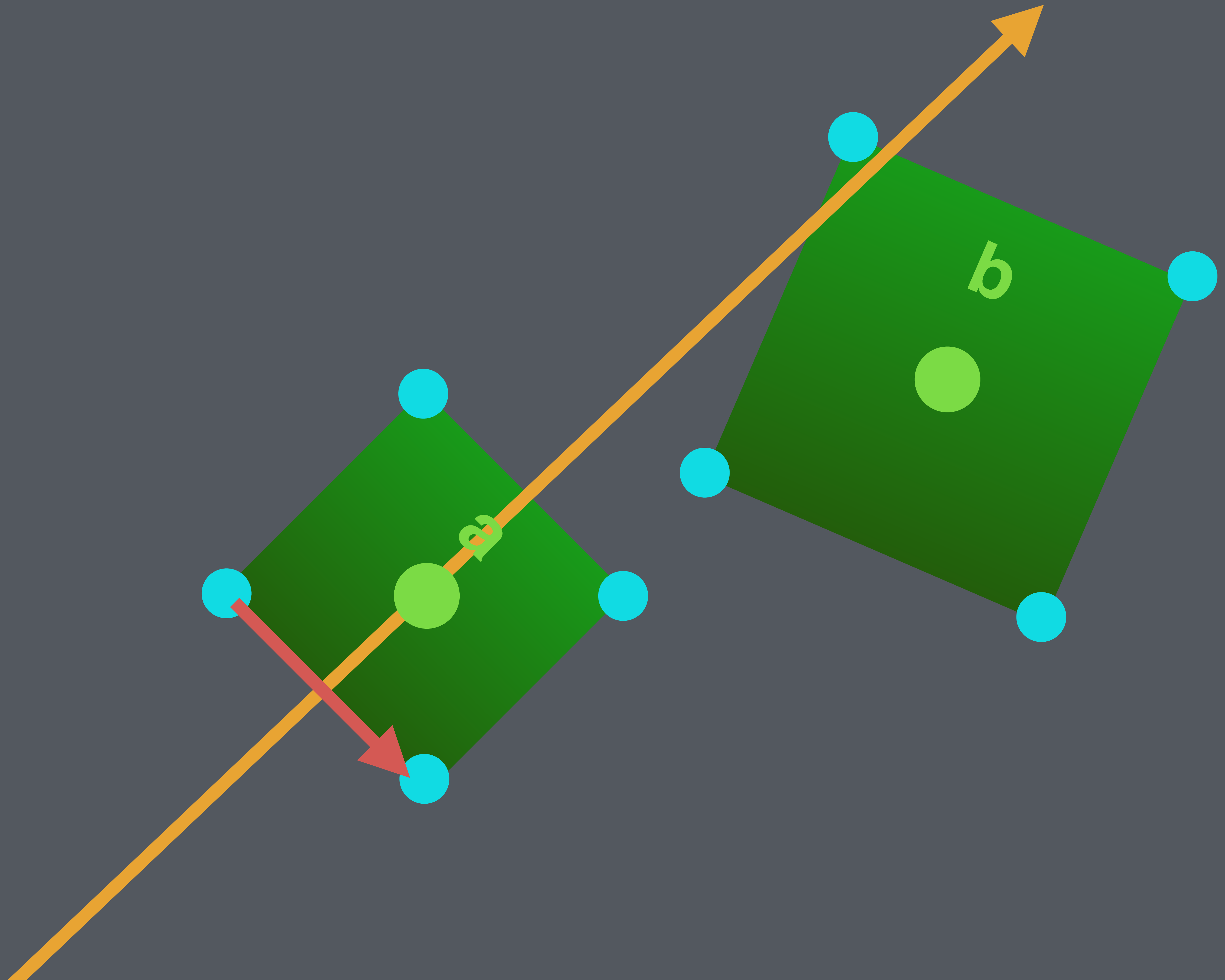
Now, normalize the normal vectors.

length = sqrt(x*x + y*y)
x /= length
y /= length

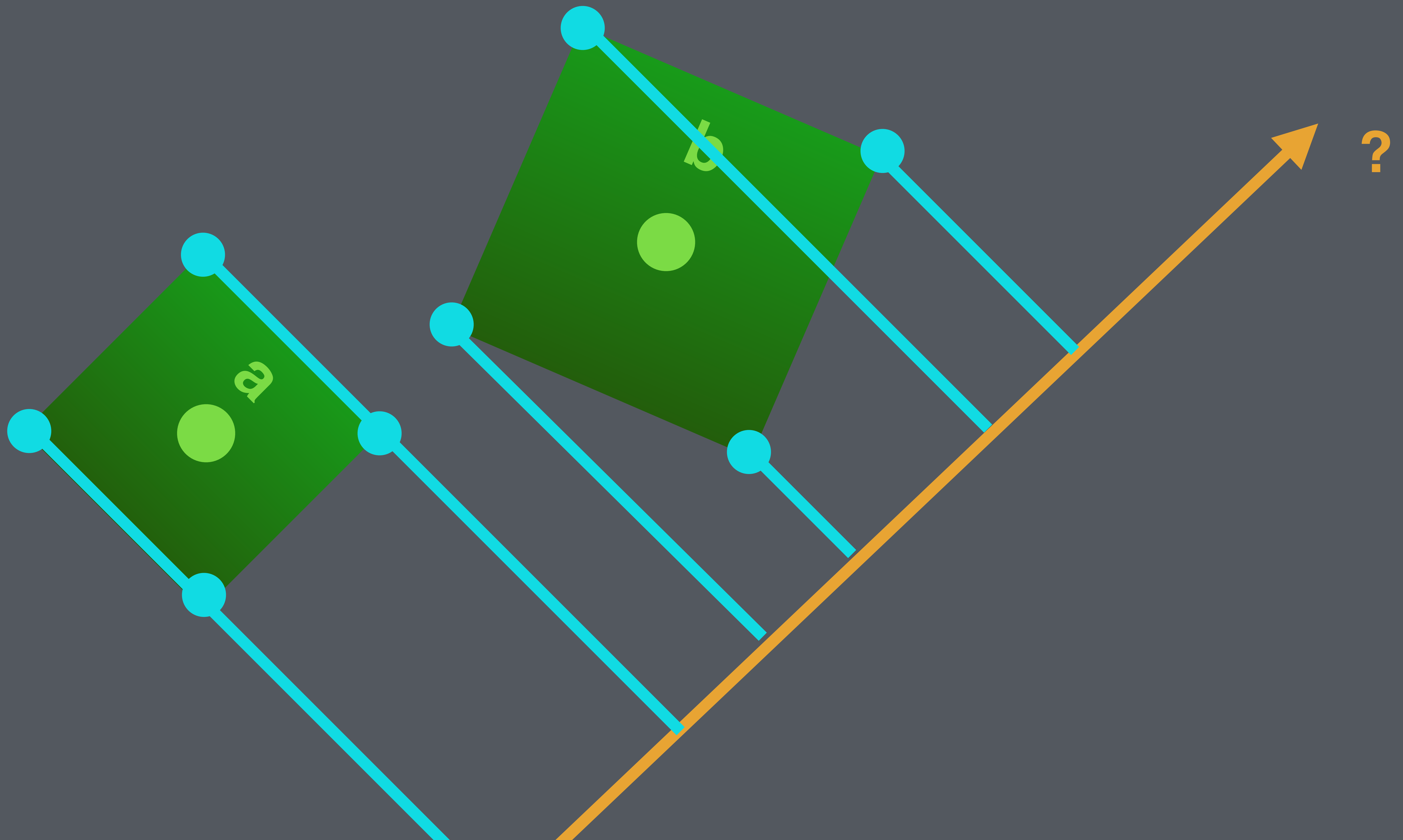
Our normals are the axes on which we check for separation.



For each edge find the normal axis and project your polygons onto it.



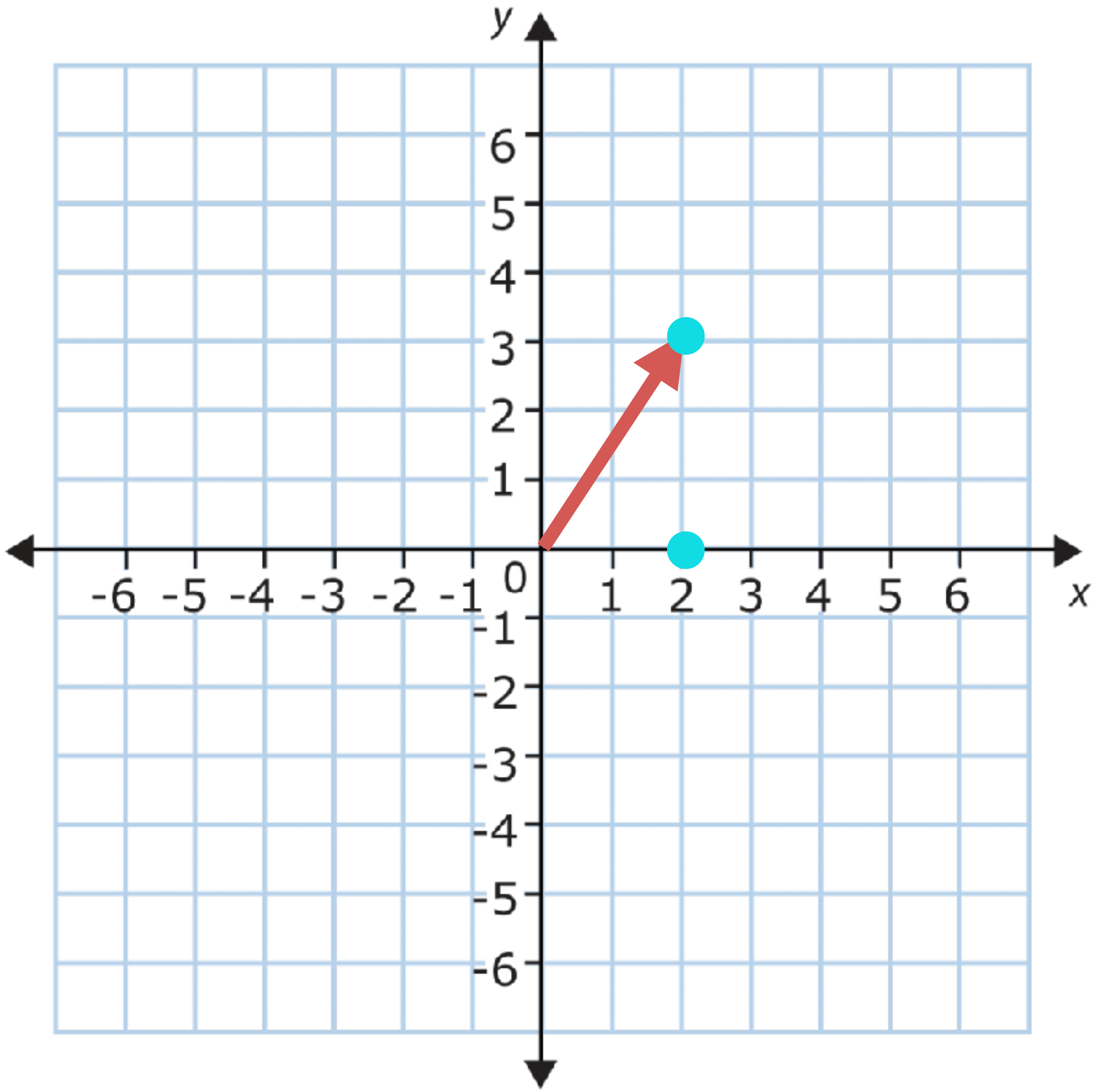
Projecting onto an arbitrary axis.



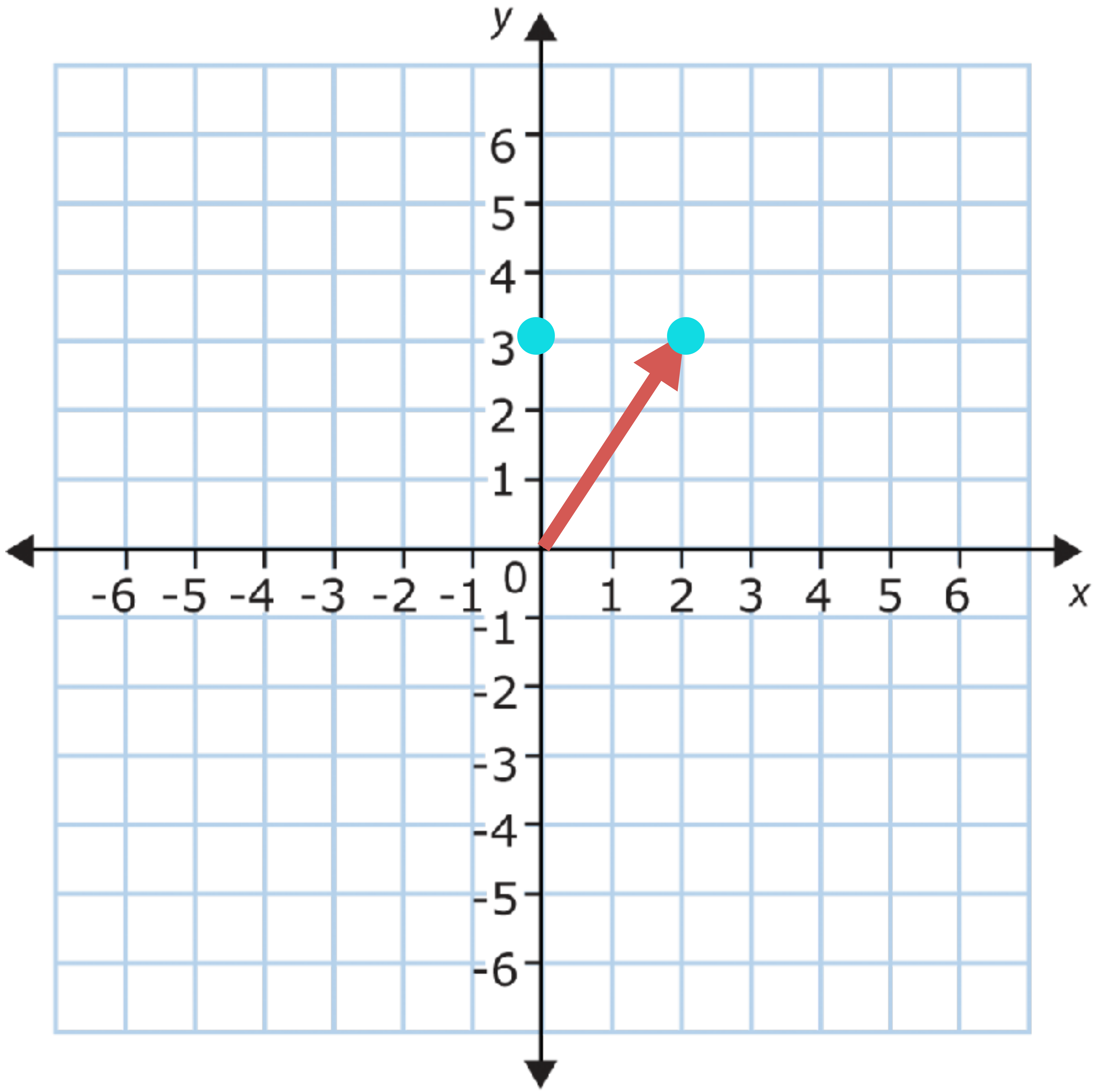
The dot product.

$$(x1*x2) + (y1*y2)$$

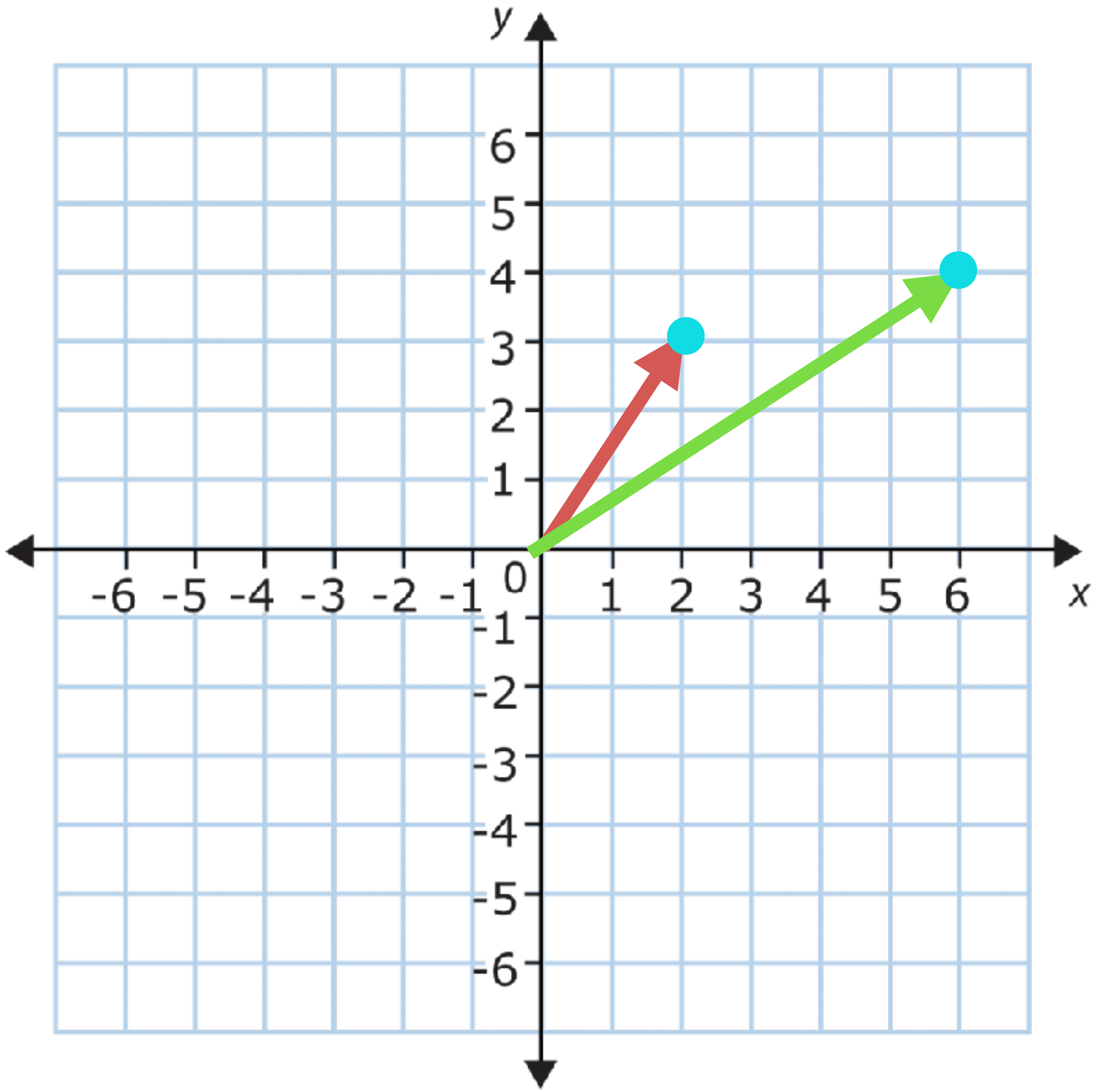
Applies one vector to another.



$$(2,3) \cdot (1,0) = (2*1) + (3 * 0) = 2$$



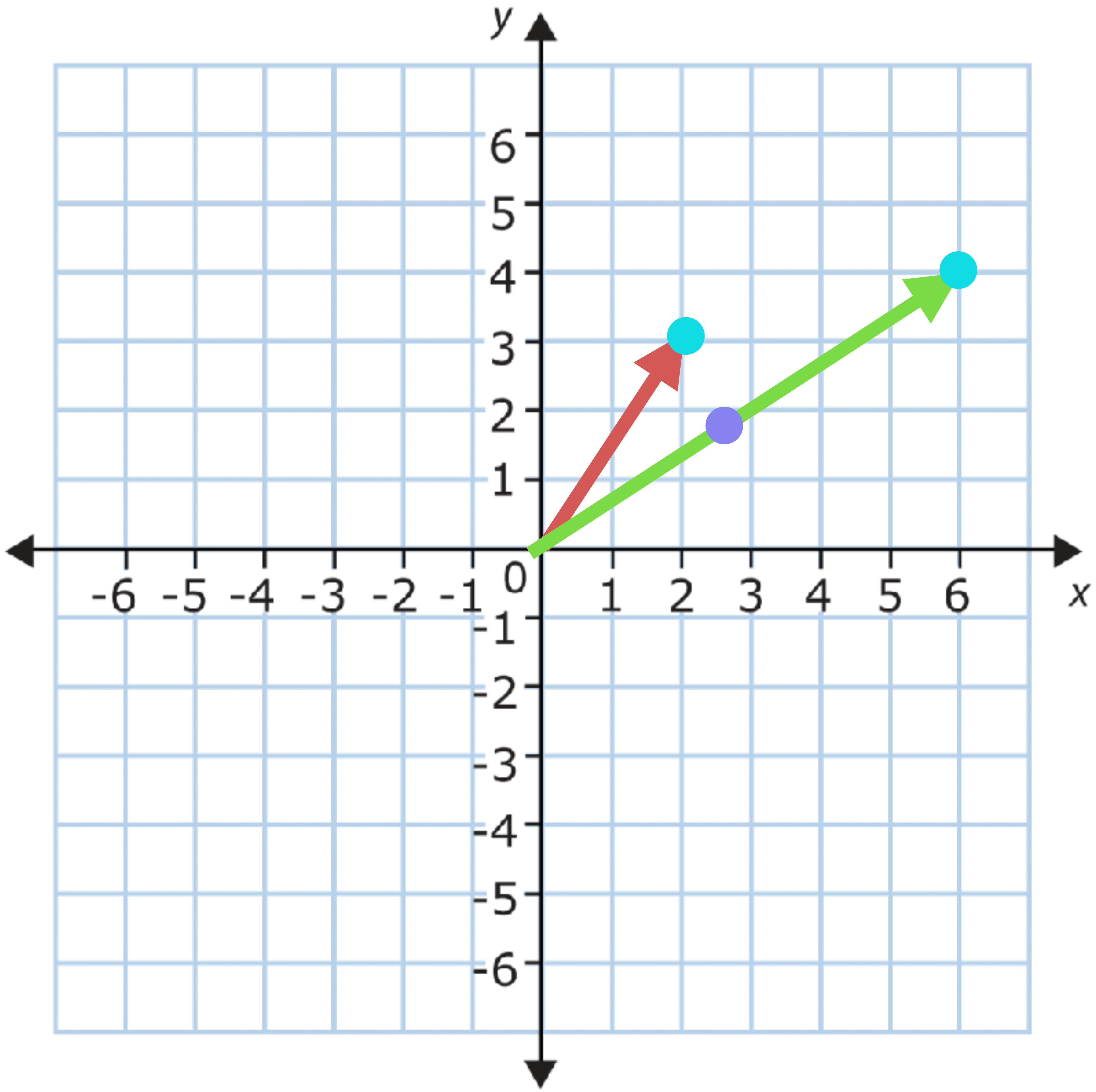
$$(2,3) \cdot (0,1) = (2*0) + (3 * 1) = 3$$



Normalize (6,4):

length = sqrt(6*6 + 4*4) = 7.2111
x = 6 / 7.2111 = 0.832
y = 4 / 7.2111 = 0.5547

(2,3) · (0.832,0.555) = (2*0.832) + (3 * 0.555)
= 1.664 + 1.665 = 3.329

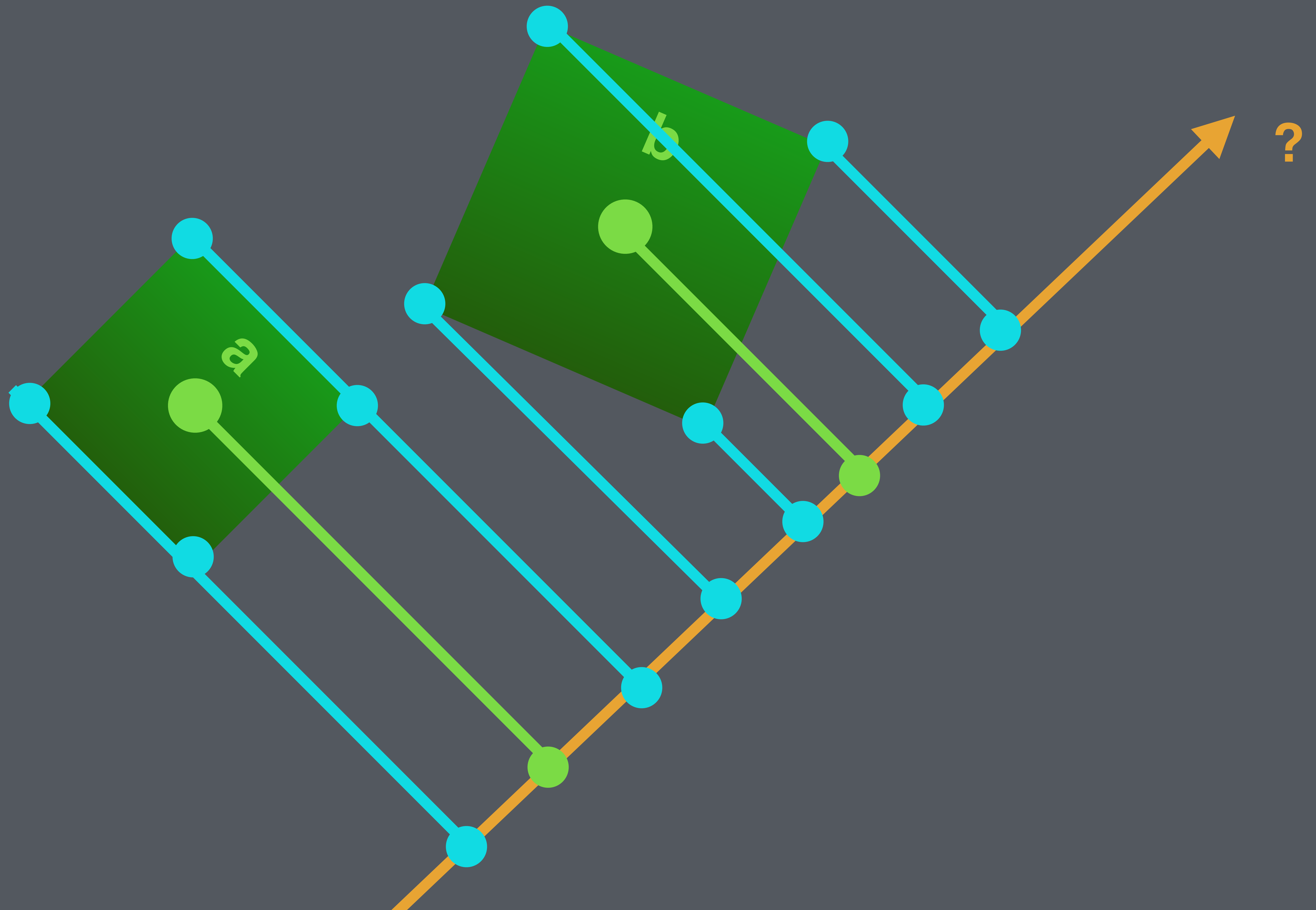


Normalize (6,4):

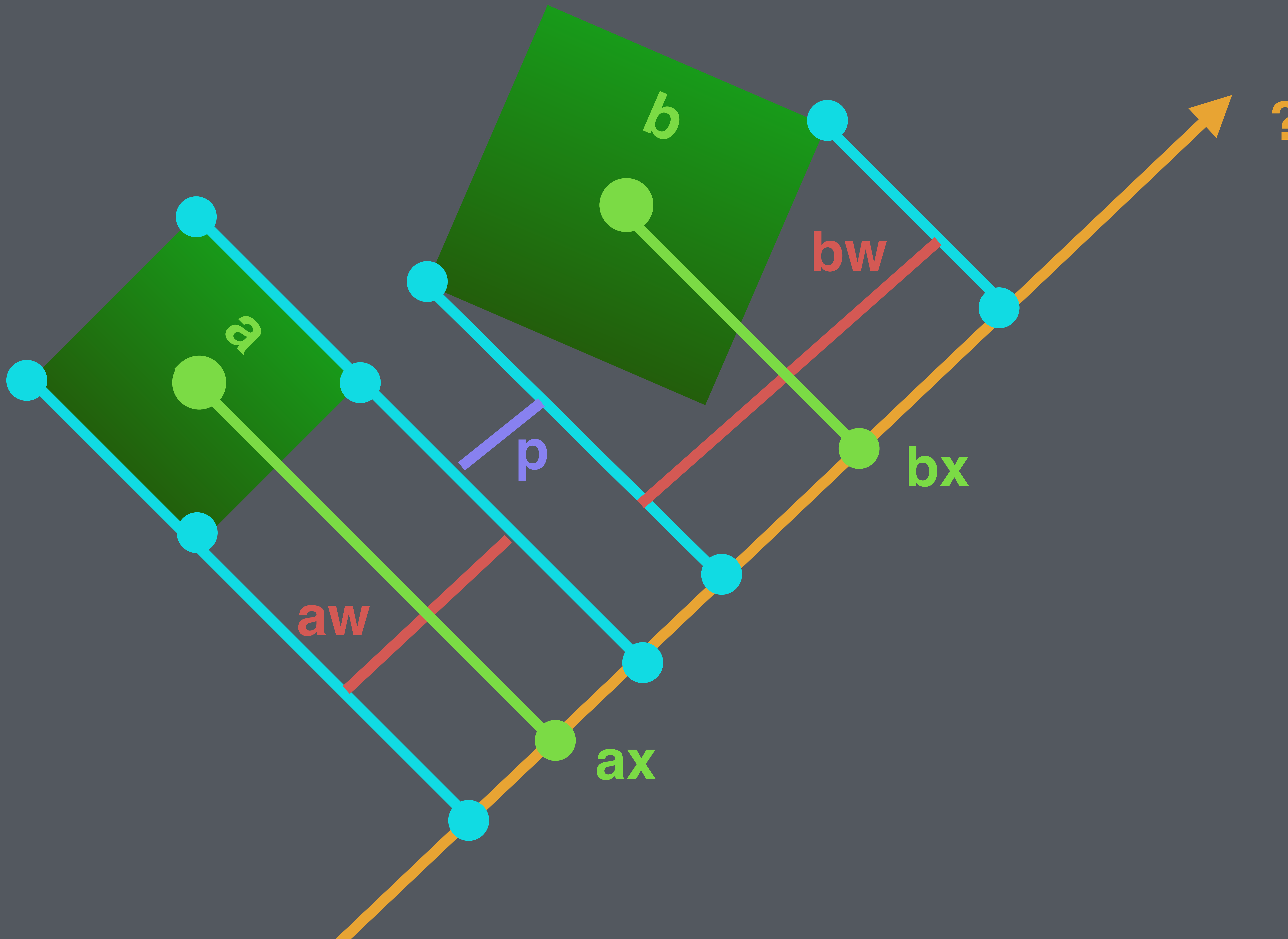
length = sqrt(6*6 + 4*4) = 7.2111
x = 6 / 7.2111 = 0.832
y = 4 / 7.2111 = 0.5547

(2,3) · (0.832,0.555) = (2*0.832) + (3 * 0.555)
= 1.664 + 1.665 = 3.329

Find dot product of each vertex with the normalized axis vector.



How far away are they **on this axis**?



$$p = |x_1 - x_2| - \frac{w_1 + w_2}{2}$$

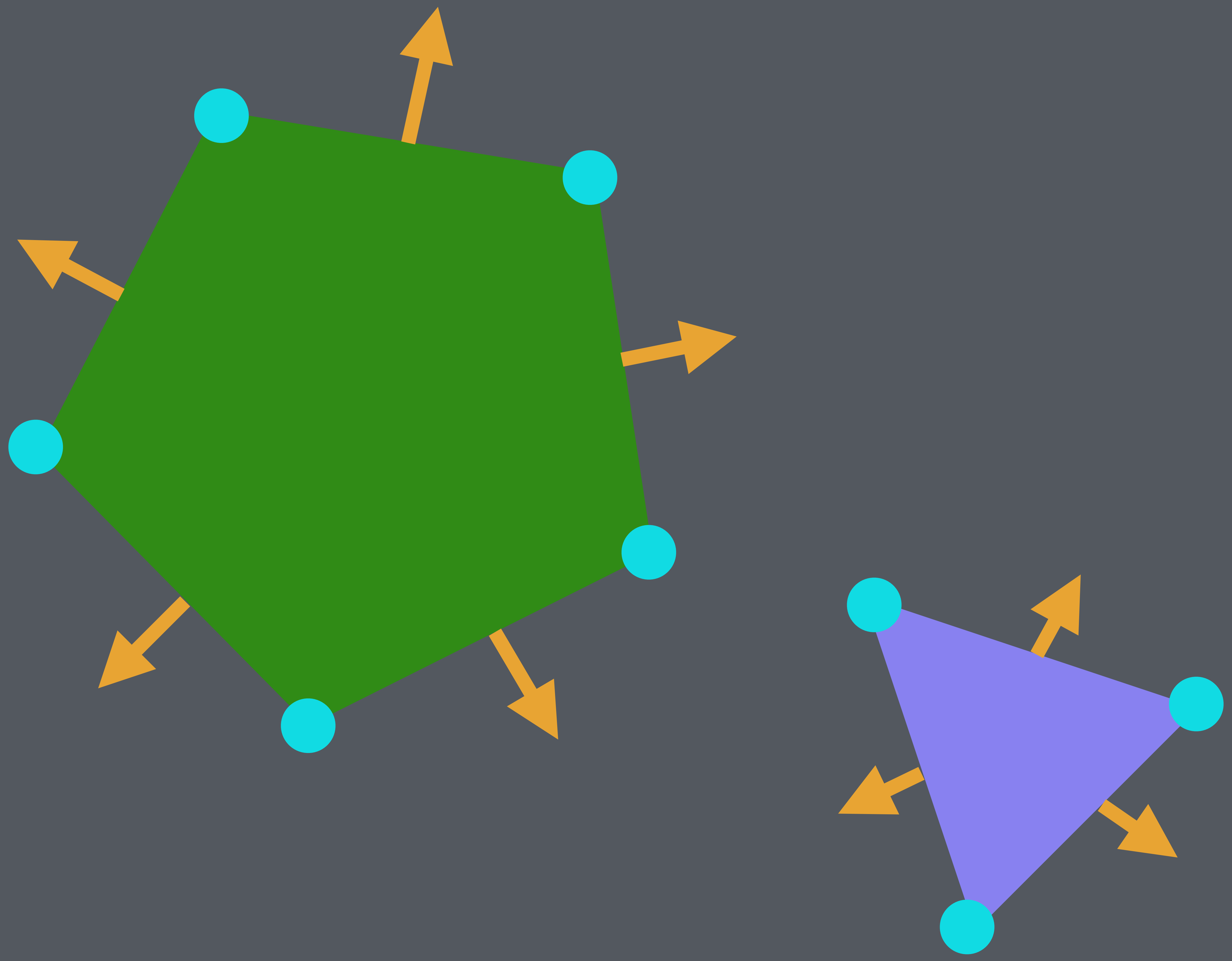
if p >= 0, we are not colliding!

Check the separation on each of the 4 normal axes

(we don’t have to check all 8 since 2 sides of each rectangle are parallel).

If on any axis, there is a separation, the collision is not occurring.

Arbitrary polygon collision.

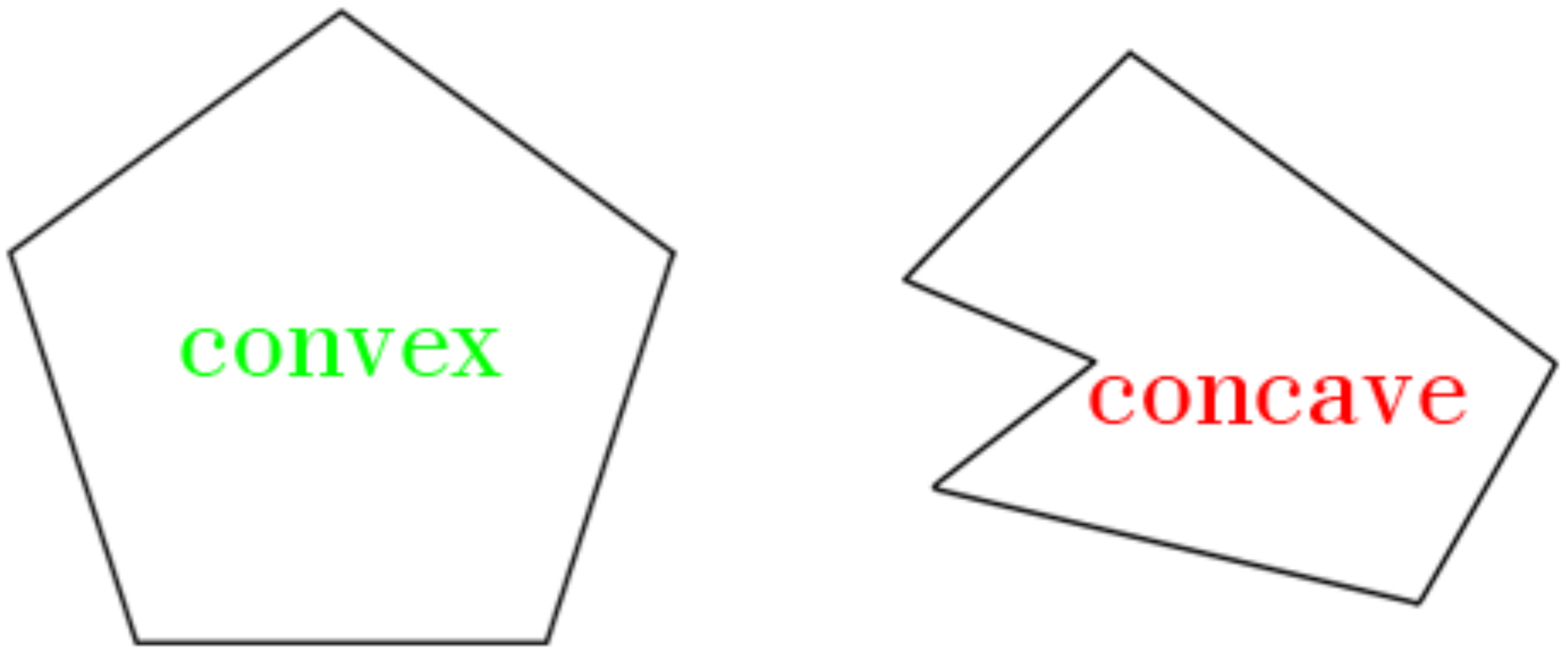


Check separation for each edge normal.

If aMin <= bMax and aMax >= bMin, we have a collision on this axis

Only works with convex polygons!

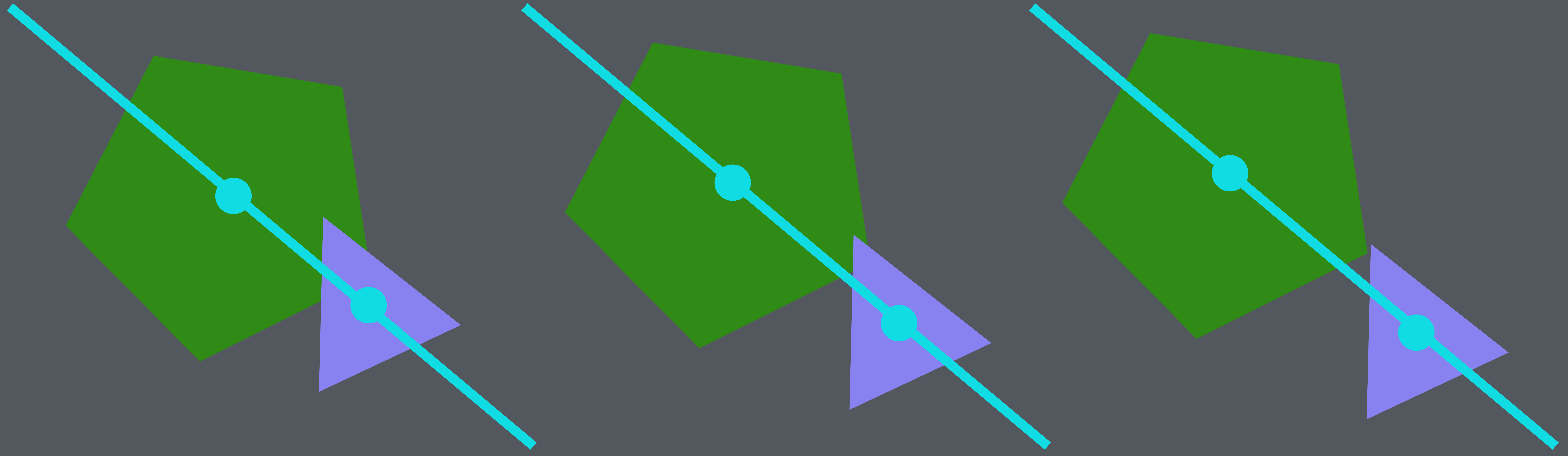
(every internal angle < 180 degrees
and it's not self intersecting)



Responding to SAT collisions.

Method 1

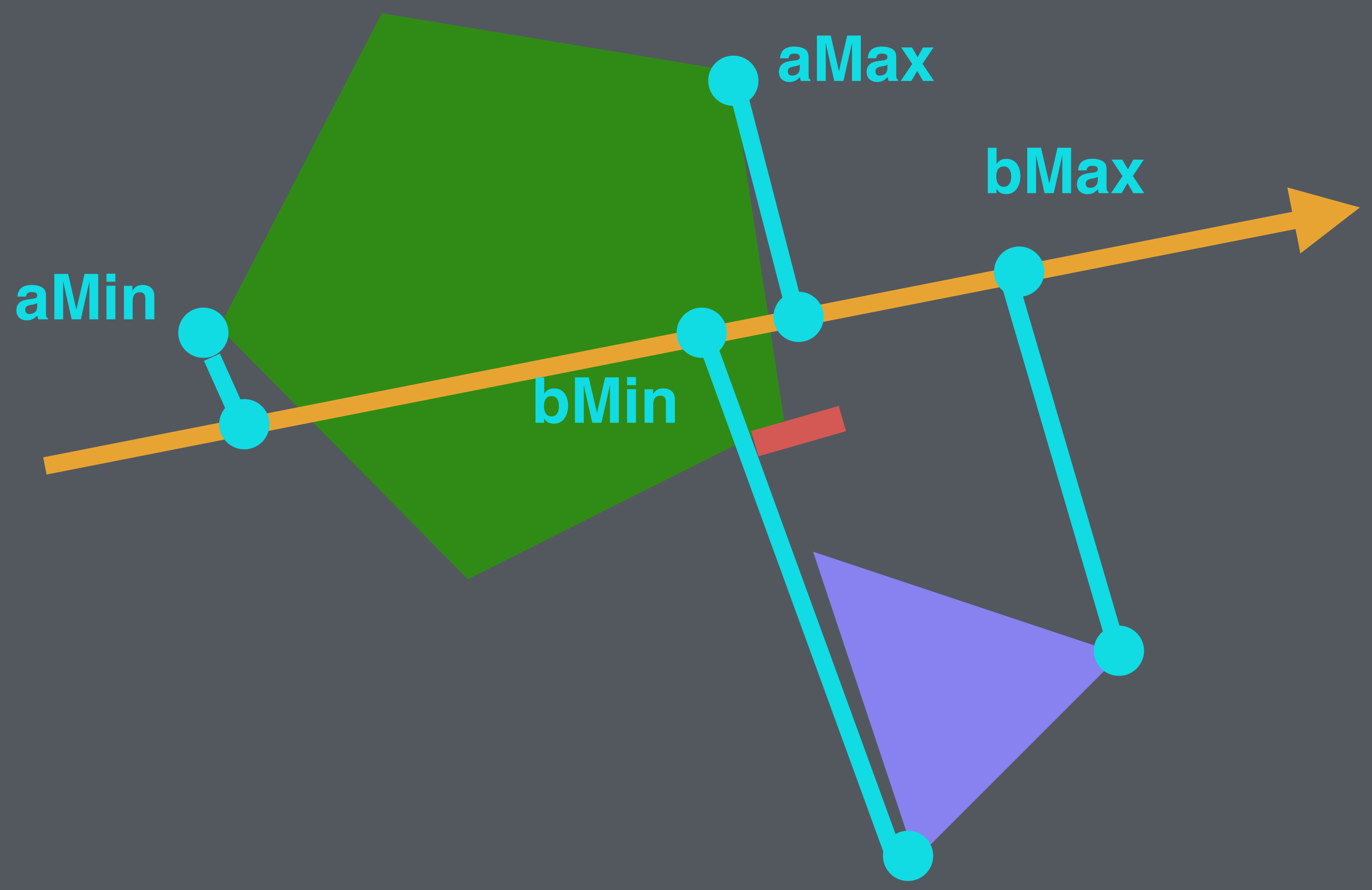
While collision between two entities is true, move them away from each other (along unit vector pointing from one entity to the other) by some small amount.



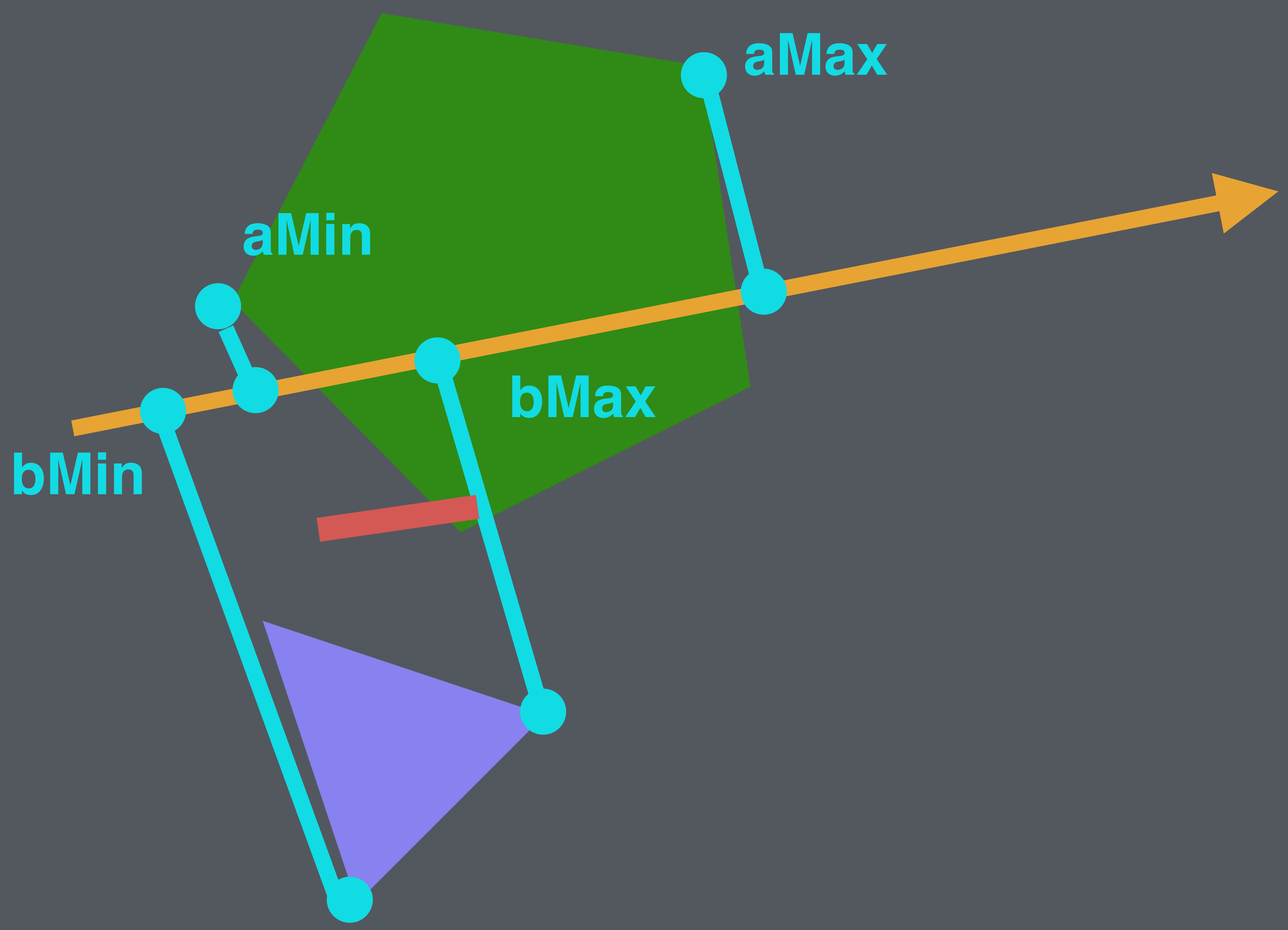
```
int maxChecks = 10;
while(checkCollision(entity1, entity2) && maxChecks > 0) {

    Vector responseVector = Vector(entity1->x - entity2->x, entity1->y - entity2->y);

    responseVector.normalize();

    entity1->x -= responseVector.x * 0.002;
    entity1->y -= responseVector.y * 0.002;

    entity2->x += responseVector.x * 0.002;
    entity2->y += responseVector.y * 0.002;
    maxChecks -= 1;
}
```

Method 2

FIND THE SMALLER PENETRATION FOR EACH AXIS



OR



aMax - bMin OR bMax - aMin

THEN TRANSLATE IT BACK INTO WORLD SPACE COORDINATES

BY MULTIPLYING BY THE AXIS NORMAL AND SAVE INTO A LIST

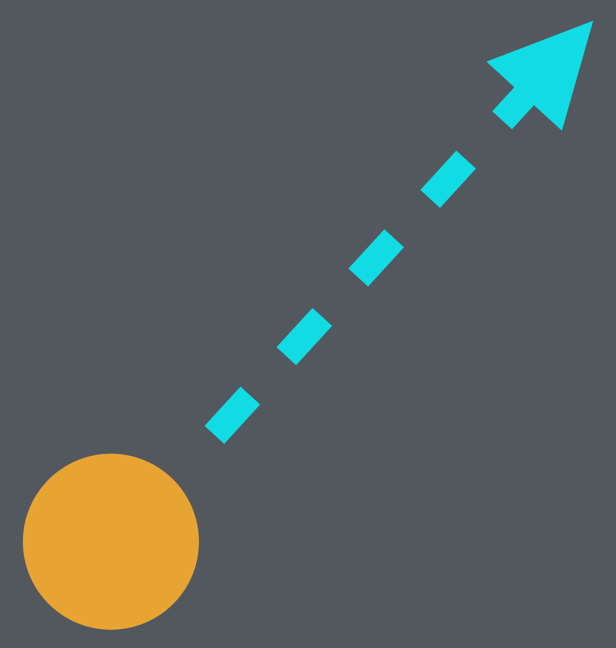
OUR ADJUST VECTOR IS THE SMALLEST PENETRATION VECTOR
FROM ALL THE AXES!

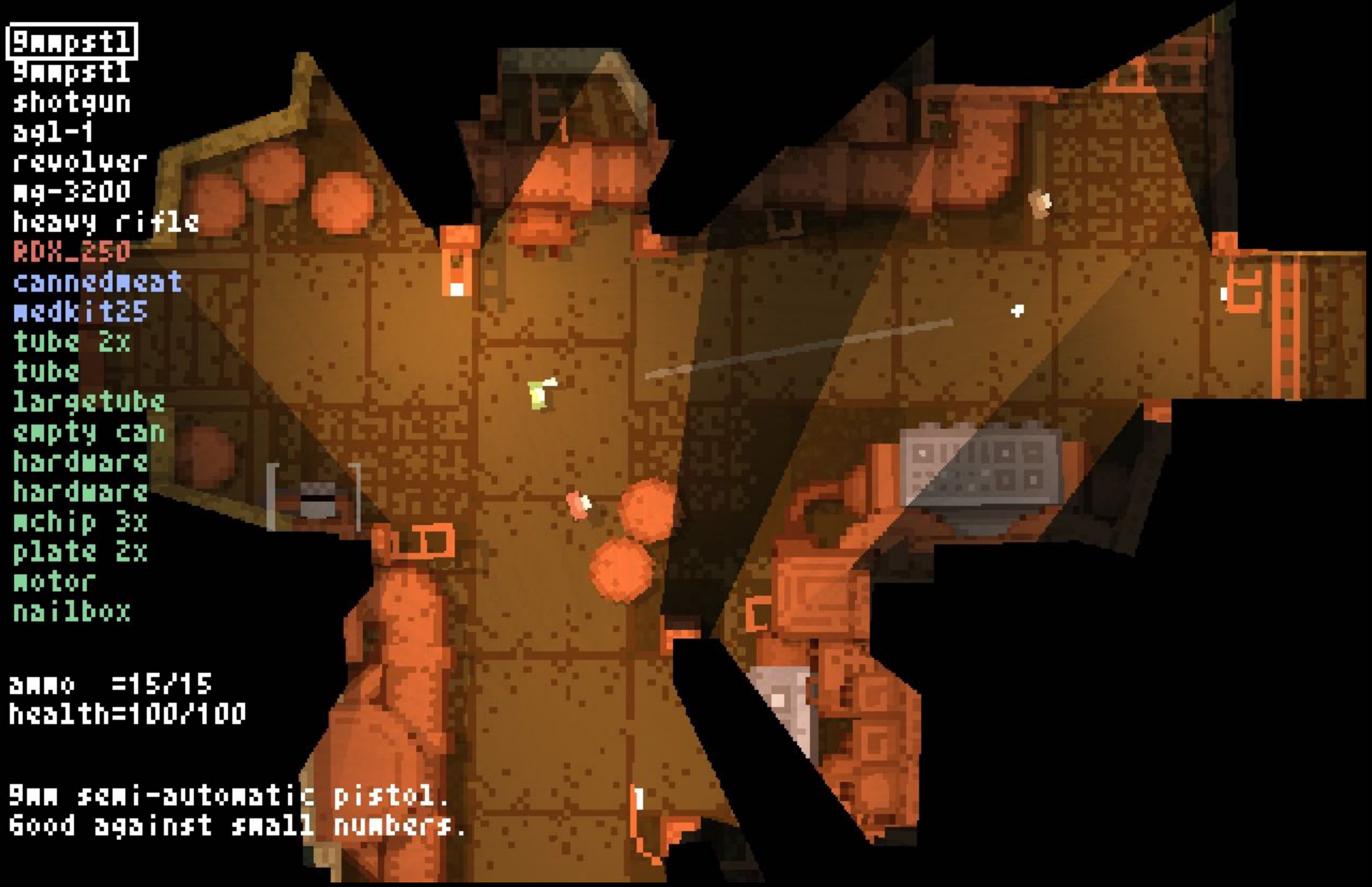
Raycasting.

What is a ray?

A ray has an origin position and a direction.

It can be defined as a two vectors, one defining the position and another (unit!) vector defining the direction.



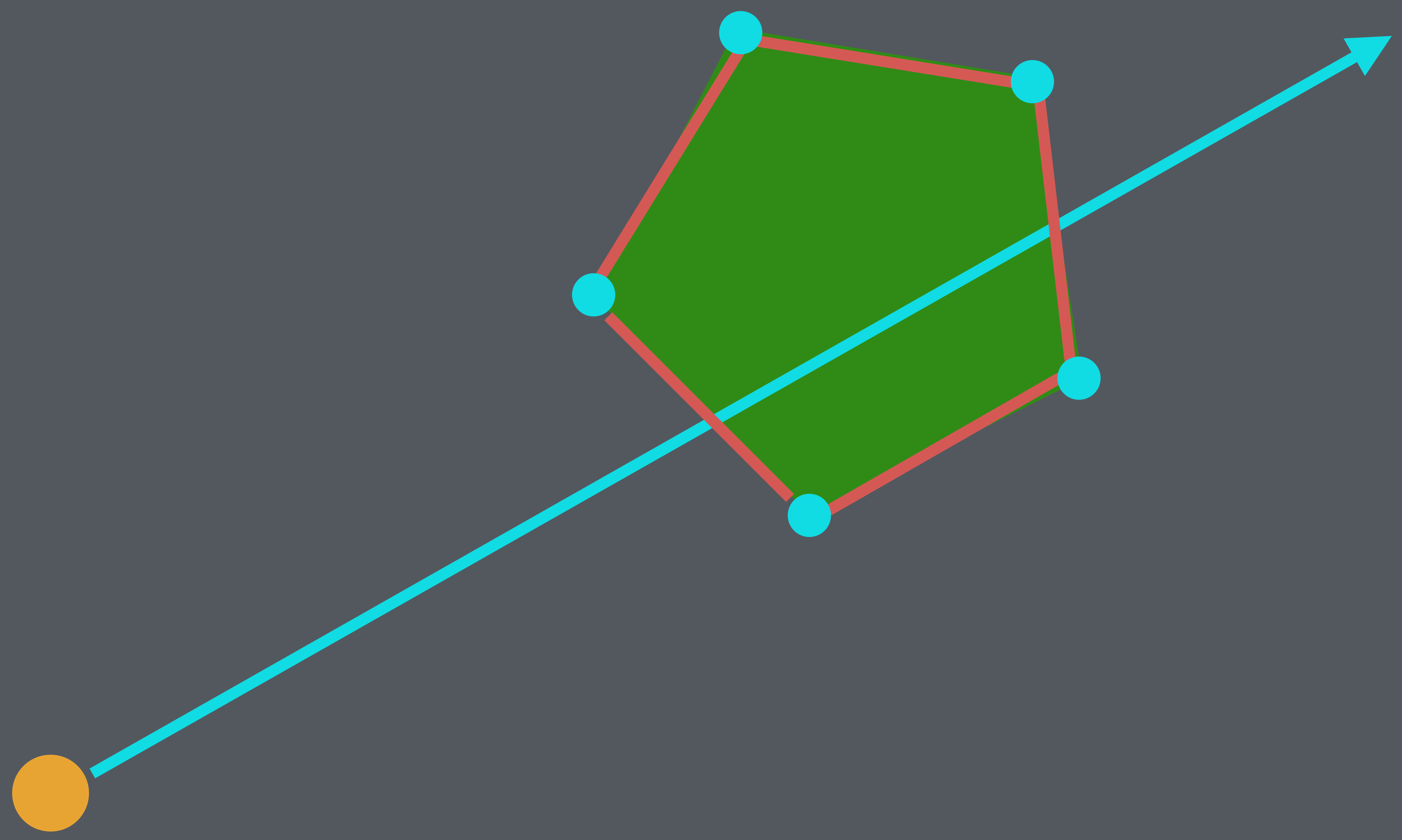

9mmpstl
9mmpstl
shotgun
agl-1
revolver
mg-3200
heavy rifle
RDX_250
cannedmeat
medkit25
tube 2x
tube
largetube
empty can
hardware
hardware
mchip 3x
plate 2x
motor
nailbox
ammo =15/15
health=100/100
9mm semi-automatic pistol.
Good against small numbers.

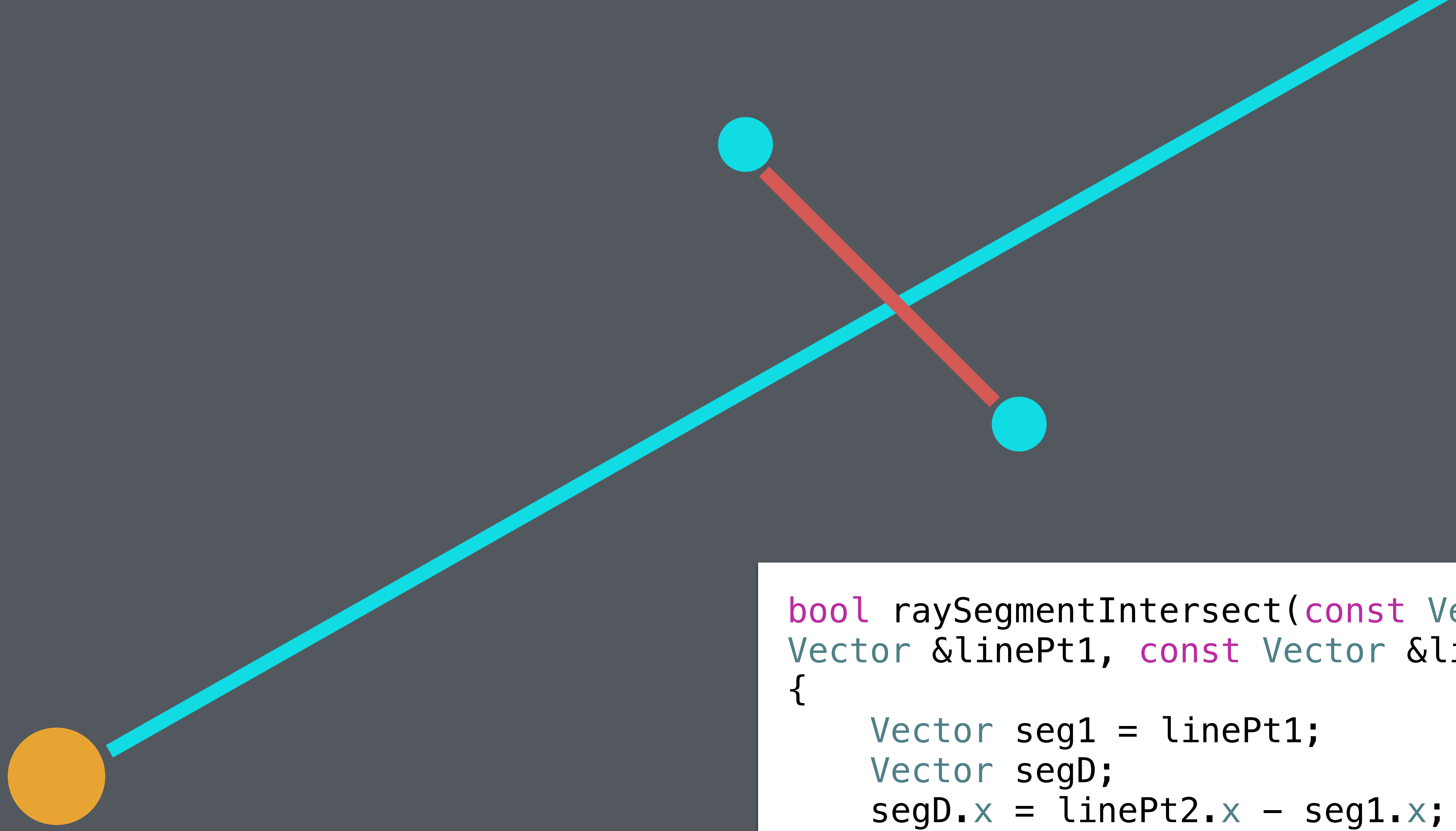

Drop
Drop
043


ZR
X
Y
29
A
Back
B
00
477


PICKED UP BODY ARMOR
PICKED UP BOX OF SHOTGUN SHELLS
92
21

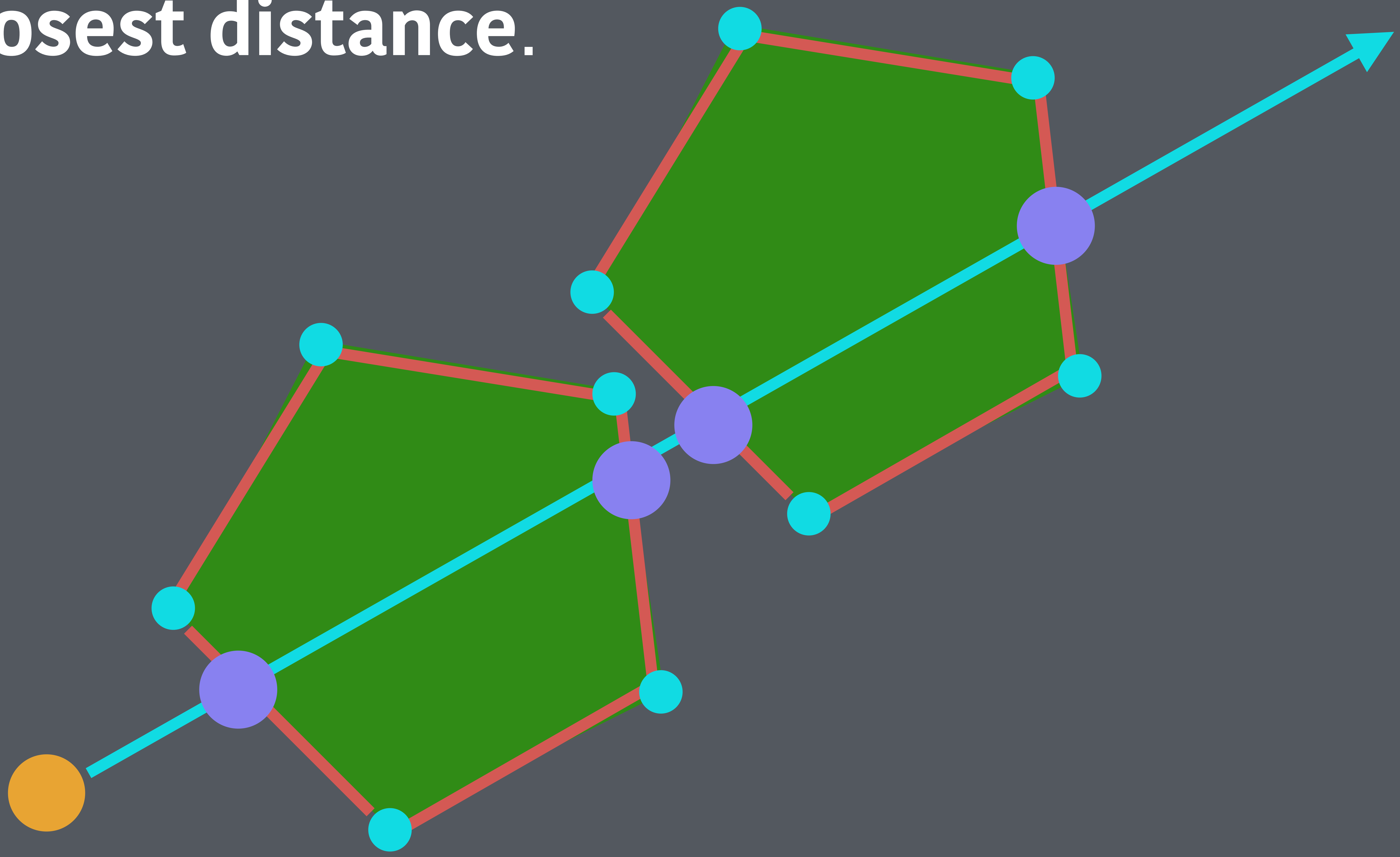
Ray/Polygon intersection test.



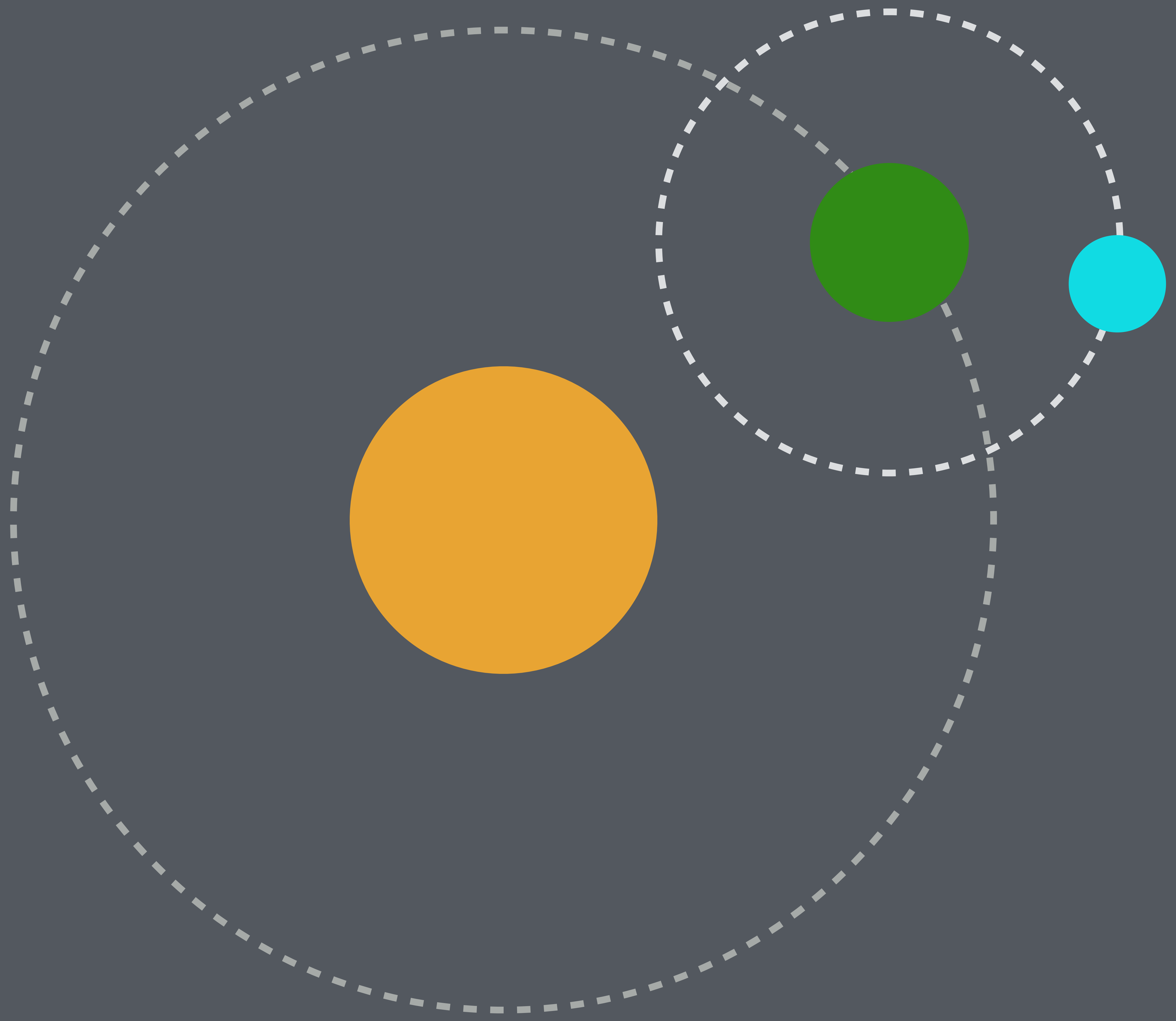


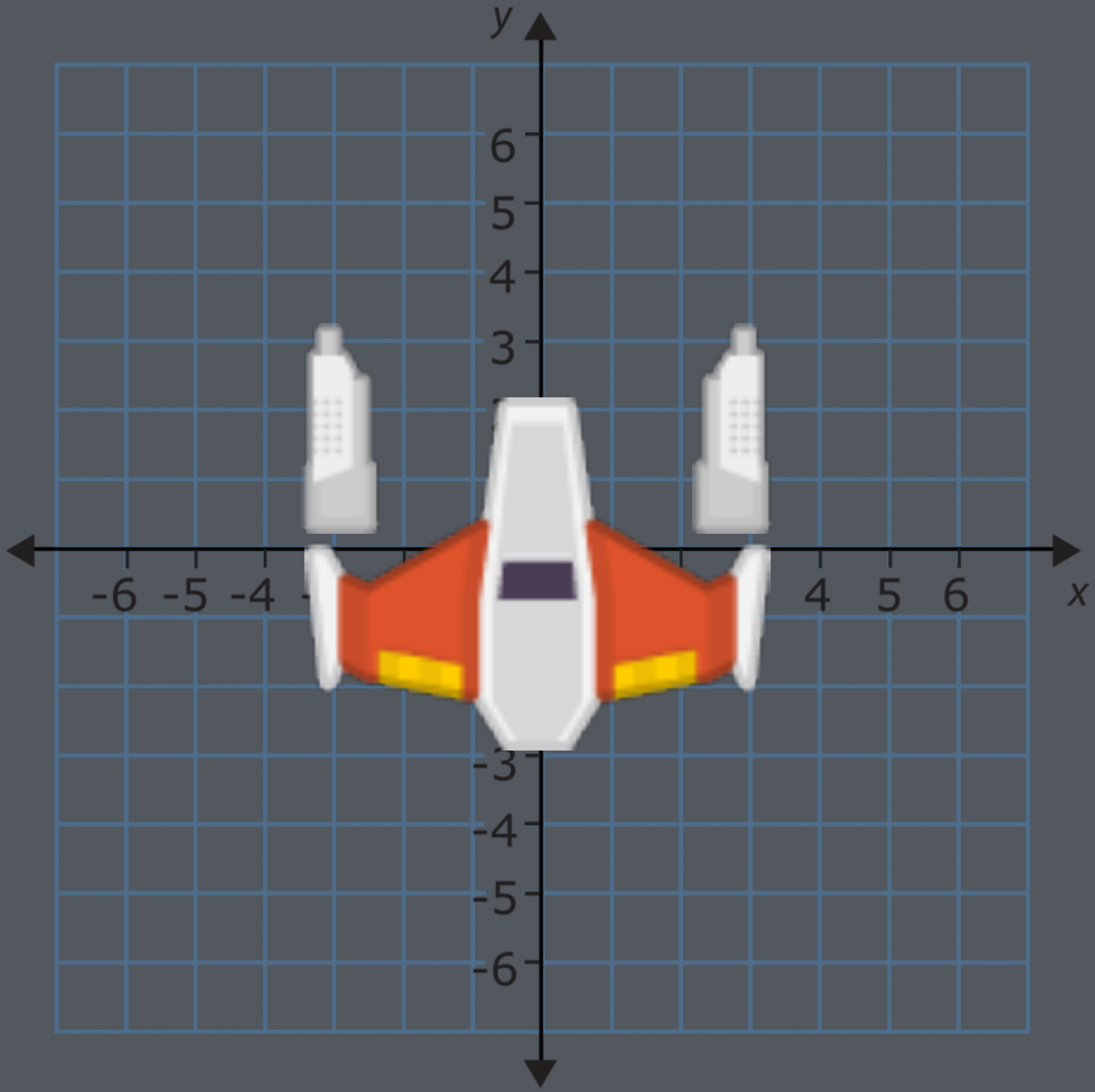
```
bool raySegmentIntersect(const Vector &rayOrigin, const Vector &rayDirection, const
Vector &linePt1, const Vector &linePt2, float &dist)
{
    Vector seg1 = linePt1;
    Vector segD;
    segD.x = linePt2.x - seg1.x;
    segD.y = linePt2.y - seg1.y;

    float raySlope = rayDirection.y / rayDirection.x;
    float n  = ((seg1.x - rayOrigin.x)*raySlope + (rayOrigin.y - seg1.y)) / (segD.y -
segD.x*raySlope);

    if (n < 0 || n > 1)
        return false;

    float m = (seg1.x + segD.x * n - rayOrigin.x) / rayDirection.x;
    if (m < 0)
        return false;

    dist = m;
    return true;
}
```

Use the **closest distance**.

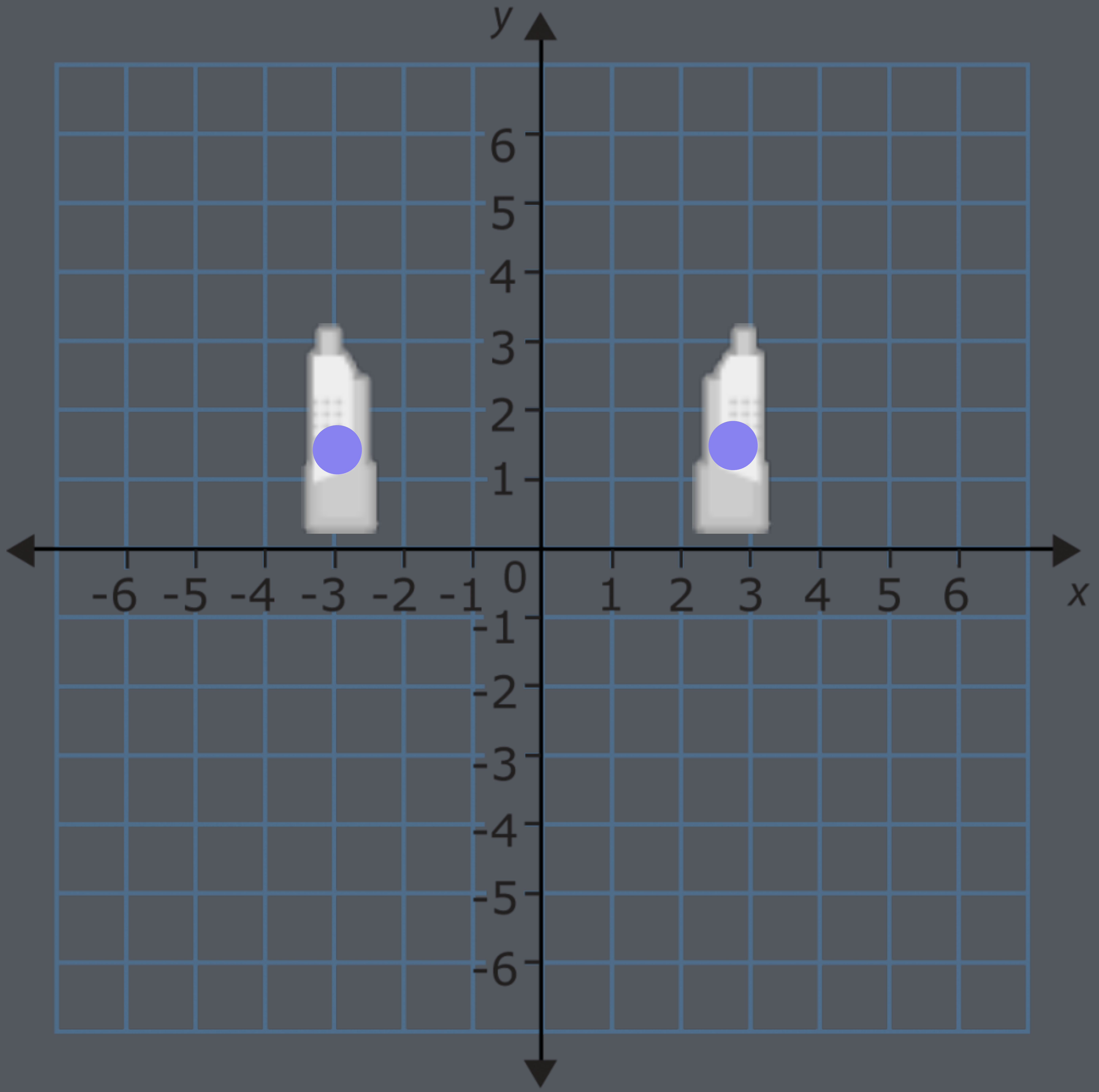


Entity hierarchies





y
6
5
4
3
-3
-4
-5
-6
-6
-5
-4
4
5
6
x



y
x
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
1
2
3
4
5
6
-6
-5
-4
-3
-2
-1
-1
-2
-3
-4
-5
-6

```cpp
class Entity {
  public:

      Entity();
      void Render();

      Entity *parentEntity;

 };


 Entity::Entity() : parentEntity(NULL) {

 }

 void Entity::Draw() {

    Matrix modelMatrix;
    // create model matrix

    if(parentEntity) {
        modelMatrix = modelMatrix  * parentEntity->matrix;
    }
 }
```

Assigning a **parent entity.**

Assignment

Create a simple Separated Axis Collision demo using colliding rectangles or polygons.
(You will be provided with the SAT collision function).

It must have at least 3 objects colliding with each other and responding to collisions. They must be rotated and scaled!