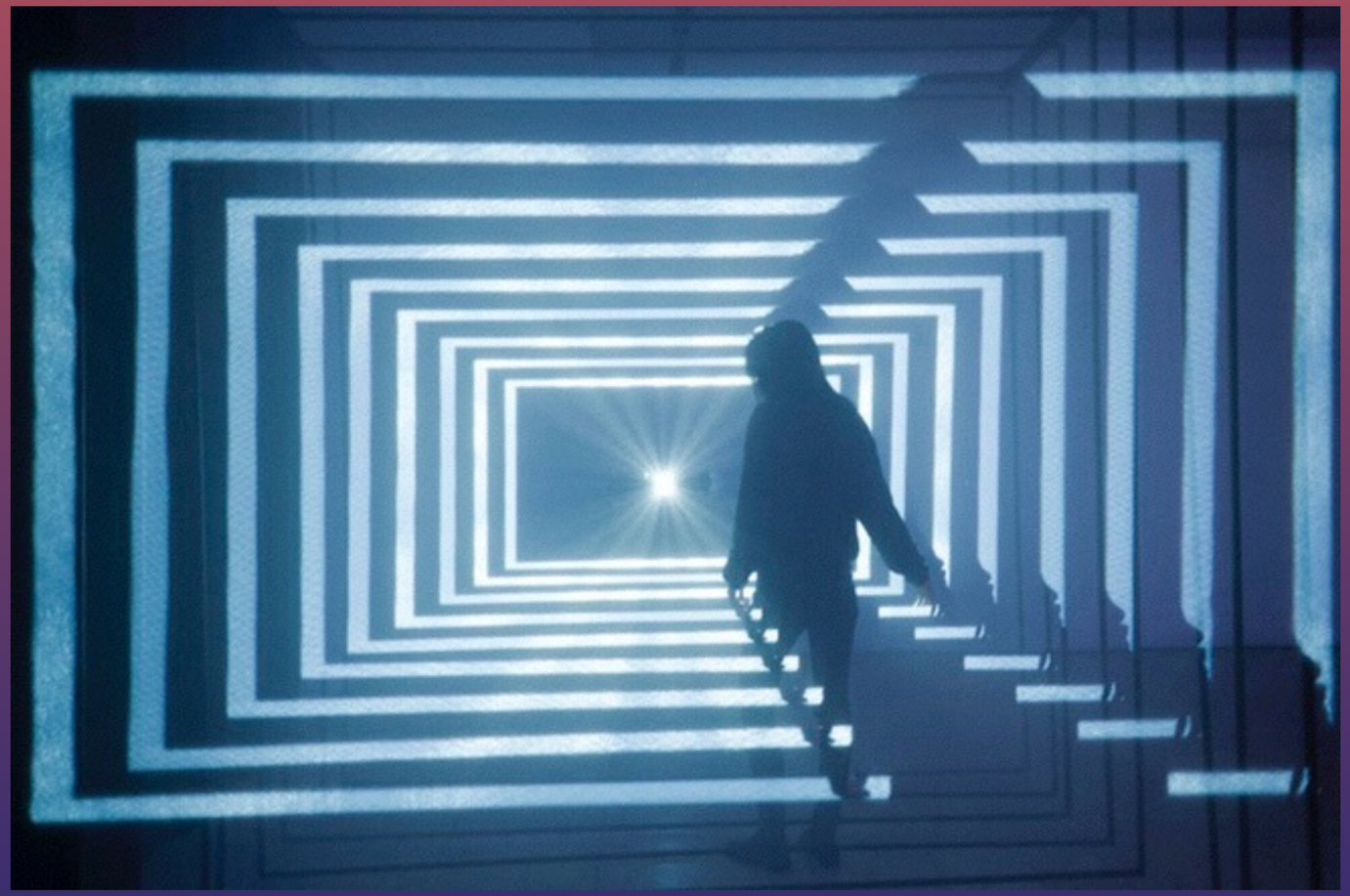
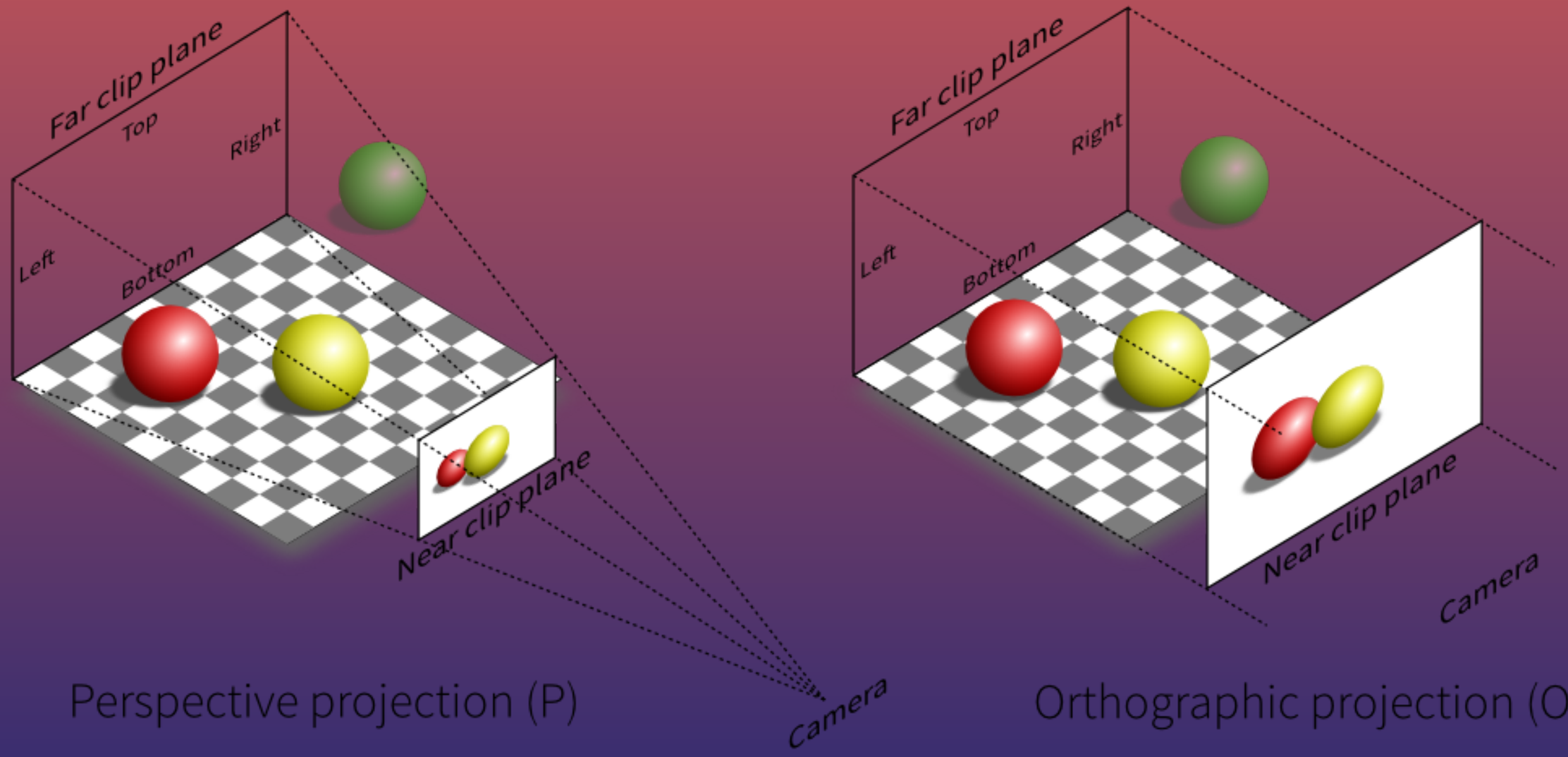
3D Graphics

Part 1



Perspective

Perspective vs. Orthographic projection.



Perspective projection (P)

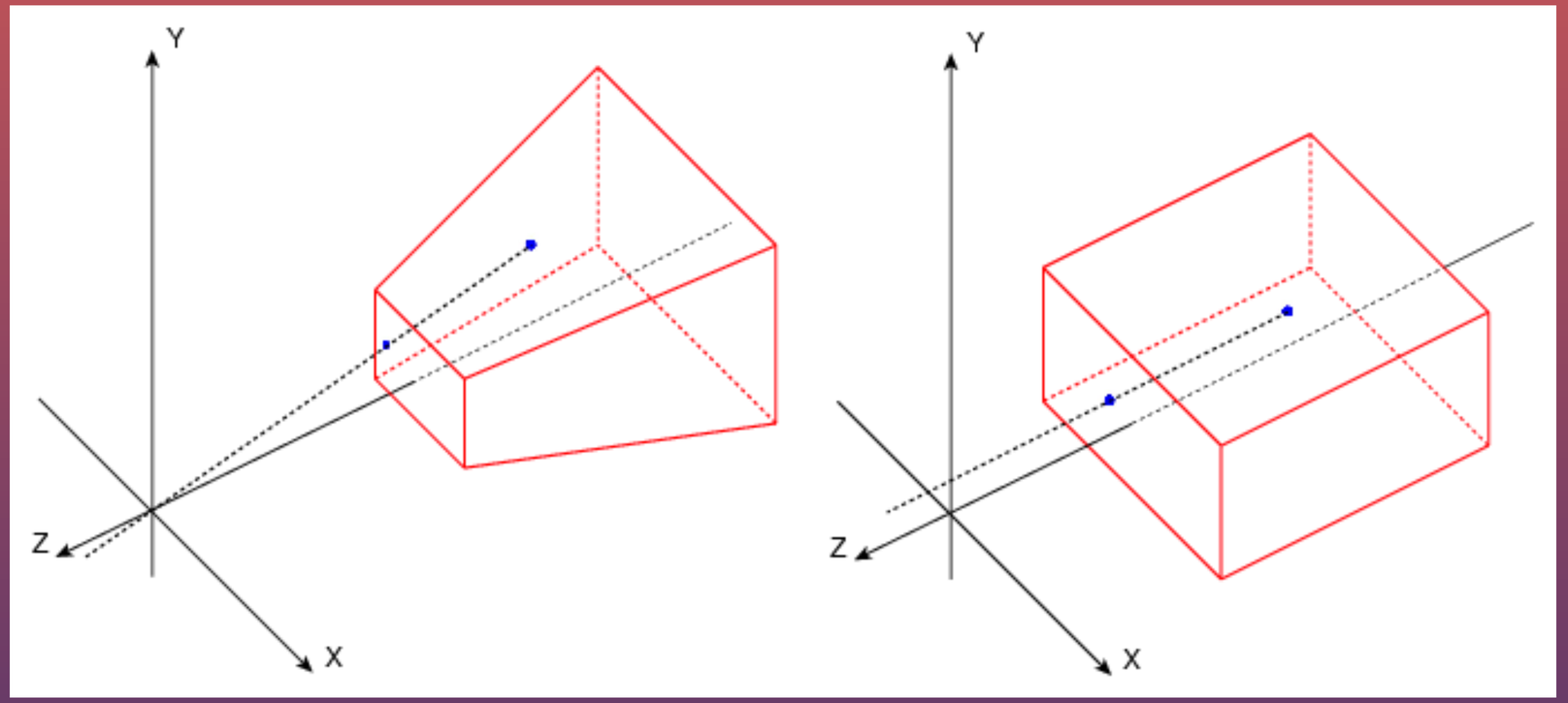
Orthographic projection (O)

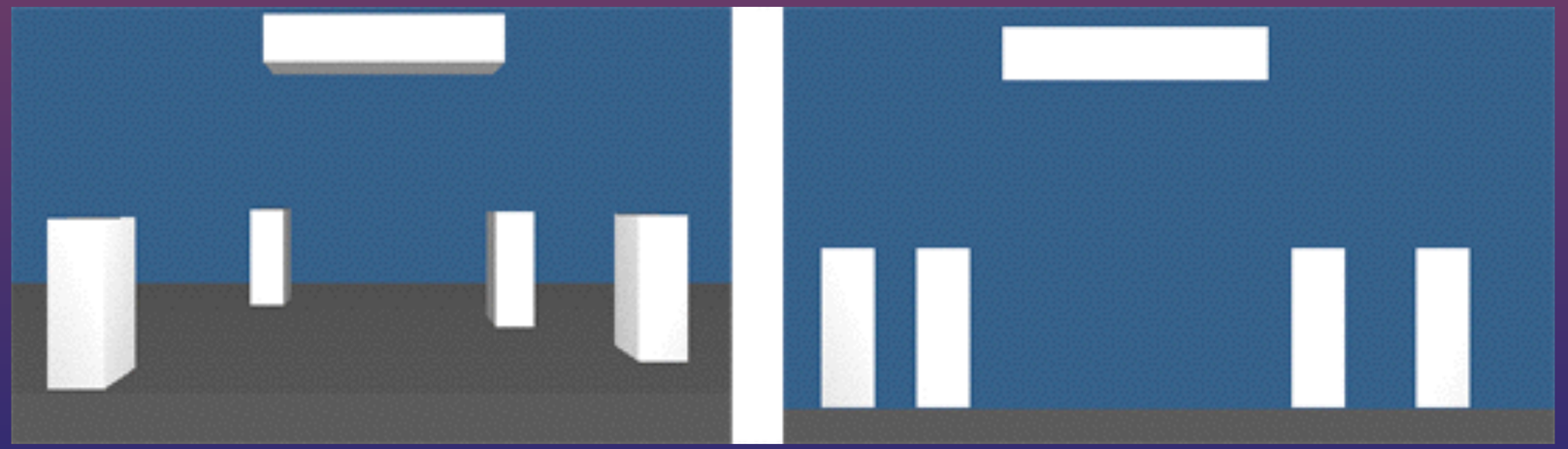
Orthographic projection matrix.

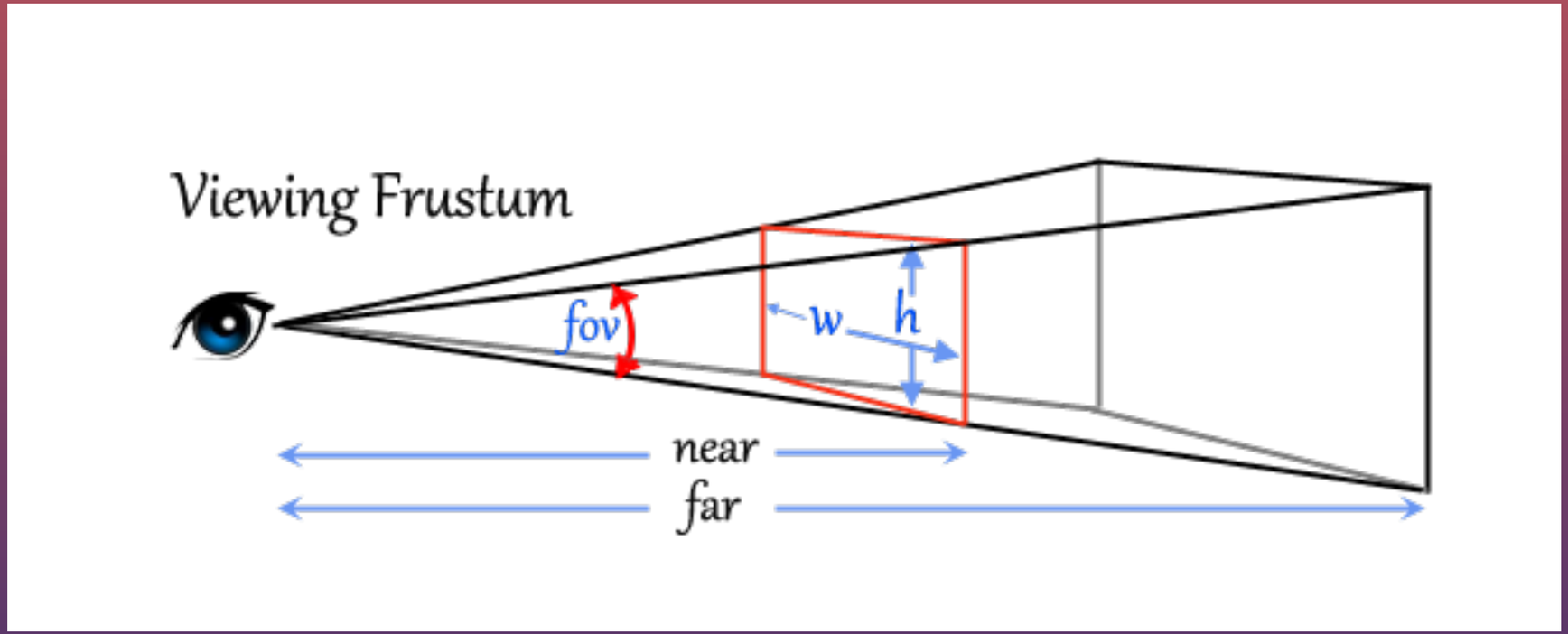
$$\begin{pmatrix} \frac{2}{r-l} & 0 & 0 & -\frac{r+l}{r-l} \\ 0 & \frac{2}{t-b} & 0 & -\frac{t+b}{t-b} \\ 0 & 0 & \frac{-2}{f-n} & -\frac{f+n}{f-n} \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Building a perspective projection matrix.

Perspective vs. Orthographic projection.





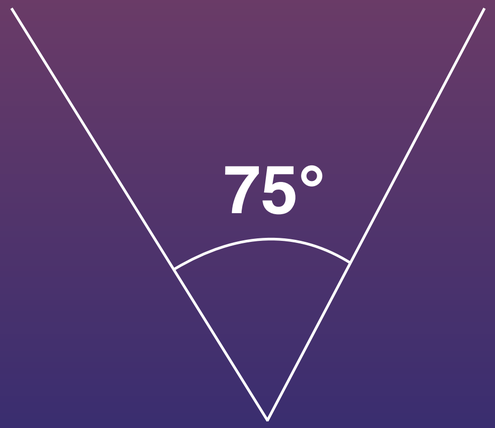

Viewing Frustum
fov
w
h
near
far

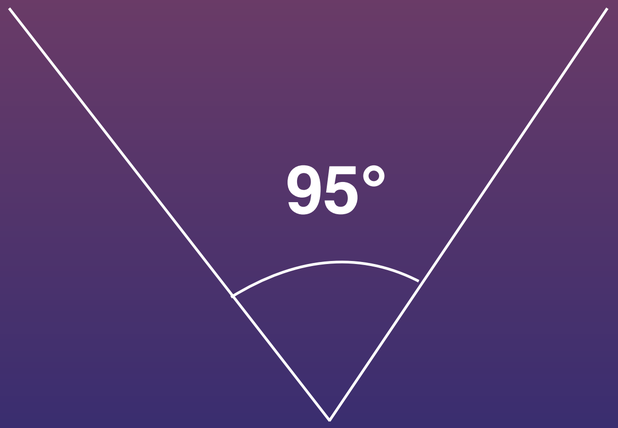

55
030


75
030


95
030


55°


75°


95°

Perspective projection matrix.

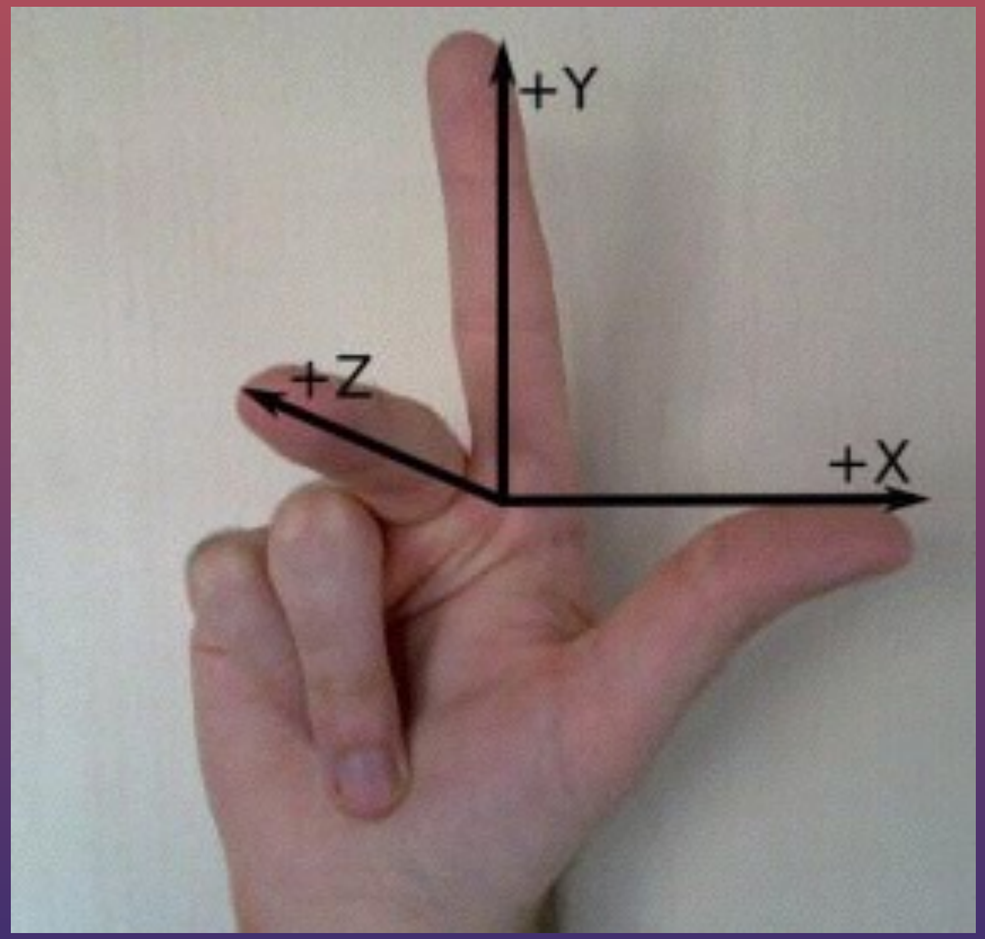
$$P = \begin{bmatrix} \frac{\cot\frac{fovy}{2}}{aspect} & 0 & 0 & 0 \\ 0 & \cot\frac{fovy}{2} & 0 & 0 \\ 0 & 0 & \frac{n+f}{n-f} & \frac{2*n*f}{n-f} \\ 0 & 0 & -1 & 0 \end{bmatrix}$$

```
#define TO_RADIANS 0.0174532925

void setPerspective(float fov, float aspect, float zNear, float zFar) {

    Matrix m;
    m.identity();
    m.m[0][0] = 1.0f/tanf(fov*TO_RADIANS/2.0)/aspect;
    m.m[1][1] = 1.0f/tanf(fov*TO_RADIANS/2.0);
    m.m[2][2] = (zFar+zNear)/(zNear-zFar);
    m.m[3][2] = (2.0f*zFar*zNear)/(zNear-zFar);
    m.m[2][3] = -1.0f;
    m.m[3][3] = 0.0f;

    glMatrixMode(GL_PROJECTION);
    glLoadIdentity();
    glMultMatrixf(m.ml);
}
```

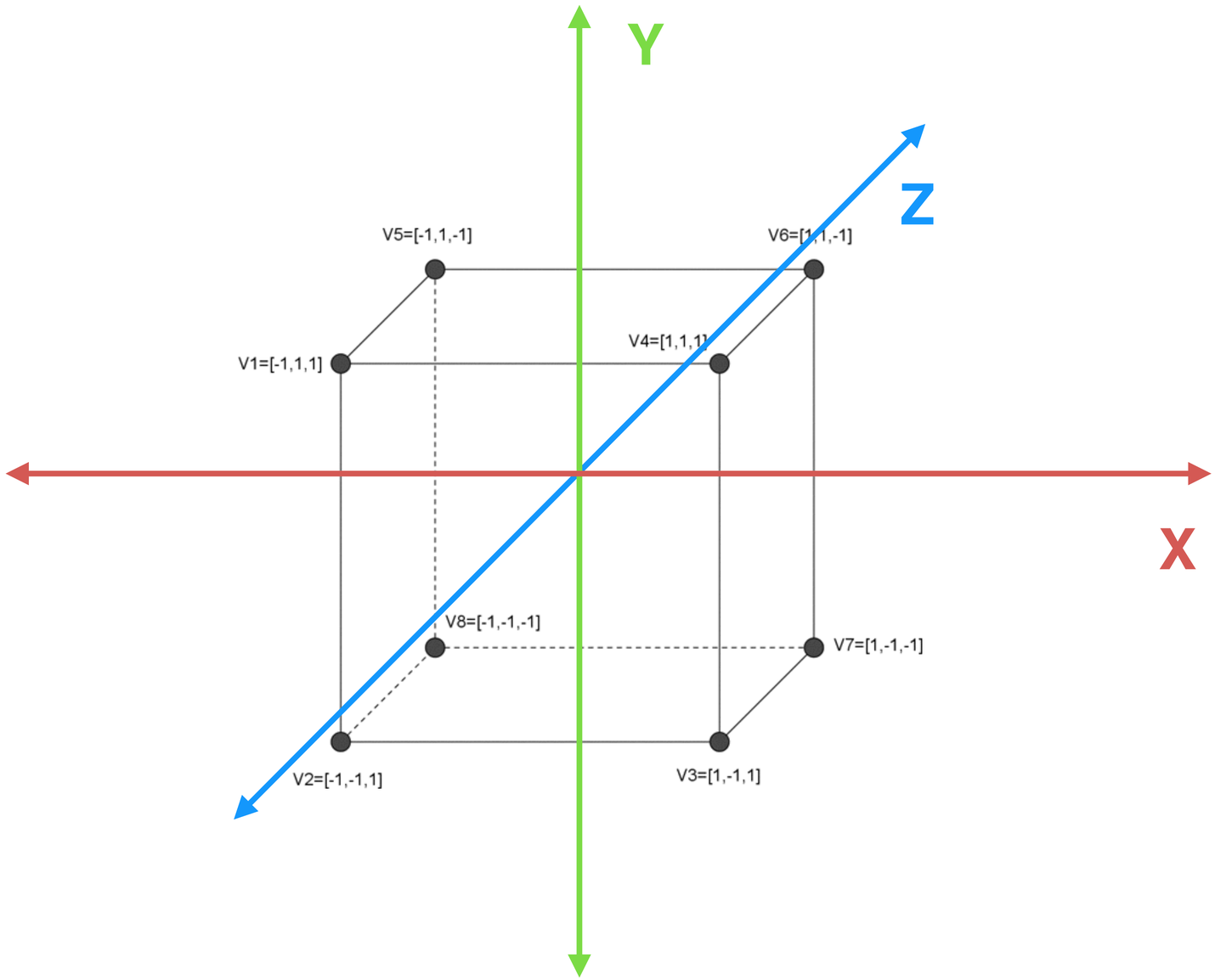
Drawing in 3D

It’s the same as drawing in 2D!
We just need to add that 3rd dimension!

Right-handed coordinate system.

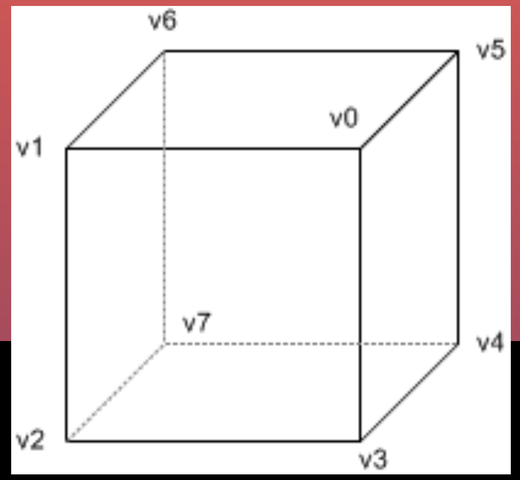


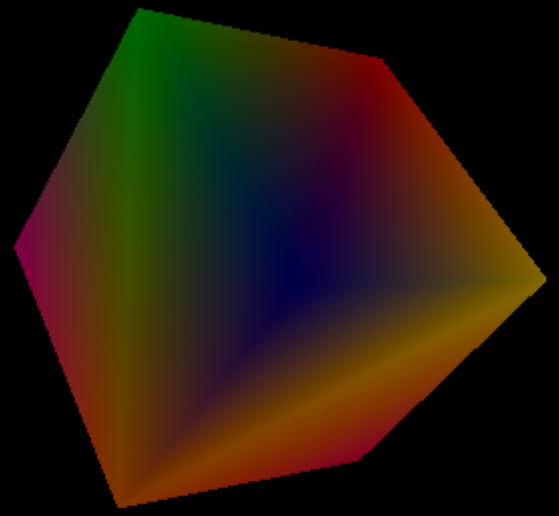
Drawing a cube.


Y
Z
X
V5=[-1,1,-1]
V6=[1,1,-1]
V1=[-1,1,1]
V4=[1,1,1]
V8=[-1,-1,-1]
V7=[1,-1,-1]
V2=[-1,-1,1]
V3=[1,-1,1]

```
float vertices[24] = {-1.0, -1.0,  1.0,
     1.0, -1.0,  1.0,
     1.0,  1.0,  1.0,
     -1.0,  1.0,  1.0,
     -1.0, -1.0, -1.0,
     1.0, -1.0, -1.0,
     1.0,  1.0, -1.0,
     -1.0,  1.0, -1.0};

float colors[24] = {1.0f, 0.0f, 0.0f,
                    0.0f, 1.0f, 0.0f,
                    0.0f, 0.0f, 1.0f,
                    1.0f, 1.0f ,0.0f,
                    0.0f, 1.0f, 1.0f,
                    1.0f, 0.0f, 1.0f,
                    1.0f, 0.5f, 0.0f,
                    1.0f, 0.0f, 0.5f};

 unsigned int indices[36] = {
     0, 1, 2,
     2, 3, 0,
     3, 2, 6,
     6, 7, 3,
     7, 6, 5,
     5, 4, 7,
     4, 5, 1,
     1, 0, 4,
     4, 0, 3,
     3, 7, 4,
     1, 5, 6,
     6, 2, 1};

 glVertexPointer(3, GL_FLOAT, 0, vertices);
 glEnableClientState(GL_VERTEX_ARRAY);

 glColorPointer(3, GL_FLOAT, 0, colors);
 glEnableClientState(GL_COLOR_ARRAY);

 glDrawElements(GL_TRIANGLES, 36, GL_UNSIGNED_INT, indices);
```

3 DIMENSIONS PER VERTEX

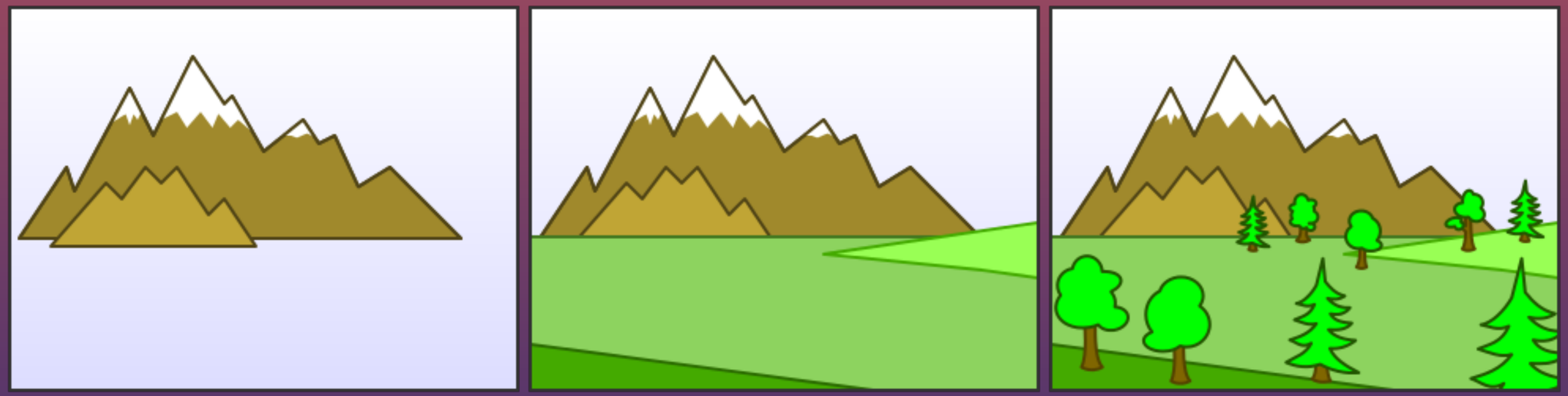




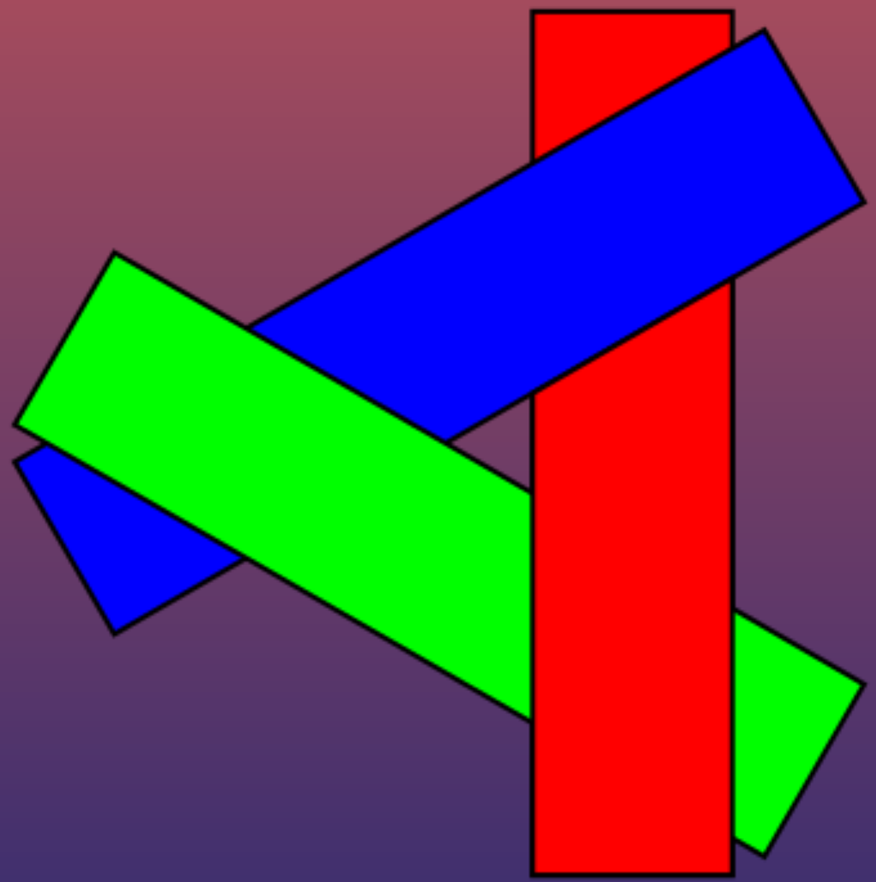
3 DIMENSIONS PER VERTEX

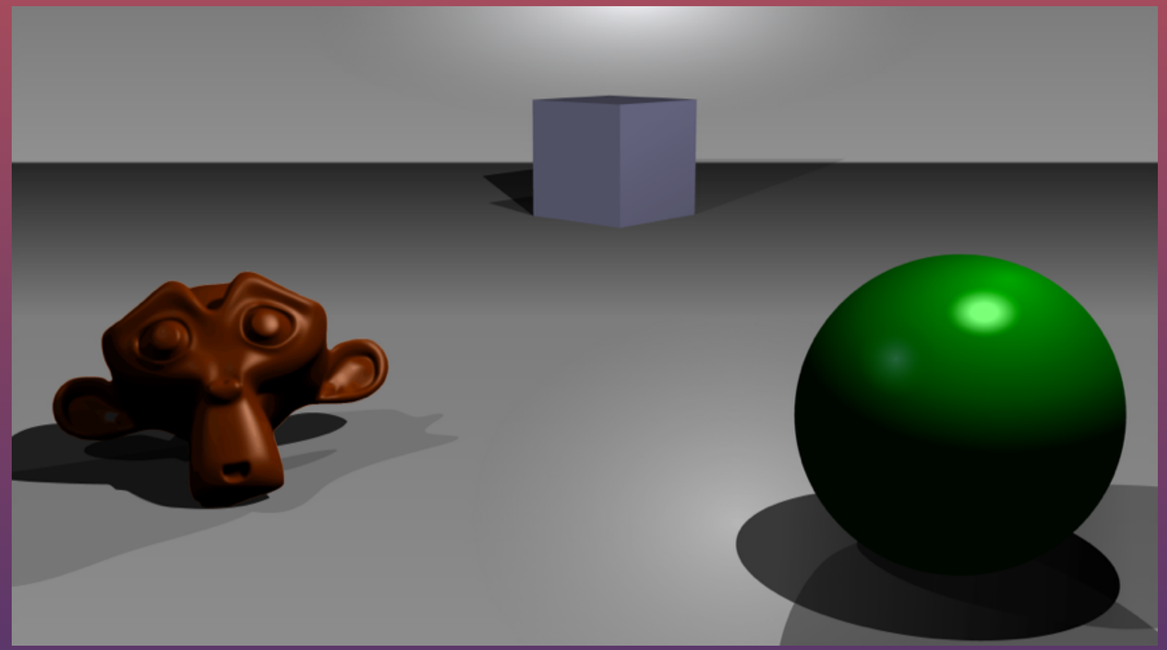
Z-Buffer

Painter’s algorithm.



???





Enabling the Z-Buffer in OpenGL.

`void glDepthMask (GLboolean flag);`

Enabes or disables depth buffer writing.

```
glDepthMask(GL_TRUE); // enable depth write
glDepthMask(GL_FALSE); // disable depth write
```

```
void glEnable (GLenum capability);
void glDisable (GLenum capability);
```

Enable or disable an OpenGL capability. Use GL_DEPTH_TEST to enable or disable depth test capability.

```
glEnable(GL_DEPTH_TEST); // enable depth testing
glDisable(GL_DEPTH_TEST); // disable depth testing
```

void glDepthFunc (GLenum func);

Specifies the function used to compare each incoming pixel depth value with the depth value present in the depth buffer.

Can be one of the following:

GL_NEVER, GL_LESS, GL_EQUAL, GL_LEQUAL, GL_GREATER, GL_NOTEQUAL, GL_GEQUAL, and GL_ALWAYS

For example if the function is **GL_LEQUAL,** the pixel will only be drawn if its depth is **LESS THAN OR EQUAL** than the pixel's depth on the screen (most of the time we want this).

```
glDepthFunc(GL_LEQUAL); // only draw pixels that are closer or equal
```

Putting it together.

Enabling depth testing/writing for 3D.

```
glEnable(GL_DEPTH_TEST);
glDepthFunc(GL_LEQUAL);
glDepthMask(GL_TRUE);
```

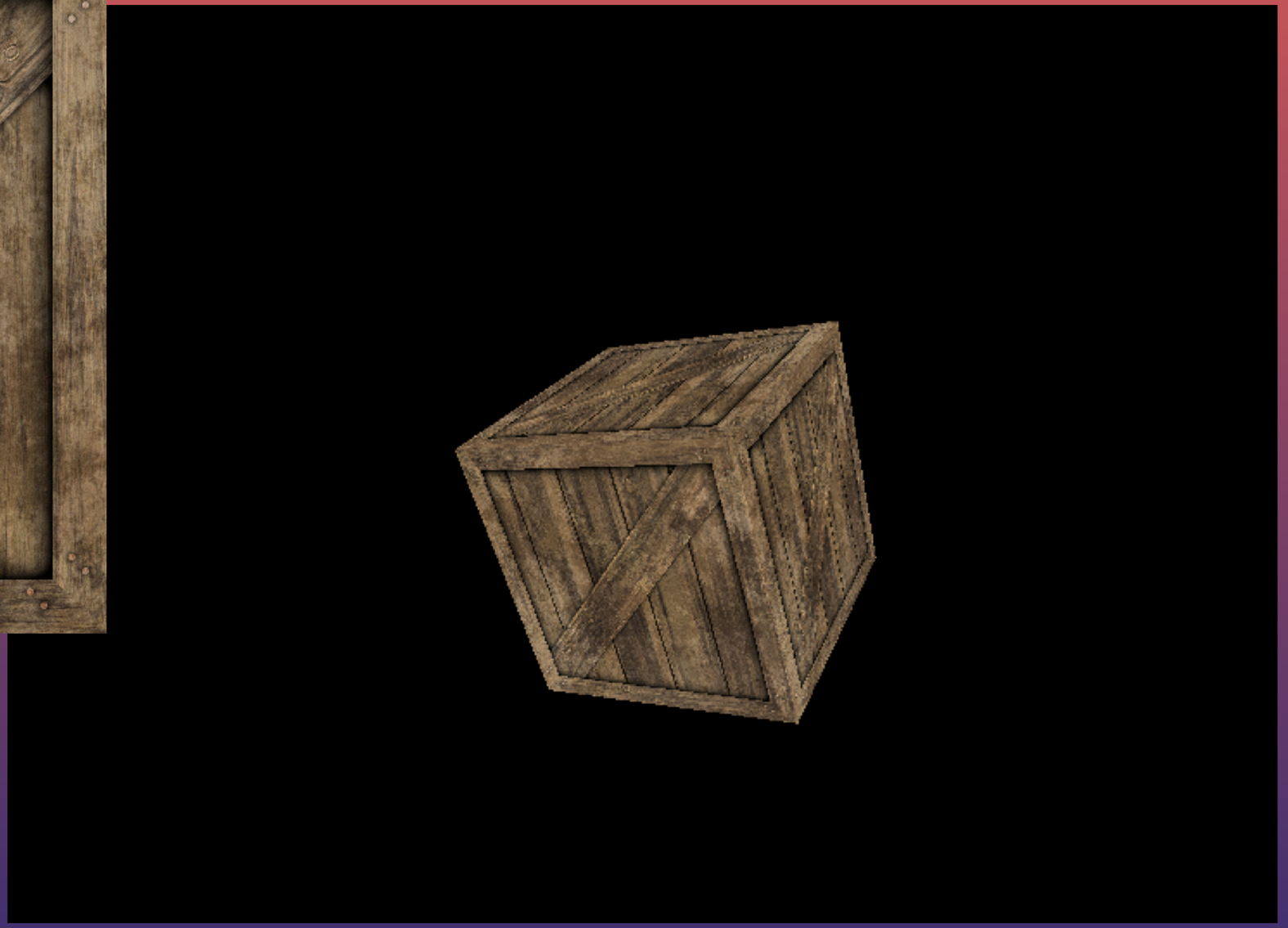
Disabling depth testing and writing.

```
glDisable(GL_DEPTH_TEST);
glDepthMask(GL_FALSE);
```

Clearing the depth buffer!

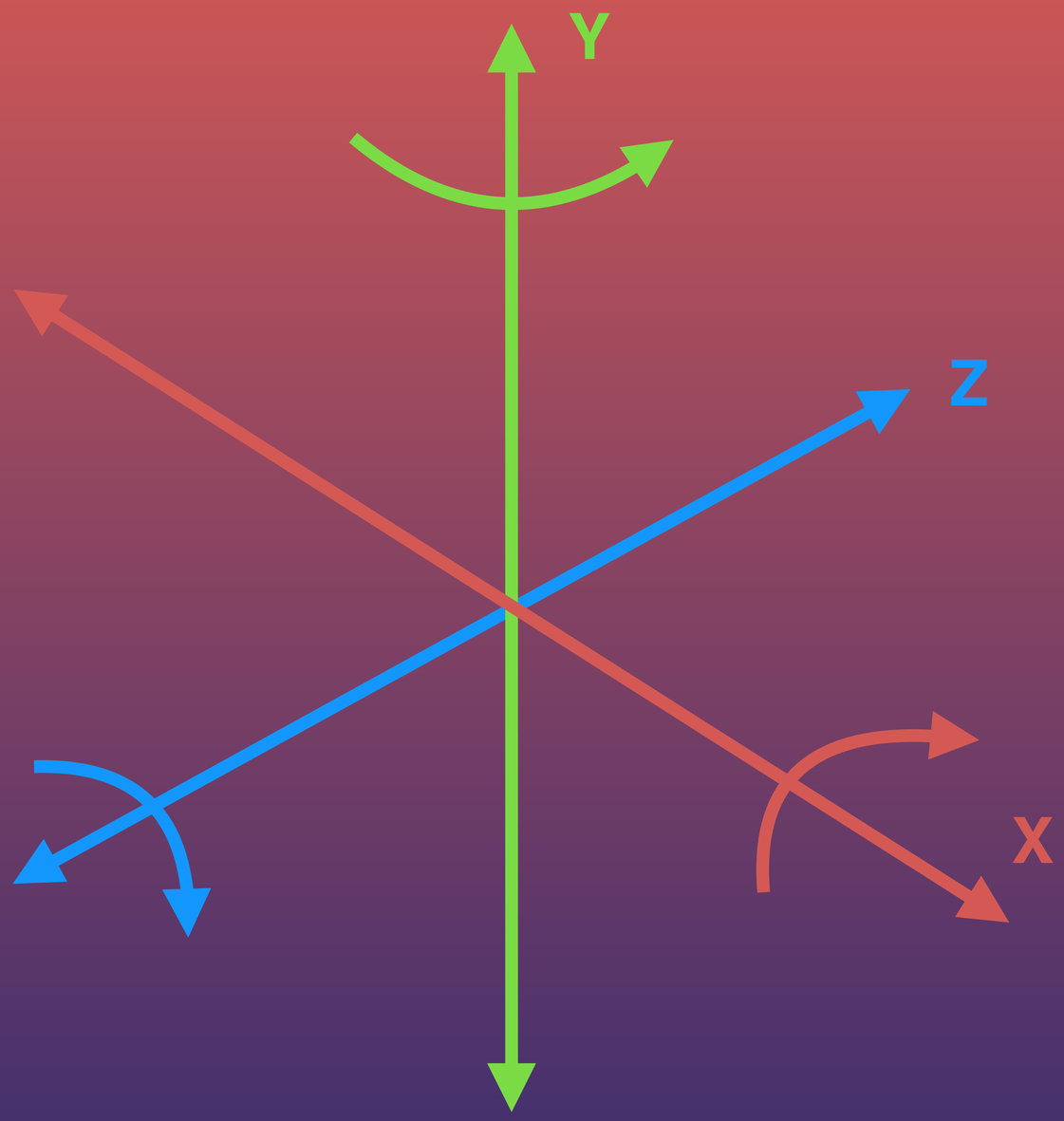
If using the depth buffer, we need to tell the OpenGL clear function to clear the depth buffer as well as the color buffer!

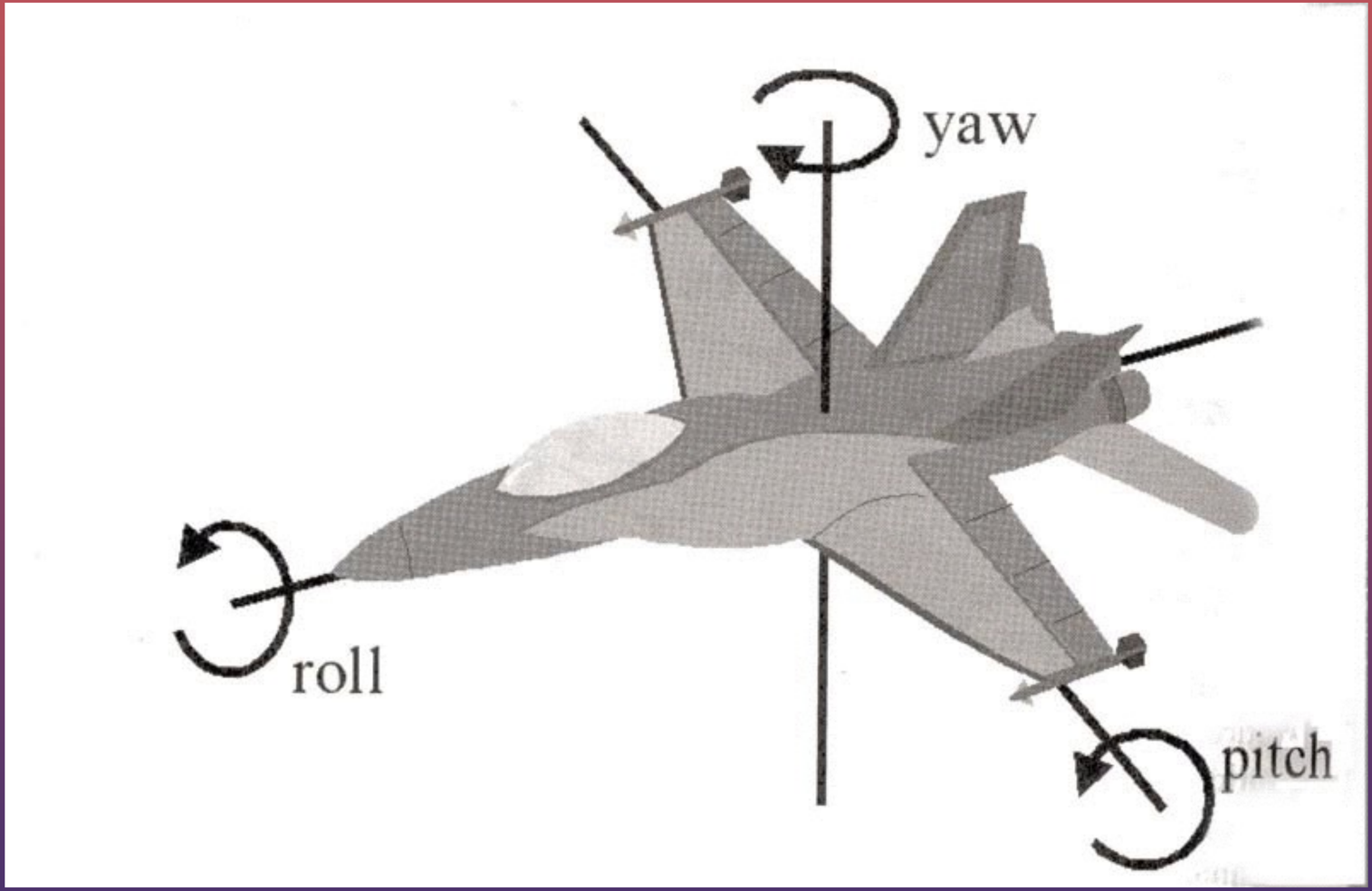
```
glClear(GL_COLOR_BUFFER_BIT|GL_DEPTH_BUFFER_BIT);
```

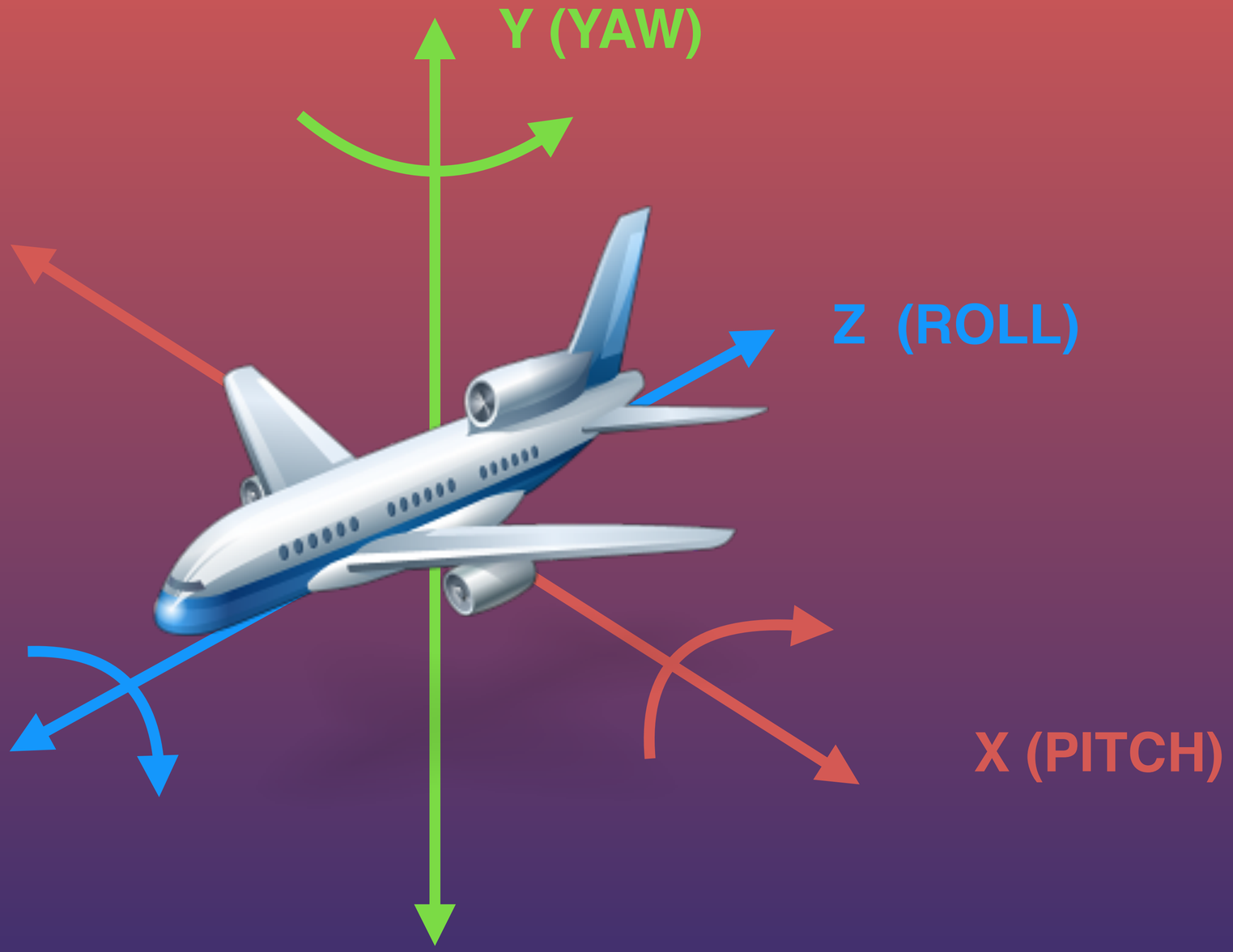


3D Entities

3 degrees of rotation.


Y
Z
X


yaw
roll
pitch


Y (YAW)
Z (ROLL)
X (PITCH)

```
class Entity {
public:

    Entity();
    void Update(float elapsed);
    void Render();
    void buildMatrix();

    void FixedUpdate();

    Matrix matrix;

    Vector position;
    Vector rotation;
    Vector scale;

    Vector velocity;
    Vector acceleration;

    unsigned int texture;
    std::vector<float> vertices;
    std::vector<float> uvs;

    bool visible;
    float friction;

};
```

Extending our entity class into the 3rd dimension

X-Rotation in 3D

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\phi & -\sin\phi & 0 \\ 0 & \sin\phi & \cos\phi & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Z-Rotation in 3D

$$\begin{bmatrix} \cos\phi & -\sin\phi & 0 & 0 \\ \sin\phi & \cos\phi & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Scale in 3D

$$\begin{bmatrix} Sx & 0 & 0 & 0 \\ 0 & Sy & 0 & 0 \\ 0 & 0 & Sz & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

(4x4)*(4x1) = (4x1)

Y-Rotation in 3D

$$\begin{bmatrix} \cos\phi & 0 & \sin\phi & 0 \\ 0 & 1 & 0 & 0 \\ -\sin\phi & 0 & \cos\phi & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Translation in 3D

$$\begin{bmatrix} 1 & 0 & 0 & Tx \\ 0 & 1 & 0 & Ty \\ 0 & 0 & 1 & Tz \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

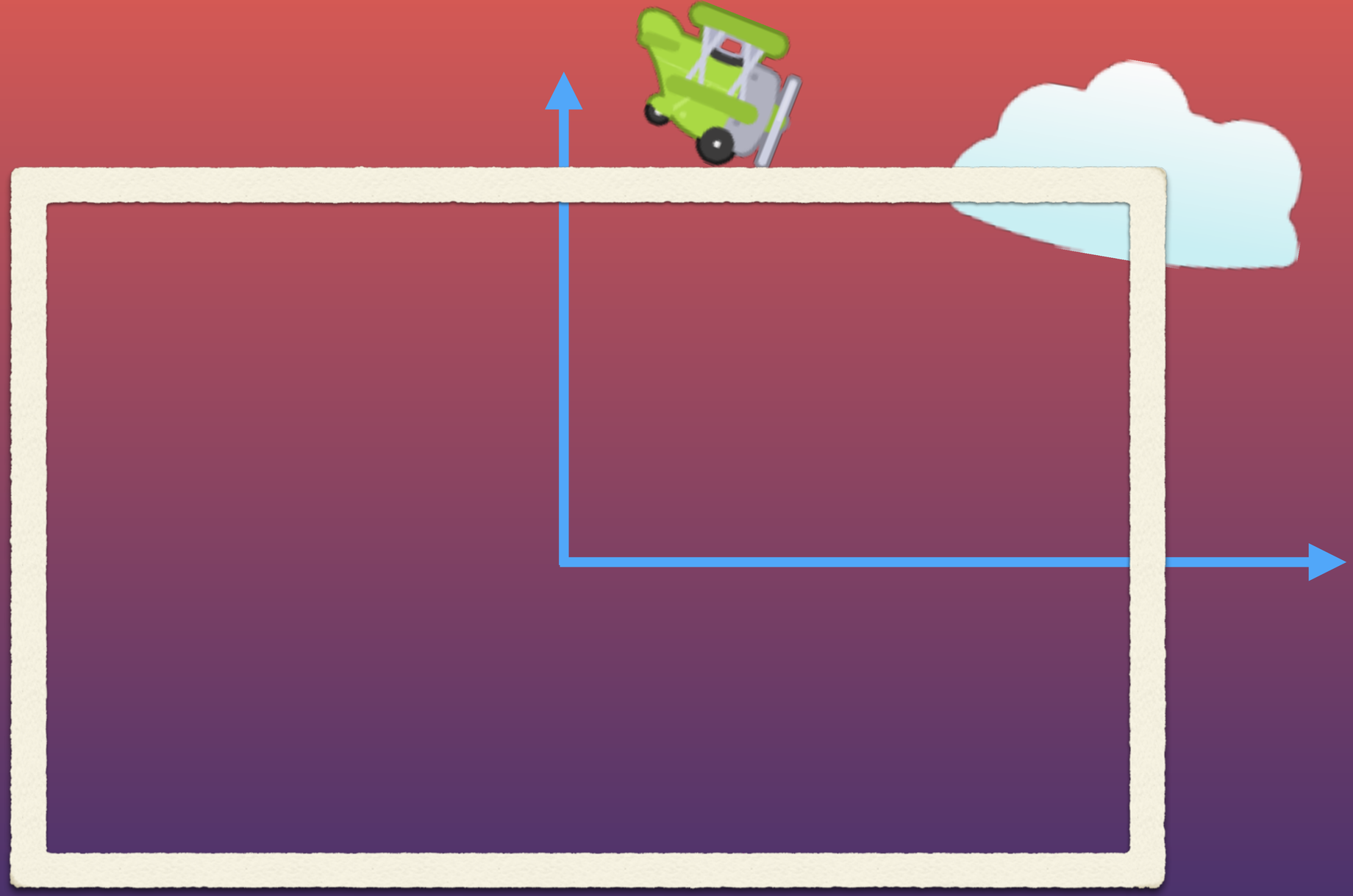
Matrix Multiplication

$$\begin{bmatrix} a & b & c & d \\ e & f & g & h \\ i & j & k & l \\ m & n & o & p \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} = \begin{bmatrix} x' \\ y' \\ z' \\ q \end{bmatrix}$$

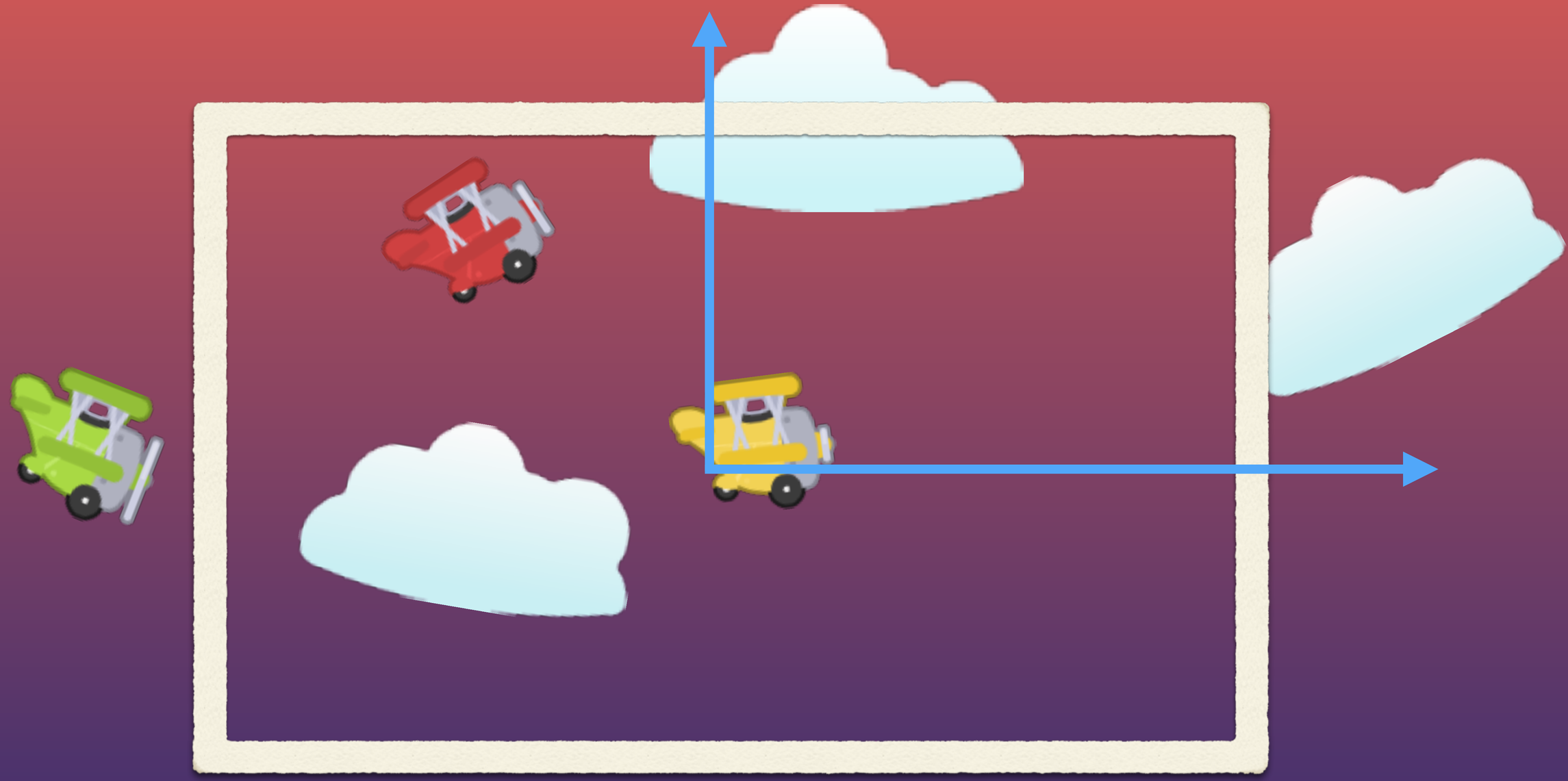
ROTATE MATRIX = ROTATE X MATRIX * ROTATE Y MATRIX * ROTATE Z MATRIX

FINAL MATRIX = SCALE MATRIX * ROTATE MATRIX * TRANSLATE MATRIX

3D “Camera”



Without camera translation.



With camera translation.

Our starting modelview matrix needs to be the inverse of the camera entity's matrix!
(this is the "view" in "modelview"!)

Mixing 2D and 3D

Rendering 3D, then 2D on top of it.

- Clear color and depth buffers
- Set perspective projection
- Enable depth testing and writing
- Draw 3D scene
- Set orthographic projection
- Disable depth testing and writing
- Render 2D scene