Lecture 13:
More 3D

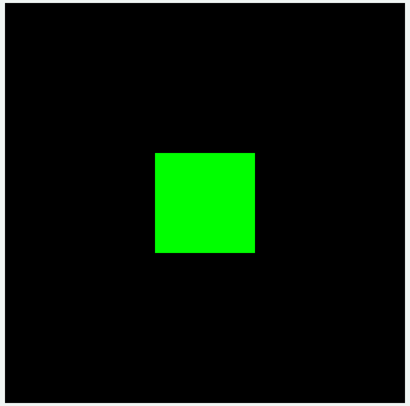
What were we really doing last time?

Get to THREE Transformations

(practice for exam)

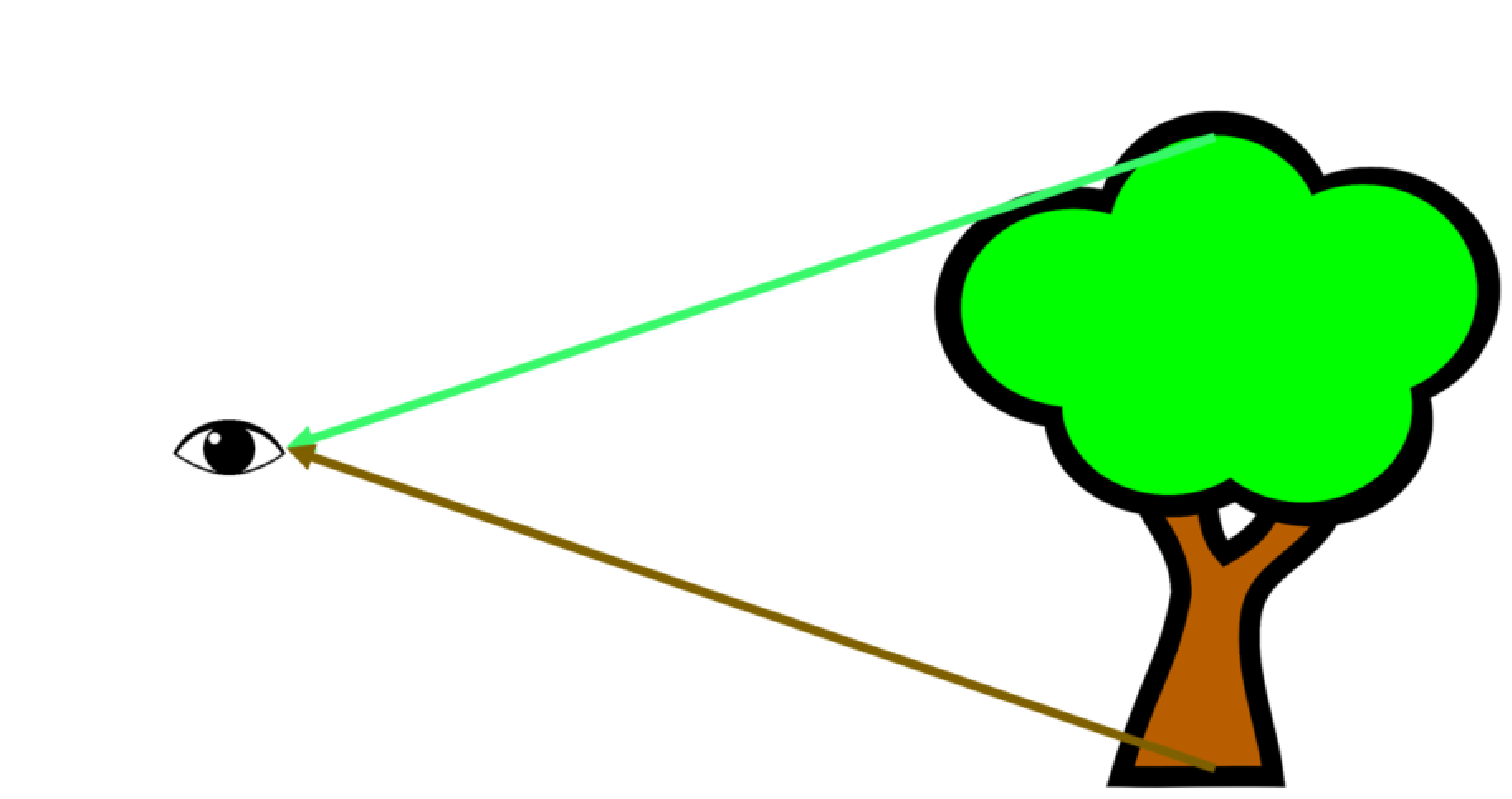
All Together

```
let renderer = new T.WebGLRenderer(); /*1*/
renderer.setSize(200,200);
document.body.appendChild(renderer.domElement);
let scene = new T.Scene(); /*2*/
let geometry = new T.BoxGeometry(1,1,1); /*3*/
var material = new T.MeshBasicMaterial( { color: 0x00ff00 } ); /*4*/
let mesh = new T.Mesh(geometry, material); /*5*/
scene.add(mesh); /*5*/
let camera = new T.OrthographicCamera(-2,2, -2,2, -2,2); /*6*/
renderer.render( scene, camera ); /*7*/
```

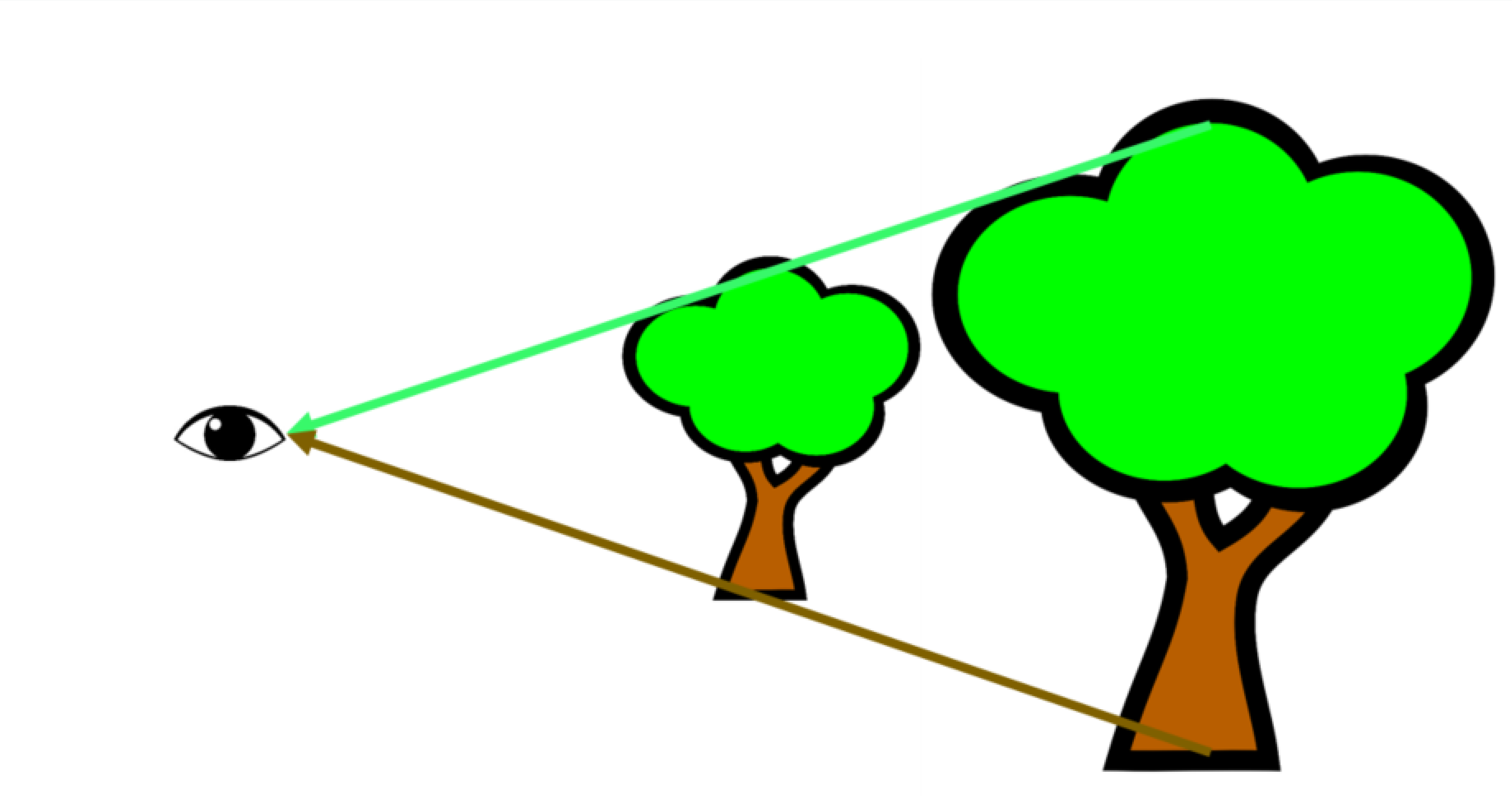


1. Create the Canvas and Set up
2. Create the World
3. Create the Cube
4. Give it a Material (how it should look)
5. Put the Cube into the World
6. Make a Camera (transform 3D to 2D)
7. Draw

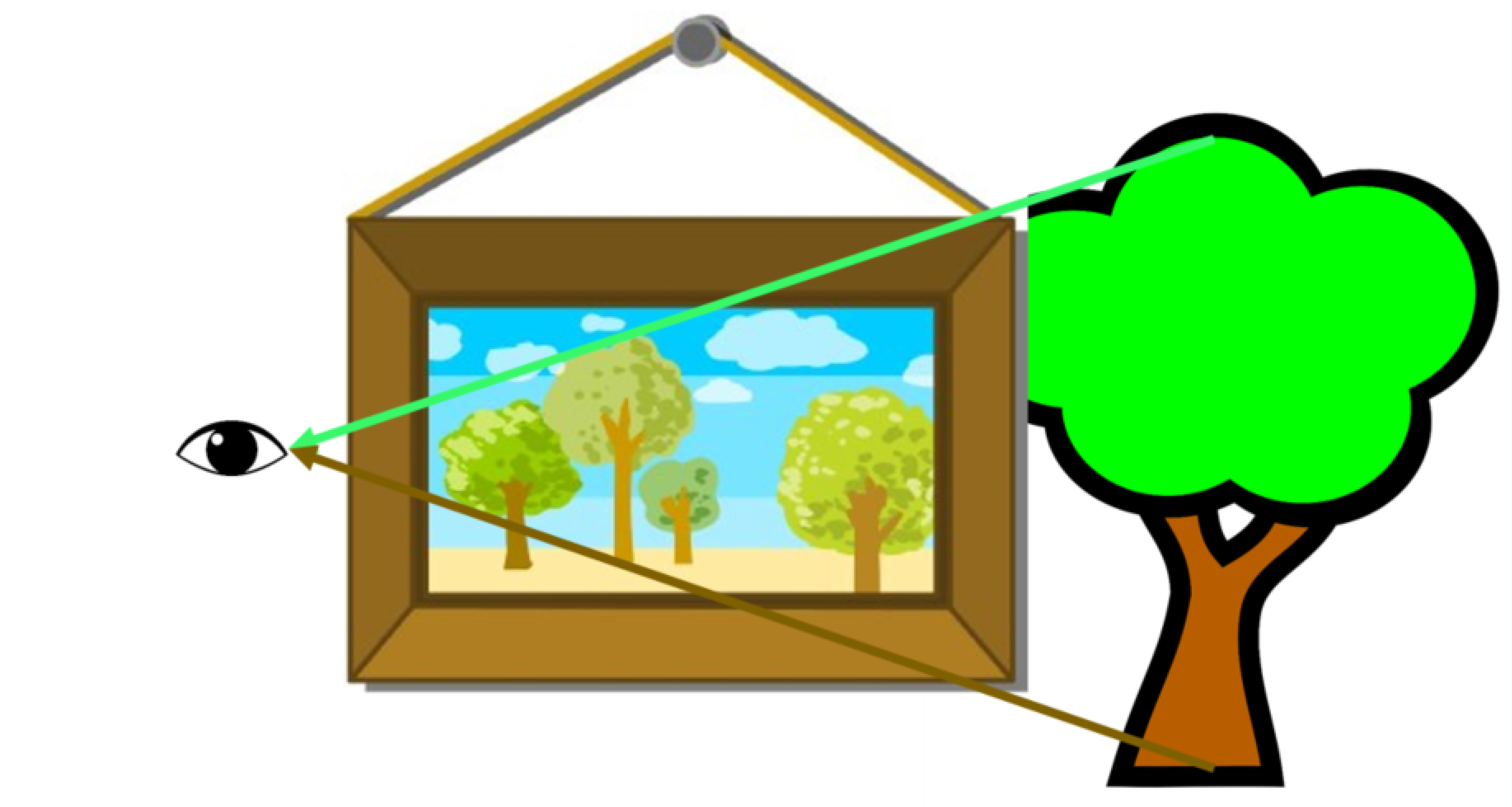
Looking at things: Depth and Distance



Looking at things: Depth and Distance



Looking at things: Depth and Distance



We sense 2D

(actually, a little more than that)

We *infer* 3D

Sensing 3D (we'll come back to this)

One eye:

- Accomodation

Two eyes:

- Vergence
- Disparity

Many eyes: (multiple times)

- Parallax
- Depth from Motion

3D Cues from One image

Occlusion

Perspective

Familiar Size

Relative Size

Lighting (shading)

Lighting (reflections/shadows)

Texture/Pattern

Horizon Elevation

Long Distance Shifts

What makes an image look 3D?

Occlusion

Perspective

Familiar Size

Relative Size

Lighting (shading)

Lighting (reflections/shadows)

Texture/Pattern

Horizon Elevation

Long Distance Shifts

OK - so how do we do that?

Some 3D Math

Coordinate systems

Right hand rule

Cross-Product

Triangles

Normals

Barycentric Interpolation

Curves vs. Surfaces vs. Volumes

A Point is 0D (just a point) - can be 2D, 3D, ...

A Curve is 1D (length) - can be 2D, 3D, ...

A Surface is 2D (area) - can be 2D, 3D, ...

A Volume is 3D (solid) - can be 3D, ...

Not all curves are the boundaries of areas

Not all surfaces are the boundaries of solids

Normals and Tangents

In 3D, the tangent to a **surface** (at a point) is a plane

In 3D, the normal to a **surface** (at a point) is a vector

For a triangle, it is constant over the whole shape

In 3D, the tangent to a **curve** is a vector

In 3D, the normal to a **curve** is a plane (defined by normal vectors)

Coordinates in 3D

X, Y and Z axes

- right hand rule
- conventions on how we use them
- I prefer "Y is up" (direction of gravity)
- exceptions for what makes sense
    - book example

Coordinate Systems in 3D

- Book
- Table
- Room
- House
- City
- GPS (world)
- Screen
- Camera

Need some coordinate system with object and camera

Cover on Book

Book on Table

Table in Room

Camera in Room

Camera's picture on Screen

"Scene" Coordinates

A Coordinate System that has the objects and camera

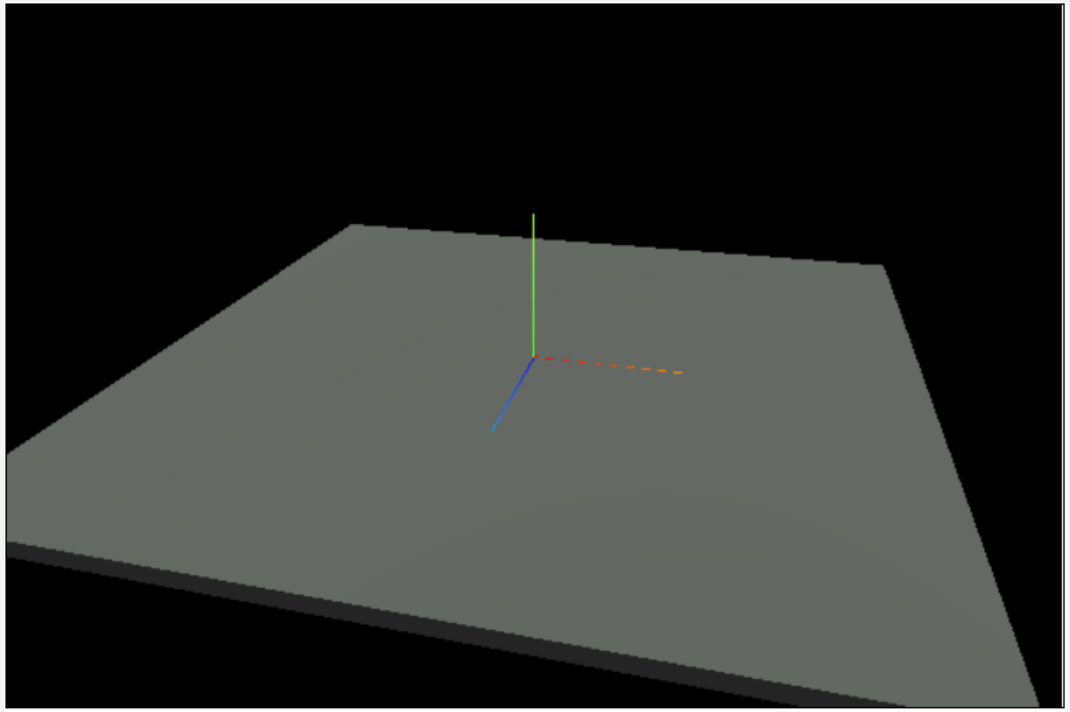
A Simple Example

Warning: the code is "fake" - because the actual code is a mix of THREE and "class Framework code"

A Simple Example

Scene

The class framework (just wait) makes a "ground plane" - a big flat object centered at the origin of the scene.



Cube in Scene

Cube in Scene

The center of the cube's coordinate system is the center of the cube

This is THREE's default

```
let cube = new T.Cube();
cube.translateY(1);
scene.add(cube);
/* cube.position.set(0,1,0); */
```

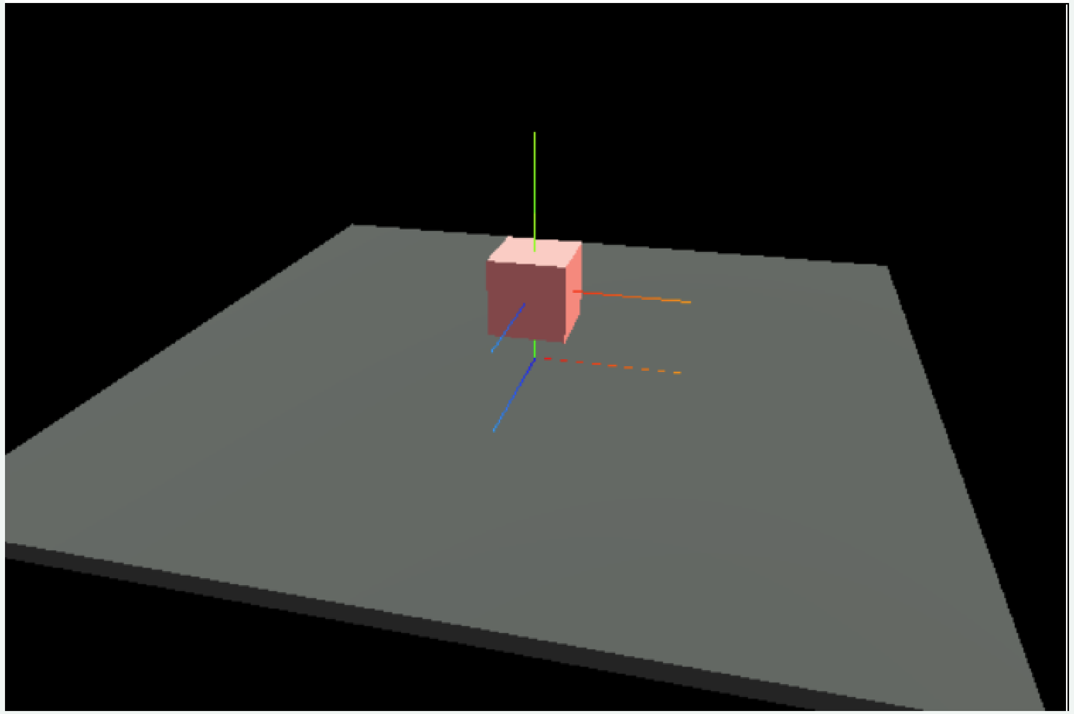
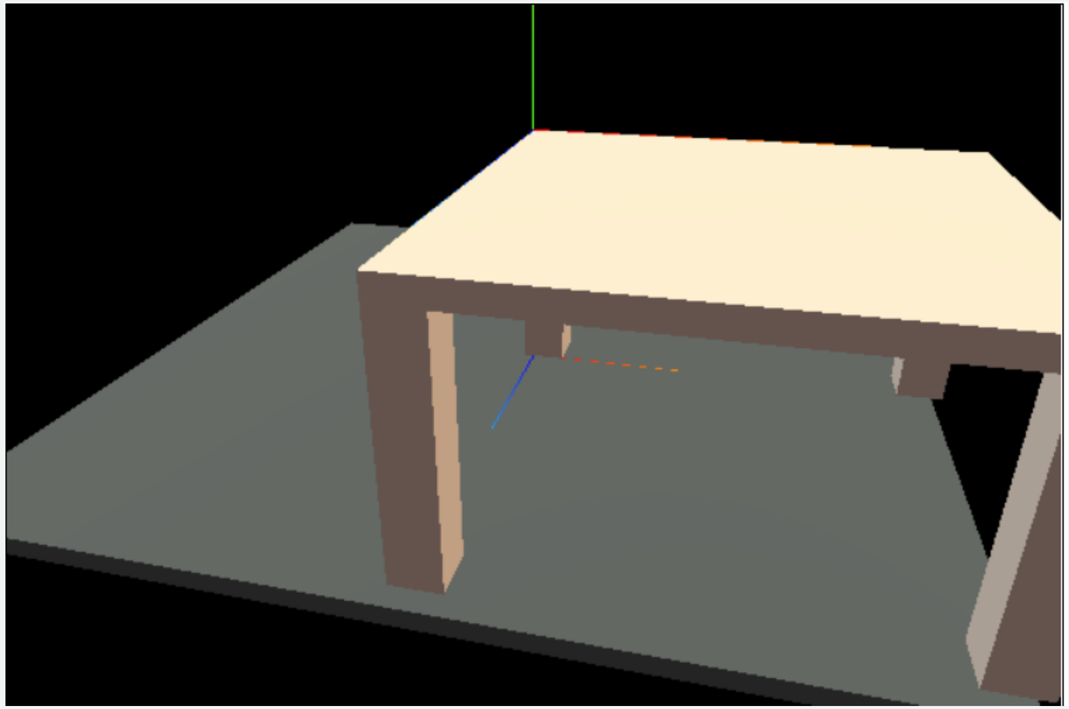


Table in Scene

Table in Scene



Note: I made the table

I defined the table to have its origin at the corner of the table top.

```
let table = new Table();
scene.add(table);
table.position.set(0,3,0);
```

Table in Scene

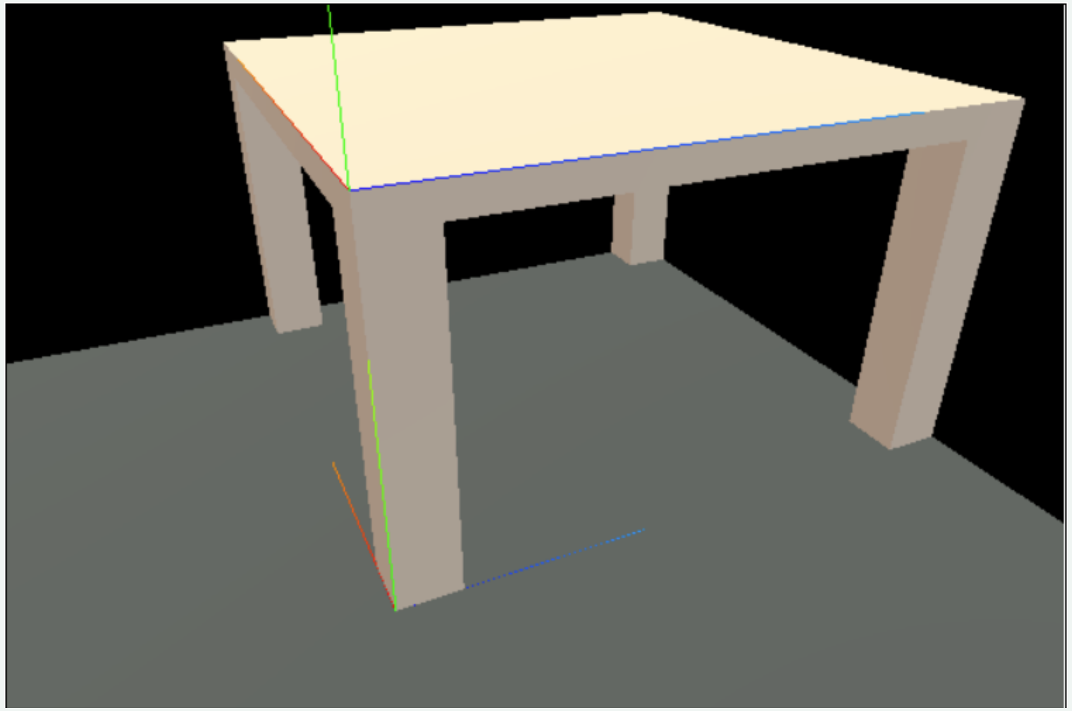
Table in Scene

I defined the table to have its origin at the corner of the table top.

I need to position the table above the floor.

(transform to change its coordinates)

```
table.position.set(0,3,0);
```



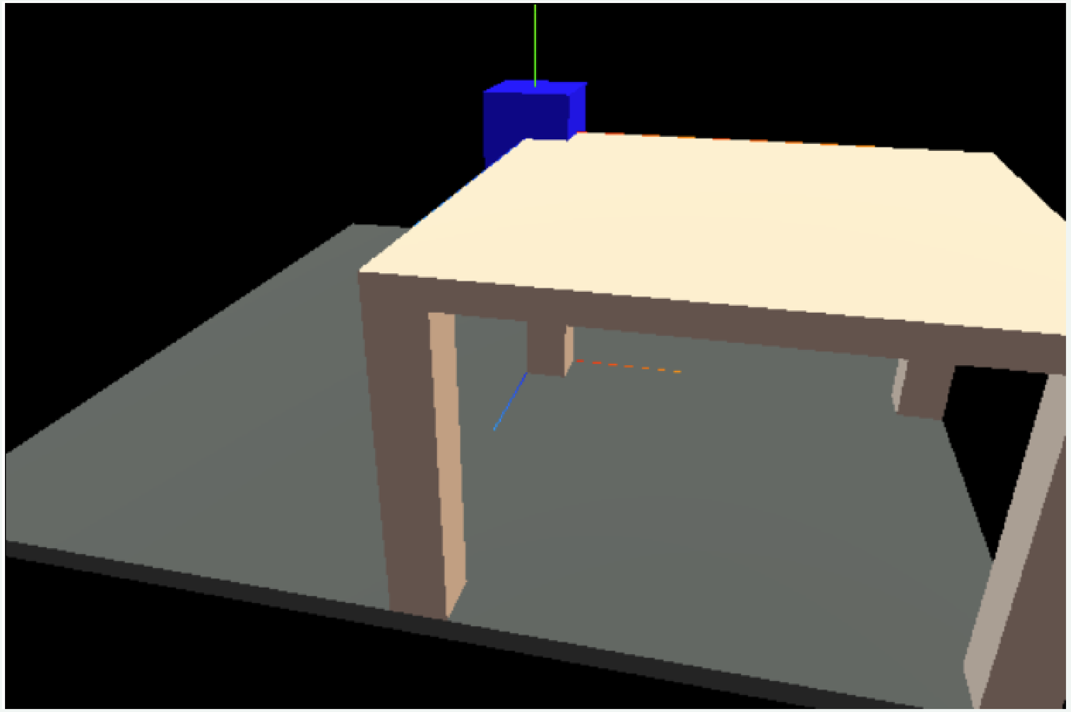
Cube on Table in Scene

Cube on Table in Scene

The cube's origin is at it's center.

If I place it "on the table" (position 0), it is actually inside the table.

```
let cube = new T.Cube();
table.add(cube);
```



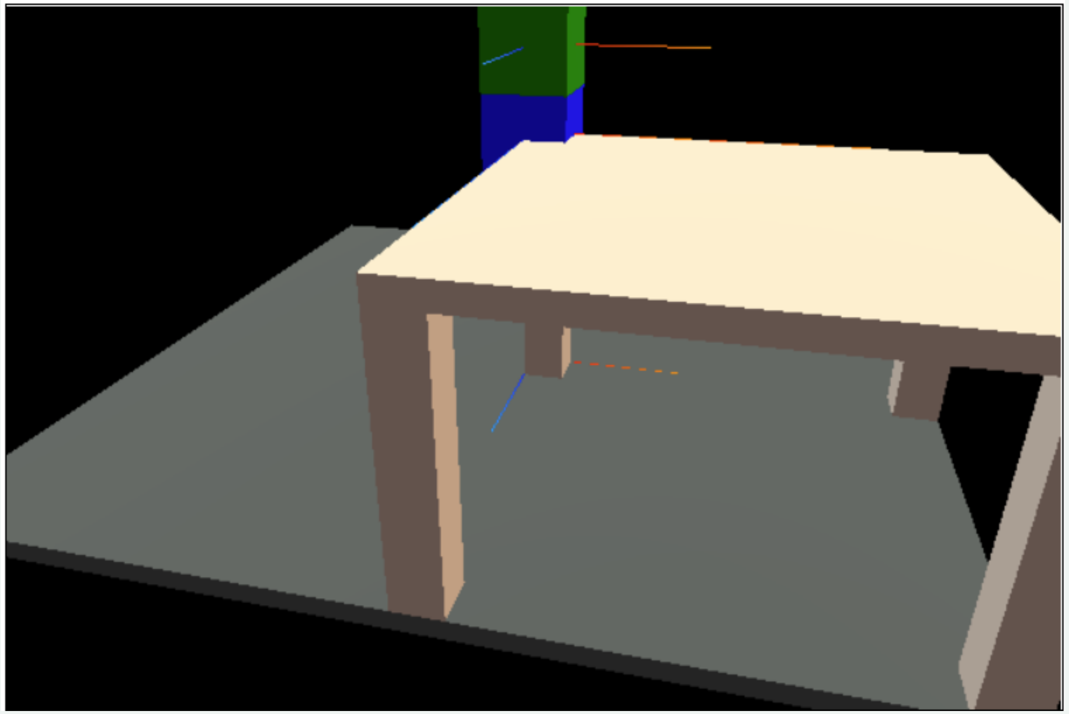
Cube on Cube on Table in Scene

Cube on Table in Scene

I transformed the second cube to be 1 unit upwards.

```
let cube1 = new T.Cube();
table.add(cube1);

let cube2 = new T.Cube();
cube1.add(cube2);
cube2.translateY(1);
/* cube2.position.set(0,1,0); */
```



Book

Book (in Scene)

I made the book to have its origin at the bottom corner (at the "top" of the book)

```
let book = new Book();
scene.add(book);
```

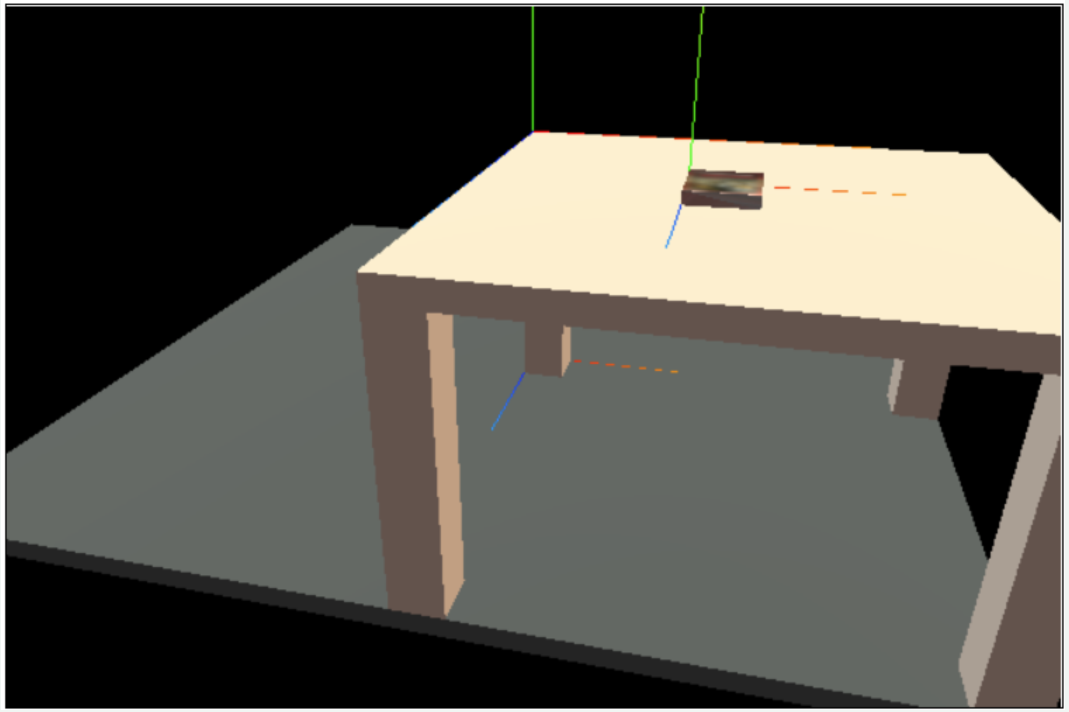
Book on Table

Book on Table (in Scene)

The book is at the origin.

The book is parented to the table

```
let table = new Table();
scene.add(table);
table.position.set(0,3,0);
let book = new Book();
table.add(book);
book.position.set(2,0,2);
```



Camera Looks at Book on Table ...

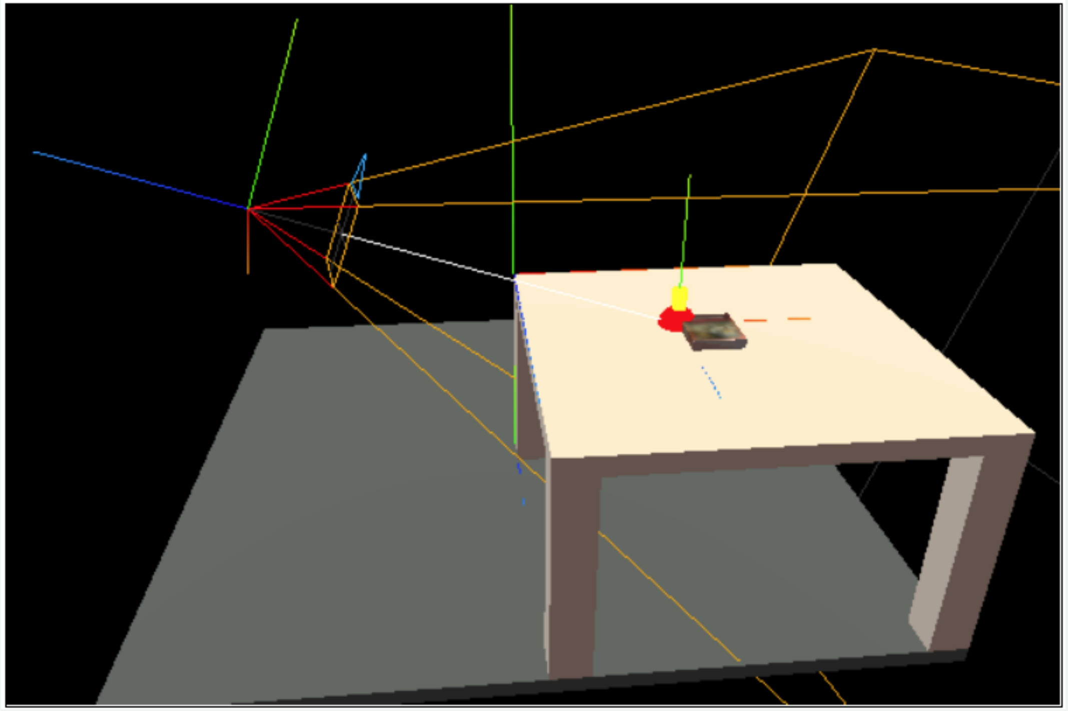
Camera in Scene

Camera looks at Book on Table
(in Scene)

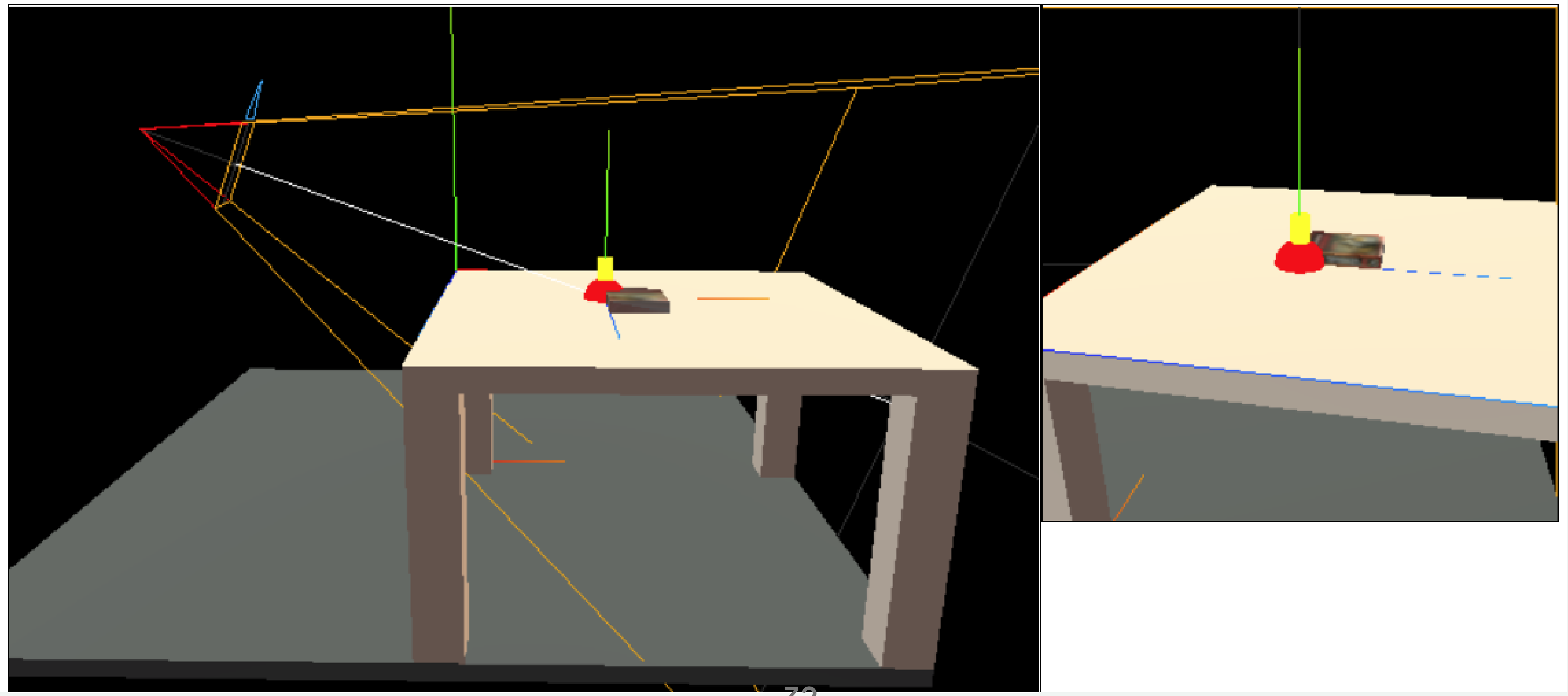
The camera is just an object

It has a coordinate system

It can be positioned and oriented



What does the camera See?



Demo

Coordinate Systems

Local Coordinates - how the object is defined

- vertices of the triangles
- sub-parts

Group Coordinates - any object's coordinate system

- child objects relative to the parent

Scene Coordinates - the scene is like an object

World Coordinates - doesn't matter, scene is OK

Camera Coordinates

The Camera is just another object (in the scene)

It has a coordinate system

We can transform objects into the camera's coordinate system

Viewing

We transform from the camera's coordinate system into "screen coordintates"

We'll discuss in detail

But... it's just another homogeneous transformation

From object to screen...

Transformations in 3D

4x4 Homogeneous Transformations

1. Affine transformations to position objects in world
2. Camera transformations to position relative to camera
3. Projection (Viewing) transformation to position on screen

Multiply matrices to combine!

THREE as an API

It is a **scene graph** API

We do need to explicitly render (immediate)

It is like SVG in some ways

Transformations in Three

Objects each have their own transformation

Objects "have" a matrix

- but it is built from pieces each time
- keep pieces separate for convenience (confusion?)

Objects have methods to perform transformations

Objects have state that can be set directly

In THREE.js

Internally, it builds the matrices for you

Provides many different ways to specify things

- rotations in several forms
- different ways to combine transformations
- hierarchies

You can control the transformations / matrices directly

- But you need to tell THREE not to over-write what you put in

Inside of a THREE object

- State: position, orientation, scale
- Orientation in many forms
- Matrix
- When when changes, others are updated
- Transformation commands

State vs. Transformation

```
cube.position.x = 5;
```

vs.

```
cube.translateX(5);
```

vs.

```
cube.position.x += 5;
```

How THREE works inside

(A hint on how to do the 2D problems for the exam)

Store state in "factored form" (Trans Rot Scale)

Move transformations through existing transformations

Scale

Is state (what is the scaling factor)

It is applied last (after translate/rotate)

It is not affected by other transformations (of its object)

It does not affect other transformations (of its object)

It does transform its children

It is the **local** scaling (according to the documentation)

Rotations

Warning: rotations in 3D are tricky!

Three gives us many different ways to do them

It always converts to a special format

We can do rotations or orientations

Summary

- We built scenes with hierarchy
- Cameras are (special) objects in the scene
- Transformations between objects
- THREE hides the transformations inside objects

What's Next

- Understand cameras and viewing
- Basics of lighting and shading
- Animation in THREE

- More details of shape and lighting
- Texture

The Viewing Transformation

From world (scene) coordinates to screen - via the camera

- the camera is in the world/scene
- we see things relative to the camera

Two parts to what we see:

1. Positioning the camera
2. Projecting from 3D to 2D

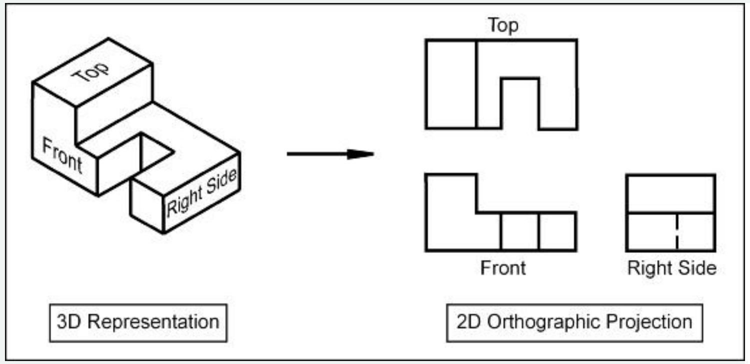
Projection 3D to 2D

We lose a dimension

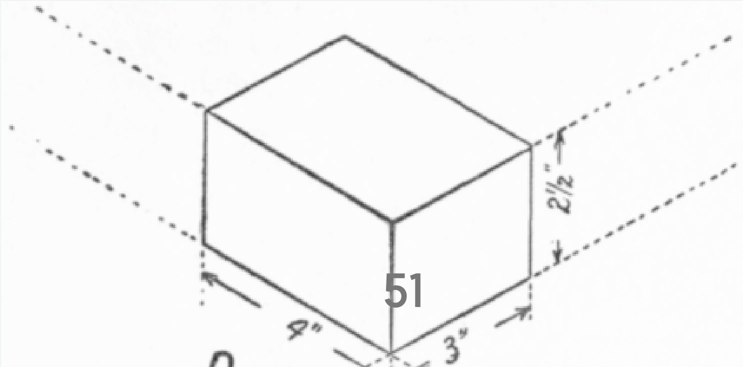
- No - we actually keep it (screen as a fishtank)
- Yes - we put as much info into 2D as possible

Types of Projections

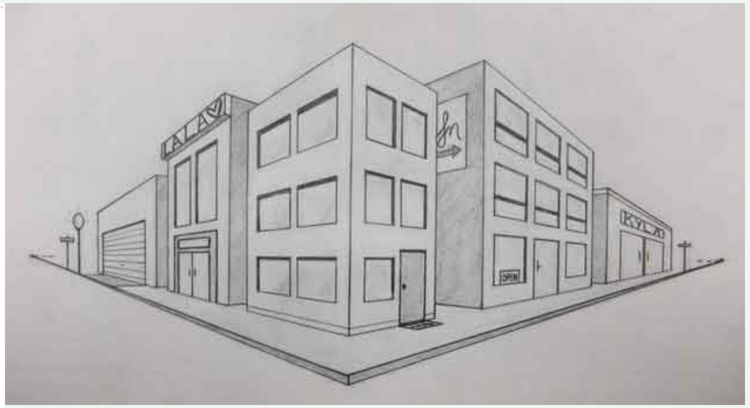
Orthographic



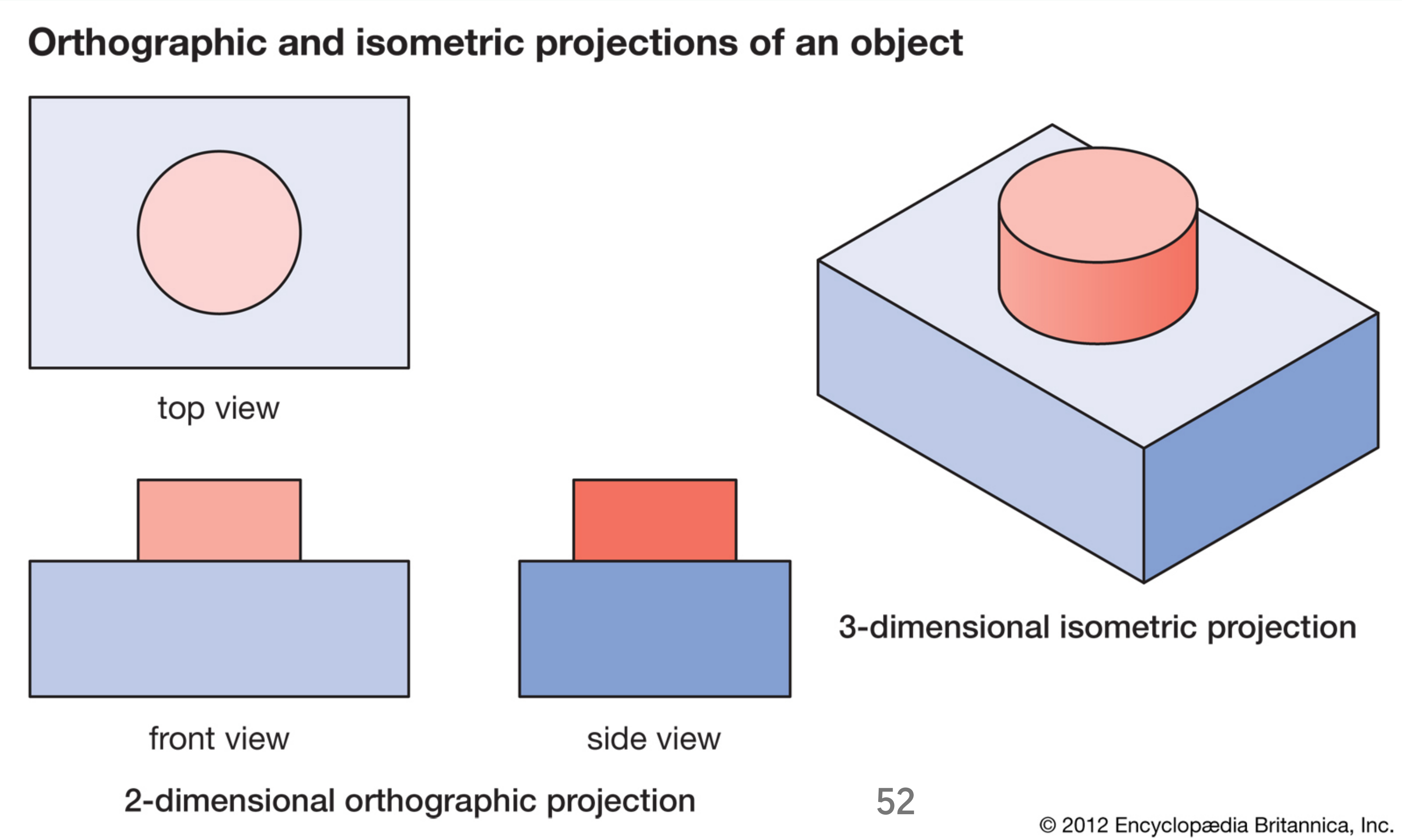
Isometric



Perspective



Mechanical Drawing Projections



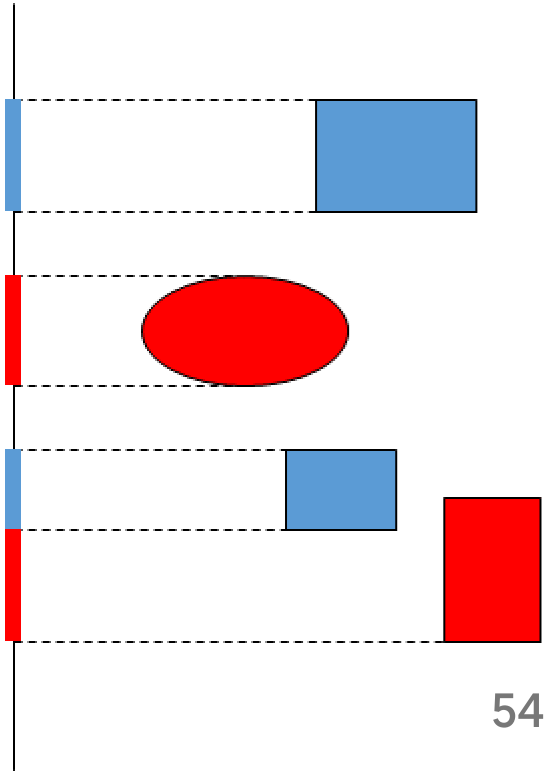
Types of Projections

Orthographic **Isometric** **Perspective**

Orthographic Projection

Projection = transformation that reduces dimension

Orthographic = flatten the world onto the film plane



Orthographic

```
new T.OrthographicCamera(-2,2, -2,2, -2,2);
```

The screen (x,y,z)

Shift and scale to fit

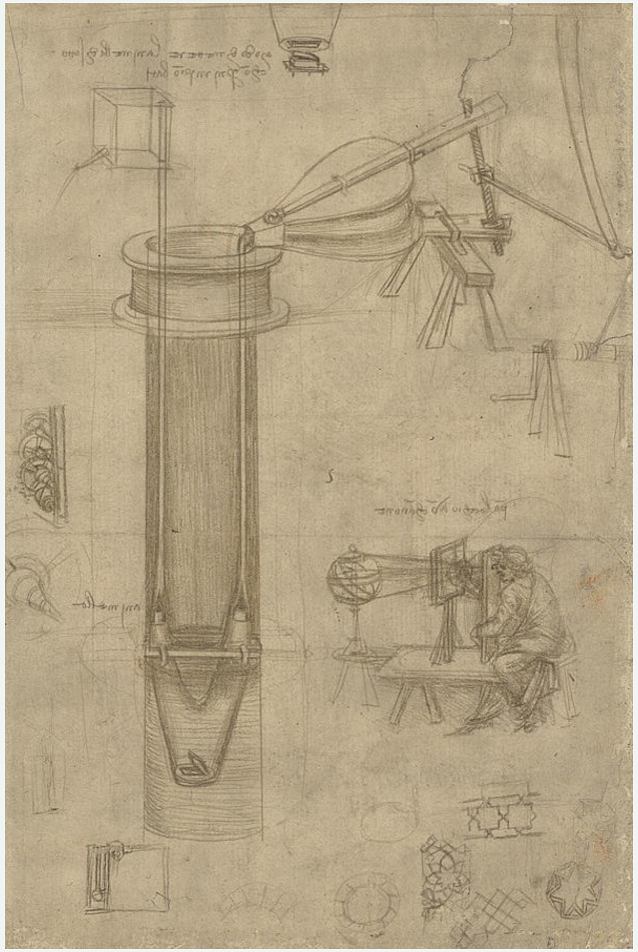
Rotations to get top, side, front

The need to scale in Z

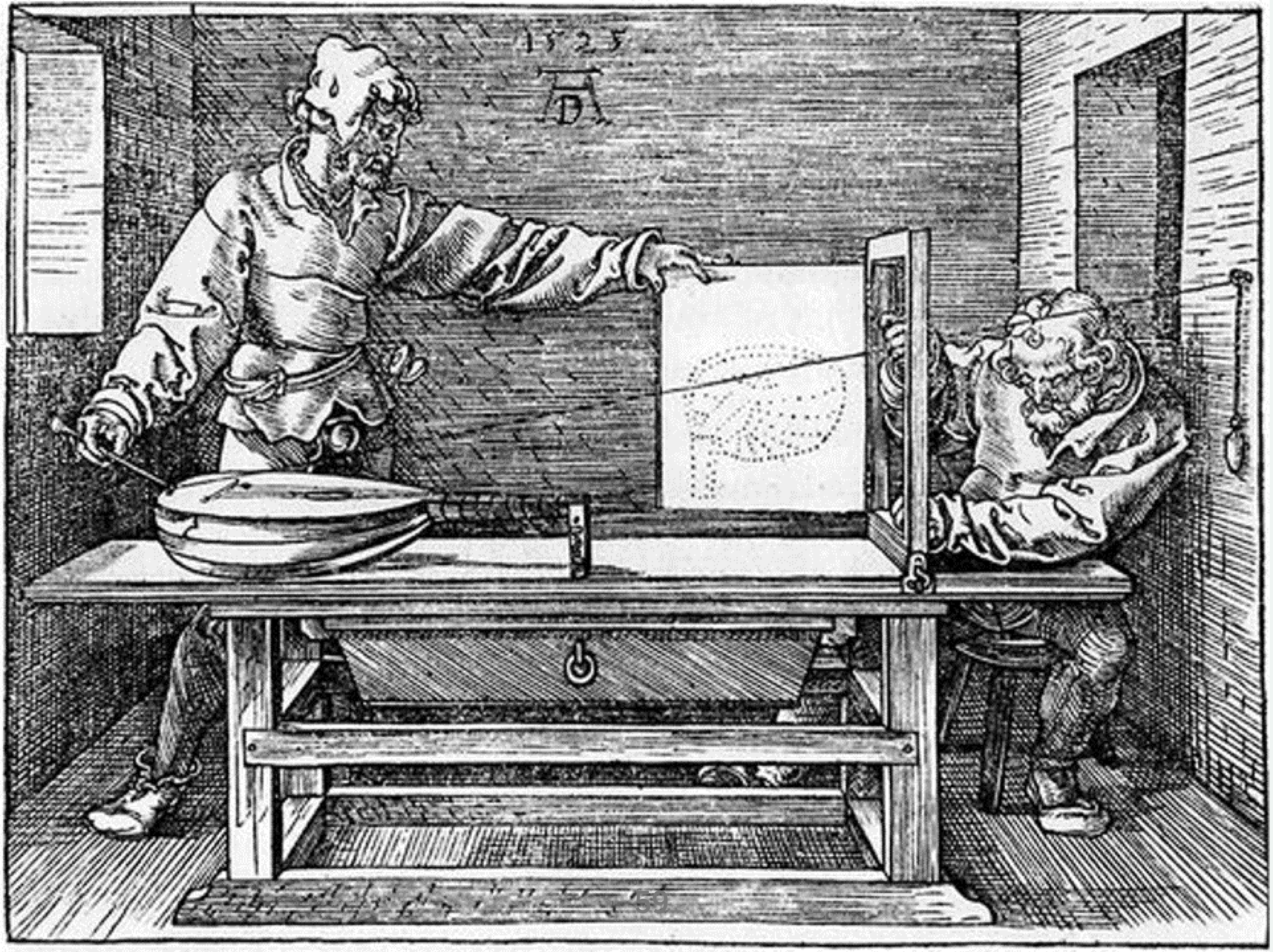
Do we always project Z?

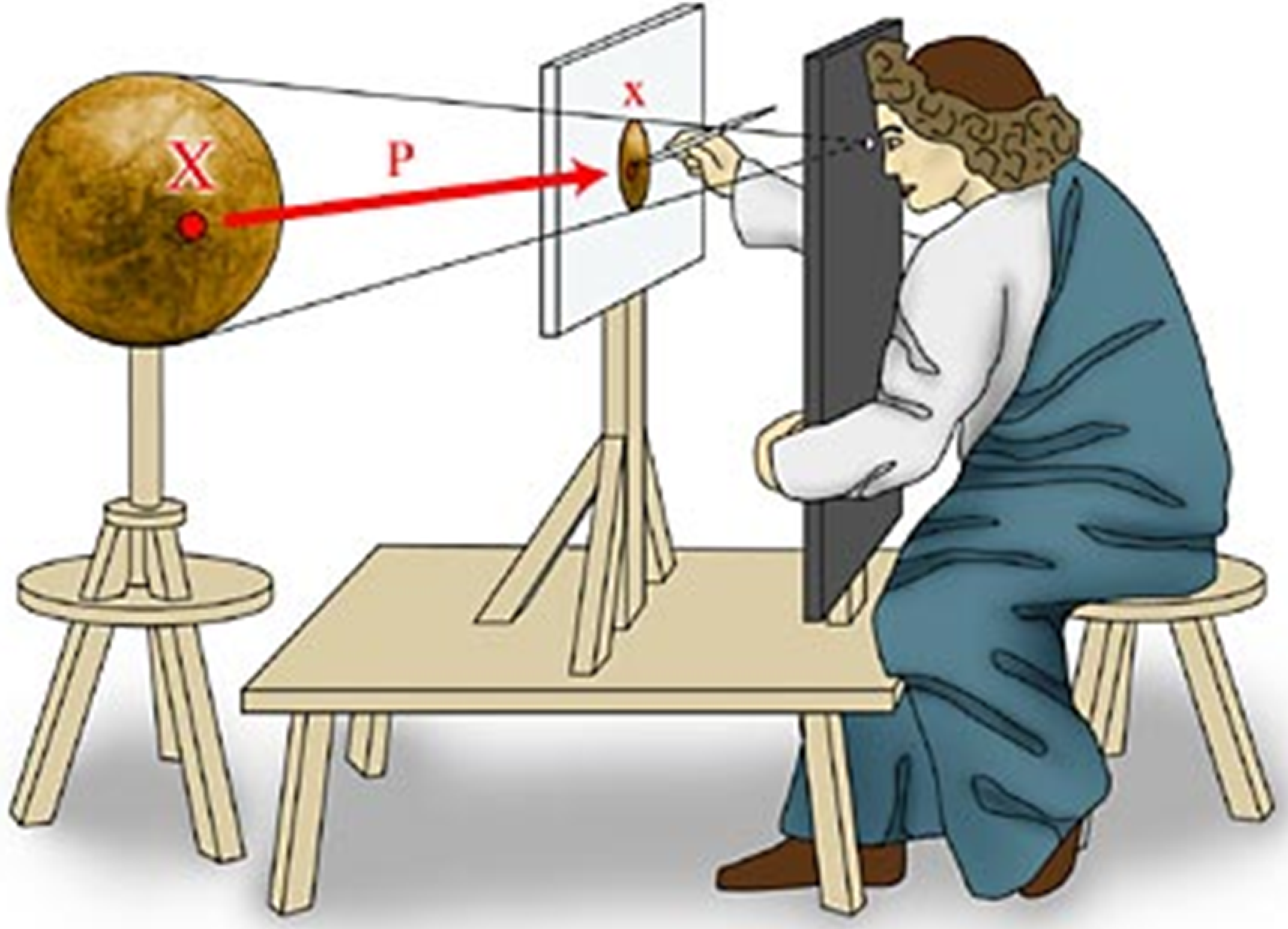
Perspective


Do it like Da Vinci!



http://fineartamerica.com/featured/bellows-perspectograph-with-man-examining-inside-from-atlantic-codex-leonardo-da-


1525



http://hans.wyrdweb.eu/about-perspective/

Perspective Imaging