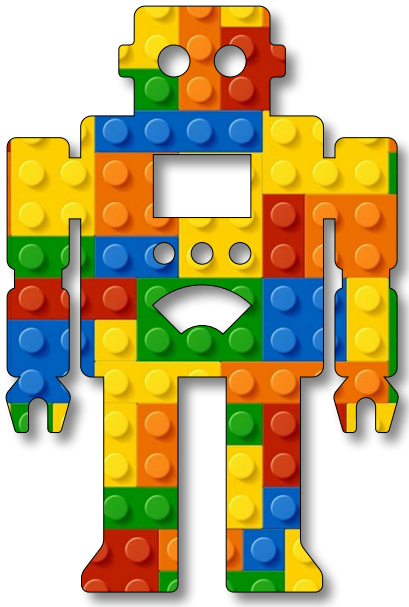
Intelligent Machines Module B Unit #1 3D shapes



Content

Module B Unit #1 3D shapes

Introduction to 3D shapes

In p5.js, WEBGL is one of the two available rendering modes, allowing you to create 3D graphics and interactive experiences alongside its default 2D mode.
Key features of WEBGL in p5.js:

- 3D shapes: Draw basic shapes like boxes (cuboids), spheres, cones, cylinders, and more using functions like `box()`, `sphere()`, etc.

- Custom geometry: Create complex models from code or load them from 3D file formats like `OBJ` and `STL`.

- Materials and lighting: Define materials like `basicMaterial()` or `specularMaterial()` and use lights like `ambientLight()` to affect object appearance.

- Camera control: Change the viewpoint using functions like `perspective()`, `ortho()`, and rotate the camera with `rotateX()`, `rotateY()`, `rotateZ()`.

- Textures: Add textures to surfaces for enhanced realism and detail.
Shaders: For advanced users, write custom shaders to achieve unique visual effects.

We will draw some of the basic shapes and learn about the co-ordinates, translation, and rotation. There are a number of very key differences between the default 2D and the 3D environment.

One of the main changes is how we use the coordinates. All coordinates are based around the centre of the 3D space. There is an `x`, `y`, and `z` component to any coordinates; if only two are specified, then it takes the `x` and `y` and relegates the `z` to zero.

The `x` component is left and right, `y` is top and bottom, and the `z` is front and back.

Sketch B1.1 standard sketch

Starting with our standard sketch.

```
function setup()
{
  createCanvas(400, 400)
}

function draw()
{
  background(220)
}
```

Sketch B1.2 adding the WEBGL

The first thing to notice is that we have the third argument in the `createCanvas()` function: `WEBGL`.

```
function setup()
{
  createCanvas(400, 400, WEBGL)
}

function draw()
{
  background(220)
}
```

🗒️ Notes

The first thing you notice is that nothing happens. What you now have is effectively a 3D canvas or space. One where you can draw in the `x`, `y`, and `z` directions.

🛠️ Code Explanation

`createCanvas(400, 400, WEBGL)`	WEGL allows to render an image in 3D

Sketch B1.3 drawing a box

What we need is a 3D shape to put into this space. We will start by drawing a cube. To draw a cube, we use the box() function; it will have dimensions of 100 pixels by 100 pixels by 100 pixels. We only need to give the single dimension, as it assumes the other two are the same. We will add the other two when we draw a cuboid later.

```
function setup()
{
  createCanvas(400, 400, WEBGL)
}

function draw()
{
  background(220)
  box(100)
}
```

🗒️ Notes

One thing you will notice is that I have not specified where to draw it. I have given it no coordinates, yet it has drawn it in the centre of the canvas. Also, it doesn't look very 3D...ish. To the first point, the centre of the canvas is in the centre in all three dimensions, the x, y, and z axes. Secondly, we need to rotate it to see it.

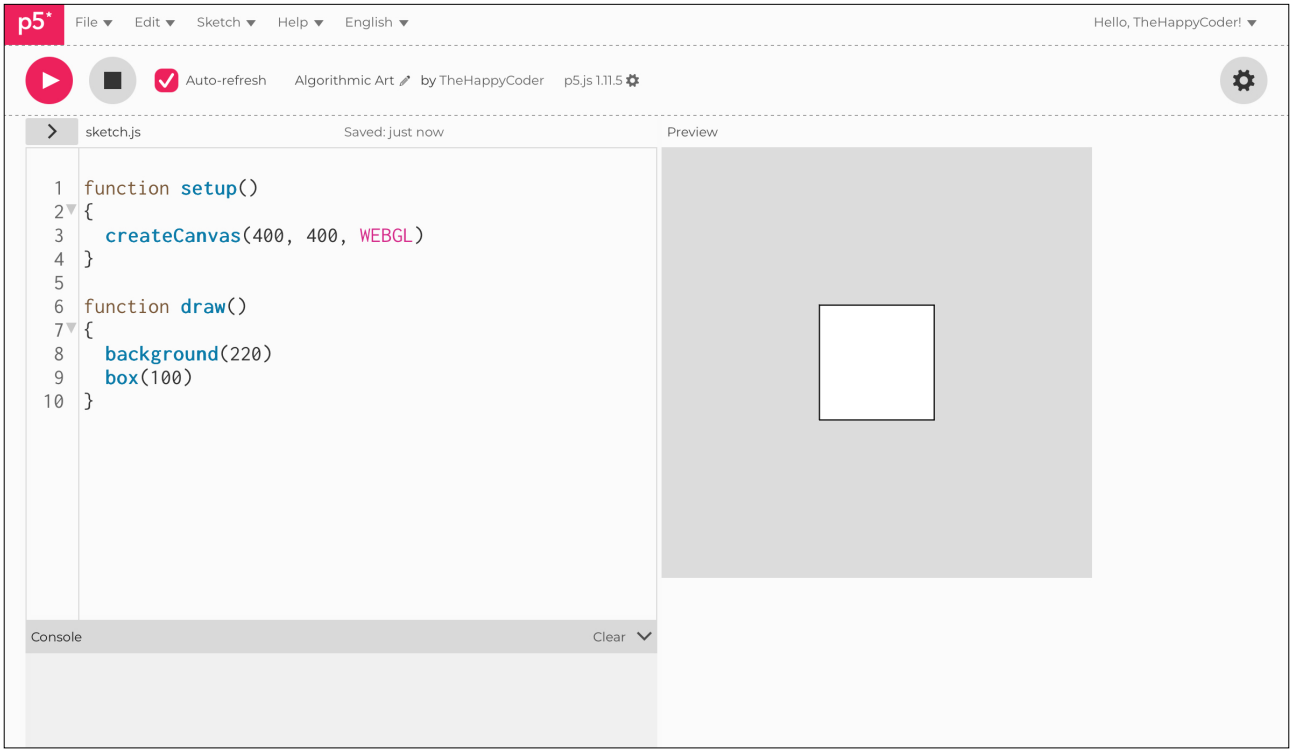
🌻 Challenge

Add the other two dimensions.

🛠️ Code Explanation

box(100)	A rectangle with each side of equal length (100)

Figure B1.3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Preview
1 function setup()
2 {
3 createCanvas(400, 400, WEBGL)
4 }
5
6 function draw()
7 {
8 background(220)
9 box(100)
10 }
Console
Clear

Sketch B1.4 rotating

We cannot simply rotate it; we have to specify which axis we want to rotate it on, whether it is the x, y, or z axis, and by some angle (measured in radians, for now). The functions we use are: rotateX(), rotateY(), and rotateZ(), which I hope are self-explanatory. We will rotate the box along the x axis by 2 radians.

```
function setup()
{
  createCanvas(400, 400, WEBGL)
}

function draw()
{
  background(220)
  rotateX(2)
  box(100)
}
```

🗒️ Notes

We can now see that it is a cube, at least from one angle.

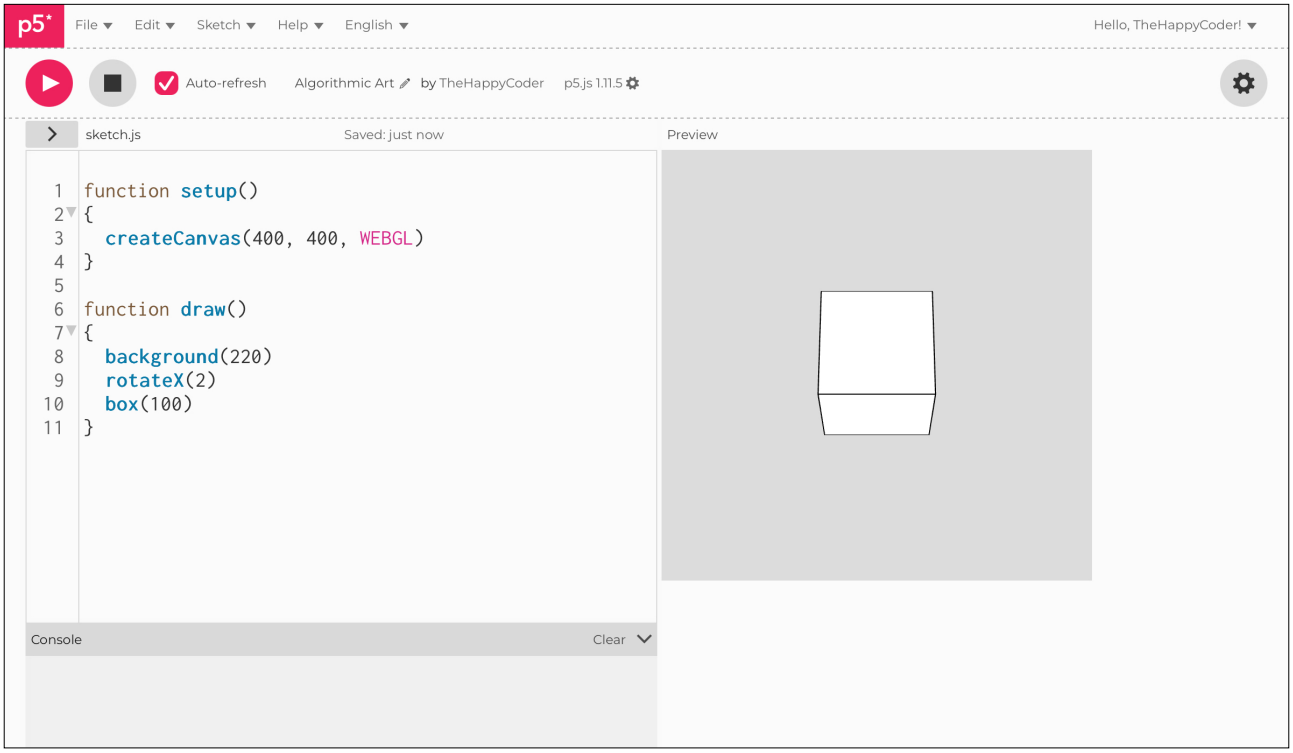
🌻 Challenge

Try other angles.

🛠️ Code Explanation

rotateX(2)	Rotate along the x axis by 2 radians

Figure B1.4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Preview
function setup()
{
createCanvas(400, 400, WEBGL)
}
function draw()
{
background(220)
rotateX(2)
box(100)
}
Console
Clear

Sketch B1.5 45° rotation

To make life a little easier to understand, I will change the angle mode to degrees, which is a bit more intuitive.

```
function setup()
{
  createCanvas(400, 400, WEBGL)
  angleMode(DEGREES)
}

function draw()
{
  background(220)
  rotateX(45)
  box(100)
}
```

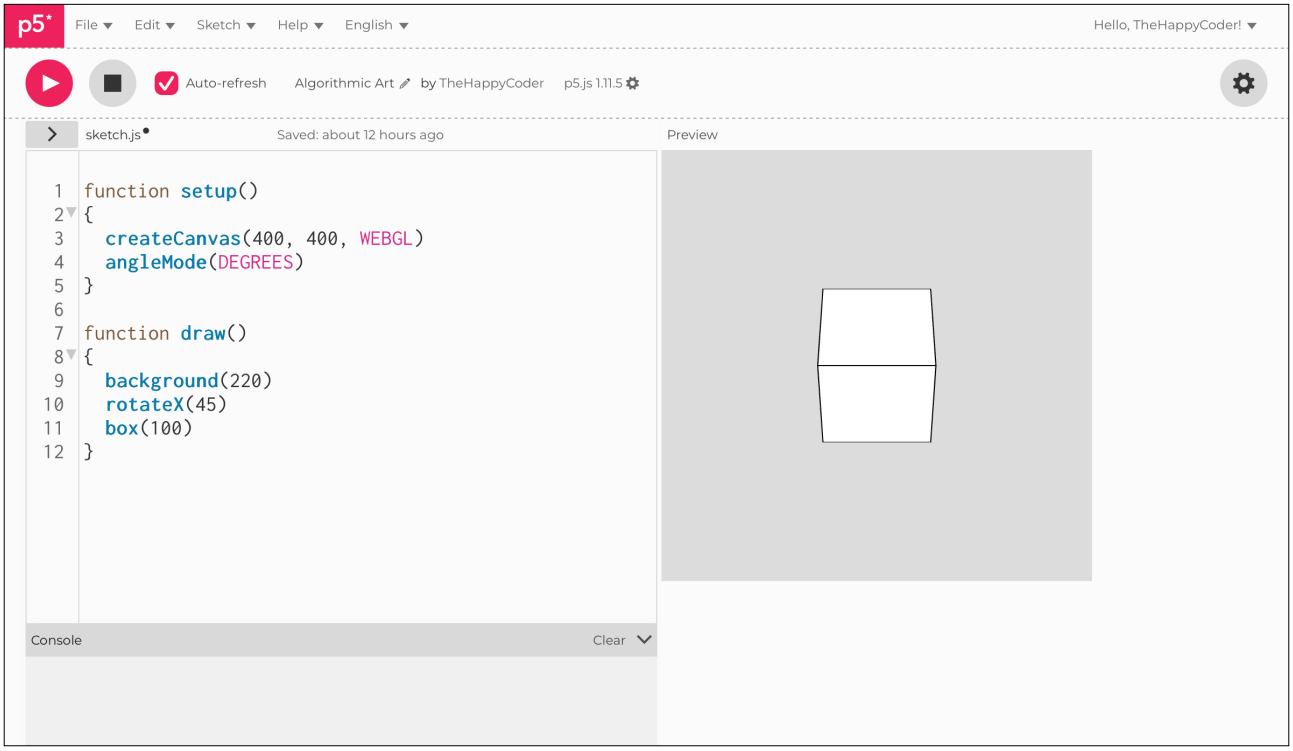
🗒️ Notes

Almost the same

🛠️ Code Explanation

`rotateX(45)`	Rotating through 45° along the x axis

Figure B1.5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2 {
3 createCanvas(400, 400, WEBGL)
4 angleMode(DEGREES)
5 }
6
7 function draw()
8 {
9 background(220)
10 rotateX(45)
11 box(100)
12 }
Console
Clear

Sketch B1.6 the x and y axis

To show how 3D it is, we are going to rotate along all three axes.

```
function setup()
{
  createCanvas(400, 400, WEBGL)
  angleMode(DEGREES)
}

function draw()
{
  background(220)
  rotateX(45)
  rotateY(45)
  rotateZ(45)
  box(100)
}
```

🗒️ Notes

That is definitely more 3D...ish.

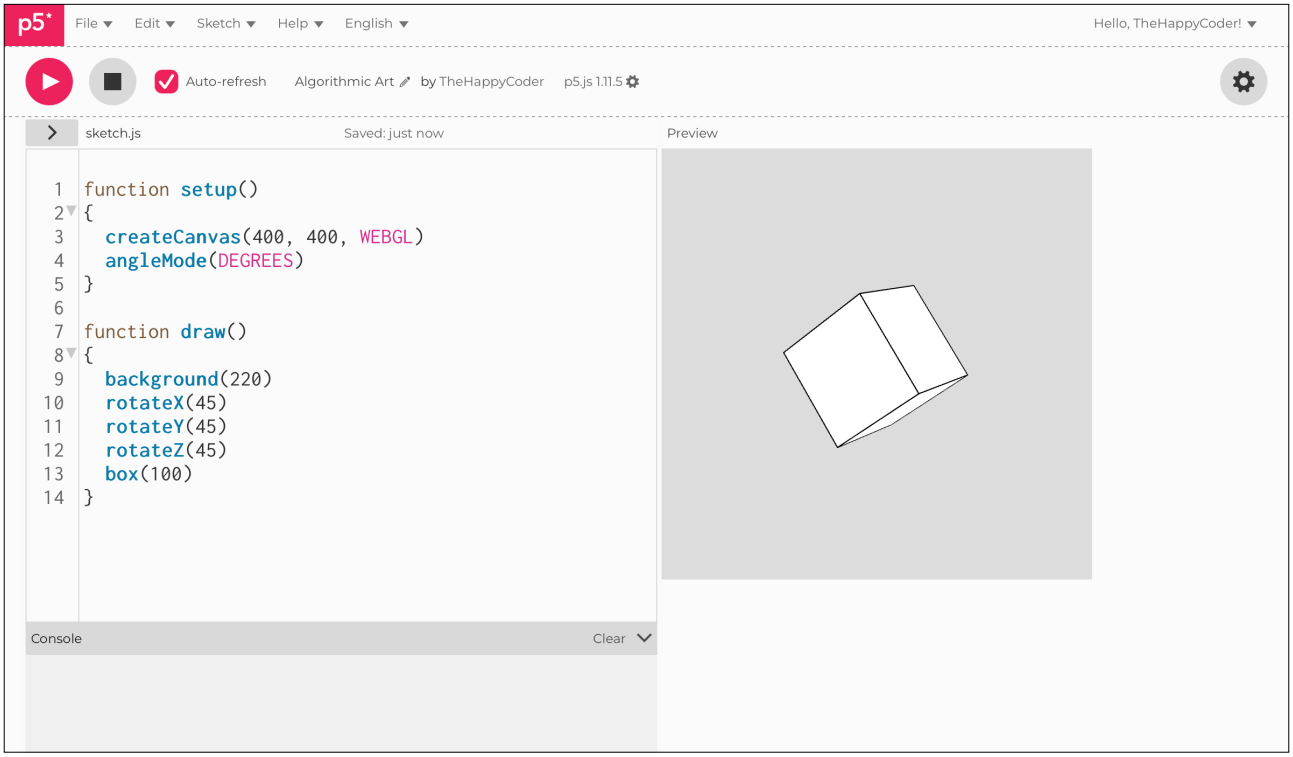
🌻 Challenge

Try different angles.

🛠️ Code Explanation

`rotateY(45)`	Rotating through 45° along the y axis
`rotateZ(45)`	Rotating through 45° along the z axis

Figure B1.6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Preview
function setup()
{
createCanvas(400, 400, WEBGL)
angleMode(DEGREES)
}
function draw()
{
background(220)
rotateX(45)
rotateY(45)
rotateZ(45)
box(100)
}
Console
Clear

Sketch B1.7 incrementing the rotation

Even better still, we can animate the rotation by introducing a variable (angle) and incrementing it.

```
let angle = 0

function setup()
{
  createCanvas(400, 400, WEBGL)
  angleMode(DEGREES)
}

function draw()
{
  background(220)
  rotateX(angle)
  rotateY(angle)
  rotateZ(angle)
  box(100)
  angle++
}
```

🗒️ Notes

You should see it rotating in all directions. We have incremented the angle of rotation by 1° on all three axes.

🌻 Challenges

1. Try -angle for one of them.
2. Move it faster: angle += 3.

Sketch B1.8 drawing a cuboid

That was just a cube; we can add other dimensions to make it a cuboid.

```
let angle = 0

function setup()
{
  createCanvas(400, 400, WEBGL)
  angleMode(DEGREES)
}

function draw()
{
  background(220)
  rotateX(angle)
  rotateY(angle)
  rotateZ(angle)
  box(100, 150, 50)
  angle++
}
```

🗒️ Notes

Nicely rotating cuboid.

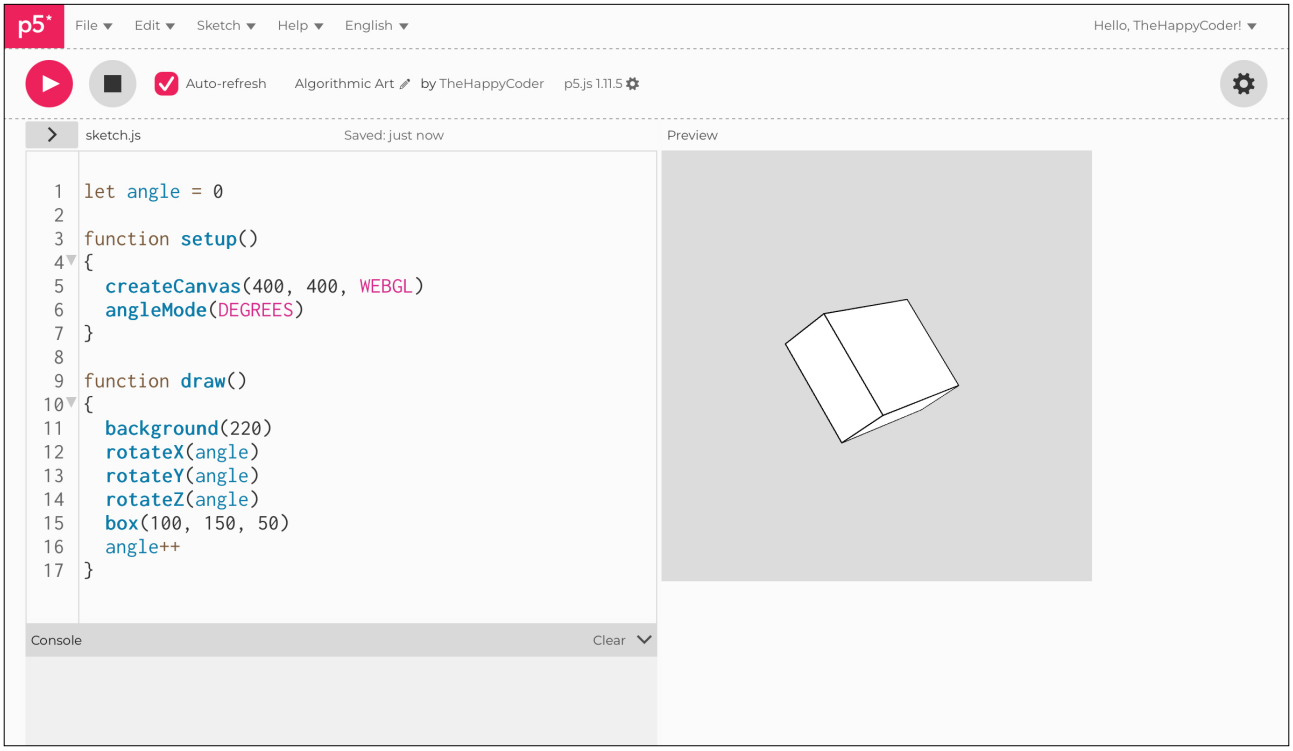
🌻 Challenge

Try other dimensions.

🛠️ Code Explanation

`box(100, 150, 50)`	Draws a cuboid 100 wide, 150 long and 50 deep

Figure B1.8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Preview
let angle = 0
function setup()
{
createCanvas(400, 400, WEBGL)
angleMode(DEGREES)
}
function draw()
{
background(220)
rotateX(angle)
rotateY(angle)
rotateZ(angle)
box(100, 150, 50)
angle++
}
Console
Clear

Sketch B1.9 drawing a plane

We will draw another shape, a simple `plane`, where it has two dimensions. Do you notice that there is a line going across it? This is because all the shapes that are created are made up of `triangles`.

```
let angle = 0

function setup()
{
  createCanvas(400, 400, WEBGL)
  angleMode(DEGREES)
}

function draw()
{
  background(220)
  rotateX(angle)
  rotateY(angle)
  rotateZ(angle)
  plane(100, 150)
  angle++
}
```

🗒️ Notes

A floating plane.

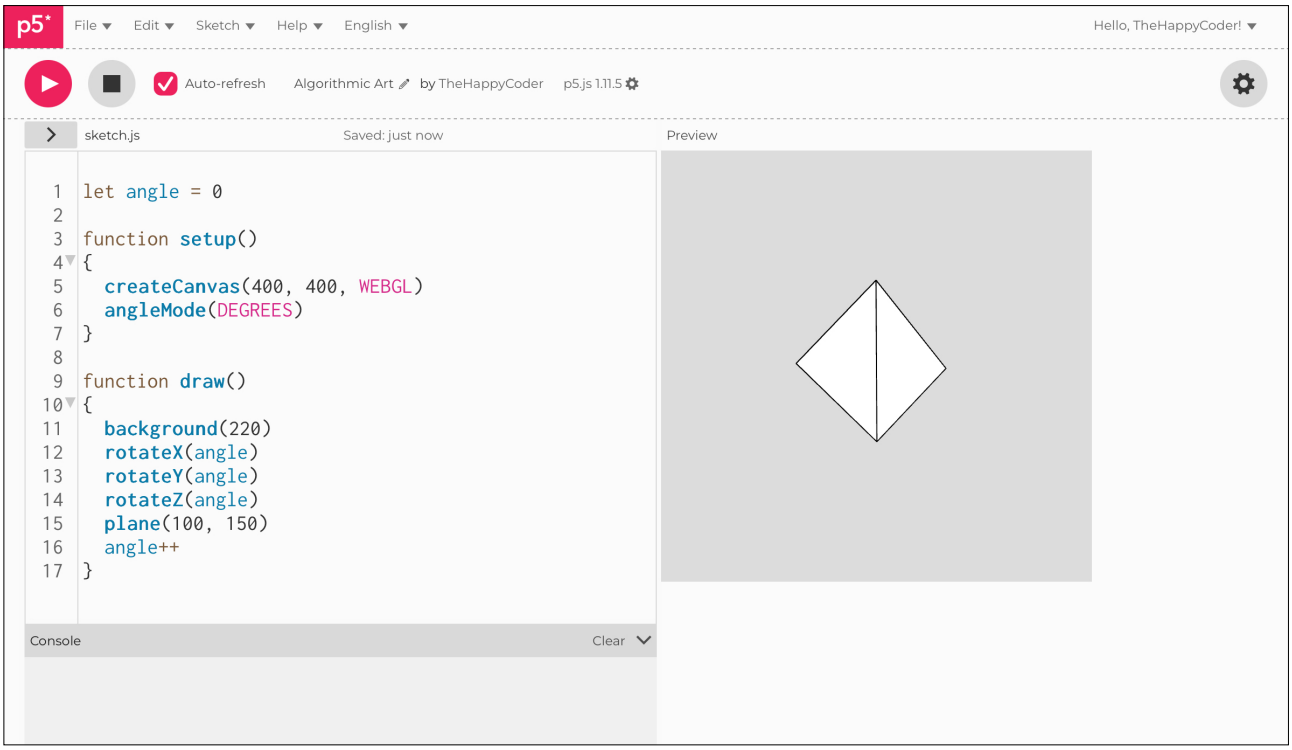
🌻 Challenge

Add `noStroke()`.

🛠️ Code Explanation

`plane(100, 150)`	Creates a flat plane 100 by 150

Figure B1.9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Preview
let angle = 0
function setup()
{
createCanvas(400, 400, WEBGL)
angleMode(DEGREES)
}
function draw()
{
background(220)
rotateX(angle)
rotateY(angle)
rotateZ(angle)
plane(100, 150)
angle++
}
Console
Clear

Sketch B1.10 drawing a cylinder

A `cylinder` has two dimensions, one for the radius and the other for the length.

```
let angle = 0

function setup()
{
  createCanvas(400, 400, WEBGL)
  angleMode(DEGREES)
}

function draw()
{
  background(220)
  rotateX(angle)
  rotateY(angle)
  rotateZ(angle)
  cylinder(100, 150)
  angle++
}
```

🗒️ Notes

The first is the diameter and the second is the length. If you use `noStroke()` you lose a lot of definition; we will use lights to address that issue (in another unit).

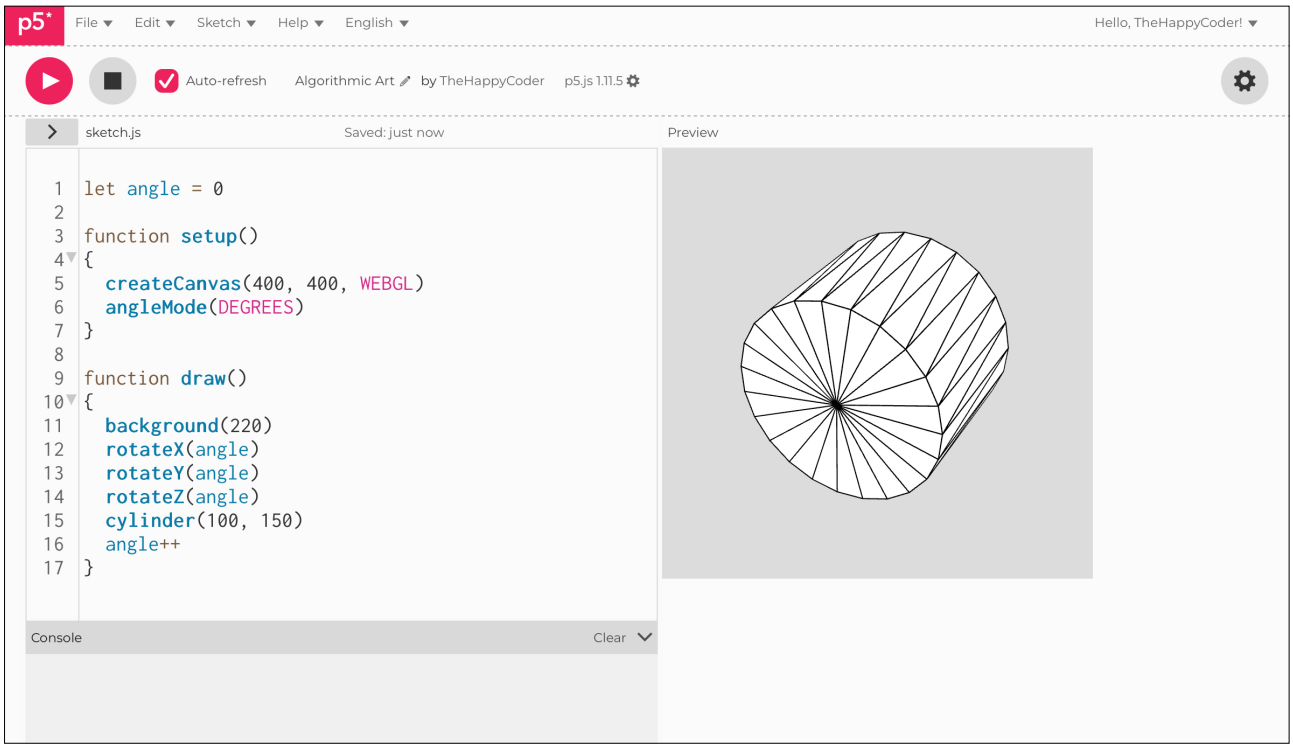
🌻 Challenge

Alter the dimensions.

🛠️ Code Explanation

`cylinder(100, 150)`	A cylinder with a radius 100 and length 150

Figure B1.10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Preview
let angle = 0
function setup()
{
createCanvas(400, 400, WEBGL)
angleMode(DEGREES)
}
function draw()
{
background(220)
rotateX(angle)
rotateY(angle)
rotateZ(angle)
cylinder(100, 150)
angle++
}
Console
Clear

Sketch B1.11 drawing a sphere

Here is a sphere with a single dimension, the radius.

```
let angle = 0

function setup()
{
  createCanvas(400, 400, WEBGL)
  angleMode(DEGREES)
}

function draw()
{
  background(220)
  rotateX(angle)
  rotateY(angle)
  rotateZ(angle)
  sphere(100)
  angle++
}
```

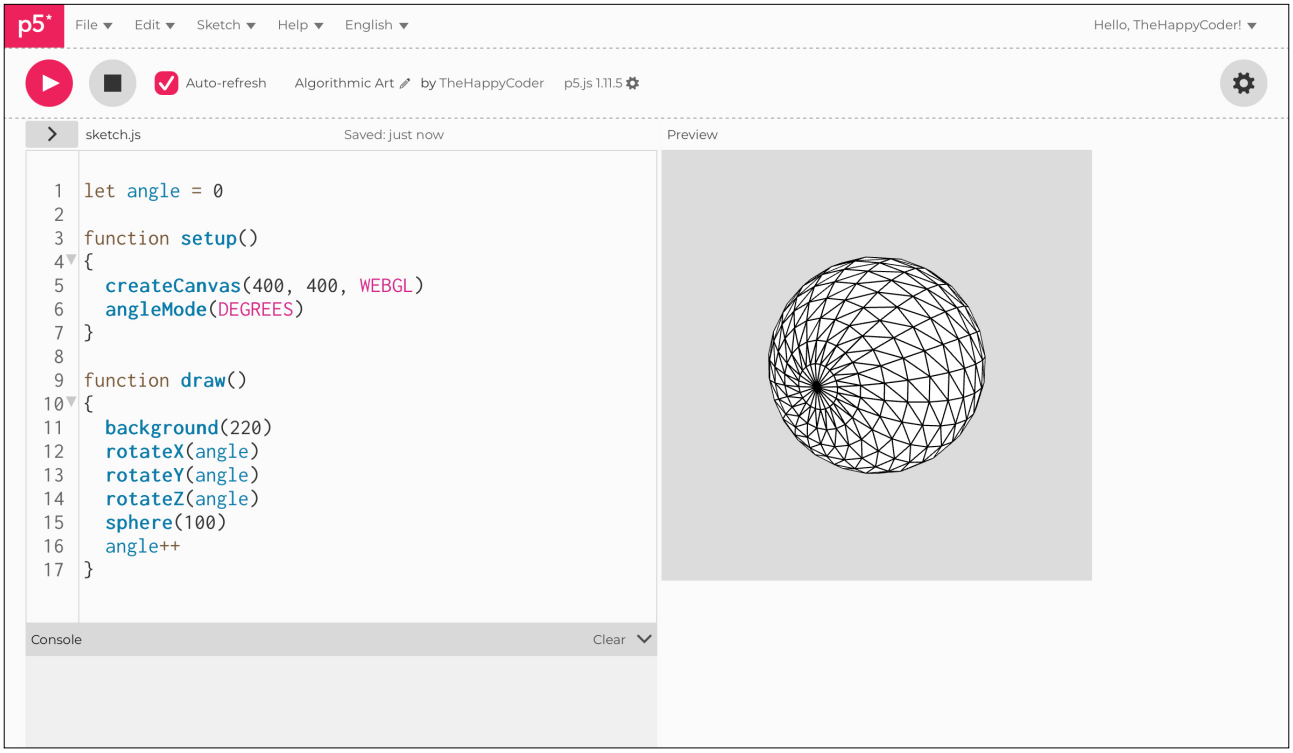
🗒️ Notes

We will explore how to make lots of shapes in different positions at a later date.

🛠️ Code Explanation

`sphere(100)`	Sphere with a radius of 100

Figure B1.11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Preview
let angle = 0
function setup()
{
createCanvas(400, 400, WEBGL)
angleMode(DEGREES)
}
function draw()
{
background(220)
rotateX(angle)
rotateY(angle)
rotateZ(angle)
sphere(100)
angle++
}
Console
Clear

Sketch B1.12 drawing an ellipsoid

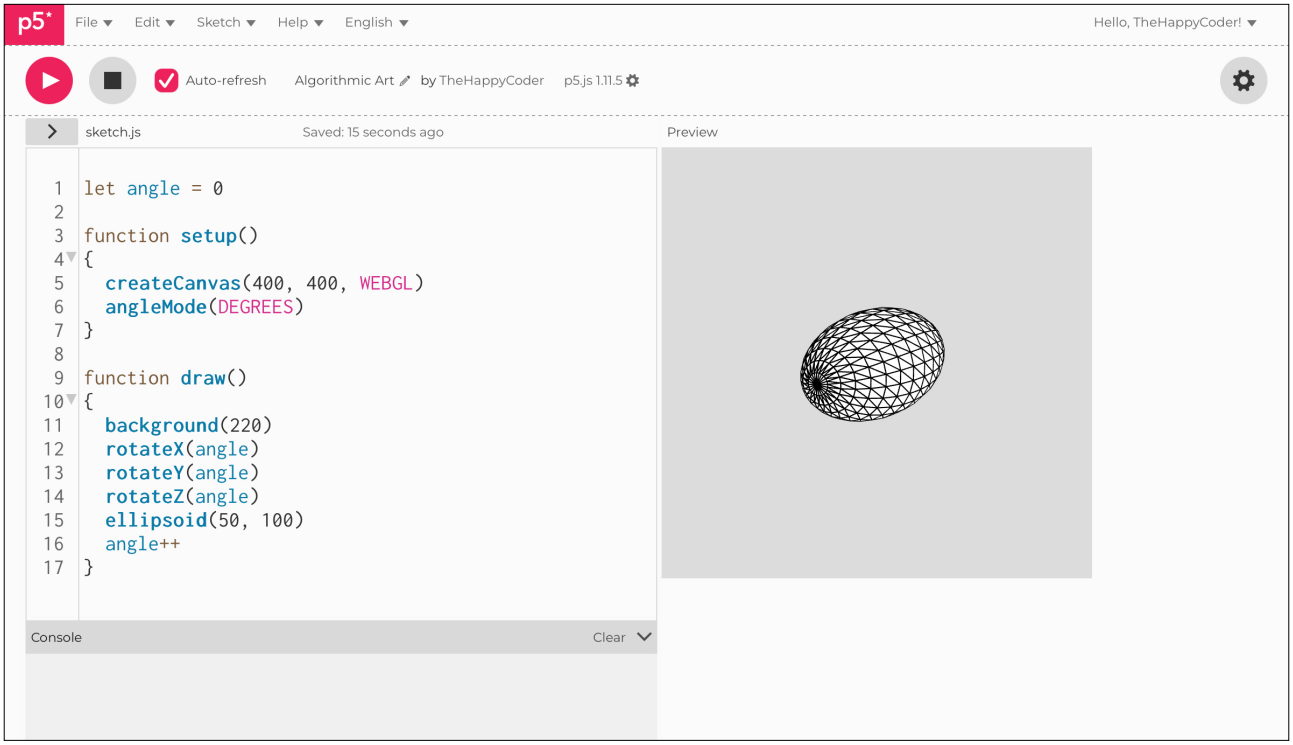
An `ellipsoid` is a sphere but with two dimension. A radius in one direction and a perpendicular radius.

```
let angle = 0

function setup()
{
  createCanvas(400, 400, WEBGL)
  angleMode(DEGREES)
}

function draw()
{
  background(220)
  rotateX(angle)
  rotateY(angle)
  rotateZ(angle)
  ellipsoid(50, 100)
  angle++
}
```

🛠️ Code Explanation

`ellipsoid(50, 100)`	Drawing an ellipsoid 50 wide, 100 long

Figure B1.12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Preview
let angle = 0
function setup()
{
createCanvas(400, 400, WEBGL)
angleMode(DEGREES)
}
function draw()
{
background(220)
rotateX(angle)
rotateY(angle)
rotateZ(angle)
ellipsoid(50, 100)
angle++
}
Console
Clear

Sketch B1.13 drawing a torus

Now for a `torus` (doughnut/donut), which has two dimensions: the torus radius and tube radius (thickness of the doughnut).

```
let angle = 0

function setup()
{
  createCanvas(400, 400, WEBGL)
  angleMode(DEGREES)
}

function draw()
{
  background(220)
  rotateX(angle)
  rotateY(angle)
  rotateZ(angle)
  torus(100, 50)
  angle++
}
```

🗒️ Notes

The radius of the torus (taken at the centre of the tube) is the first argument, and the radius of the actual tube itself is the second.

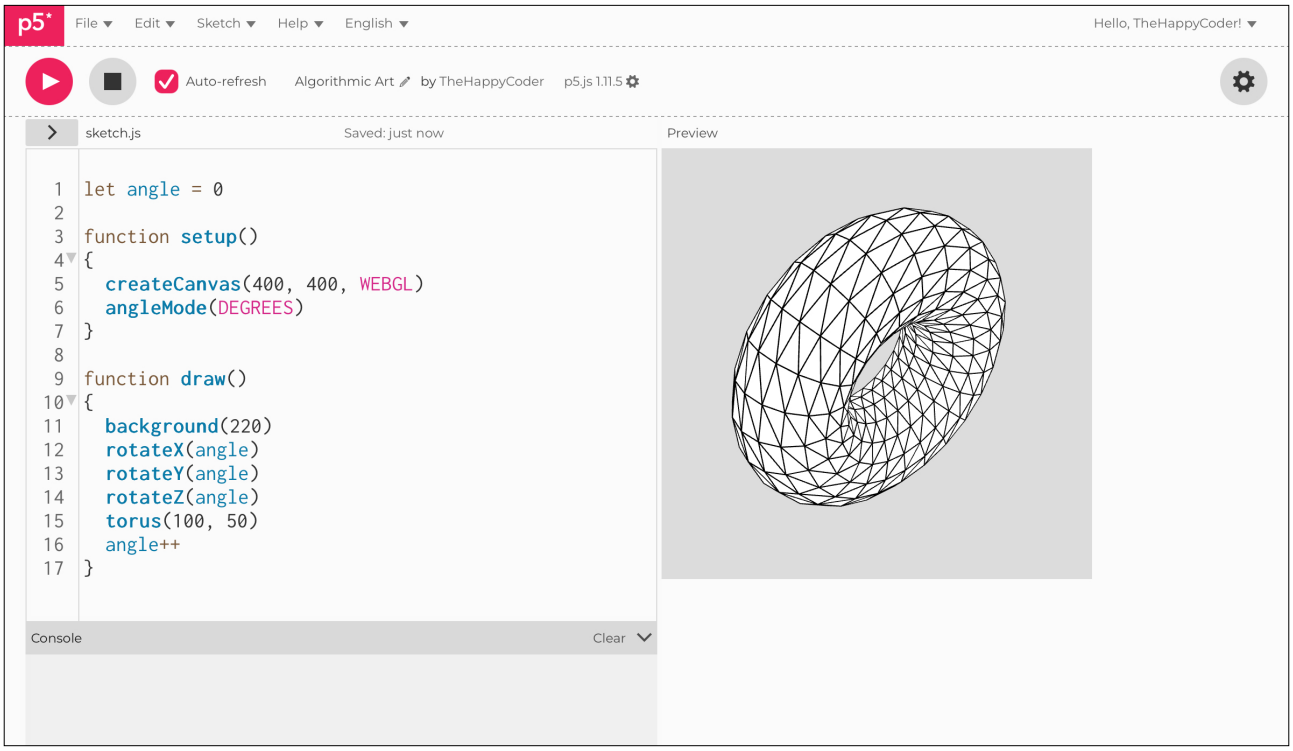
🌻 Challenge

Play with the values to get a feel for the shape.

🛠️ Code Explanation

`torus(100, 50)`	A torus with a radius of 100 and a tube dimension of 50

Figure B1.13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Saved: just now
Preview
let angle = 0
function setup()
{
createCanvas(400, 400, WEBGL)
angleMode(DEGREES)
}
function draw()
{
background(220)
rotateX(angle)
rotateY(angle)
rotateZ(angle)
torus(100, 50)
angle++
}
Console
Clear

Sketch B1.14 drawing a cone

A cone which has two dimensions, also, the first is the radius of the base and the second is the length (or height) of the cone.

```
let angle = 0

function setup()
{
  createCanvas(400, 400, WEBGL)
  angleMode(DEGREES)
}

function draw()
{
  background(220)
  rotateX(angle)
  rotateY(angle)
  rotateZ(angle)
  cone(100, 200)
  angle++
}
```

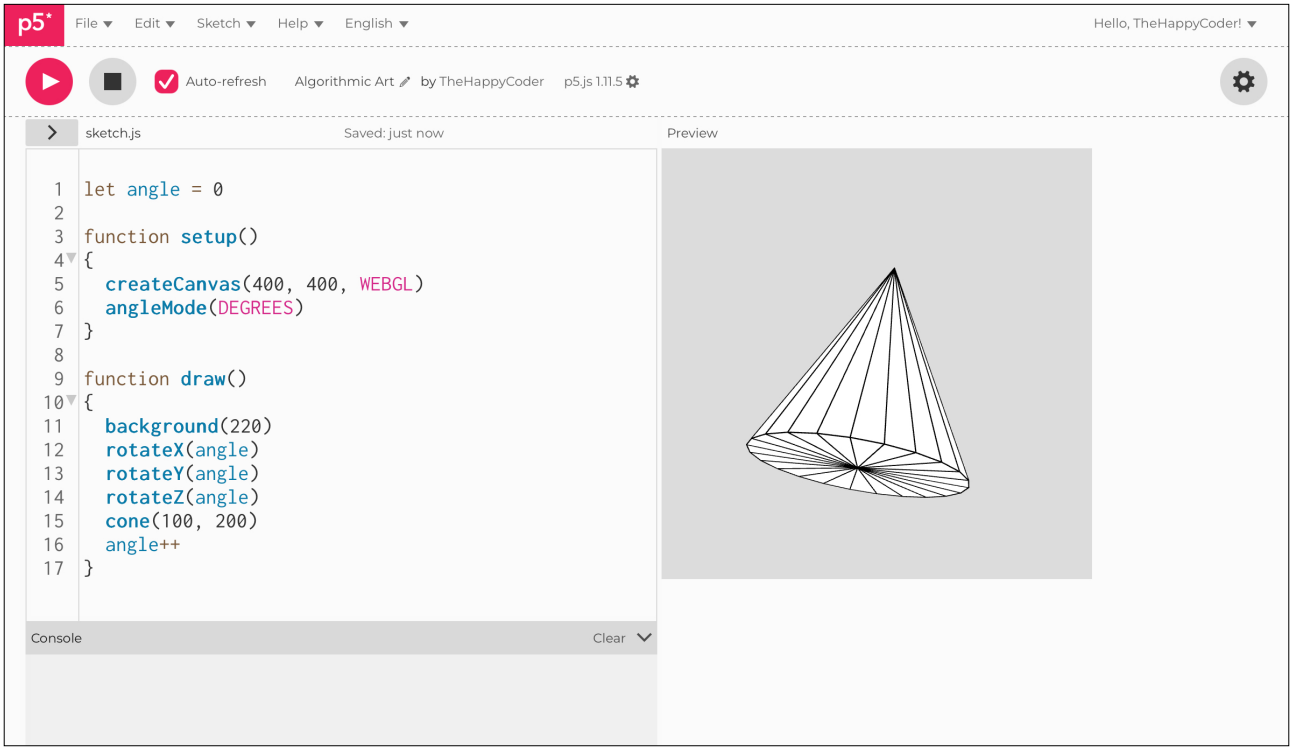
🌻 Challenges

1. Have more than one shape at the same time.
2. Use noFill().

🛠️ Code Explanation

cone(100, 200)	Draws a cone with a radius 100 and length 200

Figure B1.14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sketch.js
Saved: just now
Preview
let angle = 0
function setup()
{
createCanvas(400, 400, WEBGL)
angleMode(DEGREES)
}
function draw()
{
background(220)
rotateX(angle)
rotateY(angle)
rotateZ(angle)
cone(100, 200)
angle++
}
Console
Clear

Sketch B1.15 adding a bit of colour

❗ remove cone()

Let's go back to our simple cube. We can add colour with `fill()` and give the `background()` some colour for good measure.

```
let angle = 0

function setup()
{
  createCanvas(400, 400, WEBGL)
  angleMode(DEGREES)
}

function draw()
{
  background('darkred')
  fill('yellow')
  rotateX(angle)
  rotateY(angle)
  rotateZ(angle)
  box(100)
  angle++
}
```

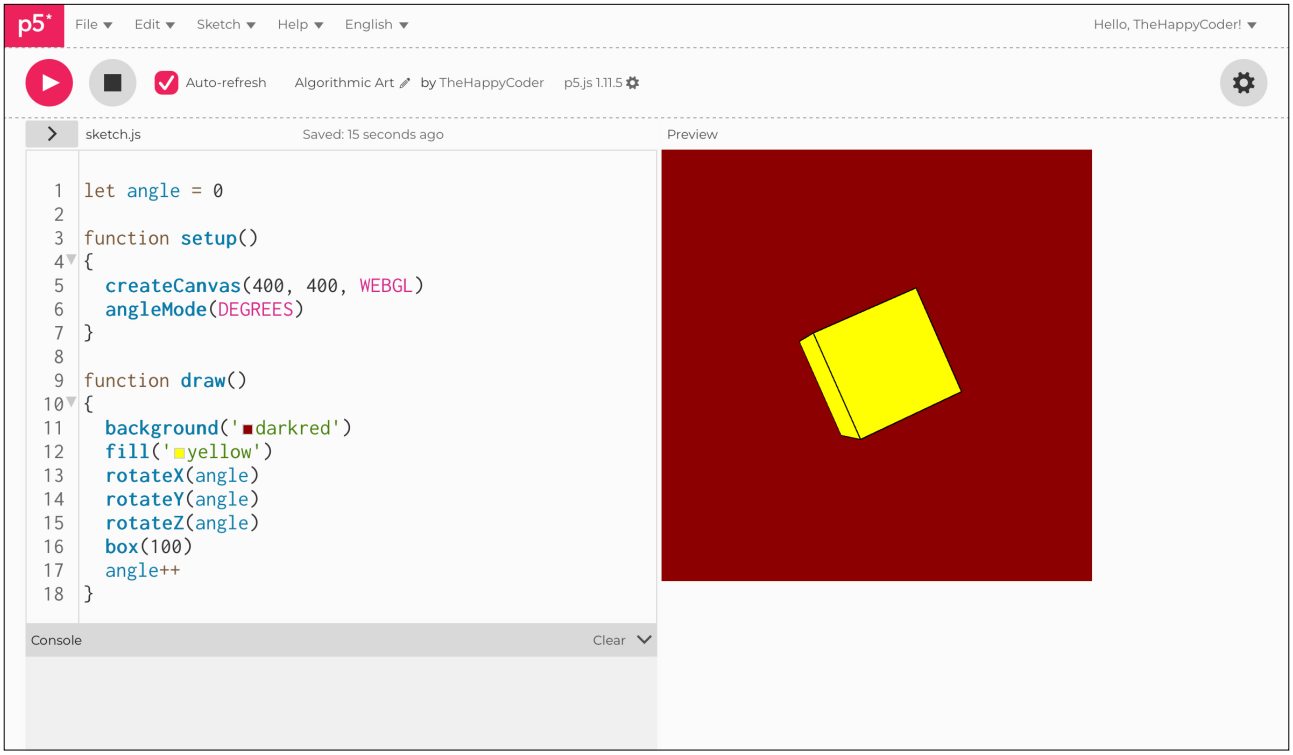
🗒️ Notes

This gives us a nice dark red background and a yellow cube. We will look at materials later.

🌻 Challenge

Explore other colours.

Figure B1.15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Preview
let angle = 0
function setup()
{
createCanvas(400, 400, WEBGL)
angleMode(DEGREES)
}
function draw()
{
background('darkred')
fill('yellow')
rotateX(angle)
rotateY(angle)
rotateZ(angle)
box(100)
angle++
}
Console
Clear

Sketch B1.16 translate

To move a shape in 3D (WEBGL), we translate the origin of the space. It takes a bit of getting used to as we are translating relative to the centre of the 3D space rather than from the top left as in the 2D canvas.

```
let angle = 0

function setup()
{
  createCanvas(400, 400, WEBGL)
  angleMode(DEGREES)
}

function draw()
{
  background('darkred')
  fill('yellow')
  translate(100, 100)
  rotateX(angle)
  rotateY(angle)
  rotateZ(angle)
  box(100)
  angle++
}
```

🗒️ Notes

This moves it down and to the right; notice that it still rotates about the new origin.

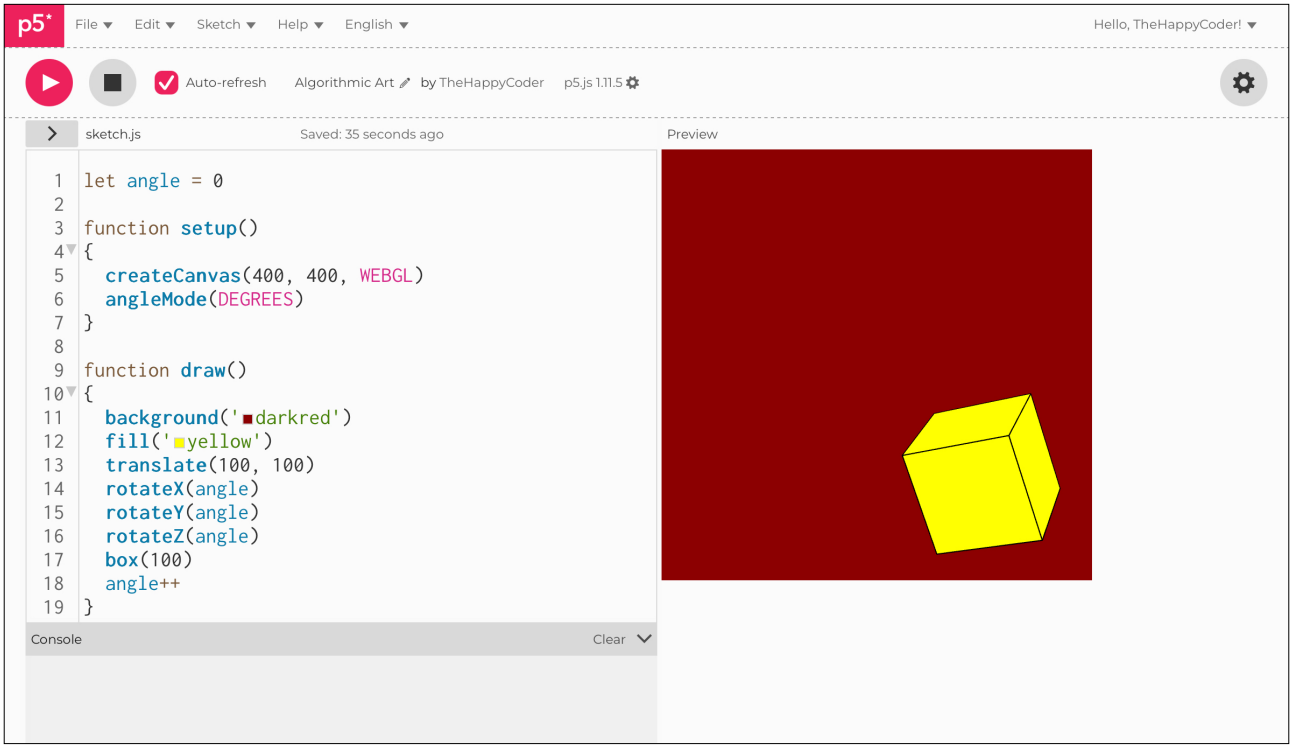
🌻 Challenges

1. Try other translations.
2. Do you know how to translate it to the left?

🛠️ Code Explanation

`translate(100, 100)`	Translating relative to the original origin

Figure B1.16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Preview
let angle = 0
function setup()
{
createCanvas(400, 400, WEBGL)
angleMode(DEGREES)
}
function draw()
{
background('darkred')
fill('yellow')
translate(100, 100)
rotateX(angle)
rotateY(angle)
rotateZ(angle)
box(100)
angle++
}
Console
Clear

Sketch B1.17 translate `tother way

Translating it to the top left-hand corner

```
let angle = 0

function setup()
{
  createCanvas(400, 400, WEBGL)
  angleMode(DEGREES)
}

function draw()
{
  background('darkred')
  fill('yellow')
  translate(-100, -100)
  rotateX(angle)
  rotateY(angle)
  rotateZ(angle)
  box(100)
  angle++
}
```

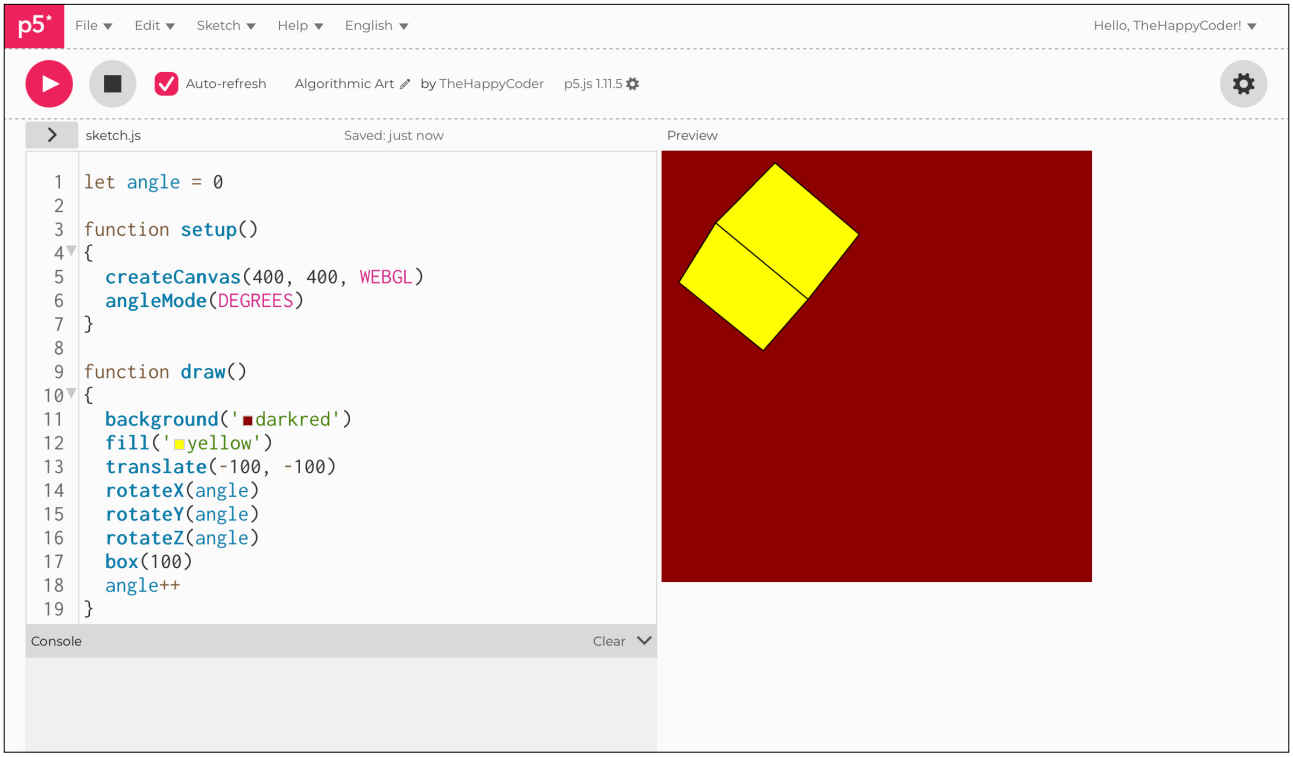
🗒️ Notes

We need to translate it negatively relative to the old origin.

🛠️ Code Explanation

`translate(-100, -100)`	Translating relative to the original origin

Figure B1.17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Preview
let angle = 0
function setup()
{
createCanvas(400, 400, WEBGL)
angleMode(DEGREES)
}
function draw()
{
background('darkred')
fill('yellow')
translate(-100, -100)
rotateX(angle)
rotateY(angle)
rotateZ(angle)
box(100)
angle++
}
Console
Clear

Sketch B1.18 translate along the z axis

But what about the z axis? We will now translate along the z axis only; we still need all three arguments for translate.

```
let angle = 0

function setup()
{
  createCanvas(400, 400, WEBGL)
  angleMode(DEGREES)
}

function draw()
{
  background('darkred')
  fill('yellow')
  translate(0, 0, 500)
  rotateX(angle)
  rotateY(angle)
  rotateZ(angle)
  box(100)
  angle++
}
```

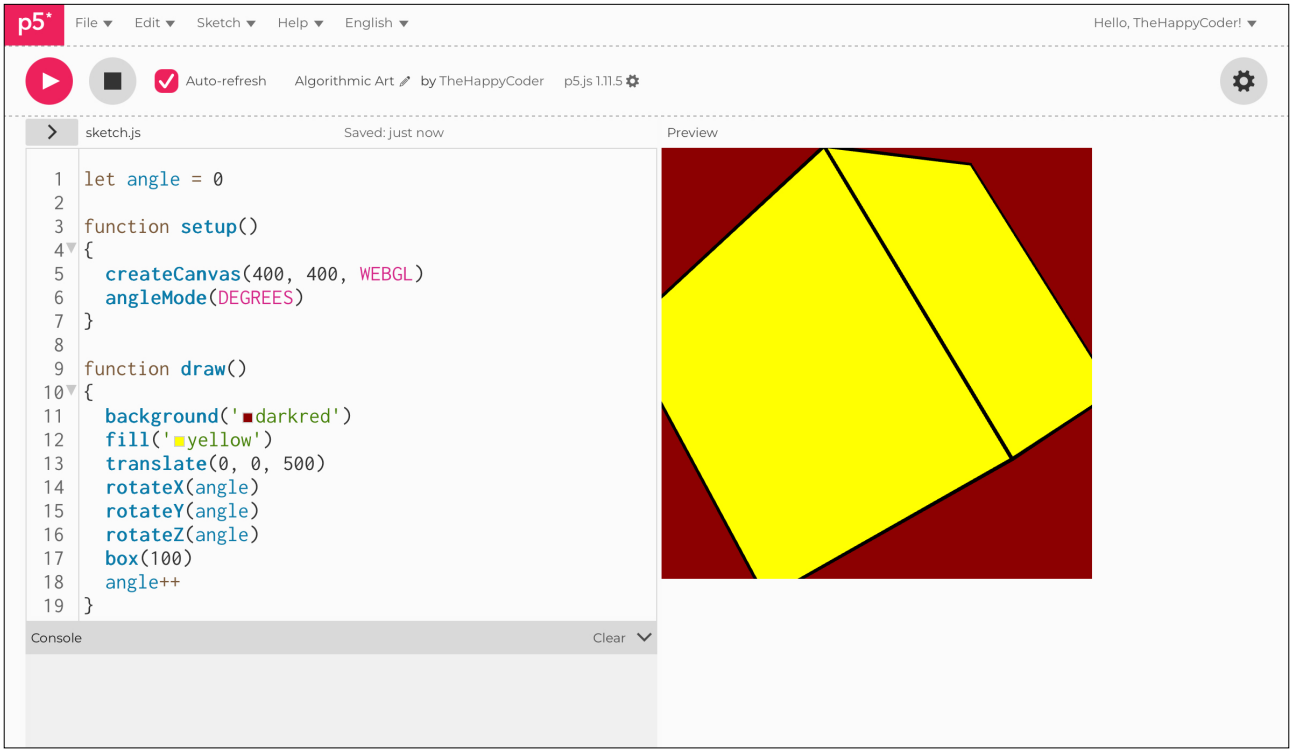
🗒️ Notes

This has moved it a lot closer; a positive value moves it towards you.

🛠️ Code Explanation

`translate(0, 0, 500)`	Translated only in the z direction, positive value brings it forwards

Figure B1.18


p5*
File
Edit
Sketch
Help
English
Hello, TheHappyCoder!
Auto-refresh
Algorithmic Art
by TheHappyCoder
p5.js 1.11.5
sketch.js
Saved: just now
Preview
let angle = 0
function setup()
{
createCanvas(400, 400, WEBGL)
angleMode(DEGREES)
}
function draw()
{
background('darkred')
fill('yellow')
translate(0, 0, 500)
rotateX(angle)
rotateY(angle)
rotateZ(angle)
box(100)
angle++
}
Console
Clear

Sketch B1.19 translate the other way

Giving it a negative value moves it further away; you are translating the space, not the shape, remember. So if you add other shapes, they too will be affected by the same amount.

```
let angle = 0

function setup()
{
  createCanvas(400, 400, WEBGL)
  angleMode(DEGREES)
}

function draw()
{
  background('darkred')
  fill('yellow')
  translate(0, 0, -500)
  rotateX(angle)
  rotateY(angle)
  rotateZ(angle)
  box(100)
  angle++
}
```

🗒️ Notes

You can see how you can position the shape relative to the origin in all three planes (axes).

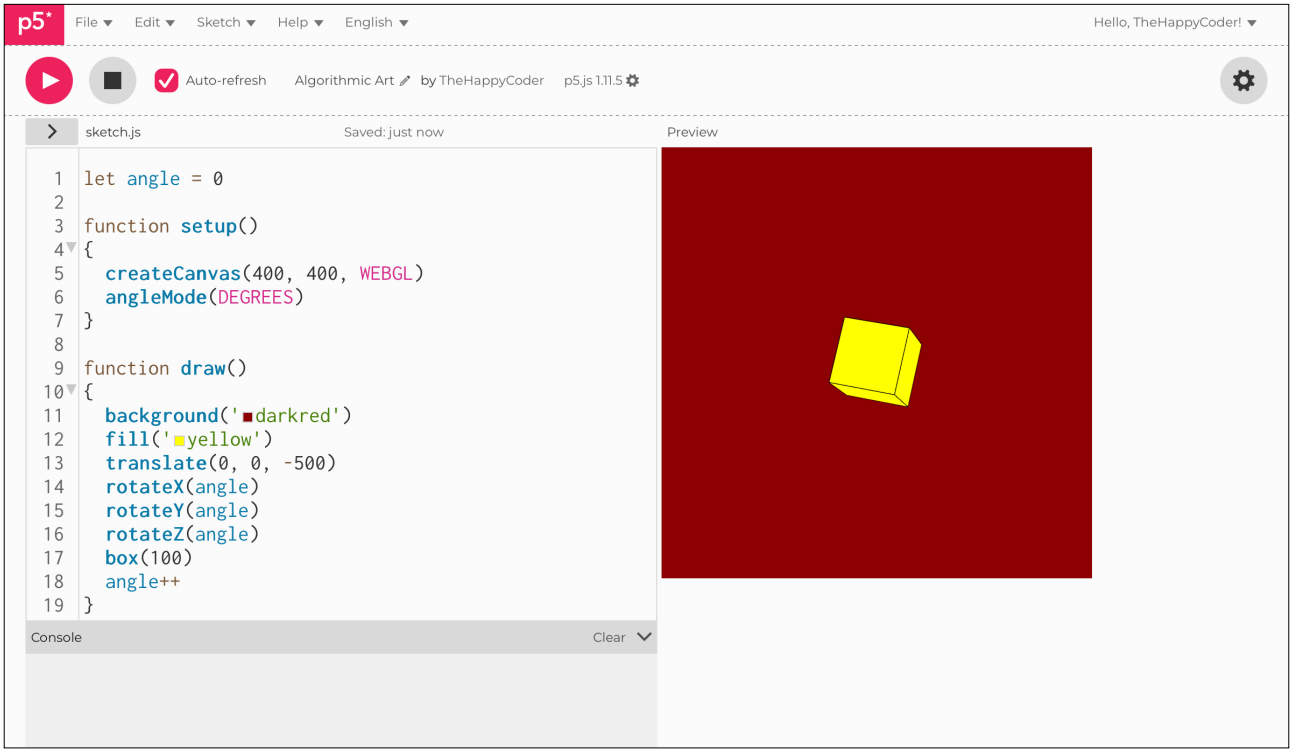
🌻 Challenge

Play with all three values.

🛠️ Code Explanation

`translate(0, 0, -500)`	Moves it further away by 500

Figure B1.19


p5*
File
Edit
Sketch
Help
English
Hello, TheHappyCoder!
Auto-refresh
Algorithmic Art
by TheHappyCoder
p5.js 1.11.5
sketch.js
Saved: just now
Preview
let angle = 0
function setup()
{
createCanvas(400, 400, WEBGL)
angleMode(DEGREES)
}
function draw()
{
background('darkred')
fill('yellow')
translate(0, 0, -500)
rotateX(angle)
rotateY(angle)
rotateZ(angle)
box(100)
angle++
}
Console
Clear

Sketch B1.20 more than one shape

But what happens if you have more than one shape occupying the same coordinates? Let's find out. We will add a cone and a torus to the box.

❗ Remove `translate()`

```
let angle = 0

function setup()
{
  createCanvas(400, 400, WEBGL)
  angleMode(DEGREES)
}

function draw()
{
  background('darkred')
  fill('yellow')
  // translate(0, 0, -500)
  rotateX(angle)
  rotateY(angle)
  rotateZ(angle)
  box(100)
  torus(100, 25)
  cone(100, 200)
  angle++
}
```

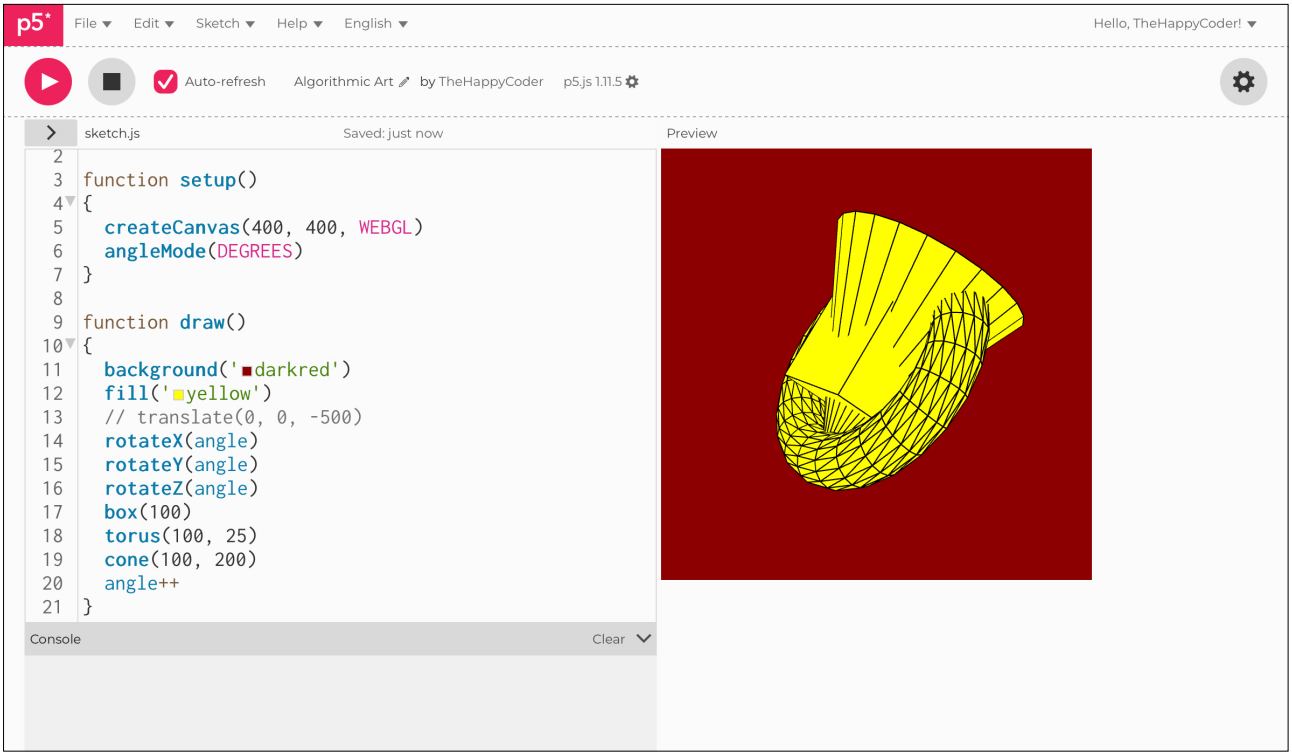
🗒️ Notes

All three are meshed together.

🌻 Challenge

Try `noFill()` and `stroke('white')`.

Figure B1.20


p5*
File
Edit
Sketch
Help
English
Hello, TheHappyCoder!
Auto-refresh
Algorithmic Art
by TheHappyCoder
p5.js 1.11.5
sketch.js
Saved: just now
Preview
function setup()
{
createCanvas(400, 400, WEBGL)
angleMode(DEGREES)
}
function draw()
{
background('darkred')
fill('yellow')
// translate(0, 0, -500)
rotateX(angle)
rotateY(angle)
rotateZ(angle)
box(100)
torus(100, 25)
cone(100, 200)
angle++
}
Console
Clear

Sketch B1.21 pushing and popping

Using `push()` and `pop()` we can rotate and translate individual shapes (or groups of shapes).

```
let angle = 0

function setup()
{
  createCanvas(400, 400, WEBGL)
  angleMode(DEGREES)
}

function draw()
{
  background('darkred')
  fill('yellow')
  // translate(0, 0, -500)
  rotateX(angle)
  rotateY(angle)
  rotateZ(angle)
  box(100)
  push()
  translate(0, 0, 100)
  rotateX(angle * 2)
  torus(100, 25)
  pop()
  cone(100, 200)
  angle++
}
```

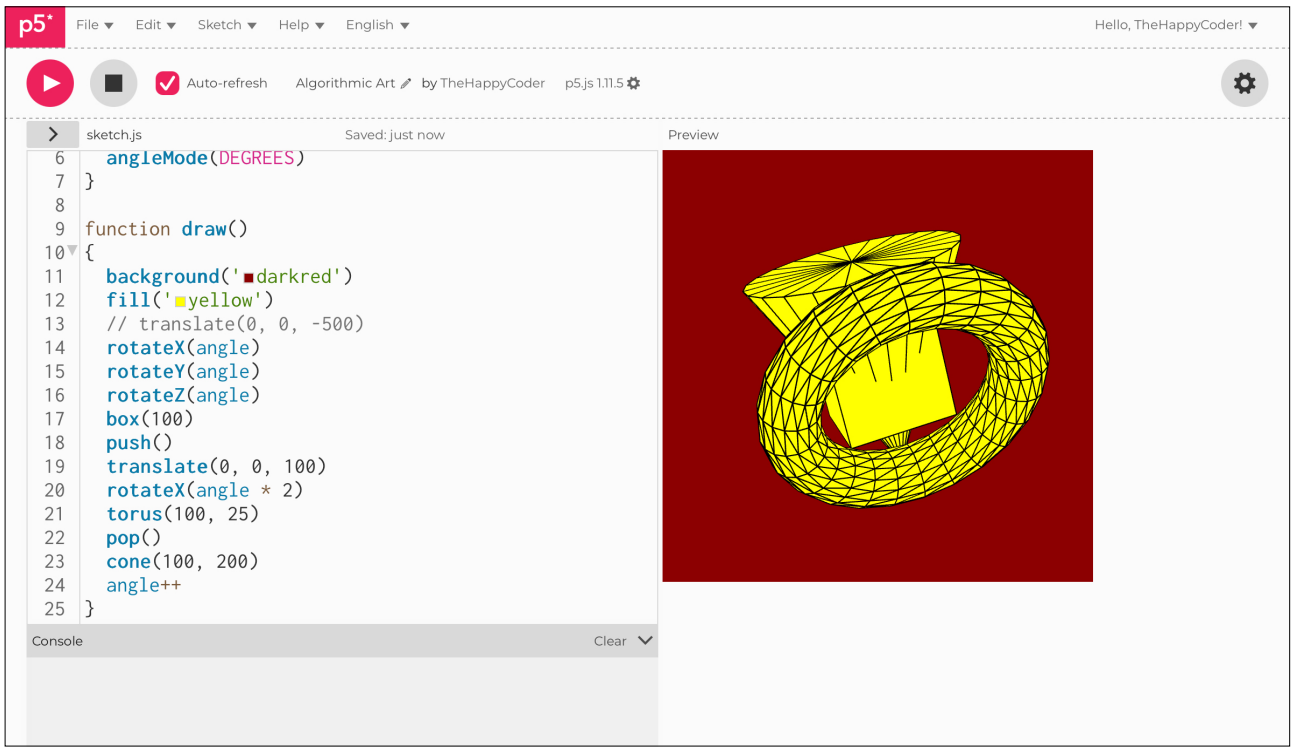
🗒️ Notes

The torus moves independently of the other two shapes, and yet all three are still moving together. There is a lot of scope to do much more.

🌻 Challenge

Just play and see what you can create.

Figure B1.21


p5*
File
Edit
Sketch
Help
English
Hello, TheHappyCoder!
Auto-refresh
Algorithmic Art
by TheHappyCoder
p5.js 1.11.5
sketch.js
Saved: just now
Preview
angleMode(DEGREES)
}
function draw()
{
background('darkred')
fill('yellow')
// translate(0, 0, -500)
rotateX(angle)
rotateY(angle)
rotateZ(angle)
box(100)
push()
translate(0, 0, 100)
rotateX(angle * 2)
torus(100, 25)
pop()
cone(100, 200)
angle++
}
Console
Clear